

# ISPMM 2013

## THE 6th INTERNATIONAL SYMPOSIUM ON PRECISION MECHANICAL MEASUREMENTS

August 8-12, 2013  
Guiyang, Guizhou, China



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International Committee on Measurements and Instrumentation (ICMI)  
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# Introduction

With the development of science and technology and the improvement of the requirement in machinery manufacturing, most Countries in the world have put lots of Human and material resources into the field of mechanical engineering precision measurement research, and new methods, new technology and new equipment appear thick and fast. Under this background, We have successfully held five sessions of International Symposium on Precision Mechanical Measurement (ISPMM), the subject and the major topics included length and angular measurement, Coordinate Measurement Technology, Micro-Nano Metrology and MEMS, Sensor Technology and Application, Online Automatic Measurement and Control Vibration, Stress and Thermal Measurement, Opto-Electronic Measurement and Image Processing, Measurement Signal Analysis and Processing, Precision Theory and Uncertainty Evaluation, Quality Engineering Theory and Technology and so on. The 6th ISPMM conference will be held in Guiyang on August 8-12, and the theme of the conference is “New century, new technology and new development”. More than 150 manuscripts have been submitted to our conference, and over 200 registered delegates will participate in the conference.

Yetai Fei/Shenghua Ye

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### **Session Chairs**

## **Session 1: Micro-Nano Metrology & MEMS**

Prof. H. Bosse, PTB, (Germany)

Prof. Q.X. Huang, Hefei University of Technology, (China)

## **Session 2: Coordinate Measurement Technology**

Prof. L.D. Yu, Hefei University of Technology, (China)

Prof. Z.Y. Shi, Beijing University of Technology, (China)

## **Session 3: Sensor Technology & Application**

Prof. H.Z. Liu, Xi'an Jiaotong University, (China)

Prof. L.Q. Zhu, Beijing Information Science & Technology University, (China)

## **Session 4: Online Automatic Measurement & Control**

Prof. P.H. Hu, Hefei University of Technology, (China)

Prof. S.W. Kim, KAIST, (Korea)

## **Session 5: Vibration, Stress & Thermal Measurement**

Prof. R.J. Pryputniewicz, WPI. (USA)

Prof. Josef Lazar, Academy of Sciences of the Czech Republic, (Czech Republic)

## **Session 6: Optical Metrology: Image Processing**

Prof. S. Ito, Tohoku University, (Japan)

Prof. L.X. Yang, Oakland University, (USA)

## **Session 7: Measurement Signal Analysis & Processing**

Prof. T.I. Liu, California State Univ.at Sacramento, (USA)

Prof. H.X. Deng, Hefei University of Technology, (China)

## **Session 8: Quality Engineering & Uncertainty Evaluation**

Prof. A.G. Song, Southeast University, (China)

Prof. M. Chang, Chung Yuan Christian University, Taiwan, (China)

## **Session 9: Optical Metrology: Optical Probe & System**

Prof. W.H. Zhou, Chinese Academy of Science, (China)

Prof. B.Y. Chen, Zhejiang Sci-Tech University, (China)

# The 6th ISPMM 2013

## Schedule in Summary

7th Aug.		8th Aug.		9th Aug.		10-12th Aug.
08:30-12:05	Registration	08:00-08:30	Registration	08:00-10:30	Registration	Post-Symposium tour
		08:30-09:00	Opening Ceremony	08:30-09:15	Keynote Speech 5	
		09:00-10:30	Keynote Speeches 1&2	09:15-09:25	Coffee Break	
		10:30-10:40	Photograph	09:25-10:55	Oral Session	
		10:40-10:50	Coffee Break	10:55-11:15	Coffee Break	
		10:50-12:20	Keynote Speeches 3&4	11:15-12:15	Oral Session	
12:00-13:30	Lunch	12:30-14:00	Lunch	12:30-14:00	Lunch	
13:30-20:00	Registration	14:00-15:30	Oral Session	14:00-15:30	Oral Session	
		15:30-15:50	Coffee Break	15:30-15:50	Coffee Break	
		15:50-16:50	Oral Session	15:50-17:10	Oral Session	
		16:50-18:00	Poster Session	17:10-18:00	Poster Session	
		18:30-20:30	Dinner	18:30-20:30	Banquet	
Time for presentation (including the question-and- answer period)		Keynote Speech		45 min		
		Invited Talk		25 min+5 min		
		Oral Presentation		15 min+5 min		

# The 6th ISPMM 2013

## Keynote Speeches

Date and time		No.	Title	Speaker	Organization	Chair	Room
Aug.8	09:00-09:45	Keynote Speech 1	Traceability of measurements at the nanoscale	Prof. Harald Bosse	PTB, (Germany)	Prof. Z.L. Zhang	Room A
	09:45-10:30	Keynote Speech 2	Nondestructive optical characterization of MEMS	Prof. Ryszard J. Pryputniewicz	Worcester Polytechnic Institute, (USA)		
	10:50-11:35	Keynote Speech 3	Accuracy improvement of machine tools	Prof. Kuang-Chao Fan	National Taiwan University, Taiwan, (China ) Hefei University of Technology, (China)	Prof. Y.S. Gao	
	11:35-12:20	Keynote Speech 4	New Possibilities of Precision Measurements using Femtosecond Pulse Lasers	Prof. Seung-Woo Kim	KAIST, (Korea)		
Aug.9	08:30-09:15	Keynote Speech 5	Dielectrophoretic Microfluidic Technology for Manipulation of Particles	Prof. Weihua Li	University of Wollongong, (Australia)	Prof. S.W. Kim	



## Oral Session Topics and Chairmen

Date and time		Session No.	Topic	Chairman	Room No.	Present. mount
Aug. 8	14:00-16:40	Session 1	Micro/Nano Coordinate Measurement	Prof. H. Bosse	Room B	7
				Prof. Q.X. Huang		
		Session 2	Coordinate Measurement Technology	Prof. L.D. Yu	Room C	7
				Prof. Z.Y. Shi		
		Session 3	Sensor Technology & Application	Prof. H.Z.Liu	Room D	7
				Prof. L.Q. Zhu		
Aug. 9	9:25-12:05	Session 4	Online Automatic Measurement & Control	Prof. P.H. Hu	Room B	7
				Prof. S.W. Kim		
		Session 5	Vibration, Stress & Thermal Measurement	Prof. R.J. Pryputniewicz	Room C	7
				Prof. J. Lazar		
		Session 6	Optical Metrology: Image Processing	Prof. S. Ito	Room D	7
				Prof. L.X. Yang		
	14:00-16:40	Session 7	Measurement Signal Analysis & Processing	Prof. T.I. Liu	Room B	7
				Prof. H.X. Deng		
		Session 8	Quality Engineering & Uncertainty Evaluation	Prof. A.G. Song	Room C	7
				Prof. M. Chang		
		Session 9	Optical Metrology: Optical Probe & System	Prof. W.H. Zhou	Room D	8
				Prof. B.Y. Chen		

## Keynote Speakers



**Prof. Harald Bosse** is the head of the department “Dimensional Nanometrology” at the Physikalisch-Technische Bundesanstalt in Braunschweig, Germany. Harald Bosse, born in 1961, studied physics at the University of Kassel in Germany. He received his PhD in 1989 working on spinwave resonance characterizations on exchange coupled magnetic thin films. In 1990 he joined the Physikalisch-Technische Bundesanstalt (PTB) in Braunschweig, the metrology institute of Germany. Until 1995 he worked in the dimensional standards section on precise form and diameter characterization and then moved to the PTB mask metrology section. In 1997 he temporarily was with the presidential staff section of the PTB and since 2000 he is head of the department for

length and angle metrology. He coordinated the international line scale comparison Nano 3 (2000-2003) and he is active as head of the WGDM DG9 discussion group on line scales and as a member in international standardization bodies in the field of nanotechnology.



**Prof. Ryszard J. (Rich) Pryputniewicz**, educated both in Poland and in the United States, is the K. G. Merriam Distinguished Professor of Mechanical Engineering as well as Professor of Electrical and Computer Engineering, and, since 1978, founding Director of the Center for Holographic Studies and Laser micro-mechaTronics (CHSLT) at Worcester Polytechnic Institute (WPI) in Worcester, MA; he is also founding Director of the NanoEngineering, Science, and Technology (NEST) Program at the Mechanical Engineering Department of WPI. His current research and teaching interests concentrate on theoretical and applied aspects of MEMS, smart sensors and structures and, in particular, nanotechnology, lasers, noninvasive metrology with nanometer accuracy

on sub-micron scale, and nondestructive testing (NDT) based on photonic methods with emphasis on heat transfer, thermal management, and design optimization. He is a Registered Professional Engineer (PE), Member of the European Academy of Sciences and Arts (EASA), Fellow of IBH (International Brotherhood of Holographers), Fellow of SPIE, Fellow of SEM, Fellow of ASME, Senior Member of IEEE, chairman of the Development Committee of the MEMS Division of ASME, President of SEM, and chairman of the Education Committee of the IEEE Nanotechnology Council.



**Prof. Kuang-Chao Fan** received the B.Sc. degree from National Taiwan University (NTU) in 1972, M.Sc. degree from the State University of New York at Buffalo in USA in 1976, and Ph.D. degree from University of Manchester Institute of Science and Technology in UK in 1984, all in mechanical engineering. He has been a Professor of Mechanical Engineering at National Taiwan University since 1989. He was the Chairman of Institute of Industrial Engineering of NTU, the

Chairman of Chinese Institute of Automation Technology, the Chairman of SME Taipei Chapter, the Director of Tjing Ling Industrial Research Institute, and the Associate Dean of Engineering College at the National Taiwan University. He has been the Cheung Kong Scholar at the Hefei University of Technology since 2001. He has been elected as distinguished professor and Chon-Juo Zhang Chair Professor by National Taiwan University since 2007. He was elected as the SME Fellow in 2008. His research interests include manufacturing metrology, precision machining, and machine tool technology. He has published more than 100 journal papers and 200 conference papers.



**Prof. Seung-Woo Kim** is the Dean of the School of Mechanical, Aerospace and System Engineering at KAIST. He received PhD in precision engineering from Cranfield University (UK) in 1984. He is currently in charge of the graduate research group of Precision Engineering & Metrology. His research interest includes ultrafast optics for ultraprecision machine design, dimensional metrology, and opto-mechatronics systems synthesis. During last two decades of research work, he has published about one hundred technical papers in international journals and conferences. He has been working as principal investigator for numerous national and industrial research projects and currently involved in an important national creative research initiative project for

the development of next generation precision engineering key technologies. He has also actively been involved in international academic societies for organizing on-time conferences for leading-edge precision engineering technologies. He is a member of SPIE, OSA, euspen and ASPE.



**Prof. Weihua Li** is working with Mechatronic Engineering as a full-time teaching-research staff. He received his B. E. and M. E. degrees from University of Science and Technology of China in 1992 and 1995 respectively, and Ph. D. degree from Nanyang Technological University Singapore in 2001. He was with the School of Mechanical and Production Engineering of Nanyang Technological University as a research fellow from 2001 to 2003. He has been with the School of Mechanical, Materials and Mechatronic Engineering as a Lecturer (2003-2005), Senior Lecturer (2006-2009), Associate Professor (2010 -2012), and Professor (2012 -). Prof. Weihua Li has published more than 200 technical articles in refereed international journals and conferences. In 2011, he was awarded Australian Government DEEWR Endeavour Research Fellowship for his

contribution on Microfluidics, Nanofluidics, Magnetorheological (MR) materials and their applications.

**Oral Sessions 1, Aug. 8, 14:00-16:40**

Oral Session 1  Room B	<b>Topic</b>	<b>Micro-Nano Metrology &amp; MEMS</b>	
	<b>Chairman</b>	<i>Prof. H. Bosse and Prof. Q.X. Huang</i>	
	<b>Oral ID</b>	<b>Presentation</b>	<b>Abs. ID</b>
	C-037	<u><i>Characteristics of the Higher-order Resonant Cantilever in Dynamic Atomic Force Microscopy (Invited Talk)</i></u> Q.X. Huang Hefei University of Technology, China	PMM13-MM1 00-211
	G-026	<i>Fast Itering of Surface Topography of Micro-Optics using Non-Local Means</i> X. C. Zhang, H. Zhang, X. Y. He, M. Xu Fudan University, China	PMM13-MM1 00-153
	C-005	<i>Structure Design and Characteristic Analysis of Micro-nano Probe Based on Six Dimensional Micro-force Measuring Principle</i> H.T. Yang, C.M. Chun, and C.Z. Fang, Anhui University of Technology, China	PMM13-MM1 00-72
	C-112	<i>Key Techniques of Ultra-Precision Aerostatic System</i> D.S. Li, J.C. Hu, T. Cui, and J.F. Li, China Jiliang University, China	PMM13-MM1 00-117
	C-136	<i>Development of a Miniature Multi-Degree-of-Freedom Measurement System for Ultra Precision Stages</i> H.Y. Wang, B.H. Liao, M.J. Chou, Y.Y. Tseng, and K.C. Fan National Taiwan University, Taiwan, China	PMM13-MM1 00-14
	C-145	<i>Nanometrology Interferometric Coordinates Measurement System for Local Probe Microscopy</i> J. Hrabina <sup>a</sup> , J. Lazar <sup>a</sup> , P. Klapetek <sup>b</sup> , O. Cip <sup>a</sup> , M. Cizek <sup>a</sup> and M. Sery <sup>a</sup> , <sup>a</sup> Institute of Scientific Instruments, Czech Republic; <sup>b</sup> Czech Metrology Institute, Czech Republic	PMM13-MM1 00-10
	G-0812	<i>Phase Modulation Dynamic AFM Measurement System Based on Tuning Fork Probe</i> T. Guo, W.J. Chen, Z.C. Wu, J.P. Chen, X. Fu, X.T. Hu Tianjin University, China	PMM13-MM1 00-91

**Oral Sessions 2, Aug. 8, 14:00-16:40**

Oral Session 2  Room C	Topic	<b>Coordinate Measurement Technology</b>	
	Chairman	<i>Prof. L.D. Yu and Prof. Z.Y. Shi</i>	
	Oral ID	Presentation	Abs. ID
	C-061	<b><u>Computational metrology for nanomanufacturing</u></b> <b><u>(Invited Talk)</u></b> S.Y. Liu, Huazhong University of Science and Technology, China	PMM13-MM1 00-27
	B-045	<b><i>Elastic Mechanism Design of the CMM Contact Probe</i></b> R.J. Li <sup>a,c</sup> , K.C. Fan <sup>a,b</sup> , Z.Y. Cheng <sup>a</sup> , Q.X. Huang <sup>a</sup> , S. Tao <sup>a</sup> , H. Chen <sup>a</sup> <sup>a</sup> Hefei University of Technology, Hefei , China, <sup>b</sup> National Taiwan University, Taiwan, China, <sup>c</sup> Anhui Electrical Engineering Professional Technique College, China,	PMM13-MM1 00-121
	B-049	<b><i>Study on The Three-Station Typical Network Deployments of Workspace Measurement and Positioning System</i></b> Z. Xiong <sup>a</sup> , J.G. Zhu <sup>b</sup> , B. Xue <sup>b</sup> , Sh.H. Ye <sup>b</sup> , Y. Xiong <sup>c</sup> <sup>a</sup> Hubei University of Technology, China; <sup>b</sup> Tianjin University, China; <sup>c</sup> Yunnan Sanhuan Sinochem Chemical Co., LTD, China	PMM13-MM1 00-46
	A-195	<b><i>Arbitrary and Absolute Length Measurement Based on Time-of-flight Method Using Femtosecond Optical Frequency Comb</i></b> S.J. Xing <sup>a</sup> , F.M. Zhang <sup>a</sup> , S.Y. Cao <sup>b</sup> , X.H. Qu <sup>a</sup> <sup>a</sup> Tianjin University, China; <sup>b</sup> National Institute of Metrology, China	PMM13-MM1 00-80
	G-103	<b><i>Critical Dimensional Linewidth Calibration Using UV Microscope and Laser Interferometry</i></b> Q. Li <sup>a</sup> , S.T. Gao <sup>a</sup> , W. Li <sup>a</sup> , M.Z. Lu <sup>a</sup> , M.K. Zhang <sup>b</sup> <sup>a</sup> National Institute of Metrology, China; <sup>b</sup> Hefei university of technology, China	PMM13-MM1 00-161
G-156	<b><i>An Experiment of Femtosecond Laser Absolute Distance Measurement By Spectrally Resolved Interferometry</i></b> W.H. Zhou <sup>a</sup> , Y. Li <sup>a,b</sup> , R.Y. Ji <sup>a</sup> , X. Yan <sup>b</sup> , D.M. Liu <sup>b</sup> <sup>a</sup> Academy of Opto-electronics, China; <sup>b</sup> Huazhong University of Science and Technology, China	PMM13-MM1 00-42	

	G-133	<b><i>Automated Surface Profile Measurement of Diamond Grid Disk By Phase-Shifted Shadow MoirÉ</i></b> T.Y.F. Chen and J. Lin National Cheng Kung University, Taiwan, China	
<b>Oral Sessions 3, Aug. 8, 14:00-16:40</b>			
Oral Session 3 Room D	<b>Topic</b>	<b>Sensor Technology &amp; Application</b>	
	<b>Chairman</b>	<i>Prof. H.Z. Liu and Prof. L.Q. Zhu</i>	
	<b>Oral ID</b>	<b>Presentation</b>	<b>Abs. ID</b>
		<b><u><i>Trans-Scale Manufacturing Technology and Its Application on Position Detecting Sensors (Invited Talk)</i></u></b> H.Z. Liu Xian jiaotong University, China	
	D-073	<b><i>Optical Magnetic Field Sensor Improved By Ndfeb Ferromagnetic Film</i></b> T.G. Nguyen <sup>a</sup> , X.B. Jiao <sup>a</sup> , W.F. Lei <sup>a</sup> , Y. Ma <sup>a</sup> , L.X. Ma <sup>a</sup> , B. Qian <sup>b</sup> <sup>a</sup> University of Shanghai for Science and Technology, China. <sup>2</sup> Suzhou Institute of Nano-tech and Nano-bionics, China	PMM13-MM1 00-62
	D-074	<b><i>Aberration Measurement for Progressive Addition Lens Based on Hartmann-Shack Sensor</i></b> L. Zhu, J.B. Chen, J.H. Xu, H.M. Pan, H.W. Zhang, S.L. Zhuang University of Shanghai for Science and Technology, China	PMM13-MM1 00-89
	D-154	<b><i>Precise Ultrasonic Ranging based on Pseudo-random Sequence Modulated Continuous Signal Processing</i></b> C.J. Qiao, Z.G. Huang, C. Zhou National University of Defense Technology, China	PMM13-MM1 00-142
	D-155	<b><i>A Robust Data Fusion Scheme for Integrated Navigation Systems Employing Fault Detection Methodology Augmented With Fuzzy Adaptive Filtering</i></b> M. Ushaq and J.C. Fang Beihang University, China	PMM13-MM1 00-43
	D-176	<b><i>Quasi-Distributed Temperature Sensor System Based On Various-Packaged FBG</i></b> Y.M. Zhang <sup>a</sup> , Q.Z. Liu <sup>a</sup> , W. He <sup>b</sup> , L.Q. Zhu <sup>a</sup> <sup>a</sup> . Beijing Information Science & Technology University, China; <sup>b</sup> . Hefei University of Technology, China	PMM13-MM1 00-199
	D-065	<b><i>Design of PSD Based Solar Direction Sensor</i></b> G.L. Xu, W. Lv, Z.W. Zhong, B. Wang, R.P. Guo, Y.P. Tian Nanjing University of Aeronautics and Astronautics	PMM13-MM1 00-148

**Oral Sessions 4, Aug. 9, 09:25-12:05**

Oral Session 4  Room B	<b>Topic</b>	<b>Online Automatic Measurement &amp; Control</b>	
	<b>Chairman</b>	<i>Prof. P.H. Hu, Prof. S.W.Kim</i>	
	<b>Oral ID</b>	<b>Presentation</b>	<b>Abs.ID</b>
	I-040	<u><i>Key Errors Analysis And Simulation of A 3-PUU Parallel CMM (Invited Talk)</i></u> P.H. Hu Hefei University of Technology, China	PMM13-MM1 00-71
	E-092	<i>Dynamic Model of Liquid Copper Temperature Based on Weighted LS-SVM</i> Y.D. Li, L.J. Ye, H.W. Guan, W.H. Zhong, X.S. Ma Ningbo Institute of Technology, Zhejiang University, China	PMM13-MM1 00-17
	E-110	<i>Measurement System for Characterizing Surface Friction Properties of Textile Materials</i> B.G. Yao, Y.J. Yang, Z.F. Zhang, L.X. Yan China Jiliang University, China	PMM13-MM1 00-192
	E-036	<i>Analysis and Experimental Study of The Spherical Joint Clearance</i> P. Zhao, P.H. Hu, X.X. Bao, S.P. Li Hefei University of Technology, China	PMM13-MM1 00-79
	G-116	<i>Multi-Beam Synchronous Measurement Based on PSD Phase Detection Using Frequency-Domain Multiplexing</i> D. Ying, J. Chao, X. Lian, Q. Lan Chongqing University, China	PMM13-MM1 00-198
		<i>Torsional Piezoelectric Fiber and Its Application</i> C.L. Pan Hefei University of Technology, China	
	E-010	<i>Development of Transmission Error Tester for Face Gears</i> Z.Y. Shi, X.N. Lu, C.H. Chen Beijing University of Technology, China	PMM13-MM1 00-233

