ISPEMI 2018

10th INTERNATIONAL SYMPOSIUM ON PRECISION ENGINEERING MEASUREMENTS AND INSTRUMENTATION

Programme & Abstracts




8-10 August 2018 / Kunming, China

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Electricity and Magnetism Committee of CSM

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Schedule at a Glance

August 8, 2018		August 9, 2018		August 10, 2018	
8:00:20:00	Reception and Registration (Hotel lobby)	8:30-8:50	Opening Ceremony	8:00-9:50	Section 1-4
		8:50-10:10	Plenary Session I (2)	9:50-10:35	Poster Section
		10:10-10:25	Coffee Break	10:35-12:15	Section 5-8
		10:25-11:45	Plenary Session II (2)	12:15-13:30	Lunch
		11:45-12:05	Photography	13:30-15:05	Section 9-12
		12:05-13:30	Lunch	15:05-15:50	Poster Section
		13:30-15:30	Plenary Session III (3)	15:50-17:45	Section 13-16
		15:30-15:45	Coffee Break	18:00-20:00	Closing Ceremony
		15:45-17:45	Plenary Session IV (3)		

Plenary speech: 40 min, keynote: 20min, Invited talk: 15 min, Ordinary presentation: 15 min.

Program on August 9, 2018

Time	Opening and Plenary Speaking	Chair
8:30-8:50	**Opening Ceremony**	Jiubin Tan
8:50-9:30	**Title: Optical fiber sensors for industrial applications** Prof. Kenneth Grattan, (*City University of London, UK*)	Tony Wilson
9:30-10:10	**Title： Miniature two-photon microscopy for brain imaging in freely behaving animals** Prof. Heping Cheng, (*Peking University, China*)	
10:10-10:25	**Coffee Break**	
10:25-11:05	**Title： Comb-based multidimensional coherent spectroscopy** Prof. Steven Cundiff, (*University of Michigan, US*)	Fu-Jen Kao
11:05-11:45	**Title: A novel high-precision mass measurement device for the new kilogram** Dr. Christian Rothleitner, (*Physikalisch-Technische Bundesanstaldt, Germany*)	
11:45-12:05	**Photography**	
12:05-13:30	**Lunch**	
13:30-14:10	**Title: Time resolved imaging with stimulated emission in pump-probe microscopy** Prof. Fu-Jen Kao, (*National Yang-Ming University, Taiwan, China*)	Seung-Woo Kim
14:10-14:50	**Title: Size matters! Understanding and exploiting the length-scale dependence of material properties and nano/micro-scale measurements** Prof. Nigel M. Jennett, (*Coventry University, UK*)	
14:50-15:30	**Title: Innovative techniques for contrast, spectrometric and viscoelastic measurements in small animal MRI** Prof. Olivier Beuf, (*INSA-Lyon, France*)	
15:30-15:45	**Coffee Break**	
15:45-16:25	**Title: Interferometric microscopy for detection and visualization of biological nanoparticles** Prof. M. Selim Ünlü, (*Boston University, US*)	Nigel M. Jennett
16:25-17:05	**Title: Plasmonics: Exotic nanophotonics beyond the limits** Prof. Satoshi Kawata, (*Osaka University, Japan*)	
17:05-17:45	**Title: Drive operational excellence through intelligent quality** Dr. Liao Lu, (*Hexagon Manufacturing Intelligence*)	
17:45-20:00	**Dinner**	

Program on August 10, 2018

Oral Presentation					
Time	**Abstract ID**	**Report ID**	**Authors**	**Author affiliation**	**Title**
Session 1 Instrumentation Theory and Methodology (1) (Chairman: Dr. Christian Rothleitner and Prof. Shuming Yang)					
8:00-8:20	3_947	**S1-1 (Keynote)**	**Hao Jiang*, Zhicheng Zhong, Shiyuan Liu***	**Huazhong University of Science and Technology**	**Metrology of shock-induced dynamic responses based on ultrafast ellipsometry**
8:20-8:35	E_033	**S1-2 (Invited)**	**Xiaodong Hou**	**Coventry University, UK**	**A brief introduction of nano-indentation and it's application in small-scale mechanical testing**
8:35-8:50	2_1024	**S1-3 (Invited)**	**Xiaodong Wang, Xingyuan Wang, Tongqun Ren, Yue Wang, Zhifeng Lou, Yi Luo**	**Dalian University of Technology**	**The measurement technology for precision peg-in-hole assembly**
8:50-9:05	1_943	**S1-4 (Invited)**	**Haihua Cui*, Zhaojie Li, Xiaosheng Cheng, Wenhe Liao**	**Nanjing University of Aeronautics and Astronautics**	**Multiple-exposure adaptive selection algorithm for high dynamic range 3D fringe projection measurement**
9:05-9:20	E_018	S1-5	Xinghui Li, Jiao Bai, Xiaohao Wang*, Qian Zhou, Kai Ni	Graduate School at Shenzhen, Tsinghua University	Design and testing of a chromatic dispersion system for displacement application by using a spatial-bandpass-filter
9:20-9:35	2_979	S1-6	Shao-Kang Li, Zhong-Peng Zheng, Lin-Yan Wang*	Xi'an Technological University	Establishment of the measuring coordinate system for large gears by gauge block
9:35-9:50	3_841	S1-7	Jianfei Zhou, Suping Chang*, Chunbing Hu, Zhongyu Zhang, Hao Wu, Zhongyu Zhang	Huazhong University of Science and Technology	Control circuit design of magnetic suspension stylus measuring instrument

Session 2 Measurement for Precision and Ultra-Precision Machining (Chairman: Prof. Jie Zhang and Prof. Yan Zhang)					
8:00-8:20	3_920	**S2-1 (Keynote)**	**Chih-Liang Chu*, Hung-Chi Chen**	**Southern Taiwan University of Science and Technology**	**Development of a parallel micro-CMM with high-precision contact scanning probe**
8:20-8:35	3_1098	**S2-2 (Invited)**	**Huijie Zhao, Mingyi Xing, Hongzhi Jiang*, Yang Xu, Xiaochun Diao, Chenghao Liu**	**Beihang University**	**A new non-contact coordinate measuring machine equipped with light-duty optical probe based on fringe projection profilometry**
8:35-8:50	E_032	**S2-3 (Invited)**	**Liping Yan, Zhouqiang Chen, Benyong Chen*, Jiandong Xie, Shihua Zhang, Yingtian Lou, Enzheng Zhang**	**Zhejiang Sci-Tech University**	**Laser phase modulation interferomertic nanometer displacement measurement with a combined sinusoidal and triangular signal**
8:50-9:05	E_065	S2-4	Mingxin Yu, Lianqing Zhu*, Mingli Dong, Guangkai Sun, Hong Li, Yanlin He	Beijing Information Science and Technology University	EEG-based pain level measurement and assessment using machine learning
9:05-9:20	2_842	S2-5	Jiamin Chen[1], Hui Zhou[2], Yuxuan Tang[1], Lei Wang[1]*	[1]Harbin Institute of Technology [2]National Instruments	A method for GMA internal magnetic field measurement based on temperature compensation
9:20-9:35	4_902	S2-6	Jing Yang[1], Sijin Wu[1]*, Weixian Li[1], Lianxiang Yang[2], Ji Liu[3]	[1]Beijing Information Science and Technology University [2]Oakland University [3]North University of China	Precise measurement of large roll angle using digital speckle pattern interferometry
9:35-9:50	E_012	S2-7	Meng Su, Linyi Huang, Huawei Xu	China Electronic Product Reliability and Environmental Testing Research Institute	Research on multi-degree-of-freedom and high-precision touch screen characteristic test instrument
Session 3 Novel Instrument and Measurement System (1) (Chairman: Prof. Michael Krystek and Prof. Jiwen Cui)					
8:00-8:20	4_1059	**S3-1 (Keynote)**	**Igor A. Konyakhin**	**ITMO University**	**Development of optic-electronic autocollimators for monitoring the angular displacements of large objects**

8:20-8:35	8_935	**S3-2 (Invited)**	**Zhiliang Gao[1], Qizheng Ji[1], Jian Chen[2], Xunbiao Zhang[3], Weihong Zhang[1], Junge Tan[1], Chenyan Wang[2]**	**[1]Beijing Orient Institute for Measurement & Test [2]Suzhou Sujing Automation Equipment Corporation [3]Shanghai Indoor Contamination Control Industry Association**	**Research on statistical measurement method of the standard particles through airborne particle counter based on FESEM**
8:35-8:50	3_881	**S3-3 (Invited)**	**Shichao Li[1], Tonggang Zhang[1,2]*, Cheng Chen[1], Jiong An[1]**	**[1]Southwest Jiaotong University [2]State-province Joint Engineering Laboratory of Spatial**	**Precision assessment of high-speed railway slab intelligent inspection system**
8:50-9:05	4_944	**S3-4 (Invited)**	**Guanhao Wu*, Lei Liao**	**Tsinghua University**	**Absolute distance measurement using synthetic wavelength interferometry of optical frequency combs**
9:05-9:20	3_1028	S3-5	Lu Zhang[1], Chunhui Zhao[1], Yingzhe Tu[1], He Yang[1], Chunwei Zhang[1], Lele Luo[1], Li Yuan[2]	[1]School of Mechanical Engineering,Xian Jiaotong University [2]First Affiliated Hospital, Xian Jiaotong University	Single-shot capturing based on polarizing coupled interferometry for phase measurement of cells
9:20-9:35	5_904	S3-6	Hewen WANG[1], Kai PENG[2], Xiaokang LIU[2]*, Zhicheng YU[1], And Hongji PU[3]	[1]Hefei University of Technology [2]Chongqing University of Technology [3]Xi'an Jiaotong University	A novel miniaturized capacitive absolute angular position sensor based on time-grating with reflective structure
9:35-9:50	8_854	S3-7	Jia Hou[1,2]*, Zi Xue[2], Yao Huang[2], Shuliang Ye[1], Yuling Gu[2]	[1]China Jiliang University [2]National Institute of Metrology, China	Study on the angular measuring accuracy of the rotary station with varying load
Session 4 Novel Instrument and Measurement System (2) (Chairman: Prof. Olivier Beuf and Prof. Weihu Zhou)					
8:00-8:20	E_041	**S4-1 (Keynote)**	**Seung-Woo Kim**	**Korea Advanced Institute of Science and Technology**	**Advanced optical metrology using mode-locked lasers**

8:20-8:35	E_009	**S4-2 (Invited)**	**Weiqian Zhao*, Lirong Qiu, Yun Wang**	**School of Optoelectronics, Beijing Institute of Technology**	**Infrared lens refractive index measurement using confocal tomography**
8:35-8:50	7_851	**S4-3 (Invited)**	**Hao Pan, Xinghua Qu, Fumin Zhang***	**Tianjin University**	**Method for high-precision distance estimation and dispersion mismatch compensation in frequency scanning interferometry**
8:50-9:05	E_063	S4-4	Fan Zhang*, Lianqing Zhu	Beijing Information Science and Technology University	Cell traction force measurement in a large field of view based on the Moire fringe method
9:05-9:20	4_992	S4-5	Qian Zhou, Peng Yan, Xinghui Li*, Kai Ni, Xiaohao Wang	Research Institute of Tsinghua University in Shenzhen	Modified mid-wave offner imaging spectrometer with low F number and large field of view
9:20-9:35	3_1089	S4-6	Feng Meng, Zhimin Zhang, Dianlong Zhang	National Institute of Metrology, China	Torque standard machine for calibration of reference torque wrench and torque transducer at NIM
9:35-9:50	E_043	S4-7	Ruitao Yang*, Hao Sun, Jiahao Guo, Haijin Fu, Hongxing Yang, Pengcheng Hu, Zhigang Fan, Jiubin Tan	Harbin Institute of Technology	Dual-comb generation from a dual-ring hybrid mode-locked fiber laser
Session 5 Modern Optics and Instruments for Precision Measurement (1) (Chairman: Prof. M. Selim Ünlü and Prof. Xiaojun Liu)					
10:25-10:45	E_039	**S5-1 (Keynote)**	**Yongsheng Gao**	**Hong Kong University of Science and Technology**	**Removal of opaque coolant barrier for in-process form profile optical measurement**
10:45-11:00	6_860	**S5-2 (Invited)**	**Dawei Xu*, Fang Cheng, Yu Zhou, Natalaray Thaddie, Peixian Lim, Liping Zhao**	**Advanced Remanufacturing and Technology Centre (Singapore A*STAR)**	**Process optimization: internal feature measurement for additive-manufacturing parts using X-ray computed tomography**
11:00-11:15	E_044	**S5-3 (Invited)**	**Lianqing Zhu**	**Beijing Information Science and Technology University**	**Optical fiber sensing techniques and its applications**

11:15-11:30	E_008	S5-4	Kun Zhang[1], Qing Yu[1]*, Changcai Cui[2], Shiwei Fu[1], Fang Cheng[1], Ming Chang[1], Ruilan Zhou[1]	[1]College of Mechanical Engineering and Automation, Huaqiao University [2]Institute of Manufacturing Technology, Huaqiao University	Development of chromatic dispersion lens for chromatic confocal microscopy
11:30-11:45	4_921	S5-5	Qiyu Wang, Jinyang Feng, Shanliang Liu, Duowu Su, Chunjian Li, Shuqing Wu*	National Institute of Metrology, China	Evaluation of the diffraction correction during the 10th International Comparison of Absolute gravimeters (ICAG 2017)
11:45-12:00	6_869	S5-6	Ying–Jun Lei[1], Rui–Jun Li[1*], Zhen–Xin Chang[1], Lian-Sheng Zhang[1], Kuang-Chao Fan[1,2]	[1]Hefei University of Technology [2]Dalian University of Technology	Design of optical accelerometer using four-quadrant photodetector
Session 6 Sensors, Actuators and Application (1) (Chairman: Prof. Nigel M. Jennett and Prof. Qibo Feng)					
10:25-10:45	E_050	**S6-1 (Keynote)**	**Zhengang Lu, Jiubin Tan*, Heyan Wang, Limin Ma, Yeshu Liu, Xi Lu, Jinxuan Cao, Shen Lin**	**Harbin Institute of Technology**	**Recent research advance in EMI shielding transparent conductors**
10:45-11:00	4_971	**S6-2 (Invited)**	**Yongying Yang[1]*, Rui Zhang[1], Zijian Liang[1], Pin Cao[2]**	**[1]Zhejiang University [2]Hangzhou Zernike Optical Technology Co., Ltd**	**Research and application of a novel randomly encoded hybrid grating interferometric wavefront sensor**
11:00-11:15	E_045	**S6-3 (Invited)**	**Masaki Michihata**	**University of Tokyo**	**Dielectric micro-sphere measurement using whispering gallery mode resonances**
11:15-11:30	10_987	**S6-4 (Invited)**	**Heng Zhao*, Dengxin Hua, Jun Wang, Qing Yan**	**Xi'an University of Technology**	**Micro-LED optical engine with biologically inspired artificial compound eyes for pico-projection display**
11:30-11:45	3_843	S6-5	Hao Wu, Suping Chang*, Chunbing Hu, Jianfei Zhou, Zhongyu Zhang	Huazhong University of Science and Technnology	Analysis of contracting characteristics on aerostatic bearing stylus displacement sensor

11:45-12:00	2_983	S6-6	Fanyi Wang, Pin Cao, Yongying Yang, Rongzhi Liu, Fan Wu, Pengfei Zhang, Jiabin Jiang, Huiting Chai, Yihui Zhang, Yubin Du, Guohua Feng, Xiang Xiao, Yanwei Li	Zhejiang University	Complicated intermittent scratches detection research on surface of optical components based on adaptive sector scanning algorithm cascading mean variance threshold algorithm
Session 7 Micro and Nano Metrology, Macro Metrology (Chairman: Prof. Seung-Woo Kim and Prof. Pengcheng Hu)					
10:25-10:45	E_031	**S7-1 (Keynote)**	**Jie Zhang**	**University of Bristol, UK**	**Ultrasonic array for NDT using total focusing method imaging algorithm**
10:45-11:00	E_042	**S7-2 (Invited)**	**Ling Hao**	**National Physical Laboratory, UK**	**Measurement and sensing for graphene and 2D materials by microwave resonance**
11:00-11:15	5_1038	**S7-3 (Invited)**	**Lu Wang , Dejiang Lu*, Libo Zhao, Zhuangde Jiang**	**Xi'an Jiaotong University**	**Novel double-FBARs-on-beam for PZT micro-accelerometer**
11:15-11:30	4_872	**S7-4 (Invited)**	**Qun Hao, Yan Ning, Yao Hu***	**Beijing Institute of Technology**	**Applications of wavefront modulation devices in aspheric and freeform measurement**
11:30-11:45	9_837	S7-5	Chuan-Zhi Fang[1, 2], Qiang-Xian Huang[1]*, Meng Mi[1], Chao-Qun Wang[1], Li-Juan Chen[1], Lian-Sheng Zhang[1]	[1]Hefei University of Technology [2]Anhui Institute of Information Technology	A measurement method for probe microsphere of micro-CMM with double SPMs
11:45-12:00	11_870	S7-6	Shan-Liang Liu, Jin-Yang Feng, Qi-Yu Wang, Duo-Wu Su, Chun-Jian Li, Shu-Qing Wu*	National Institute of Metrology	Investigation on the dynamic characteristics of CG-6 relative gravimeter for the micro-gravity network
Session 8 Laser Measurement Techniques and Instruments (1) (Chairman: Prof. Igor Konyakhin and Prof. Xiaodong Wang)					

10:25-10:45	E_038	**S8-1 (Keynote)**	**Shuang Zhang**	**University of Birmingham**	**Weyl degeneracies in topological metamaterials**
10:45-11:00	E_016	**S8-2 (Invited)**	**Weihu Zhou*, Dabao Lao, Fengdeng Dong, Rongyi Ji, Jingguo Zhu**	**Academy of Opto-Electronics, Chinese Academy of Sciences**	**The advance of laser precision measurement instrumentation in the Academy of Opto-Electronics, Chinese**
11:00-11:15	8_1083	**S8-3 (Invited)**	**Hongfang Chen*, Liang Tang, Huixu Song, Bo Yu, Zhaoyao Shi**	**Beijing University of Technology**	**Energy analysis method of the laser tracing measurement optical system**
11:15-11:30	E_060	S8-4	Wen Zhang, Lianqing Zhu*, Mingli Dong*	Beijing Information Science and Technology University	All-fiber Fabry-Perot interference structure: key technology and its applications
11:30-11:45	6_1060	S8-5	Tong Guo*, Zhenshan Sun, Jinping Chen, Xing Fu, Xiaotang Hu	Tianjin University	Development of hybrid measuring system for the complex micro-arrayed surface
11:45-12:00	8_863	S8-6	Sen Wang, Guanbin Gao, Jun Zhao, Wen Wang	Kunming University of Science and Technology	Kinematics identification and measurement accuracy verification of articulated arm coordinate measuring machines
Session 9 Instrumentation Theory and Methodology (2) (Chairman: Prof. Ling Hao and Prof. Liandong Yu)					
13:30-13:50	E_049	**S9-1 (Keynote)**	**Pengcheng Hu, Haijin Fu, Hongxing Yang, Ruitao Yang, Jiubin Tan***	**Harbin Institute of Technology**	**Displacement laser interferometry with sub-nm or deep sub-nm accuracy**
13:50-14:05	4_1091	**S9-2 (Invited)**	**Xiaobing Feng[1]*, Rong Su[1], Tuomas Happonen[2], Jian Liu[3], Richard Leach[1]**	**[1]University of Nottingham [2]VTT Technical Research Centre of Finland [3]Harbin Institute of Technology**	**All-optical difference engine for in-process defect inspection for roll-to-roll printed electronics**
14:05-14:20	5_1104	**S9-3 (Invited)**	**Chao-Ching Ho*, Jhih-Jia Lu, Po-Chieh Li**	**National Taipei University of Technology**	**Development of auto defect inspection system for cell phone silicone rubber gasket**

14:20-14:35	8_846	S9-4	Jintao Wang[1]*, Jinyue Zhang[2], Kai Wei[1], Lin Tong[1], Xuesong Bao[1]	[1]National Institute of Metrology [2]China Jiliang University	Measurement on deionized water density based on single silicon sphere
14:35-14:50	5_954	S9-5	Wei Wang[1], Zhaoyao Shi[1], Donglin Peng[2]*	[1]Beijing University of Technology [2]Chongqing University of Technology	A novel signal process system for angular displacement sensor of time-grating
14:50-15:05	5_1036	S9-6	Chengliang Pan*, Ting Zhang, Tianliang Dai, Haojie Xia, Liandong Yu	Hefei University of Technology	Design and simulation of a 2-DOF parallel linear precision platform utilizing piezoelectric impact drive mechanism
Session 10 Instrument and Measurement System Calibration (1) (Chairman: Prof. Yongsheng Gao and Prof. Zi Xue)					
13:30-13:50	E_040	**S10-1 (Keynote)**	**Michael Krystek**	**Physikalisch-Technische Bundesanstalt**	**Dealing with systematic effects in measurement uncertainty calculations**
13:50-14:05	E_047	**S10-2 (Invited)**	**Sen Han[1,2]**	**[1]University of Shanghai for Science and Technology [2]Suzhou H&L Instruments LLC**	**Advanced measurement of super- smooth surface**
14:05-14:20	E_036	**S10-3 (Invited)**	**Guanhao Wu, Lijiang Zeng**	**Tsinghua University**	**Dual-comb ranging**
14:20-14:35	5_908	S10-4	Aiganym Sakhariyanova*, Igor Konyakhin	ITMO University	The optical-electronic autoreflection sensor for angular deformations measurement
14:35-14:50	E_062	S10-5	Hong Li, Lianqing Zhu*, Fanyong Meng, Mingli Dong*	Beijing Information Science and Technology University	In-line optical fiber Mach-Zehnder sensor fabricated by CO2 laser and its applications
14:50-15:05	8_882	S10-6	Shengyang Zhou[1]*, Chenguang Cai[2], Ying Wang[1], Zhihua Liu[2], Ming Yang[1]	[1]Beijing University of Chemical Technology [2]National Institute of Metrology	A novel earth's gravity method for accelerometer calibration

Session 11 Signal Processing and Image Processing (Chairman: Prof. Jian Liu and Prof. Xinghui Li)					
13:30-13:50	E_048	**S11-1 (Keynote)**	**Junning Cui*, Xingyuan Bian, Yesheng Lu, Shaokai Wang**	**Harbin Institute of Technology**	**Ultraprecision 3D non-contact probing for measurement of micro-structure with high aspect ratio**
13:50-14:05	2_1074	**S11-2 (Invited)**	**Xiupeng Hao*, Kuang-Chao Fan, Xiaodong Wang**	**Dalian University of Technology**	**A measuring method of spindle rotation error using circular grating and self-collimator**
14:05-14:20	7_1069	**S11-3 (Invited)**	**Xiao-Qia Yin, Wei Tao*, Hui Zhao**	**Shanghai Jiaotong University**	**A curve segment method based on fixed dynamic programming and cycled optimization techniques**
14:20-14:35	2_940	**S11-4 (Invited)**	**Yuhua Cheng[1], Xue Chen[1], Bingbai Li[1], Lulu Tan[1], Bin Liu[2], Haichao Yu[1]**	**[1]University of Electronic Science and Technology of China [2]Harbin Engineering University**	**A fast infrared thermal imaging detection method based on spatial correlation**
14:35-14:50	1_1018	S11-5	Jiawei Ding, Jiandong Ma, Yunliang Qin, Jing Fan, Bo Fang, Jiacheng Hu	China Jiliang University	The method of solving the accurate displacement rule with acceleration signal
14:50-15:05	4_883	S11-6	Ying Zhang[1]*, Chenguang Cai[1], Zhihua Liu[1], Ming Yang[2]	[1]National Institute of Metrology [2]Beijing University of Chemical Technology	A high precision edge detection method for the blurred image in motion measurement
Session 12 Sensors, Actuators and Application (2) (Chairman: Prof. Shuang Zhang and Prof. Yongying Yang)					
13:30-13:50	E_017	**S12-1 (Keynote)**	**Taehwa Lee, Cheng Zhang, Qiaochu Li And L. Jay Guo**	**University of Michigan**	**Ultrasound detection and imaging using microring resonators and laser generated focused ultrasound**

13:50-14:05	E_046	**S12-2 (Invited)**	**Lingxiao Zhu, Shuhua Yan, Aiai Jia, Chunhua Wei, Qixue Li, Xu Zhang, Jun Yang***	**National University of Defense Technology**	**Cold atom interferometry gravimeter**
14:05-14:20	E_007	**S12-3 (Invited)**	**Qiao Sun*, Jie Bai, Lei Du, Zhe Fan, Hongbo Hu**	**National Institute of Metrology, China**	**Establishment of standard device for high rotational speed generation**
14:20-14:35	5_984	S12-4	Liang Wu*, Shi Xu, Rui Zhang, Yang Liu	Chongqing University of Technology	A novel two-dimensional inductive sensor based on planar coils
14:35-14:50	5_1088	S12-5	Yu Chen, Chunling Yang*, Yan Zhang*, Yuze Li	Harbin Institute of Technology	A domain adaptation deep transfer method for image classification
14:50-15:05	6_877	S12-6	Liang Yu[1,2]*, Gabor Molnar[2], Sebastian Bütefisch[2], Christian Werner[2], Rudolf Meeß[2], Hans-Ulrich Danzebrink[2], Jens Flügge[2]	[1]Harbin Institute of Technology [2]Physikalisch-Technische Bundesanstalt	Micro Coordinate Measurement Machine (μCMM) using voice coil actuator with interferometric position feedback
Session 13 Laser Measurement Techniques and Instruments (2) (Chairman: Prof. Dengxin Hua and Prof. Donglin Peng)					
15:50-16:10	E_030	**S13-1 (Keynote)**	**Guoan Zheng**	**University of Connecticut**	**Fourier ptychographic imaging**
16:10-16:25	4_957	**S13-2 (Invited)**	**Igor A. Konyakhin, Hoa M. Tong**	**ITMO University**	**Multi-matrix optic-electronic systems for measuring the line shifts of the points on the radio-telescope main mirror**
16:25-16:40	5_861	**S13-3 (Invited)**	**Dajuan Lyu[1], Peide Liu[2], Wentao Zhang[2]*, Liangming Xiong[1]**	**[1]Yangtze Optical Fibre and Cable Joint Stock Limited Company [2]Institute of Semiconductors, Chinese Academy of Sciences**	**Measurement of 3-dB linewidth of FBG Fabry–Perot interferometer using tunable fiber laser**
16:40-16:55	4_950	S13-4	Changli Li, Min Fu*, Ge Zhu, Zhiwei Pu, Xiaoyu Yu	Chongqing University of Technology	Study on integrated linear time-grating displacement sensor with single alternating light field

16:55-17:10	7_977	S13-5	Bin Mao[1,2], Jianjun Cui[2]*, Kai Chen[3], Honglin Shu[3], Hongwei Shao[2]	[1]Shanxi Institute of Metrology Science [2]National Institute of Metrology [3]Henan Polytechnic University	Deformation measurement of testing machine based on laser interference method
17:10-17:30	E_021	S13-6	Xinghui Li, Weihan Yuan, Kai Ni*, Qian Zhou, Xiaohao Wang	Graduate School at Shenzhen, Tsinghua University	A two-probe linear encoder by using an arrayed scale grating stitched by multiple separate short gratings
17:30-17:45	9_1002	S13-7	Cheng Chen[1], Hong Zhu[1], Jian Fu[1], Chi Zhang[1], Jian Wang[1], Xiaojun Liu[1],Wenlong Lu[1]*, Xiangqian (Jane) Jiang[1,2]	[1]HuaZhong University of Science and Technology [2]University of Huddersfield, Huddersfield	Corrected differental fitting for height extraction in confocal microscopy
Session 14 Novel Instrument and Measurement System (3) (Chairman: Prof. Benyong Chen and Prof. Lianqing Zhu)					
15:50-16:10	E_029	**S14-1 (Keynote)**	**Erwan Sourty**	**Thermo Fisher Scientific, China**	**Thermo scientific themis Z: the ultimate in optical performance, reproducibility and flexibility**
16:10-16:25	7_1081	**S14-2 (Invited)**	**Tao Jin[2]*, Zhi Li[1], Lars Daul[1], Helmut Wolff[1], Ludger Koenders[1], Wenmei Hou[1]**	**[1]Physikalisch-Technische Bundesanstalt (PTB) [2]University of Shanghai for Science and Technology**	**Interferometric characterization of large-stroke nano-positioning stage using an optical fiber interferometer with subatomic resolution**
16:25-16:40	3_1097	**S14-3 (Invited)**	**Huijie Zhao, Yang Xu, Hongzhi Jiang, Xiaochun Diao, Chenghao Liu, Mingyi Xing**	**Beihang University**	**Real-time 3D shape measurement by fringe projection and GPU parallel computing**
16:40-16:55	11_923	**S14-4 (Invited)**	**Yao Huang[1]*, Zi Xue[1], Dan Qiao[2]**	**[1]National Institute of Metrology [2]Beijing Aerospace Times Optical-electronic Technology Co.**	**Measurement uncertainty analysis for self-calibration angle encoder**
16:55-17:10	6_1025	S14-5	Changchun Chai, He Zhou, Peng Zhou, Chi Zhang, Hz Yan, Xt Guo, Xiaojun Liu*	Huazhong University of Science and Technology	More efficient optical sectioning structured illumination microscopy

17:10-17:30	2_1109	S14-6	Huaxia Deng[1], Lijun Ren[1], Jin Zhang[1]*, Mengchao Ma[1], Xiang Zhong[1]*, Pengcheng Wen[2]	[1]Hefei University of Technology [2]AVIC Xi'an Aeronautics Computing Technique Research Institute	Measurement of unmanned aerial vehicle attitude angles based on a single captured image
17:30-17:45	E_006	S14-7	Lei Dong*, Zhen Li, Gang Zheng	Shaanxi Institute of Metrology Science	Error analysis method of weighing cycles based on robotic mass measurement system
Session 15 Modern Optics and Instruments for Precision Measurement (2) (Chairman: Prof. Lijiang Zeng and Prof. Zhaoyao Shi)					
15:50-16:10	E_028	**S15-1 (Keynote)**	**Haoyu Li**	**Harbin Institute of Technology**	**Three-dimensional imaging of live-cell dynamics using light-field microscopy**
16:10-16:25	E_035	**S15-2 (Invited)**	**Qibo Feng, Bin Zhang*, Fajia Zheng, Jiakun Li**	**Beijing Jiaotong University**	**Method for simultaneously measuring 6DOF motion errors of linear and rotary axes of CNC machine tools**
16:25-16:40	4_1112	**S15-3 (Invited)**	**Dian Bian, Xinyu Yan, Yang Lu, Liandong Yu***	**Hefei University of Technology**	**Development of surface profile measurement system based on super luminescent diode light source**
16:40-16:55	E_019	**S15-4 (Invited)**	**Xinghui Li, Haiou Lu, Weihan Yuan, Qian Zhou, Kai Ni, Xiaohao Wang***	**Graduate School at Shenzhen, Tsinghua University**	**Holographic fabrication of two-dimensional scale gratings for surface encoder by using an orthogonal type two-axis Lloyd's mirror interference lithography**
16:55-17:10	10_1047	S15-5	Tong Wang[1,2], Tao Liu[1], Shuming Yang[1]*, Biyao Cheng[1], Qiang Liu[1], Kang Liu[1]	[1]Xi'an Jiaotong University [2]Zhengzhou University of Light Industry	Subwavelength focusing and experimental detection of large-scale metallic multi-annular metasurfaces
17:10-17:30	1_967	S15-6	Yayong Wang, Shujie Liu*, Shixin Zhang, Yubin Huang, Kuang-chao Fan	Dalian University of Technology	A filter algorithm based on ARMA model to suppress the influence of atmospheric disturbance in laser straightness measurement

17:30-17:45	E_064	S15-7	Xu Zhang, Yang Hu, Daoming Qu, Guangkai Sun, Lianqing Zhu*	Beijing Information Science and Technology University	Optical fiber sensing technology in morphing aircrafts and soft robotics
Session 16 Instrument and Measurement System Calibration (2) (Chairman: Prof. Steven T. Cundiff and Prof. Qun Hao)					
15:50-16:10	E_025	**S16-1 (Keynote)**	**Yan Zhang*, Xinke Wang, Jiasheng Ye, Shengfei Feng, Peng Han, Wenfeng Sun**	**Capital Normal University**	**Ultrathin Terahertz wavefront modulator based on metasurface**
16:10-16:25	4_931	**S16-2 (Invited)**	**Yongmeng Liu[1]*, Cuilian Zuo[1], Chuanzhi Sun[1]*, Hui Jin[2], Jihui Ma[3], Jiubin Tan[1]**	**[1]Harbin Institute of Technology [2]Changchun institute of optics, fine mechanics and physics, Chinese Academy of sciences [3]Beijing Institute of Spacecraft Environment Engineering**	**EMI shielding performance evaluation model of the randomized overlapping ring metallic mesh**
16:25-16:40	1_961	**S16-3 (Invited)**	**Yongfeng Song, Liangzhou Chen*, Chang Song, Xiaojun Liu**	**Huazhong University of Science and Technology**	**The optimization of segment's supporting for large astronomical telescopes**
16:40-16:55	E_026	**S16-4 (Invited)**	**Lei Liu[1], Zhi Zhong[1], Mingguang Shan[1]*, Bin Liu[1], Guangyu Luan[2]**	**[1]Harbin Engineering University [2]Heilongjiang Bayi Agricultural University**	**Dual-wavelength off-axis quasi-common-path digital holography using polarization-multiplexing and flipping**
16:55-17:10	E_061	S16-5	Wei He, Lianqing Zhu*, Mingli Dong*	Beijing Information Science and Technology University	Key technology and applications of fiber grating fabricated by femtosecond laser
17:10-17:30	3_1056	S16-6	Lei Du*, Qiao Sun, Jie Bai, Zhe Fan	National Institute of Metrology	Field test method and standard instruments for verification of traffic speed meters based on actual traffic
17:30-17:45	11_839	S16-7	Hongtao Yang, Li Li, Yongjun Pang, Bangshen Chen, Shidai Zhang	Anhui university of science and technology	Theoretical determination and validation of thermal deformation critical point of CNC machine tool bed

Poster Presentation

9:50-10:35, Aug. 10, 2018, Poster Presentation (Odd Numbered Poster ID will be attended)

15:05-15:50, Aug. 10, 2018, Poster Presentation (Even Numbered Poster ID will be attended)

Abstract ID	Poster ID	Authors	Affiliation	Title
1_850	P1-1	Lin Jiang, Jingzhi Huang*, Xiangshuai Ding, Xiangzhang Chao	Harbin Institute of Technology	Method for spherical form error evaluation using cuckoo search algorithm
1_856	P1-2	Wei Xia, Junbao Chen, Yufeng Tao, Hui Hao, Dongmei Guo, Ming Wang	Nanjing Normal University	Research on photonic detection method of laser self-mixing interference
1_905	P1-3	Jingzhi Huang*, Huixin Zheng, Lin Jiang, Xiangzhang Chao, Xiangshuai Ding	Harbin Institute of Technology	Design of Gaussian filters based on odd and even function continuation for non-closed circular profile
1_942	P1-4	Yang Bai, Yunfeng Lu, Zhengkun Li, Dawei Wang, Qing He, Zhonghua Zhang	National Institute of Metrology	Misalignment recognition of mass pan in joule balance
1_975	P1-5	Binghe Wang, Yanhui Kang	National Institute of Metrology	Method of squareness measurement based on laser alignment measuring system
1_985	P1-6	Ivan S. Nekrylov, Maksim A. Kleshchenok, Anastasia A. Blokhina, Elena A. Sycheva, Igor Konyakhin, Sergey V. Mednikov	ITMO University	Choosing parameters of active reference mark optical-electronic systems spatial position control
1_991	P1-7	Mednikov V. Sergey, Vasilev S. Alexandr, Blokhina A. Anastasia, Kleshchenok A. Maksim, Nekrylov S. Ivan, Konyakhin A. Igor	ITMO University	Research of the temperature influence on the errority of incremental optical-electronic encoders of linear displacements based on raster structures
1_1005	P1-8	Jian Bao, Zai Luo, Dong Li*	China Jiliang University	Research of technologies in image-based omnidirectional AGV
1_1166	P1-9	Zhe Li, Jiwen Cui, Jianwei Wu Tong Zhou, Jiubin Tan	Center of Ultra-precision Optoelectronic Instrument, Harbin Institute of Technology	A Uniform and flexible model for three-dimensional measurement of line-structured light sensor