**Oral Sessions 5, Aug. 9, 09:25-12:05**

Oral Session 5  Room C	Topic	<b>Vibration, Stress &amp; Thermal Measurement</b>	
	Chairman	<i>Prof. R.J. Pryputniewicz, and Prof. J. Lazar</i>	
	Oral ID	Presentation	Abs.ID
	C-148	<b><i><u>Interferometry With Suppression of Fast Fluctuations of The Refractive Index of Air for Nanometrology (Invited Talk)</u></i></b> J. Lazar, Institute of Scientific Instruments, Czech Republic	PMM13-MM1 00-28
	F-100	<b><i>Vibration Criteria for Vibration-Sensitive Laboratory Based on Intrinsic Microseism</i></b> C.G. Cai, B. Zhou, J.S. Li National Institute of Metrology, China	PMM13-MM1 00-242
	F-144	<b><i>Analysis of The Forces in Electrostatic Force Microscopy for Profile Measurement of Micro-Structured Surface of Dielectric</i></b> G.F. He <sup>a,b</sup> , Z.G. Jia <sup>b</sup> , S. ITO <sup>b</sup> , Y. Shimizu <sup>b</sup> , W. GAO <sup>b</sup> <sup>a</sup> Chongqing University of Science and Technology, China, <sup>b</sup> Tohoku University, Japan	PMM13-MM1 00-73
	F-193	<b><i>Variable Stiffness and Damping Semi-Active Vibration Control Technology Based on Magnetorheological Fluids</i></b> S.Y. Zhao, H.X. Deng, J. Zhang, S.S. Sun and L. Wang Hefei University of Technology, China	PMM13-MM1 00-202
	G-056	<b><i>A New Thin-Wall Beam Modal Testing Method Based On Single Point Laser Continuous Plane Scanning Vibration Measurement</i></b> J.G. Wu, B. Qin, X.J. Li, Q.C. Zhao Hunan University of Science and Technology, China;	PMM13-MM1 00-68
	G-169	<b><i>Dynamic Measurement of Deformation Using Fourier Transform Digital Holographic Interferometry</i></b> X.Y. Gao, S.J. Wu, L.X. Yang Beijing Information Science & Technology University, China	PMM13-MM1 00-188
I-194	<b><i>Error Analysis of 3D Reconstruction Induced By Asynchronous Cameras in Dynamic Measurement</i></b> Y.Wang, J. Zhang, H.X. Deng, R.Y. Fan Hefei University of Technology, China	PMM13-MM1 00-187	



**Oral Sessions 6, Aug. 9, 09:25-12:05**

Oral Session 6  Room D	<b>Topic</b>	<b>Optical Metrology: Image Processing</b>	
	<b>Chairman</b>	<i>Prof. S. Ito, and Prof. L.X. Yang</i>	
	<b>Oral ID</b>	<b>Presentation</b>	<b>Abs.ID</b>
	C-143	<i><u>Dimensional Measurement of Micrometer-Scale Structures With A Nanopipette Ball Probe By Using Shear-Force Detection (Invited Talk)</u></i> S. Ito, Tohoku University, Japan	PMM13-MM1 00-215
	G-124	<i>An Improved SURF Descriptor Based On Sector Area Partitioning</i> L.Zeng, Y. Zhai, X.H. Fang Academy of Equipment, China	PMM13-MM1 00-92
	G-0502	<i>Numeric Character Recognition Method Based On Fractal Dimension</i> T. He, Y.L. Xie, J.Y. Chen, L.F. Cheng Hubei University of Technology, China	PMM13-MM1 00-44
	G-132	<i>Using Jones Calculus to Extract The Circular Birefringence and Circular Dichroism of The Anisotropic Optical Media Measured By A Heterodyne Polarimeter</i> Y.L. Lo, C.Y. Li and C.C. Liao National Cheng Kung University, Taiwan, China	
	G-186	<i><u>Review and Comparison of Temporal- and Spatial-Phase Shift Speckle Pattern Interferometry for 3D Deformation Measurement (Invited Talk)</u></i> L.X. Yang <sup>a,b</sup> , <sup>a</sup> Oakland University, Rochester, USA; <sup>b</sup> Hefei University of Technology, China	PMM13-MM1 00-235
	G-160	<i>Surface Roughness Measurement of Digital Laser Speckle Pattern By Markov Random Fields Model in Wavelet Domain</i> L. Yang, R.S. Lu, Z.J. Liu, C. Liu, L.Q. Lei Hefei University of Technology, China	PMM13-MM1 00-157
	G-201	<i>Image Measurement Technique on Amplitude of Ultrasonic Horn</i> Y.B. Zhang, Z.Q. Wu, J.P. Zhu, J.G. He, G.M. Liu Institute of Machinery Manufacturing Technology, China	PMM13-MM1 00-55

**Oral Sessions 7, Aug. 9, 14:00-16:50**

Oral Session 7 Room B	<b>Topic</b>	<b>Measurement Signal Analysis &amp; Processing</b>	
	<b>Chairman</b>	<i>Prof. T.I. Liu and Prof. H.X. Deng</i>	
	<b>Oral ID</b>	<b>Presentation</b>	<b>Abstract ID</b>
	J-141	<u><i>Using Acceleration Measurements and Neuro-Fuzzy Systems for Monitoring and Diagnosis of Bearings (Invited Talk)</i></u> T.I. Liu California State University, Sacramento, USA	PMM13-MM 100-181
	G-165	<i>An Effective Signal Separation and Extraction Method Using Multi-Scale Wavelet Decomposition for Phase-sensitive OTDR System</i> H.J. Wu, X.Y. Li, H.Y. Li, Y. Wu, Y. Gong, Y.J. Rao University of Electronic Science & Technology of China, China	PMM13-M10 0-151
	H-0113	<i>FPGA-based Signal Processing Method of Automatic Interference Comparator</i> Z.Y. Wang <sup>a</sup> , H.T. Chang <sup>a</sup> , H.T. Gao <sup>b</sup> , X.Y. Ye <sup>b</sup> <sup>a</sup> Beihang University, China, <sup>b</sup> National Institute of Metrology, China,	PMM13-MM1 00-34
	H-1531	<i>A Novel DSSS Based TOF Measurement Method for Short Baseline and Its Application in Sound Velocimeter</i> S. Zhao, Y.K. Wang, C.J. Qiao, C. Zhou National University of Defense Technology, China	PMM13-MM1 00-67
	G-083	<i>Optimization of BRDF Measurement Method Using Spectralon White Reflectance Standard</i> H.R. Tao, X.H. Qu, F.M. Zhang, Y.Q. Zhu Tianjin University, China	PMM13-MM1 00-58
	G-146	<i>Digital Approach to Stabilizing Optical Frequency Combs and Beat Notes of CW Lasers</i> M. Čížek, O. Číp, R. Šmíd, J. Hrabina, B. Mikel, J. Lazar Institute of Scientific Instruments of the ASCR, Czech Republic	PMM13-MM1 00-83
C-077	<i>A Regression-Based Approach to Tolerance Values Forecasting in Micro/Meso-Scale for Micro Non-Monolithic Components</i> X.Y. Liu, X.P. Wei, J. Li, S.P. Zhao Sichuan University, China	PMM13-MM1 00-29	

## Oral Sessions 8, Aug. 9, 14:00-16:50

Oral Session 8 Room C	<b>Topic</b>	<b>Quality Engineering &amp; Uncertainty Evaluation</b>	
	<b>Chairman</b>	<i>Prof. A.G. Song, and Prof. M. Chang</i>	
	<b>Oral ID</b>	<b>Presentation</b>	<b>Abstract ID</b>
	G-025	<u><i>Adaptive Fractional Differential Method Based on CSGV to Extract Image Texture Feature (Invited Talk)</i></u> A.G. Song, Southeast University, China	PMM13-MM1 00-166
	J-009	<i>Study on Real-time Elevator Brake Failure Predictive System</i> J. Guo, J.W. Fan Beijing University of Technology, China	PMM13-MM1 00-56
	I-027	<i>Uncertainty Evaluation for a Three Dimensional Rotary Measuring System by a Markov Chain Monte Carlo Method</i> B. Chen, X.C. Zhang, H. Zhang, X.Y. He, M. Xu Fudan University, China	PMM13-MM1 00-150
	I-047	<i>The Optimal Design for Measurement Systems Based on Uniform Accuracy Life</i> Z.Y. Cheng <sup>a</sup> , X.H. Chen <sup>a</sup> , R.J. Li <sup>a</sup> , M.L. Jiang <sup>b</sup> <sup>a</sup> Hefei University of Technology, China, <sup>b</sup> Zhejiang Normal University, China	PMM13-MM1 00-146
	I-051	<i>Measurement Error Analysis of the 3D Four-wheel Aligner</i> Q.C. Zhao, D.Z. Huang, T.L. Yang, X. Ding Hunan University of Science and Technology, China	PMM13-MM1 00-173
	I-082	<i>The Combined Measurement and Compensation Technology for Robot Motion Error</i> R. Li, X.H. Qu, Y.G. Deng, B.D. Liu Tianjin University, China	PMM13-MM1 00-49
I-198	<i>Uncertainty Evaluation of Combining Measurement System based on Monte-Carlo Method</i> H.N. Zhao, L.D. Yu, Y. Du, H.Y. Zhang Hefei University of Technology, China	PMM13-MM1 00-234	

## Oral Sessions 9, Aug. 9, 14:00-16:50

Topic	<b>Optical Metrology: Optical Probe &amp; System</b>	
Chairman	<i>Prof. W.H. Zhou and Prof. B.Y. Chen</i>	
Oral ID	Presentation	Abstract ID
	<u><i>Laser Tracking Measurement Based on Optical Frequency Comb (Invited Talk)</i></u> W.H. Zhou Academy of Opto-electronics, Chinese Academy of Sciences, China	
G-054	<i>An Apparatus for Non-contact Measuring Profile of Precision Rotor Based on Laser Triangulation</i> X.Y. Yin, T.L. Yang, Q.C. Zhao, D.Z. Huang Hunan University of Science and Technology, China	PMM13-MM 100-170
G-058	<i>Full-Field 3-D Topography of Transparent Surfaces Utilizing Low Coherence Interferometry</i> C.C. Cui <sup>a</sup> , M. Chang <sup>a, b</sup> , G.L. Su <sup>b</sup> , Q. Yu <sup>a</sup> , P.C. Chen <sup>b</sup> <sup>a</sup> Huaqiao University, China; <sup>b</sup> Chung Yuan Christian University, Taiwan, China;	
G-062	<i>Correction on the Effect of Numerical Aperture in Optical Scatterometry</i> W.Q. Li, S.Y. Liu, C.W. Zhang, X.G. Chen, and H.G. Gu Huazhong University of Science and Technology, China	PMM13-MM 100-25
G-086	<i>Fiber-Optic Interferometer Fringe Projector Using Sinusoidal Phase-Modulating</i> C.G. Lv, F.J. Duan, X.J. Duan, F.K. Zhang, E. Bo, F. Fan Tianjin University, China	PMM13-MM 100-167
G-147	<i>Calibration of Elongation of Fiber Bragg Gratings By Laser Interferometer</i> B. Mike , M. Cizek, S. Rerucha and O. Cip Institute of Scientific Instruments, Czech Republic	PMM13-MM 100-82
G-161	<i>LED Uniform Illumination System for DMD-Based Confocal Microscopy</i> K.M. Xiao, W.M. Hou, Q.X. Xu, B.F. Peng, University Shanghai for Science and Technology, China	PMM13-MM 100-81
G-024	<i>Optical Fiber Fences: Research &amp; Applications</i> Yun-Jiang Rao University of Electronic Science and Technology of China, China	PMM13-MM 100-152

Oral Session  
9  
Room D

## Poster Session

Poster ID	Poster	Abstract ID
G-008	<p><b><i>Multimodal Images Registration Based on SURF and KD Tree</i></b>                      Y. X. Yin, Z. Y. Gu,                      Anhui University of Traditional Chinese Medicine, China</p>	PMM13-MM 100-177
E-0111	<p><b><i>Data Repair in Incomplete Free-surface Measurement</i></b>                      Z. Y. Wang, Q. Li, H. Yan, Q. Wang                      Beihang University, China</p>	PMM13-MM 100-31
D-0112	<p><b><i>Radial Pressure Sensor of Sucker Rod Based on LabVIEW</i></b>                      Z. Y. Wang, H. Yan, Q. Li                      Beihang University, China</p>	PMM13-MM 100-33
G-014	<p><b><i>Digital Image Correlation Method for Measuring Thermal Deformation of Composite Materials</i></b>                      Li. Jiang<sup>a</sup>, K. Liu<sup>a</sup>, D. W. Wang<sup>a</sup>, X. H. Cheng<sup>a</sup>, W. R. Wu<sup>b</sup>  <sup>a</sup>Beijing Aerospace Institute for Metrology and Measurement ,China  <sup>b</sup>Lunar Exploration and Aerospace Engineering Center, China</p>	PMM13-MM 100-47
F-016	<p><b><i>Experimental research on anti-vibration interferometry based on time-frequency-domain analysis</i></b>                      H. Yao, Q. Hao, F. H. Zhang, Y. H. Tian                      Beijing Institute of Technology, China</p>	PMM13-MM 100-179
G-017	<p><b><i>Measuring the lens focal length by laser confocal technique</i></b>                      H. L. Wu, J. M. Yang, L. R. Qiu, W. Q. Zhao                      Beijing Institute of Technology, China</p>	PMM13-MM 100-128
B-019	<p><b><i>A kinematic parameter Calibration method for Articulated Arm Coordinate Measuring Machine</i></b>                      S. Zhao, L. Q. Zhu, Q. S. Chen, Z. K. Pan, Y. K. Guo                      Beijing Information Science &amp; Technology University, China</p>	PMM13-MM 100-114
F-029	<p><b><i>Feasibility study of detection of chatter by using FBG during boring</i></b>                      P. Y. Zhu<sup>a</sup>, W. Peng<sup>b</sup>, Z. Wang<sup>b</sup>, Z. J. Hu<sup>b</sup>  <sup>a</sup>Guangzhou University, China  <sup>b</sup>Hunan University of Science and Technology, China</p>	PMM13-MM 100-182

G-031	<p><b><i>Radius measurement using a parallel two-step spatial carrier phase-shifting common-path interferometer</i></b>  B.G.Hao, M. Diao, Z. Zhong, M. G. Shan, Y. B. Zhang  Harbin Engineering University, China</p>	PMM13-MM 100-94
G-032	<p><b><i>Image edge enhancement for moving objects with a spiral phase filter</i></b>  S. S. Bao, Z. Zhong, M. G. Shan, B. G. Hao, C. Q. An  Harbin Engineering University, Harbin, China</p>	PMM13-MM 100-100
D-035	<p><b><i>Measurement of transient surface temperatures during rubbing using infrared thermography</i></b>  T. You, J. W. Yu, X. F. Yu  Hefei University of Technology, China</p>	PMM13-MM 100-172
I-041	<p><b><i>Evaluation of Measurement Uncertainty Based on Bayesian Information Fusion</i></b>  S. Wang, X. H. Chen  Hefei University of Technology, China</p>	PMM13-MM 100-77
D-042	<p><b><i>Research of Temperature Field Measurement Using a Flexible Temperature Sensor Array for Robot Sensing Skin</i></b>  Y. Huang, S. Y. Wu, R. Q. Li, Q. H. Yang, Y. G. Zhang, C. X. Liu  Hefei University of Technology, China</p>	PMM13-MM 100-149
H-043	<p><b><i>A Robust Sinusoidal Signal Processing Method for Interferometers</i></b>  X. L. Wu<sup>a</sup>, H. Zhang<sup>a</sup>, Y. Y. Tseng<sup>b</sup>, K. C. Fan<sup>b</sup>  <sup>a</sup>Hefei University of Technology, China  <sup>b</sup>National Taiwan University, Taiwan, China</p>	PMM13-MM 100-61
G-044	<p><b><i>DSPI system based on Spatial Carrier Phase Shifting (SCPS) technique</i></b>  Y. H. Wang<sup>a</sup>, J. R. Li<sup>a</sup>, J. F. Sun<sup>a</sup>, L. X. Yang<sup>a,b</sup>  <sup>a</sup>Hefei University of Technology, China  <sup>b</sup>Oakland University, USA</p>	PMM13-MM 100-231
C-046	<p><b><i>Dual AFM probes alignment based on vision guidance</i></b>  H. K. Zhang<sup>a</sup>, S. T. Gao<sup>a,b</sup>, M. Z. Lu<sup>b</sup>  <sup>a</sup>HeFei University of Technology, China  <sup>b</sup>National Institute of Metrology, China</p>	PMM13-MM 100-108
H-048	<p><b><i>A high-accuracy signal processing algorithm for frequency scanned interferometry</i></b>  S. Zhang<sup>a</sup>, L. G. Yang<sup>a,b</sup>, X. Z. Wang<sup>a,b</sup>, Z. S. Zhai<sup>a,b</sup>, W. C. Liu<sup>a,b</sup>  <sup>a</sup>Hubei University of Technology, China  <sup>b</sup>Key Lab of Modern Manufacture Quality Engineering, China</p>	PMM13-MM 100-70

G-0501	<p><b><i>Positioning method for a visual guiding system in a laser welding machine</i></b>  T. He, Y. Q. Fan, Y. L. Xie, Q. H. Wu  Hubei University of Technology, China</p>	PMM13-MM 100-65
E-053	<p><b><i>Optimized design of a low frequency narrowband band-pass filter</i></b>  B. Tian<sup>a</sup>, G. H. Fu<sup>a</sup>, X. Y. Liao<sup>a</sup>, H. Cheng<sup>a,b</sup>, G. Li<sup>a</sup>  <sup>a</sup>Hunan University of Science and Technology, China  <sup>b</sup>Chinese Academy of Science, China</p>	PMM13-MM 100-171
F-055	<p><b><i>Mine Refuge Chamber Dynamics Modeling and Stress Analysis</i></b>  S. Y. Yang, J. J. Li, Y. B. Sun  HuNan University of Science and Technology, China</p>	PMM13-MM 100-180
G-057	<p><b><i>Self-adaptive grain recognition of diamond grinding wheel and its grain assessment</i></b>  C. C. Cui, L. J. Zhou, Q. Yu, H. Huang, R. F. Ye  Huaqiao University, China</p>	PMM13-MM 100-115
D-064	<p><b><i>Optical Characteristic and Calibration of 3D Vision Sensor</i></b>  F. Y. Liang<sup>a,b</sup>, H. Zhang<sup>a</sup>, H. C. Chen<sup>a</sup>, G. L. Xiong<sup>a,b</sup>, R. H. Zhang<sup>a</sup>, G. P. Liu<sup>a</sup>, X. M. He<sup>a</sup>  <sup>a</sup>Naked eyes 3d&amp;VR research center, Nanchang China.  <sup>b</sup>Nanchang properasia optoelec Sci-Tech Dev Co.,Ltd,Nanchang China</p>	PMM13-MM 100-156
D-0701	<p><b><i>Simulation and design of a fiber Bragg grating flow sensor</i></b>  Q. Jiang, F. F. Gao  Shandong University, China</p>	PMM13-MM 100-221
D-0702	<p><b><i>Design and study of a vibrating string accelerometer based on fiber Bragg grating</i></b>  Q. Jiang, M. H. Yu, L. L. Sun  Shandong University, China</p>	PMM13-MM 100-223
D-072	<p><b><i>Placement of the Material Temperature Sensor during Measuring the Accuracy of CNC Machine Tools</i></b>  D. S. Zhao, M. Q. Jia, J. Zhang, L. Sun, W. J. Li  Shandong Polytechnic University, China</p>	PMM13-MM 100-178
G-075	<p><b><i>A Study on the quality of micro-hole of Ti-6Al-4V by EDM process with on-machine measurement techniques</i></b>  J. Li, X. Y. Liu, X. P. Wei, S. P. Zhao  Sichuan University, China</p>	PMM13-MM 100-48

H-080	<p><b><i>Simulation and signal analysis of Akiyama probe applied to Atomic force microscope</i></b>  L. L. Wang<sup>a,b</sup>, M. Z. Lu<sup>b</sup>, T. Guo<sup>a</sup>, S. T. Gao<sup>b</sup>, H. K. Zhang<sup>b</sup>  <sup>a</sup>Tianjin University, China;  <sup>b</sup>National Institute of Metrology, China</p>	PMM13-MM 100-78
I-084	<p><b><i>An indirect accuracy calibration and uncertainty evaluation method for large scale inner dimensional measurement system</i></b>  B. L. Liu, X. H. Qu  Tianjin University, China;</p>	PMM13-MM 100-12
D-087	<p><b><i>Soil Water Evaporation Measurement of Lysimeter Based on Fiber Bragg Grating Sensor</i></b>  K. J. Yan, J. Liu, L. P. Miao, L. Bai, W. T. Zhong  Xi'an University of Technology, China</p>	PMM13-MM 100-140
G-088	<p><b><i>Retrieval of aerosol size distribution based on GCV regularization with optical data of Lidar</i></b>  H. Zhao<sup>a,b</sup>, D. X. Hua<sup>a</sup>, H. G. Di<sup>a</sup>, Y. F. Wang<sup>a</sup>, H. Zhao<sup>a</sup>  <sup>a</sup>Xi'an University of Technology, China  <sup>b</sup>Beifang University of Nationalities, China</p>	PMM13-MM 100-21
H-089	<p><b><i>Pulse Modulation Method for LED Lidar Light Source</i></b>  W. T. Zhong, J. Liu, D. X. Hua, F. Wang, K. J. Yan  Xi'an University of Technology, China</p>	PMM13-MM 100-36
G-090	<p><b><i>Design of Dual Wavelength Micro Pulse Polarization Lidar System</i></b>  Y. H. Song, D. X. Hua, S. C. Li, Y. F. Wang, W. H. Xin, H. G. Di  Xi'an University of Technology, China</p>	PMM13-MM 100-53
G-091	<p><b><i>A Novel Retinex Algorithm Based On Alternating Direction Optimization</i></b>  X. Y. Fu, Q. Lin, W. Guo, Y. Huang, D. L. Zeng, X. H. Ding  Xiamen University, China</p>	PMM13-MM 100-37
E-093	<p><b><i>Design of Energy-saving Control System for LED Street Lamps</i></b>  X. Ding<sup>a,b</sup>, W. G. Jin<sup>a</sup>  <sup>a</sup>Zhejiang University, China;  <sup>b</sup>Ningbo Institute of Technology, Zhejiang University, China</p>	PMM13-MM 100-75
E-094	<p><b><i>Spectrum Measurement for LED-Based Spectrum-Tunable Source</i></b>  N. JIA<sup>a,b</sup>, Z. R. Zheng<sup>a</sup>, Y. Yang<sup>a</sup>, H. H. Wang<sup>a</sup>  <sup>a</sup>Zhejiang University, China;  <sup>b</sup>Hangzhou Vocational and Technical College, China</p>	PMM13-MM 100-159



G-095	<p><b>Noise reduction of laser scanning data based on self-estimated angular threshold</b></p> <p>Y. F. Wu<sup>a</sup>, W. Wang<sup>b</sup>, K. Q. Lu<sup>b</sup>, Y. D. Wei<sup>a</sup>, Z. C. Chen<sup>a</sup>  <sup>a</sup>Zhejiang University, China  <sup>b</sup>Hangzhou Dianzi University, China</p>	PMM13-MM 100-90
C-096	<p><b>Research status and developing trends of grating nanometer measuring technology</b></p> <p>M. L. Jiang, H. F. Li, X. D. Wang, J. G. Shen  Zhejiang Normal University, China</p>	PMM13-MM 100-57
A-098	<p><b>Roundness measuring instrument for 2-dimensional standards</b></p> <p>W. N. Wang  National Institute of Metrology, China</p>	PMM13-MM 100-131
C-102	<p><b>Development and measurement of single layer thickness standard</b></p> <p>J. J. Cui<sup>a,b</sup>, S. T. Gao<sup>b</sup>, H. Du<sup>b</sup>  <sup>a</sup>Tianjin University, China  <sup>b</sup>National Institute of Metrology, China</p>	PMM13-MM 100-16
J-105	<p><b>Bearing Fault Diagnosis Based on Scale-transformation Stochastic Resonance</b></p> <p>Y. Cui, J. Zhao, T. T. Guo, Y. Q. Song  China Jiliang University, China,</p>	PMM13-MM 100-45
E-107	<p><b>Research on Dedicated On-line Detecting System of Auto Air Dryer</b></p> <p>C. Y. Shi, Z. Luo  China Jiliang University, China</p>	PMM13-MM 100-93
E-109	<p><b>Detection Technology Research On The One-way Clutch of Automatic Brake Adjuster</b></p> <p>W. S. Jiang, Z. Luo, Y. Lu  China Jiliang University, China</p>	PMM13-MM 100-22
H-113	<p><b>ROIC with on-chip sigma-delta AD converter for HgCdTe e-APD FPA</b></p> <p>G. Q. Chen<sup>a,b</sup>, J. L. Zhang<sup>a</sup>, P. Wang<sup>a,b</sup>, J. Zhou<sup>a,b</sup>, L. Gao<sup>a,b</sup>, R. J. Ding<sup>a</sup>  <sup>a</sup>Chinese Academy of Sciences, China  <sup>b</sup>University of Chinese Academy of Sciences, China</p>	PMM13-MM 100-11
D-119	<p><b>A novel design of parallel piezoelectric six-degree-of-freedom accelerometer</b></p> <p>H. Y. Lv, L. Qin, J. Liu  Chongqing University, China</p>	PMM13-MM 100-158

I-121	<b><i>Dynamic high-speed acquisition system design of transmission error with USB based on LabVIEW and FPGA</i></b> Y. Zheng, Y. Chen Chongqing University of Technology Chongqing, China	PMM13-MM 100-35
D-122	<b><i>Dynamic self-calibration of time grating sensors based on self-adaptive Kalman filter algorithm</i></b> Z. R. Chen Chongqing University of Technology, China	PMM13-MM 100-184
B-126	<b><i>Kinematic Modeling and Simulation of an Articulated Arm Coordinate Measuring Machine based on MCPC Method</i></b> J. Lu, G. B. Gao, H. P. Yang Kunming University of Science and Technology, China	PMM13-MM 100-165
E-129	<b><i>Optimizing the structure of a four-axis polarized scattering instrument using a double-loop approach</i></b> C. J. Shih <sup>a</sup> , T. L. Teng <sup>b</sup> , Y. A. Huang <sup>a</sup> <sup>a</sup> Tamkang University, Taiwan, China <sup>b</sup> Hsiuping University of Science and Technology, Taiwan, China	PMM13-MM 100-50
E-130	<b><i>The performance of an inspection system for indium tin oxide circuits by using a PDLC/ITO film</i></b> C. H. Chan <sup>a</sup> , Y. T. Zou <sup>b</sup> , C. T. Chen <sup>b</sup> , T. K. Liu <sup>b</sup> , C. H. Chen <sup>b</sup> , H. W. Wang <sup>b</sup> , S. C. Lin <sup>a</sup> <sup>a</sup> National Tsing Hua University <sup>b</sup> Industrial Technology Research Institute Hsinchu, Taiwan, China	PMM13-MM 100-54
B-134	<b><i>Development of a micro-CMM with scanning touch probe and high-precision coplanar platform</i></b> C. L. Chu, C. T. Lu, H. C. Chen, J. S. Ke, C. M. Chang Southern Taiwan University of Science and Technology, Taiwan, China	PMM13-MM 100-195
F-135	<b><i>A three-degree-of-freedom hybrid vibration isolation system using adaptive proportional control supported by passive weight support mechanism</i></b> Y. H. Liu, W. H. Wu, C. L. Chu Southern Taiwan University of Science and Technology, Taiwan, China	PMM13-MM 100-230
D-138	<b><i>The Investigation of electrochemical surface roughening for PCB copper foil</i></b> S. J. Lee, C. K. Liu College of Engineering Yuan Ze University, Taiwan, China	PMM13-MM 100-239
D-152	<b><i>Development of automobile tyre lateral runout measurement sensor</i></b> X. MA <sup>a</sup> , L. J. Ye <sup>b</sup> , G. H. Yao <sup>b</sup> , D. Wang <sup>b</sup> <sup>a</sup> Ningbo Dahongying College, China; <sup>b</sup> Ningbo Institute of Technology, Zhejiang University, China	PMM13-MM 100-229

H-1532	<p><b><i>Transmitting pulse signal design for ultrasonic time of flight measurement in short baseline framework</i></b></p> <p>S. Zhao, Y. K. Wang, C. J. Qiao, C. Zhou National University of Defense Technology, China</p>	PMM13-MM 100-15
D-157	<p><b><i>Design of scrap copper separation control system based eddy current sensor</i></b></p> <p>D. Wang<sup>a,b</sup>, X. S. Ma<sup>a</sup>, L. J. Ye<sup>a</sup>, G. H. Yao<sup>a</sup>, S. M. Zhang<sup>a,b</sup> <sup>a</sup>Ningbo Institute of Technology, Zhejiang University, China; <sup>b</sup>Taiyuan University of Science and Technology, China</p>	PMM13-MM 100-226
F-159	<p><b><i>Design and finite element analysis of the vibration isolation system of STM</i></b></p> <p>Y. Q. Liu, X. Fu, L. Y. Xu, Y. P. Song Tianjin University, China</p>	PMM13-MM 100-238
H-166	<p><b><i>Harmonic Distortion Analysis of a Mach-Zehnder Intensity Modulator</i></b></p> <p>X. Q. Zhang<sup>a</sup>, S. L. Hu<sup>b</sup>, Y. D. Jia<sup>a</sup>, Z. H. Zhou<sup>a</sup>, L. Liao<sup>a</sup> <sup>a</sup>Beijing Information Science &amp; Technology University, China <sup>b</sup>Beijing University of Aeronautics and Astronautics, China</p>	PMM13-MM 100-208
G-167	<p><b><i>Design of High Current Voltage Conversion Circuit Based on LT3743</i></b></p> <p>G. Cai, X. P. Lou, Y. M. Zhang, Y. X. Na, Q. Z. Liu Beijing Information Science and Technology University, China</p>	PMM13-MM 100-203
G-168	<p><b><i>Structure parameters optimization and system simulation of a double-triangulation probe</i></b></p> <p>D. Cheng, X. P. Lou, Q. Z. Liu, M. L. Dong Beijing Information Science &amp; Technology University, China</p>	PMM13-MM 100-132
G-170	<p><b><i>All-Fiber Q-Switched Ytterbium-Doped Fiber laser in MOPA Configurations</i></b></p> <p>W. He<sup>a</sup>, L. Q. Zhu<sup>a,b</sup>, Y. M. Zhang<sup>b</sup>, M. L. Dong<sup>b</sup>, X. H. Chen<sup>a</sup> <sup>a</sup>Hefei University of Technology, China <sup>b</sup>Beijing Information Science and Technology University, China</p>	PMM13-MM 100-147
G-171	<p><b><i>The Acquisition, Amplification and Adjustment of Nanosecond Light Pulse</i></b></p> <p>H. Liu, N. G. Lv, X. P. Lou, Q. Z. Liu, Y. X. Na, Y. M. Zhang Beijing Information Science &amp; Technology University, China</p>	PMM13-MM 100-193
G-172	<p><b><i>Technique of Laser Confocal and Raman Spectroscopy for Living Cell Analysis</i></b></p> <p>X. C. Meng, L. Q. Zhu Beijing Information Science and Technology University, China</p>	PMM13-MM 100-13

G-173	<p><b><i>An improved centroid location algorithm for infrared LED feature points</i></b>  S. Q. Wang, B. X. Yan, M. L. Dong, J. Wang, P. Sun  Beijing Information Science &amp; Technology University, China</p>	PMM13-MM 100-137
I-174	<p><b><i>Simulation research of acousto optic modulator drive based on Multisim</i></b>  S. Q. Wang, Y. K. Guo, L. Q. Zhu, Y. X. Na, Y. M. Zhang, Q. Z. Liu  Beijing Information Science and Technology University, China</p>	PMM13-MM 100-160
G-175	<p><b><i>An accuracy evaluating method for image point location based on linear fitting</i></b>  L. Xu, M. L. Dong, J. Wang, P. Sun  Beijing Information Science &amp; Technology University, China</p>	PMM13-MM 100-124
G-177	<p><b><i>Optical tweezers based on cylindrical vector beams</i></b>  Y. H. Xu, Z. H. Zhou, X. L. Zhang, Z. D. Zhao, L. Q. Zhu  Beijing Information Science and Technology University, China</p>	PMM13-MM 100-169
G-178	<p><b><i>A variable weighted centroid method for Retro Reflective Target locating</i></b>  W. Zhuang, M. L. Dong, P. Sun, J. Wang  Beijing Information Science &amp; Technology University, China</p>	PMM13-MM 100-103
E-182	<p><b><i>A study on the fabrication of main scale of linear encoder using continuous roller imprint method</i></b>  S. J. Fan, Y. S. Shi, L. Yin, L. Feng, H. Z. Liu  Xi'an Jiaotong University, China</p>	PMM13-MM 100-98
B-183	<p><b><i>Study on Technology of Double Parallel-joints Coordinate Measuring Machine</i></b>  G. S. Xia, R. Q. Yu, Y. J. Fu  Nanchang HangKong University, China</p>	PMM13-MM 100-207
G-184	<p><b><i>Three-dimensional shape measurement based on a combination of gray-code and phase-shift light projection</i></b>  Z. G. Wang, Y. J. Fu, J. Yang, G. S. Xia, J. S. Wang  Nanchang Hangkong University, China</p>	PMM13-MM 100-66
G-185	<p><b><i>The Design of the Fiber Probe Sintering Plant Control System</i></b>  Z. J. Ai, S. S. Dong, Q. Yang, N. Lin, Y. Xu  Hefei University of Technology, China</p>	PMM13-MM 100-200

D-187	<p><b><i>An Improving Demodulation of Interferometric Fiber Optic Sensor Technology</i></b>  L. Gao<sup>a</sup>, Y. Li<sup>b</sup>, Z. R. Chu<sup>b</sup>, M. Wu<sup>c</sup>, N, Lin<sup>b</sup>  <sup>a</sup>HuaiNan Union University, China.  <sup>b</sup>Hefei University of echnology, China  <sup>c</sup>China Electronics Technology Group Corporation No.8 Research Institute, China.</p>	PMM13-MM 100-205
G-190	<p><b><i>Digital Optimeter Based on Linear CCD</i></b>  Q. Hu, Y. L. Xu  Guiyang Xintian OETECH Co., Ltd, China</p>	PMM13-MM 100-116
D-191	<p><b><i>Research on Suitable Detection Distance of Non-contact of the Magneto-elastic Stress Sensor</i></b>  Y. F. Guo, G. Q. Tang, W. Y. Wang  Hunan University of Science and Technology, China</p>	PMM13-MM 100-213
G-196	<p><b><i>The accuracy analysis of the intersection measurement on the moving ships</i></b>  M. Wang, Q. S. Shan, K. Liu  Xi'an institute of optics and precision mechanics of Chinese Academy of Science, China</p>	PMM13-MM 100-24
D-199	<p><b><i>Extending the measuring range of fiber optic displacement sensor with differential evolution optimized extreme learning machine</i></b>  X. D. Wang, M. Y. Ye  Zhejiang Normal University, China;</p>	PMM13-MM 100-110
	<p><b><i>Study on detection method of inner wall of small-diameter workpiece based on cone reflector</i></b>  W. J. Lu<sup>a</sup>, Y. Yao<sup>b</sup>, C. Li<sup>b</sup>, X. Chen<sup>a</sup>, L. C. Shen<sup>b</sup>, L. H. Lei<sup>c</sup>, W. B. Sun<sup>c</sup>  <sup>a</sup>Shanghai Jiao Tong University, China  <sup>b</sup>Shanghai Institute of Spaceflight Control Technology, China  <sup>c</sup>Shanghai Institute of Measurement and Testing Technology, China</p>	PMM13-MM 100-228
A-162	<p><b><i>A Verification Device for the Stylus Profilometer Sensor</i></b>  L. Guo<sup>a</sup>, X. J. Liu<sup>a</sup>, W. L. Lu<sup>a</sup>, W. B. Zhong<sup>a</sup>, J. Wang<sup>a</sup>, Y. Luo<sup>b</sup>  <sup>a</sup>Huazhong University of Science and Technology, China  <sup>b</sup>Wuhan Marine Machinery Plant co.,LTD, China</p>	PMM13-MM 100-246
D-181	<p><b><i>A Small Angle Dynamic Measuring Device</i></b>  J. Wang, X. J. Liu, L. P. Zhou, W. L. Lu, L. Guo, Y. M. Zou  Huazhong University of Science and Technology, China</p>	PMM13-MM 100-247
	<p><b><i>Comprehensive evaluation of surface topography in running-in wear Process</i></b>  G. P. Zhang, X. J. Liu, W. L. Lu  Huazhong University of Science and Technology, China</p>	PMM13-MM 100-248

	<p><b><i>Research on Pre-processing of QR Code</i></b>  H.X. Sun, H.J. Xia, N. Dong  Hefei University of Technology, China</p>	PMM13-MM 100-250
G-033	<p><b><i>3D Measurement Method Based on Combined Temporal Encoding Structured Light</i></b>  X.Y. Yu, Y. Wang, S. Yu, H. Chen, X.M. Sun, S.C. Yu, D.Y. Chen  Harbin University of Science and Technology, China</p>	PMM13-MM 100-174
I-123	<p><b><i>Error Analysis and Modeling for the Time Grating Length Measurement System</i></b>  Z.H. Gao<sup>*1,2</sup>, J.Q. Feng<sup>1,2</sup>, D.L. Peng<sup>1,2</sup>, X.K. Liu<sup>1,2</sup>  Chongqing University of Technology, China</p>	PMM13-MM 100-63

# *Abstracts of Papers*

**C-037 PMM13-MM100-211**

## **Characteristics of the Higher-order Resonant Cantilever in Dynamic Atomic Force Microscopy**

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### **ABSTRACT**

In order to improve the performances of dynamic atomic force microscopy (AFM), a higher-order resonant cantilever which is driven at its second order or even higher-order resonant frequency instead of its first order resonant frequency is proposed. Due to the increase in the frequency and quality factor of the higher-order resonant cantilever, the response time, air damping coefficient are reduced and the detecting sensitivity of the cantilever is improved. Meanwhile, because the angular deflection of the cantilever under higher-order resonant vibration is larger than that under the first order resonant vibration, the optical magnification level of the higher-order resonant cantilever is several times larger than that of the first order when the optical lever method is adopted to detect the variation of the cantilever. Theoretical analysis and experimental results show that the scanning method done by a higher-order cantilever is effective and feasible, and the scanning characteristics of dynamic AFM with the higher-order resonant cantilever are promoted obviously compared with that of the AFM operated in the first-order.

**Keywords:** Higher-order Resonance, Optical Lever Method, Cantilever, Atomic Force Microscopy

**G-026 PMM13-MM100-153**

## **Fast Filtering of Surface Topography of Micro-Optics using Non-Local Means**

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### **ABSTRACT**

Micro optical components are more and more widely used in precision engineering due to their small sizes and novel functionalities. Characterization of the surface topography of these components is very difficult due to the existence of sharp edges and complex features. Conventional filtering algorithms cannot be used directly for non-smooth structured surfaces. In this paper we present a filtering algorithm using the non-local means method. Instead of assigning weights according to the closeness or similarity between individual data points, this method are based on the similarity of the patches surrounding data points. This method can effectively separate the detailed textures of non-smooth surfaces while preserving primary features. Proper adaptation and improvement are made for the applications in precision engineering. The k-means clustering method is used to reduce the computational cost. Numerical experiments prove that the non-local means method is able to separate small-scaled textures from the primary surface shapes without ruining the sharp features.



**Keywords:** micro-structured surface, surface topography, edge-preserving filtering, non-local means

## **C-005 PMM13-MM100-72**

### **Structure Design and Characteristic Analysis of Micro-nano Probe Based on Six Dimensional Micro-force Measuring Principle**

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#### **ABSTRACT**

In order to develop micro-nano probe having error self-correcting function and good rigidity structure, a new micro-nano probe system was developed based on six-dimensional micro-force measuring principle. The structure and working principle of the probe was introduced in detail. The static nonlinear decoupling method was established with BP neural network to do the static decoupling for the dimension coupling existing in each direction force measurements. The optimal parameters of BP neural network were selected and the decoupling simulation experiments were done. The maximum probe coupling rate after decoupling is 0.039% in X direction, 0.025% in Y direction and 0.027% in Z direction. The static measurement sensitivity of the probe can reach  $10.76 \mu\text{E} / \text{mN}$  in Z direction and  $14.55 \mu\text{E} / \text{mN}$  in X and Y direction. The modal analysis and harmonic response analysis under three dimensional harmonic load of the probe were done by using finite element method. The natural frequencies under different vibration modes were obtained and the working frequency of the probe was determined, which is higher than  $10000 \text{ Hz}$ . The transient response analysis of the probe was done, which indicates that the response time of the probe can reach 0.4 ms. From the above results, it is shown that the developed micro-nano probe meets triggering requirements of micro-nano probe. Three dimension measuring force can be measured precisely by the developed probe, which can be used to predict and correct the force deformation error and the touch error of the measuring ball and the measuring rod.

**Key words:** micro-nano probe; six dimensional micro-force measuring; static decoupling; static character; dynamic character

## **C-112 PMM13-MM100-117**

### **Key Techniques of Ultra-Precision Aerostatic System**

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#### **ABSTRACT**

In the process of ultra-precision machining and measuring, nanoscale rotary and linear motion can be realized by aerostatic system. Aerostatic restrictors are one of core components in aerostatic system. An aerostatic restrictor with multi-micro channels was designed and developed, combined with the orifice and torus throttling methods. Besides, the

mentioned restrictor has two individual parts assembled together by interference fit, which can alleviate the contradiction between its stiffness and stability. Its maximum bearing capacity was 708.4N when the supply gas pressure was 0.5MPa. Numerical simulation and experimental investigation indicates the pressure in gas film of this restrictor gradually reduces to atmospheric pressure from the center to the surrounding. The temperature decreases from the outlet to the edge and the maximum temperature difference is more than 5°C, which verifies Joule-Thomson effect in the throttling process. In order to reduce the influence of gas source fluctuation on the parameters such as gas film thickness, pressure and temperature, high accuracy stable pressure source was developed applying two-stage series closed-loops feedback control, which can make the outlet pressure error below 1%. Because of the influence of ambient noise on ultra-precision aerostatic system, high precision vibration-isolation platform was developed applying air spring vibration-isolation technology, whose natural frequency can be as low as 1.22Hz.

**Keywords:** aerostatic restrictor, bearing capacity, stable pressure source, air spring vibration-isolation

## **C-136 PMM13-MM100-14**

### **Development of a Miniature Multi-Degree-of-Freedom Measurement System for Ultra Precision Stages**

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#### **ABSTRACT**

Any linear stage has inherent geometrical errors due to manufacturing errors. The induced Abbé errors have to be compensated for the accuracy of positioning. In addition, although the commercial laser interferometer is capable for the displacement sensing to nanometer resolution, it is, however, bulky in size, expensive in cost and not able to correct the Abbé errors caused by angular errors of the moving stage. In order to minimize and simplify the interferometer as a practically useful sensor for nanopositioning stages in industrial use, this paper presents a newly developed miniature multi-degree-of-freedom measurement system (MDFMS), which is constructed by a wavelength corrected Michelson interferometer and a dual-axis autocollimator. The wavelength correction of the miniature laser interferometer is calibrated by SIOS and controlling the temperature within  $\pm 2$  °C, the wavelength stability is less than  $10^{-6}$ . After calibration, the accuracy of the miniature laser interferometer can reach 32 nm for the travel of 20 mm long. The collimator has accuracy of  $\pm 0.3$  arc-sec within the range of  $\pm 30$  arc-sec. This MDFMS has been integrated into the developed Micro-CMM as a feedback sensor in each axis of the coplanar stage.

**Keywords:** Multi-degree-of-freedom measurement system (MDFMS), Abbé error, Michelson interferometer, wavelength correction, Micro-CMM

## **C-145 PMM13-MM100-10**

### **Nanometrology interferometric coordinates measurement system for local probe microscopy**

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## ABSTRACT

We present an overview of approaches to the design of nanometrology measuring setups with a focus on methodology of nanometrology interferometric techniques and associated problems. The design and development of a positioning system with interferometric multi-axis monitoring and control involved for scanning probe microscopy techniques (primarily atomic force microscopy, AFM) for detection of the sample profile is presented. Coordinate position sensing allows upgrading the imaging microscope techniques up to quantified measuring. Especially imaging techniques in the micro and nanoworld overcoming the barrier of resolution given by the wavelength of visible light are a suitable basis for design of measuring systems with the best resolution possible. The system is being developed in cooperation with the Czech metrology institute and it is intended to operate as a national nanometrology standard combining local probe microscopy techniques and sample position control with traceability to the primary standard of length.