1_1167	P1-10	Jiwen Cui*, Yarui Ma, Houhu Lai, Hui Wang, Jiubin Tan	Institute of Ultra-precision Optoelectronic Instrument Engineering, Harbin Institute of Technology	Multi-structure elements morphology for improved anti-noise edge detection
2_835	P2-1	An Jin, Jie Lin, Jiamin Chen, Wenguo Yang, Xinggang Wang, Peng Jin, Lei Wang*, Jiubin Tan	Harbin Institute of Technology	Error analysis of target trajectory tracking applied for measurement of high speed spindle
2_890	P2-2	Yawei Li, Xiaodong Wang, Yi Luo, Shengsheng Sun	Dalian University of Technology	Force control and visual measurement in precision assembly system
2_913	P2-3	Yuansong Zheng, Zhifeng Lou, Xiaodong Wang*	Dalian University of Technology	A measuring method of coaxiality errors for far apart axis
2_936	P2-4	Miao Li, Xueyang Ma, Wei Yu, Yikang He, Lianwen Zhou, Yiwei Shen	Shanghai Institute of Aerospace Control Technology	Research on an accuracy test method of star sensor based on spatial transform
2_999	P2-5	Jianzhen Cai	Beijing orient institute of measurement	Variable frequency big current calibration technique
2_1019	P2-6	Yafei Yuan, Yu Zhang*, Weihong Zhang, Qizheng Ji, Na Feng, Ming Yang, Shanshan Ma, Jihao He	Beijing oriental institute of measurement and test	The effect of contact pressure on resistance measurement of antistatic material
2_1004	P2-7	Jianguo Tao	China Jiliang University	Fast measurement of small modulus gears based on machine vision
3_836	P3-1	Yuqing Xiao, Jie Cao, Zihan Wang, Qun Hao, Haoying Yu, Qiang Luo	Beijing Institute of Technology	Bionic vision improves the performances of super resolution imaging
3_848	P3-3	Xinyu Ma, Jintao Wang, Ziyong Liu	National Institute of Metrology	Measurement method of the compression coefficient of near-monocrystalline silicon density liquid
3_865	P3-4	Shengsheng Sun, Yi Luo, Xiaoxu Qiao, Xiaodong Wang	Dalian University of Technology	An exchangeable end effector for multi-part-assembly system
3_887	P3-5	Anton Nogin, Igor Konyakhin	ITMO University	Hough transform based image processing algorithm in the optical-electronic angle measuring device
3_898	P3-6	Jing Wang, Lei Wang*, Yixin Li, Junzhong Li, Xiaoyu Zhu	Harbin Institute of Technology	A Differential giant magnetostrictive mitro-displacement actuator
3_900	P3-7	Zhen Zhang, Lei Wang*, Junzhong Li, Jing Wang, Jiamin Chen, Pengxuan Li, Yunfei Han	Harbin Institute of Technology	Design of active vibration isolation system based on electromagnetic and floatation hybrid support

3_916	P3-9	Qiancheng Zhao, Jiang Shao*, Tianlong Yang	Hunan University of Science and Technology	Robust concrete crack recongnition based on improved image segmentation and SVM
3_919	P3-10	Meiju Zhang, Wei Liu, Defeng Liu, Feiyue An, Honglei Chen, Zenghua Liu	Beijing University of Technology	Development of portable digital ultrasonic guided wave detector based on COM express
3_938	P3-11	Hubing Du*, Jianhong Yu, Shaofeng Zhang	Xi'an University of Technology	Research on self-calibrating phase shifting shadow moiré technique
3_996	P3-12	Zhuo Zhao[1,2], Bing Li[1,2]*, Fei Gao[1], Lei Chen[1], Meiting Xin[1]	[1]Xi'an Jiaotong University, [2]State Key Laboratory for Manufacturing System Engineering	An online vision system for battery FPC connector defects detection based on ASM template matching method
3_1022	P3-13	Lu Zhang, Lele Luo, Zewen Yang, Yingzhe Tu, Chunhui Zhao, Chunwei Zhang, Li Yuan	Xi'an Jiaotong University	Recognition and classification of label-free leukocyte scattering detection in peripheral blood basing on pattern recognition method
3_1031	P3-14	Lihua Peng	Huazhong University of Science and Technology	A new method for generating large area &tunable non-diffraction structured light
3_1040	P3-15	Yesheng Lu, Junning Cui*, Yue Zhao	Harbin Institute of Technology	Fast response circulating cooling water temperature control system based on Smith predictor
3_1043	P3-16	Xili Duan, Jing Le*, Yuyang Ming, Shaowei Chen, Mingxing Tang	Xi'an University of Technology	Research on adaptive segmentation method of embossed character image based on wellner algorithm
3_1050	P3-17	Zhenwei Huang, Jina Liang, Lei Liu, Jiacheng Hu	China Jiliang University	Method for detecting ring gear surface defects of wheel speed sensor based on neural network
3_1057	P3-18	Lei Du, Qiao Sun, Jie Bai, Zhe Fan	National Institute of Metrology	Field test method and standard instruments for verification of traffic speed meters based on test vehicle
3_1067	P3-19	Yindi Cai, Baokai Feng, Kuang-Chao Fan	Dalian University of Technology	Construction of a compact laser wavemeter with controlling laser angular drift
3_1070	P3-20	Yue Wang, Xingyuan Wang, Xiaodong Wang	Dalian University of Technology	Ultrasonic characteristics of contact stress of small interference fitting parts
3_1076	P3-21	Liang Xu, Zhifeng Lou*, Kuang-Chao Fan, Liding Wang, Yuchen Tian	Dalian University of Technology	Calibration of geometric error in passive laser tracker
3_1080	P3-22	Yubin Du, Pin Cao, Yongying Yang, Fanyi Wang, Rongzhi Liu, Fan Wu, Pengfei Zhang, Huiting Chai, Jiabin Jiang, Yihui Zhang, Guohua Feng, Xiang Xiao, Yanwei Li	Zhejiang University	Defect detection method for complex surface based on human visual characteristics and feature extracting

3_1102	P3-23	Jiahao Ou, Xian Wang*, Zhou Xu	HuNan University Of Science and Technology(HNUST)	An identification method for casing weld in complex environment
3_1117	P3-24	Hongfu Zhou, Yanghua He, Yuguang Mo	South China U of Tech	Architecture of rail and wheelset NDT detecting test rig
3_1120	P3-25	Yalu Chen, Zhihui Li*	Shanghai Institute of Satellite Equipment	A design of high-accuracy angle measurement system for satellite ait processing
3_1140	P3-27	Guolong Wu, Haijin Fu, Hongxing Yang*, Pengcheng Hu	Harbin Institute of Technology	Design and performance analysis of a novel thermos-structure for measuring thermal drift of optics in a next generation interferometer
3_1161	P3-28	Duxi Liu*, Jinshun Xu, Tong Li	Northwestern Polytechnical University	Long-range automatic precision displacement measuring of winding system using double timing belt transmission
4_895	P4-1	Yuexin Wang*, Fuzhong Bai, Xiaojuan Gao, Ying Wang	Inner Mongolia University of Technology	Comparison of spacing detection algorithms for optical straight fringes images
4_911	P4-2	Qian Zhou, Peng Yan, Xinghui Li, Kai Ni, Xiaohao Wang	Research Institute of Tsinghua University in Shenzhen	Improved design principle of Dyson concentric infrared imaging spectrometer
4_917	P4-3	Daria A. Drozdova, Victoria A. Ryzhova	ITMO University	Research of scintillation crystal's refractive index's homogeneity based on ellipsometric method
4_960	P4-4	Yin-fei Pan, Rong-sheng Lu*	Hefei University of Technology	FPGA-accelerated one-dimensional Fourier reconstruction LCD defect detection algorithm LCD defect detection algorithm
4_965	P4-5	Pingping Jia[1,2], Hong Zhao[1], Yuwei Qin[2], Meiqi Fang[1], Xiaopeng Guo[1]	[1]Xi'an Jiaotong University, [2]Weinan Normal University	Non-destructive rapid inspection methods for sptial light modulator using swept source optical coherence tomography
4_986	P4-6	Hoang Anh Phuong, Gorbachev A. Alexey	ITMO University	Image displacement analysis for electro-optical system for deflection measurement of floating docks
4_989	P4-7	Qian Zhou, Peng Yan, Xinghui Li*, Kai Ni, Xiaohao Wang	Research Institute of Tsinghua University in Shenzhen	Modified visible offner imaging spectrometer with low F number and large field of view

4_990	P4-8	Qian Zhou, Peng Yan, Xinghui Li*, Kai Ni, Xiaohao Wang	Research Institute of Tsinghua University in Shenzhen	Modified short-wave offner imaging spectrometer with low F number and large field of view
4_1046	P4-9	S.S. Baev[12*], V.V. Korotaev[1], V.N. Kuzmin[2], A.A. Maraev[1], K.A. Tomsky[2]	[1]ITMO University, [2]TKA Scientific Instruments	Choice of optimal resolution and array for integrated photosynthetically active radiation spectroradiometer
5_830	P5-1	Zihan Wang, Jie Cao, Qun Hao*, Fanghua Zhang	Beijing Institute of Technology	Combining compound eyes and human eye: a hybrid bionic imaging method for FOV extension and foveated vision
5_897	P5-2	Junzhong Li, Lei Wang*, Bo Zhao, Guolong Zhao, Jing Wang, Zhen Zhang, Jiamin Chen, Shitong Wang	Harbin Institute of Technology	Parameter identification of inertial velocity sensor for low-frequency vibration measurement
5_973	P5-3	Hongbin An, Liangzhou Chen, Xiaojun Liu, Bin Zhao	Huazhong University of Science and Technology	Microfluidic contact lens for continuous non-invasive intraocular pressure monitoring
5_974	P5-4	Shuxian Wang, Donglin Peng, Zhiyi Wu, Tianheng Zhang, Yangyang Wang	Hefei University of Technology	Revise compensation to the angle estimate error using multi-groups sensor
5_1020	P5-5	Kejun Yan, Jun Liu, Na Sun, Wenting Zhong	Xi'an University of Technology	Soil moisture sensor design based on fiber Bragg grating
5_1030	P5-6	Heming Gao, Bingyan Fan, Huiwen Deng, Yingxing Min, Jun Liu	Xi'an University of technology	Dynamic sensitivity distribution of linear electrostatic sensor matrix
5_1032	P5-7	Xingyuan Bian, Junning Cui*, Jiubin Tan	Harbin Institute of Technology	Bias electric field distribution analysis for a non-contact nano-probe based on tunneling effect
5_1054	P5-8	Anastasia Blokhinaa, Maksim Kleshchenoka , Ivan Nekrylova , Sergey Mednikova, Victoria Ryzhovaa, Igor Konyakhin	ITMO University	The meat product quality control by a polarimetric method
5_1107	P5-9	Jianmin Zhou, Faling Wang, Chenchen Zhang, Xiaosu Liao	East China Jiaotong University	Eye positioning based on windowed gray-scale integral projection algorithm
5_1114	P5-10	Yazhuo Li*, Xiangdong Zhou	Jianghan University	Using carbon nanotube membrane as counter electrode in voltammetric electronic tongue system
5_1128	P5-11	Sili Liu, Jianyun Chen*, Jiahao Li	National University of Defense Technology	Autonomous time synchronization method of wireless ad hoc sensor network and its implementation on CC1350 system

5_1155	P5-12	Zhigang Wang[1], Chi Xiao[1], Yinming Zhao[2], Yongqian Li[1]*, Zili Zhou[3]	[1]Northwestern Polytechnical University, [2]Beijing Changcheng Institute of Metrology & Measurement, [3]Chinese Aeronautical Establishment	Strain transfer characteristics of resistance strain-type transducer
5_1158	P5-13	Zhigang Wang[1], Chi Xiao[1], Yunlong Mao[a], Yinming Zhao[2], Zili Zhou[3], Yongqian Li[1]*	[1]Northwestern Polytechnical University, [2]Beijing Changcheng Institute of Metrology & Measurement, [3]Chinese Aeronautical Establishment	Dependence of stress distribution in electrical strain gauges on micro-morphology of sensitive grids
5_1163	P5-14	Hong Dang, Kunpeng Feng, Xun Sun, Yihua Jin, Jiwen Cui*, Jiubin Tan	Center of Ultra-precision Optoelectronic Instrument, Harbin Institute of Technology	A high resolution and response speed interrogation method for fbgs-based sensors
6_1001	P6-1	Xuewei Cui, Hengzheng Wei, Weinong Wang	China Jiliang University	Research and evaluation of geometric element data fitting software for coordinate measurement machine
6_1164	P6-3	Su Zhang, Jingtao Li, Limin Zou*, Hui Zhong, Xuemei Ding	Institute of Ultra-precision Optoelectronic Instrument Engineering, Harbin Institute of Technology	Super-resolution scanning microscopy with virtually structured illumination
7_858	P7-1	Liheng Shi, Dongmei Guo*, Lingwen Kong, Ming Wang, Wenkui Cai	Nanjing Normal University	Orthogonally polarized self-mixing grating interferometer for two-dimensional displacement measurement
7_899	P7-2	Fuzhong Bai, Jun Kong, Tieying Zhang, Yongxiang Xu, Xingrong Shi	Inner Mongol University of Technology	Angle measurement for cross-line target image based on Fourier-polar transform algorithm
7_907	P7-3	Anastasia Bulykina, Victoria Ryzhova, Valery Korotaev, Igor Konyakhin	ITMO University	Analysis of modern non-invasive methods of optoelectronic control of the skin
7_910	P7-4	Leonid V. Smirnov*, Victoria A. Ryzhova, Alexander S. Grishkanich, Igor Konyakhin	ITMO University	Sensing the atmosphere of coastal areas of laser detection methods
7_925	P7-5	Zhi-Feng Zhang*, Xue-Nian Fu, Jian-Wei Chen, Yu-Rong Li, Jia-Min Chang, Yu-Sheng Zhai, Li-Jie Geng	Zhengzhou University of Light Industry	Cotton neps on-line measurement based on near-infrared structured light images fusion light images fusion
7_929	P7-6	Hang Chen, Yue Gao, Peng Jin, Jiubin Tan, Jie Lin*	Harbin Institute of Technology	Displacement measurement with MEMS based slit sensor

7_994	P7-8	Jianning Liu, Zheng Lu, Lina Ren, Mingxing Jiao, Xiaoyun Bian	Xi'an University of Technology	Study on the temperature characteristics of the triangular prisms ring cavity
7_1000	P7-9	Ke Kou, Tianhong Lian, Cuo Wang, Guanlei Zhan	Xi'an University of Technology	Doppler-shifted laser self-mixing interferometry for enhanced detection sensitivity
7_1012	P7-10	Haiyan Hou, Jun Liu, Wenting Zhong, Kejun Yan, Huige Di	Xi'an University of Technology	Aerosol particle size distribution retrieval algorithm and error analysis based on multi-wavelength radar
7_1013	P7-11	Yun Liu, Xuan Li, Junhong Xing,	Xi'an University of Technology	Comparison and analysis of automatic focusing methods on pure phase objects in digital holographic microscopy
7_1015	P7-12	Guili Xu, Danyu Mu, Shuanggao Li, Huang Xiang, Dawei Zeng	Nanjing University of Aeronautics and Astronautics	Research on the key technology of detecting the defects of wheelset tread based on photoelectricity
7_1023	P7-13	Juan Su, Mingxing Jiao, Fei Jiang, Junhong Xing	Xi'an University of Technology	Research on laser frequency locking system using orthogonally demodulated pound–drever–hall method
7_1034	P7-14	Ang Wu, Juanhua Zhu, Zeliu Tao, Hao Zhang	Henan Agricultural University	Non-destructive detection of seed viability based on biospeckle technique
7_1075	P7-15	Ying Li, Zhifeng Lou, Kuang-Chao Fan	Dalian University of Technology	The Structural optimal design and stability improvement of dual-axis optoelectronic level
7_1085	P7-16	D.T. Nguyen, E.G. Lebedko	ITMO University	The possibility of measuring low altitudes above the sea surface with pulsed laser altimeter under conditions of fog and haze
7_1090	P7-17	L. Yang*, F. Ji, Y. Z. Zhang, M. J. Xu, J. J. Chen, R. S. Lu	School of Instrument Science and Opto-electronics Engineering, Hefei University of Technology	Characterization of surface roughness by double blanket model from laser speckle images

7_1096	P7-18	Chien-Kai Chung[1]*, Chen-Chang Lin[1], Ming-Fu Chen[1], Shih-Feng Tseng[2]	[1]Instrument Technology Research Center, National Applied Research Laboratories, [2]Department of Mechanical Engineering, National Taipei University of Technology	Design, fabrication, identification and test of a closed-loop moving magnetic scanning module for RGB laser projector
7_1108	P7-19	Beishen Wei, Lin Zhou*	South China U of Tech.	Data processing for Femur Model Laser scanning
7_1131	P7-21	Ke Wang, Haijin Fu, Di Chang, Pengcheng Hu*, Hongxing Yang, Ruitao Yang, Jiubin Tan	Harbin Institute of Technology	An auto-gain based homodyne laser vibrometer with enhanced adaptability to reflectivity
7_1132	P7-22	Haijin Fu, Yue Wang, Ruidong Ji, Pengcheng Hu*, Hongxing Yang, Ruitao Yang, Jiubin Tan	Harbin Institute of Technology	A real-time nonlinear error measurement method with picometer accuracy and free from target motion state
8_873	P8-2	Guisuo Xia, junfeng Qin, Yanjun Fu, Ziyang Qin	Nanchang Hangkong University	Research on high accuracy calibration method of rotary axis of tube parts
8_880	P8-3	Qi Lv, Chenguang Cai, Guodong Zhai, Zhihua Liu, Jiachun Cheng	China University of Mining & Technology	Study on resonant high-acceleration calibration system
8_885	P8-4	Anastasiya Y. Lobanova, Victoria A. Ryzhova, Igor A. Konyakhin*	ITMO University	Research of the polarization-optical parameters of a solid-state matrix photomultiplier
8_892	P8-5	Beichen Guo, Jingjing Li, Zhi Sun	Beijing Oriental Measurement Institute	Keysight B1505A power device analyzer output pulse current calibration method
8_948	P8-6	Song Zhang, Jiamin Liu, Hao Jiang, Shiyuan Liu	Huazhong University of Science and Technology	Characterization of beam splitter using Mueller matrix ellipsometry
8_952	P8-7	Maksim Kleshchenok*, Ivan Nekrylov , Anastasia Blokhina, Sergey Mednikov, Valery Korotaev, Igor Konyakhin	ITMO University	Parameter optimization of measuring and control elements in the monitoring systems of complex technical objects with triple reflector
8_958	P8-8	Xiang Cheng, Xiaojun Liu*, Hongzhou Yan, Jian Luo, Hong Zhu, He Zhou	Huazhong University of Science and Technology	Wavelength calibration system for diode laser
8_959	P8-9	Zhenmin Zhu*, Xinyun Wang, Quanxin Liu	East China Jiaotong University	Analysis of the extraction accuracy of the corner point of the camera using polarization imaging

8_962	P8-10	Xu Liu, Rongsheng Lu	Hefei University of Technology	Directional phase-shift circular arrays targets for out-of-focus camera calibration
8_980	P8-11	Xiaotong Wu, Shenghuai Wang, Chunlong Zou	Hubei University of Automotive Technology	Fabrication and characterization of nanostructure multi-step sample
8_1003	P8-12	Qiyu Wang, Lishuang Mou, Shuqing Wu, Chunjian Li, Duowu Su	National Institute of Metrology, China	Study of gPhone gravimeter-119 for gravity variations observation during International Comparison of Absolute Gravimeters 2017
8_1009	P8-13	Ye Ruan	Dalian University of Technology	A calibration method of micro device reconfigurable assembly system
8_1017	P8-14	Na Feng, Ya-Fei Yuan, Yu Zhang, Shan-Shan Ma, Qi-Zheng Ji	Beijing Oriental Institute of Measurement and Test	Study on the calibration technology of electrostatic field tester
8_1064	P8-15	Honggang Gu, Peng Wei, Xiuguo Chen, Hao Jiang, Chuanwei Zhang, Shiyuan Liu	Huazhong University of Science & Technology	Characterization of a liquid crystal variable retarder by Mueller matrix ellipsometry
8_1078	P8-16	Yuchen-Tian, Zhifeng Lou, Kuang-Chao Fan, Liang Xu, Ying Li	Dalian University of technology	Parallelism measurement based on rail stack installation
8_1119	P8-17	Run Zhang, Wenhui Bao, Huining Zhao, Huakun Jia, Liandong Yu*	Hefei University of Technology	Self-calibration method of precision shafting angle measurement error based on multiple reading heads
10_941	P10-1	Danyang Li, Jian Guan, Peng Jin, Jie Lin	Harbin Institute of Technology	Optimization algorithm to shape optical beam for laser direct writing
11_838	P11-1	Chenzhe Hang[1,2], Guoyuan Ma[1,*], Jianli Liu[3], Dinghua Xu[2]	[1]Beijing University of Technology,[2]National Institute of Metrology,[3]Henan Institute of Metrology	A chi-square statistic of arithmetic mean and its application in inter-laboratory comparison
7_1130	P11-2	Jiale Kang, Dengxin Hua, Tingyao He, Jingjing Liu, Qing Yan, Jun Wang*	Xi'an University of Technology	Decoupling atmosphere Rayleigh-Brillouin scattering spectrum in kinetic regime
11_840	P11-3	Haiyun Zhang[1]*, Dinghua Xu[1], Jianli Liu[2], Tiepeng Zhao[3]	[1]National Institute of Metrology, [2]Henan Institute of Metrology, [3]China Academy of Building Research	Based on MATLAB: the analysis of Key Comparison Reference Value (KCRV) and its uncertainty using Markov Chain Monte Carlo (MCMC) method
11_918	P11-4	Jingjing Li, Xiaoding Huang, Huan Zhang, Beichen Guo, Beibei Hu	Beijing Oriental Institute of Measurement and Test	An expression method of cmc based on unitary linear regression equastion

11_982	P11-5	Peili Yin, Jianhua Wang	Xi'an Technological University	Evaluation of task specific measurement uncertainty for gear measuring instrument using VGMI
11_1011	P11-6	Zeliang Cai, Za Luo, Hui Liu	China Jiliang University	Probe error analysis of articulated arm coordinate measuring machine
11_1026	P11-7	Yinbao Cheng[1], Zhongyu Wang[1], Xiaohuai Chen[2], Hongli Li[2], Jing Lü[3], Huadong Fu[3]	[1]Beihang University, [2]Hefei University of Technology, [3]China National Accreditation Service for Conformity Assessment	Misjudgment risk estimation for product inspection based on measurement uncertainty
E_001	P12-1	Dongzhao Huang, Qiancheng Zhao	Hunan University of Science and Technology	A Fast global calibration method for T-type 3D four-wheel aligner
E_002	P12-2	Dongliang Liu, Peng Zheng, Zhanxin Zhi	Mechanical Engineering Institute of Zhengzhou University	A new method for measuring the geometrical characteristics of crankshaft in-situ
E_003	P12-3	Qi Chang*, Heming Gao, Weixi Yang, Guoqiang Shi	School of mechanical and precision instrument engineering, Xi'an university of technology	A research on bolt loosening monitoring based on Lamb wave
E_004	P12-4	Meng Su*, Linyi Huang, Huawei Xu	China Electronic Product Reliability and Environmental Testing Research Institute	Design and implementation of flexible display reliability testing instrument
E_010	P12-5	Meng Su, Linyi Huang, Huawei Xu	China Electronic Product Reliability and Environmental Testing Research Institute	Instruments and equipment monitoring system based on the internet of things technology
E_013	P12-6	Tongqun Ren, Bo Qin, Xiangdong Xu, Zhirou Liu, Xiaodong Wang	Dalian University of Technology	The internal air gap measurement equipment for dynamic pressure motor
E_014	P12-7	Dianhong Yu, Ximin Li, Lin Li	Xi'an University of Technology	Theoretical analysis and digital simulation of a new capacitive sensor
E_015	P12-8	Yan Zhang[1], Zili Zhang[2,3], Yueqiang Li[1], Weihu Zhou[2,3]*, Yang He[1], Wei Li[1]	[1]Beijing Information Science & Technology University, [2]Chinese Academy of Science, [3]University of Chinese Academy of Sciences	Phase measuring method and error compensation in 3D profile measurement
E_020	P12-9	Qian Zhou, Kai Hu, Kai Ni, Xinghui Li*, Xiaohao Wang	Graduate School at Shenzhen, Tsinghua University	An underwater detecting system based on photoacoustic effect for underwater ranging and 3D topography measurement
E_022	P12-10	Xinghui Li, Yaping Shi, Peirong Wang, Kai Ni, Qian Zhou*, Xiaohao Wang	Research Institute of Tsinghua University in Shenzhen	A compact design of optical scheme for a two-probe absolute surface encoder

E_023	P12-14	Xinghui Li, Su Xiao, Qian Zhou, Kai Ni*, Xiaohao Wang	Research Institute of Tsinghua University in Shenzhen	Real-time distance measurement data processing platform based on absolute two-dimensional grating scale
E_024	P12-15	Xinghui Li, Xiang Xiao, Haiou Lu, Kai Ni, Qian Zhou*, Xiaohao Wang	Research Institute of Tsinghua University in Shenzhen	Design and testing of a compact optical lens module for multi-degree-of freedom grating interferometry application
E_027	P12-16	Han Zhou, Bingkun Wu, Mingguang Shan, Lei Liu, Haichao Yu, Zhi Zhong, Bin Liu*	Harbin Engineering University	Optical fiber Fabry-Perot acoustic sensor based on large PDMS diaphragm
E_051	P12-18	Cun Chang[1]*, Tianjian Wu[1], Wanfu Yang[1], Hao Li[2], Zhonghan Hao[3], Qing Chang[1]	[1]College of Engineering, Heilongjiang University, [2]Heilongjiang Provincial Institute of Measurement & Verification, [3]East China University of Science and Technology	System design of lithium battery internal resistance measurement using Labview
E_052	P12-19	Haitao Li[1]*, Jiangong Sun[1], Xianming Gao[1], Xinlong Yang[2], Junjie Guo[3]	[1]Shaanxi University of Science & Technology, [2]Xi'an Institute of Space Radio Technology, [3]Xi'an Jiaotong University	Error mapping for rotary axes of machine tools based on pose measurement principle
E_053	P12-20	Fuan Cheng, Xugang Feng*, Jiayan Zhang	Anhui University of Technology	Probe design of nano coordinate measuring machine based on grating strain sensor
E_054	P12-21	Fan Zhu*, Xinran Tan, Jian Shi, Yang Yu, Jiubin Tan*	Harbin institute of technology	Improved two dimensional micro-/nanoradian angle generator with single rotation center located on tilting plane and error compensation of capacitive sensors
E_055	P12-22	Wei Jin[1], Qi Li[2]*, Yushu Shi[2], Sitian Gao[2], Wei Li[2], Shi Li[2]	[1]China Jiliang University, [2]National Institute of Metrology	Automatic real-time compensation of wavelength of heterodyne interferometer
E_056	P12-23	Qi Zhou[1,2], Qi Li[2], Yu-Shu Shi[2], Shi Li[2], Lu Huang[2], Si-Tian Gao[2]*	[1]Zhejiang Sci-tech University, [2]National Institute of Metrology	Experimental study on non-linear calibration of two-dimensional nano-positioning stage
E_005	P12-24	Guodong Liu, Qifeng Luo, Bingguo Liu*, Binghui Lu, Pan Guo	Harbin Institute of Technology	Embedded intelligent camera algorithm based on hardware IP
6_833	P12-25	Cong Cao*, Dongsheng Zhao, Ying Tang, Tingting Peng	Shandong Institute of Metrology	Synthesis and metrology of cellulose nanocrystal films

E_057	P12-26	Lingcheng Liu, Xuemin Cheng*	Graduate School at Shenzhen, Tsinghua University	Fabrication process and error detection technologies for injection molding aspheric lens
E_058	P12-27	Yong Ren, Xuemin Cheng*	Graduate School at Shenzhen, Tsinghua University	Review of convolutional neural network optimization and training in image processing
E_059	P12-28	He Ni, Jingtao Li, Limin Zou*, Peng Zhang, Xuemei Ding	Department of Automatic Test and Control, Harbin Institute of Technology	Research on key technologies of quadrupole electromagnetic tweezer
7_1111	P12-29	Jingzhong Xu, Ge Wang*, Lina Ma, Jiarong Wang	Wuhan University	Extracting road edges from MLS point clouds via a local planar fitting algorithm
E_011	P12-30	Lu Wang, Mingdong Lv, Xuerong Ye*	Harbin Institute of Technology	Optimization on metering accuracy of smart electricity meter by temperature compensation
E_066	P12-31	Xiaoding Huang[1], Yazhen Tong[1], Jianzhen Cai[1],Jianting Zhao[2], Xin Zhang[3]	[1]Beijing Orient Institute of Measurement and Test, [2]National Institute of Metrology, [3]ShenyangZhongchuan Measurement Technology Co., LTD	Research of variable-frequency big current calibration
E_067	P12-32	Jincheng Song, Lizhen Guo, Hao Zhu, Yinxiao Miao, Ke liu	Beijing Aerospace Institute for Metrology and Measurement Technology	Study on FMCW laser ranging technology based on nonlinear error compensation

Plenary Session I

Title: Optical fiber sensors for industrial applications

8:50-9:30, Aug. 9, 2018
Chairman: Prof. Tony Wilson

Prof. Kenneth Grattan

President of the International Measurement Confederation (IMEKO)
Dean, City Graduate School
Royal Academy of Engineering - George Daniels Professor of Scientific Instrumentation
City University of London, UK

Professor Grattan graduated in Physics from Queen's University Belfast with a BSc (First Class Honors) in 1974 and a PhD in Laser Physics. His research involved the use of laser-probe techniques for measurements on potential new laser systems. Following Queen's, in 1978 he became a Research Fellow at Imperial College of Science and Technology, sponsored by the Rutherford Laboratory to work on advanced photolytic drivers for novel laser systems. This involved detailed measurements of the characteristics and properties of novel laser species and a range of materials involved in systems calibration. In 1983 he joined City University as a "new blood" Lecturer in Physics, being appointed Professor of Measurement and Instrumentation in 1991 and Head of the Department of Electrical, Electronic and Information Engineering. He was appointed Dean of the Schools of Engineering & Mathematical Sciences and of Informatics in 2008, serving until 2012 when he became Dean of the newly formed City Graduate School. His research interests include the use of fiber optic and optical systems in the measurement of a range of physical and chemical parameters. The work has been sponsored by a number of organizations including EPSRC, the EU, private industry and venture capital and he holds a number of patents for his work with industry. He obtained a DSc from City University in 1992 for his sensor work.

Professor Grattan is extensively involved with the work of the professional bodies having been Chairman of the Science, Education and Technology of the Institution of Electrical Engineers, the Applied Optics Division of the Institute of Physics and he was President of the Institute of Measurement and Control during the year 2000. He was awarded the Callendar Medal of the Institute of Measurement and Control in 1992, the Hartley Medal of the same Institution in 2015 and the Honeywell Prize for work published in the Institute's journal as well the Institute of Physics Applied Optics Divisional Prize in 2010. Professor Grattan had been Deputy Editor of the Journal Measurement Science and Technology for several years and currently serves on the Editorial Board of several major journals in his field in the USA and Europe. In January 2001 he was appointed Editor of the IMEKO Journal "Measurement" and now is Editor Emeritus of the Journal. After many years serving on their General Council, he was appointed the President of the International Measurement Confederation (IMEKO) in 2015. He is the author and co-author of about 1300 publications in major international journals and at conferences and is the co-editor (with Professor B T Meggitt) of a five volume topical series on Optical Fiber Sensor Technology. Professor Grattan was Dean of the School of Engineering & Mathematical Sciences and also Dean of the School of Informatics at City University from 2008 to 2012 and in that year was appointed as the Inaugural Dean of the new City Graduate School at the University.

Plenary Session I

Title: **Miniature two-photon microscopy for brain imaging in freely behaving animals**

9:30-10:10, Aug. 9, 2018
Chairman: Prof. Tony Wilson

Prof. Heping Cheng

Leader of Institute of Molecular Medicine, Peking University
Fellow of the Chinese Academy of Sciences

Professor Heping (Peace) Cheng received his bachelor and master degrees in applied mathematics & mechanics and biomedical engineering, with physiology as his minor, from Peking University, China. Upon graduation, he served as a junior faculty member in the Department of Electrical Engineering at the same university before earning his Ph.D. degree in physiology in 1995 from the University of Maryland at Baltimore. He then joined the NIH Intramural Research Program as a senior staff fellow, was selected as a tenure-track investigator in 1998 and became the head of the Ca2+ Signaling Section in the Laboratory of Cardiovascular Science, National Institute of Aging, NIH. He was promoted to senior investigator in 2004. He is now a senior investigator heading the Laboratory of Ca2+ Signaling & Mitochondrial Biomedicine in the Institute of Molecular Medicine at Peking University. He was elected to the Chinese National Academy of Sciences in 2013. Co-discovering “Ca2+ sparks” in 1993 and mitochondrial “superoxide flashes” in 2008, he strives to resolve elemental physiological signals in the pursuit of principles of cell signaling. Currently he is engaged in developing novel imaging technology for reverse engineering of brain information processing.

Plenary Session II

Title: **Comb-based multidimensional coherent spectroscopy**

10:25-11:05, Aug. 9, 2018
Chairman: Prof. Fu-Jen Kao

Prof. Steven Cundiff

Fellow Adjoint of JILA. Harrison M. Randall Collegiate Professor of Physics, University of Michigan, Ann Arbor
Fellow of the IEEE, Fellow of the APS, Fellow of the OSA, OSA Meggers Award, Humboldt Research Award

Professor Cundiff and his research group work on several aspects of ultrafast optics. One area involves generating and controlling ultrashort pulses, which, of course, provides the foundation for the field of ultrafast optics. However, the group is primarily interested in using ultrashort light pulses for a variety of scientific applications. A natural application is to use the very short duration of the pulses to study processes that occur on similar timescales, which is generally known as ultrafast spectroscopy. Ultrafast spectroscopy not only gives dynamical information, but it also provides information about the fundamentals of how light interacts with matter. One type of ultrafast spectroscopy, known as optical multidimensional coherent spectroscopy, has been developed over the last decade as has proven to be very powerful. The Cundiff group uses ultrafast spectroscopy, including multidimensional coherent spectroscopy, to study a range of system including semiconductors, semiconductor nanostructures and atomic vapors.

Plenary Session II

Title: **A novel high-precision mass measurement device for the new kilogram**

11:05-11:45, Aug. 9, 2018
Chairman: Prof. Fu-Jen Kao

Dr. Christan Rothleitner

Leading scientist of the group mass metrology for Planck balances,
Physikalisch-Technische Bundesanstaldt (PTB)
Member of German physical society DPG and American physical society

Dr. Christian Rothleitner studied physics in Germany, Italy and Venezuela. He received his PhD in experimental physics at the Max Planck Institute for the Science of Light, in Germany, about the development of two free-fall absolute gravimeters in the group of Prof. Lijun Wang (now at Tsinghua University, China). After he received his PhD he made a postdoctorate at the University of Luxembourg where he developed a free-fall experiment to measure the Newtonian constant of gravitation. Thereafter, he joined the German national metrology institute, the Physikalisch-Technische Bundesanstaldt (PTB), where he gained several years of experience in length metrology with a special focus on computed tomography. Now he is the leading scientist of the group mass metrology for Planck balances at PTB. In this position he is responsible for developing a high-precision weighing instrument that will allow to make primary realizations of the SI unit kilogram after its re-definition by end of 2018. This is done in collaboration with the Technical University of Ilmenau where Dr. Rothleitner is also doing his ‘habilitation’, a qualification as a lecturer. Dr. Rothleitner published more than 30 scientific articles in international peer reviewed journals. He is member of the German physical society DPG and of the American physical society APS.

Plenary Session III

Title: **Time resolved imaging with stimulated emission in pump-probe microscopy**

13:30-14:10, Aug. 9, 2018
Chairman: Prof. Seung-Woo Kim

Prof. Fu-Jen Kao

Professor, Institute of Biophotonics, National Yang-Ming University (2004-)
Association of Asia Pacific Physical Societies (2016-)

Professor Fu-Jen Gao is now in Institute of Biophotonics, National Yang-Ming University since 2004 and also the association of Asia Pacific Physical Societies. He was the president of Physics Society of ROC (2012-2014), vice president of Physics Society of ROC (2012-2014), associated Dean of Office of Research & Development, NYMU (2006-2011), and also the director, Institute of Biophotonics, NYMU (2004-2011). His research interests are in the field of Stimulated emission based pump-probe microscopy, 4-channel Stokes vector resolved SH polarization microscopy and biomedical optical instrument for endoscopy. During his academic career, the long working distance fluorescence and lifetime measurement via stimulated emission, and laser illumination for endoscopy are the two research highlights.

In the field of “long working distance fluorescence and lifetime measurement via stimulated emission”, Prof Gao and his team are focusing on the unique aspect of spatial coherence as a result of stimulated emission, which is utilized for long distance fluorescence detection and lifetime imaging. In contrast with the case of spontaneous emission, high numerical aperture optics is not required to collect the stimulated emission signal efficiently.

Meanwhile, in the field of “Laser illumination for endoscopy”, Prof Gao’s team have successfully established a novel ultra-compact endoscopic imaging system, which uses a miniature CMOS sensor (O.D. <1.0 mm) and a few multimode fiber for light delivery. Critically, the illumination is realized by coupling the output of a supercontinuum or RGB laser into the fiber. In this way, very high brightness is possible with extremely small footprint on the illumination part. As a result, the overall diameter (< 1.2 mm) of the endoscope can be much smaller than the currently used models.

Plenary Session III

Title: **Size matters! Understanding and exploiting the length-scale dependence of material properties and nano/micro-scale measurements**

14:10-14:50, Aug. 9, 2018
Chairman: Prof. Seung-Woo Kim

Prof. Nigel M Jennett

Professor of Materials, Mechanics and Measurement at Coventry University
Chairs of the BSI indentation hardness committee

Professor Nigel M Jennett BSc (Hons) (Physics), PhD (Physics), CSci CPhys MinstP has over 25 years' experience of fabrication and characterization of nano-structured materials and 20 years' developing nano-mechanical test methods. He is: Professor of Materials, Mechanics and Measurement at Coventry University, visiting Professor of Engineering at Leicester University, Associate Editor of Philosophical Magazine (and Philos. Mag. Letters), international chair of VAMAS Technical Working Area 22 'Mechanical properties measurement of thin films and coatings', UK technical expert on the CIPM consultative committee hardness working group (CCM-WGH), chairs the BSI indentation hardness committee, leads the UK delegation for ISO working groups drafting standards for indentation-based test methods. Nigel has also served two terms (six years) on the European Commission Certification Advisory Panel for Physical and Physicochemical Properties.

Nigel studied Physics at Bristol University (Physics Laboratory prize in 1984 and 1986, and the Raychem prize in 1985). He spent six years researching magnetic multilayers (1990 PhD, 1991 Chartered Physicist), before moving to NPL (1992) to develop traceable Scanned Probe Microscopy and nano-mechanical measurements. In 1998 he created his own research group focused on surfaces, coatings and nano-mechanics and was awarded a Glazebrook Fellowship in 2003 and the NPL Rayleigh award in 2010. Nigel is an experienced leader of projects (Government, Industry and European Commission), and is a regular invited speaker at international conferences.