**Keywords:** Nanometrology, Interferometry, Traceability, Local probe microscopy, Nanopositioning

## G-0812 PMM13-MM100-91

### Phase modulation dynamic AFM measurement system based on tuning fork probe

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## ABSTRACT

In this paper, we design a phase modulation dynamic AFM measurement system based on the characteristics of the novel tuning fork probe. The AFM head based on the tuning fork probe can work cooperatively with the displacement positioning platform driven by the piezoelectric actuators to achieve the feedback in z direction. The large range nanometer positioning stage can be used to scan the sample in x and y directions. With nanoscale resolution, the whole system has a range of 25mm×25mm in horizontal. The measurement data can be traced back to the definition of meter through three embedded laser interferometers. We measure the internal working current of the tuning fork by experiment, and gain the electro-mechanical coupling factor of the probe, and achieve the calibration of AFM head. To guarantee the system's feasibility, the AFM measuring system accomplishes the measurement of typical grid structure's surface morphology in phase modulation mode.

**Key words:** AFM, Tuning fork probe, Phase modulation, Electro-mechanical coupling factor

## C-061 PMM13-MM100-27

### Computational metrology for nanomanufacturing

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## ABSTRACT

One critical challenge for high-volume nanomanufacturing requires the on-line monitoring and measurement of the nanostructures manufactured. Computational metrology is expected to provide a novel means for fast, low-cost, nondestructive, and accurate measurement in high-volume manufacturing. Computational metrology refers to a measurement method where a complicated measurement process is modeled as a forward problem and some measured data are obtained by a specific instrument under a certain measurement configuration, and then the measurands are precisely and accurately reconstructed by solving the corresponding inverse problem. Thus computational metrology is essentially a model-based metrology and a typical process to solve an inverse problem. The key issues in computational metrology, such as the measurability, the measurement error analysis and precision estimation, the measurement configuration optimization, the fast and accurate forward modeling, and the fast and robust measurand reconstruction, and their generalized solution methods are explored in this paper, with an emphasis on the significance and necessity to apply modern mathematical theories and tools in solving the related problems. Some case studies carried out in my research group are presented to demonstrate the capability of computational metrology.

**Keywords:** computational metrology, model-based metrology, measurability, measurement error analysis, measurement configuration, model order reduction, inverse problem solving.

## B-045 PMM13-MM100-121

### Elastic mechanism design of the CMM contact probe

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## ABSTRACT

The measurement of miniature components with a micro- or nano-coordinate measuring machine requires a high precision contact scanning probe. The elastic mechanism of low stiffness is a major component of the contact scanning probe. A new elastic mechanism is analyzed by the theory of elasticity and finite element analysis in this paper. It is to realize the probe's mechanical behavior and stiffness when designing an elastic mechanism for a contact scanning probe. The contact scanning probe is composed of a tungsten stylus with a ruby ball tip, a mechanism of floating plate suspended by four V-shaped leaf springs, and a 3D optical sensor. The leaf spring experiences elastic deformation when a contact force is applied. Uniform stiffness model is analyzed. Simulation and experimental results verify the correctness of the analysis.

**Keywords:** Contact probe, elastic mechanism, Stiffness, Micro/nano-coordinate measurement machine

## B-049 PMM13-MM100-46

### Study on the three-station typical network deployments of workspace Measurement and Positioning System

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## ABSTRACT

As a novel network coordinate measurement system based on multi-directional positioning, workspace Measurement and Positioning System (wMPS) has outstanding advantages of good parallelism, wide measurement range and high measurement accuracy, which makes it to be the research hotspots and important development direction in the field of large-scale measurement. Since station deployment has a significant impact on the measurement range and accuracy, and also restricts the use-cost, the optimization method of station deployment was researched in this paper. Firstly, positioning error model was established. Then focusing on the small network consisted of three stations, the typical deployments and error distribution characteristics were studied. Finally, through measuring the simulated fuselage using typical deployments at the industrial spot and comparing the results with Laser Tracker, some conclusions are obtained. The comparison results show that under existing prototype conditions, I\_3 typical deployment of which three stations are distributed in a straight line has an average error of 0.30 mm and the maximum error is 0.50 mm in the range of 12 m. Meanwhile, C\_3 typical deployment of which three stations are uniformly distributed in the half-circumference of an circle has an average error of 0.17 mm and the maximum error is 0.28 mm. Obviously, C\_3 typical deployment has a higher control effect on precision than I\_3 type. The research work provides effective theoretical support for global measurement network optimization in the future work.

**Keywords:** Network coordinates measurement, measurement uncertainty, typical deployment, spacing optimization method

## A-195 PMM13-MM100-80

# Arbitrary and Absolute Length Measurement Based on Time-of-flight Method Using Femtosecond Optical Frequency Comb

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## ABSTRACT

In this paper, the application of femtosecond optical frequency comb for length measurement is analyzed and developed. Based on the modified Michelson interferometer by combining with multiple pulse train interference and time-of-flight method, an arbitrary and absolute length measurement system is set up. The timing difference is calculated by the first-order and second-order optical cross-correlation signals separately; therefore the absolute distance is obtained. An experiment of measuring a 60cm length is conducted and the results are compared with that from a high precision laser displacement sensor. Results show a good measuring linearity with the measurement precision of  $\pm 0.5\mu\text{m}$ .

**Keywords:** femtosecond optical frequency comb, arbitrary and absolute length measurement, modified Michelson interferometer, time-of-flight, multiple pulse train interference

## **G-103 PMM13-MM100-161**

### **Critical Dimensional linewidth calibration using UV microscope and laser interferometry**

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#### **ABSTRACT**

In order to calibrate the critical dimensional (CD) uncertainty of lithography masks in semiconductor manufacturing, NIM is building a two dimensional metrological UV microscope which has traceable measurement ability for nanometer linewidths and pitches. The microscope mainly consists of UV light receiving components, piezoelectric ceramics (PZT) driven stage and interferometer calibration framework. In UV light receiving components they include all optical elements on optical path. The UV light originates from Köhler high aperture transmit/reflect illumination sources; then goes through objective lens to UV splitting optical elements; after that, one part of light attains UV camera for large range calibration, the other part of light passes through a three dimensional adjusted pinhole and is collected by PMT for nanoscale scanning. In PZT driven stage, PZT stick actuators with closed loop control are equipped to push/pull a flexural hinge based platform. The platform has a novel designed compound flexural hinges which nest separate X, Y direction moving mechanisms within one layer but avoiding from mutual cross talk, besides this, the hinges also contain leverage structures to amplify moving distance. With these designs, the platform can attain 100  $\mu\text{m}$  displacement ranges as well as 1 nm resolution. In interferometer framework a heterodyne multi-pass interferometer is mounted on the platform, which measures X-Y plane movement and Z axis rotation, through reference mirror mounted on objective lens tube and Zerodur mirror mounted on PZT platform, the displacement is traced back to laser wavelength. When development is finished, the apparatus can offer the capability to calibrate one dimensional linewidths and two dimensional pitches ranging from 200nm to 50 $\mu\text{m}$  with expanded uncertainty below 20nm.

**Keywords:** metrological UV microscope, critical dimension, linewidth, flexural hinge, heterodyne, interferometer.

## **G-156 PMM13-MM100-42**

### **An experiment of femtosecond laser absolute distance measurement by spectrally resolved interferometry**

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#### **ABSTRACT**

An experiment of absolute distance measurement by spectrally resolved interferometry has been executed. A Ti:Sapphire femtosecond laser without stable frequency and stable phase was used as an optical source of the measurement system. It greatly simplifies the complexity of the measurement system. A Fabry-Perot Etalon made by ourselves was employed as an optical filter to pick up frequency modes from the broad bandwidth spectrum of femtosecond laser pulse. To achieve the absolute distance, a linear array CCD detector was used to get the interferometric phase information for the calculation of distance. The measurement experiment was carried out in the non-ambiguity range and ranging precision of less than 5  $\mu\text{m}$  was achieved. The result indicates that it's feasible to measure the absolute distance by spectrally resolved interferometry with a simple femtosecond laser.

Keywords: Simplicity, high precision, experiment, spectrally resolved interferometry

**G-186 PMM13-MM100-235**

## **Review and Comparison of Temporal- and Spatial-Phase Shift Speckle Pattern Interferometry for 3D Deformation Measurement**

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### **ABSTRACT**

High accuracy full field three dimensional (3D) deformation measurements have always been an essential problem for the manufacturing, instrument, and aerospace industry. 3D deformations, which can be translated further into 3D strain and stress, are the key parameter for design, manufacturing and quality control. Due to the fast development of the manufacturing industry, especially in the automobile and aerospace industry, rapid design and optimization concepts have already widely accepted. These concepts all require the support of rapid, high sensitive and accuracy 3D deformation measurement. Advanced optical methods are gaining widely acceptance for deformation and strain measurement by industry due to the advantages of non-contact, full-field and high measurement sensitivity. Of these methods, Electronic Speckle Pattern Interferometry (ESPI) is the most sensitive and accurate method for 3D deformation measurement in micro and sub micro-level. ESPI measures deformation by evaluating the phase difference of two recorded speckle interferograms under different loading conditions. Combined with a phase shift technique, ESPI systems can measure the 3D deformation with dozens of nanometer level sensitivity. Cataloged by phase calculation methods, ESPI systems can be divided into temporal phase shift ESPI systems and spatial phase shift ESPI system. This article provides a review and a comparison of temporal and spatial phase shift speckle pattern interferometry for 3D deformation measurement. After an overview of the fundamentals of ESPI theory, temporal phase-shift and spatial phase-shift techniques, 3D deformation measurements by the temporal phase-shift ESPI which is suited well for static measurement and by the spatial phase-shift ESPI which is particularly useful for dynamic measurement will be discussed in detail. Basic theory, brief derivation and different optical layouts for the two systems will be presented. The potentials and limitations of the both ESPI systems will be demonstrated by examples of precise and simultaneous measurement of 3D deformations under either static or dynamic loadings.

**Keywords:** 3D deformation measurement, temporal phase-shift, spatial phase-shift, Speckle Pattern Interferometry

## **D-073 PMM13-MM100-62**

### **Optical magnetic field sensor improved by NdFeB ferromagnetic film**

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#### **ABSTRACT**

In this paper, two types of optical magnetic field sensors have been prepared, one was pure garnet magnetic field sensor, another was garnet with Ta/NdFeB/Ta film grown by magnetron sputtering method at the base pressure of  $1.0 \times 10^{-5}$  Pa, and the working pressure was 0.8 Pa. Ta film worked as buffer layer and protective layer, and the NdFeB worked as ferromagnetic film, the atom proportion of NdFeB was 2:14:1. The measuring was based on Magneto-optical Faraday effect. The Faraday rotation was obtained under the conditions of  $1.55 \mu\text{m}$  near-infrared light and the magnetic field in range of -150-150 Oe. It was found that the garnet sensor with NdFeB film has lower linearity error 0.125% compared with pure garnet sensor 1.42%, and the difference was attributed to the presence of NdFeB ferromagnetic film interact on the garnet.

**Keywords:** Faraday Effect, sensor, NdFeB film, linearity error

## **D-074 PMM13-MM100-89**

### **Aberration measurement for progressive addition lens based on Hartmann-Shack Sensor**

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#### **ABSTRACT**

Progressive addition lens (PAL) is a kind of lens with which optical power gradually increases from top to bottom. Hartmann-Shack Sensor (HSS) is a kind of measuring instrument for wavefront aberration. Considering that the exit pupil of the measured optical system and the entrance pupil of HSS in general are different, we must bring them together and make them with same size in order to make full use of the aperture of HSS, and to meet the requirements that all the emergent light of the measured optical system enter into the sensor. In this paper, 4F system was proposed to realize the cohesion between the two pupils, combined with HSS to measure the diopter and aberration distribution of the PAL. The principle of the system was expounded in the paper. Also the conversion relation between the detection result according to HSS and the actual situation of the PAL was researched. Precision measurements of diopter and aberration of the PAL based on HSS was achieved ultimately.

**Keywords:** Progressive addition lens, Hartmann-Shack, Diopter, Wavefront aberration



**D-154 PMM13-MM100-142**

## **Precise ultrasonic ranging based on pseudo-random sequence modulated continuous signal processing**

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### **ABSTRACT**

The ultrasonic ranging equipment usually need to measure the “time of flight”, that it takes for acoustic waves to travel the measured distance. Due to the influence of various noises, ultrasonic distance measurement using the pulse signal is difficult to obtain accurate measurement results. Continuous signal phase detected method can achieve the precision measurement of the transmission time, and has a strong noise resistance capability. When single-frequency signals are used, the measurement range is limited to a small extent. This problem can be solved by dual-tone or multi-frequency method. But in short distance ranging applications especial in the restricted space fields, there usually exists strong multiple echoes. Because of the echoes, the ranging accuracy will be significantly decreased. In this paper, a single-frequency continuous signal modulated by a pseudo-random sequence is used, since the pseudo-random sequence has excellent autocorrelation properties. On the other hand, an improved signal phase estimation algorithm is used to realize the high-precision measurement of TOF. An experimental measurement system was built, and experiments showed that the method can get micron degree precision.

**Keywords:** Ultrasonic ranging, pseudo-random sequence, time of flight, time delay, precision, uncertainty, autocorrelation, sound speed.

**D-155 PMM13-MM100-43**

## **A robust data fusion scheme for integrated navigation systems employing fault detection methodology augmented with fuzzy adaptive filtering**

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### **ABSTRACT**

Integrated navigation systems for various applications, generally employs the centralized Kalman filter (CKF) wherein all measured sensor data are communicated to a single central Kalman filter. The advantage of CKF is that there is a minimal loss of information and high precision under benign conditions. But CKF may suffer computational overloading, and poor fault tolerance. The alternative is the federated Kalman filter (FKF) wherein the local estimates can deliver optimal or suboptimal state estimate as per certain information fusion criterion. FKF has enhanced throughput and multiple level fault detection capability. The Standard CKF or FKF require that the system noise and the measurement noise are zero-mean and Gaussian. Moreover it is assumed that covariance of system and measurement noises remain constant. But if the theoretical and actual statistical features employed in Kalman filter are not compatible,

the Kalman filter does not render satisfactory solutions and divergence problems also occur. To resolve such problems, in this paper, an adaptive Kalman filter scheme strengthened with fuzzy inference system (FIS) is employed to adapt the statistical features of contributing sensors, online, in the light of real system dynamics and varying measurement noises. The excessive faults are detected and isolated by employing Chi Square test method. As a case study, the presented scheme has been implemented on Strapdown Inertial Navigation System (SINS) integrated with the Celestial Navigation System (CNS), GPS and Doppler radar using FKF. Collectively the overall system can be termed as SINS/CNS/GPS/Doppler integrated navigation system. The simulation results have validated the effectiveness of the presented scheme with significantly enhanced precision, reliability and fault tolerance. Effectiveness of the scheme has been tested against simulated abnormal errors/noises during different time segments of flight. It is believed that the presented scheme can be applied to the navigation system of aircraft or unmanned aerial vehicle (UAV).

**Keywords:** Integrated Navigation, Strapdown, GPS, Celestial, Doppler, Fuzzy Adaptive, Kalman, Fault Detection

## **D-176 PMM13-MM100-199**

### **Quasi-distributed temperature sensor system based on various-packaged FBG**

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#### **Abstract**

Different package of fiber Bragg grating (FBG) temperature sensors were introduced. The temperature sensitive factors of the sensors were derived analytically and verified by experiments. A quasi distributed temperature sensor system consisted of different-packaged FBG, wideband light source, and FBG interrogator was set up successfully. The experiment results of the different FBG temperature sensors were compared by analyzing the variety properties of center wavelength in identical conditions. From the experimental results, it is shown that the central wavelength of FBG temperature sensor with different package shifts diversely; while good linearity and preferable repeatability are present among the various FBG sensors, and there is almost no hysteresis effect. The temperature sensing ability of the packaged FBG sensor is improved and the temperature sensitivity coefficient is about 3 or more times as much as that of the bare FBG. The temperature resolution of the packaged FBG sensor can reach up to 0.03 °C. It is indicated that all the packaged FBG sensors are suitable to measure temperature according to specific application environment.

**Keywords:** Fiber Bragg grating; Temperature sensing; Packaging technique; Sensitivity

## **D-065 PMM13-MM100-148**

### **Design of PSD Based Solar Direction Sensor**

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#### **ABSTRACT**

For the purpose of high-accuracy detection and tracking of sun position, a measuring sensor based on Position Sensitive Detectors (PSD) has been designed. The PSD is installed at the bottom of the canister which has a narrow light pinhole so that light could pass through it. Sunlight spot projects on the surface of the PSD and then the information about position can be captured through PSD. The solar position information can be changed into electrical signal by signal processing circuit, which can be further send to the follow-up system. The experimental results show that the accuracy of this sensor is about 0.05 °at  $\pm 12^\circ$  acceptable angle, and this sensor can run stably and can work as designed.

Key words: Solar energy; Solar direction detection; PSD; Photoelectric detection

## **I-040 PMM13-MM100-71**

### **Key errors analysis and simulation of a 3-PUU parallel CMM**

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#### **ABSTRACT**

A new 3-PUU parallel CMM is proposed in this paper, and according to kinematic model space coordinate of measuring head is solved with the readings of three grating reading heads. Measuring accuracies affected by errors of parallel structure parameters are mainly analyzed and measuring error model is established. The error analysis interface of measuring head coordinate and data processing results are finished by using Matlab, and based on the results of key errors analysis 3-PUU parallel CMM is further optimized by improving accuracy of manufacturing and assembling workpiece, calibration and error compensation of structure parameters.

**Key words:** Parallel Mechanism, CMM, Measuring error model, Error analysis

## **E-092 PMM13-MM100-17**

### **Dynamic Model of Liquid Copper Temperature Based on Weighted LS-SVM**

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#### **ABSTRACT**

Aimed to the difficult temperature measurement of scrap copper smelting process, this paper proposed a method of dynamic prediction method of furnace temperature based on weighted least squares support vector machine (WLS-SVM). In this method, the main input and output variables of the process squared error is given different weights to overcome the impact of the training sample anomalies, and use PSO for WLS-SVM parameters optimization, enhanced ability to adapt of dynamic model for the nonlinear time-varying characteristics, improved the prediction

accuracy of the model. Finally, simulated through actual operating data of scrap copper smelting process, and verified the effectiveness of the method.

**Keywords:** Scrap copper smelting; least squares; support vector machine; dynamic prediction method

## **E-110 PMM13-MM100-192**

### **Measurement system for characterizing surface friction properties of textile materials**

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#### **ABSTRACT**

A new test method and a measurement system were proposed, which can be used to characterize the surface friction properties of textile materials such as fabrics. The measurement system simulates the dynamic friction contacts between the skin and fabrics under a variety of test conditions in a mechanical measuring device with measuring head and a slider, and can measure both the static and dynamic coefficient of friction of textile materials automatically. A series of indices were defined to characterize the friction performance of the textile materials. The measurement principle, the evaluation method, the experiments and the test results were introduced. The test results show that there are significant differences in the surface friction properties among the fabrics to all indices.

**Keywords:** Surface friction properties, Measurement, Evaluation, Textile materials

## **E-036 PMM13-MM100-79**

### **Analysis and experimental study of the spherical joint clearance**

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#### **ABSTRACT**

The spherical joint clearance is a key error factor, which influenced and restricted the application of parallel mechanism in high precision field. This paper discusses the regularity of the spherical joint clearance in the parallel mechanism and its influence on the accuracy of the parallel mechanism in both theoretical and experimental aspects. A spherical joint clearance measuring instrument is introduced and used to measure the joint clearance. And the relationship between the clearance and its work pose is revealed. Based on the theoretical and experimental analysis, it is concluded that the clearance of the spherical joint is near-linear proportional to the applied load as well as the clearances in different poses obey the Rayleigh distribution approximately under the same load.

**Keywords:** spherical joint, clearance, parallel mechanism

## **G-116 PMM13-MM100-198**

# **Multi-beam synchronous measurement based on PSD phase detection using frequency-domain multiplexing**

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### **ABSTRACT**

According to the principle of centroid measurement, position-sensitive detectors (PSD) are commonly used for micro displacement detection. However, single-beam detection method cannot satisfy such tasks as multi-dimension position measurement, three dimension vision reconstruction, and robot precision positioning, which require synchronous measurement of multiple light beams. Consequently, we designed PSD phase detection method using frequency-domain multiplexing for synchronous detection of multiple modulated light beams. Compared to previous PSD amplitude detection method, the phase detection method using FDM has advantages of simplified measuring system, low cost, high capability of resistance to light interference as well as improved resolution. The feasibility of multi-beam synchronous measurement based on PSD phase detection using FDM was validated by multi-beam measuring experiments. The maximum non-linearity error of the multi-beam synchronous measurement is 6.62%.

**Keyword:** position-sensitive detector, multi-beam synchronous measurement, FDM, phase detection

## **E-010 PMM13-MM100-233**

# **Development of Transmission Error Tester for Face Gears**

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### **ABSTRACT**

A tester for measuring face gears' transmission error was developed based on single-flank rolling principle. The mechanical host was of hybrid configuration of the vertical and horizontal structures. The tester is mainly constituted by base, precision spindle, grating measurement system and control unit. The structure of precision spindles was designed, and rotation accuracy of the spindles was improved. The key techniques, such as clamping, positioning and adjustment of the gears were researched. In order to collect the data of transmission error, high-frequency clock pulse subdivision count method with higher measurement resolution was proposed. The developed tester can inspect the following errors, such as transmission error of the pair, tangential composite deviation for the measured face gear, pitch deviation, eccentricity error, and so on. The results of measurement can be analyzed by the tester; The tester can meet face gear quality testing requirements for accuracy of grade 5.

**Keywords:** Transmission error; face gear; gear measurement; single-flank rolling principle; integrated error

## **C-148 PMM13-MM100-28**

# **Interferometry with suppression of fast fluctuations of the refractive index of air for nanometrology**

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### **ABSTRACT**

We present an interferometric technique based on differential interferometry setup for measurement in the subnanometer scale in atmospheric conditions. The motivation for development of this ultraprecise technique is coming from the field of nanometrology. The key limiting factor in any optical measurement are fluctuations of the refractive index of air representing the greatest source of uncertainty. Our proposal is based on the concept of combining overdetermined interferometric setup where a reference wavelength is derived from a mechanical reference for compensation of fast fluctuations and traditional indirect evaluation of the refractive index compensating on the other hand the long-term drift of the mechanical reference caused by thermal expansion. The technique allows to track the variations of the refractive index of air on-line directly in the line of the measuring beam and to compensate for the fluctuations. The optical setup consists of three interferometers sharing the same beam path where two measure differentially the displacement while the third evaluates the changes in the measuring range acting as a tracking refractometer. The principle is demonstrated on an experimental setup and a set of measurements describing the performance is presented.

**Keywords:** Nanometrology, Interferometry, Refractometry

## **F-100 PMM13-MM100-242**

# **Vibration Criteria for Vibration-Sensitive Laboratory Based on Intrinsic Microseism**

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### **ABSTRACT**

Establishment of appropriate vibration criteria is essential for vibration-sensitive laboratories. The vibration criterion curves are commonly used in the evaluation of the ambient vibration. The maximum level of VC-E criterion curve is 3.1 $\mu$ m/s. The intrinsic microseism in the Changping experimental base of National Institute of Metrology has been measured since 2003. The frequency of the intrinsic microseism is about 3.2 Hz, and the velocity magnitude of the intrinsic microseism is about 0.05 $\mu$ m/s, which is much less than the VC-E criterion. The vibration criteria values that are less than the magnitude of the intrinsic microseism cannot be realized, whereas limits that are too broad may result in degradation of the performance of measurement equipment. So the vibration criteria of National Institute of Metrology are established based on the intrinsic microseism and VC curves. Because the VC curves are expressed in the terms of root-mean-square vibration velocity in the band of the one-third octave, it is difficult to identify the vibration interferences from machines such as fans and cooling towers. The vibration criteria of National Institute of Metrology

are expressed in terms of both the one-third octave vibration velocity spectrum and velocity average spectrum of the ambient vibration. From the velocity average spectrum, the ambient vibration of vibration-sensitive laboratories can be evaluated and the vibration interferences can be identified by comparison with the intrinsic microseism.

**Keywords:** Intrinsic microseism, vibration-sensitive laboratory, metrology, VC curves, ambient vibration

## **F-144 PMM13-MM100-73**

### **Analysis of the forces in electrostatic force microscopy for profile measurement of micro-structured surface of dielectric**

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#### **ABSTRACT**

For measuring the surface profile of many micro-optical components which are made of non-conductive material, such as diffractive grating and Fresnel lens, with complicated shapes on their surfaces, the electrostatic force microscopy (EFM) was recommended in noncontact condition. When a bias voltage is applied between the conducting probe tip and a back electrode where a non-conducting sample was put on, an electrostatic force will be generated between the probe tip and the sample surface. The electrostatic force will change with the distance between the probe tip and the sample surface. Firstly, the relationship between the electrostatic force and the tip-sample distance was analyzed based on the dielectric polarization theory. The theoretical result shows that the electrostatic force is proportional to  $1/d^2$ , where  $d$  is the distance between the probe tip and sample surface. Then, a numerical method (finite element method -FEM) was employed to calculate the electrostatic force and the result shows accordance with the theoretical method. Finally, the prototype of a scanning electrostatic force microscopy was built which is composed of a conducting probe unit with a Z scanner driven by piezoelectric actuators, a XY scanner unit for mounting the sample and back electrode and a circuit unit for detecting the frequency shift. The force curve, which shows the relationship between the electrostatic force and the tip-sample distance, was achieved by using the EFM prototype. All results demonstrated that it is feasible for using the EFM system to measure the surface profile of non-conductor.

**Keywords:** Scanning electrostatic force microscopy (SEFM), profile measurement, dielectric, polarization force

## **F-193 PMM13-MM100-202**

### **Variable Stiffness and Damping Semi-active Vibration Control Technology Based on Magnetorheological Fluids**

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#### **ABSTRACT**

Vibration is a source to induce uncertainty for the measurement. The traditional passive vibration control method has low efficiency and limited working conditions. The active vibration control method is not practical for its power demanding, complexity and instability. In this paper, a novel semi-active vibration control technology based on magnetorheological(MR) fluid is presented with dual variable stiffness and damping capability. Because of the rheological behavior depending on the magnetic field intensity, MR fluid is used in many damping semi-active vibration control systems. The paper proposed a structure to allow the both overall damping and stiffness variable. The equivalent damping and stiffness of the structure are analyzed and the influences of the parameters on the stiffness and damping changing are further discussed.

**Keywords:**semi-active system, magnetorheological fluid, variable stiffness and damping, equivalent stiffness and damping

## **G-056 PMM13-MM100-68**

### **A new thin-wall beam modal testing method based on single point laser continuous plane scanning vibration measurement**

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#### **Abstract**

A high precision and fast testing method for pure modal of vibration body by continuous constant speed plane scanningvibration measurementusing single point laser doppler vibrometer is proposed.Thin-walled beam as test object, single point laser continuous plane scanning vibration measurement modal testing scheme is proposed. The processing method for the actual vibration signal isinvestigated, and the calculating method for the upper and lower alternate envelope of vibration displacement signal is proposed. Thin-walled beam as test object, The modal test platform based on single point laser continuous constant speed plane scanningvibration measurement is put up, and the validity of the modal testing method is verified by themodal testing of thinsheet beam.

**Keyword:**single point laser vibration measurement,continuous plane scanning,modal testing

## **G-169 PMM13-MM100-188**

### **Dynamic measurement of deformation using Fourier transform digital holographic interferometry**

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## ABSTRACT

Digital holographic interferometry (DHI) is a well-established optical technique for measurement of nano-scale deformations. It has become more and more important due to the rapid development of applications in aerospace engineering and biomedicine. Traditionally, phase shift technique is used to quantitatively measure the deformations in DHI. However, it cannot be applied in dynamic measurement. Fourier transform phase extraction method, which can determine the phase distribution from only a single hologram, becomes a promising method to extract transient phases in DHI. This paper introduces a digital holographic interferometric system based on 2D Fourier transform phase extraction method, with which deformations of objects can be measured quickly. In the optical setup, the object beam strikes a CCD via a lens and aperture, and the reference beam is projected on the CCD through a single-mode fiber. A small inclination angle between the diverging reference beam and optical axial is introduced in order to physically separate the Fourier components in frequency domain. Phase maps are then obtained by the utilization of Fourier transform and windowed inverse Fourier transform. The capability of the Fourier transform DHI is discussed by theoretical discussion as well as experiments.

**Keywords:** Digital holographic interferometry; Fourier transform; Deformation measurement; Phase extraction

**I-194 PMM13-MM100-187**

## **Error analysis of 3D reconstruction induced by asynchronous cameras in dynamic measurement**

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## ABSTRACT

Dynamic measurement normally is point test using sensors such as accelerators. With the development of binocular stereo vision, the full field dynamic measurement becomes possible. However the dynamic measurement based on binocular stereo vision encounters several challenges. One of the major challenges is that the error of dynamical testing using binocular stereo vision is unknown. In this paper, two models of dynamic testing based on binocular stereo vision are established. The proposed models mainly analyze non-synchronized errors in dynamical measurement and can be used to minimize errors for improving the measurement accuracy.

**Keywords:** binocular stereo vision, dynamic measurement, error analysis, 3D reconstruction

**C-143 PMM13-MM100-215**

## **Dimensional measurement of micrometer-scale structures with a nanopipette ball probe by using shear-force detection**

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## ABSTRACT

A nanopipette ball probe has been introduced for the dimensional measurement of the micrometer-scale structures. A hollow glass nanopipette, which is fabricated by thermal pulling process, is used as the shaft of the probe for the detection of the contact. Since the stiffness of the glass nanopipette is lower than that of metal shaft which is similar size of the glass nanopipette, the contact force between the probe and the sample will be able to reduce in comparison with the probe of the metal shaft. The edge of the nanopipette is filled with the thermosetting resin, and a micro glass sphere with 9 mm diameter is fixed on the edge of the nanopipette probe by the thermosetting resin. By attaching the micro sphere at the edge of the nanopipette, the edge of the probe will be possible to maintain a uniform shape in all directions. With regard to the detection of the contact, the method of the shear-force detection has been employed because of its high-sensitivity and nanometer-scale resolution. The resolution and the sensitivity of the nanopipette probe are evaluated, and then surface profile measurement of the microstructure is demonstrated.

**Keywords:** Nanopipette ball probe, shear-force detection, Frequency modulation detection, dimensional measurement, nanometrology

## G-124 PMM13-MM100-92

### An improved SURF descriptor based on sector area partitioning

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## ABSTRACT

In order to improve the robustness and real time performance of SURF based image matching algorithms, a constructing method of SURF descriptor based on sector area partitioning in a circular region was proposed and the dimension of descriptors was reduced from 64 to 32. We compute the new descriptor in a circular local region (the radius set to 10s). Firstly, the local region is divided into 8 equal sector areas according to the dominant orientation in inverse time order. Secondly, Define the dominate orientation and its orthogonal orientation as x and y axis of the key-point's local frame. Thirdly, compute the Haar wavelet response in x and y directions within the key-point local region. In order to reduce the boundary effect and outer noise, Haar wavelet response in the same Grid of different triangle is both assigned to each sector in different weight, and then a gaussian weighting function is used. Compute the histogram of Haar wavelet response and absolute Haar wavelet response, so each sector sub-region constitutes a vector with 4 dimensions. Finally, a descriptor with 32 dimensions is constituted and the descriptor is normalized to achieve illumination invariance. The experimental results indicate that the average matching speed of the new method increase of about 31.18%. The matching performance of the new descriptor is even better than original SURF descriptor.

**Key words:** Computer vision, Image matching, Feature descriptor, SURF, Sector area partition

## G-0502 PMM13-MM100-44

### Numeric character recognition method based on fractal dimension

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## ABSTRACT

An image processing method based on fractal dimension is proposed in this paper. This method uses fractal dimension to process the character images firstly, and rises the analysis of each grid to the analysis of interrelation between the grids to eliminate interference. Box-counting method is commonly used for calculating fractal dimension of fractal, which uses small box whose side length is  $r$ , that is the topological dimension of the box is  $d$ , to cover up the image. Because there are various levels of cavities and cracks, some small boxes are empty and some small boxes cover a part of fractal image which is called non-empty box (here refers to the average gray of the part that contained in the small box is larger than a certain threshold). We note down the number of non-empty boxes, analyze and calculate them. The method is used to image process the polluted characters, which can remove ink and scratches around the contour of the characters and remain basic contour, then the characters can be recognized by using template matching. In computer simulation experiment for polluted character recognition, this method can recognize the polluted characters quickly, which improve the accuracy of the recognition of the polluted characters.

**Keywords:** image processing, numeric character recognition, fractal dimension, box dimension, template matching

## G-132

# Using Jones calculus to extract the circular birefringence and circular dichroism of the anisotropic optical media measured by a heterodyne polarimeter

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## ABSTRACT

This study proposes a method based on the Jones calculus for measuring the circular birefringence (CB) and circular dichroism (CD) properties of chiral samples using an integrated heterodyne polarimeter system and an electronic signal processing scheme. The proposed method not only decouples the CB and CD properties in the extraction process, but also enables both properties to be measured over the full range. In most previous studies, the CB and CD parameters are not decoupled in the extraction model, and thus accumulated errors readily occur. Hence, the accuracy of the measurement results proposed in this study is improved by the analytical model. The validity of the proposed method is demonstrated by measuring the optical rotation angle and circular diattenuation of pure CB and CD samples and a composite sample with both CB and CD properties. The standard deviations of the optical rotation angle and circular dichroism are found to be  $3.07 \times 10^{-3}$  degrees and  $9.3 \times 10^{-4}$  for a hybrid CD/CB sample, respectively.

**Keywords:** Optical rotation angle, circular birefringence, circular dichroism, heterodyne interferometer

## G-133

# Automated surface profile measurement of diamond grid disk by phase-shifted shadow Moiré

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### ABSTRACT

Diamond grid disk dresser is frequently employed to remove the accumulated debris lest the polishing surface glazes. The surface warpage of diamond grid disk must be small enough to assure the flatness of polished wafers during chemical mechanical planarization process. In this study, phase-shifted shadow moiré method was employed to measure the surface profile of diamond grid disk. To eliminate erroneous bright or black spots caused by the diamond grids, a new approach is proposed by automatically selecting a proper threshold value from the differentiated image resulting from the addition of four phase-shifted images. According to the largest size of erroneous spot, the size of a structuring element is determined for morphology filtering. Thereafter the phase can be calculated and unwrapped correctly. Test of the method on a diamond grid disk is demonstrated and discussed.

**Keywords:** Surface profile measurement, Diamond grid disk, Phase-shifted shadow Moiré Morphology, Phase unwrapping.

## G-160 PMM13-MM100-157

# Surface roughness measurement of digital laser speckle pattern by Markov Random Fields Model in wavelet domain

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### ABSTRACT

Based on computer texture analysis methods, a new non-contact surface roughness measurement technique is put forward. Grinding metal surface is illuminated by laser, the digital camera captured digital laser speckle pattern. Digital laser speckle pattern is preprocessed by wavelet transform because the surface roughness information is immersed in the high frequency sub-band of the speckle pattern. In the wavelet transform high frequency sub-band, Markov Random Fields model is used, feature parameters are calculated, and the texture features are extracted. The relationships curves are drawn between the texture features and surface roughness Ra. The experiment results show that the surface roughness contained in the digital laser speckle pattern has a good monotonic relationship with texture features. This measuring system needs calibration of standard samples of surface roughness beforehand. The surface roughness of components, which have the same material and processing method with the standard samples, could be measured from only one laser speckle pattern in this technique.

**Keywords:** Digital laser speckle pattern, surface roughness, texture feature, *Markov Random Fields* model, wavelet transform

## **G-201 PMM13-MM100-55**

# **Image Measurement Technique on Vibration Amplitude of Ultrasonic Horn**

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### **ABSTRACT**

The paper proposes a method to measure vibration amplitude of ultrasonic horn which is a very important component in the spindle for micro-electrical-chemical discharging machining. The method of image measuring amplitude on high frequency vibration is introduced. Non-contact measurement system based on vision technology is constructed. High precision location algorithm on image centroid, quadratic location algorithm, is presented to find the center of little light spot. Measurement experiments have been done to show the effect of image measurement technique on vibration amplitude of ultrasonic horn. In the experiments, precise calibration of the vision system is implemented using a normal graticule to obtain the scale factor between image pixel and real distance. The vibration amplitude of ultrasonic horn is changed by modifying the voltage amplitude of pulse power supply. The image of feature on ultrasonic horn is captured and image processing is carried out. The vibration amplitudes are got at different voltages.

**Keywords:** Ultrasonic horn, vibration amplitude, image processing

## **J-141 PMM13-MM100-181**

# **Using Acceleration Measurements and Neuro-Fuzzy Systems for Monitoring and Diagnosis of Bearings**

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### **ABSTRACT**

Ball bearing is an important type of bearings. The radial acceleration of ball bearings has been measured for monitoring and diagnosis. Feature extraction is used to extract essential features from the experimental data. Three features, including peak amplitude of the frequency domain, percent power, and peak RMS, have been extracted from the radial acceleration of ball bearings. Then Sequential Forward Search Algorithm (SFS) was utilized for feature selection in order to effectively obtain the best vibration features. Adaptive Neuro Fuzzy Inference Systems (ANFIS) have been used. The selected features were the inputs to the neuro-fuzzy system. Whether there is a defect or not and what types of defects were the outputs of this system. Although there is no analytical relationship between the input and the output of the neuro-fuzzy system, this system still can establish the input/output relationship. In other words, this approach can most accurately, most quickly, and most reliably determine whether there is a defect or not and what types of defects, which is very important for preventive monitoring, diagnosis, and maintenance of ball bearings.

**Keywords:** Radial Acceleration; Feature Selection; Neuro Fuzzy Systems

**G-165 PMM13-M100-151**

## **An Effective Signal Separation and Extraction Method Using Multi-Scale Wavelet Decomposition for Phase-sensitive OTDR System**

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### **ABSTRACT**

Phase-sensitive Optical-Time-Domain Reflectometry (OTDR) system is a typical distributed fiber-optic sensing technology to detect and locate multiple dynamic disturbances from the outside, which provides a cost-effective and highly sensitive solution especially for monitoring long or ultra-long perimeters. However, the system is liable to be interfered by laser frequency drifts and environmental noises due to its phase sensitivity. The fluctuant and time-varying backgrounds severely obscure real intrusion signals, which always cause bad detection results or high Nuisance Alarm Rates (NARs). In this paper, an effective signal separation method is proposed to extract true intrusion information from the complicated noisy backgrounds of phase-sensitive OTDR system. The sensing signal in the time-domain at each spatial point is obtained by accumulating the changing trails at different moments. Multi-scale wavelet decomposition is employed on the temporal signal to get the detailed components at different scales. By selectively recombining the scale components, it can easily extract the real intrusion signal, and separate the fluctuant frequency-drift induced phase noises, and the time-varying sound or other interferences caused by the air movements, which are respectively located at different time-frequency components. Moreover, the experimental results show that the event type could be divided and discerned from the time-frequency energy distribution at different scale. Thus nuisance and false alarms in practical applications of phase-sensitive OTDR system can be decreased significantly by this way of signal separation and extraction. This technique provides a useful solution for the intrusion detection and identification of the phase-sensitive OTDR in complicated environments, and paves the way for many important applications such as long perimeter security, oil or gas pipe safety monitoring, large-scale structure health detection and fault diagnosis and so on.

**Keywords:** signal separation and extraction, detection and identification, Phase-sensitive OTDR, distributed optical fiber sensing

**H-0113 PMM13-MM100-34**

## **FPGA-based Signal Processing Method of Automatic Interference Comparator\***

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### **ABSTRACT**

Automatic interference comparator (AIC) is a high precision one-dimensional length measurement machine for investigation and calibrations of line scales, linear encoders and length gauges. This paper emphasizes a novel electronic subdivision method for the AIC to realize precision measurement, which is composed of integer fringe counting, fraction fringe counting and electronic strobe. The realization of the whole system is based on FPGA. A standard line scale has been calibrated by this method on the AIC of the National Institute of Metrology(NIM) in China. The experimental results show the measurement repeatability is less than 7.5 nm, which demonstrates the feasibility of the new signal processing method.

**Keywords:** Length measurement, calibration, subdivision, fringe counting

## **H-1531 PMM13-MM100-67**

### **A novel DSSS based ToF measurement method for short baseline and its application in sound velocimeter**

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#### **ABSTRACT**

The short baseline framework is commonly used in ultrasonic parameter measurement, and ToF (time of flight) of which is essential in sound velocimeter and other applications. Different from conventional steady-state and transient methods, this paper proposed a new method using DSSS (Direct Sequence Spread Spectrum) signal to extract the ToF. DSSS signal possesses excellent auto-correlation features, thus it does not need to adjust path-length or the acoustic frequency, nor avoid the impact of the multiple echoes. The DSSS signal and measurement system are modeled and the detailed theoretical process of ToF estimation is derived to demonstrate the measurement principles, and the principles of echoes-resistance are analyzed. Measurement experiments are carried out using distilled water at ambient pressure with temperature ranging from 19 °C to 30 °C. The test results indicate that the relative precision of ToF is in bounds of 2 ppm and the bias of sound speed derived is within 0.06m/s compared to Del Grosso's equation.

**Keywords:** Short baseline framework, time of flight, time delay, direct sequence spread spectrum, sound speed, sound velocimeter, phase shift, multiple echoes.

## **G-083 PMM13-MM100-58**

### **Optimization of BRDF measurement method using Spectralon white reflectance standard**

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#### **ABSTRACT**

There are two kinds of methods to measure the bidirectional reflectance distribution function (BRDF), direct method and relatively method. The relatively method is widely used because of its convenience and small error. However, the BRDF of the Spectralon white reflectance standard in relatively method was found to deviate from the Lambertian BRDF. It was found to vary with the angle of incidence, the wavelength of incidence and the states of polarization of the incident and reflected light. This paper proposes an optimized measurement formula of BRDF. The result is corrected. Taking the BRDF of standard roughness specimens for example, experimental results show that the measurement accuracy is improved comparing with the original formula. Finally the error analysis is carried out on the accuracy of measurement. The research has certain reference significance for the study of target characteristics on non-cooperative target ranging.

**Keywords:** reflectance, BRDF, white reflectance standard, scatter, error analysis

**G-146 PMM13-MM100-83**  
**Digital Approach to Stabilizing**  
**Optical Frequency Combs and Beat Notes of CW Lasers**

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**ABSTRACT**

In cases when it is necessary to lock optical frequencies generated by an optical frequency comb to a precise radio frequency (RF) standard (GPS-disciplined oscillator, H-maser, etc.) the usual practice is to implement phase and frequency-locked loops. Such system takes the signal generated by the RF standard (usually 10 MHz or 100 MHz) as a reference and stabilizes the repetition and offset frequencies of the comb contained in the RF output of the f-2f interferometer. These control loops are usually built around analog electronic circuits processing the output signals from photo detectors. This results in transferring the stability of the standard from RF to optical frequency domain. The presented work describes a different approach based on digital signal processing and software-defined radio algorithms used for processing the f-2f and beat-note signals. Several applications of digital phase and frequency locks to a RF standard are demonstrated: the repetition (frep) and offset frequency (fceo) of the comb, and the frequency of the beat note between a CW laser source and a single component of the optical frequency comb spectrum.

**Keywords:** optical frequency combs, digital signal processing, software-defined radio, beat note, stabilization

**C-077 PMM13-MM100-29**  
**A regression-based approach to tolerance values forecasting in**  
**micro/meso-scale for micro non-monolithic components**

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## ABSTRACT

Compared to the function-oriented tolerancing rules for micro monolithic components, the lack of specific tolerancing rules for micro non-monolithic ones results in difficulties in bulk production and quality assurance. In order to regulate micro non-monolithic components in micro/meso-scale, a mathematical model of power function is adopted to forecast the tolerance values of nominal sizes in 10~10,000 microns by the linearized regression analysis. The goodness-of-fit qualifies the regression with the power function model and the forecasting results are reasonable in the view of relative accuracy. It is hoped that the improved numerical value table of tolerance can provide some beneficial proposals for the establishment of new tolerancing rules for micro non-monolithic components in micro/meso-scale.

**Keywords:** Tolerance, micro-manufacturing, regression, forecasting, micro-scale, meso-scale

## G-025 PMM13-MM100-166

# Adaptive Fractional Differential Method Based on CSGV to Extract Image Texture Feature

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## ABSTRACT

As the sensitivity of the fractional differential algorithm for detail image texture extraction and the difficulty of the best fractional differential order finding, a novel adaptive fractional differential method is proposed, which can adaptively select the fractional differential order according to the mask window size, definition of fractional differential equations, the composite sub-band gradient vector (CSGV) obtained from the sub-images through a wavelet decomposition of a texture image, and human visual property. The fractional differential operator mask based on G-L formula is designed and realized by employing the adaptive order. The evaluation parameters of image texture feature extraction such as the image information entropy and multi-scale structural similarity (MS-SSIM) are used for quantitative analysis of the extraction method in experiment. The experiment results show that for grey texture image this method is able to extract image texture and edge details completely, which approximate the results of optimal fractional differential order and more satisfies human visual sense. It is an effective approach to extract fine texture features of images.