Plenary Session III

Title: **Innovative techniques for contrast, spectrometric and viscoelastic measurements in small animal MRI**

14:50-15:30, Aug. 9, 2018
Chairman: Prof. Seung-Woo Kim

Prof. Olivier Beuf

Senior CNRS research scientist
Team leader “NMR and optics: From measure to biomarker”
Director of the CREATIS lab (CNRS UMR5220, INSERM U1206)

Dr. Olivier Beuf is the senior CNRS research scientist in France. He obtained his PH.D in physics from Université Claude Bernard Lyon 1 in 1998. Dr. Beuf has widely research interests in the field of MR imaging, RF coils, multi-parameters quantitative imaging, liver analysis, cartilage ultra-structure and morphology, and so on.

He published more than 80 peer reviewed international journal articles and 8 book chapters. His research works are 1105 citations in WOS and the h-index is as high as 19. Meanwhile, the transfer of technology are 3 patents. Dr. Beuf is also the supervisor of 17 PhD students (14 defended and 3 still supervised). Dr. Beuf is the chairman of the “journées scientifiques sur les nouvelles méthodologies en imagerie du vivant”, Lyon, France (300 delegates). He is the distinguished reviewer of Journal of Magnetic Resonance Imaging (2011 and 2014) and Magna Cum Laude Merit Award of the 30th Meeting of the International Society for Magnetic Resonance in Medicine (2012).

Plenary Session IV

Title: **Interferometric microscopy for detection and visualization of biological nanoparticles**

15:45-16:25, Aug. 9, 2018
Chairman: Prof. Nigel M. Jennett

Prof. M. Selim Ünlü

Distinguished Professor of Engineering appointed in electrical and computer engineering, biomedical engineering, physics, and graduate medical sciences. Boston University
IEEE Fellow and OSA Fellow
Editor-in-Chief for IEEE Journal of Quantum Electronics
Contact Information: selim@bu.edu www.bu.edu/OCN

Professor M. Selim Ünlü received the B.S. degree from the Middle East Technical University, Ankara, Turkey, in 1986, and the M.S.E.E. (1988) and Ph.D. (1992) degrees from the University of Illinois at Urbana-Champaign, all in electrical engineering. Since 1992, he has been a professor at Boston University. He is currently a Distinguished Professor of Engineering appointed in electrical and computer engineering, biomedical engineering, physics, and graduate medical sciences. He has also served as the Associate Dean for Research and Graduate Programs in engineering. His research interests are in the areas of nanophotonics and biophotonics focusing on high-resolution solid immersion lens microscopy of integrated circuits and development of biological detection and imaging techniques, particularly in high-throughput digital biosensors based on detection of individual nanoparticles and viruses.

Dr. Ünlü was the recipient of the NSF CAREER and ONR Young Investigator Awards in 1996. He has been selected as a Photonics Society Distinguished Lecturer for 2005-2007 and Australian Research Council Nanotechnology Network (ARCNN) Distinguished Lecturer for 2007. He has been elevated to IEEE Fellow rank in 2007 for his “contributions to optoelectronic devices” and OSA Fellow rank in 2017 for his “for pioneering contributions in utilization of optical interference in enhanced photodetectors and biological sensing and imaging.” In 2008, he was awarded the Science Award by the Turkish Scientific Foundation. His professional service includes serving as the chair of the Annual Meeting for IEEE Photonics Society and Editor-in-Chief for IEEE Journal of Quantum Electronics.

Plenary Session IV

Title: **Plasmonics: Exotic nanophotonics beyond the limits**

16:25-17:05, Aug. 9, 2018
Chairman: Prof. Nigel M. Jennett

Prof. Satoshi Kawata

Professor Emeritus, Osaka University
Honorary Scientist RIKEN
Osaka University, Suita, Japan
Office: P3-300, Photonics Center
Email:kawata@ap.eng.osaka-u.ac.jp

Professor Satoshi Kawata is now Professor Emeritus at Osaka University and Honorary Scientist of RIKEN. He is the founder and the Chairman of the Board of Nanophoton Corp. He is a Fellow of OSA, IOP, SPIE, and JSAP.

Satoshi Kawata received his BSc, Msc, and PhD all in Applied Physics in 1974, 76, and 79, respectively, from Osaka University. After the experience of postdoctral fellow of JSPS, he spent two years in University of California, at Irvine as a Research Associate. He joined Osaka University as a faculty member in 1981 and was promoted to Professor of Applied Physics in 1993, and then Distinguished Professor in 2013. In 2002, he joined RIKEN as a Chief Scientist as Head of Nanophotonics Laboratory until his retirement in 2012, and Team Leader of RIKEN until 2015.

Professor Kawata is now the Professor Emeritus of Osaka University and Honorary Scientist of RIKEN. He has served as the President of JSAP (Japan Society of Applied Physics) from 2014 to 2016, and the President of Spectroscopical Society of Japan from 2007 to 2008, the Editor of Optics Communications from 2000 to 2009.

He is one of the pioneers in near field optics (the inventor of tip-enhanced near-field microscopy), three-dimensional microscopy (laser CT microscopy, 3D optical data storage), plasmonics (SPR sensors, plasmon holography, plasmon laser, plasmonic microscopy), two-photon engineering (two-photon polymerization, two-photon isomerization, two-photon photorefraction, two-photon SPP, etc), bio-imaging, and signal recovery. The "8-micron bull" fabricated with his invented two-photon technology has been awarded in Guinness World Record Book 2004 Edition.

Plenary Session IV

Title: **Drive operational excellence through intelligent quality**

17:05-17:45, Aug. 9, 2018
Chairman: Prof. Nigel M. Jennett

Ms. Liao Lu

Hexagon Manufacturing Intelligence Global Product Marketing Manager

Ms. Liao Lu is now Hexagon Manufacturing Intelligence Global Product Marketing Manager. She is also HxGN SMART Quality Product Marketing Manager. With more than 20 years of industrial experience in precision measurement, Ms. Liao Lu has extensive market knowledge and internationalized view on measuring technology and customer application, and has made important contributions to the application and popularization of advanced measuring technology. She received her MSc degrees in Precision Measuring Technology from Tianjin University in 2003.

Abstract: Quality is not just dimensional inspection. Quality minimises the difference between the intended and the actual. Intelligent Quality means the active use of data to make quality improvements throughout the product lifecycle. This presentation will review the mindset changing in quality management, blending the innovation hardware and software technology trends on data collection in shop floor, digital connectivity, advanced analytics, and further drive quality improvement via insights gained from digitally connected equipment, people, processes, and operational systems. Introduce using the concept of 3D digital thread to create a rich information ecosystem for smarter manufacturing.

Contents

Oral Presentation

Session 1 Instrumentation Theory and Methodology (1) [8:00-9:50, Aug. 10, Room 1]

S1-1 Metrology of shock-induced dynamic response based on ultrafast ellipsometry [Keynote]

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An ultrafast ellipsometry system is proposed to measure the shock-induced dynamic response of materials. Since the ultrafast measurement technique is combined with the ellipsometry, the proposed system can simultaneously obtain the kinematic parameters and the optical constants of the shocked materials in a single measurement. The ultrafast ellipsometry system employs a pump-probe configuration. An ultrashort and high-power laser pulse pumps the materials to generate the shock waves while a chirped laser pulse probes the shocked region of the sample. A space-shifted frequency domain interferometer (SSFDI) is used to detect the dynamic changes in the phase and amplitude of the reflected probe beam. The dynamic responsive characteristics of shocked materials can be obtained in a single shot. We use a transparent polycarbonate film as the sample to be measured and build a double-layer thin film model for the sample. The simulation results show that the dynamic parameters of the shocked polycarbonate can be extracted with a relatively high precision, which indicates that the ultrafast ellipsometry system with the corresponding method is feasible and effective in the metrology of the shock-induced dynamic response of the transparent materials.

S1-2 A brief introduction of nano-indentation and it's application in small-scale mechanical testing [Invited]

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Instrumented indentation testing (IIT) was originally conceived as a means of hardness measurements from below the optical limit, widely used for measurement of small material components and coatings; therefore, IIT is commonly known as nano-indentation. Actually, instrumentation of the indentation process sparked an explosion of test methods. IIT became a trusted tool in many sectors for the determination of both elastic modulus and hardness of small volumes of material, with mapping of these properties becoming routine. The use of spherical indenters made the measurement of the indentation analogue of the stress-strain curve (Mean indentation pressure vs indentation strain for spherical indentations) much easier than when first attempted by Tabor in the 1950's using Brinell indentation. This talk will give a brief introduction of IIT and discuss the plasticity size effect closely associated with nano-indentation testing. This talk will also give an broad overview of IIT based small-scale mechanical testing and point out the challenges it imposes on the currently scientific understandings and testing method standardisation.

S1-3 The measurement technology for precision peg-in-hole assembly [Invited]

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Measurement is the prerequisite technology for assembling precise devices in order to guarantee the excellent qualities and efficiency. As a typical category of assembly, peg-in-hole is the most widely employed assembly method in industrial fields, including precision instruments and machinery. The peg-in-hole assembly can be divided into clearance fits and interference fits. To ensure the assembly quality, the precision clearance fits require mating surfaces to avoid collisions during assembly; for the precision

interference fits, the mating surfaces should not have abrasive chips after press-fit. Therefore, the hole-shaft alignment and attitude adjustment are the key factors affecting the assembly quality. Furthermore, real-time monitoring and connection strength measurement is also the key for interference fit assembly. Therefore, the purpose of this paper is to achieve precise hole-shaft alignment and attitude adjustment of these two kinds of fits and to real-time monitor the assembly process, as well as connection strength assessment of the interference fit. Two assembly instruments were built for interference fits and clearance fits to achieve precise alignment, attitude adjustment, and real-time monitoring. In addition, an ultrasonic testing apparatus was built to evaluate the connection strength. After calibration, the precision press-fit instrument can achieve high assembly accuracy and verified by assembly experiments. The prediction results of connection strength are in good agreement with experimental results with a relative error less than 20%. Furthermore, the instrument for clearance fits was also designed and introduced in detail.

S1-4 Multiple-exposure adaptive selection algorithm for high dynamic range 3D fringe projection measurement [Invited]

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In order to cover the high dynamic exposure range requirement of high reflective surface, the paper develops a phase shifting 3D measurement method based on multiple-exposure adaptive selection algorithm. At first, the camera response curve function is calibrated by the sequences images covered the highest and lowest intensity value of the phase shifting fringe. The intensity value of the sampled pixels of different exposure time are used to computed the nonlinear curve function which shows the image intensity value and exposure value, then the irradiance value of captured image is calibrated based on the linear relation between the exposure time and value. The relative irradiance value of all the image pixels is computed with the camera response curve function. And then, the adaptive selection algorithm for exposure time is proposed based on the double threshold principle. The captured image pixel intensity value isn't exceeding the highest value V_1 and the lowest value V_2 used for phase shifting measurement. At last, different exposure time node is selected adaptively. The sequences images with multi-exposure time are fused. In order to evaluate the performance of this method, some typical metal parts and blade with high range of reflectivity surfaces are used for 3D measurement and construction experiment. The experiment results verify the feasibility of the proposed method.

S1-5 Design and testing of a chromatic dispersion system for displacement application by using a spatial-bandpass-filter

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Chromatic confocal displacement measurement is a newly developed technology for linear precision positioning with a sub-micron meter accuracy over a millimeter order range. In this technique, the chromatic spectrum of a white light source is coded by an optical dispersion system. The coded spectrum disperses along the axial direction, with which the axial position can be detected by a spectrometer with a high precision. Thus, the optical dispersion system that determines the final measurement precision is required to be has a large dispersion capacity and a small spherical aberration. A chromatic dispersion lens (CDL) module and a spatial-bandpass-filter (SBF) were proposed in this research to improve the dispersion performance. Based on the geometrical imaging principle, the CDL and SBF parameters were preliminarily designed and further tested by the optical design software ZEMAX. The testing results verified that combination of the SBF and CDL, the spherical aberration was largely reduced and the imaging quality was greatly modified. The focus beam spot of the central wavelength 550 nm can be as small as 10μm. Under such a condition, the measurement error is no larger than ±0.7μm over a 1700μm measurement range.

S1-6 Establishment of the measuring coordinate system for large gears by gauge block

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In this paper, the establishment of the measuring coordinate system for large gears in situ measurement was studied and discussed. The solution based on gauge block was proposed and the scheme was devised. The mathematical model for the establishment of the measuring coordinate system was deduced. The main factors that influence the establishment precision of the measuring coordinate system were determined, such as the alignment error of the initial position of the block, the installation eccentricity error of the gauge block and the error caused by the tilt of the rotary table and the different working length of the gauge block. The experiments were carried out on the C40 gear measurement center with four-axis control under the condition of constant temperature and humidity. The experimental results showed the precision of R axis of the measuring coordinate system was higher than that of the T axis of the measuring coordinate system. When the working length of the gauge block is within 300mm, the measuring coordinate precisions of R axis and T axis were less than 2.5 μm and 4 μm, respectively, which can meet the requirement of the medium precision large gear measurement.

S1-7 Control circuit design of magnetic suspension stylus measuring instrument

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During the measurement, the traditional lever type measuring instrument will introduce a nonlinear error due to the rotation of the lever, which will affect the measurement result. A magnetic levitation stylus measuring instrument was designed based on it. It changed the lever supporting mode from the stylus shaft to the vertical direction linear translation, which can eliminate the nonlinear error and improve the measurement accuracy. This paper introduces the measuring principle based on the magnetic levitation bearing stylus surface topography sensor, designs the electronic control system of the magnetic levitation contact measuring instrument, and finally conducts the surface topography measurement test. The experimental results show that the designed electronic control system can meet the design requirements of the magnetic levitation system.

Session 2 Measurement for Precision and Ultra-Precision Machining [8:00-9:50, Aug. 10, 2018, Room 2]

S2-1 Development of a parallel micro-CMM with high-precision contact scanning probe [Keynote]

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The purpose of this study is to develop a parallel micro-CMM with high-precision contact scanning probe, can be applied to the measurement of micro-mold, micro-structure and micro components. In this study is use of parallel mechanism, which includes the structural design of traction bar and displacement sensing position coaxial, and the intersection of the three traction bars is located at the circular probe. It is therefore the design of this study will improve the displacement of traction bar and Abbe error resulted from the angle variation of displacement sensor, and effectively improve the accuracy of the machine. The aforementioned designs can reduce the error of the instrument so that the micro-CMM reaches a positioning accuracy of $\pm 5\mu m$.

S2-2 A new non-contact coordinate measuring machine equipped with light-duty

optical probe based on fringe projection profilometry [Invited]

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In the modern industrial manufacturing, how to effectively obtain the three-dimensional data of the parts profile is the key component for precision test and subsequent analysis. A light-duty design scheme for optical vision probe, which can be installed with a PH10T motorized probe head in CMM, is discussed in this paper. The optical probe can overcome several defects of the traditional measurement mode of CMM, such as poor efficiency and sparse point cloud. Therefore, the problem of 3D measurement and quality analysis for complicated parts can be solved. To splice data in different fields of view, a registration method using a new designed artifact is proposed. Experiments demonstrated the feasibility of the designed non-contact CMM integrated with optical 3D probe for precise 3D shape measurement. The measurement uncertainty of the optical probe can reach 0.012mm within the measuring volume width 200mm and the measurement uncertainty of the global 3D measurement is less than 0.03mm in 1500mm.

S2-3 Precision PGC demodulation for homodyne interferometer modulated with a combined sinusoidal and triangular signal [Invited]

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A precision PGC demodulation for homodyne interferometer modulated with a combined sinusoidal and triangular signal is proposed. Using a triangular signal as additional modulation, a continuous phase-shifted interference signal for ellipse fitting is generated whether the measured object is in static or moving state. The real-time ellipse fitting and correction of the AC amplitudes and DC offsets of the quadrature components in PGC demodulation can be realized. The merit of this modulation is that it can eliminate thoroughly the periodic nonlinearity resulting from the influences of light intensity disturbance, the drift of modulation depth, the carrier phase delay, and non-ideal performance of the low pass filters in the conversional PGC demodulation. The principle and realization of the signal processing with the combined modulation signal are described in detail. The experiments of accuracy and rate evaluations of ellipse fitting, nanometer, and millimeter displacement measurements were performed to verify the feasibility of the proposed demodulation. The experimental results show that the elliptical parameters of the quadrature components can be achieved precisely in real time and nanometer accuracy was realized in displacement measurements.

S2-4 EEG-based pain level measurement and assessment using machine learning

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Pain is a complex human experience and a symptom numerous medical conditions with anatomic, physiologic, psychosocial, and cultural determinants. Clinicians depend on patients' self-reported information as well as assessments of multiple clinical cues. Although pain is considered an important factor in patient care, few methods are available for objective measurement and assessment of pain. In practice settings, the most common measures available for pain assessment are verbal rating scales, visual analog scales, and numeric rating scales. However, theses self-reporting measures, which come from patients' individual assessments, suffer from high variability. Consequently, objective measurement of pain has long been clinicians' Holy Grail for effective pain treatment and management. In this presentation, we will introduce an objective measurement procedure based on electroencephalograph and two innovative approaches to objective assessment of pain level using machine learning. These findings

may pay the way for providing a direct and objective measure of subjective perception of pain, which help clinicians prescribe correct medications in correct doses and avoid under-treating that can cause physical suffering or over-treating that can lead to opioid dependency.

S2-5 A method for GMA internal magnetic field measurement based on temperature compensation

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A method to measure the magnetic field inside the Giant Magnetostrictive Actuator (GMA) is proposed. Improved Preisach Model is applied to eliminate the unavoidable nonlinearity error in the measurement. The effect of temperature on measurement can be eliminated by double Fiber Bragg Grating (FBG) structure. The double-sagnac loop combined with Polarization Maintaining Fiber (PMF) is used to demodulate the center wavelength. Sensing model of the FBG is established to realize temperature compensation for the measurement system. Experiment results show that resolution of 2.1×10^{-4}T can be achieved over a range of 127 mT, and the repeatability of overall measurement is 0.227%. Therefore, the proposed method can be used to measure the internal magnetic field of GMA effectively and reliably.

S2-6 Precise measurement of large roll angle using digital speckle pattern interferometry

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Recently, a non-cooperative method of roll angle measurement using digital speckle pattern interferometry (DSPI) is introduced. Mechanism was deduced and the mathematic model of roll angle measurement was established. The novel method also enjoys some other advantages, such as high-accuracy, stand-off, non-contact, and full-field measurement. However, this method is only used for precise measurement of very small roll angle which is up to a few milliradians due to the limitation of DSPI's measuring range. In this article, a means of range enlargement for DSPI roll angle measurement is introduced. With this means, large roll angle can be divided into a number of small angles which are measured in sequence. Therefore, the large angle is then determined by calculating the sum of these small angles. The proposed method of roll angle is characterized by high-resolution and large-range measurement.

S2-7 Research on multi-degree-of-freedom and high-precision touch screen characteristic test instrument

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This paper takes the touch screen characteristic test as an example, through the multi-dimensional automatic motion platform, the test pen is driven to move on the touch screen according to the set trajectory. The actual feedback track of the touch screen control board is compared with the previously given track, and the test error is passed. To judge the touch screen's touch sensitivity and linear accuracy. The test system selects the upper computer and the lower computer to control the mode. The upper computer software is used for data acquisition and master control. The upper computer adopts the project database management mode. It can perform the playback analysis and waveform display of the original data of each movement; the lower computer takes The PLC and the three-degree-of-freedom motion

slide, etc., control the entire equipment operation by controlling the PLC and the step controller through the host computer software. Through the management system software, motion data and curves can be displayed in real time, data is stored to the database, and the history is played back.

Session 3 Novel Instrument and Measurement System (1) [8:00-9:50, Aug. 10, 2018, Room 3]

S3-1 Development of optic-electronic autocollimators for monitoring the angular displacements of large objects [Keynote]

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Ways of improving autocollimators for monitoring angular displacements are analyzed. The results of an analysis of control elements based on tetrahedral reflectors with flat and cone reflecting sides are presented. The technical characteristics of experimental models of control elements are presented. The features of tetrahedral reflector as the control elements for three-axis autocollimators are discussed.

S3-2 Research on statistical measurement method of the standard particles through airborne particle counter based on FESEM [Invited]

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The traceability of cleanness parameter has received high attention from the metrology industry of light-scattering airborne particle counter. Based on the metrology method of the big particle concentration and the traceability method of airborne particle counter's counting performance on small particle size by statistical analysis, this paper tries to build a coordinate system of the particle distribution on AAO (Anodic Aluminum Oxide) membrane through the particle counter, choose the statistical sample from the coordinate system by aerodynamics, observe the particles on membrane by FESEM (Field Emission Scanning Electron Microscope), evaluate the uncertainty of measurement on standard particle statistics using the formula of the total particles number on membrane, analyze the measurement uncertainty range and the key affecting factors, and put forward a method of improving standard particle statistics accuracy in test process control. The test results prove that the method has value on improvement of the theory of the cleanness traceability system based on FESEM and statistical analysis.

S3-3 Precision assessment of high-speed railway slab intelligent inspection system [Invited]

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With the rapid development of high-speed railway, there are many problems with the traditional railway slab assessment method. The traditional method is slow, and its precision is limited by the precision of specified tools for railway slab inspection. Scholars have developed a variety of inspection systems for railway slab geometry. Since those systems' precision assessment relies on railway slab testing tools that are complex for operation, this paper proposes a novel method to assess the precision of an intelligent

slab inspection system itself by using the spatial position deviation between the point cloud of a benchmark slab and the corresponding digital 3D model. The proposed method takes the RMSE of the deviation value of points in the key surfaces as the evaluation index. The key surfaces are the two shoulder surfaces and the rail-bearing surface of the rail-bearing platform, which can be extracted by the region growing algorithm associated with surface normals. Based on the real point cloud processed by an intelligent slab inspection system, the experimental results show that the system can align the slab point cloud to its corresponding 3D digital model. The deviation is distributed on the model uniformly, and its precision is 0.1 mm. In addition, this procedure is consistent with that of general slab inspection and can be used as a self-verification tool for daily precision evaluation of the system itself.

S3-4 Absolute distance measurement using synthetic wavelength interferometry of optical frequency combs [Invited]

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We present a synthetic-wavelength based heterodyne interferometer of optical frequency combs with wide dynamic measurement range for absolute distance measurement. The interferometric phase of the synthetic wavelength is used as a mark for the pulse-to-pulse alignment, which greatly improves the accuracy of traditional peak finding method. The dynamic measurement range is enlarged by using long fiber to increase the length difference of the reference and probe arms. The experimental results show the present system can realize an accuracy of 75 nm in 350 mm distance measurement.

S3-5 Single-shot capturing based on polarizing coupled interferometry for phase measurement of cells

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It is well known that the morphological differences of various types of cells in human blood are closely related to various human major diseases. Also, the activity and the original ecological characteristics of the cells play an important role in the follow-up therapeutic efficacy and drug susceptibility. Therefore, finding a detection method for label-free cell intrinsic state in non-invasive conditions has become the key point of research. In this paper, we proposed a method for cells morphological detection based on single-shot interferometric microscopy. In this method, a single-shot interferograms based on polarizing coupled interferometry is captured by a CCD camera. And then the Hilbert transform is applied to achieve phase fast measurement to realize a kind on-contact and on-line measurement with high-accuracy for cells in different dynamic environment (such as in microfluidics). A coverslip with thickness 300μm, polystyrene beads with diameter 20μm and clinical blood cells with diameter about 10μm are examined respectively by our experimental system. The results after the Hilbert transform show that the phase of a coverslip is recovered clearly, which prove that this method is expected to provide an advantageous approach for label-free phase detection of clinical cells in a dynamic environment.

S3-6 A novel miniaturized capacitive absolute angular position sensor based on time-grating with reflective structure

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With the development of portable intelligent instrumentations, the demand for high-precision, absolute-position, low-cost and compact-size angular position sensors has substantially increased. In this paper, a novel miniaturized capacitive angular position sensor based on time-grating, which adopts a reflective structure to realize absolute position measurement and simultaneously achieve high-precision, is proposed. The sensor is comprised of a stator and a rotor both covered with three rings of metal electrodes. The middle ring of the sensor adopts a single-row structure to obtain a high-precision initial travelling signal and reflect it to the stator through the outer ring. The inner loop obtains the final travelling wave signals and initial travelling wave signals varies periodically with a period of 360° when the rotor rotates; thus, this phase difference can be used to realize the coarse absolute position measurement. Phase detection is realized using the time pulses interpolation technology of time-grating, and the angular displacement is measured with time. High-precision absolute angular positioning is achieved through a compact structure. A prototype sensor with an outer diameter of 60mm and an inter diameter of 24mm is fabricated by printed circuit board technique to evaluate the performance. Experimental results show that the proposed sensor achieved a ±3″ measurement accuracy over an entire circumference. Moreover, the rotor is wireless owing to the reflective structure, which has a wider range of applications in engineering.

S3-7 Study on the angular measuring accuracy of the rotary station with varying load

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The varying load may lead to varying deformation of the bearing system of the rotary station. This paper presents the influence mechanism of bearing system deformation on angular measuring deviation. The attachment error due to eccentricity and inclination of the graduation to the bearing was analyzed in numerical simulation. The 1st and 2nd order Fourier components of the angular deviation curves were obtained at the attachment condition of eccentricity and inclination separately. A serial of cross-calibration experiments of an air bearing rotary station with varying load were carried out. The maximum differences obtained between the results of the experiments were 0.4''. These differences were analyzed as well.

Session 4 Novel Instrument and Measurement System (2) [8:00-9:50, Aug. 10, 2018, Room 4]

S4-1 Advanced optical metrology using mode-locked lasers [Keynote]

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Precision is a common aspect that governs most of today's leading-edge technologies including IT, BT, NT and aerospace technology. In response to ever-growing demands on precision, various laser sources have been used to attain sub-wavelength precision in many fields of fabrication and metrology by means of photons. This precision-directed laser-based photonics will continue to advance to the direction of ultraprecision to achieve better resolutions, larger functional ranges, higher throughputs, and more improved stability. Nonetheless, the light sources available today are limited in the wavelength bandwidth, photon energy, spatial and temporal coherence, and peak power, which consequently hinders breakthroughs toward the realm of ultraprecision. The research objective of the Precision Engineering & Metrology Group at KAIST is to investigate the technological possibilities of ultrashort mode-locked lasers with the aim of establishing the new foundations for ultraprecision that will enable nano-fabrication and distance and dimensional metrology over extensive ranges as demanded in the next generation of precision engineering. To the end, a systematic approach will be pursued to generate noble

coherent light sources covering the broad optical spectrum spanning from THz waves, infrared, visible to extreme violet light radiation by making the most of ultrafast femtosecond laser pulses.

S4-2 Infrared lens refractive index measurement using confocal tomography [Invited]

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A infrared confocal refractive index measurement (IR-CRIM) method is proposed for high-precision measurement of the component refractive index of an infrared (IR) lens. Using the property that the vertex of a confocal axial intensity curve corresponds exactly to the focus point of the focusing beam, IR-CRIM tomography focus the front and back vertices of the test lens to obtain its optical thickness d, and subsequently uses this measured d together with a ray-tracing algorithm to calculate the lens refractive index n. Preliminary experimental results and theoretical analyses indicate that this technique achieves an accuracy of 6×10^{-5} in the wavelength of 1064nm. IR-CRIM provides a novel approach for the high-precision, non-contact, and convenient measurement of the refractive index of an IR lens.

S4-3 Method for high-precision distance estimation and dispersion mismatch compensation in frequency scanning interferometry [Invited]

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The long fiber frequency sampling method has been widely used to eliminate the nonlinearity of laser tuning in the frequency-modulated continuous wave laser ranging technique. Then, fast Fourier transform (FFT) is performed on the resampling signal to obtain the distance spectral information. However, due to the picket fence and leakage of FFT-based methods, it is hard to find the precise location and achieve better range precision. In this paper, we propose a novel frequency estimation method, multiple signal classification (MUSIC), to be used instead of the conventional fast Fourier transform (FFT)-based algorithm to obtain better range precision. In addition, the induced-fiber dispersion could also lead to poor accuracy and precision in the large-bandwidth and long-distance measurements scenes. To solve this problem, a phase compensation method for resolution-enhancement is proposed.

S4-4 Cell traction force measurement in a large field of view based on the Moire fringe method

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This paper reports measuring contractility of neonatal rat ventricular myocytes (NRVM) using a novel cell force sensor, namely, a double-sided micropillar array (DMA) developed for both single cell force measurements using conventional microscopy as well as high-throughput cell force mapping based on the optical moiré effect. The contraction force map of NRVM cultured on DMA was acquired with nanonewton and submicron scale resolution using confocal microscopy. For the moiré-based method, the local average of the cell contraction force was derived from the moiré pattern, which allows mapping cell contraction force using a 20X objective lens, enabling the acquisition of a larger field-of-view than conventional microscopy.

S4-5 Modified short-wave offner imaging spectrometer with low F number and large field of view

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Dyson and offner are two typical concentric imaging spectrometer configuration with dual telecentricity in object and image space, a small F number, low smile and keystone etc. In some condition such as Ocean color remote sensing, the imaging spectrometers require small F number to obtain higher luminous flux. However, when F number is small, off-axis aberration becomes larger. In short-wave infrared waveband, the spectral response band of the selected visible detector is 3.7~4.8μm with 640×512 pixel numbers and 15×15μm pixel size. When F number is 2.0, we select fused silica as material of the plano-convex lens, and use traditional two-wavelength astigmatism method to design the visible imaging spectrometer based on Dyson configuration. In resulting Dyson spectroscopic imaging system, the plano-convex has a thickness of 130.922mm.

S4-6 Torque standard machine for calibration of reference torque wrench and torque transducer at NIM

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The paper describes a new torque standard machine at NIM. The new reference torque standard machine is designed to calibrate the reference torque wrench and torque transducer. The relative expanded uncertainty of this torque standard from 10Nm to 5000Nm is better than 5×10^{-4} (k=2). The calibration experiment of three kinds of reference torque wrenches by the new reference torque standard machine is described in the paper.

S4-7 Dual-comb generation from a dual-ring hybrid mode-locked fiber laser

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Dual-comb generation with bidirectional fiber ring laser is highly prospective for its compactness and coherency. In this paper, we propose a dual-ring hybrid mode-locked fiber laser for dual-comb generation. The dual-ring laser contains elements of hybrid mode-locking for each sub-ring individually, while sharing the bidirectionally pumped erbium-doped fiber (EDF). The hybrid mode-locking is realized by transmission semiconductor saturable absorber (SESA) and nonlinear polarization evolution (NPE). With the help of two three-port optical circulators, non-ideal reflection of two SESAs are eliminated. Accordingly, two series of short pules are generated in each sub-ring with different direction individually. Experimental observations and analyses demonstrate that dual comb of about 300 kHz difference in repetition rates are generated by inserting a 10 cm cavity length difference between the two sub-rings. With the help of hybrid mode-locking and large power bidirectional pumping, the mode-locking of dual combs are stable and self-starting.

Session 5 Modern Optics and Instruments for Precision Measurement (1) [10:25-12:00, Aug. 10, 2018, Room 1]

S5-1 Removal of opaque coolant barrier for in-process form profile optical

measurement [Keynote]

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In this paper, models of the proposed methods are introduced together with the working principles and the key features of the four methods. New in-process form profile optical measurement systems are developed, which are capable of measuring workpiece surface $y(x, z)$ at high precision under coolant condition. Measurement system performance tests are presented. Coolant removal capabilities of the four methods and performance enhancements are also discussed. Experimental results show that workpiece surface $y(x, z)$ can be measured successfully with the standard deviation up to 0.301 μm even under a massive amount of coolant where the coolant thickness is 15 mm. This means a relative uncertainty of 2σ is up to 4.35% and the workpiece surface is deeply immersed in the opaque coolant.

S5-2 Process optimization: internal feature measurement for additive-manufacturing parts using X-ray computed tomography [Invited]

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X-ray computed tomography (CT) is a non-destructive approach to verify internal features of various industrial components built by additive manufacturing (AM) or other processing methods. The respective dimensional measurement was highly impacted by numerous factors. In this study, DoE (Design of Experiments) was conducted to statistically study impacts of error source of X-ray CT metrology; optimal settings were recommended for different internal geometrical features. By applying the optimal settings, experimental data showed that the accuracy of X-ray CT measuring AM internal features was significantly improved.

S5-3 Optical fiber sensing techniques and its applications [Invited]

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Optical fiber sensors have their advantages of slender and light, anti-electromagnetic interference, corrosion resistance, and composite implantable. Especially, it supports a variety of encoding multiplexing, multiple parameters, and programmable, self-detection, easy to realize large scale, high density, multi point network and distributed measurement. Optical fiber sensing has become a hotspot in many international research fields. In this presentation, we will describe the characteristics and the development of optical fiber sensing. It will be followed by the fundamental sensing principle. We will also describe and summarize the fiber sensing application and the key technology, especially on aerospace vehicles. And then we conclude with our research and the future aspects of optical fiber sensing technology.

S5-4 Development of chromatic dispersion lens for chromatic confocal microscopy

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Chromatic confocal microscopy (CCM) has been widely applied in industry, medicine and other research

fields. Compared to traditional laser scanning confocal microscopy (LSCM), CCM focuses on the relationship between displacement along the optical axis and wavelength of light source. Thus, the optical element of axial chromatic dispersion is the key device in CCM. Unfortunately, the relationship of the axial chromatic dispersion versus the wavelength is not linear, and the chromatic dispersion range is fixed in generally. In this paper, a novel chromatic dispersion lens, which is named tube lens (TL), was designed to solve the problems mentioned above. The function of TL was to generate a large and linear chromatic dispersion along the optical axis; and a replaceable objective was added to control the chromatic dispersion range. Both the simulation and the experiment results indicated that the chromatic dispersion range modulated by TL and replaceable objective was variable; and the most important thing was the nonlinearities of these chromatic dispersions were almost all better than 1%, which was highly linear. Thus, the designed TL could be fit to versatile measuring demands.

S5-5 Evaluation of the diffraction correction during the 10th International Comparison of Absolute gravimeters (ICAG 2017)

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In this paper, we present a fast and automatic measurement of beam waist diameter by an automatic M^2-measurement instrument named CinSquare, which is manufactured by CINOGY Technologies GmbH. CinSquare is a compact and fully automated system to measure the beam quality with related outputs such as M^2, beam waist diameter and beam waist position. This system consists of a fixed focusing lens in front of a motorized translation stage and the beam is received by a CCD beam profiler. The beam is first focused by the lens and then measured by the beam profiler with several beam profiler along the beam caustic. Finally the beam waist diameter is acquired by a hyperbola fit to these data, where new developed algorithms are used to ensure high accuracy for beam quality measurements.

S5-6 Design of optical accelerometer using four-quadrant photodetector

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Low-frequency vibration is a harmful factor that affects the accuracy of micro/nano-measuring machines. Low-frequency vibration cannot be completely eliminated by passive control methods, such as the use of air-floating platforms. Therefore, low-frequency vibration must be measured before being suppressed actively. In this study, the design of a low-cost high-sensitivity optical accelerometer is proposed. This optical accelerometer mainly comprises three components: a seismic mass, a leaf spring, and a sensing component based on a four-quadrant photodetector (QPD). When a vibration is detected, the seismic mass moves up and down due to the effect of inertia, and the leaf spring exhibits a corresponding elastic deformation, which is amplified by using an optical lever and measured by the QPD. Then, the acceleration can be calculated. The resonant frequencies and elastic coefficients of various seismic structures are simulated to attain the optimal detection of low-frequency low-amplitude vibration. The accelerometer is calibrated using a homemade vibration calibration system, and the calibration experimental results demonstrate that the sensitivity of the optical accelerometer is 4.92 $V/(m \cdot s^{-2})$, the measurement range of the accelerometer is 0.0095~2.58 $m \cdot s^{-2}$, and the operating frequencies range from 5 Hz to 15 Hz. The efficacy of the optical accelerometer in measuring low-frequency low-amplitude dynamic responses is verified.

Session 6 Sensors, Actuators and Application (1) [10:25-12:00, Aug. 10, 2018, Room 2]

S6-1 Recent research advance in EMI shielding transparent conductors [Keynote]

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The rapid development of information technology, especially the rapid rising of modern electronics and wireless communications has created significant electromagnetic energy in the earth environment. The ubiquitous electromagnetic waves can cause unacceptable malfunction of electronic equipment used in a wide range of industrial and commercial applications, and it is reported that long-term exposure in the intensive radiation environments may cause several health hazards for human beings. Therefore, electromagnetic energy pollution attracts more and more attentions from all of the world and electromagnetic interference (EMI) shielding become an important issue in many fields. Optical element is a special case for EMI shielding because the high optical transparency and strong shielding is hard to trade off. Transparent conductors including commercial indium tin oxide (ITO) films, metallic meshes, networks and nanowires, carbon-based nanomaterials have attracted much attentions as promising materials in transparent EMI shielding area. In this paper, we focus on the introduction of recent research advance in EMI shielding transparent conductors constructed by metallic meshes and stacked graphenes.

S6-2 Research and application of a novel randomly encoded hybrid grating interferometric wavefront sensor [Invited]

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In this paper, a novel randomly encoded hybrid grating (REHG) interferometric wavefront sensor with the features of high-precision, high-resolution, high-dynamic-range and anti-vibration is proposed. The REHG consists of a randomly encoded binary amplitude grating and a phase chessboard. The far filed Fraunhofer diffractions only contain ±1 orders in two orthogonal directions. Different from the cross grating lateral shearing interferometer (CGLSI), there is no need of order selection mask for quadriwave lateral shearing interference. Without the influence of periodical Talbot effect, a continuously variable shear ratio can be obtained with the REHG, which makes it possible to control the dynamic range and measurement sensitivity of the wavefront sensor. A high-precision calibration method for shear ratio based on the shearing wavefront feature extraction and the generalized wavefront retrieval algorithm are employed to ensure the accuracy of the wavefront measurement results. The REHG wavefront sensor can work in collimated beam and convergent beam modes. Due to self-referenced and common-path characteristics, the REHG wavefront sensor can applied to different application fields in situ. Compared to the ZYGO interferometer, the results of the optical aberration and spherical surface measured by the REHG are highly precise and also show good repeatability. By applying two REHG wavefront sensors with different shear ratio, a wideband sensitivity-enhanced interferometric microscopy with real-time visualization can retrofit existing bright-field microscopes into quantitative phase microscopes.