**Key words:** fractional differential; composite sub-band gradient vector; image texture extraction

## J-009 PMM13-MM100-56

# Study on Real-time Elevator Brake Failure Predictive System

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## ABSTRACT

This paper presented a real-time failure predictive system of the elevator brake. Through inspecting the running state of the coil by a high precision long range laser triangulation non-contact measurement sensor, the displacement curve of the coil is gathered without interfering the original system. By analyzing the displacement data using the diagnostic algorithm, the hidden danger of the brake system can be discovered in time and thus avoid the according accident.

**Keywords:** Elevator Brake; Failure Predictive; Online Inspection; Triangulation Measurement

### I-027 PMM13-MM100-150

## Uncertainty Evaluation for a Three Dimensional Rotary Measuring System by Markov Chain Monte Carlo Method

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## ABSTRACT

Uncertainty evaluation, which is an effort to set reasonable bounds for the measurement results, is important for assessing the performances of precision measuring systems. The three dimensional measurement is affected by a large number of error sources. The distributions of the primary error sources are analyzed in this paper. The multiple-try Metropolis (MTM) algorithm is applied for sampling and propagation of uncertainty for these error sources due to its advantage in dealing with large dimensional problems. The uncertainties of the three coordinates of a measured point on the workpiece  $r$ ,  $z$ , and  $\theta$  are evaluated before and after error separation, respectively. The differences between the two types of uncertainties are compared to find out the influence of the error separation to the uncertainty. Finally, numerical experiments are implemented to demonstrate the uncertainty assessment process.

**Keywords:** Uncertainty evaluation, rotary workpieces, Markov chain Monte Carlo, error separation

### I-047 PMM13-MM100-146

## The optimal design for measurement systems based on uniform accuracy life

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## ABSTRACT

The accuracy lives of a measurement system and its components are generally different and it will lead to a waste of resources. In order to make full use of the system's resources and improve its accuracy life, a novel design method based on uniform accuracy life for measurement systems is proposed in this paper. According to the theory of error

decomposition and tracing, Hilbert-Huang transform (HHT) method is employed to decompose the total errors of an error test system for a dial gauge and then the accuracy loss functions for the total system and some error parameters are obtained. Based on the analysis of the transfer function for the accuracy loss between the different parts of the measurement system, a constraint model consisting with the uniform accuracy life principle is set up. Taking the maximum life of the measurement system as the objective function, the uniform design model has been solved by means of the optimization methods. The uniform design method can be used to promote the accuracy life of the measurement system.

**Keywords:** Accuracy loss, Uniform accuracy life, HHT, Error test system for a dial gauge

## **I-051 PMM13-MM100-173**

### **Measurement Error Analysis of the 3D Four-wheel Aligner**

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#### **ABSTRACT**

Positioning parameters of four-wheel have significant effects on maneuverabilities, securities and energy saving abilities of automobiles. Aiming at this issue, the error factors of 3D four-wheel aligner, which exist in extracting image feature points, calibrating internal and external parameters of cameras, calculating positional parameters and measuring target pose, are analyzed respectively based on the elaborations of structure and measurement principle of 3D four-wheel aligner, as well as toe-in and camber of four-wheel, kingpin inclination and caster, and other major positional parameters. After that, some technical solutions are proposed for reducing the above error factors, and on this basis, a new type of aligner is developed and marketed, it's highly estimated among customers because the technical indicators meet requirements well.

**Keywords:** machine vision, 3D four-wheel aligner, error, calibration

## **I-082 PMM13-MM100-49**

### **The Combined Measurement and Compensation Technology for Robot Motion Error**

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#### **ABSTRACT**

Robot parameter errors are mainly caused by the kinematic parameter errors and the moving angle errors. The calibration of the kinematic parameter errors and the regularity of each axis moving angle errors are mainly researched in this paper. The errors can be compensated by the error model through pre-measurement. So robot kinematic system accuracy can be improved in the case where there are no external devices for real-time measurement. Combination

measuring system which is based on the laser tracker and the biaxial orthogonal inertial measuring instrument is designed and built in the paper. The laser tracker is used to build the robot kinematic parameter error model which is based on the minimum constraint of distance error. The biaxial orthogonal inertial measuring instrument is used to obtain the moving angle error model of each axis. The model is preset when the robot is moving in the predetermined path to get the exam movement error and the compensation quantity is feedback to robot controller module of moving axis to compensation the angle. The robot kinematic parameter calibration bases on distance error model and the distribution law of each axis movement error are discussed in this paper. The laser tracker is applied to prove that the method can effectively improve the control accuracy of the robot system.

**Keywords:** Robot, combined measurement, distance error model, movement error compensation

## **I-198 PMM13-MM100-234**

### **Uncertainty Evaluation of Combined Measurement Systems**

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#### **ABSTRACT**

The combined measurement technology plays an increasingly important role in the digitalized assembly. This paper introduces a combined measurement system consists of a Laser tracker and a FACMM, with the applications in the inspection of the position of the inner parts in a large-scale device. When these measurement instruments are combined, the resulting coordinate data set contains uncertainties that are a function of the base data sets and complex interactions between the measurement sets. Combined with the characteristics of Laser Tracker and Flexible Articulated Coordinate Measuring Machine (FACMM), Monte-Carlo simulation method is employed in the uncertainty evaluation of combined measurement systems. A case study is given to demonstrate the practical applications of this research.

**Keywords:** Combined measurement system, Uncertainty, Monte-Carlo, Laser Tracker, FACMM

## **G-054 PMM13-MM100-170**

### **An Apparatus for Non-contact Measuring Profile of Precision Rotor Based on Laser Triangulation**

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#### **ABSTRACT**

Surface of a precision rotor, a typical helical surface with complicated 3-D shape, is hard to measure with CMM accurately due to the difficulties of spiral scan and probe compensation. Aiming at this problem, an apparatus, avoiding

probe compensation directly by means of non-contact measuring, is designed and developed based on laser triangulation, and the corresponding method for measuring parameter lead and transverse section profile is proposed based on geometric feature model expressing the surface of precision rotor. After apparatus is calibrated with a standard plane and ring gauge, experiments are carried out to scan spiral line and measure transverse section profile respectively, and results of lead error detection and profile error evaluation satisfactorily match the theoretical values provided by manufacturer.

**Keywords:** non-contact measuring, profile, rotor, helical surface, laser triangulation

## G-058

### Full-Field 3-D Topography of Transparent Surfaces Utilizing Low Coherence Interferometry

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#### ABSTRACT

In this study, a rapid full-field surface profile measurement system for objects with transparent surfaces is developed. The measurement is executed with a Mirau type microscopic interferometer accompanied by a single vertical scanning stage and an auto-focusing algorithm. Based on the idea of shape from focus and the characteristic of interference forming only when the optical path of two beams of low coherent light is close, it enhances the high-frequency signal at the focusing position of transparent surfaces and achieves the purpose of high precision positioning. Experiments were carried out with both micro profile evaluation for a small part of objects and full-field macro profile inspection via an X-Y stage. The scope for horizontal measurement is defined within the travelling range of X-Y stage and the maximum vertical scanning stroke is 20 mm offered by the adopted Z stage. Dependent on the sampling spacing and travel range in vertical scanning, the positioning time for a single measurement is usually 0.1~1.5 seconds. Conducting the measurement with a 20X Mirau interferometric objective lens the current measuring accuracy has reached sub-micrometer level.

**Keywords:** Mirau Type Microscopic Interferometer, Low Coherence Interferometry, Transparent Surfaces, Profile Measurement, Auto-focusing

## G-062 PMM13-MM100-25

### Correction on the effect of numerical aperture in optical scatterometry

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## ABSTRACT

Optical scatterometry, also referred to as optical critical dimension (OCD) metrology, has been introduced for critical dimension (CD) monitoring and overlay metrology with great success in recent years. Forward modeling to calculate the optical signature from the measured diffractive structure is one of the most important issues in OCD metrology. To simplify the forward modeling approach, such as rigorous coupled-wave analysis (RCWA), the incidence and azimuthal angles are usually assumed to be constant. However, since some focusing elements, such as focusing lens or parabolic mirrors with finite numerical aperture (NA), are always used to gain a sufficient small spot size onto the sample, this assumption is not true in the whole exit pupil of the focusing elements, leading to a modeling error in forward modeling, and finally leading to a fitting error in OCD metrology. In this paper, we propose a correction method with consideration of the effect of NA to decrease the modeling error in the forward modeling. The correction method is an average integral method based on Gaussian quadrature in two dimensions inside a circle, and is performed on forward modeling with varied incidence and azimuthal angles over the exit pupil. Experiments performed on silicon gratings with a Mueller matrix polarimeter have demonstrated that the proposed correction method achieves a higher accuracy in OCD metrology.

**Keywords:** optical scatterometry, optical critical dimension (OCD) metrology, rigorous coupled-wave analysis (RCWA), numerical aperture (NA).

## G-086 PMM13-MM100-167

# Fiber-optic interferometer fringe projector using sinusoidal phase-modulating

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## ABSTRACT

A novel fiber-optic interferometer fringe projector with the sinusoidal phase-modulating method is presented. The system utilizes the integrating bucket method to detect the desired phase or the displacement and a CMOS image sensor to detect four frames obtained by integration of the time-varying intensity in an interference image during the four quarters of the modulation period. Since this technique with the method modulating the injection current of the piezoelectric transducer (PZT), measurement accuracy is not affected by an intensity modulation that usually appears in the current modulation. The system also utilizes the Fresnel reflection signal to adjust the phase-modulation coefficient  $z$  to eliminate the disturbance of initial phase  $\varphi_0$ . The experimental results for surface profiles of a convex hull show that the sinusoidal phase modulating interferometer proposed here confirms its applicability to practical application.

**Keywords:** phase profilometry, fiber-optic interferometer fringe projector, sinusoidal phase modulation, feedback control.

# **G-147 PMM13-MM100-82**

## **Calibration of elongation of fiber Bragg gratings by laser interferometer**

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### **ABSTRACT**

We present method of measurement of fiber Bragg gratings (FBG) stretching by laser interferometer. We are oriented to research, development and to methodology of the production and application of FBGs. The elongation of FBGs can be calculated from frequency drift of the Bragg resonance wavelength and from the change of the grating period during stretching. The inhomogeneity of optical fibers and of the FBGs can induce change of the grating period (Bragg resonance wavelength) of FBG which can be nonlinear with elongation of the optical fiber with FBG. The calibration of FBGs will be used to preparation and to the realization of the technology of measurement of shape deformation of concrete buildings.

**Keywords:** fiber Bragg sensors, laser interferometry, optical spectrum analysis, fiber sensors.

# **G-161 PMM13-MM100-81**

## **LED uniform illumination system for DMD-based confocal microscopy**

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### **ABSTRACT**

Due to the coherence of laser light source it could produce coherent noise in parallel confocal microscopy based on Digital Micromirror Device (DMD) and thus affect the resolution. LED light source instead of the laser light source can give full play because of its incoherence characterization. In this paper, free-form surface lens is used for LED secondary optics design. According to the LED characteristics and the law of refraction, we have established differential equations of free-form surface. We solved equations with the method of Runge-Kutta by Matlab and the model was built in Tracepro for optical simulation. The results show that the uniformity on the DMD is better than 90% and the lighting efficiency is higher than before. The measured data show us a much more uniform illumination on DMD and LED uniform illumination system successfully avoided the gray error which was caused by the uneven illumination. The LED driver circuit using DC power supply provides us a more stable light source. The axial optical tomography is more accurate and the reconstruction of three-dimensional image is more clearer.

**Key words:** confocal microscopy; DMD; LED; secondary light distribution; Tracepro

**G-024 PMM13-MM100-152**

## **Optical Fiber Fences: Research & Applications**

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### **ABSTRACT**

This article reviews the recent research work on fiber-optic fences and its application progress at University of Electronic Science & Technology of China (UESTC). Three novel fiber-optic fences are described and compared technically: the M-Z Interferometer-based fence for short or medium-range applications, the FBG-based fence for highly reliable detection and precise location, and the OTDR-based fences for monitoring long or ultra-long distance perimeters. To meet the practical requirements for better performances, the key issues including distance extension and signal processing are discussed in details. Significant progress has been achieved in the instrumentation of these fiber-optic fences and their applications to electrical transformer substation, military base, national borderline, et al, offering systematical solutions for more important applications, such as safety monitoring of oil/gas pipe lines, electrical power lines, large-scale civil structures, et al.

**Keywords:** optical fiber sensors, intrusion detection, fiber-optic fence, perimeter security, interferometer, FBG, OTDR

**G-008 PMM13-MM100-177**

## **Multimodal Image Registration Based on SURF and KD Tree**

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### **ABSTRACT**

Aiming at the requirements of multimodal medical image registration for good robustness, high-accuracy and speed, this paper proposes a registration algorithm of multimodal brain medical image based on Speeded-Up Robust Features (SURF) and K-dimension (KD) tree. This algorithm first of all extracts SURF feature points from images and creates feature vector, then build KD tree to complete the image matching, and finally the image registration process is accomplished by estimating space geometric varied parameters according to the matching point pair. The algorithm combines robustness of SURF and high efficiency of improved KD tree. Experimental results show that under the conditions of images with noise, non-uniform intensity and large range of the initial misalignment, the proposed algorithm achieves better robustness, higher speed as well as good registration accuracy.



**E-0111 PMM13-MM100-31**  
**Data Repair Method in Incomplete  
Free-surface Measurement\***

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**ABSTRACT**

Measurement instrument such as coordinate measuring machine or laser scanner is widely applied in the modern industrial manufacturing to reconstruct the shapes of free-surface. However this reconstruction method is determined by the extraction integrity of the shape parameter in the measured part. Some problems occur frequently for the partial surface damage, measurement block, accessible extent, etc., and which result in the measured data incomplete. This paper presents a data repair method based on the gray model combined with neural network theory. The data of the defect surface is divided into different part and the new data sequence is generated. The accumulated generation operation is applied to the new sequence. The normalization processing can then be done before the gray accumulation generation input into the neural network model. The relevant factor sequence by accumulation generation of normalization processing is taken as the RBF neural network input, while the accumulated feature sequence is considered as the output of the network. The defect surface to be repaired is composed of point cloud data. The value of each point can be calculated in the three directions so that the output of the neural network also has three characteristic data. The simulation experimental results show this method can be applied easily in the data repair in the incomplete free-surface with a high accuracy.

**Keywords:** Data repair, free-surface, incomplete, measurement

**D-0112 PMM13-MM100-33**

**Radial Pressure Sensor of Sucker Rod Based on LabVIEW\***

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**ABSTRACT**

The eccentric wear, fracture and other phenomena often occur to the sucker rod in major oil fields. It turns out that the radial pressure of sucker rod suffered is the main reason for its eccentric wear. It is necessary to analyze the eccentric wear and fracture of sucker rod in the pumping process. It is also important to measure the radial pressure for the down-hole sucker rod accurately. The radial pressure could be analyzed when sucker rod is extruded, collided or sustained friction based on the material mechanics and the fluid dynamics. The mechanical structure is designed for measuring the radial pressure. The data processing system for radial pressure of down-hole sucker rod based on LabVIEW is developed in this paper. The functions are real-time data acquisition and processing for sucker rod radial pressure. The communication of LabVIEW and Access database had been realized. The database management system

for radial pressure of sucker rod is built, which could be used to achieve the data storage, historical data retrieval & analysis, data organization and calculation. The computer simulation is carried out to verify the reasonability of the theoretical analysis and structure design.

**Key words:** Radial pressure, data acquisition, data processing, sucker rod, Access database

**G-014 PMM13-MM100-47**

## **Digital Image Correlation Method for Measuring Thermal Deformation of Composite Materials**

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### **ABSTRACT**

Thermal deformation measurement of the high-speed aircrafts under the high temperature is significant for reliability assessment, life prediction, and safety design for the materials and structures. This paper presents a digital image correlation method to accurately measure the full-field thermal deformation of composites under the environment of high temperature. First, real-time deformation images of experimental objects under different loads are acquired with CCD camera. Based on the digital speckle correlation theory, the bilinear interpolation algorithm is employed to measure the thermal deformation. Last, the comparative analyses on measurement results by the proposed and traditional methods are conducted, as well as factors impacting measurement errors are analyzed.

**Keywords:** Composite materials, Thermal deformation, Digital image correlation, Band-pass filter

**F-016 PMM13-MM100-179**

## **Experimental research on anti-vibration interferometry based on time-frequency-domain analysis**

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### **ABSTRACT**

Phase-shifting interferometry is a non-contact precision measuring method for optical surface, but it is highly sensitive to external vibrations. A time-and-frequency-domain (TFD) anti-noise phase-shifting interferometry is proposed to eliminate the effect of vibrations and improve the precision of measurement. According to simulations and preliminary experiments, active phase-shifting speed as well as interferogram capture speed should be increased to improve the anti-vibration capability of the TFD method. In this paper, a fast phase-shifting approach based on PZT actuator and interferogram detection with high-speed camera is proposed. Preliminary experimental results are given to

demonstrate the approach.

**Keywords:** Phase-shifting, Interferometry, Anti-vibration, High-speed camera, PZT-actuator

## **G-017 PMM13-MM100-128**

### **Measuring the lens focal length by laser confocal technique**

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#### **ABSTRACT**

A new laser confocal focal-length measurement (LCFM) is proposed for the high-accuracy measurement of lens back focal length. LCFM uses the peak point of confocal response curve to precisely identify the lens focus, and uses the elastic contact between reflector R and the lens last surface to determine the test lens last vertex. The distance between the reflectors on these two positions is then measured by a laser distance interferometer, and then the accurate back focal-length of test lens is obtained. Compared with existing methods, LCFM significantly improves the measurement accuracy and simplifies the system structure by laser confocal technique, and reduces the product development cost. LCFM is especially suitable for the back focal-length measurement of large aperture lens.

**Keywords:** high-accuracy, confocal, focal-length measurement, positioning

## **B-019 PMM13-MM100-114**

### **A kinematic parameter Calibration method for Articulated Arm Coordinate Measuring Machine**

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#### **ABSTRACT**

A method is introduced for calibrating the kinematic parameters of articulated arm coordinate measurement machines (AACMM) to improve its accuracy. The kinematic model of AACMM is firstly built according to Denavit-Hartenberg method. Then specific kinematic parameters and the errors of which are analyzed. A nonlinear programming genetic algorithm is adopted to seek the global optimal solution of the kinematic parameters. Computation result indicates that the method can be used to implement the calibration precisely and quickly.

**Keywords:** Articulated arm coordinate measuring machines, D-H method, parameter calibration, nonlinear programming genetic algorithm

## **F-029 PMM13-MM100-182**

### **Feasibility study of detection of chatter by using FBG during boring**

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#### **ABSTRACT**

A novel real-time monitoring system based on Fiber Bragg Grating (FBG) sensor has been developed to detect chatter in boring process. In the system, a boring bar with large length-to-diameter ratio (FSTUP3225R/L-16S) was the test subject. The FBG sensor was installed on the surface of the boring bar with the length of 225mm. A classical strain gauge was employed to measure the vibratory strain and compare the results with the ones from FBG sensor. The measurements were carried out using various cutting parameters to obtain the desired chatter phenomenon. The analysis of the experimental data was verified the chatter happened during the deep hole boring. Comparison between the experimental results from two kinds of sensors demonstrated that the measurement technique could be used to detect the dynamic strain, as well as the permitting one to research the method to identify boring chatter on-line by using optical fiber sensor system.

**Keywords:** Boring chatter, Fiber Bragg Grating (FBG), detection, dynamic strain

## **G-031 PMM13-MM100-94**

### **Radius measurement using a parallel two-step spatial carrier phase-shifting common-path interferometer**

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#### **ABSTRACT**

A curvature radius (CR) measurement method using a parallel two-step spatial carrier phase-shifting common-path interferometer is presented. This interferometer is built on a 4f optical system with two windows in the input plane and a ronchi grating outside the fourier plane. A test lens is placed in front of one of the two windows. The phase of the test lens is retrieved from the two phase shifted interferograms recorded using this interferometer and then the profile can be obtained. The CR of the test lens is thus directly derived from the profile according to their geometrical relations. The theoretical model and experimental setup are established to illustrate this method and the measurement processes. Experiments are constructed to verify the effectiveness of the CR measurement using this interferometer. The results prove that this interferometer is an effective approach for the CR measurement with inherent simplicity, high robustness and accuracy.

**Keywords:** Radius measurement, parallel two-step, spatial carrier, phase-shifting, two windows

## **G-032 PMM13-MM100-100**

### **Image edge enhancement for moving objects with a spiral phase filter**

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#### **ABSTRACT**

A fast image edge enhancement method for moving objects is presented with a spiral phase filter using radial Hilbert transform theory. The spiral phase filter is placed in the Fourier plane of a 4f optical system, and used to process the spectral of objects image to achieve 2-D image edge enhancement of shape-free objects. All the directions of object edge can be enhanced similarly because there is a phase difference  $\pi$  along any diameter direction of the spiral phase filter. The results show that this method has good performance for enhancing the edge of moving objects. The advantages of this method are simple operations, clear edge images, high measurement speed and automatic measurement.

**Keywords:** Spiral phase filter, edge enhancement of moving objects, radial Hilbert transform

## **D-035 PMM13-MM100-172**

### **Measurement of transient surface temperatures during rubbing using infrared thermography**

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#### **ABSTRACT**

Infrared thermometer could provide IR radiance information to get the corresponding temperature as the machine is working. But the emissivity coefficient, which converts IR radiance to temperature, would vary with change of surface properties during rubbing, and this would bring dynamic error in measurement. In this study, we introduced a special tester, in the side of which compact IR thermometer are mounted. The thermometer enables us to measure contact surface temperature directly during tests of a rotating ring and a flat block which had a laser diode fixed under its contact surface. Based on Kirchhoff theory, the calculate model of the spectral emissivity is constructed. The normal emissivity at target region are measured through trigonometric ray consisted of InGaAsP laser source, PbSe detector and objective surface. So the temperature value from the IR thermometer could be corrected dynamically according to the real-time emissivity. The structure and the principle of the apparatus are described. The key technologies and the corresponding solution methods are briefly discussed. The error due to the rapid variations of emissivity value with change in contact conditions was shown, and it must be taken into consideration in radiometric temperature measurement in rubbing and could be especially useful in the verification of friction surface temperature predictions.