S6-3 Dielectric micro-sphere measurement using whispering gallery mode resonances [Invited]

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Calibration is necessary process for the dimensional metrology such as microcoordinate measurement. A sphere is frequently used as a reference for calibration in the 3-dimensional metrology because of its isotropic shape. Assuring an accuracy of the reference sphere is responsible for measurement uncertainty of 3D metrology. For micro-scale 3D metrology, size of the reference sphere is also micro-scale from several hundred micrometers to a few tens of micrometers, which has to be measured with accuracy of better than 10 nm. Therefore, we proposed the new measurement principle of a diameter for the micro-scale sphere to achieve 10 nm of the measurement accuracy. As a measurement principle for the diameter of a microsphere, the new method using whispering gallery mode (WGM) has proposed. WGMs are the light propagation mode inside a sphere, where the light propagates along with a equatorial line. When an integer multiple of the wavelength of the propagating light is equivalent to the circumference of the

sphere, the light resonates, which is so-called WGM resonance. Based on the resonant wavelengths (WGM wavelength), it is possible to estimate the length of circumference, that is, the diameter of the sphere.

S6-4 Micro-LED optical engine with biologically inspired artificial compound eyes for pico-projection display [Invited]

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Light emitting diodes (LEDs) have recently gained much interest as projection light sources. In this work, a compound parabolic concentrator (CPC) coupled to a biologically inspired compound-eye array is designed and fabricated as a light collection engine of a pico-projector. The results indicate that more than 90% light emitted by a monolithic LED array can be collected by the CPC coupled to a compound-eye array and transmitted within the designed angle. This method is advantageous in many respects compared with those available, such as compact volume, high collection efficiency, rectangular radiation pattern and controllable output divergence angle. The result validates that the system reaches a collection efficiency of 87% of micro-LED emitted light. Moreover, the beam collimation quality has been analyzed obtaining a residual divergence of less than 2°. Thus, the results achieved by the proposed optical system improve those obtained with several commercially available devices.

S6-5 Analysis of contracting characteristics on aerostatic bearing stylus displacement sensor

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In this paper, the dynamic and static contact characteristics of the aerostatic bearing stylus displacement sensor are analyzed, including static contact damage and dynamic response. The dynamic response at frequency and different speeds is studied and obtained the relationship between the measured force and frequency and velocity. The stylus does not contact well from the surface when the measuring force is less than 0. In this case, the traceability of the tip can be analyzed based on the characteristics of the amplitude. Finally, the experimental verification of the relevant theory is obtained by measuring the aluminum turning sample at different speeds.

S6-6 Complicated intermittent scratches detection research on surface of optical components based on adaptive sector scanning algorithm cascading mean variance threshold algorithm

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In inertial confinement fusion system, the intermittent scratches on the polished surface of single-sided polished and bottom surface frosted optical components are complex, and it's of great difficulty to extract them completely. In order to solve this problem, established in the light-field surface detection system, this paper brings forward a novel intermittent scratch detection method based on adaptive sector scanning algorithm (ASC) cascading mean variance threshold algorithm (MVTH). In the preprocessing step, dividing the original image into subimages with a number of integer multiple of cores so as to fully compress image processing time utilizing parallel processing, using mean filter to balance background and then obtaining binary subimages utilizing morphology and threshold operations, finally, utilizing

Two-pass algorithm to label the connected domains of binary subimages. In the detection step, considering the complexity of the pattern of intermittent scratches, ASC is first used for routine intermittent scratches stitching and then supplemented by MVTH. In the verification step, in order to prove that the detected intermittent scratches satisfy the criteria for scratches in human eyes, the method of support vector machine (SVM) pattern recognition is utilized to compare the detected results with the continuous scratch samples detected by human eyes. This algorithm has high degree of parallelism, high speed and strong robustness. The experimental results illustrate that the complete extraction rate of intermittent scratches is 93.59% , the average processing time of single image is merely 0.029 second and the accuracy rate of detection is up to 98.72% by SVM verification.

Session 7 Micro and Nano Metrology, Macro Metrology [10:25-12:00, Aug. 10, 2018, Room 3]

S7-1 Ultrasonic array for NDT using total focusing method imaging algorithm [Keynote]

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In recent years, the use of ultrasonic arrays for non-destructive evaluation (NDE) has been revolutionized by using of full matrix capture (FMC) which records the time-domain signals associated with every possible transmitter-receiver element combination. Under FMC, all beam-forming takes place in post-processing, allowing very sophisticated imaging and defect characterization techniques to be employed, e.g., Total Focusing Method (TFM). In TFM, for a FMC array data set captured using an immersion inspection configuration, by exploiting reflections off geometric features, mode conversions at interfaces, and using different paths for transmitted and received waves, images showing multiple different views of the same region can be generated. In this lecture, the concept of FMC and TFM is first introduced, the development of FMC/TFM relevant techniques for structure inspection in recent years are then presented through the examples of inspecting specimens with various surface geometries. Finally, future directions and barriers for the technology will be examined.

S7-2 Measurement and sensing for graphene and 2D materials by microwave resonance [Invited]

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At NPL we are developing a non-contacting microwave resonance technique, able to directly measure the conductivity and therefore the two dimensional sheet resistance of graphene films, within a range from a few ohms to one megohm or more. Because this is a high speed and contactless method it is proving highly useful for quality control measurements on graphene and is particularly well suited to on-line and roll-to-roll quality control. We have demonstrated that the non-contact sheet resistance measurements, each of which takes less than 100ms, with uncertainty better than 1% and, in comparison with conventional van der Pauw contact measurements, the agreement is better than 5%.

Developing from our microwave resonator system for large area graphene measurement we have also demonstrated a Near-field Scanning Microwave Microscope (NSMM). A quarter-wave coaxial dielectric microwave resonator has a sharp tip (with a radius of only a fraction of a micrometre) attached to the centre conductor. This is brought close to the surface of the graphene and the proximity of the graphene influences the Q of the microwave dielectric resonator. By scanning across the surface of the graphene we can probe the local conductivity of graphene, on the length scale of around a micrometre. It provides a powerful method for understanding how the local properties are affected by impurities, defects etc. The conductivity variations could be compared with Raman microscopy scans as well as scanned probe microscopy (atomic force microscopy (AFM) and scanning Kelvin probe microscopy (SKPM) to test the correct assignment of layer number for the graphene and to test for strain in the deposited films.

In addition, we have developing the microwave method for sensitive traced gas detection using graphene film. The exposed nature of the graphene surface makes the electrical properties very sensitive

to functionalisation by gaseous molecules. This means it may be used to detect trace concentration of polluting gases such as nitrogen dioxide or ammonia. Our microwave technique can allow gas sensors to be realised without the need for film patterning or electrical contacts. We have demonstrated tens of parts per billion sensitivity with this method.

Our microwave dielectric resonator technique is proving useful across a number of graphene areas but also has potential applications for measurements of thin conducting or semiconducting films, with future implications for fast reliable metrology in the semiconductor growth and fabrication industries.

S7-3 Novel double-FBARs-on-beam for PZT micro-accelerometer [Invited]

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Thin film bulk acoustic resonator (FBAR) combined with silicon based inertial force sensing structure can construct high-frequency MEMS resonant accelerometer. Finite element simulation is used in this paper by COMSOL Multiphysics. In order to improve the sensitivity of FBAR, three kinds of piezoelectric materials including PZT, ZnO, and AlN are compared. And the quality factor Q simulation results show that the FBAR of the PZT piezoelectric material has the highest Q value. In addition, a novel double-FBAR-on-beam micro-accelerometer is designed based on PZT piezoelectric material. The resonant frequency, vibration mode, impedance curve and quality factor of the structure are obtained through simulation. Moreover, the temperature and stress compensation characteristics of the series double FBAR are discussed. The FBAR differential synthesis method is used to establish the simulation model of the FBAR stress resonance frequency shift characteristic analysis, and the relationship between the material stress and the change of the FBAR resonant frequency is obtained. The a-Δf sensitive characteristic curve of the FBAR accelerometer is fitted through the simulation data. Finally, the MEMS preparation process of the double-FBAR-on-beam micro-accelerometer is presented.

S7-4 Applications of wavefront modulation devices in aspheric and freeform measurement [Invited]

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Wavefront modulation devices are of great significance in optical information processing systems. These devices capable of phase modulation are used in a variety of optical applications: wavefront correction, optical metrology, adaptive optics, aberration compensation, etc. The liquid crystal spatial light modulators (LC-SLMs) and deformable mirrors (DMs) have been regarded as the promising device for their flexibility and programmability on wavefront modulations. This paper presents applications of LC-SLMs and DMs when they are used as aberration compensators in testing of aspheric and freeform. Besides, a pixel-wise method based on analysis of the phase maps obtained by a Fizeau interferometer for calibrating the phase modulation characteristics of the LC-SLM is proposed. A PLUTO-VIS-020 LC-SLM produced by the Holoeye Company is employed in the calibrating experiment. A Zygo interferometer based on Fizeau interference theory is also employed. The experimental results demonstrate that the phase modulation characteristics of LC-SLM and a specific lookup table (LUT) for every pixel of the LC-SLM aperture can be obtained by utilizing the proposed method with convenience and high efficiency. The device calibrated in this paper provides a high phase shift up to 6π at 632.8nm wavelength and has a linearized phase distribution. It coincides well with the average modulation curve offered in the manual of the device. This paper provides a simple and accurate method for pixel-wise phase modulation characteristics calibration.

S7-5 A measurement method for probe microsphere of micro-CMM with double SPMs

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Probe tip of the Micro-coordinate Measuring Machine (Micro-CMM) is a microsphere with diameter of several hundred microns, and its sphericity is generally controlled at tens to hundreds of nanometers. Due to the small size and high precision requirement, the measurement of the microsphere morphology is difficult. In this paper, a measurement method for probe microsphere of Micro-CMM is proposed based on two SPM (Scanning Probe Microscope) probes, and a ruby microsphere of a Renishaw commercial CMM stylus is measured by the proposed method. In the experiment, the repeatability error of a maximum section profile is test, and the repeatability error is 41 nm (peak-to-peak value). Two perpendicular maximum section profiles are measured, and the corresponding diameter and roundness are estimated by the least squares method.

S7-6 Investigation on the dynamic characteristics of CG-6 relative gravimeter for the micro-gravity network gravimeter for the micro-gravity network

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CG-6 is a new generation of full-automatic relative gravimeter produced by Scintrex Company, Canada. It can be used to measure the vertical gravity gradient accurately. This paper mainly addresses dynamic precision analysis of the vertical gravity gradient measurement based on CG-6 gravimeter. We analyze the repeatability and consistency of several CG-6 gravimeters in dynamic test. The static and dynamic experimental data based on the four number of CG-6 gravimeters show that the dynamic precision of this instrument is better than $3\mu Gal \cdot h^{1}$. The static zero drift rates are all less than $3\mu Gal \cdot h^{-1}$. One of the CG-6 gravimeters has been used to monitor the NIM (National Institute of Metrology, China) local gravity network, especially in monitoring the vertical gravity gradient. We should consider the evaluation of dynamic performance of CG-6 gravimeters and

Session 8 Laser Measurement Techniques and Instruments (1) [10:25-12:00, Aug. 10, 2018, Room 4]

S8-1 Weyl degeneracies in topological metamaterials [Keynote]

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Metamaterials have attracted tremendous attention due to their exotic optical properties and functionalities that are not attainable from naturally occurring materials. In particular, metamaterials can be designed to introduce strong spin-orbit coupling for light and consequently nontrivial topological properties. In this talk, I will start with a brief introduction to the concepts of Berry curvature, Chern number, Weyl degeneracies, and topological photonics. I will show that combination of chirality and hyperbolicity — an extreme form of anisotropy, can result in nontrivial topological orders in metamaterials and consequently topologically protected photonic surface states that are immune from scattering by defects and sharp edges. The Weyl points in such systems result from the crossing between the bulk longitudinal plasmon mode and the transverse circularly polarized propagating modes. The photonic ‘Fermi arcs’ were directly observed in the microwave regime.

S8-2 The advance of laser precision measurement instrumentation in the Academy of Opto-Electronics, Chinese Academy of Sciences [Invited]

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The research and development advance of laser precision measurement instruments in the academy of Opto-Electronics, Chinese Academy of Sciences is presented. The instruments mainly include femtosecond laser tracker, distance ranger based on femtosecond optical comb, multi-reading head precision goniometer, 6 DOF laser tracker, automatic alignment system for rail inspection, Lidar, etc. Some key technologies will be addressed and solutions will be proposed.

S8-3 Energy analysis method of the laser tracing measurement optical system [Invited]

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This paper proposes an energy analysis method of the laser tracing measurement optical system. Based on the principle of the laser tracing measurement optical system, an energy model is established to analyze the effects of non-ideal optical elements on the energy of the optical system. The simulation results show that the interference pattern is the most obvious when the split ratios of the beam splitters in the interference part and the tracing part are respectively 6:4 and 7:3. Under the above split ratios, the interference signal energy values of four receivers are close to each other and the visibility of fringe pattern reaches 0.99. The visibility of fringe patterns of four interference signals is reduced when the reflectivity of all polarization beam splitters is under non-ideal conditions in an entire optical system. The non-ideality of the transmittance of the polarization beam splitters does not affect the visibility of fringe patterns. The paper provides the theoretical basis for the accuracy improvement, reliability evaluation, optical system design and the selection of optical elements of laser tracing measurement systems.

S8-4 All-fiber Fabry-Perot interference structure: key technology and its applications

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With the rapid development of modern science and technology, nondestructive testing (NDT) has been widely used in aerospace, nuclear energy, petrochemical and mechanical manufacturing industries, thus playing a key role in controlling and improving the product quality. Compared to other NDT technology, optical fiber devices have many advantages including light weight, small size, easy fabrication, corrosion resistance, electromagnetic immunity and high sensitivity. Currently, fiber optic devices are widely used for measuring physical parameters including strain, temperature, refractive index, pressure, torsion, and so on. Fabry-Perot interference structure is a classic optical mode with two reflective surfaces fabricated by various technologies. Since the interference happens when two light beams reflect back successively after arriving at two surfaces, its reflection spectrum are mainly used for signal demodulation. This talk explores the key technology and wide applications of all-fiber Fabry-Perot interference structure, and our experimental results have demonstrated its great potential as an emerging integratable component for high sensitive, ultra compact, and flexible multi-parameter measurement towards biomedical applications.

S8-5 Development of hybrid measuring system for the complex micro-arrayed surface

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As the ultra-precision machining technology developing in various directions and evolving into a higher level, the micro/nano measuring technology is also developing constantly. The measurement requirements of micro/nano measurement technology varies with different manufacturing processes and materials. Optical Microscopy (OM), Scanning Probe Microscopy (SPM) or Scanning Electron Microscopy (SEM) are not able to meet the requirements of high efficiency, high resolution, and three dimensional morphology characteristics obtaining at the same time. Hence a kind of hybrid measuring system is constructed which contains the Atomic Force Microscopy (AFM) and vertical scanning white-light interferometry. The measurement function of AFM is verified through scanning a one-dimensional grating. In comparison with the 3D contour instrument's measurement results on a step structure, the vertical scanning white light interference shows good measuring function. The micro-arrayed structure's surface was measured by white light vertical scanning, in the same coordinate system, the vertex of the microarray cell structure is scanned with AFM. This experiment verifies the complex measurement function of the system on the complex surface with micro-arrayed structures.

S8-6 Kinematics identification and measurement accuracy verification of articulated arm coordinate measuring machines

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The Articulated Arm Coordinate Measuring Machine (AACMM) is a kind of coordinate measuring device in the form of an articulated robot. To improve the accuracy of AACMM, a kinematic identification method is presented in this paper. Firstly, we perform the kinematics modeling and simulation to realize the kinematic transformation from the joint space to the coordinate space. Then, we establish an error model and use least squares method to identify kinematic parameters. And the effectiveness of the least squares method for kinematic parameter identification is studied. Finally, the experiments of single point repeatability accuracy and the standard gauge accuracy are performed. The experimental results show that proposed the kinematic identification method can effectively improve the measurement accuracy of the joint coordinate measuring machine.

Session 9 Instrumentation Theory and Methodology (2) [13:30-15:05, Aug. 10, 2018, Room 1]

S9-1 Displacement laser interferometry with sub-nm or deep sub-nm accuracy [Keynote]

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Based on Michelson interference principle, the homodyne or heterodyne laser interferometry has the advantages of direct traceability, high resolution, long range and high accuracy up to several nanometers. Laser Interferometry has already been widely used in the field of ultra-precision manufacturing. It plays important roles in manufacturing/metrology equipment. Recently, driven by the cutting-edge industries and astronomy, there are demands for next generation interferometry with sub-nm or deep sub-nm accuracy.

According to the error budget of laser interferometry, the key issues in developing next generation laser interferometry are enhancing laser wavelength accuracy, decreasing periodic error, enhancing phase resolution, etc. Over the past few years, our research group has conducted in-depth study on next generation laser interferometry. Firstly, with a water-cooling offset frequency locking method, the relative laser frequency accuracy/stability has been enhanced to 4.2×10-10. Secondly, we have built heterodyne interferometers with spatially separated beams, in which the periodic nonlinearity error is under several tens of pico-meter. Lastly, different phase evaluate methods have been studied and

optimized to achieve phase resolution as high as several pico-meter.

S9-2 All-optical difference engine for in-process defect inspection for roll-to-roll printed electronics [Invited]

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The increasing capabilities of roll-to-roll (R2R) printing processes present challenges for quality control, requiring in-process inspection of large substrates with high resolution at high speed. In this paper, an all-optical difference engine (AODE) sensor has been developed for in-process defect inspection for R2R printed electronics. The AODE sensor achieves high-speed inspection by utilising the principle of coherent optical subtraction to minimise data processing. The capability of the developed sensor is demonstrated using industrial printed electrical circuity samples and the sensor is capable of inspecting areas of 4 mm width with a resolution of the order of several micrometres.

S9-3 Development of auto defect inspection system for cell phone silicone rubber gasket [Invited]

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This paper proposes a machine-vision-based system for the inspection of the geometrical features of cell phone rubber gaskets. The system consists of two industrial cameras and an industrial computer. To begin the inspection process, the cell phone gaskets inside the camera field were identified and a novel transparent fixture were employed to guide the lighting to highlight the defects. To characterize the metrological features of cell phone gaskets, image preprocessing procedure was then implemented and defect classification algorithmic strategies was described in detail. Finally, experimental results on images of different type of the cell phone gaskets are reported together with the metrological classification of the proposed measurement system. The geometrical quality of every individual silicone rubber gasket, which could be evaluated and guaranteed to the full grade of assessment which the proposed system can achieve.

S9-4 Measurement on deionized water density based on single silicon sphere

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Due to good stability, deionized water is usually used as reference material for liquid or solid density measurement. It is very important to determine the density of deionized water under different temperature. The most common method is by using fitting formula, such as Tanaka Equation. However, almost all the fitting formula is for pure water or SMOW. It is necessary to carry out research on the suitability of these formulas for deionized water. Hydro weighing method is used to measure the density of deionized water, which is based on Archimedes's principle. One 93mm single silicon sphere is used as solid density reference, and the sphere density is determined by XRF method and high-accuracy comparator.

S9-5 A novel signal process system for angular displacement sensor of time-grating

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The angular displacement sensor based on time-grating is a novel kind of displacement sensor, but there is a limitation in some applications with harsh environment owing to extracting angular information uses the analog phase detector. To reduce the error comes from solution and improve the static stability of sensor, a novel signal process system is presented. In comparison to the traditional method using analog electrical technology to obtain angular displacement, the proposed method uses the All phase Fast Fourier transform (AP-FFT), that has a perfect performance on suppressing the spectrum leakage and the property of phase invariant, to obtain the phase angle. In the paper, we design the core system for data sampling and processing. Firstly, it utilizes AP-FFT to transform the sensing signal from time domain to frequency domain; in addition, the angle is calculated in the phase spectrum. Finally, the experimental platform is designed to verify the performance of the proposed technique. The error of the novel method is compared to that of the traditional method, it can be concluded that the proposed method is very effective in suppressing noise and enhances the stability in a static condition.

S9-6 Design and simulation of a 2-DOF parallel linear precision platform utilizing piezoelectric impact drive mechanism utilizing piezoelectric impact drive mechanism

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With rapid developments of micro/nano science and technology, precision platforms are widely required in the research and industry fields. This paper presents a 2-DOF parallel linear precision platform utilizing piezoelectric impact drive mechanism. With symmetrical flexible structure and specific piezoelectric driving manner, effective and decoupled actuation of the stator is achieved. FEA simulations are conducted to investigate the characteristics of the stator. With established dynamic model of the platform, motion responses of stator and slider in the two directions are simulated and analyzed. With simultaneous actuation of the 2-DOF motions, a motion interaction phenomenon is raised and discussed.

Session 10 Instrument and Measurement System Calibration (1) [13:30-15:05, Aug. 10, 2018, Room 2]

S10-1 Dealing with systematic effects in measurement uncertainty calculations [Keynote]

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Systematic measurement deviations are unavoidable in principle. They change the expected value of the measured quantity under consideration and increase its standard measurement uncertainty. Concerning systematic effects the Guide to the expression of uncertainty in measurements (GUM) has very little to offer. In this presentation will be shown, how to deal with systematic effects by using the Bayesian theory of measurement uncertainty. A procedure to calculate the values of the best estimate of a known systematic error and its associated uncertainty based on the available information will be given. It will be outlined, how the product rule of probability theory, Bayes' theorem, the marginalisation equation and the principle of maximum entropy can be used to obtain the probability density functions involved. The application of the proposed procedure is demonstrated by the effect of thermal expansion in length measurement as an example.

S10-2 Advanced measurement of super-smooth surface [Invited]

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In this paper, the high accurate testing method using odd-even function is introduced. Experimental results are achieved by using commercial interferometer. The results verify the effectiveness of this method and shows the possibility of eliminating the system error of the interferometer and the flatness error of the reference surface. The accuracy of the absolute measurement is reached at $\lambda/100$ PV and repeatability at λ /1500 RMS. Based on this method, many other high accurate functions have been expanded, for example the homogeneity of glass materials, the 90° error of right angle prism and corn cube.

S10-3 Dual-comb ranging [Invited]

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Absolute distance measurement is essential for high-accuracy manufacturing and assembling. Dual-comb ranging is an emerging tool that exploits phase resolution and frequency accuracy for precise and fast distance measurement. Using two coherent frequency combs, dual-comb ranging allows time and phase response to be measured rapidly. It breaks through the limitations related to the responsive bandwidth, ambiguity range, and dynamic measurement characteristics of conventional ranging tools. In this talk, I will introduce dual-comb ranging and summarizes the key techniques for realizing this ranging tool. Firstly, I will introduce TOF-based dual-comb ranging, including principles of system and parameter optimization, and then discuss the synthetic wavelength interferometry and carrier wave interferometry in a dual-comb ranging system in the absence of phase noise and intensity noise. Consider that dual-comb ranging must contend with finite linewidths, comb drift, and intensity fluctuations, I discuss these noise sources and methods for realizing a low-noise dual-comb ranging system. As optical frequency comb technology progresses, dual-comb ranging is promising for various applications.

S10-4 The optical-electronic autoreflection sensor for angular deformations measurement

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The construction features of autocollimation systems for measurement the large-sized and extended objects deformations at industry, power and scientific instrument making are considered. The conditions of increase of a distance of measurement are analyzed in comparison with the serial autocollimation devices. The error of measurement by the restriction of a working beam is investigated. The structure of algorithm for reduces the systematic error of the measurement which based on received analytical expression of function of an error is determined.

S10-5 In-line optical fiber Mach-Zehnder sensor fabricated by CO2 laser and its applications

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The Mach–Zehnder interferometer (MZI) is a device used to determine the relative phase shift variations between two collimated beams derived by splitting light from a single source. Compared to the traditional MZI based on spatial light path or double fiber coupler cascade, all-in-fiber MZIs are particularly notable for its stability, low loss, and multiplexing capability, which are useful components in a variety of optical applications, including optical modulation, signal processing, and physical, chemical, and biological sensing. A compact in-line optical fiber MZI sensor is proposed and experimentally demonstrated. The fabrication mechanism of the optical fiber microstructures by CO2 laser are described in detail. The sensor with symmetrical structure is fabricated by splicing a segment of seven-core fiber and two fiber balls. The mode field of the fiber ball used in our experiments close to the region of hexagonally distributed fiber cores of the SCF, which help to obtain a high coupling efficiency. A clear interference spectrum of the proposed MZI is obtained by injecting a broadband light into a lead-in single mode fiber. Such an MZI could be used to realize the measurement of temperature, curvature, displacement and magnetic, et al.

S10-6 A novel earth's gravity method for accelerometer calibration

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Advanced low frequency vibration calibration is imperative required as the wide applications of low frequency accelerom-eters. Low frequency calibration is commonly realized by the Earth's gravity method or the laser interferometry. However, affected by the limited stroke of the standard vibration shaker, the calibration precision of laser interferometry at very low frequency is usually not ideal. Although the Earth's gravity method can avoid this low calibration precision at very low frequency, its calibration frequency usually <5Hz due to the influence of rotator centripetal acceleration. In this paper, the Earth's gravity method mentioned in ISO 16063-16 is improved by using an effective image feature detection method. This method detects the angel between Earth's gravity field direction and acceleration sensitivity axis direction to improve the Earth's gravity static calibration accuracy.

Session 11 Signal Processing and Image Processing [13:30-15:05, Aug. 10, 2018, Room 3]

S11-1 Ultraprecision 3D non-contact probing for measurement of micro-structure with high aspect ratio [Keynote]

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In order to make ultraprecision dimensional and profile measurement of small structures with high aspect ratio possible, a 3D probing method based on spherical capacitive effect is proposed for 3D non-contact probing with nanometer resolution. A spherical capacitive probe with identical sensing characteristic in any arbitrary spatial direction is used to convert the micro gap between the plate and the part being measured into a capacitive signal. Most of the electric lines of force of the spherical capacitive plate concentrate within a small region between the plate and the part being measured, so that the properties of 3D non-contact probing, isotropy characteristics, approximate point sensing and measurability of small structures with large aspect ratio are effectively combined in the proposed probing method. Experimental results indicate that with a 3 mm spherical probing head and a stylus with aspect ratio of 46:1, the probing system has a measurement range of 10 μm and a resolution better than 1 nm. With nonlinearity corrected, its residual nonlinear error is less than 10nm in the full measurement range. A series of probes has been fabricated and tested, and the results show that the resolution of the probing system has the potential to reach sub-nanometer order.

S11-2 A measuring method of spindle rotation error using circular grating and self-collimator [Invited]

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Rotary table is the key moving component of multi-axis CNC, and its motion error, especially radial motion error has a deep influence on the machining accuracy. In this paper, a model of the relationship between the angular position error and radial error of the spindle was established, and a method of measuring the radial rotation error of the spindle by using a circular grating and a self-collimator is proposed. According to this method, a high-precision rotary table can be designed. This rotary table can realize high-precision measurement of the radial error. At the same time, high-precision positioning of the rotation angle can also be achieved.

S11-3 A curve segment method based on fixed dynamic programming and cycled optimization techniques [Invited]

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Curve segment is a fundamental step for its further analysis. In practical applications, the curve is not always smooth but with various noises. In this paper, a method based on fixed Dynamic Programming and cycled optimization techniques is proposed to segment the noisy curve accurately. Firstly, the traditional Dynamic Programming method is modified to weaken the influence of noise and save time, which uses a fixed point number to control the result of Dynamic Programming method. Secondly, the breakpoints detected by the fixed Dynamic Programming method are optimized locally, and a cycled optimization method is proposed to weaken the influence of correlation between breakpoints. Finally, simulations and experiment are implemented to evaluate the proposed curve segment method. In simulations, noise is added into the smooth curve, and the proposed method is applied to segment the noisy curve. In the experiment, a noisy laser stripe centerline is segmented by using the proposed method. The simulations and experiment results verify that the proposed method can weaken noise effectively and segment noisy curve accurately.

S11-4 A fast infrared thermal imaging detection method based on spatial correlation [Invited]

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The existing infrared thermal imaging detection methods usually process the whole video stream data collected by a thermal camera, which involve large amounts of data and have a negative effect on the efficiency of defect detection. In this paper, we propose an infrared thermal imaging detection method which considers the spatial correlation of the adjacent images in the video stream data. By extracting the edge information and analyzing the correlation between two adjacent frames, the defect area and the non-defect area show different correlation coefficients, and only part of the video data is required for defect detection. Furthermore, fusion method is introduced to enhance the image quality. The experiment results demonstrates that the proposed method can not only reflect the change of heat in the defect area during the heating process but also reduce computation time involved in the subsequent processing.

S11-5 The method of solving the accurate displacement rule with acceleration signal

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The accurate measurement of displacement and load in the oil well dynamometer diagram is the need to achieve energy saving, efficiency and stable production. Wherein, the displacement signal is calculated from the acceleration signal in the dynamometer. Theoretically, the acceleration signal can be integrated by two time-domain integrations to obtain the displacement signal. However, the noise and direct-current (DC) components in the time-domain signal would produce a drift-type principle error after two integrals. It caused the calculation error to be dispersed state and difficult to apply in engineering. In order to solve this problem, this paper has proposed a frequency domain integral-based displacement solution method. Meanwhile, this paper has expounded the principle of frequency domain integration and analyzed the possible sources of error of the obtained results. Finally, this paper has proposed an evaluation model for measurement uncertainty. Through experimental verification, this method can effectively improve the accuracy of displacement measurement of dynamometer diagram. This research has important implications for improving the economic benefits of the oil field.

S11-6 A high precision edge detection method for the blurred image in motion measurement

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The motion measurement based on machine vision has been more and more widely used in robots, object tracking and other fields. However, the relative motion between camera and object often causes images blurred, which decreases the reliability of detection. To improve the detection accuracy of the motion-blurred images edges, a comprehensive method is proposed. By analyzing the grayscale distribution of the object images in different motion directions, we used different methods to enhance the low frequency sub-band images which were obtained by wavelet transform. The sub-pixel edge detection method based on cubic spline interpolation was applied to detect the edges of the blurred and enhanced images, respectively. Experimental results show that the proposed method avoids the misdetection of the blurred images edges, and obtains higher edge detection accuracy.

Session 12 Sensors, Actuators and Application (2) [13:30-15:05, Aug. 10, 2018, Room 4]

S12-1 Ultrasound detection and imaging using microring resonators and laser generated focused ultrasound [Keynote]

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Optical detection of ultrasound is based on the interaction of strain field and optical field in an optical resonator for sensitive detection. Special optical transmitters generate and focus ultrasound, targeting high-amplitude focused ultrasound for imaging and therapeutic applications.

S12-2 Cold atom interferometry gravimeter [Invited]

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The work presented in this talk focusses on the construction of high precision absolute gravimeter in National University of Defense Technology (NUDT). The instrument is based on interfering ensembles

of laser cooled 87Rb atoms in the configuration of the Mach-Zehnder type interferometer. Atomic wave packets are split and recombined by three Raman light pulses. The resulting interference fringes are sensitive to the movement of the atoms within a gravitational potential. Currently we have realized a resolution of 5.1mGal within 100s in measuring gravity, which is comparable with the state-of-the-art gravimeters. More details of the performance limitation and the methods for further improvements will be discussed in the talk.

S12-3 Establishment of standard device for high rotational speed generation [Invited]

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The high rotational speed standard device based on brushless DC coreless micro motor and FPGA technology for high-accuracy rotational speed control was investigated and established, with resolution of 1 r/min in the measurement range of 40000 r/min to 100000 r/min. The expanded calibration uncertainty of this standard device is 1×10^{-5}, k=3 The structure of the device and key technology involved were described . The dual closed-loop control solution was explained. The calibration results were provided. This high rotational speed standard device is used as an important working standard for the feasible traceability of high-precision optical tachometers and rotational speed measuring instruments at measurement range above 40000 r/min.

S12-4 A novel two-dimensional inductive sensor based on planar coils

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The precision measurement of two-dimensional displacements is needed in many domains, such as precision fabrication and detection. This paper presents a novel inductive sensor with the capability of measuring displacements in x- and y- directions simultaneously. The sensor consists of two parts: a ferromagnetic plate with primary windings which are composed of four layers of planar coils, a ferromagnetic plate with secondary windings which are composed of four layers of planar coils. Primary windings are supplied with two orthogonal 20kHz altering current to generate traveling wave magnetic field along x- and y- directions separately. Secondary windings output two signals whose phases are proportional to linear displacements of X and Y directions respectively. The structure and working principles of the sensor are proposed. Meanwhile, a sensor model is simulated to verify the feasibility of the working principle and a sensor prototype is fabricated for physical experiment. According to the analysis of experiment results, the measurement range is 140mm$\times$140mm, and the maximum linearity in one pitch is 1%. The performance of sensor may be improved by optimizing the layout of primary & secondary windings and signal processing circuit.

S12-5 A domain adaptation deep transfer method for image classification

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The deep learning models have recently shown outstanding performance in many computer vision applications. However, this superior performance requires a very large number of annotated image samples, pre-venting application to problems with limited training data. To overcome this limitation, we propose a Do-main Adaptation Deep Transfer Model (DADTM) in this paper. The DADTM improves the classical transfer models by the proposed domain invariance value metric and a domain invariance reconstruction, increasing the model transferability and enhancing the classification performance. The comparative experiments are performed to evaluate the DADTM-based classification algorithm. The results show that the proposed mod-el and algorithm outperform the traditional methods.

S12-6 Micro Coordinate Measurement Machine (μCMM) using voice coil actuator with interferometric position feedback

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Quantitative determination of dimensional properties like length, diameter, height, etc. is essential in research, development and in production process control. To meet these requirements the widely used approach is the coordinate measurement technique. The equipments-the coordinate measuring machines (CMMs) – using the mentioned technique cover a wide measurement range from metre to nanometre. Below a newly developed equipment for the micro scale is presented. The system – the micro coordinate measuring machines (μCMM) - consists of a probing system, voice coil based actuators and an integrated interferometric measurement system. The key component - in addition to the probing system – is the positioning stage, since the characteristics of the position acquisition and control directly influences the achievable accuracy of the complete measurement system. In contrast to a standard interferometer the presented system utilizes a 2D CMOS image sensor to capture the measurement signal. To drive the stage, a commercial voice coil actuator is used: the scanning range of the introduced system covers about 15 mm, and can be easily extended. The applied probing system uses a ruby ball stylus probe. It is a measuring probe, which means that it provides a signal corresponding to the occurring deflections of the probe ball for all three spatial directions. The probe achieves nanometer resolution.

Session 13 Laser Measurement Techniques and Instruments (2) [15:50-17:45, Aug. 10, 2018, Room 1]

S13-1 Fourier ptychographic imaging [Keynote]

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Fourier ptychography (FP) is a recently developed phase retrieval approach for large field-of-view and high-resolution imaging. This technique stitches together many variably illuminated, low-resolution measurements in the Fourier space to expand the frequency passband and recover the high-resolution complex object image. Without involving any mechanical scanning, it facilitates large field of view imaging in a simple and robust manner. In this talk, I will discuss the principle of the FP approach and its applications in gigapixel microscopy, quantitative phase imaging, 3D holographic imaging, long-range macroscopic imaging. I will also discuss how to model the Fourier ptychographic imaging process using a neural network and the extension of the FP approach for incoherent imaging settings. The FP innovation may provide new insights for the development of high-resolution imaging platforms using photon, X-ray, and electron.

S13-2 Multi-matrix optic-electronic systems for measuring the line shifts of the points on the radio-telescope main mirror [Invited]

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The mirror construction of the radiotelescope RT-70 (Suffa) for millimetre wave range requires measuring the line deformation of mirror's surface. Following issues dealing with this problem are described in this article: 1) the possibility of the design of deformation measurement system based on triangular method 2) the new scheme of optic-electronic measurement system. The great attention during

the research was paid to the experimental approval of the theoretical results. The model of the described system had the following characteristics: infrared emission diode AL107B by power 15 mWt as sources of radiation; the objective by the focal length 405 mm as aperture of receiver video-camera, the CMOS matrix receiver by type OV05610 Color CMOS QSXGA with 2592*1944 pixels and one pixel size (2.8*2.8)μm^2 produced OmniVision as image analyzer. The computer simulation error and the experimental error measurement was 0.05 mm at the range 30 mm on a working distance 25 m, which allows measuring the deformation of radiotelescope construction with the mirror diameter 70 m.

S13-3 Measurement of 3-dB linewidth of FBG Fabry–Perot interferometer using tunable fiber laser [Invited]

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We present a simple method to measure the 3 dB linewidth of the sharp peak in the spectrum of the fiber Bragg grating-based Fabry–Perot (FBG-FP) interferometer. A narrow linewidth tunable laser is used for sweeping the FBG-FP to achieve the reflection spectrum. A triangle wave is used to drive the narrow linewidth tunable laser. The linewidth of the sharp peak is measured with a resolution of 0.001 pm.

S13-4 Study on integrated linear time-grating displacement sensor with single alternating light field with single alternating light field

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It is difficult to control consistency of light source and large volume in current linear time-grating displacement sensor with four-channel alternating light field. A novel integrated linear time-grating displacement measurement system with single alternating light field is proposed. Single alternating light field and micro-controlling phase-shift method are used to synthesize a signal of traveling wave. And the measurement of linear displacement is achieved by measuring a difference of zero-crossing time between a signal of traveling wave and a reference signal. Design of structural miniaturization, design of integrated circuit, design of transmitting surface of cosine and design of optimization of existing time-grating displacement sensor are analyzed in detail. According to measuring principle, manufacture of light source and photoelectric receiver are completed, and corresponding experimental platform is built. Experimental results indicate that the measuring errors of optimized sensor are reached within±0.2μm using grating pitch of 0.1mm in the measuring range of 100mm.