**Keywords:** rubbing, infrared radiometry, emissivity, transient measurement

**I-041 PMM13-MM100-77**

## **Evaluation of Measurement Uncertainty Based on Bayesian Information Fusion**

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### **ABSTRACT**

This paper raises a new method for evaluating uncertainty that taking count of both the record and the data. By using Bayesian Statistical Principle, the prior distribution and the posterior one, provided by the record and the data, were combined together. The statistical characteristics parameter estimation was descended from the posterior distribution, so that a formula of the uncertainty, which combined the advantages of type A and B, was acquired. By simulation and verification, this measurement shows great advantages compared with the others, especially to small size of data analysis.

**Keywords:** Bayesian Statistical Principle; information fusion; uncertainty assessment; simulation and verification

**D-042 PMM13-MM100-149**

## **Research of Temperature Field Measurement Using a Flexible Temperature Sensor Array for Robot Sensing Skin**

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### **Abstract**

This paper presents a novel temperature sensor array by dispensing conductive composites on a flexible printed circuit board which is able to acquire the ambient temperature. The flexible temperature sensor array was fabricated by using carbon fiber-filled silicon rubber based composites on a flexible polyimide circuit board, which can both ensure their high flexibility. It found that CF with 12 wt% could be served as the best conductive filler for higher temperature sensitivity and better stability comparing with some other proportion for dynamic range from 30°C to 90°C. The preparation of the temperature sensitive material has also been described in detail. Connecting the flexible sensor array with a data acquisition card and a personal computer (PC), some heat sources with different shapes were loaded on the sensor array; the detected results were shown in the interface by LabVIEW software. The measured temperature contours are in good agreement with the shapes and amplitudes of different heat sources. Furthermore, in consideration of the heat dissipation in the air, the relationship between the resistance and the distance of heat sources with sensor array was also detected to verify the accuracy of the sensor array, which is also a preparation for our future work. Experimental results demonstrate the effectiveness and accuracy of the developed flexible sensor array, and it can be used as humanoid artificial skin for sensation system of robots.

**Keyword:** temperature sensor array, flexible, carbon fiber/silicon rubber composites, temperature field measurement

## **H-043 PMM13-MM100-61**

# **A Robust Sinusoidal Signal Processing Method for Interferometers**

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### **ABSTRACT**

Laser interferometers are widely used as a reference for length measurement. Reliable bidirectional optical fringe counting is normally obtained by using two orthogonally sinusoidal signals derived from the two outputs of an interferometer with path difference. These signals are subject to be disturbed by the geometrical errors of the moving target that causes the separation and shift of two interfering light spots on the detector. It results in typical Heydemann errors, including DC drift, amplitude variation and out-of-orthogonality of two sinusoidal signals that will seriously reduce the accuracy of fringe counting. This paper presents a robust sinusoidal signal processing method to correct the distorted waveforms by hardware. A corresponding circuit board has been designed. A linear stage equipped with a laser displacement interferometer and a height gauge equipped with a linear grating interferometer are used as the test beds. Experimental results show that, even with a seriously disturbed input waveform, the output Lissajous circle can always be stabilized after signal correction. This robust method increases the stability and reliability of the sinusoidal signals for data acquisition device to deal with pulse count and phase subdivision.

**Keywords:** Sinusoidal signal, Waveform error, Laser interferometer, Waveform correction

## **G-044 PMM13-MM100-231**

# **DSPI system based on Spatial Carrier Phase Shifting technique**

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### **ABSTRACT**

Digital Speckle Pattern Interferometry (DSPI) is an optical method for measuring small displacement and deformation. It allows whole field, non-contacting measurement of micro deformation. Traditional Temporal phase shifting has been used for quantitative analyses in DSPI. The technique requires the recording of at least three phase-shifted interferograms, which must be taken sequentially. This can lead to disturbances by thermal and mechanical fluctuations during the required recording time. In addition, fast object deformations cannot be detected. In this paper a DSPI system using Spatial Carrier Phase Shifting (SCPS) technique is introduced, which is useful for extracting quantitative displacement data from the system with only two interferograms. The sensitive direction of this system refers to the illumination direction and observation direction. The frequencies of the spatial carrier relates to the angle between reference light and observation direction. Fourier transform is adopted in the digital evaluation to filter out the frequencies links to the deformation of testing object. The phase is obtained from the complex matrix formed by inverse Fourier transform, and the phase difference and deformation are calculated subsequently. Comparing with conventional temporal phase shifting, the technique can achieve measuring the vibration and transient deformation of testing object.

Experiment set-ups and results are presented in this paper, and the experiment results have shown the effectiveness and advantages of the SCPS technique.

**Keywords:** DSPI, Spatial Carrier Phase Shifting, Nondestructive Measurement, Fourier transform, Deformation

**C-046 PMM13-MM100-108**

## **Dual AFM probes alignment based on vision guidance**

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### **ABSTRACT**

Atomic force microscope (AFM) with dual probes that operate together can measure both side walls excellently at the same time, which virtually eliminates the prevalent effect of probe width that contributes a large component of uncertainty in measurement results and finally obtains the critical dimension (CD)(e.g. the linewidth) through data synthesis. In calibration process, the dual probes must contact each other in advance, which realizes the alignment in the three dimensions, to establish a zero reference point and ensure the accuracy of measurement. Because nowadays the optical resolution of advanced lens have exceeded micrometer range, and the size of probes is within micro level, it is possible to acquire dual probes images in both horizontal and vertical directions, through which the movement of the probes can be controlled in time. In order to further enhance the alignment precision, sub-pixel edge detection method based on Zernike orthogonal moment is used to obtain relative position between these two probes, which helps the tips alignment attains sub-micron range. Piezoelectric nanopositioning stages calibrated by laser interferometer are used to implement fine movement of the probes to verify the accuracy of the experimental results. To simplify the system, novel self-sensing and self-actuating probe based on a quartz tuning fork combined with a micromachined cantilever is used for dynamic mode AFM. In this case, an external optical detection system is not needed, so the system is simple and small.

**Keywords:** atomic force microscope (AFM); dual-probe; critical dimension (CD); Metrology; alignment; vision guidance

**H-048 PMM13-MM100-70**

## **A high-accuracy signal processing algorithm for frequency scanned interferometry**

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### **ABSTRACT**



A high-accuracy signal processing algorithm was designed for the absolute distance measurement system performed with frequency scanned interferometry. The system uses frequency-modulated laser as light source and consists of two interferometers: the reference interferometer is used to compensate the errors and the measurement interferometer is used to measure the displacement. The reference interferometer and the measurement interferometer are used to measure synchronously. The principle of the measuring system and the current modulation circuit were presented. The smoothing convolution was used for processing the signals. The optical path difference of the reference interferometer has been calibrated, so the absolute distance can be measured by acquiring the phase information extracted from interference signals produced while scanning the laser frequency. Finally, measurement results of absolute distances ranging from 0.1m to 0.5m were presented. The experimental results demonstrated that the proposed algorithm had major computing advantages.

**Keywords:** Absolute distance measurement, Frequency-sweeping, Current modulation, Smoothing convolution

## **G-0501 PMM13-MM100-65**

### **Positioning method for a visual guiding system in a laser welding machine**

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#### **ABSTRACT**

Combined with the development of guiding systems in laser welding, a visual guidance based positioning method for coaxial installation with a laser welding head is researched. A system calibrating method has been researched and designed, which is to install calibration cylinder in the part fixing a machined part, and test the calibration cylinder center coordinates works calibration of the system. A localization method based on template matching and characteristics of the target image are extracted as target image for templates, guiding two localizations both coarse positioning and fine positioning. Coarse positioning can reduce the influence of other information on the target image. Fine positioning is the second location of targets on the basis of the coarse positioning, reducing the information and keeping effect information of target image characteristics. And the method of sub-pixel localization based on least square method is fixed the center position of the target.

**Key words:** laser welding, visual guidance, template matching, least square method

## **E-053 PMM13-MM100-171**

### **Optimized design of a band-pass filter with low frequency and narrow bandwidth**

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### **ABSTRACT**

An underwater metal pipeline detector is designed based on the principle of artificial source electromagnetic detection, which is used for detecting the deeply buried in underwater metal pipes. Narrowband band-pass filter in the receiver can well separate the specific frequency signal from mixed signal which is containing strong noise. Authors deduced the narrowband filter transfer function and simulated in computer, and the detector was applied in instrument prototype. Experiment results show that the error of the center frequency of the band-pass filter is small, and the gain is stable. In conclusion the detector has good performance.

**Keywords:** Pipeline detection, background noise, band-pass filter

## **F-055 PMM13-MM100-180**

### **Mine Rescue capsule Dynamics Modeling and Stress Analysis**

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### **ABSTRACT**

Mine rescue capsule is used for emergency mine shelter. It should meet the impact of anti-explosion, water pressure of anti-static load, fire prevention and good air tightness performance. At present, mine rescue capsule design is mainly based on traditional experience design of sealed pressure vessels. In-depth theoretical analysis on structure and mechanical calculation for rescue capsule is lack. The structure deformation and distribution of equivalent stress were investigated under different explosion pressure conditions based on the elastic-plastic finite element theory and software ANSYS. The results provide certain design basis for the mine rescue capsule structural design.

**Keywords:** rescue capsule, ANSYS, stress, structural design

## **G-057 PMM13-MM100-115**

### **Self-adaptive grain recognition of diamond grinding wheel and its grains assessment**

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### **ABSTRACT**

An improved Canny operator based on the method of Maximum Classes Square Error is adopted to get a self-adaptive threshold for grain recognition. First, a grinding wheel surface was measured by using a vertical scanning white light interferometric (WLI) system and reconstructed with an improved centroid algorithm; then the grains were extracted using the proposed method based on the fact that the peak intensity difference ( $\Delta I$ ) between maximum and minimum

intensities on interferometric curve from diamond is larger than that from bond due to different reflective characteristics of different materials; third the grain protrusion parameters are investigated for grinding performance analysis. The experiments proved that the proposed grain recognition method is effective and assessment parameters are useful for understanding grinding performance.

**Keywords:** Grain recognition, assessment, Canny operator, Method of Maximum Classes Square Error, grain assessment parameters, diamond grinding wheel

**D-064 PMM13-MM100-156**

## **Optical Character and Calibration of 3D Vision Sensor**

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### **ABSTRACT**

The 3D image sensor simulating human vision has an important application prospect in stereo camera, human-computer interaction, and three-dimensional measurement. Based on the optical properties of 3D vision sensor, the character of TFT LCD's high precision made pixel and high flatness are used to make color image target, and this operation overcomes the limitation of the static target. The optimization method of Harris corner detection algorithm is also discussed in this paper, then a new measuring method of 3D sensor color distortion is proposed. The calibration, which calibrates the internal and external parameters of 3D vision sensor and color distortion, is completed by the programming software of 3D sensor calibration. The experimental results demonstrate the proposed calibration method is feasible.

**Keywords:** vision measurement; 3D sensor; corner detection; color distortion

**D-0701 PMM13-MM100-221**

## **Simulation and design of a fiber Bragg grating flow sensor**

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### **ABSTRACT**

A novel flow sensor based on fiber Bragg grating is put forward in this paper. Chock parts and elastomers are employed as conversion elements. Two FBGs with the same parameter are installed on elastomers separately. An effective solution Double-grating structure has been taken. The temperature natural compensation and its measuring sensitivity are improved. The sensor can be used to measure the flow of gas and fluid. Its structure and the fluid field around it are simulated and analyzed by ANSYS software within the velocity of 1-20m / s . The sensitivity of the sensor is simulated and calculated. The performances of the sensor packaging before and after are tested and the reflection spectrum signal characteristic values of the fiber grating are extracted with good linearity, high response sensitivity of 1.71 nm / kg and 0.103 nm / kg , respectively. The experiment results show that the flow sensor owns simple structure, good linearity and

high sensitivity.

**Keywords:** Fiber Bragg grating; Finite element analysis; Novel flow sensor

**D-0702 PMM13-MM100-223**

## **Design and study of a vibrating string accelerometer based on fiber Bragg grating**

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### **ABSTRACT**

In this paper, a novel one-degree-of-freedom micro-seismic sensor based on Fiber vibrating wire is put forward. The oscillator is penetrated by the optical fiber and mounted near the grating to make a micro-seismic detecting structure. This design contributes to fiber Bragg grating's response to tiny vibration directly. Some advantages such as small volume, high sensitive, easy for multiplexing, immunity of electromagnetic interference, low cost will be obtained. The new sensor with convenient zero adjust structure is fabricated as well. An experimental system based on high speed FBG interrogation analyzer is set up to demodulate vibration signal and analyze testing data. The micro-seismic simulation experimental results indicate that the sensor owns good performance with low frequency and high sensitivity. This study will be meaningful and helpful in Engineering seismic detection and Earthquake prediction application.

**Key words:** micro-seismic, fiber vibrating wire, fiber Bragg grating, accelerometer sensor, high sensitive

**D-072 PMM13-MM100-178**

## **Placement of the Material Temperature Sensor during Measuring the Accuracy of CNC Machine Tools**

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### **ABSTRACT**

In view of the dispute on the placement of material sensor when measuring the positional accuracy of a linear axis of a CNC machine tool, this paper presents the method and principle of deciding where to put the material temperature sensor. The positional accuracy of the linear axis of the machine tool is one of the most important performance parameters, and it must be measured when setup and check. The placement of the material temperature sensor has great influence on the measurement accuracy. At present, there are two main views on this issue: one is to place the sensor on the table of the machine tool, the other is to place it on the feedback system. This conflict between these two debates often makes the measurers feel confused and as a result influences the measure quality, sometimes. This thesis attempts to classify the CNC machine tools positional accuracy measurement according to its different purposes, then further

presents the best placement. The thesis also elaborates other relevant questions of the placement of the material temperature sensor.

**Keywords:** CNC machine tool, laser interferometer, material temperature sensor, positional accuracy

## **G-075 PMM13-MM100-48**

### **A Study on the quality of micro-hole of Ti-6Al-4V by EDM process with on-machine measurement techniques**

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#### **ABSTRACT**

A new on-machine measurement technique is proposed to observe the quality of micro-hole in micro Electrical Discharge Machining (EDM) progress. Images of micro-hole are captured by means of a simple configuration use a light-emitting diode (LED) illuminator, optical fiber, and a camera charge-coupled device (CCD). The device does not make contact with workpiece and acquire the image from the contour of the finished micro-hole. Because of using the optical fiber to transmit the real-time image, the device can work in the narrow and small place. Based on the detected feature points, the geometrical features of the finished micro-hole such as its aperture can be obtained in real time. Meanwhile, the measuring result shows the micro-hole is whether or not qualified and can optimize the process parameters.

**Keywords:** machine vision, EDM, fiber image bundles, micro-parts.

## **H-080 PMM13-MM100-78**

### **Simulation and signal analysis of Akiyama probe applied to Atomic force microscope**

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#### **ABSTRACT**

Atomic force microscope is one of indispensable measurement tools in nano/micronano precision manufacture and critical dimension measurement. To expand its industry application, a novel head and system are newly designed combined with Nanosensors cooperation's patented probe—Akiyama probe, which is a self-sensing probe. The modal analysis and resonance frequency are obtained by finite element (FE) simulations. Using the Locked-in amplifier, the effective and available signal can be obtained. Through the experiment analysis, the retracting and extending curve reflects the tip and sample interaction. Furthermore, the measurement on the calibrated position system demonstrates that

the whole system resolution can reach the nanometer scale.

**Keywords:** atomic force microscope, self-sensing probe, FE simulations, Locked-in amplifier

## **I-084 PMM13-MM100-12**

### **An indirect accuracy calibration and uncertainty evaluation method for large scale inner dimensional measurement system**

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#### **ABSTRACT**

In view of present problem of low accuracy, limited range and low automaticity existing in the large-scale diameter inspection instrument, a precise measuring system (robot) was designed based on laser displacement sensor for large-scale inner diameter in this paper<sup>1</sup>. Since the traditional measuring tool of the robot is expensive and hard to manufacture, an indirect calibration method is proposed. In this study, the system eccentric error is calibrated by ring gauge of laboratory. An experiment, which changes the installed order of located rods to introduce located rods' eccentric error, is designed to test whether the spindle eccentric error remains unchanged. The experiment result shows the variation of spindle's eccentricity after changing rods is within 0.02mm. Due to the spindle is an unchanged part of robot, based on  $\Phi 584$  series robot calibrated by ring gauge, other series robot can be deduced combining with the length of extended arm<sup>2</sup>.

**Keywords:** large scale pipes; inner diameter ; indirect calibration; ring gauge

## **D-087 PMM13-MM100-140**

### **Soil water evaporation measurement of lysimeter based on fiber Bragg grating sensor**

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#### **ABSTRACT**

A lysimeter weighing system based on fiber Bragg grating (FBG) sensor for measuring the soil water evaporation was presented in this paper. By the use of three mechanical levers and balance weight, the weight loaded on the FBG sensor was reduced K times (here, K was the ratio of levers). So the amount of water change in the soil container of tons can be weighted. A two-hole cantilever was selected as the elastomer structure of FBG weighing sensor, and an optimum design was carried on using the finite element method to meet the small-scaled design requirements. Using the matching fiber Bragg grating demodulation method based on LabVIEW, the demodulation system was easy to be

implemented. Then the FBG center wavelength drift was converted into a time interval, and the weight can be obtained automatically through measuring the interval by computer. Preliminary experiment showed that this weighing system has the ability of measuring soil water evaporation accurately.

**Keywords:** Lysimeter, soil water evaporation, FBG weighing sensor, matching grating demodulation, LabVIEW

## **G-088 PMM13-MM100-21**

### **Retrieval of aerosol size distribution based on GCV regularization with optical data of Lidar**

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#### **ABSTRACT**

Atmospheric aerosol particles influence the Earth's radiation balance both directly and indirectly. The aerosol size distribution (ASD) is one of the most important microphysical properties. In this paper, the generalized cross-validation (GCV) regularization method is used for the retrieval of ASD from three-wavelength lidar optical data. The numerical simulations are carried out using synthetic backscatter and extinction coefficients. Simulations results demonstrate that the ASD depends on particle refractive index. Choosing the suitable refractive index is crucial to retrieve aerosol size distribution accurately. Moreover, the numerical results show that, for the same refractive index, it is more suitable to retrieve broad ASD, which has larger mode width  $\sigma$ . The GCV regularization method has been tested for a set of experimental data from three-wavelength lidar, which provides backscatter coefficient at 355, 532 and 1064 nm and extinction coefficient at 355 and 532 nm. Experimental result shows that the retrieved size distribution belongs to the urban industrial type and fine mode. The result shows good agreement with the actual atmospheric aerosol size distribution of local area. Both the simulation and the experiment demonstrate that the GCV regularization method is feasible to retrieve the aerosol size distribution.

**Keywords:** Aerosol Size Distribution, Lidar, Generalized Cross-Validation, regularization, retrieval

## **H-089 PMM13-MM100-36**

### **Pulse modulation method for LED lidar light source**

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## ABSTRACT

A LED lidar system program was proposed for atmospheric aerosol detection. Compared with the conventional lidar using the laser, this system employs LED as the detection light source. Due to the wealth wavelength of LED, LED lidar achieves aerosol detection at a specific wavelength, and it makes the detection of aerosol particle size distribution easier. This paper presents a pulse modulation system for high-power LED light source. The system consists of pulse generator, narrow pulse driving circuit, and high-power LED array. A FPGA system is designed to generate the pulse whose frequency is adjusted by remote control. Using avalanche switching characteristics, the avalanche transistor circuit produces ultra-narrow pulses to drive the high-power LED array. Using U.S. standard atmospheric model, the detection capability of LED lidar system was simulated. Simulation result shows that the designed LED pulse light source used for lidar can meet the requirements of lower atmospheric aerosol detection.

**Keywords:** LED light source, pulse modulation, avalanche transistor, FPGA, aerosol detection, LED lidar

## G-090 PMM13-MM100-53

### Design of dual wavelength micro pulse polarization lidar system

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## ABSTRACT

A dual wavelength micro pulse polarization lidar system is designed, in which Nd:YAG laser at 1064nm and 532nm is employed as the exciting source, to research the depolarization ratio, the lidar ratio and the angstrom coefficient of aerosols. Numerical simulations are performed with the standard atmospheric model to verify the detection ability of the system. The simulation results show that the lidar system is capable of detecting the depolarization ratio of aerosols up to a height larger than 6 km at night and 2 km in the daytime with a signal to noise ratio of 10. In the meantime, the lidar system can also be used to detect the angstrom coefficient, and can provide important scientific data for studies of the relationship among these parameters.

**Key words:** atmospheric optics; polarization lidar; depolarization ratio; lidar ratio; angstrom coefficient

## G-091 PMM13-MM100-37

### A Novel Retinex Algorithm Based On Alternating Direction Optimization

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## ABSTRACT

The goal of the Retinex theory is to removed the effects of illumination from the observed images. To address this



typical ill-posed inverse problem, many existing Retinex algorithms obtain an enhanced image by using different assumptions either on the illumination or on the reflectance. One significant limitation of these Retinex algorithms is that if the assumption is false, the result is unsatisfactory. In this paper, we firstly build a Retinex model which includes two variables: the illumination and the reflectance. We propose an efficient and effective algorithm based on alternating direction optimization to solve this problem where FFT (Fast Fourier Transform) is used to speed up the computation. Comparing with most existing Retinex algorithms, the proposed method solve the illumination image and reflectance image without converting images to the logarithmic domain. One of the advantages in this paper is that, unlike other traditional Retinex algorithms, our method can simultaneously estimate the illumination image and the reflectance image, the later of which is the ideal image without the illumination effect. Since our method can directly separate the illumination and the reflectance, and the two variables constrain each other mutually in the computing process, the result is robust to some degree. Another advantage is that our method has less computational cost and can be applied to real-time processing.