S13-5 Deformation measurement of testing machine based on laser interference method

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Tensile, compressive and universal testing machine (Hereinafter referred to as testing machine) is an important instrument for analyzing the pressure of materials. In order to reasonably assess the influence of the deformation of the beam and jig on the strength analysis of the tested material, the deformation of

the beam and jig of the tested machine which under the stress state should be studied. Firstly, the laser interference method is proposed to measure the mechanical deformation characteristics of the beam and jig. Secondly, we should analyze the structure and theory of measurement technology, give the test method and then calculate the relationship between the deformation of crossbeam and fixture and the stress. Finally, the experimental data are summarized, and the numerical correction method of material shape variables is obtained when testing materials are measured. The experimental results show that the shape variables between the testing machine beam and jig reaches to 0.63mm when the force value reaches to 5 KN. By using this measurement method, the shape variables of the beam and jig of the tester can be measured accurately, and the material deformation can be correspondingly corrected during the material strength test and analysis, which can improve the accuracy of the material deformation measurement of the tester.

S13-6 A two-probe linear encoder by using an arrayed scale grating stitched by multiple separate short gratings

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A linear encoder composed of a two-probe reading head an arrayed scale grating stitched by multiple separate gratings was proposed, constructed and evaluated in this research for expanding the measurement range. The scale grating is stitched by multiple separate short gratings fabricated by a holographic lithography that is able to provide sub-micron order grating period. Differing from the conventional stitched grating, in which the gap of the adjacent two gratings should be strictly controlled so that a continuous phase can be ensured, the gap in this research is not necessary to be controlled, neither the gap width nor the phases, by using a two-probe reading head. In contrast to the reading head in conventional linear encoder, the two-probe reading head was designed in such a manner that a collimated laser beam with a diameter of 1mm was divided into two parallels probes (probe A and probe B) by a specially designed prism lens. These two probes are projected perpendicularly onto the transmission type arrayed scale grating. Taking Probe A as an example, after passing the grating, the positive and negative first-order diffraction beams follow a typical grating interferometry principle, including propagating direction changing, co-path by a beam splitter and a polarize for a phase delay module and finally interfere with each other, from which the displacement can be obtained. The two probes propagate along similar optical path. The two probes can ensure as least one can be projected onto the grating. By stitching the two probe outputs suitably, the continuous output of the scale grating can be measured accurately. The jig for stitching the separate gratings was investigated and tested. The two-probe reading head prototype was constructed and evaluated.

S13-7 Corrected differental fitting for height extraction in chromatic confocal microscopy

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As for chromatic confocal sensor system with limited computational capacity, a fast peak extraction algorithm with considerate accuracy is in urgent demand. However, current peak extraction algorithms such as the centroid algorithm (CA) and nonlinear fitting algorithms cannot balance the accuracy and computational efficiency. Thus, we propose an accurate peak extraction algorithm with good computational efficiency called corrected differential fitting algorithm (CDFA). At first, the differential signal derived from the original axial response signal is linearly fitted for initial peak extraction. Then corresponding systematic error of this linear fitting operation is analyzed using a first-order linear nonhomogeneous differential equation. At last, error compensation, that is, the solution to this equation is

implemented with an introduction of "sum differences of sampling intensity". The performance of CDFA is compared with two conventional peak extraction algorithms including the CA and Gaussian fitting algorithm (GFA) using Monte Carlo simulations. CDFA is found to have a comparable accuracy performance with GFA while have a much higher computational efficiency.

Session 14 Novel Instrument and Measurement System (3) [15:50-17:45, Aug. 10, 2018, Room 2]

S14-1 Thermo scientific themis Z: the ultimate in optical performance, reproducibility and flexibility [Keynote]

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Recent advances in electron microscopy have not been dedicated so much on improving the optical resolution as it has been on making this resolution accessible to more operators on more specimens, in fact, making it independent of the operator by relying on an automatic adjustment of 1st and 2nd order aberrations in a fast and reproducible way right on the region of interest. Other major advances have been on detection, with iDPC using segmented detectors to ptychography, which has very recently set a new spatial resolution world record, on the EMPAD pixelated detector.

S14-2 Interferometric characterization of large-stroke nano-positioning stage using an optical fiber interferometer with subatomic resolution [Invited]

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For the purpose of traceable investigation of the quasi-static and the dynamic performance of large-stroke nano-positioning stages, a low-finesse Fabry-Perot interferometer is developed, which utilizes the typical single-mode fiber-interferometric configuration with a single detector. The micro-F-P cavity is formed by the (uncoated) fiber end surface and an (uncoated) glass plate (surface flatness $\lambda/10$), which is fixed onto the stage under calibration. Care has been taken to choose the optical fiber components, including isolator, fiber coupler and detector, so as to optimize the overall performance of the fiber-optic sensor.

S14-3 Real-time 3D shape measurement by fringe projection and GPU parallel computing [Invited]

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When fringe projection profilometry is applied for real-time 3D shape measurement, several problems remain to be solved such as multi-wavelength heterodyne phase unwrapping is sensitive to motion and the computation cost is high. In this paper, a real-time 3D shape measurement method with optimized multi-wavelength heterodyne phase unwrapping and GPU parallel computing is proposed. Experimental results demonstrate that the proposed method can acquire 3D shape at 40 fps. Dynamic object with discontinuities can be measured and the phase unwrapping mistakes are eliminated by smoothing the phase of beat frequency during multi-wavelength heterodyne phase unwrapping.

S14-4 Measurement uncertainty analysis for self-calibration angle encoder [Invited]

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At national institute of metrology, China (NIM), a set of self-calibration angle encoder was developed and tested. The measurement uncertainty of this system was analyzed based on its measurement principle and test result. The measurement model of the self-calibration angle encoder was put forward. The main sources of measurement uncertainty are analyzed and discussed in detail. The sources of measurement uncertainty were distinguished as measurement repeatability, the leaving out Fourier components of self-calibration algorithm, the position error of scanning head, the output difference of the scanning heads, and the non-closure of bearing. Eventually, the cross-calibration experiment was carried out and the calibration result proved the estimation result very well.

S14-5 More efficient optical sectioning structured illumination microscopy

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In this paper, a technology of surface topography microscopic measurement based on structural illumination is studied and a more efficient optical sectioned image reconstruction algorithm was proposed. Compared with other method, it can avoid strip artefacts problems of in-focus images resulting from the sinusoidal phases mismatch of spatial domain in conventional three-step phase-shifting and the phase-shifting steps decreases from three to one, which can reduce the measurement time effectively. The experimental test is carried out to verify the measurement precision in our developed SIM system.

S14-6 Measurement of unmanned aerial vehicle attitude angles based on a single captured image

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The limited load capacity and power resources of small-scale fixed-wing drones mean that it is difficult to employ internal high-precision inertial navigation devices to assist the landing procedure. As an alternative, this paper proposes an attitude measurement system based on a monocular camera. The attitude angles are obtained from a single captured image containing five coded landmark points using the radial constraint method and three-dimensional coordinate transformations. The landing procedure is simulated for pitch angles from -15°to -40°and roll angles from -15°to +15°. For roll and pitch angles of approximately 0°and -25°, respectively, the accuracy of the method reaches 0.01 ° and 0.04 ° . This UAV attitude measurement system obtains attitude angle by a single captured image, which has great potential for assisting the landing of the small-scale fixed-wing UAV.

S14-7 Error analysis method of weighing cycles based on robotic mass measurement system

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Robotic mass measurement system, which used automatic measurement and data processing, has become the trend of the high accuracy mass measurements. In international comparison and mass-related scientific research, automatic measurement system together with ABABAB weighing cycles can reduce or eliminate the linear drift greatly and improve the accuracy of measurement results further. In this paper, three linear drift error elimination methods of ABABAB weighing cycle model were analyzed, and the corresponding mathematical expressions of error calculation were given, then experimental data was

analyzed and compared. All of these three methods based on ABABAB weighing cycle can be applied for automatic measurement in the future.

Session 15 Modern Optics and Instruments for Precision Measurement (2) [15:50-17:45, Aug. 10, 2018, Room 3]

S15-1 Three-dimensional imaging of live-cell dynamics using light-field microscopy [Keynote]

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In this work, we develop a high resolution light field microscopy (HR-LFM) for live-cell imaging by simultaneous, dense sampling of both spatial and angular information. It uses a novel defocus optical design involved in the microscope imaging module as a relax imaging relationship to restrain the aliasing of the recorded 4D information and attain artifact-minimized of the optical signals on the camera sensor at low light intensity levels. HR-LFM achieves a 3D spatial resolution of 300-700 nm, an imaging depth of several micrometers, and a volume acquisition time down to milliseconds. We demonstrate the technique by capturing various cellular dynamics and structures including mitochondria, Golgi-derived vesicles, as well as tracking single particles with a volume acquisition rate even up to milliseconds.

S15-2 Method for simultaneously measuring 6DOF motion errors of linear and rotary axes of cnc machine tools [Invited]

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The way to improve the accuracy of CNC machine tools has been a hot and long-standing issue in the field of mechanical manufacturing. The error compensation is an effective way. On the premise of the mature compensation model, the way to obtain the error parameters efficiently and accurately is the key. The motion axis of a five-axis CNC machine tool is composed of the linear axis and the rotary axis. Focusing on quickly and accurately measurement of motion errors of CNC machine tools, a simultaneous measurement method which combines the fibre coupling dual-frequency interference technique with the laser collimation technique for six-degree-of-freedom (6DOF) motion errors of the linear and rotary axes is proposed. The position error of the linear axis and the radial motion error in X direction of the rotary axis are achieved by heterodyne interferometry, and the other 5DOF motion errors are obtained by laser collimation measurement. The heat generated by He-Ne laser source is removed from the sensor head by a fibre connection, improving the thermal stability of the measurement instrument. A common-path compensation method is integrated into the proposed system to eliminate the influence of laser beam drift on the measurement accuracy. The influence of the error crosstalk and optical element fabrication error on the measurement is analyzed, and the measurement model is established using the ray-tracing method. A series of experiments are performed to demonstrate the reliability and effectiveness of the proposed method.

S15-3 Development of surface profile measurement system based on super luminescent diode light source [Invited]

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This system dedicated to the development of a surface profile measurement system based on the SLD (Super Luminescent Diode) light source. This system uses the principle of the Michelson interferometer, which uses the sub-amplitude method to generate double beams in order to achieve interference. Through

adjusting the interferometer to produce equal-thickness interference fringes and equal-angle interference fringes and using the 56- precision sliding table to make the reference mirror move, and then a scanning of the surface of the measurement target is performed. According to the acquired interference fringe image, we conduct data image processing on it and accurately obtain the surface morphology of the tested workpiece, and the function of scanning the surface of the object is achieved. This project has its own unique features and innovations. Compared to using the white light which its spectral bandwidth is 100 nm or more as a light source, the optical system used a 1550 nm SLD light source with only 50 nm spectral bandwidth. The light source has smaller bandwidth, resulting in low coherence, and making the interference fringes more visible. Due to the periodic characteristics of the interference fringes, when using the narrow band light source, the coherence length of the light source is usually greater than the path length difference of the interferometer. It made the measurement have a phase ambiguity of 2π, which may severely limit the application of the measurement. However, this project uses a short coherent length SLD light source, it can avoid 2π phase ambiguity problems. Besides, it can perform a full scan in a larger step and achieve rapid on-line measurement of the target surface.

S15-4 Holographic fabrication of two-dimensional scale gratings for surface encoder by using an orthogonal type two-axis Lloyd's mirror interference lithography [Invited]

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In this paper, an orthogonal type two-axis Lloyd's mirror interference lithography technique was employed to fabricate two-dimensional planar scale gratings for surface encoder application. The two-axis Lloyd's mirror interferometer is composed of a substrate and two reflective mirrors, which are placed edge by edge perpendicularly. An expanded and collimated beam was divided into three beams by this interferometer, a direct beam and two reflected beam. The unnecessary beam section was blocked by a home designed filter. These two reflected beams interfere with the direct beam respectively, generates perpendicularly cross patterns for forming two-dimensional scale gratings. The two reflected beams also interfere with each other and generate an undesired grating pattern along a 45°direction, which influences the pattern uniformity in a certain degree. The undesired grating pattern can be eliminated by polarization modulation, yet which will influence the grating area. Theoretical and experimental study was carefully carried out to evaluate the fabrication quality with and without polarization modulation. Two-dimensional scale gratings with a 1 μm period in X- and Y-directions were achieved by using the constructed experiment system with a 442 nm HeCd laser source. Atomic force microscope (AFM) images and diffraction performances verified that the two-axis Lloyd's mirror interferometer with a small undesired interference between two reflected beams under an order of nominal value of 0.1 can provide a better fabrication result for scale gratings application.

S15-5 Subwavelength focusing and experimental detection of large-scale metallic multi-annular metasurfaces

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To realize a long working distance and high resolution focusing for diffraction optical element, the large-scale optical elements needed to be employed. Based on the vectorial angular spectrum theory and genetic algorithm, a large-scale metallic multi-annular metasurface (MAM) was designed. The MAM realizes subwavelength focusing and has a main focal spot within the range of 0-140μm. The focal length is 113.5μm. Using electron beam lithography, the designed MAM was fabricated. The experimental setup was built. We experimentally obtained the intensity distribution of the main focal spot. The theoretical and experimental results have a good agreement, which show that the proposed method can be used to design the large-scale MAM.

S15-6 A filter algorithm based on ARMA model to suppress the influence of atmospheric disturbance in laser straightness measurement

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Atmospheric disturbance influence the measurement accuracy greatly in laser precision measurement of long distance. A real-time filtering algorithm based on time series analysis theory is proposed in this paper. Firstly, ARMA (Auto-Regressive and Moving Average) model of sample data is set up based on the theory of time series analysis, then the mathematical expectation is obtained according to the model as the filtering result, finally, it is integrated into the laboratory laser beam drift measurement system for real-time filtering measurement. It is evident from the simulation results that high accuracy can be obtained after filtering. The experimental results show that the stability of the filtered drift increases by about 20%.

S15-7 Optical fiber sensing technology in morphing aircrafts and soft robotics

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We demonstrate the optical fiber sensing technology in morphing aircrafts and soft robotics. In the aspect of morphing aircrafts, the 3D shape sensing of polyimide thin film skin for flexible morphing wing using fiber Bragg grating (FBG) sensors is presented. The calibration curves of the FBG sensors are measured experimentally to ensure relative accurate conversion between Bragg wavelength shift (BWS) and bending curvature of the polyimide skin. The variation tendency of the BWS values with the airfoil profiles are analyzed. The bending curvatures of the polyimide thin film skin at different airfoil profiles are calculated using the measured BWS values of the FBG sensors and the linear interpolation algorithm. The 3D shapes of the polyimide skin at different airfoil profiles are reconstructed based on the measured bending curvatures and the interpolation and curve fitting functions. The 3D precise visual measurements are conducted using a digital photogrammetry system, and then the correctness of the shape reconstruction results are verified. The optical fiber sensing method is effective for the shape sensing of flexible morphing wing. In the aspect of soft robotics, an optical fiber based sensing membrane for posture monitoring of soft pneumatic bending actuators. The membrane is embedded into a soft pneumatic bending actuator as the strain limited layer. The relationship between the bending curvature and optical wavelength shift is derived using the pure bending model. The characteristics of the sensing membrane is analyzed. The curvatures of the soft pneumatic actuator are measured at four bending status, and the postures are reconstructed. The measurement error is less than 2.1% of the actual bending curvature. The sensitivity is up to 212.8pm/m^{-1}, and the signal fluctuation in repeated measurements is negligible. The sensing membrane is simple in configuration and easy to fabricate. It has broad application prospects in soft robotics.

Session 16 Instrument and Measurement System Calibration (2) [15:50-17:45, Aug. 10, 2018, Room 4]

S16-1 Ultrathin Terahertz wavefront modulator based on metasurface [Keynote]

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Terahertz (THz) radiation has many potential applications which has attracted a lot of interesting. It can be used in defense security, quality monitoring, nondestructive testing, and so on. However, the size of the THz optical devices is quite larger due to the longer wavelength property of THz radiation. Matesurface provides a good approach for multi-functional, planar, and smart devices designed. In this presentation, we will introduce several THz optical devices, including lens, vortex beam generators, and holograms. These devices are designed based on the metasurface concept, fabricated using the conventional lithography technology, and characterized with a home-built focal plane imaging system. Many multiplexing technologies are employed to enhance the functions of the devices. Experiment results demonstrate the validity of the fabricated devices which correspond to the theoretical expectation well. This approach will pave an avenue for practical applications of THz technology.

S16-2 EMI shielding performance evaluation model of the randomized overlapping ring metallic mesh [Invited]

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We proposed an evaluation model of the EMI shielding effectiveness performance of the random overlapping ring metallic mesh, simultaneously. The equivalent circuit model for random overlapping ring mesh is established. The coefficient b in the equivalent circuit model is revised according to the simulation results of Ansoft designer software. In order to guide the optimization of the electromagnetic shielding effectiveness of random overlapping ring mesh, the effects of the diameter 2R and period g on the electromagnetic shielding efficiency were simulated and analyzed. The electromagnetic shielding effectiveness is better than 23dB in the 2-18GHz band. The randomized overlapping ring mesh based on the random method can realize high optical transmittance, low image-degradation and strong shielding effectiveness simultaneously. It can be applied to precision optical instrument window, touch screen, digital display and so on.

S16-3 The optimization of segment's supporting for large astronomical telescopes [Invited]

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Existing axial support for segments mostly adopts the Whiffletree support mode. The location of the support point will have a great influence on the surface precision of the primary mirror, and then influence the final imaging quality of the telescope. At present, there is no special support technology for traditional and thin mirror. In this paper, the research is based on LOT's hexagonal segment (the surface is hyperboloid, diagonal line is 1.2m, thickness is 45mm, material is Zerodur), which is designed by Huazhong university of science and technology. The optimization of the Whiffletree axial support point of the segment is carried out. Efficient optimization algorithm is used in the research. After building parameterized model of segment support point location, FEM is used to obtain segment surface deformation. Taking the minimum RMS of deformation on segment surface under gravity as the goal, optimized software ISIGHT is applied to find the best support point location. Zernike orthonormal polynomials for hexagonal pupils is used to remove rigid-body motion. Finally, the best support point location point is obtained, the RMS of the segment surface deformation is 11.56nm and the PV is 63.98nm. The result can meets the requirement of LOT design well.

S16-4 Dual-wavelength off-axis quasi-common-path digital holography using

polarization-multiplexing and flipping [Invited]

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We build a two-wavelength off-axis quasi-common-path digital holography for quantitative phase imaging (QPI) using polarization-multiplexing and flipping. The interference is performed by flipping the relative position of a sample and reference beam, and the dual-wavelength information is spatially multiplexed onto a monochromatic CCD camera simultaneously using polarization-multiplexing. Due to orthogonal interference fringes of two-wavelengths, the unwrapped information on the phase and thickness for the sample can be extracted from a single interferogram. Our setup requires no pinholes, gratings or dichroic mirror with straightforward alignment. Additionally, a division algorithm for dual-wavelength off-axis digital holography with the help of a specimen-free multiplexed interferogram is proposed to extract the phase of a specimen. We demonstrate the operation of the setup with step target and circular pillar.

S16-5 Key technology and applications of fiber grating fabricated by femtosecond laser

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Owing to advantages such as a high sensitivity, excellent tensile properties, radiation resistance, and long working life, the femtosecond laser inscription fiber Bragg grating (FS-FBG) and long period fiber grating (FS-LPFG) are a widely-used tool within applications including fiber lasers, fiber communications, optical sensing, etc. Compared with phase mask inscription method, point-by-point inscription has more flexibility for writing different types of gratings and different grating periods. In addition, fiber coatings usually need to be removed during traditional fiber grating fabrication processes, resulting in increased fragility of the fiber grating. We propose a point-by-point inscription method for FBG and LPFG fabrication using a femtosecond pulsed laser focused through a fiber polyimide or acrylate coating. A femtosecond laser acts as the inscription laser, focused by an oil lens. The different wavelength fiber grating was fabricated by changing grating inscription interval, and femtosecond pulsed laser was focused directly on the fiber core through the polyimide or acrylate coating and fiber cladding. High wavelength sensitivity and linearity of the fiber grating were demonstrated by temperature-sensing testing.

S16-6 Field test method and standard instruments for verification of traffic speed meters based on actual traffic

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In this paper, we introduce a field test method based on actual traffic with no need to close the road. This field test method can meet the requirements of the recommendation in OIML R 91 about the metrological field tests, with the advantage of the overall experiments of possible errors due to the complexity of factors affecting the result of measurement, such as shape of antenna pattern, reflection characteristics of target vehicle, change of lane during target vehicle passage through measurement region, braking or accelerating, presence of more than one vehicle, etc. We introduce the principle of the field test method and the requirement for the standard speed-measuring instrument, give the three main speed-measuring sensors used in the standard speed-measuring instrument, and analyze the numerical comparison results in this paper.

S16-7 Theoretical determination and validation of thermal deformation critical point of cnc machine tool bed

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In order to analyze the correlation between the thermal deformation of the CNC machine tool bed and the error of the grating measurement system,and to reduce the influence of the grating measurement system caused by the thermal deformation error of the machine tool bed, the concept of thermal deformation critical point on grating mounting line of machine tool bed was proposed in this paper. The new grating installing method by using thermal deformation critical point can reduce or eliminate the additional influence of zero thermal drift and indication thermal error of the grating measurement system caused by the thermal deformation error of the machine tool bed. In order to determine the position of the thermal deformation critical point of the machine tool bed accurately, various factors influencing the thermal deformation of the machine bed were analyzed in this paper. Taking the BV75 CNC machine tool as an example, a theoretical position determination model of the thermal deformation critical point on the grating installation line of the machine tool bed was deduced by using the material science, thermal elasticity theory, nonlinear thermal deformation theory and modern mathematical tools. The specific position of the thermal deformation critical point of the bed during the actual machining of the machine tool was calculated by using the above theoretical position determination method. Three-dimensional model of BV75 CNC machine tool was built according to its actual structure size. The position of thermal deformation critical point on the grating installation line of machine tool bed was also determined according to the thermal analyzing results by using the workbench finite element and the three-dimensional model, which was used to verify the calculation accuracy of the theoretical position determination model. The comparison results shows that the thermal deformation critical point position of the machine tool bed determined by the theoretical position determination model is basically consistent with the results obtained by the finite element simulation analysis. So the calculation accuracy of the proposed theoretical position determination model is verified, which can be used to determine the actual position of the thermal deformation critical point of the machine tool bed and to reduce the additional impact of the thermal deformation of the machine bed on the grating system error. The above researched results supplies a theoretical foundation for the high-precision compensation of the comprehensive error of the CNC machine tool on-machine measurement system.

Poster Presentation

Poster 1 Instrumentation Theory and Methodology

P1-1 Method for spherical form error evaluation using cuckoo search algorithm

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To obtain the accurate evaluation of minimum zone sphericity, this paper investigates a method in Cartesian coordinates using cuckoo search (CS) algorithm. In this method, an appropriate space is set as the search zone according to the solution obtained which is based on least square criteria. The aim of search is to find the best candidate position infinitely approximating the ideal reference center of minimum zone sphere. In order to improve the search efficiency, two essential parameters in CS, namely the control coefficient α of step size and the probability p_a of discovering an invasive cuckoo's egg are set to 0.618 (value of golden ratio) and 0.05 (common value of statistical significance), respectively. The updating of the candidate points is carried out by Levy flights and biased/selective random walk mechanisms. Levy flights mechanism can ensure the real global optimum is not missed, biased/selective random walk mechanism guarantee the diversity of search direction and adaptability of search step size. During the updating, the new solution can be kept when it is better than the old one. In each search iteration, the position which corresponds to the smallest sphericity is regarded as the present optimum solution. When the iteration terminal condition is satisfied, the optimum position and corresponding sphericity are output as evaluation results. The validness of the proposed CS algorithm was tested by an application example, the results indicate that the proposed method has the advantage of excellent convergence and high efficiency, which is suitable for the hith-precision evaluation of minimum zone sphericity efficiently.

P1-2 Research on photonic detection method of laser self-mixing interference

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Laser self-mixing interference (SMI) technology has many advantages such as simple structure, high measurement accuracy, good stability, and the adaptation to non-cooperative targets. It has become an important precision test method, and has been widely used in measurements for displacement, vibration, velocity, acceleration, and many physical quantities. In order to solve the problems of low signal-to-noise ratio(SNR), fringe inclination, and complexity of subsequent processing circuits in traditional self-mixing interferometry, this paper proposes a method to improve the SNR of laser self-mixing Doppler frequency signals using the two-photon absorption effect of silicon detectors. The system uses fiber grating edge filtering to enhance the laser self-mixing interference Doppler frequency signal. In order to suppress the higher harmonics contained in the frequency domain of the interference signal, the self-mixing interference beam is tightly focused on the photo-sensitive surface of the silicon detector to obtain the two-photon absorption effect. Such high order absorption effect filters out harmonic components and realizes an ultra-wideband filter, which not only improves the SNR of the signal, but also greatly simplifies the processing of subsequent self-mixing interference signals.

P1-3 Design of Gaussian filters based on odd and even function continuation for non-closed circular profile

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In order to solve boundary effect for non-closed circular profile with conventional Gaussian filter, two modified Gaussian filters based on odd and even functions are put forward. By extending original profile data on the boundary effect area, the sampling information on the boundary effect area of non-closed circular profile can be used fully, and then open-loop Gaussian filter is used for filtering. The validity of two designed filters was tested by numerical simulation and experiment. The results demonstrate that the modified Gaussian filter based on even function is more effective to reduce boundary effect than that based on odd function.

P1-4 Misalignment recognition of mass pan in joule balance

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Joule balance is one of the precise instruments to measure the Plank constant for redefining the kilogram. During the measurement of the joule balance, two electrified coils produce an electromagnetic force to balance the gravity of a standard mass on the mass pan. However, if the mass pan is in a misalignment state, during the mass exchanging it will waggle and change the posture of the suspended coil. Then the alignment errors will be induced. In joule balance, the posture of the mass pan cannot be directly measured, which however can be decoupled by measuring the posture of the suspended coil. In this paper, the recognition method of the mass pan misalignment status will be discussed. By measuring and calculating the positon changing of the suspended coil, the alignment states of the mass pan can then be evaluated.

P1-5 Method of squareness measurement based on laser alignment measuring system

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In order to measure the squareness of large-size workpieces, a method of squareness measurement based on laser alignment system was introduced. The structure and principle of the laser alignment system were presented. The squareness measuring method of the squareness measuring system and the laser alignment system were described respectively. This paper improved the method of squareness measurement based on laser alignment system and made the accuracy satisfied with the requirement of most in-site measurement. The experiments show that the squareness measurement accuracy of the laser alignment system can be improved to 5μm/500mm.

P1-6 Choosing parameters of active reference mark optical-electronic systems spatial position control

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Subject of the research. Parameters relations in active reference mark optical-electronic system spatial position control in presence of vertical temperature gradient is considered. The operation principle of the dispersion method of the vertical temperature gradient determination using colour camera and RGB optical radiation source is described. The basic condition for choosing parameters of active reference mark optical-electronic system is derived from relations that define hardware realization of the system and parameters of the air tract which are used in the dispersion method. **Method.** The principle of equal influence of error components on the total error is used. There is an assumption that there are no fluctuations of the air tract refractive index in time and space. **Main results.** The basic condition for choosing parameters of active reference mark optical-electronic system for spatial position control in presence of vertical temperature gradient is proposed. The efficiency of the dispersion method vertical

temperature gradient influence minimization is proved. The basic condition proposed condition allows to estimate this efficiency and choose the hardware parameters. **Practical significance.** The results given in the paper can be used in design of active reference mark optical-electronic systems where the influence of the air tract is strong.

P1-7 Research of the temperature influence on the errority of incremental optical-electronic encoders of linear displacements based on raster structures

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The currently existing incremental optical-electronic linear displacement encoders (OELDE) use raster conjugation, which allows for the measurement of linear motion with high accuracy by means of the conversion of optical signals in the opto-electronic path. In such devices, informative signals constantly undergo transformations associated with their processing. Variable environmental factors, especially temperature, have a harmful effect on signal conversion processes and cause additional error. The aim is to analyze the results of theoretical and experimental studies of the additional error from the effect of changes in ambient temperature on incremental OELDE's. Analyzing the effect of temperature on the course of information transformation, it is possible to divide the main emerging partial components of the additional error into two groups:
- errors due to changes in the relative spatial position of the elements of the OELDE;
- errors due to changes in parameters and characteristics of elements of the OELDE.

P1-8 Research of technologies in image-based omnidirectional AGV

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This topic mainly studies the navigation parameters obtained by image processing technology to achieve omnidirectional mobile AGV autonomous navigation. The camera is mounted on the bottom of the body of the AGV and captures the black tape path on the ground. Image preprocessing is performed, including image graying, improved CANNY algorithm edge detection. Then the Hough transform is used to detect the path of the preprocessed image. Finally, a straight line is selected to obtain the effective edge line, and the navigation deviation parameters are extracted. Experimental results show that the effectiveness of the guidance techniques in this paper has achieved the expected results.

P1-9 A uniform and flexible model for three-dimensional measurement of line-structured light sensor

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With the rapid development of manufacturing and industry fields in recent years, the demands for three-dimensional form-position measurement and depth defect detection technology further increase. The realizations of high-precision part machining and good component reliability rely on high accuracy and fast three-dimensional measurement technology. Line-structured light sensor is a three-dimensional active optical triangulation measurement method, which combines the advantage of high precision and speed, applicable in many fields. The mathematical model of line-structured light sensor is an essential foundation, which determines measurement precision. Generally, mathematical models of line-structured light sensor are established by three typical modeling ways: the model based on coordinate transformations and perspective projection, the model based on line-plane or line-line intersection and perspective projection, and the model based on triangulation and perspective projection. The similarity of models mentioned above is that the camera model is the pinhole model, that is, it based on perspective

projection, which is the relationship between the space point and the image point, and the camera intrinsic parameters are called inner parameters in general in line-structured light sensors. Through the comparison of the three representative models, which are deduced from different starting points and analysis of the model constraint conditions, we build a uniform and flexible model which shows the common characteristics and connections of the previous models and combines the flexibility and clear geometric meanings of the structured parameters with a correctable constraint condition. All these models include the uniform model are based on the camera pinhole model, the differences are the expressions and constraint conditions. So they are essentially the same. The uniform model shows the common characteristics and connections. The uniform model based on the three models combines the flexibility and clear geometric meanings of the structured parameters with a correctable constraint condition. The uniform model can be applied to most conditions and it has the guiding significance in the design of the structured parameters of line-structured light sensor. It is suitable to most conditions and structured parameters design of line-structured light sensor.

P1-10 Multi-structure elements morphology for improved anti-noise edge detection

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Edge detection is crucial in the field of computer vision and image processing. Moreover, it is an essential pre-processing step in pattern recognition, medical image analysis, etc. The key question of edge detection is obtaining more edge information while filtering more noises. The traditional edge detector is sensitive to noise, and it is difficult to accomplish the information extraction of complex edge effectively. In the area of edge detecting, the mathematical morphology method (MM) shows its attractive strengths, such as acceptable response to different edges, better noise immunity, short computing time, and so on. In view of the deficiencies of traditional edge detectors, including traditional MM, this paper presents a novel anti-noise edge extraction algorithm on the basis of the improvement of the previous edge detection methods.

Poster 2 Measurement for Precision and Ultra-Precision Machining

P2-1 Error analysis of target trajectory tracking applied for measurement of high speed spindle

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The measurement of spindle radial error motion is achieved based on target trajectory tracking (TTT). Error analysis of TTT method is performed in this paper. Target trajectory doesn't contain information about axial error motion. The tilt error motion is included in the target trajectory. However, the tilt error motion is small enough to be ignored. The roundness error of the target trajectory is assessed to obtain the radial error motion of the spindle. The experimental results confirm that the proposed method can be applied to measure the radial error motion of a high-speed spindle having a maximum rotational speed of 6000r/m.

P2-2 Force control and visual measurement in precision assembly system

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On account of the assembling demand for the component of laser gyro, a precision assembly system was developed in this paper. One critical issue in the precision assembly system is the vision measurement of the part dimension. Due to the part is larger than the field of the vision system, thus an appropriate image mosaic and processing is crucial to get the characteristic of the part, and benefit to the assembly efficiency and accuracy simultaneously. In order to feedback the contact force between the part and the end effector, a cantilever force sensor integrated with the gripper is developed, which can detect the assembling force and prevent the overload situation in real time.

P2-3 A measuring method of coaxiality errors for far apart axis

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Mechanical failure is primarily caused by the coaxiality errors of axis. Traditional methods (synthetic gauge testing methods, method of rotary axis, coordinate measuring machine, etc.) for detecting coaxiality have some disadvantages such as: low efficiency, sensitive to human factors and cannot be used to measure the axis that is far apart without connection. In this paper, based on the principle of laser collimation, a method for measuring non-connecting axis coaxiality errors with long distance was proposed. By rotating the laser module and the QPD module, the center and radius of the circle that formed by the laser spot were used to calculate the angular deviation and the parallel deviation. Finally, a measurement system based on the Precision instrument deflection was designed to verify the rationality of the method.

P2-4 Research on an accuracy test method of star sensor based on spatial transform

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This paper makes use of the relatively stable ground speed and the real starry sky under the condition of outfield stargazing. The relative transformation of the space and motion of the star sensor pattern is carried out. We test the accuracy of the star sensor by calculating the vector angle, and overcomes the disadvantages such as the existing technology cannot simulate the real starry sky. It provides an effective method to test the precision of the ground-facing star sensor.

P2-5 Variable frequency big current calibration technique

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Variable frequency power is extensively used in aircraft, China Railways High-speed(CRH) and electrically driven ships. The working power is so big up to thousands of Ampere and frequency 1kHz that hard to be calibrated. Traditional big AC current is about 50Hz in power area to 400Hz in airplane area. There is no appropriate calibration standard for variable frequency big current. For variable frequency big current calibration, the variable frequency big current should be transform to small variable frequency current firstly. And secondly the small variable frequency current need to be converted to variable frequency voltage. We use zero flux transformer to do the first step, and using AC-DC difference calculable AC resistor to do the second step. The calibration for variable frequency big current is completed. The variable frequency big current can be calibrated using this technique with measurement uncertainty 10^{-5}. This calibration technology has been applied in aircraft project, feeding back good results.

P2-6 The effect of contact pressure on resistance measurement of antistatic material

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The electrostatic leakage resistance is one of the most important characteristics of the antistatic materials. During the measurement of the resistance, the contact pressure applied on the electrode of the resistance tester would influence the results significantly and thus affecting the accuracy and reliability of the results. To standardize the assessment, the correlation between the measured resistance value of various antistatic materials and the contact pressure are investigated. The results show that the contact pressure will lead to a great difference on the measurement results, especially for those soft materials with compressive deformation characteristics. The difference is about several orders of magnitude, which may lead to misleading assessment on the antistatic materials property. Furthermore, the resistance of antistatic clothing and shoes are investigated under different contact pressure. Based on the experiment results, the dependence of resistance measurement on the contact pressure is analyzed and suggestions are provided on standardized measurement and test.

P2-7 Fast measurement of small modulus gears based on machine vision

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Small module gears are an important component in the precision instrument industry. The detection of geometric quantities is of great significance to the development of the industry. The traditional contact measurement technology and equipment can not fully meet the requirements of quality inspection in terms of accuracy, speed, and non-destructiveness, and even some special occasions cannot even achieve measurement. Using machine vision instead of the traditional contact measurement method, the rapid and accurate non-destructive testing of precision parts is one of the trends in the field of industrial parts inspection. The small module gear detection system introduces the machine vision measurement technology and completes the design and construction of the measurement system hardware and software equipment. This paper mainly studies the edge extraction and defect detection of the small module gear.

Aiming at the problems of slow detection speed and low accuracy of traditional gear detection instruments, this paper proposes a machine vision inspection method for missing tooth defects. Firstly, the gear image is subjected to preprocessing such as graying, filtering, binarization, and morphological operations. The effect of the background image is eliminated and a clear gear target is obtained. Then the gear profile is detected to identify the gear feature point. The point on the gear teeth is extracted to realize the automatic detection of the number of teeth and the accurate identification of missing teeth defects.

Post 3 Novel Instrument and Measurement System

P3-1 Bionic vision improves the performances of super resolution imaging

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A novel super resolution reconstruction method is proposed to improve super resolution image performance. The proposed method uses bionic vision sampling model to obtain low resolution images and performs super resolution reconstruction in logarithmic polar coordinates. We carry out comparative experiments between the proposed method and the traditional method in terms of Peak Signal to Noise Ratio (PSNR), Structural Similarity Index Measure (SSIM) and Mean Squared Error (MSE). The results show that the performances of proposed method are better than that of the traditional method. Especially

the SSIM of global image (butterfly), the proposed method is 34.45% higher than the traditional method.

P3-3 Measurement method of the compression coefficient of near-monocrystalline silicon density liquid

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The standard near-silicon liquid (2329kg/m^3) is a mixture liquid of tribromopropane and dibromoethane in a certain proportion. This liquid is used to measure the density of single crystal silicon spheres by a static suspension method and the analysis of the difference in the micro density between two silicon spheres. Measuring the difference in the micro-density of the silicon spheres is of great significance for the new definition of the new mass of kilograms. In order to obtain the micro-density difference of the silicon spheres, it is necessary to calculate the static pressure value and the temperature by separately adjusting the single-crystal silicon spheres to the same suspension state and the compression coefficient of the near-mono-crystalline silicon density liquid. Through the adjustment of the same hydrostatic suspension state of a single silica ball in different suspension states, the linear constants measured by the linear model are analyzed to calculate the liquid compression coefficient. For this purpose, a static suspension measuring device for a single crystal silicon ball was designed to maintain the water bath within a range of ±0.1mk within 3 hours, and the position control of the silicon ball was determined by controlling the pressure of the upper computer.

P3-4 An exchangeable end effector for multi-part-assembly system

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Automatic assembly is widely used in precision component fabrication, and the manually assembled task for a small batch of the precise component is replaced by automatic system gradually. One of the key issues is manipulating the workpiece reliably. With the quick updating of the products, the end effectors need to pick more parts with different dimensions and configurations. In this paper, an exchangeable end effector for laser gyroscope assembly is presented. The end effector integrated with adsorption and clamping is designed to suitable for different type of workpieces. The three-position two-way magnetic valve is used to switch the adsorption and clamping. Based on the dimension and shape characteristics of the parts, the adsorption and clamping position of the end-effector was calculated. The maximum weight of the part is 0.5N, thus vacuum degree required for adsorption is 0.078MPa and the reaction time is 0.653s. The clamp for this gas circuit can generate the clamping force of 10N, which meets the requirement of clamping. Finally, the assembly tests were carried out to prove the feasibility of this exchangeable end effort.

P3-5 Hough transform based image processing algorithm in the optical-electronic angle measuring device

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The article is based on some research which is considering the three-axis angle measuring autocollimator and Hough transform based image processing algorithm for it. In order to measure angular displacements around the three main coordinate axes (OX, OY, and OZ), special control elements are used. The use of a special control element generally improves the characteristics of the device, but it creates a problem of

label overlapping. This issue creates a zone of inoperability of the device and makes measurement and control impossible. In this paper, the algorithm is proposed, and the results of its testing are presented. This algorithm can reduce the malfunction area thereby The range of measurements is extending and accuracy at the label overlapping is increasing. Application of this algorithm in autocollimator with a special control element allows to reduce the size and cost of such devices significantly, and also it allows to control two or three angles simultaneously. The algorithm uses the Hough transform to find intersecting labels, and the magnitude of the gradient vector is used as the weight function.

P3-6 A differential giant magnetostrictive mitro-displacement actuator

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Actuators made of Giant Magnetostrictive Material (GMM) are used more and more widely in ultra-precision positioning, processing, measurement, and vibration isolation of equipment. While a single Giant Magnetostrictive Actuator (GMA) has low load capacity and non-ideal dynamic output characteristics, this paper presents a differential Giant Magnetostrictive Mitro-Displacement Actuator. The effect of the equivalent stiffness and quality of the load on the output characteristics of the actuator is analyzed by establishing the dynamic model of differential GMA. The experimental results show that compared to a single GMA micro-displacement actuator system, the differential GMA system has a positioning noise of $\pm$3nm, a resolution of 6 nm within a 18.5μm travel range. In the composite control system, a hysteresis-free sinusoidal displacement output with an amplitude of 3μm within 200 Hz is realized, and the maximum output error is 0.6μm, which effectively improves the dynamic performance of the actuator and improves the load capacity of the actuator.

P3-7 Design of active vibration isolation system based on electromagnetic and floatation hybrid support

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Compared with passive vibration isolation, active vibration isolation can provide a vibration control especially for low frequency and ultra-low-frequency vibrations, reduce the vibration frequency and high frequency transmission rate, so low-frequency micro-vibration suppression must use active vibration isolation control. In order to effectively reduce the impact of environmental micro-vibration on precision instruments and equipment, improve the positioning accuracy and vibration isolation performance of the vibration isolation system. In this paper, the aerostatic structure isolator with low stiffness and low natural frequency and the non-contact electromagnetic voice coil motor actuator are used to perform composite support and vibration isolation control for the vibration isolation system, designed corresponding active vibration isolation control method, achieved accurate positioning and active vibration isolation of vibration isolation system, and improved the system's positioning accuracy and vibration isolation performance.

P3-9 Robust concrete crack recongnition based on improved image segmentation and SVM

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This work presents an automatical crack recognition approach. Compared with the existing methods, it provides a significant increase in robustness and efficiency for large-scale use under widely varying field conditions. Inherent characteristics of crack images are exploited using proportional segmentation, combined with robust feature extraction to improve machine learning classifier performance. Experiments show that this method performs well in classify crack images captured from concrete

structures.

P3-10 Development of portable digital ultrasonic guided wave detector based on COM express

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This paper proposes a portable ultrasonic guided wave detector based on ADLINK COM Express (Computer On Module Express) computer module. This detector is equipped with Windows 7 operating system and uses the PCIe (Peripheral Component Interconnect Express) bus as the FPGA (Field Programmable Gate Array) of COM Express and Xilinx. The data transmission rate can reach 500MB/s in the transmission line. In addition, a self-developed high-voltage pulse signal generation circuit and signal acquisition circuit are used in the analog circuit. Finally, this developed detector is used to excite ultrasonic guided waves in the aluminum plate and the pipe to realize the identification of defect echo signals in these two structures, which verify the reliability of the designed detector.

P3-11 Research on self-calibrating phase shifting shadow Moiré technique

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The phase shifting shadow moiré is an efficient technique for 3-D object surface measurement for its merits. However, and there's room for improvement. Our recent research focuses on improving its measurement accuracy without addition the complication of the experimental set-up. In the proposed method, we firstly calibrate the geometric parameters of our setup by stereovision technique-based method. Then a method is proposed to determine the grating translation difference. After that an iterative self-tuning algorithm is use to retrieve the accurate phase. The proposed method is fast and can be implemented easily in many applications. Optical experiments are implemented to verify the feasible of this method.

P3-12 An online vision system for battery FPC connector defects detection based on ASM template matching method

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In this paper, a quality detection method for battery FPC (Flexible Printed Circuit) connectors based on active shape model template matching is proposed. It can deal with different kinds of connector appearance defects. Firstly, construct template data set of connector, acquire test images and apply cutting operation to original image, then execute tilt correction and image reconstruction by means of least square method and affine transformation to fulfil the pre-processing stage. Then, match and locate connector region in per-processing image with the help of the active shape model (ASM) based template matching method. To deal with different kinds of defect (soldering offset/tilt, exposed copper clad layer in FPC, broken edge in FPC, defects in center area of connector, defects on metal and plastic components), independent detection algorithm units are integrated in the system. Template can also be real-timely updated according to detection result. Finally, the defects will be classified, located and marked in detection image. In addition, aimed at the need of battery industry, a set of detection system with low cost, high performance and strong stability has been designed. It can be concluded from online and offline experiments that the method proposed in this paper is of high detection rate, good real-time

performance and strong robustness.

P3-13 Recognition and classification of label-free leukocyte scattering detection in peripheral blood basing on pattern recognition method

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The diagnosis of diseased blood cells in label-free conditions has many advantages, for example, it doesn't destroy cells' activity, composition, morphological and physiological structures. It plays an important role in clinical diagnosis of diseased cells in the future. The key scientific problem in this research is to find out label free cell's inverse principles which can match up with label free cells' types and specificity in their light scattering patterns. In order to solve this problem, the large clinical data is required. Therefore pattern recognition methods are applied in this study. On the other hand, different from conventional pattern recognition methods, a method which can be helpful to trace the laws for pattern recognition seems very important, because it can figure out the relations between scattering features and label free cell's biological characteristics. Aiming to this purpose, the decision tree method is paid more attention in our researches. 140 clinical mature lymphocytes from healthy people, 29 clinical immature lymphocytes collected from a patient with primary Acute Lymphoblastic Leukemia, 6 clinical lymphocytes collected from a patient who ever undergoes chemotherapy with Acute Lymphoblastic Leukemia and 7 gastric cells which are cultured in laboratory are applied. Firstly, their scattering patterns are calculated by FDTD (Finite-Difference-Time Domain) algorithm after obtaining their confocal image stacks. Then their scattering features are analyzed by the decision tree and other pattern recognition methods for mature, immature lymphocytes and gastric cells.

P3-14 A new method for generating large area & tunable non-diffraction structured light

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Structured light illumination is limited for the short focal depth and small measurement scope. A novel projection system is proposed for generating tunable approximate non-diffracting grating structured light with large area (one-dimensional extension), which consists of a prism beam expander (PBE) and two adjustable plane mirrors. The number of prism, magnification and apex angle of single prism are optimized to improve the efficiency of the PBE. Besides, the impact of the incidence angle θ, apex angle γ and exit angle α of the biprism on the magnification M and transmittance T are analyzed by numerical simulation based on the prism refraction theory.

The analysis of the total transmittance suggests the number of prism is not more than 4. So three prisms with the apex angle of 38°, 37° and 38° are chosen. Combined with analysis of the total transmittance and exit angle the M_{max} can be obtained when the acute angle β between plane mirror and optical axis is 108°. With these parameters above, the system generates fringe with fringe spacing of 2.26μm whose area is approximately 9 times the area of incident beam (one-dimensional extension). Theoretical analysis and simulation are carried out to build the model of generating structured light by the interference theory. The simulation result of the optimal optical system shows that a large area of structured light with flexible tenability is formed, when a collimated beam propagates through the system, which shows great prospect in structured light measurement.

P3-15 Fast response circulating cooling water temperature control system based on Smith predictor

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Thermal pollution plays a key role which limits the further improvement of precision and performance in ultra-precision measuring instruments and manufacturing equipment, such as lithography machines in semiconductor industry, SPM scanners and picometer laser interferometers in fields of precision engineering, ultra-precision machining tools, such as LODTM, etc. In a lithography machine, although, the average power of thermal pollution which is resulted from motors, drivers, laser sources may be up to several kilowatt, the power of these thermal pollution is curtain, since the machine runs according to designed manufacturing procedure. Therefore, when circulating cooling water is introduced to reduce the thermal pollution, if cooling power of the circulating cooling water could be regulated along with the power of the thermal pollution, an optimal thermal pollution reduction effect would be realized. However, current research works and commercial products more focus on improving the temperature stability of the circulating cooling water rather than enhancing the dynamic performance of temperature regulation. Since the circulating cooling water temperature control system has the characteristics of distributive large delays, control algorithm is the key factor to achieve the better dynamic performance of temperature regulation. In this paper, a novel controller based on Smith predictor is proposed and illustrated for the circulating cooling water temperature control system to realize ideal dynamic performance of temperature regulation. A circulating water loop driven by a pump is constructed, connected to the cooling channel inside the power devices. a refrigeration module using arrays of thermal electric cooler devices as refrigerating devices is used to extract heat from the circulating water, and a heating module using electrical heating-tube devices which is agile in control because of their most small heat capacity. Then, a variety of model identification experiments are carried out to extract property parameters of refrigeration and heating modules, and the feedback transfer function of the circulating cooling water temperature control system is identified based on the relay feedback identification method. A controller with Smith predictor is illustrated based on model identification results.

P3-16 Research on adaptive segmentation method of embossed character image based on wellner algorithm

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The image of pressed characters on the surface of metal workpieces in industry has obvious unimodal characteristics, for this feature, this paper proposes an adaptive segmentation method based on Wellner algorithm, this method is used to segment the pressed character image whose character gray value is similar to background gray value. Firstly, we use uniform illumination to capture grayscale images. Next, the Retinex algorithm is used to enhance the details of the character edge, the grayscale distribution range is expanded to improve the image contrast. Then, the bilateral filtering algorithm is used to filter the image noise. In this paper, the pixel gray value of a certain point is selected as the center, the row and column mean value of the pixel is calculated, at the same time, the mean value of the pixel gray value in the 8-connected region that it belongs to the pixel selected to be the center is calculated. The algorithm applies the “center-around” idea, the Wellner algorithm is improved with the mean value and the image pixel points are traversed to achieve image binarization. Finally, the final segmentation result is obtained by combining morphological operations. The verification experimental results show that the proposed method has good self-adaptiveness and accuracy for the gray-scale histogram image with unimodal characteristics.

P3-17 Method for detecting ring gear surface defects of wheel speed sensor based on neural network

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In view of the low efficiency and slow speed caused by the manual inspection of the wheel speed sensor ring gear in the automotive parts industry, this paper proposes a method for detecting the surface defects

of the ring gear of the wheel speed sensor based on the neural network. The method is based on the single hidden layer BP neural network model, and the L-M algorithm is used to train the network to achieve stability, the defect types are identified by combining the image feature parameters of various gear ring surface defects. The surface defects detection results of the wheel speed sensor ring gear show that the defects classification accuracy of this method is more than 94%, and the detection time of each ring gear is less than 4s. The detection result is better than the manual visual method.

P3-18 Field test method and standard instruments for verification of traffic speed meters based on test vehicle

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Since most of traffic speed meters are fixedly installed on the roadside, above the road or under the road, where it is difficult to disassemble and remove them from the road to the laboratory for annual verification, annual verification for these traffic speed meters must change to examined and tested in the field by using a standard speed measuring instrument. The field test method based on test vehicle is the most widely used annual field verification method in China now. We introduce the principle of the field test method and the requirement for the standard speed-measuring instrument, give the three main speed-measuring sensors used in the standard speed-measuring instrument, and analyze the numerical comparison results in this paper.

P3-19 Construction of a compact laser wavemeter with controlling laser angular drift

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A compact diffracting grating based laser wavemeter is constructed in this paper. Wavelength is the length unit of laser interferometers, it must be very accurate and stable during the length measurement. An air sensor, which is employed to correct the air refractive index through an empirical equation, is essential in laser interferometers. However, the empirical equation is suffered from indirect measurement, the correction accuracy is depended on the measurement accuracy of the air sensor. Slow response is other disadvantages of the empirical equation. Additional, the empirical equation is not applicable to correct the laser diode wavelength. Therefore, a direct measurement method of laser diode wavelength, based on the diffraction principle, is proposed and a compact, low-cost and simple wavemeter is constructed in this paper. Laser beam drift is recognized as one of critical error source in laser measurement. Therefore, a novel laser beam drift active compensation method is thus proposed in this study that integrates the functions of automatic type angle turning and PID controlled fine angle motion. After introducing the principles of wavelength measurement and laser beam drift compensation, the effectiveness of the wavemeter in real-time wavelength measurement is well verified by the experimental results.

P3-20 Ultrasonic characteristics of contact stress of small interference fitting parts

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Press-fit assembly is one of the traditional methods for assembly of interference fitting parts, but the assembly quality cannot be acquired directly from this method. At present, the press-fit curve is employed for quality estimation, and thick-walled cylinder theory (TCT) is used for standard press-fit curve prediction. However, the evaluation results have a great limitation, which it cannot predict the stress concentration occurs on the mating surface, and most interference fitting parts fail due to this reason. So the purpose of the research was to explore ultrasound as a tool for non-destructive evaluation

of contact stress, develop an automatic testing apparatus, and the contact stress distribution can be acquired eventually. Therefore, it is more convenient and intuitive to evaluate the assembly quality based on this method.

P3-21 Calibration of geometric error in passive laser tracker

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The geometric error calibration plays an important role in the accuracy performance of all kind of laser tracker. However, the commonly used methods such as the two-face method and the length measurement are sensitive to some errors, which cannot separate directly. In this paper, a series of geometric error calibration methods for a passive stand-alone laser tracker are presented. The passive laser tracker is composed of two orthogonal precision turntables and a telescopic plate through the axes of the rotating shafts. Due to the errors of manufacture and assembly. There are calibrated through a precision two-dimensional moving platform. The calibration methods presents in this paper are easy to implement and the effectiveness are proved by comparing the accuracy performance of the compensated passive laser tracker.

P3-22 Defect detection method for complex surface based on human visual characteristics and feature extracting

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Aimed at the problem of uneven illumination and significant noise in complex surface, a complex surface defect detection method based on human visual characteristics and feature matching is proposed. Image segmentation and background adaptive equalization operation are applied firstly to adjust the overall grayscale spatial distribution of the image and correct the effect of uneven illumination. And then the improved frequency tuned salient region extraction algorithm is applied combined with the mask obtained by dilation-differential algorithm to extract the defect region which human eyes are concerned with. Thus the effect of background significant noise to defect region is reduced. In view of information lack in large space range defect extraction process, a directional feature matching and merging algorithm is proposed. Experiment results show that the method can retain the complete defect morphology and achieve considerable defect extraction effect and successful detection rate.

P3-23 An identification method for casing weld in complex environment

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This paper provides anindentification method for casing weld in complex environment. Firstly, detecting a region of interest (ROI) of pipe to narrow the searching range. Copper pipe is segmented by combining grayscale characteristics and color characteristics. Secondly, based on the characteristics that the casing weld on copper pipe could be eroded in binary image, the weld potential regions are obtained by the morphological operation to reduce interference on pipe. Finally, according to the position of the weld characteristics on the copper pipe to identify the welds. The experiment results show that the casing weld could be identified accurately by this method.

P3-24 Architecture of rail and wheelset ndt detecting test rig

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The research designs a test rig of rail and wheelset crack detecting with non-destructive testing (NDT) method. The test rig is a building block mode, which consists of three components, one in ultrasonic transducer, other in embedded system with transmitting and receiving circuit, and another in receiving signal process with computer. In the research, it designs the transducer with a curve shape in contact area to fit the wheel set tread surface contour. In NDT detect, it adopts ultrasonic A-scanner method to detect the rail and wheelset flaw in railway, and analyzes the flaws with the detecting image.

P3-25 A design of high-accuracy angle measurement system for satellite AIT processing

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In order to solve the problems and shortcomings of current angle measurement methods for satellites assembly and inspection, such as limited field of vision, relatively low precision and low degree of automation, a novel design of high accuracy angle measurement system is proposed. The new system composed of auto-collimator, electronic gradienter, two-dimensional precise turntable and standard mirrors works by actual collimation measuring among the measured target, auto-collimator and standard mirrors with the measuring basis of earth, which is built by electronic gradienter. This paper focuses on the specific structure design, engineering modal and arrangement plan of automatic measuring, also includes precision calibration test in the end. According to the result of the test, the angle measurement system reaches the precision of 3″ and repeatability of 1.1″.

P3-27 Design and performance analysis of a novel thermos-structure for measuring thermal drift of optics in a next generation interferometer

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In this paper, we propose a design of a novel thermo-structure for measuring thermal drift of optics in a next generation interferometer. The thermo-structure, with thermo electric coolers intergrated inside as the source of heat, is used to change the temperature of IUT to a certain value by radiation. Besides, for the thermo-structure, it is made of multilayers stacked by aluminum and fiber reinforced polymer (FRP) in a specific order. The multilayers make the thermo-structure to provide a uniform temperature field while protect the IUT from disturbance of environmental radiation. To evaluate the performance of the system, finite element analysis has been made and simulation results show that the thermo-structure can achieve a uniform temperature field which temperature difference is less than 0.2 °C and protect the IUT from affect of environmental radiation.

P3-28 Long-range automatic precision displacement measuring of winding system using double timing belt transmission

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The winding system has a long travel range, often reaching several meters or even hundreds of meters. Conventional longrange displacement measuring methods have a large measurement error and are difficult to realize bidirectional measuring. An innovative long-range automatic displacement measuring

method and device of winding system is proposed and designed, which uses double timing belt transmission pairs as precise clamping conveyer. Double rotary encoders are used to measure the displacement simultaneously, which can effectively reduce the measurement error caused by the slippage of the timing belt transmission. By analyzing the displacement error of linear transmission caused by the polygon effect of trapezoid tooth and circular arc tooth, this paper proposes to use circular arc tooth timing belt to reduce the measurement error. The proposed method and device has been used successfully in cable displacement measurement of trailing cone automatic retracting and releasing system for air static pressure measurement in aircraft test flight. The experimental results show that the proposed method is correct and feasible, and the displacement measurement error is less than 0.5%.

Poster 4 Modern Optics and Instruments for Precision Measurement

P4-1 Comparison of spacing detection algorithms for optical straight fringes images

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Optical fringe is one of important output information from the optical systems. Some important optical or system parameters can be obtained by analyzing the fringe information from optical system such as interferometer system or diffraction setup. The straight fringe is a kind of optical fringes frequently appearing in Yong's double slit interference and single-slit diffraction and other optical structures. For the information extraction of straight fringes, it is often necessary to calculate the fringe spacing parameters. Popular straight fringes analysis methods include the fringe center method and the Fourier transform method. In addition, some image processing methods realized line detection can also be used to analyze this straight fringes image, which include Hough transform and Radon transform. In this paper, four algorithms for fringe analysis are discussed and compared, which focus on method's principle, algorithm's simulation and performance when they be applied to detect the fringes spacing. At the same time, the anti-noise performance of two image processing algorithms including Hough transform and Radon transform are analyzed.

P4-2 Improved design principle of Dyson concentric infrared imaging spectrometer

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Dyson concentric structure has advantages of 1:1 magnification ratio, compact size, light weight, large numerical aperture, less smile and distortion. However, volume of initial structure calculated by two-wavelength astigmatism method is relatively large. Meanwhile, we only obtain one smaller structure for long wavelength infrared range through another improved method widening aberrations. In this paper, we proposed new design method of Dyson concentric push-broom infrared imaging spectrometer, which can calculate all smaller initial Dyson structures satisfying requirements of spectral range and resolution in different infrared wavebands. First, obtain initial grating groove density using two-wavelength astigmatism. Then widening aberration, search all of initial Dyson structures satisfying ideal imaging condition under 1 to 10 times of initial grating groove density. Lastly, select infrared materials and detectors suitable for short infrared, medium-wave infrared and long-wave infrared wavebands respectively to demonstrate feasibility of this new method. As results shown, volume of all initial Dyson structures has reduced in different levels for different infrared wavebands with different spectral resolutions, which benefits for infrared concentric imaging spectrometer with wide waveband, small volume. When keeping one of groove density of concave grating, radius of plano-convex lens and concave grating substrate constant, we can improve spectral resolution in all infrared wavebands by selecting suitable values of the other two of them.

P4-3 Research of scintillation crystal's refractive index's homogeneity based on

ellipsometric method

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In this work we propose ellipsometric method applied to the analysis of scintillation crystal's refractive index in order to define it's uniformity throughout the whole structure of the investigated crystal. The method used in this work is normal incidence transmission ellipsometry. The technique consists of directing plane monochromatic wave normally incident onto crystal's surface. By knowing features of light illuminating the object and some essential parameters of crystal's structure (such as information about it's isotropy and internal structure) we can calculate polarization angles Ψ и Δ, using equations ,that connect crystal's features and parameters of light that illuminate the investigating object. Computation of these angles is basis of this method and it gives us a possibility to calculate and analyze crystal's features we are interested in. One of the main problems with scintillation crystals is structure's heterogeneity that leads to different value of characteristics that are essential for further calculations and use of investigating crystal in various schemes. There are currently many ellipsometrical methods used in different cases, one of the most popular is based on non-normal light incidence, that later reflects from the crystal's surface to the analyzer. However, in this study it is not very effective to use it due to impossibility of taking measurements on particular levels of highness for to compare refractive index's value on the same levels but different surfaces of light incidence. During this experiment, we used ellipsometer LEF-3M-1 as an instrument that gives us a possibility to make precise measurements. This device was also preferable because of economic reasons.

During this research we have noticed non-uniformity of the crystal's refractive index distribution. The results of this study are important for future application of the investigated crystal in schemes of different devices and they will certainly be useful for fundamental understanding of scintillation crystal's features and how its advantages and disadvantages can be taken into account. On the other hand, these results are on considerable practical importance in terms of optimization of the scintillation crystals operational conditions for improving their functionality.

P4-4 FPGA-accelerated one-dimensional Fourier reconstruction LCD defect detection algorithm

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With the development of high-generation production lines for Liquid Crystal Display (LCD) panel, online real-time detection of large-scale, high-resolution LCD surface defect imposes stringent requirements on image algorithms and computing platforms. This paper aims at the edge effect in the traditional one-dimensional Fourier reconstruction LCD detection algorithm. Based on the potential periodicity of the Fourier transform and the approximate periodic arrangement of the element array in LCD panel images, a complete period truncation image preprocessing strategy is proposed. The processing strategy not only eliminates the ring effect at the connection joint caused by the original algorithm's extending period at both ends of the image, but also reduces the length of the Fourier operation, which is even more noticeable when detecting large-size panels. In addition, in order to adapt to the fast Fourier transform input interface, the resampling method is applied to the complete period truncated image whose length is not an integer power of 2, and an FPGA-based resampling acceleration structure is designed. The experimental results show that compared with the traditional one-dimensional Fourier reconstruction algorithm, our proposed method not only performs better in eliminating LCD global periodic texture, but also reduces the amount of data to be processed. The FPGA acceleration scheme even reduces the scanning detection time of a 8.5-generation LCD panel to 12.5s.

P4-5 Non-destructive rapid inspection methods for sptial light modulator using swept source optical coherence tomography

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A high speed swept source optical coherence tomography (SS-OCT) system has been proposed for tomographic map of spatial light modulator. In the optical arrangement, a swept-source with 100 kHz axial-scanning rate and a compact Michelson interferometer was applied. The implemented SS-OCT system has an axial resolution of 15μm and penetration depth of 12mm. The two-dimensional tomographic grayscale maps of the sample can be obtained in real time. As a result, the thickness of glass substrate, liquid crystal layer and the silicon substrate could be obtained simultaneously. Compared with the traditional detection methods, The SS-OCT system has the characteristics of fast imaging speed, stable repeatability of measurement with high-resolution and non-destructive.

P4-6 Image displacement analysis for electro-optical system for deflection measurement of floating docks

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An influence of external conditions can lead to a random rotation of the base unit of the electro-optical deflectometer. This will affect the variation of the image coordinates of the control elements in relation to base position, and, as a result, will cause the error in determining the deflection of the analyzed structure. The changes in the position of the image coordinates of the reference marks before and after the base unit rotation of the electro-optical deflectometer was estimated with the help of elements of vector algebra and matrix analysis. The results of the analysis show that errors in the assignment of the coordinates of the control elements are affected not only by the angle of rotation, but also by the position of rotation axis around which the base unit rotates.

P4-7 Modified visible offner imaging spectrometer with low F number and large field of view

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Dyson and offner are two typical concentric imaging spectrometer configuration with dual telecentricity in object and image space, a small F number, low smile and keystone etc. In some condition such as Ocean color remote sensing, the image spectrometers require smaller F number to obtain higher luminous flux. However, when F number is smaller, off-axis aberration becomes larger. In visible waveband, the spectral response band of the selected visible detector is 0.4~0.8μm with 1250×1000 pixel numbers and 4.8×4.8μm pixel size. When F number is 2.0, we select BK-7 as material of the plano-convex lens, and use traditional two-wavelength astigmatism method to design the visible imaging spectrometer based on Dyson configuration. In resulting Dyson spectroscopic imaging system, the plano-convex has a thickness 45.917mm.

P4-8 Modified short-wave offner imaging spectrometer with low F number and large field of view

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Dyson and offner are two typical concentric imaging spectrometer configuration with dual telecentricity in object and image space, a small F number, low smile and keystone etc. In some condition such as Ocean color remote sensing, the imaging spectrometers require smaller F number to obtain higher luminous flux. However, when F number is smaller, off-axis aberration becomes larger. In short-wave infrared wave band, the spectral response band of the selected visible detector is 0.9~1.7μm with 640×512 pixel numbers and 15×15μm pixel size. When F number is 2.0, we select fused silica as material of the plano-convex lens, and use traditional two-wavelength astigmatism method to design the visible imaging spectrometer based on Dyson configuration. In resulting Dyson spectroscopic imaging system, the plane-convex has a thickness of 97.349mm. This type of lens is difficult to manufacture in practice, and the Dyson configuration also has the problem of detector placement.

P4-9 Choice of optimal resolution and array for integrated photosynthetically active radiation spectroradiometer

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The article is devoted to development of a spectroradiometer for an automatic controlled lighting system for plants cultivated in a greenhouse. The error of the spectroradiometer due to the discreteness of the multielement photodetector and the ratio of the entrance slit monochromatic image half-width to the step of the elements are considered. Relative error of photosynthetically active radiation bands ratio measurement for various instrument line functions is calculated. The results of an experiment for mass-produced optical multi-element photodetectors with different widths of sensitive elements for different entrance slit monochromatic image half widths of a polychromator are presented.

Poster 5 Sensors, Converters, and Control System

P5-1 Combining compound eyes and human eye: a hybrid bionic imaging method for FOV extension and foveated vision

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Based on artificial compound eyes and human vision mechanisms, we propose a hybrid bionic imaging method to achieve field of view (FOV) extension and foveated imaging simultaneously. The imaging model of the proposed method is built, and the key parameters are deduced. Then, simulations are carried out to estimate the properties of the model, including FOV extension ratio (FER), foveal ratio, fovea moving range and so on. Finally, a prototype is developed, and imaging experiments are carried out. The experimental results accord with the simulations well, proving the potential of the proposed method for intelligent surveillance, automatic object detection and recognition with low cost.

P5-2 Parameter identification of inertial velocity sensor for low-frequency vibration measurement

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Whether velocity sensor can accurately acquire payload vibration information has become the most important factor that restricts vibration isolation performance. In order to get accurate sensor parameters, DC excitation method is used to measure the central frequency, damping ratio and sensitivity of inertial velocity sensor. The influence of different currents on the measurement accuracy of sensors such as response voltage, central frequency, damping ratio and sensitivity is analyzed, and the optimal current value is determined, which provides a powerful guarantee for obtaining accurate sensor parameters. Finally, the GS-11D sensor is used to carry out the experiment. The experimental results show that the relative error of the central frequency, damping ratio and sensitivity of the DC excitation method can meet the application requirements.

P5-3 Microfluidic contact lens for continuous non-invasive intraocular pressure monitoring

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This paper proposes a microfluidic contact lens for continuous non-invasive intraocular pressure (IOP) monitoring. The microfluidic contact lens is the reference-sensing structure, and fabricated by using the chemical assisted bonding and next thermoforming technologies. The curvature of the contact lens is made corresponds substantially to that of cornea, so as that, the PDMS (Polydimethylsiloxane) sensing layer can wear on cornea to “feeling” its expansion. The cornea’s deformation is varied in pace with IOP, while the IOP can be simply monitored by using the smart phone to optically detect the movement of visible liquid in the microchannels. The simulation and measurement results of the devices with different designs are presented, showing a good linearity in the measurement of artificial eye pressure tests. In next work, the devices will be redesigned to meet the needs of intraocular pressure monitoring and test in vivo.

P5-4 Revise compensation to the angle estimate error using multi-groups sensor

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The magnetoresistance (MR) sensor has been successfully demonstrated in rotational speed and position detection, however, the uneven magnetic field or the installation eccentricity are all decrease the signal quality and influence the reliability of measurement. Therefore, this paper presents the theory of time grating in displacement calculation and proposes a reverse compensation method using multi-groups sensor to improve measurement performance. A pair of linear tunnel magnetorsistance (TMR) sensors are spatially displaced by 90° electrical and excited by sin or cos signals. The other pairs sensors are reverse placed and 180 electrical degrees apart to the former. A compensated traveling wave is got whose phase is proportional to the displacement of rotation. The angle displacement is measured by counting the time pulses that serve as measurement standards. The effectiveness of the proposed scheme is verified through a prototype permanent magnet motor system. That shows the amplitude of the measurement error from the 0.17° to 0.04°, which reduces 75% by the special arrangement of the multi-groups TMR sensors. Even though the magnetic sensor presented here uses TMR sensors, the proposed technique is suited without any modification for Hall and other MR sensors as well.

P5-5 Soil moisture sensor design based on fiber Bragg grating

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This paper presents a soil moisture sensor design based on fiber Bragg grating (FBG) and its performance test. The polyimide with high water sensitivity and high linear expansion coefficient was coated to the surface of FBG. The center wavelength of the FBG will change due to moisture absorption and expansion of the polyimide material when moisture changes. Using this basis principle, the soil moisture can be measured. This paper describes the sensing principle of the FGB coated with polyimide, the method of the temperature compensation, the sensor design and its packaging structure. The performance of the sensor was tested. The experimental results show that the measuring range of moisture is 10%RH~75%RH, the sensitivity is 12.6pm/%RH, and the accuracy of the sensor is ±10.26%.

P5-6 Dynamic sensitivity distribution of linear electrostatic sensor matrix

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Particle charging is a universal phenomenon due to the collision and contact between particle and particle, particle and wall in the powder pneumatic conveying process. The linear electrostatic sensor matrix (LESM) is able to capture the dynamic information of the moving charged particles in pipeline, whose spatial filtering characteristics has been employed to obtain the flow velocity of particles in gas-solid flow. The spatial filtering characteristics of LESM are closely related to its dynamic sensitivity (DS) distribution. In this paper, the 3D simulated model of the LESM was built by finite element method and the effects of its structural parameters on its dynamic sensitivity and spatial filtering characteristics were studied. The geometric dimensionless model of dynamic sensitivity of LESM was further established. Finally the experiment was carried out on a gravity-fed solids flow rig, and the experimental results was verified the simulation results.

P5-7 Bias electric field distribution analysis for a non-contact nano-probe based on tunneling effect

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A new probe based on tunneling effect is being studied and developed, and it shows great advantages over existing nano-probes in non-contact measurement, spherical probing, nano-resolution and high aspect ratio measurement capacity. During modelling of the tunneling effect and characterization of the probe, analysis of the bias electric field (BEF) distribution between the spherical electrode of the probe and the metal surface to be measured is a key step. However, when the spherical electrode which serves as probing ball of the probe approaches the surface to be measured, analytic methods of electric field modeling are impractical to use here because of the boundary irregularity of the BEF to be analyzed. Moreover, the diameter of the spherical electrode on the probe proposed is on millimeter/sub-millimeter scale, while the gap between the spherical electrode and the surface to be measured is usually on nanometer/micrometer scale. In other words, the boundary of the BEF to be analyzed is on the scale, which can be thousands of times larger than the scale of the gap. In this case conventional numerical methods like finite difference method have to face either low accuracy or vast amount of computation which will inevitably result in huge consumption of time and memory, and that is unacceptable for modelling the tunnel effect of the nano-probe on personal computers. In a word, it is impracticable for conventional electric field modeling methods to analyze the BEF of the new probe.

P5-8 The meat product quality control by a polarimetric method

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Research is conducted in the field of food freshness control. The research object is a sample of meat product. A variant of the investigation of meat samples using a polarimetric method is proposed. It

includes the illumination of a sample by polarized radiation with a given state of polarization, the registration of this radiation after passing through the object of investigation and analysis of its polarization parameters. It is supposed that it is possible to conduct experimental tests and mathematical modeling of the processes that are taking place. To accomplish this, it is necessary to study the features of the investigation object structure, which is a turbid, highly scattering medium. The use of the polarimetric method becomes possible due to the presence in the biotissue of anisotropic structures. Taking into account the structure of a meat product flat sample, it is proposed to represent it in the form of a set of plane-parallel plates having different parameters. During the research modeling of radiation passage through a plane sample of muscle tissue was carried out, the degree of polarization at the output of the system was obtained. In addition, a model of the setup has been developed, which makes it possible to evaluate the Stokes vector of output emission experimentally.

P5-9 Eye positioning based on windowed gray-scale integral projection algorithm

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Eye positioning is an important prerequisite for vehicle-mounted fatigue driving monitoring. In this paper, a windowed gray-scale integral projection algorithm based eye-positioning method is introduced. Firstly, the human eye is positioned by Adaboost algorithm, then the eyebrows are separate by the windowed gray-scale integral projection algorithm, consequently, the accurate positioning of human eye parts is achieved. The experimental results show that the separation effect is obvious and the speed of human eye positioning is significantly improved.

P5-10 Using carbon nanotube membrane as counter electrode in voltammetric electronic tongue system

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Carbon nanotube membrane (CNTM) has been employed as the counter electrode in a two-electrode voltammetric electronic tongue system. Owing to its large surface area, CNTM provides significant double layer capacitance at the solid/solution interface, and offer a constant potential during the electrochemical detection. In order to characterize the analytical possibilities of the electronic tongue system, hydrogen peroxide has been detected. Principal component analysis (PCA) is used for identification. This electronic tongue system using CNTM counter electrode shows better performance than that using large surface stainless steel counter electrode which is commonly used in two-electrode voltammetric electronic tongue system.

P5-11 Autonomous time synchronization method of wireless ad hoc sensor network and its implementation on CC1350 system

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Wireless ad hoc sensor networks have been used more and more in recent years, and they are mainly used in the continuous monitoring of complex environment. The low power and dual frequency characteristics of the Simple Link CC1350 Launch Pad micro control platform are very suitable for the research of wireless ad hoc sensor networks. Because the synchronization of each node clock is the premise of the normal work of wireless sensor network, this paper mainly studies the time synchronization problem of CC1350 development board. In this paper, the advantages and disadvantages of the existing time synchronization methods are analyzed, then the LTSP algorithm is selected at the end, and the

experimental verification is carried out on MATLAB software platform and CC1350 system. The experiment result shows that the time synchronization precision and extensibility of the algorithm can meet the requirement of networking.

P5-12 Strain transfer characteristics of resistance strain-type transducer

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To ensure that the resistance strain gauge has excellent strain transfer performance and low hysteresis, it is recommended that the paste thickness should be strictly controlled, and the STZ ratio should be less than 10%. The bonding process of resistance strain-type transducer into the surface of elastomer element must be strictly controlled to ensure adequate bonding strength and insulation resistance. At the same time, it requires that ground adhesive glue has twice the area of the film substrate layer. The ground adhesive glue layer should be as thin as possible, while its shear modulus should be as large as possible. The end-effect due to the grid width can be reduced by increasing the grids length or by optimizing the grids patterns. Selecting a ground adhesive glue with a large elasticity modulus can effectively reduce the influence of the thickness of the ground adhesive glue on the average strain transfer ratio.

P5-13 Dependence of stress distribution in electrical strain gauges on micro-morphology of sensitive grids

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The uneven surface topography will make the stress distribution of the whole structure uneven, so that the maximum stress at the stress concentration is larger than the ideal. At the same time, the measurement error of the stress is increased, and the measurement accuracy is lowered. When the sinusoidal profile has a certain period, the maximum stress increases with the increase of the amplitude, and the average stress decreases with the increase of the amplitude, that is, the stress transfer rate decreases. Therefore, in practical applications, the amplitude of micro-morphology of the sensitive grids of resistance strain gauge is controlled to be as small as possible. The sidewall of the resistive strain sensitive grids has a certain amplitude of the sinusoidal profile, the maximum stress decreases with the increase of the period, and the average stress increases with the increase of the period, that is, the stress transfer rate increases. It can be seen that increasing the period of the contour protrusion is beneficial to improve the performance of the strain gauge. Moreover, the variation of stress in the range of 20~120μm is relatively large, and the variation is relatively gentle in 120μm~200μm. The sinusoidal contour period should be controlled above 100μm.

P5-14 A high resolution and response speed interrogation method for FBGs-based sensors

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Recently, fiber Bragg gratings (FBGs) have played significant roles in a variety of fields such as optical communication, dimensional metrology, buildings health monitoring, ultrasonic waves and vibration measurement, petrochemical and other harsh/remote environments owing to their excellent performances

like electromagnetic insensitivity, high accuracy and long term stability. In general, FBGs-based sensors are usually decoupled by detecting the variations of FBGs' central wavelength, wherein, the accuracy and dynamic characteristics of the FBGs-based sensing are directly dependent on the spectrum resolutions and response speed of the interrogation method. However, conventional spectrum interrogation methods, which directly utilize an optical spectrum analyzer (OSA) with a low resolution and response speed cannot satisfy the requirements of detecting small and dynamic variations of the FBGs' central wavelength accurately. It is therefore of significance to find a FBGs interrogation method with high resolution and high response speed. In this paper, a high resolution and response speed interrogation method based on reflective-matched Fiber Bragg Gratings scheme is investigated in detail. The nonlinear problem of the reflective-matched FBGs sensing interrogation scheme is solved by establishing and optimizing the mathematical model. A mechanical adjustment to optimize the interrogation method by tuning the central wavelength of the reference FBG is investigated to improve the stability and anti-temperature perturbation performance. To satisfy the measuring requirement of the optical and electric signal processing, an acquisition circuit board is well-designed, and experiments on the performance of the interrogation method are carried out. Experimental results indicate that the optical power resolution of the acquisition circuit border is better than 8 pW, and the stability of the interrogation method with the mechanical adjustment can reach 0.06%. Moreover, the linearity of the interrogation method is 3.3% in the measurable range of 60 pm; the influence of temperature is significantly reduced to 9.5%; the wavelength resolution and response speed can achieve 0.34 pm and 500 kHz, respectively.

Poster 6 Optoelectronic System and Optical Instruments Design

P6-1 Research and evaluation of geometric element data fitting software for coordinate measurement machine

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Standard geometry element fitting software is a critical important part of the coordinate measuring machine (CMM). It is used for coordinate data processing and data evaluation. At present, the commercial fitting software of the coordinate machine manufacturer is not disclosed to the public. So it is inconvenient to develop secondary applications. This work developed a kind of geometric element fitting software based on open source code. The software can be used to fit CMM measurement data to common geometric elements including lines, circles, planes, spheres, cylinders, and cones. The core algorithm of software is based on a least-squares algorithm and a Gauss-Newton iterative algorithm. Least squares is a data optimization technique that seeks the best function match of the data by the sum of the squares of the smallest errors. The basic idea of the Gauss-Newton iteration method is to replace the nonlinear regression model with the Taylor series expansion approximation. Then through multiple iterations, the regression coefficient is modified several times so that the regression coefficient continuously approaches the optimal regression coefficient of the nonlinear regression model. Finally, the residual square sum of the original model is minimized. The accuracy of fitting results are verified with the standard reference data developed by national institute of standards and technology. The software can be used to the geometry element measurement uncertainty evaluation.

P6-3 Super-resolution scanning microscopy with virtually structured illumination

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The resolution of optical microscopes fundamentally limited by diffraction is at best 200 nm. In the theory of Fourier optics, this phenomenon is explained that the resolution limit of a microscope is depended on the extent of its optical transfer function (OTF), the normalized Fourier transform of the

point spread function (PSF). The microscope substantially works as a low-pass spatial filter. Super-resolution structured illumination microscopy (SR-SIM) provides an elegant way of overcoming the diffraction limit in conventional wide-field microscope by superimposing a grid pattern generated through interference of diffraction orders on the specimen while capturing images. The use of nonuniform illumination field "shift" high specimen frequencies which are out-of-band into the pass-band of the microscope through spatial frequency mixing with the illumination field. Therefore the effective bandwidth of SR-SIM is approximately twice as conventional microscopy, corresponding to a 2-fold resolution enhancement, if the difference between excitation and emission wavelength is ignored. However, such a wide-field scheme typically can only image optically thin samples and is incompatible with multiphoton processes such as two-photon fluorescence, which require scanning point by point with a focused laser beam. Although the scheme, scanning patterned illumination (SPIN) microscopy, employs modulation of the excitation intensity combined with temporally cumulative imaging by a nondescanned array detector can achieve multiphoton imaging. But the modulation of excitation intensity increases the complexity of the mechanism and compromises the quality of scanning laser beam that lead to unexpected artifacts. We propose a Super-resolution scanning scheme with virtually structured illumination, utilizes detection sensitivity modulation on line by programming or off line by numerical processing together with temporally cumulative imaging, the excitation intensity is constant while capturing images. In this case a nondescanned array detector such as CCD camera is needed. When combined with multiphoton excitation, this scheme can image thick samples with three-dimensional optical sectioning and much improved resolution.

Poster 7 Laser Measurement Techniques and Instruments

P7-1 Orthogonally polarized self-mixing grating interferometer for two-dimensional displacement measurement

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Self-mixing interference (SMI) or laser feedback interference (LFI) has been widely used for sensing displacement, velocity, absolute distance, and other laser cavity related measurements. By replacing the reflective mirror of the interferometer with a diffraction grating in SMI, we have developed a novel self-mixing grating interference (SMGI) with Littrow configuration for in-plane displacement sensing. It can provide a very compact system because only a light source with photoelectric detector (PD) and a hologram reflective grating are required in such SMGI. It is noticed that, when the grating moves with an out-of-plane displacement, it also affects the signal of SMGI. Here, we must not only consider the grating Doppler Effect, but also take into account the influence of the optical path differences. One-dimensional in-plane and out-of-plane displacements can also be simultaneously observed by a pair of symmetrically placed SMGIs with Littrow configurations. In the process of moving along the direction of incident light, the reflection grating plays the same role as the mirror, so it can be explained by classical self-mixing interference (SMI) theory.

P7-2 Angle measurement for cross-line target image based on Fourier-polar transform algorithm

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In visual detection fields based on line structured light, the analysis of optical stripe image is a key problem. For the cross-line target image, through measuring the angle between two linear optical stripes the target position or some system's parameters can be obtained. The traditional technique usually needs

many preprocessing steps including image filtering, threshold segmentation, thinning processing and so on. For the images with low signal noise ratio or non-uniform intensity distribution, their application performance will be challenged. Based on the characteristic of translation invariance and rotation synchronization of two-dimensional Fourier transform, the paper combines Fourier transform with polar transform to form new Fourier-polar transform algorithm. It implements the angle measurement in the frequency-domain replaced in the spatial domain. At the same time, to improve the convenient of compute, the polar transform is adopted to calculate the distribution direction of amplitude spectrum energy. The proposed Fourier-polar transform algorithm uses the overall information of the image, and the calculating process is simple and no requirement of image preprocessing. Therefore, it can be applied to measure the angle of cross-line target image in low quality image such as low signal-to-noise ratio or with noise.

P7-3 Analysis of modern non-invasive methods of optoelectronic control of the skin

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At present, optical methods are becoming more common and widely used in medicine. The propagation of optical methods is explained by the safety of the application and the possibility of non-invasively obtaining a number of parameters in real time. The use of optical radiation makes it possible to obtain information on the structure and composition of the skin, to study the processes taking place in the tissues, without adversely affecting it. The use of optical radiation in accordance with the diagnostic windows of skin transmission allows one to investigate deeply lying structures of the skin. Despite the spread of optical methods of diagnosis of the skin, the dermatologist cannot always correctly assess the condition of the tumor. This is due to the lack of a large practical experience with working with neoplasms, insufficient informativeness of the method of investigation, the complexity of classification of the neoplasm. The development of optical diagnostic methods will make it possible to protect a person from the development of malignant pathologies The purpose of this work is the development of an optoelectronic system for the control of the skin by the scattering ellipsometry method. At this stage of the study, the analysis of modern non-invasive methods of optoelectronic control in the field of the study of the skin was carried out. The review of existing foreign and domestic fundamental research based on the use of opto-electronic methods of skin control was carried out, their comparative analysis was carried out with the identification of advantages and disadvantages.

P7-4 Sensing the atmosphere of coastal areas of laser detection methods

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In this paper, a weather phenomenon called a hurricane is considered. Major components are considered and selected. After the analysis of the components, the indicator substances are chosen, according to which the detection of the incipient phenomenon will be carried out in the future. The method of remote sensing is considered for detecting small concentrations of indicator substances in the air. The sounding area is chosen to study the atmosphere for the presence of indicator substances. The results of calculating the backscattering power for some indicator substances are presented, depending on the range.

P7-5 Cotton neps on-line measurement based on near-infrared structured light images fusion light images fusion

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This paper presents a method to detect the cotton neps on-line measurement based on near-infrared structured light images fusion. Firstly, the line structure near-infrared laser light is used to scan the cotton surfaces. Secondly, the near-infrared images of cotton were captured by infrared CCD. Then, images are processed with the adjacent subtraction fusion (ASF) algorithm. Finally, the neps images were

segmentation processed and inspected. The quality of cotton can be determined by the netps content. Samples included Xinjiang cottons and Inland cottons, 5 batch numbers. 5000 samples in each batch numbers were selected and measured, manual and optical methods, respectively. The average results were compared to the National Standard and the cotton grades were obtained. The experimental results show that the method can effectively extracted the neps in the raw cotton and can meet the cotton inspection requirement.

P7-6 Displacement measurement with MEMS based slit sensor

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For the requirement of high speed and high resolution large displacement range measurement, the two-dimensional reflective optical displacement encoder based on grating imaging was proposed. The proposed schematic consisted of a binary amplitude reflective grating and a slit displacement sensor (SDS). The SDS was fabricated by MEMS technology in our lab. The binary amplitude reflective grating served as scale grating. The divergent light generated by a diode laser illuminates the binary amplitude reflective grating by the through hole in the designed two-dimensional SDS. Then the light is diffracted by the binary amplitude reflective grating, and the interference pattern of the diffracted light are the grating image. The grating image transmitted the slit of SDS. The transmitted optical pattern are obtained by a two-dimensional detector array and the 90° electrically phase-shifted signals are generated also. Based on the arrangement of the measurement system, the displacement measurement sensor was high accuracy.

P7-8 Study on the temperature characteristics of the triangular prisms ring cavity

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The refractive indexes of prisms are affected by temperature, hence the optical characteristics of triangular prisms ring cavity is disturbed enough to affect the stability of the laser gyro. Considering the temperature perturbation, the transmission matrices of the reflected and refracted beams on the prism surfaces have been modified. The modified results are the old 2×2 beam transfer matrices are corrected to new 3×3 matrices and the temperature perturbations are added. According to the self-consistent theory of the laser ring cavity, a physical model of the ring cavity light transmission with the temperature disturbance has been established. The theoretical analysis shows that when the temperature varies from -40℃ to 70℃, the changes of the optical cavity-length, frequency offset, and scale factor are 49μm, 0.011MHz and 1.96×10^{-10}, respectively. An experimental system of the prism laser gyroscope has been established whose temperature can be changed, and the experimental results agree with the theoretical values.

P7-9 Doppler-shifted laser self-mixing interferometry for enhanced detection sensitivity

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During the last several decades, laser self-mixing interferometry (SMI) has attracted lots of research interest world wide, mainly due to its intrinsic merit of self-alignment, high-sensitivity, absence of

complex optical components and regardlessness of laser types. Among the literatures focusing on SMI, the laser diode (LD) is the most frequently utilized laser type, while the solid-state laser (SSL) has rarely been reported. The opencavity type SSL has more adjustment flexibility but suffers from external vibration and air disturbance, whereas, the microchip (MC) SSL shows more compact configuration and stable performance, catching attention from some researchers already. It has been reported that a pair of acousto-optic modulator (AOM) (one up-shifting, the other down-shifting) has been employed to achieve appropriate frequency shifts of the order of 10^5~10^6Hz, which is approximately the relaxation oscillation frequency level of the MC. Benefiting from this, ultrahigh sensitivity and non-cooperative measurements have been demonstrated. However, the AOM scheme has the drawbacks of high cost and complex configuration. This manuscript aims at another frequency shifting technique, which is based on Doppler effect, to move the shifted frequency towards the relaxation oscillation frequency of a MC to further enhance the SMI sensitivity.

P7-10 Aerosol particle size distribution retrieval algorithm and error analysis based on multi-wavelength radar

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In order to alleviate the ill-posed problem of the ill-conditioned equation, the regularization algorithm combined with averaging method is used to retrieve the aerosol particle size distribution. In this method, the selection of the optimal average interval is crucial. According to the spectral of LED, fourteen wavelengths for the LEDs are selected, and different optical parameter combinations are set. By the retrieval of multiple sets of original volume concentration distribution and error statistics, the optimal average interval of each optical parameter combination is obtained. The retrieval simulations of logarithmic-normal volume concentration distribution were completed. The simulation results show that when using a combination of ten backscatter and ten extinction coefficients, the reconstructed monomodal distribution has the best fitting effect, and the relative error of effective radius and volume are the smallest. And when using a combination of six backscatter and six extinction coefficients, the reconstructed bimodal distribution has the best fitting effect, and the relative error of effective radius and volume are the smallest.

P7-11 Comparison and analysis of automatic focusing methods on pure phase objects in digital holographic microscopy

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For the pure phase object with transparency, its focused reconstructed image is smoother than the defocused reconstructed image. When the speckle existed due to the use of laser, the multiple minima points and maxima points may appear in the automatic focusing curve, which results in the judgment difficult and the defocused reconstructed image occurs. In the paper, several automatic focusing methods including gray difference cube function, gray variance functions, Fourier transform functions, discrete wavelet transform function and Tamura function are proposed for the pure phase object. Their characteristics and limitations are analyzed and summed up, respectively. The pre-amplification DHM arrangement is set up. In the image-plane and image-front recording conditions, the experiment research on automatic focusing methods is carried out for the pure phase object. The experimental results show that the automatic focusing curve judged by Tamura method only has single minimum point, thus the reconstructed result is best. Whereas the curves judged by other four methods have several local minima points and maxima points in the influence of speckle, reducing the reconstructed accuracy. The experiment selects the micro-hole array as pure phase object.

P7-12 Research on the key technology of detecting the defects of wheelset tread based

on photoelectricity

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This paper designs and constructs a wheel tread defect detection system according to the practical application scene and detection requirements. A system structure for wheel tread dynamic full-circumference detection is proposed, in which the key parameters is designed and optimized. Moreover, the data fusion of multi-line light bars is researched to solve the problem of detecting the wheel tread defects with multi-line structured light. We make study of line structure light center extraction, which has a critical impact in the detection accuracy. Considering the insufficient sensitivity to complex abrupt shape changes in existing methods, a new center line extraction method based on the adaptive template is proposed according to distribution characteristics of line structure light image gradient. The center of the light bar is located by constructing the adaptive weight template and the correction template, which makes the algorithm more sensitive to morphological changes of the light bar and the influence caused by the scattered light reduced. Compared with the Steger method, the algorithm consumes one tenth of the time with the error reduced by 30%. Then, in order to solve the problem of 3D-reconstruction of the wheel tread and translational and rolling objects, the 3D-reconstruction is transformed into the matching of multi-frame detection data according to the spatial morphological characteristics of the detection data in this application scenario. Compared with the original method, the matching accuracy of the improved method is increased by 15% after the same number of iterations. The superiority of this method in reconstruction effect and robustness is proved through the comparison between this method and the ICP method. Finally, a sparse representation over complete atomic library is designed to solve the problem, that the tread profile standard signal is difficult to be obtained precisely according to the tread signal characteristics. The defect-free template signal is reconstructed through the sparse representation algorithm based on the detection signal, which makes the detection system unnecessary to obtain the template of tread profile in advance. To solve the problem of depth image defect detection, the defect signal is acquired by matching with the standard signal, and the 2D depth image is generated by 2D interpolation of the 3D defect signal. A method of quantitatively detecting the defect based on the depth image is put forward. Besides, the defect detection and classification of the tread 2D image are carried out through the deep learning network. After experimental verification, the error of the quantitative calculation based on the depth image is within 5%, and the required time is one-twentieth of the conventional three-dimensional method. In this paper, the accuracy of 2D image extraction is about 85%, which is more than 12% higher than that of the traditional convolutional neural network method.

P7-13 Research on laser frequency locking system using orthogonally demodulated pound–drever–hall method

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Based on the principle of orthogonal demodulation, a Pound-Drever-Hall laser frequency locking scheme is developed. In the orthogonal demodulation Pound-Drever-Hall system, three sine signals are generated simultaneously using a direct digital synthesizer. A 0° phase sine signal is used to drive an electro-optic modulator to produce the phase sidebands, and 180° and 270° phase sine signals are used as reference signals for phase demodulation. The phase-modulated laser beam is coupled with a reference Fabry–Pérot cavity, and the reflected beam is sent into a photo-detector, whose output is mixed with two orthogonal reference signals to obtain two orthogonal components of the error signal. Using an analog-to-digital converter, the two orthogonal components are processed using orthogonal phase sensitive detection to obtain the error signal on a host computer. The Pound-Drever-Hall laser frequency discrimination and tracking system is established and investigated experimentally using the orthogonal demodulation method. A frequency discrimination curve is obtained, and it is observed that the resonant frequency of the Fabry–Pérot cavity can automatically track laser frequency variation.

P7-14 Non-destructive detection of seed viability based on biospeckle technique

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The biospeckle is a phenomenon produced naturally when biological material is illuminated by laser. Laser speckle technology can reflect the internal particle activity of seeds and characterize the seeds viability. The scattering particles of high-vibration seeds move faster and the corresponding speckle intensity fluctuates faster, while the scattering particles of low-vibration seeds have slower motion and the corresponding speckle intensity fluctuation is also slower. Statistical analysis of fluctuations in speckle intensity can determine seeds viability. The system employed was a He-Ne red beam laser (632.8 nm; 10 mW) and a CCD camera. A beam disperser was employed in order to allow the laser beam to illuminate a larger area of the seed. The speckle image was numerically analyzed using a gray-level co-occurrence matrix. Through experimental verification of corn seeds with different activities, the results show that the bio-speckle technique can effectively detect the activity of the seeds. The laser speckle method has the advantages of rapidity, simplicity, non-pollution and noncontact, and is a potentially important method for rapid detection of seed viability.

P7-15 The structural optimal design and stability improvement of dual-axis optoelectronic level

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The level structure is substitute a four-sided frame structure instead of original 5_mm thick aluminum plate spliced structure. All the optical components are distributed on a flexible hinge. The adjustment of the optical path depends on the two adjustment screws, which are fixed on the flexible hinge. However, the drawback of the screws is easily slippery during adjustment. So, a new optical path is designed. The beam splitter (BS) is instead of a right-angle mirror used to adjust the direction of the beam. And the large flexible hinge is replaced with a small two-dimensional adjustment structure which will reduce the inertia of adjust part. All optical components are clamped with fixtures. There is an obvious zero drift in the existing level caused by the laser beam drift during the measurement process. The impact of laser angular drift can be eliminated by calibration and calculation.

P7-16 The possibility of measuring low altitudes above the sea surface with pulsed laser altimeter under conditions of fog and haze

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Analyzed backscattering return of fog and haze with various density. With considering the coefficient of reflection from the sea surface less than 5%, proposed measurement based on the drop of the backscattering return. Determined the range and estimated error of measurement depending on the transfer function of the receiving-amplifying circuit in case of inertial and non-inertial detection. Determined the energy compensation for specified measurement precision.

P7-17 Characterization of surface roughness by double blanket model from laser speckle images

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The surface laser speckle image is obtained by the reflected and scattered light beams from a rough surface when illuminated by laser. Based on the fractal theory, Double Blanket Model (DBM) is proposed to analyze with the laser speckle images. The dimension of the space surface is regarded as the characteristic parameter in Double Blanket Model method. Laser speckle images are preprocessed to remove interference and noise from the environment at first. The optimum window size and window direction are researched. The DBM characteristic parameter is calculated under the optimum window. The relationships are researched between DBM characteristic parameter and surface roughness Ra. The results show that the surface roughness contained in the surface speckle images has a good monotonic relationship with DBM characteristic parameter. To obtain roughness value through a laser speckle image, the fitting functional relationship between Ra and the DBM characteristic parameter is established, and the fitting function stability is analyzed by experiments. The experiment results show that surface roughness measurement based on DBM method of laser speckle is feasible and applicable to on-line high-precision roughness detection, which has some advantages such as non-contact, high accuracy, fast, remote measurement and simple equipment.

P7-18 Design, fabrication, identification and test of a closed-loop moving magnetic scanning module for RGB laser projector

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Galvanometric scanning systems are high inertial behavior and high-speed movement widely that be used in laser marking, drilling, full screen projecting and so on. Therefore, the presented galvanometric scanning system and its applications for laser projector system. In includes a galvanometric unit, motor, position detector and control circuit. All components were discussed and developed by this study. The magnetic rotor and a stator magnet are the main components of the scanner system. The moving magnet is composed of NdFeB material and the stator consists of the coil. In addition, the moving capacitive sensor is used to receive signal feedback. The driver is assembled by the high response performance OP-amplifier circuit. Finally, frequency domain methods were used to identify the scanning system.

P7-19 Data processing for Femur Model Laser scanning

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In human medicine implant manufacture, it need precision measurement to reconstruction implant 3D model, and precision manufacture to fabricate the surgical implant. In this research, it designs a total femoral implant, where builds femur bone model with plasticine first, scans the model with laser scanning to get surface cloudy point data, processes the data with Rapid Form software, and redesigns the implant to generate the 3D model of total femoral implant. In the implant measurement, it uses laser scanning method to gets the cloudy point data by a laser scanning test rig. In software calculateing, it processes the cloudy point data with Rapid Form software to rebuild the 3D model.

P7-21 An auto-gain based homodyne laser vibrometer with enhanced adaptability to reflectivity

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This study presents an enhanced homodyne laser vibrometer with adaptability to reflectivity. The reflectivity could be quite different when measuring different target, which caused the variation of the intensity of the interference signals. In order to enhance the measurement range for the reflectivity of the target, an auto-gain module, which could enlarge the interference signals to an optimal range of the analog-to-digital converter, is implemented in the signal-processing card. The intensity of the interference signals could be calculated in the auto-gain module, and then amplified according to a predetermined rule by using programmable gain amplifiers. The experimental results indicated that the laser vibrometer proposed is capable of measuring vibration with surface reflectivity down to 0.08%.

P7-22 A real-time nonlinear error measurement method with picometer accuracy and free from target motion state

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Nonlinear error measurement technology is critical for the development of heterodyne laser interferometer. The existing periodic nonlinear error measurement methods is limited in measuring the nonlinear error of the heterodyne interferometer with double-direction Doppler frequency shift during the measured target non-constant velocity motion. To solve the problem, this paper presents a new method of measuring the nonlinearity in picometer level based on the double-channels orthogonal demodulation. A pair of orthogonal signals generated by FPGA multiply with the two output signals of the interferometer, respectively. And two pairs of beat frequency signals are obtained through low pass filtering, which are then mutually multiplicative and obtain the sine and cosine components containing the overall nonlinear errors of the interferometer by mathematical operations. At length the nonlinear errors are obtained through them. The experiments show that the method can measure the periodic nonlinear error in real-time free from target motion state and the measurement accuracy is in picometer level.

Poster 8 Instrument and Measurement System Calibration

P8-2 Research on high accuracy calibration method of rotary axis of tube parts

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This paper presents a calibration method for rotating axis based on coordinate transformation. Tilt the planar target over the rotary table and adjust the target position. Rotate the turntable for at least one week, collect the target image at each position, extract the coordinates of the characteristic corner points of the target, and fit the coordinates of the rotation axis. Move the line-structured light sensor to the measurement position, collect the image and extract the feature corner coordinates. According to the coordinates of the coordinates of the corner point of the planar target at the last position acquired by the line structure light sensor at the calibration position and the measurement position, coordinates are converted to complete the calibration of the rotation axis. From the experimental results, the maximum error of the method X_C is usually 0.2837mm, and the maximum error of Y_C is 1.2061mm. However, with the extraction rotation axis calibration method of this paper, the maximum error of X_C is 0.0671mm, and the maximum error of Y_C is 0.1018mm. Compared with the traditional method, this method greatly improves the calibration accuracy of the rotating shaft and has certain practicability and other calibration methods based on rotary tables can use this calibration method to calibrate the rotary axis.

P8-3 Study on resonant high-acceleration calibration system

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High-acceleration vibrations have a strong effect on parts damage and engine life in the aerospace field. Demand for high-acceleration vibration calibration devices is urgently required. In this paper, a set of resonant high-acceleration calibration system was established. This system generates high-acceleration based on the principle that the resonant beam reaches its natural frequency at the outside frequency to amplify the acceleration amplitude. Experimental results show the system can achieve accurate calibration of sensors at high-acceleration.

P8-4 Research of the polarization-optical parameters of a solid-state matrix photomultiplier

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The work is devoted to the research of the polarization-optical parameters of a solid-state matrix photomultiplier. The main parameters of the performance of the SiPM form from the sensitivity of the photodetector. As an object of study, a silicon photomultiplier ARRAY-C 60035-4P was chosen, which consists of 4 photosensitive sites. The pixels of the SiPM are avalanche photodiodes that are separated from each other by elements that do not participate in the formation of the useful signal and serve to suppress the secondary optical signal due to the optical coupling between. In this paper, experimental studies of the state of polarization reflected from the surface of each of the active regions of the matrix of a silicon photomultiplier are performed using a laser photoelectric ellipsometer LEF-3F-1. The action of the ellipsometer is based on the zero method of determining the polarization angles. In the course of the experiment the contractions of ellipsometric angles were determined. The experiment was carried out at four angles of incidence on the surface of the receiver, which corresponds to a set of reflective characteristics of a silicon photoelectric multiplier. With the help of these data, the estimation of the distribution of the reflection and transmission coefficients becomes possible, as well as the sensitivity distribution over the different sites of the SiPM.

P8-5 Keysight B1505A power device analyzer output pulse current calibration method

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Keysight B1505A Power Device Analyzer has many functional testing projects, the calibration method is more complex. This paper focuses on how to control the output current of Agilent B1505A, solves the problem of impedance matching when calibrating pulse width and we investigate the relatively high accuracy test pulse amplitude method. After comparing the technical specification of the oscilloscope TDS3032C with output current resolution, this paper uses the high-precision digital meter 3458A instead of oscilloscope as the standard for measuring the amplitude of pulse current. In this paper, we investigate the configuration problem of 3458A for the trigger level, the delay time and the integration time in the pulse test, which makes the test result more accurate. A calibration system is designed to convert the pulsed current through the Tektronix Company's current amplifier TCPA300 to smaller voltage signal, which can be read by 3458A. Thus, the 3458A is used to measure the high accuracy of 1-2V voltage amplitude. The method is verified through calibration to show higher accuracy, which has a strong practical application value. At last, we give the uncertainty evaluation in the calibration process, the result is less than Urel=0.2% (k=2). More accuracy than using an oscilloscope as a standard measurement.

P8-6 Characterization of beam splitter using Mueller matrix ellipsometry

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Polarization distortion is a phenomenon, which the polarization state of output light deviates from the theoretical expectation. Due to the design defects and process limitations, polarization distortion in beam splitter is inevitable, which results in the significant errors in the optical systems. A theoretical analysis method based on Mueller matrix is proposed for characterizing the beam splitter. In the propose approach, polarization distortion in the beam splitter including depolarization, linear and circular birefringence, and linear diattenuation, circular dichroism have been considered. With the proposed method, we can characterize the beam splitters and extract the related effective optical parameters of polarization distortion. The Mueller matrices of two different commonly used beam splitters measured by a commercial Mueller matrix ellipsometer (MME) are consistently fitted by the proposed method and the residual errors have shown the improvement compared to the conventional methods.

P8-7 Parameter optimization of measuring and control elements in the monitoring systems of complex technical objects with triple reflector

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The aim of the work is to study the methods of minimizing errors associated with nonlinear fluctuations of the light flux in the control system of complex structural and dynamic objects, and the development of distributed, adaptable, modular optical-electronic channels of control of transverse displacements of elements of extended structures based on the autoreflection measurement scheme with several retroreflectors and a controlled, energy-efficient source of optical radiation, in the case of numerical analysis of the CMOS matrix field with its displays, the specified error value and control range are provided in real time under changing external conditions.

P8-8 Wavelength calibration system for diode laser

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Currently the diode laser is widely used in the field of optoelectronics, especially in precious measurement based on laser interferometry. In the measurement, laser wavelength stability is especially important. Since the laser wavelength is easy to be influenced by the environment and drive current, real-time monitoring and calibration of diode laser wavelength is particularly important for interferometry. In this paper, a real-time wavelength monitoring and calibration system for diode laser based interference measurement was developed. The experiment system was built and experiments were conducted to verify the feasibility of the system.

P8-9 Analysis of the extraction accuracy of the corner point of the camera using polarization imaging

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In view of the traditional method of corner extraction, the main idea is to improve the corner extraction algorithm and ignore the imaging process of the calibration image. In this paper, an optimal polarization angle image corner extraction algorithm based on linear polarization feedback is introduced in the process of camera calibration. This method is mainly aimed at the problem of high-light regions, which are difficult to detect and eliminate in the multi-position calibration image of space under natural light. The method firstly adopts the linear feedback of Stokes variable through a CCD camera with polarizing plates and obtains the corner image of the optimal angle of the checkerboard lattice in different positions in space, then we use the sub-pixel level detection algorithm and GAUSS's fitting method to precisely locate the corner points in the image and to solve the sub-pixel coordinates of the image corner, at last,

the two-dimensional pixel coordinates of the corner points in each checkerboard image are extracted.

P8-10 Directional phase-shift circular arrays targets for out-of-focus camera calibration

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We design a directional phase-shift circular arrays targets to calibrate camera system under the assumption that targets are in a defocus condition. In contrast to conventional camera calibration method, we can achieve accurate camera calibration with severely defocused images by using the proposed directional phase-shift circular arrays targets. In this paper, three directional phase-shift circular arrays targets are used to calibrate the measurement system. We set up a mathematical model to detect the feature points accurately even though the targets images are seriously blurred. In the experiments, the targets are displayed in a LCD monitor. Camera system can capture the three targets images at the same position to extract the feature points. Gaussian filters are utilized to blur the targets images of the actual camera system. We have done a series of comparative tests with checkerboard. We evaluate the performance of the proposed method on simulated and real data. Finally, the measurements of displacement and morphology are implemented. Experimental results indicate that the directional phase-shift circular arrays targets can be used to achieve accurate camera calibration parameters.

P8-11 Fabrication and characterization of nanostructure multi-step sample

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With the rapid development of nanotechnology and ultra-precision processing technology, the scale and structure of nano-devices are also getting smaller, Scanning electron microscope (SEM), Scanning probe microscope (SPM), Scanning tunneling microscope (STM) and other measuring instruments as an important mean in the field of nanometer measurement. In this paper, the nanostructure multi-step sample with nominal heights of 8nm, 18nm, and 44nm is fabricated by atomic layer deposition (ALD) and inductively coupled plasma (ICP). The nanoscale multi-step height structures were compared with the VLSI Step height standards and it were measured, analyzed, characterized by ellipsometry, AFM, and SEM. Through the characterization of nanostructure multi-step sample, The results show that the nanostructure multi-step sample fabricated in this paper can meet the needs of rapid positioning, high-precision measurement, and multi-scale measurement of nanoscale steps.

P8-12 Study of gPhone gravimeter-119 for gravity variations observation during International Comparison of Absolute Gravimeters 2017

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The 10th International Comparison of Absolute Gravimeters (ICAG-2017) was held in Changping campus of National Institute of Metrology (NIM), China in October 2017. The observation of gravity variations using relative gravimeters plays an important role in absolute gravimeter comparison and the link of gravity reference value after comparison. We carried out a continuous observation of gPhone gravimeter-119 simultaneously alongside a superconductive gravimeter iGrav-012 for several months. The calibration factor of gPhone-119 is determined to be 0.99355±0.00004 with a precision of 0.004%. When the observation time exceeds 33000 minutes, the calibration values and uncertainties tend to be stable and the precision is better than 0.01%. The non-tidal gravity changes during ICAG-2017 recorded by gPhone-119 are analyzed. The tendency of gravity variations is roughly consistent with that recorded by iGrav-012. The result indicates that the peak-to-peak value of gravity changes is less than 1.5 μGal during the

period of ICAG-2017.

P8-13 A calibration method of micro device reconfigurable assembly system

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The trend to miniaturization of devices has become popular in scientific research and industrial applications over the last decade. It brings higher requirements in device design, production, assembly, and inspection processes than ever. With the advancement of manufacturing technology, devices are becoming common, which consists of multiple parts made of different materials. In the entire device production, the assembly cost can account for 60% to 90% of the total production cost. Many universities and research institutes have hitherto developed custom equipment for specific device assembly, and some have proposed modular or reconfigurable assembly equipment for industrial applications. This paper proposes an assembly system structure based on modular design that can be reconfigured following the current device production, meeting the need for rapidly changing low-batch device manufacturing. The basic structure consists of a manipulating arm module, a vision measurement module and a workbench module. The system is capable of assembling devices with micro components and flat-shaped parts. The concentricity and the parallelism of the assembled parts is less than Φ0.02mm and 0.01mm respectively.

P8-14 Study on the calibration technology of electrostatic field tester

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The calibration of the electrostatic field tester is of great significance for improving the detection precision of the space plasma field, ensuring the safe launch of the satellite, and accurately predicting the lightning and so on. However, there isn't any high precision calibration device and corresponding calibration specification in China. The paper studied calibration technology based on parallel plate capacitor. With an aluminum honeycomb panel combined high pressure ring, the paper processed the parallel plate with a diameter of 1m, and formed the calibration system with DC high voltage source, vertical moving mechanism of electric field instrument and probe clamp. The influence of plate flatness and parallelism on the uniformity of electric field was tested, and uncertainty analysis of the calibration system was completed with method of simulation. The result showed that the calibration accuracy of the device can reach 1%. Finally, with the calibration system, the paper tested atmospheric electric field instrument and the MEMS electric field sensor. The results are in good agreement with the theoretical calculation.

P8-15 Characterization of a liquid crystal variable retarder by Mueller matrix ellipsometry

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With the maturing of liquid crystal technology, liquid crystal variable retarder (LCVR) has been widely used in optical systems. In practice, it is of great importance to characterize the polarization properties of the LCVR for its control and applications to accurately modulate the polarization state of the light in the optical systems. In this paper, the Mueller matrix ellipsometry (MME) is applied to comprehensively characterize the polarization properties including the retardance and the fast axis azimuth of the LCVR versus the driving voltage, the wavelength, as well as the incidence and the azimuth of the light. An analytical model is constructed to describe the LCVR based on the Mueller matrix calculus, in which the influences of the incidence and the azimuth of the light are considered. A house-developed spectroscopic Mueller matrix ellipsometer is employed to perform the experiments. Simulations and experiments about a commercial LCVR product are presented and discussed to verify the proposed method.

P8-16 Parallelism measurement based on rail stack installation

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With the development of the machinery industry, the accuracy and scalability of the movement device needs to be improved continuously. Telescopic tube is the common telescopic device in present market. However, the manufacturing precision of the slender tube is difficult to perform, which results in high manufacture cost. So it has great disadvantage of product of the telescopic device. In this paper, a new type of telescopic device is proposed, which realizes its extension function adopting rail stack installation. In order to realize the parallelism, adjustment between the upper rail and lower one of the telescopic device, this paper introduces mainly the measuring method of straightness of the rail stack installation. The angle between the upper and lower rails can be obtained by measuring the straightness of the telescopic device precisely, which provides data support for the parallelism adjustment of the two rails of the telescopic device and providing theoretical support for realizing the product of the high precision telescopic device.

P8-17 Self-calibration method of precision shafting angle measurement error based on multiple reading heads

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With the continuous improvement of equipment measurement accuracy and production efficiency requirements, calibration method with external reference standard can no longer meet the quality and efficiency requirements. In order to solve the online calibration problem and effectively improve the calibration efficiency of the Articulated Arm Coordinate Measuring Machines (AACMMs) in practical application, a self-calibration system of circular grating angle sensor, which is applied to joints of the AACMMs was established. Based on the harmonic analysis of the angle measurement error, this paper deduces and analyzes the error suppression principle of the layout of the scanning heads on the calibration result, and establishes a non-uniform layout of the scanning heads to eliminate more and higher order harmonic errors. The simulation and test results show that the self-calibration method using this layout form of multiple reading heads can effectively suppress the measurement angle error without increasing the number of scanning heads, and improve the calibration efficiency and measurement accuracy of the AACMMs.

Poster 10 Micro and Nano Optics

P10-1 Optimization algorithm to shape optical beam for laser direct writing

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In order to shape the writing beam, the diffraction optics element (DOE), which is designed by optimization algorithm, are widely applied to obtain the flat-topped beams. The Gerchberg-Saxton algorithm (GS algorithm), simulated annealing algorithm (SA algorithm) and Fourier iterative algorithm are widely used to design such DOE. However, GS, SA and Fourier iterative algorithms are usually time consuming and local optimized. Here we proposed a hybrid Fourier iterative SA (FISA) algorithm to design a DOE to shape the incident Gaussian profile beam in a flat-topped beam. The proposed algorithm is numerically demonstrated time saving and global optimized. SA algorithm is effectively suppress the sensitivity of initial value. However, the optimization results are not stable during the iterative process.

Fourier iterative algorithm can reduce the iteration number and also improve the iteration accuracy. However, Fourier iterative algorithm cannot solve the sensitive problem of initial value. The proposed hybrid FISA algorithm, which reduces the dependence on the initial phase value and save the iteration times, achieve DOE optimization with higher precision. Hybrid FISA algorithm is considered as an improved algorithm based on GS algorithm

Poster 11 Accuracy Theory and Uncertainty Analysis

P11-1 A chi-square statistic of arithmetic mean and its application in inter-laboratory comparison

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Under the condition that comparison results are Gaussian distributed with a common mean, a chi-square statistics of arithmetic mean is proposed and investigated through the Monte Carlo simulation. Simulation results show that the arithmetic mean has its own (n – 1)th-order chi-square statistics under the condition that the uncertainties of participants are comparable. Furthermore, the density curve of the proposed statistics is confined between the (n – 1)th-order and first-order chi-square under the condition that the uncertainties of participants are incomparable. However, the expected value of this statistics equals n – 1, which is unaffected by the uncertainties. Based on these properties, the proposed statistics is applied to the common mean model and the random effects model by examples.

P11-2 Decoupling atmosphere Rayleigh-Brillouin scattering spectrum in kinetic regime

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In the detection of atmospheric temperature profile by Rayleigh scattering, the influence of Brillouin scattering is usually ignored and the accuracy of temperature detection is reduced. Current researches on Brillouin scattering are mainly focusing on hydrodynamic and Knudsen regime, few researches has been done on the kinetic regime. In order to improve the precision of atmospheric temperature measurement, a mathematical model based on three Gaussian distributions was adopted to study the Rayleigh-Brillouin scattering spectrum (RBS) in kinetic regime, the mixed Rayleigh and Brillouin signal in atmospheric echo signal is separated to obtain independent Rayleigh and Brillouin spectrum. Finally, the experimental platform was set up to control simulation of atmospheric environment system and we established a hyperspectral splitting optical system based on Fabry-Perot interferometer. The spectrum obtained by the experiment was used to optimize the mathematical model and improve the detection accuracy of atmospheric temperature profiles.

P11-3 Based on MATLAB: the analysis of key comparison reference value (KCRV) and its uncertainty using Markov chain Monte Carlo (MCMC) method

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The analysis of Key Comparison data is to determine the Key Comparison Reference Value (KCRV) and its uncertainty. In recent years, many papers have been published on this issue. In the current model, the weighted mean is used as KCRV which is put forward by M, G, Cox. However, the method qualifies the measurement results as Gaussian distribution and does not apply to T distribution or other, which causes the risks of chi-square test failure. When the data analysis is invalid based on conventional statistics, the Bayesian approach may be a valid and welcome alternative. Bayesian inference is often required to solve high-dimensional integrations which Markov chain Monte Carlo (MCMC) is such a method. Here is a simple example used to illustrate the application of this method in metrology. The Metropolis-Hastings algorithm is the most flexible and efficient algorithm in MCMC method. In this paper, its basic concepts are explained and the algorithm steps are given. Besides, we obtain the KCRV and its uncertainty using the Metropolis-Hastings algorithm through MATLAB. Then, the convergence of MCMC is diagnosed. In principle, the MCMC method works for any starting value and any proposal distribution. In practice, however, both choices affect performance. We illustrate this influence with the example.

P11-4 An expression method of CMC based on unitary linear regression equastion

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Calibration and Measurement Capability (CMC) is a calibration laboratory that can provide calibration and measurement capability to the user in the normal conditions, the CMC has a variety of expressions. Regression analysis is a statistical technique for studying correlation between key quality characteristics and the cause variables. After independently collecting n groups of experimental data (x_i, y_i), i=1, 2, … , n, we can measure the relevancy between the two variables with the correlation coefficient. According to the stipulations of digital multimeter's calibration method in JJF1587-2016《Calibration Specification for Multimeters》, we can analyze the sources of the measurement uncertainties mainly includes the following aspects: 1) uncertainties of the measurements introduced by the standard instruments; 2) uncertainties of the measurements introduced by the measuring instrument's resolution; 3)uncertainties of the measurements introduced by the measure repeatability. This paper analyze the components of the above uncertainties, an expression method of CMC based on unitary linear regression equation has given. Take Agilent 34401A 10V DC voltage range as an example, when the measured value is 1V, the uncertainty calculated is 3.88×10^{-5}V; when the measured value is 10V, the uncertainty calculated is 1.14×10^{-5}V. The CMC can be expressed as $y=3.08\times10^{-6}x+7.50\times10^{-6}$ in a straight line fitting on the 34401A DC voltage 10V range.

P11-5 Evaluation of task specific measurement uncertainty for gear measuring instrument using VGMI

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This paper aims to evaluate the task specific measurement uncertainty for GMI using a Virtual Gear Measuring Instrument (VGMI). With the aid of Modular Simulation and Monte Carlo method, the uncertainty evaluation model is established on VGMI. The measurement uncertainty of the tooth profile deviation is evaluated by VGMI taking the tooth profile deviation of the involute cylindrical gear as the measured parameter. The uncertainty sources are considered in the simulation including the geometric error, the head error and the workpiece installation error. To verify the measurement uncertainty model of VGMI, we designed three involute tooth surface models with different reference precision, and their profile deviation measurement uncertainties are simulated by VGMI. The research results show that VGMI is feasible, effective and correct for the measurement uncertainty evaluation. VGMI provides a new tool for evaluating the task specific measurement uncertainty for the gear measurement instrument. It can realize the seamless connection with the real measurement software. The ability to change measured workpiece model without reestablishing the VGMI model is also a significant advantage.

P11-6 Probe error analysis of articulated arm coordinate measuring machine

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Researched on the probe's diameter error of the articulated arm coordinate measuring machine (AACMM) in the measuring process. Based on the analysis of the influence of the error source on the accuracy of the probe, the influence of the contact force on the measuring diameter of the probe was analyzed emphatically. It was proposed to use the coordinate measuring machine (CNM) to identify the probe diameter error of the AACMM and apply the least square method to compensate the probe diameter error. The results show: the research method has certain feasibility. The maximum error of the length measurement is reduced by about 47μm. The average error is reduced from 0.0315mm to 0.0046mm, which improved the measurement accuracy of the AACMM.

P11-7 Misjudgment risk estimation for product inspection based on measurement uncertainty

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The new generation Geometrical Product Specifications (GPS) is a standard system based on the metrology technology. It requires consideration of the effects of measurement uncertainty in the Geometric Dimensioning & Tolerancing (GD&T) inspection. Research on the misjudgment risk assessment of GD&T test based on measurement uncertainty is of great significance to improve the reliability of inspection results of mechanical measurement. Based on the measurement uncertainty, the product qualification can be divided into a qualified area, an unqualified area and an uncertainty area, and the research on the qualification misjudgment risk is carried out with measurement results located in the uncertainty area. Through the use of an absolute probability model and a conditional probability model, the paper deduces the estimation formula of the total inspection misjudgment rate, studying the calculation methods of qualification determination and misjudgment rate of the full inspection results. The paper focuses on the methods of misjudgment rate of sampling inspection and qualification determination of measurement results based on the total inspection misjudgment rate and calculated the misjudgment rate of measurement results based on the exhaustive method and the Monte-Carlo simulation. Moreover, the paper estimated the measurement results and the uncertainty by integrating the statistical production information into the product detection results to rationally and fairly narrow the uncertainty area of qualification determination, demonstrating the validity of the proposed method and theory through the example analysis. The conclusions of this paper is as follows. The present research carried out the conformity assessment of the product inspection and calculated the misjudgment rate based on the measurement uncertainty, solving the misjudgment risk assessment of the product inspection based on the measurement uncertainty. It deduced the estimation formula of the misjudgment rate of the total inspection of absolute probability model and conditional probability model, respectively. It studied the conformity assessment of the total inspection results and the calculation method of the misjudgment rate based on the distribution of measurement uncertainty. It estimated the misjudgment rate of the sampling inspection based on the misjudgment rate of the full inspection, discussing the conformity assessment method of the sampling inspection results. It verified the effectiveness of the proposed method by conducting an experimental study based on the exhaustive method and Monte-Carlo method; It integrated the statistical production information into the GD&T test results and re-estimated the measurement results and their uncertainty to reduce the uncertainty results rationally and fairly. It also narrowed the uncertainty area and expanded the qualified area of the product inspection effectively; It provided relevant suggestions for GD&T inspection based on experimental results. It allocated measurement resources reasonably by estimating the misjudgment risk. It calculated the conformity assessment and the misjudgment rate combining with the measurement uncertainty to ensure the reliability of the product inspection results.

Poster 12 Advanced Measurement Techniques

P12-1 A fast global calibration method for T-type 3D four-wheel aligner

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The vehicle four-wheel aligner is very important to maintain driving safety and other performance for a car. T-type 3D four-wheel aligner based on monocular vision needs calibrate transformation matrix from each camera coordinate system to the whole world coordinate system. Global calibration accuracy of a 3D aligner will affect final alignment accuracy for a vehicle. Common calibration method has some disadvantages such as high cost, complicated operation, etc. Based on the above method, a 3D four-wheel aligner using commonly industrial cameras, which are 1.3 million pixels, has been verified by Shenzhen academy of metrology & quality inspection, National Hi-tech metrology station in 2016. The results showed that can meet the requirement of the measurement accuracy, and the measurement errors are less than some foreign famous brands.

P12-2 A new method for measuring the geometrical characteristics of crankshaft in-situ

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Aiming at the requirement of high-precision and high-efficiency measurement of crankshaft grinding machining, a new method for measuring the geometrical characteristics of crankshaft in-situ is proposed and a crankshaft grinding in-situ measurement system is constructed by this method. Firstly, the overall plan for in-situ measurement system is formulated to confirm the composition of the in-situ measurement system. Secondly, a new type of measurement device is designed and constructed to convert the change in size into the change in inductance to analyze the geometric characteristics of the workpiece during machining. Geometric error operation operator based on the new generation Geometrical Product Specification (GPS) is constructed. And mathematical models for on-site machining measurement such as shaft diameter and roundness are established. The final step is to design the measurement and active measurement controller then develop its corresponding software. The real-time geometric feature information of the crankshaft machining acquired by the measuring device is obtained, analyzed and applied to the control and adjustment of the workpiece geometry in the grinding process. In doing this, it can be proved that the in-situ measurement device can greatly improve the production efficiency and precision of crankshaft grinding.

P12-3 A research on bolt loosening monitoring based on Lamb wave

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For the mechanical industry, bolts are an important guarantee for the safety of connection between parts. The traditional method for monitoring bolt loosening is mainly through human judgment, but this method has a large error and cannot be monitored online. At present, the dynamic change process of the bolt loosening can be learned in more detail through the Lamb wave monitoring technology. In this paper, the piezoelectric transducer (PZT) is used to generate the Lamb wave in aluminum structure to monitor the looseness of the bolt on it. The signal with bolt looseness information received by another PZT is analyzed and processed. The S0 modal of the signal is chosen to extract the amplitude of it. After analysis it can be seen that the amplitude of the S0 modal reduces as the bolt gone loose. The relationship between the amplitude and bolt looseness have been drowned. And the functional relationship is presented.

P12-4 Design and implementation of flexible display reliability testing instrument

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In this paper, to the reliability life test of flexible display as the research target, the main factors affecting the flexible screen's reliability performance were analyzed and establishes a reliability automation test system based on LabVIEW. We will use open, modular design and flexible hardware framework, can increase the hardware configuration according to customer product testing requirements, has a good price and good versatility. The test process will be automated, the test results will be displayed in real time, and the test data storage, analysis and print. Through the establishment of this system, the entire testing process is automated, which greatly saves the cost of testing and improves the degree of automation and reliability of the test.

P12-5 Instruments and equipment monitoring system based on the internet of things technology

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For daily use process of monitoring instruments, improve the efficiency of using equipment, this will have especially important significance to establish equipment running condition monitoring system based on Internet of things. This study will focus on different instruments and equipment in the course of everyday use switch machine, working time, power consumption and status of remote monitoring, transmission, recording and analysis of management, easy to master by the instrument use and management of each instrument for a period of time. Instruments and equipment for daily use monitoring system to realize the instruments and equipment in different departments of the remote wireless or LAN monitoring, the server software for real-time analysis of testing data, it is concluded that the instrument for a period of time of use.

P12-6 The internal air gap measurement equipment for dynamic pressure motor

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The size of internal air gap of dynamic pressure motor is an important index to determine its performance and running stability. In order to improve the precision and automation degree of the internal air gap measurement for dynamic pressure motor, an automatic measurement equipment was developed based on modular design concept. The equipment was mainly composed of clamping module, automatic forcing module, and displacement measurement module. During measurement, the stator was mounted by clamping module with a flexible support at two ends. Then an external force was loaded by forcing module, which was a 3-D electric precision motion platform integrating one triaxial force transducer. A relative displacement was generated because of the internal air gap. And the relative displacement increased until the rotor and stator touched each other. Thus the air gap was transformed into an external micro displacement. Finally, the displacement was measured by measurement module, a 2-D precision motion platform integrating double inductive probes, with relative measurement principle. Experimental results showed that the measurement accuracy was about 0.2μm.

P12-7 Theoretical analysis and digital simulation of a new capacitive sensor

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In order to research a new detection principle of capacitive sensor, a new capacitive sensor based on the edge effects of non-parallel polar plates is proposed in this paper. The capacitance field of the sensor includes two parts, the electric field between the polar plates and the edge electric field. When a special medium is in the edge electric field, it will change the distribution of the electric field line of the edge electric field and cause the change of the capacitance value of the sensor, and then the non-contact detection of the detected object can be realized. This paper studies the relationship between the range of the edge electric field and the basic parameters of the sensor. The model and formula of the sensor are analyzed theoretically in this paper, and these typical projects were simulated by ANSYS. The results show that the detection principle of the new capacitive sensor is reasonable and correct.

P12-8 Phase measuring method and error compensation in 3D profile measurement

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3D profile measurement is widely used in many areas such as manufacturing, computer-aided design, virtual reality and medical diagnostics. As one of the core technologies in 3D profile measurement, digital fringe pattern projection is a highly sensitive noncontact technique for obtaining the 3D shape of an object. Then the grating pattern deformed by the measured object is captured by CCD cameras and decoded using appropriate algorithms so that the shape of the object can be deduced. In this paper, three sets of phase shift fringe patterns with different frequencies are projected on the surface of the measured object by a DLP projector and the deformed patters are captured by two camera. Then the four-step phase shift method is used to solve the three groups of fringe patterns phases, and the three-frequency heterodyne method is adopted to unwrap the phase and obtain the absolute phase. The causes of the phase errors are analyzed and the subsequent compensation method of gamma correction of grating pattern is proposed to eliminate the main errors. Experiments are carried out and the results verify the accuracy and effectiveness of the proposed methods.

P12-9 An underwater detecting system based on photoacoustic effect for underwater ranging and 3D topography measurement

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In this paper, an underwater detecting system based on photoacoustic effect for underwater ranging and 3D topography measurement is proposed. The basic principle of this system is to obtain the distance between the target and the detecting system by measuring the propagation time of sound wave produced by photoacoustic effect occurring on the target surface. In this proposal, the pulsed laser of 532nm is adopted. After it's propagation in water, the pulsed laser is absorbed or partially absorbed by a solid target, and photoacoustic effect is generated on the surface of the target and sound wave is radiated outwards. Thus the distance can be obtained with the propagation time of sound wave and the acoustic velocity. According to the above principle, a set of underwater ranging system is set up. The results of the measurement experiments show that the system achieves the ranging accuracy of 0.5mm for target of 45# steel within 0.1-0.85m, and can excite sound wave at the farthest distance of 6.2AL(attenuation length). Based on this underwater ranging system, the 2D profile and 3D topography of custom samples are measured and the corresponding experimental results show that the measured results agree well with the design topography.

P12-10 A compact design of optical scheme for a two-probe absolute surface encoder

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An improved optical scheme of plane encoder is presented in this paper. The modulation of diffractive beams from scale grating and reference grating is analyzed systematically. On this basis, independent modulation of eight diffractive beams from scale grating and reference grating, with no cross effect between each other, is achieved with an improved design of easy to adjust and simple in structure, which is low cost and flexible in used and can be used in optical scheme of linear encoder. Further, the research subdivides the optical design into three function area: modulation of diffractive beams, optical subdivision and photoelectric detection. Separate design decreases the coupling relationship between various optical elements, which improves the convenience of optical alignment and reduces the cumulative error in debugging process to a certain extent. In this study, a standard interference ranging system is set up by using a grating with a 1μm period. The typical four path interference signals are collected. The quality of the interference signal verified the feasibility and superiority of the innovative design.

P12-14 Real-time distance measurement data processing platform based on absolute two-dimensional grating scale

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Among various nano-scale linear displacement sensors, grating scales have been widely used in industrial fields due to their strong anti-interference ability, cost-effectiveness and compactness. The main development directions of the scale are: high precision, large range, high speed, high dimension and absolute type. Our team has completed the optical layout design of the absolute two-dimensional grating rule, which brings new challenges to the design data acquisition and processing hardware system due to the requirements of multiple dimensions and high speeds. There is no real-time data processing system suitable for absolute two-dimensional scales. This paper presents our latest progress in designing and implementing an absolute two-dimensional grating distance measurement real-time data processing platform. Our platform mainly contains four different functional modules. First, the circuit conditioning module performs I-V conversion and signal amplification and filtering on the weak current signal output from the photodiode. Secondly, an 8-channel high-speed data acquisition module with 14-bit resolution and 80 MSPS maximum sampling rate was designed to convert analog laser pulse signals into digital signals. Third, we have established a real-time data processing module that allows 16 bits of data to be entered in the FPGA to calculate the absolute two-dimensional scale distance. Finally, a data transfer module based on 128MB DDR SDRAM and USB 2.0 was added so that we can easily debug the platform on a PC. The performance of our system is evaluated in real time. The test platform consists of a laser, a two-dimensional grating optical path, and our data processing system. The absolute two-dimensional scale has a moving speed of 1m/s, a signal frequency of 10MSPS, a laser emitting signal wavelength of 540nm, and a moving distance of 10-15mm. Experimental results show that our system can output at a rate of 2500 points per second. Measurement results, measurement deviation is less than 50nm.

P12-15 Design and testing of a compact optical lens module for multi-degree-of freedom grating interferometry application

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In this research, a key optical component for multi-degree-of-freedom (MDOF) surface encoder was designed, fabricated and evaluated. In a MDOF grating interferometry system, there are four diffraction beams from the scale grating and reference grating. For further modulation, these beams will propagate more than 100 mm, which makes paralleling these beams necessary. In previous researches, separate

prisms and a home fabricated diffraction device by combining four separate one-axis line gratings in a glass substrate have been demonstrated. However, large power loss and assembly complicity makes this technique less competitive. For solving this problem, this research proposed a new lens module, which is an improved type prism, quadrangular frustum pyramid. The prism is designed in such a way that these four reflected beams from the grating are symmetrically incident into the prism through the upper surface, total reflected on the inner sides of the prism, and then paralleling propagate through the bottom surface. A prism that allows an incident beam diameter of 1 mm and four paralleling beams with a 10 mm distance between the two diffraction beams along one direction was designed, fabricated and tested. Testing results based on an entire grating interferometry system verified that the proposal in this research is greatly effective in beam paralleling in terms of less power loss and high paralleling and greatly reduce the assembly complicity, which will eventually be beneficial for grating interferometry application.

P12-16 Optical fiber Fabry-Perot acoustic sensor based on large PDMS diaphragm

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An extrinsic Fabry-Perot interferometric fiber microphone based on PDMS diaphragm was proposed. The large free-standing PDMS diaphragm, with a diameter of 4 mm, is prepared by a simple “spin-strip” process. Experimental result shows that the fabricated sensor has a high dynamic pressure sensitivity of about -136 dB re 1 rad/μPa in the range of 100~2000Hz. The noise equivalent acoustic signal level of the microphone, limited by the environmental noise, is about 1000 μPa/Hz1/2. And the dynamic range is tested to be more than 62 dB. The proposed microphone is expected to be used in the field of weak acoustic pressure testing.

P12-18 System design of lithium battery internal resistance measurement using Labview

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Currently, the methods of measuring the internal resistance of lithium battery include the direct current method, the AC injection method, and the conductance test method. Taking the disadvantages and disadvantages of the three methods into consideration, we opted for the AC injection method for internal resistance measurement. To overcome the existing shortcomings in the internal resistance measurement of lithium ion batteries, we designed a new measurement system for the internal resistance. The measurement system uses the AC injection method and the four-wire connection method to inject the AC current signal, with frequency of 1kHz, into the lithium batteries. After the measurement system has measured the weak AC voltage signals at both ends of the battery, its internal resistance value can be calculated by Ohm's law. The main components of the design include straight circuit, voltage acquisition, differential amplification, bandpass filtering, phase-locked amplification, and others. This new design can effectively isolate DC components, suppress noise and interference. With simplified measurement, this design can achieve on-line measurement of internal resistance of lithium ion batteries. The design outlines system principles, system block diagrams, test system diagrams, principles and realization method of the quadrature vector phase-locked amplifiers.

P12-19 Error mapping for rotary axes of machine tools based on pose measurement principle

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Laser tracker has been introduced successfully for geometric deviations calibration of multi-axis machine tools. In this paper, a new method called "pose measurement principle" is developed for measuring geometrical error of rotary axes by means of a single laser tracker and NC precise table. The reflector is mounted on the NC precise table with eccentricity, and the NC precise table is mounted on rotary table. A single laser tracker located at different base stations in order is used for coordinate determination of three fixed points of the reflector to get the pose information of rotary axes, then calculate the pose deviations and identify all the errors. For the error identification, first of all, with the extension of the definition of geometric errors, the 6 geometric errors are represented by pose deviation. Second, 3 angular errors are identified geometrically first, the eliminate the angular error of all measuring coordinates to obtain the 3 straightness errors. Finally, the 6 errors mathematical model for rotary table is developed. The validity of the proposed method has been confirmed by simulations and experiments. From both of them, it has been confirmed that the proposed method gives precise results and is able to apply to the measurement of rotary axes effectively.

P12-20 Probe design of nano coordinate measuring machine based on grating strain sensor

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The aim of this paper is to improve the measuring accuracy of Nano Coordinate Measuring Machine and meet the requirements of the accurate measurement of the complex surfaces or microstructures. A novel optical fiber Bragg grating (FBG) based micro contact probe system with high sensitivity and repeatability and its performance was investigated. Firstly, the novel FBG probe was put forward, that is, the probe with a fused spherical tip, a fiber Bragg grating has been utilized as a strain sensor in the probe stem. The fundamentals of the optical fiber probe was introduced and its simulation for the strain distributions along the optical fiber probe under axial and lateral load was made by using the finite element software ANSYS 11, which shows that it is consistent with the theoretical results. Then by experiment to test the sensitivity and resolution of the optical fiber probe, the test results show that a measurement resolution of 60 nm under axial loading can be yielded under a piezoelectric transducer stage with a displacement resolution of 1.5 nm. So, the optical fiber probe has the high sensitivity and better resolution, and its performance proved to meet the demands of actual measurement.

P12-21 Improved two dimensional micro-/nanoradian angle generator with single rotation center located on tilting plane and error compensation of capacitive sensors

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An improved two dimensional micro-/nanoradian angle generator (2D-MNAG) with single rotation center located on the tilting plane and error compensation of capacitive sensors is presented in this study. The 2D-MNAG is structured on an optimized flexure hinge with single rotation center in orthogonal axes. The rotation center is located on the center of tilting plane of 2D-MNAG so that there is no linear displacement coupled in the angular output of the tilting plane. Three capacitive sensors are used in the 2D-MNAG to monitor the angular output for feedback control. The principle error of capacitive sensor while used in angle measurement is compensated using an established model, thus to improve the accuracy and repeatability of the angular output. A synthetic output error of 0.212 arcsec of 2D-MNAG is obtained using Monte Carlo simulation while the distance from rotation center to each driving and angle monitoring point is 40 mm with manufacturing and mounting errors in the range of [-0.01, 0.01] mm in rectangular distribution. The performance of the angular output monitoring unit and the strategy for closed-loop control are the key for improving the 2D-MNAG while the mechanical structure and driving

unit are optimized.

P12-22 Automatic real-time compensation of wavelength of heterodyne interferometer

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Heterodyne interferometer is a nanometer measurement system that uses the laser wavelength as the working reference for length measurement. Under ideal conditions, the laser wavelength is the wavelength λ_0 of the light wave in the vacuum. But in practical applications, the laser wavelength will change with the influence of the air refractive index and the refractive index of air is greatly affected by the environment. This will have a great influence on the measurement results of the high-precision and high-resolution nano-displacement measurement system. Therefore, it is necessary to correct the air refractive index to compensate the laser wavelength. In this paper, the air refractive index in the initial measurement is obtained by using the Edlen empirical formula. Then the relationship between the current air refractive index and the initial air refractive index is obtained by using the wavelength compensation unit to achieve the automatic real-time compensation of the wavelength. The wavelength compensation component is mainly composed of an interference mirror and a fixed length etalon. Through the measurement of air refractive index and the experiment of compensation, the feasibility of the method is confirmed. The relative error after wavelength compensation is less than 0.03% relative to the relative error before compensation.

P12-23 Experimental study on non-linear calibration of two-dimensional nano-positioning stage

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This paper presents the control and non-linear calibration of large-scale two-dimensional nanometer displacement stage. The stage consists of a monolithic compliant mechanism, which using flexible hinge superimposed branch as a transmission part, driven by three piezoelectric actuators, To certify excellent performance of the stage, a micro-displacement measurement system which based on the measurement principle of a laser interferometer was set up, then comparison of several stage parameters accomplished between before and after calibration. Based on the measurement of optical path and composition of dual-frequency laser interferometer, an experimental study on nano-positiong stage was carried out. The non-linear calibration method, which based on newton-steffensen accelerated iteration are described; the accuracy of the calibration method was verified through experiments. Experiments show that: before calibration, the maximum nonlinearity error of x-axis and y-axis were 4.012μm and 2.875μm. After calibration, the maximum non-linearity of the x-axis is 8 nm and the maximum nonlinearity error of the y-axis is 10 nm, Meanwhile, a mathematical model is established to calculate the coupled displacement and yaw angle, The actual coupled displacement and yaw angle of X\Y were limited to 380nm and 1.4μrad.

P12-24 Embedded intelligent camera algorithm based on hardware IP

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With the rapid development of embedded technologies, traditional PC-based instruments and devices have gradually been replaced by embedded processor solutions due to their large size, high cost, and long hardware upgrade cycles. This article designed an embedded smart camera based on the ZYNQ-7000

development board, which has an ARM+FPGA architecture. The system functions are divided into three parts: image acquisition, image processing and image display, each of them adopting a modular design. The image acquisition part adopts OV7725 camera and USB camera to achieve dual-channel acquisition. The image processing section uses the Vivado HLS development kit to design hardware IP-based image processing algorithms. Compared with the traditional HDL-based IP core design method, HLS method that use C/C++ to design IP reduces the development difficulty and shortens the development cycle. Hardware IP implemented through HLS includes image preprocessing, spot-based centroid positioning algorithm, edge detection and corner detection. For complex image processing algorithms, it is still used software to implement, while preprocessing are accomplished through hardware IP. The VDMA channel realizes high-speed data interaction between hardware and software. The image display part is based on the embedded Linux system, OpenCV, and cross-platform C++ graphical user interface development framework QT to implement the GUI interface. The entire embedded smart camera system finally achieves acceleration processing based on hardware IP, such as spot location, Sobel edge detection, and corner detection.

P12-25 Synthesis and metrology of cellulose nanocrystal films

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Cellulose nanocrystal (CNC) is an emerging nanomaterial that has drawn increasing attention recently. It is abundant, sustainable, renewable, and biodegradable. They have unique chemical and mechanical characteristics that cannot be met by traditional cellulose-derived materials, such as high aspect ratio, low density, high stiffness, high tensile strength and very low coefficients of thermal expansion. This paper is focused on the formation and characterization of CNC films and the subsequent traceable metrology of CNC film thickness by atomic force microscopy (AFM). The AFM is calibrated by a series of certified reference materials, and thus the measured values can be traceable to the laser wavelength reference (meter definition). Results show that CNC films with negative charges on surface can be formed via physisorption to an amine-terminated thiol layer on gold through spin coating. The CNC film thickness can be controlled by CNC solution concentration. A thorough understanding of CNC metrology is the foundation for further study of CNC chemical and mechanical characteristics and applications.

P12-26 Fabrication process and error detection technologies for injection molding aspheric lens

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Aspherical optical components increasingly used in optical systems, as they have advantages in improving aberration correction and imaging quality, simplifying optical system structures, and reducing optical system volume. Accurate measurement of optical aspheric surface is a prerequisite for ensuring machining accuracy. Thus, aspheric optical plastic molding technology is an advanced technology for the manufacture of plastic aspheric optical elements, including injection molding, pressing and forming. Aspheric optical plastic injection molding technology has many advantages. It is lightweight, low cost, saves assembly work, easy mass production, and is the main processing method for aspheric optical plastic lenses. The current problems in injection molding production are low efficiency and low yield. The reason for the low efficiency is that the cavity repeatedly produced and tested. In the injection molding process, the mold design and the lens production cycle are long, the mold material cost and the lens material wasted due to the need for the trial mold, thereby increasing the production cost. Each lens produced by the cavity needs to be measured by other commercial software. Because most of the commercial software has a single test factor, the measurement is time-consuming, and the cost of measurement is increased. For large volume production of injection-molded lenses, measurement is also a constraint. The production lens yield is low because the injection molding process is complicated, and the injection molding process has many influence parameters. Moreover, the optical plastic has a large temperature dependence, a large thermal expansion coefficient, a large hygroscopic expansion, and easily thermal deformation and shrinkage. The aspheric plastic lens errors produced by injection molding mainly include surface shape, eccentricity, thickness, inclination, refractive index and asymmetry. This

study summarizes the error sources in the process of optical plastic injection molding, and presents the current development status of error detection technologies. In the beam propagation path, material defects and surface errors inside the optical component, optical system assembly errors, temperature changes and internal stress changes of the transmission medium, air disturbances, and mechanical vibrations can cause distortion of the wavefront. The distorted wavefront reflects the error characteristics of the optical components in the optical path. In this study, a method based on wavefront sensing technology for aspheric optical lens error detection is proposed. The potential for developing error detection technologies applied in aspheric optical lenses is then discussed.

P12-27 Review of convolutional neural network optimization and training in image processing

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Machine learning is a science of artificial intelligence, and most research focuses on how to improve the performance of specific algorithms by training. By inputting a large amount of data, the computer can summarize the experience and inductive logic to get a model that can be used for prediction and inference. Deep learning has been developed from the basis of machine learning, which is derived from artificial neural networks (ANNs). ANNs mainly include an input layer, an output layer, and a hidden layer connected by weights in the middle. We can represent information through a deep ANN. However, a convolution neural network (CNN) mainly consists of an input layer, an output layer, a convolution layer, and a pool layer. The network uses a convolution instead of matrix multiplication so that in the same layer, convolution weights can be shared, which will reduce the number of parameters. The method can extract local features. Through the convolution network, the features are constantly combined so that CNN can classify and recognize image well. In classification and regression problems, the ANN can fit the regression function using the input layer, output layer, convolution layer, and activation function. We can design the network structure, activation function, and weight update method. Major breakthroughs in the fields of image processing, pattern recognition, and scene classification have recently been made through the use of CNNs and deep learning in recent years. If the training set is sufficient, a CNN performs better than traditional machine learning algorithms and differs from them in many ways. In CNNs, feature extraction is more intelligent, so researchers no longer require extensive knowledge about the specific topic. They can focus on the CNN itself, including the structural design of the network, the model optimization, and the numerical solution. The key to solve classification and regression problems is to use neural networks that fit the best function. By calculating the difference between the data and the model output, we can obtain the loss function, so the main process of training the neural network is to get the feedback from the output layer, and then using the loss function to measure the difference between the outputs of the neural network and the labels of the data. By solving the minimum value of the loss function, we can obtain the best parameters in the ANN to update the weights of CNN. The many articles on CNNs published over the past few years propose many neural network models. Methods of training and optimization for CNNs have also been proposed. This paper reviews the history of CNNs, introduces the commonly established CNN structure, and summarizes methods and tips for CNN training.

P12-28 Research on key technologies of quadrupole electromagnetic tweezer

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In this paper, the quadrupole electromagnetic tweezer installed in a fluorescent microscope was developed for the purpose of achieving precise control of magnetic microspheres' motion trajectory. The key technologies of magnetic microsphere control and positioning by such quadrupole magnetic tweezers were systematically studied. An electromagnetic quadrupole magnetic tweezer system was designed and constructed, a current-magnetic force model of the quadrupole magnetic tweezer was established, and the magnetic force-current inverse force model was derived and simplified. A fluorescence microscopy imaging system was set up and the related program design was completed. The position of magnetic fluorescent microspheres was monitored by a high-speed CCD with sampling frequency of 200 Hz. A proportional-integral closed-loop feedback controller was built up for magnetic microspheres. The

experimental results demonstrated that the magnetic force range available at the center of the work area was [-80pN, 80pN]. Besides, magnetic microspheres were tested to possess a displacement resolution up to 400 nm as well as the capacity of moving in any direction in a two-dimensional plane. Based on the obtained results, it is expected that the quadrupole electromagnetic tweezer can function one of the effective devices for evaluation of cell mechanical properties.

P12-29 Extracting road edges from MLS point clouds via a local planar fitting algorithm

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As the basic element of a road, road edges are of great significance for intelligent transportation and urban foundational geographic information construction. Mobile laser scanning (MLS) provides an effective way to extract road information, but it is difficult to extract accurate road edges from a large-scale dataset with complex road conditions. In this paper, we propose a method to extract road edges from MLS data based on a local planar fitting algorithm. First, scanning lines are extracted based on the horizontal projection distance between the laser points. Second, a planar fitting method is adopted to extract road curb points. Road curb points are then clustered and optimized by differentiating the distance between road curb points and the auxiliary line. Finally, a linear least squares fitting method is applied to obtain the road edges. Three experimental datasets with multi-type road markings were used to evaluate the performance of the proposed method. The results demonstrate the feasibility and effectiveness of the proposed method.

P12-30 Optimization on metering accuracy of smart electricity meter by temperature compensation

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Smart electricity meters are playing an indispensable role in modern society, and their measurement accuracy affects the economic interests of both power units and users. In this paper, a compensating method based on neural network approximate modeling is proposed to increase the accuracy of electric energy measurement among the whole range of operational temperature. Based on the measurement data and the internal structure of the smart electricity meter, a MATLAB/Simulink model of the meter is built to evaluate the consistency of power measurement at different temperature levels. The FEM (finite element method) thermal simulation model of the meter device is carried out in ANSYS Icepak to obtain the temperature contours of the smart meter in different operating conditions. Afterwards, based on the simulation data, the component temperature in the metering circuit is evaluated according to the approximation model built by RBF (Radial basis function) neural network. At last, a temperature compensation program is realized in the MCU (Micro-Controller Unit) to adjust the metering accuracy. According to the final testing results, the proposed method significantly enhances the metering accuracy among full temperature range.

P12-31 Research of variable-frequency big current calibration

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Measuring Variable-frequency big current has a great technical difficulty, you first need transfer Variable-frequency big current to small current is easy to measure, and then transfer variable frequency small current to a voltage. In this paper, we uses a zero flux current transformer transfer high current into a small current, after then use a shunt transfer alternating current to a variable frequency voltage, realizing high accuracy variable-frequency big current calibration, measurement uncertainty up to 1×10^{-4},

which can meet the needs of the current calibration,it has been used in many project, and achieved good results.

P12-32 Study on FMCW laser ranging technology based on nonlinear error compensation

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Frequency modulated continuous wave (FMCW) laser ranging technology can achieve high precision of distance measurement and has a very good development prospects in military and civil use. It has become an important technical direction in the field of precision laser ranging recent years. The basic principle and technical characteristics of FMCW laser ranging technique are introduced and the source of the non-linear error is analyzed in this paper. Non-linear error correction branch is designed and the error is corrected by the error loop iteration method. The nonlinear error closed-loop correction branch is composed of high-speed AD sampling, time-frequency analysis, nonlinear error calculation and error conversion iteration. The experiments shows that the nonlinear error of loop iteration method is effective for the FMCW laser ranging nonlinear correction. After 2~3 loops nonlinear error iteration, the nonlinear is improved obviously. If the loop iterations n>10, the frequency error of the beat frequency signal (IF) can be controlled in the range of ±25Hz. Base on the nonlinear error correction, the method of spread spectrum phase error compensation is adopted and the compensation pathway is designed. The echo signal phase error is compensated effectively and the ranging accuracy is improved directly. Finally, the linear frequency modulation continuous wave laser ranging system is tested with the output power of the laser less than 20 mW, modulation cycle 1 kHz, deep modulation bandwidth. In the distance measuring range of 0~50m, the measurement error is less than 50μm.

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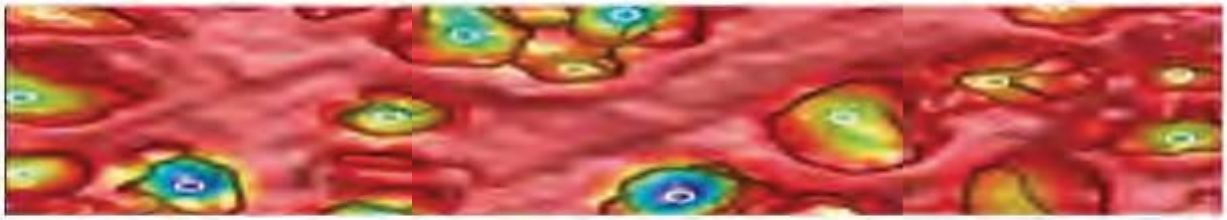

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