**Keywords:** Retinex theory, alternating direction optimization, image enhancement

## **E-093 PMM13-MM100-75**

### **Design of Energy-saving Control System for LED Street Lamps**

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#### **ABSTRACT**

Based on the energy-saving and safe-driving requirements of road lighting, a kind of energy-saving system is proposed for street lamps in this paper, which is handled by two controllers. At daybreak and dusk, the lamps are turned on or off according to local sunrise and sunset. And at night, it is controlled by a fuzzy controller. Traffic flow and its variation rate, the highest road speed limit are taken as the inputs of the controller, at the same time, the lighting comfort and the experience of driver are defined as the fuzzy sets and control rules. LED lamps are used in the system as illuminant. The numerical simulation in MATLAB and analysis on the practical measured data show that the system is effective in energy-saving for road lighting.

**Keywords:** LED street lamp; Fuzzy control; Energy-saving; MATLAB simulation

## **E-094 PMM13-MM100-159**

### **Spectrum measurement for LED-based spectrum-tunable source**

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## ABSTRACT

This study focuses on the theory, construction and the performance measurement of a spectral-tunable LED light source. The light source is mainly combined by the LED illumination body, the spectral matching module as well as LED control driver module. The LED illumination includes thousands of high power LEDs across the whole visible spectral region. The received iterated data are allocated via LED data distribution card to drive LEDs on the illumination body, and precisely control the current of each LED by PWM (Pulse Width Module), to achieve 256 and above gray scale illumination. Through the study, the spectral-tunable light source with size of 3 by 1.5 square meter including 1700 LEDs has been constructed and the optical performance has been tested. The white light with color temperature of 5000K is taken as the simulation target. The results show that the optical performance such as luminous flux and color temperature are gradually stabilized, which differ due to the LED type. The spectrum distribution is not so accurate to the target one. And some methods to minimize the difference are discussed as well.

**Keywords:** LED-based, spectral tunable, spectral matching, spectrum measurement

## G-095 PMM13-MM100-90

### Noise reduction of laser scanning data based on self-estimated angular threshold

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## ABSTRACT

Laser scanning is widely applied to reverse engineering. Nonetheless, the involvement of scanning equipment and laser probe, as well as the measurement environment itself renders the process more vulnerable to noise which will cause failures in boundary detection, data segmentation and reconstruction of smooth curves and surfaces, thus putting forward the demand for noise reduction. Among the methods used in noise reduction of laser scanning data, the angular method is particularly suitable for scan line data. However, this method as well entails threshold that largely relies on the experience of engineers, which may introduce unwanted uncertainty. In this paper, an algorithm based on self-estimated angular threshold for reducing noise of laser scanning data is proposed. Firstly, the factors affecting angular threshold are analyzed and a mathematical model for SAT is established. Then the concrete algorithm that consists of judgment of impulse noise, modification of the coordinates and average filtering is described. Finally, a simulation test and an experimental case are employed to evaluate the performance of the algorithm on noise reduction of laser scanning data.

**Keywords:** laser scanning data, noise reduction, self-estimated angular threshold, reverse engineering

## C-096 PMM13-MM100-57

### Research status and developing trends of grating nanometer measuring technology

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### ABSTRACT

Along with the progress of rating and signal processing technology, because of its advantages and wide application, grating measuring technology has become a research hotspot in the precision measuring field. Nanometer measuring has become urgently to solve problem with the need of industrial development and scientific research from sub micrometer to nanometer precision measurement. This paper systematically discusses its research status, existing problems, developing trends and other issues about grating nanometer measuring technology. It provides references to grating nanometer measuring technology researches and its development.

**Keywords:** nanometer measuring; grating; Moore technology; research status; developing trends

## **A-098 PMM13-MM100-131**

### **Roundness measuring instrument for 2-dimensional standards**

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### ABSTRACT

Combined with an optical probe and a traditional roundness measuring instrument, a new type of roundness measuring instruments for 2-dimensional patterns has been developed. The instrument inherits measurement procedure and evaluation method of traditional roundness measuring instrument, aiming to unify the evaluation methods of roundness measurements for 2D- and 3D- objects. The roundness of 2-dimensional patterns on this instrument is then calculated from more than 3600 points per circle; the filters can be selected like traditional roundness measuring instruments. This roundness result includes more information than the measurement with only around 30 points by imaging probe CMMs. It should be calibrated for a 2-dimensional pattern if it will work as reference objects. Special reference objects are designed for adjustment of the developed instrument. Researches were done for the traceability of the instrument. A reference sphere was used for traceability of the rotatory shaft and a laser interferometer for the optical sensor. The instrumental uncertainty is  $U=0.16\mu\text{m}$  ( $k=2$ ). Based on the one-year-long test, the stability of the instrument is excellent.

**Keywords:** roundness, measuring instrument, 2-dimensional patterns, measurement procedure

## **C-102 PMM13-MM100-16**

### **Development and measurement of single layer thickness standard**

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## ABSTRACT

To study the different measurement results come from different kinds of instruments for the thin film thickness measurement, a serial of the thin film thickness standard samples with single layer are developed, these thickness values are about from 5 nm to more than 100 nm. These standard samples designed specially can be calibrated by X- ray reflectometry, and also can be calibrated by some kinds of 3D surface profiler including some non-contact optical profilometers, stylus contact surface profilometers and scanning probe microscopies, because some specific film graphs are made in some zones on the layer. It is found through some measure experiments comparison done that the film thickness measurement uncertainty is small than 1nm by X- ray reflectometry, and more than 2~10 nm by other measurement instruments. And then, to analyze the reasons for different measure methods have different values and uncertainties for the same layer thickness standard, such as the unperfected graphs influence of film thickness on the standard samples and the size and shape of probe tip for contact measure instrument, even including the difference of performance of the measure systems and computational approaches to the film thickness.

**Keywords:** metrology; nano-metrology; thin film thickness; XRR; film thickness standard

# **J-105 PMM13-MM100-45**

## **Bearing Fault Diagnosis Based on Scale-transformation Stochastic Resonance**

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## ABSTRACT

A weak fault feature extraction method of rolling bearing based on scale-transformation stochastic resonance (STSR) is proposed. Combined with ensemble empirical mode decomposition (EEMD), the vibration signal with noise is adaptively decomposed for antialiasing by EEMD method to get intrinsic mode functions (IMFs) of different frequency bands, then the IMFs are inputted into scale-transformation mono-stable system. The low frequency fault features are extracted by using a frequency scale  $R$  to change the step length of numerical calculation and the adjustment of mono-stable system parameters, and finally slice bi-spectrum is adopted to perform the postprocessing of the output of the mono-stable system. Simulation analysis is performed to validate the characteristics of STSR, and analysis of measured signal of the rolling bearing with strong background noise shows that the approach can extract the weak fault features of rolling bearing successfully.

**Keyword list:** Scale-transformation stochastic resonance (STSR); ensemble empirical mode decomposition (EEMD); weak fault of rolling bearing; slice bi-spectrum

## **E-107 PMM13-MM100-93**

### **A Dedicated On-line Detecting System for Auto Air Dryers**

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#### **ABSTRACT**

According to the correlative automobile industry standard and the requirements of manufacturer, this dedicated on-line detecting system is designed against the shortage of low degree automatic efficiency and detection precision of auto air dryer in the domestic. Fast automatic detection is achieved by combining the technology of computer control, mechatronics and pneumatics. This system can detect the speciality performance of pressure regulating valve and sealability of auto air dryer, in which online analytical processing of test data is available, at the same time, saving and inquiring data is achieved. Through some experimental analysis, it is indicated that efficient and accurate detection of the performance of auto air dryer is realized, and the test errors are less than 3%. Moreover, we carry out the type A evaluation of uncertainty in test data based on Bayesian theory, and the results show that the test uncertainties of all performance parameters are less than 0.5kPa, which can meet the requirements of operating industrial site absolutely.

**Key words:** auto air dryer; on-line detecting; performance of pressure regulating valve; sealability

## **E-109 PM13-MM100-22**

### **Detection Technology Research On The One-way Clutch of Automatic Brake Adjuster1**

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#### **ABSTRACT**

In this article, we provide a new testing method to evaluate the acceptable quality of the one-way clutch of automatic brake adjuster. To analysis the suitable adjusting brake moment which keeps the automatic brake adjuster out of failure, we build a mechanical model of one-way clutch according to the structure and the working principle of one-way clutch. The ranges of adjusting brake moment both clockwise and anti-clockwise can be calculated through the mechanical model of one-way clutch. Its critical moment, as well, are picked up as the ideal values of adjusting brake moment to evaluate the acceptable quality of one-way clutch of automatic brake adjuster. we calculate the ideal values of critical moment depending on the different structure of one-way clutch based on its mechanical model before the adjusting brake moment test begin. In addition, an experimental apparatus, which the uncertainty of measurement is  $\pm 0.1\text{Nm}$ , is specially designed to test the adjusting brake moment both clockwise and anti-clockwise. Than we can judge the acceptable quality of one-way clutch of automatic brake adjuster by comparing the test results and the ideal values instead of the EXP. In fact, the evaluation standard of adjusting brake moment applied on the project are still using the EXP provided by manufacturer currently in China, but it would be unavailable when the material of one-way clutch changed. Five kinds of automatic brake adjusters are used in the verification experiment to verify the accuracy of the test method. The experimental results show that the experimental values of adjusting brake moment both clockwise and

anti-clockwise are within the ranges of theoretical results. The testing method provided by this article vividly meet the requirements of manufacturer's standard.

**Key words:** detection technology; the acceptable quality; failure; automatic brake adjuster; one-way clutch; the mechanical model; the adjusting brake moment test; an experimental apparatus; evaluation standard

## **H-113 PMM13-MM100-11**

### **ROIC with on-chip sigma-delta AD converter for HgCdTe e-APD FPA**

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#### **ABSTRACT**

HgCdTe electron injection avalanche photodiodes (e-APDs) work at linear mode. A weak optical current signal is amplified orders of magnitude due to the internal avalanche mechanism and it has been demonstrated to be one of the most promising methods to focal-plane arrays (FPAs) for low-flux like hyper-spectral imaging and high-speed applications such as active imaging. This paper presents the design of a column-shared ADC for cooled e-APDs FPA. Designing a digital FPA requires fulfilling very stringent requirements in terms of power consumption, silicon area and speed. Among the various ADC architectures sigma-delta conversion is a promising solution for high-performance and medium size FPA such as 128×128. The performance of Sigma-delta ADC rather relies on the modulator structure which set over-sampling and noise shaping characteristics than on critical analog circuits. This makes them quite robust and flexible. A multistage noise shaping (MASH) 2-1 single bit architecture sigma-delta conversion with switched-capacitor circuits is designed for column-shared ADC, which is implanted in the GLOBALFOUNDRIES 0.35um CMOS process with 4-poly and 4-metal on the basis of a 100um pixel pitch. It operates under 3.3V supply and the output range of the quantizer is 2V. A quantization noise subtraction circuit in modulator is designed to subtract the quantization noise of first-stage modulator. The quantization noise of the modulator is shaped by a high-pass filter. The silicon area and power consumption are mainly determined by the decimation low pass filter. A cascaded integrator-comb (CIC) filter is designed as the digital decimator filter. CIC filter requires no multipliers and use limited storage thereby leading to more economical hardware implementation. The register word length of the filter in each stage is carefully dimensioned in order to minimize the required hardware. Furthermore, the digital filters operate with a reduced supply voltage to 1.5V. Simulation results show that the modulator achieves the resolution higher than 14bits and 2.4mW power consumption per ADC at 7.7k Samples/s rate.

**Keywords:** HgCdTe e-APD, ROIC, CTIA, sigma-delta ADC, cooled FPA.

## **D-119 PMM13-MM100-158**

### **A novel design of parallel piezoelectric six-degree-of-freedom accelerometer**

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### ABSTRACT

According to the drawback of elastic style six-degree-of-freedom (6-DOF) accelerometer, a novel parallel piezoelectric six-degree-of-freedom accelerometer is proposed. First, the operating principle and structure of the accelerometer is presented, then the finite element model of accelerometer is established by ANSYS analysis tools, and getting some parameters, such as output charge sensitivity, resonance frequency etc. Finally, on the basis of analysis of simulation results, a conclusion can be given that cross-axis sensitivity is less than 1%. The resonance frequency is more than 5900Hz, the accelerometer has simple and rational structure and all parameters meet requirement.

**Keywords:** six-degree-of-freedom accelerometer, piezoelectric, FEM analysis

## I-121 PMM13-MM100-35

### Dynamic high-speed acquisition system design of transmission error with USB based on LabVIEW and FPGA

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### ABSTRACT

To realize the design of dynamic acquisition system for real-time detection of transmission chain error is very important to improve the machining accuracy of machine tool. In this paper, the USB controller and FPGA is used for hardware platform design, combined with LabVIEW to design user applications, NI-VISA is taken for develop USB drivers, and ultimately achieve the dynamic acquisition system design of transmission error.

**Keywords:** Acquisition system, TE, USB drivers, FPGA, LabVIEW

## D-122 PMM13-MM100-184

### Dynamic self-calibration of time grating sensors based on self-adaptive Kalman filter algorithm

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## ABSTRACT

As regarding the errors caused by mechanical installation and signal processing, a novel self-adaptive kalman filter algorithm is proposed. According to kalman filter recursion formula, the current value can be estimated with the last estimated value and the current measured value. Therefore, the kalman filter algorithm does not need recorder the past series of the estimated value and the current measured value, the calculated load is not too heavy to implement. The respond speed and the quality of time grating can be improved significantly. Experiment results prove the valid of the proposed method.

**Keywords:** kalman filter algorithm, time grating sensor, self- adaptive

## **B-126 PMM13-MM100-165**

### **Kinematic modeling and simulation of articulated arm coordinate measuring machines based on MCPC method**

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## ABSTRACT

The Articulated Arm Coordinate Measuring Machine (AACMM) is a new type of non-orthogonal system precision instrument with the advantages of large measuring range, small volume, low weight and portability. The kinematic models of AACMM are commonly established with the Denavit-Hartenberg (D-H) method. However, the D-H model exhibits the singularity in consecutive parallel joint axes due to it is neither complete nor parametrically continuous. The kinematic model of the AACMM established with MCPC (modified complete and parametrically continuous) method overcomes the disadvantages of incomplete and parametrically discontinuous of the D-H method. The transformation matrixes are obtained based on the MCPC method, which realizes the mapping form the joint space to measuring space of the AACMM. Numerical calculation and graphic simulation are used to verify the kinematic model of the AACMM. The result shows that the kinematic model is correct. The kinematic model of the AACMM based on MCPC method can provide a theoretical basis for measurement and calibration, and it also introduces a new kinematic modeling approach for the AACMM.

**Keywords:** articulated arm, coordinate measuring machine, kinematic model, modified complete and parametrically continuous

## **E-129 PMM13-MM100-50**

### **Optimizing the structure of a four-axis polarized scattering instrument using a double-loop approach**

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### ABSTRACT

A new four-axis polarized scattering instrument is presented in this paper. In order to capture instrumental characteristics, the finite element analysis has been utilized to investigate the static behaviors such as the structural volume and tip deflection. Both topological and parametric optimization in presenting double-loop approach results in optimum material distribution and volume fraction. The resulting optimum model has been further modified to a solid prototype for final product design. The ultimate result shows that the tip deflection, material volume can evidently be optimized so that the enhancement of instrumental precision can be achieved. The proposed exploration of process and skill can provide for general mechanical structural design in creative sense.

**Keywords:** polarized scattering instrument, topological structural optimization, mechanical engineering design, CAD.

## **E-130 PMM13-MM100-54**

### **The performance of an inspection system for indium tin oxide circuits by using a PDLC/ITO film**

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### ABSTRACT

An inspection system for indium tin oxide (ITO) circuits has been developed with the use of a polymer dispersed liquid crystal (PDLC)/ITO film which was used as a sensing device to locate faulty shut/open circuits. With the power on, the PDLC/ITO film covering the conducting area was changed from translucent state to clear state while those covering the non-conducting area was remain translucent. In this study, simulations and experiments were conducted to evaluate the performance of the proposed system and study effects of system parameters on the limitation of the proposed system. It is of interest to find that the increase in applied external voltage will improve the capability of identifying conducting area while that will generally degrade the capability of identifying non-conducting area with the range studied.

**Keywords:** transparent conductive oxide (TCO) film, polymer dispersed liquid crystal (PDLC), transparent circuit

## **B-134 PMM13-MM100-195**

### **Development of a micro-CMM with scanning touch probe and high-precision coplanar platform**

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## ABSTRACT

This study develops a micro-CMM incorporating a scanning touch probe and a high-precision coplanar platform. The measurement performance of the proposed system was enhanced through the use of a rigid aluminum double-arch-bridge structure to support the scanning touch probe. For the working stage, a linear motor was used for long-stroke positioning and a piezoelectric actuator was then employed to fine-tune the positioning so as to achieve a requirement of high-precision. The platform has two characteristics: (i) the driving and measuring axes are designed along the same line so that Abbe error of the stage can be eliminated; (ii) the coplanar design makes the X and Y axes reach a goal of two-axis concurrent. The aforementioned two designs can reduce the error of the platform so that the micro-CMM reaches a positioning accuracy of  $\pm 0.1\mu\text{m}$  for a working volume of  $80\times 80\times 40\text{ mm}^3$ . Furthermore, the reliability of the probe mechanism of three degrees of freedom was analyzed and validated. The sensor coordinates a laser diode with Position Sensor Detectors (PSD) working with an optical path to measure placement of Z-axis and angle placement of XY-axis. By validation through an experiment, the three dimensional scanning touch probe developed by this study has a measuring range of  $\pm 1\text{mm} \times \pm 1\text{mm} \times 1\text{mm}$  with a unidirectional repeatability of  $0.6\mu\text{m}$ .

**Keywords:** micro-Coordinate Measuring Machine, Double-arch-bridge structure, Coplanar platform, Abbe error, Scanning touch probe

## **F-135 PMM13-MM100-230**

### **A three-degree-of-freedom hybrid vibration isolation system using adaptive proportional control supported by passive weight support mechanism**

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## ABSTRACT

This paper presents a three-degree-of-freedom hybrid vibration isolation system integrated with an active sky-hook damper and a passive weight support mechanism for highly sensitive measurement equipment, e.g. atomic force microscopes, suffering from building vibration. Active sky-hook damper applies proportional controller incorporated with an adaptive filter to reduce the resonance of the passive weight support mechanism at nature frequency. The absolute vibration velocity signal acquired from an accelerator and being processed through an integrator is input to the controller as a feedback signal, and the controller output signal drives the voice coil actuator to produce a sky-hook damper force. The adaptive filter is used to compensate the phase error between the measuring input signal and the absolute vibration velocity. An analysis of this active vibration isolation system is presented, and model predictions are compared to experimental results. The results show that the system could effectively reduce transmissibility at resonance without the penalty of increased transmissibility at higher frequencies both in vertical and horizontal directions.

**Keywords:** active sky-hook damper, proportional control, adaptive filter, absolute vibration velocity, voice coil actuator

## **D-138 PMM13-MM100-239**

# **The Investigation of electrolytic surface roughening of PCB copper foil**

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### **ABSTRACT**

This study is the application of the principle of electrochemical. The anodic dissolution has no concentration polarization. Hence, electrolyte life is substantially increased. The waste copper is high in ion concentration with a recovery value. As compared with the current PCB chemical pre-treatment method, it may have advantages of cost-saving, improvement of overall efficiency, reduction of production costs and reduction of the amount of waste generated. In the development of the copper foil for electrochemical roughening process, the use of electrolysis reaction affects the copper surface dissolution to form a unique bump coarsening. It will increase in the surface area of the copper foil to improve dry film solder mask and the adhesion between the copper surfaces. Four neutral salts and acid electrolytes selected to explore the best of the electrolytic roughening parameters of temperature, time and voltage. The surface roughness and the surface morphology of the copper foil were measured before and after the electrolytic surface roughening. Finally, after repeated experiments, chlorine ion electrolyte copper generates obvious inter-granular corrosion, resulting in a rough surface similar to the chemical pre-treatment. On the other hands, the surface morphology resulted from non-chlorine ionic electrolyte appears more like pitting. Both electrolytic could generate surface roughness of Ra 0.3 um roughened copper surface higher than industrial standard.

## **D-152 PMM13-MM100-229**

# **Development of automobile tyre lateral runout measurement sensor**

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### **ABSTRACT**

Automobile tyre lateral runout is one of the important indexes to measure the quality of the tyre, it will affect the safety of the automobile in moving. This paper introduces a sensor for automobile tyre lateral runout measurement. The variation of the automobile tyre lateral runout causes the change of guide rod probe displacement and deforms of the cantilever beam which connects with the guide bar. The deformation of the cantilever beam leads to the change of the resistance value of strain gauge which is pasted on the cantilever beam. Through measuring circuit, the resistance value of the strain gauge is converted into output voltage that has a certain relationship with automobile tyre lateral runout. Then, the voltage signal is transformed by A/D convertor and send to SCM to process and display the value of runout. Meanwhile, SCM output control signal to control the actuator and adjust the equipment running status in real time so as to ensure the tyre lateral runout is within the allowed range.

**Keywords:** tyre lateral runout, resistance strain gauge, measuring circuit, SCM, nonlinear error

## **H-1532 PMM13-MM100-15**

# **Transmitting pulse signal design for ultrasonic time of flight measurement in short baseline framework**

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### **ABSTRACT**

The SBF (short baseline framework) is commonly used in ultrasonic parameter measurement, and ToF (time of flight) of which is essential in sound velocimeter and other applications. Different from general ultrasonic measurement research work mainly on ToF estimation method, this paper studies the criterion and way of establishing the optimum signal. For given transducers, the optimum signal achieves the most accuracy, and the pulsed form signal is stress here. To find the optimum signal, firstly, the transmitting is illustrated in its Fourier series form, which establishes the waveform, and the problem of transmitting wave design is converted into finding the optimum Fourier series. Secondly, as the accuracy is in inverse ratio to the sensitivity of the measured signal, the problem of finding the optimum Fourier series is equivalent to maximizing the sensitivity, resulting into a form of nonlinear optimization problem. For optimum parameter derivation, the sensitivity is expressed in form of vector and matrix, and a novel method based on SCHUR decomposition on the matrix is proposed to solve the nonlinear optimization problem. Simulation with a typical narrowband system testifies that the proposed method can synthesize transmitting waveform efficiently.

**Keywords:** short baseline framework, time of flight, pulse signal, wave design, schur decomposition, parameter optimization, ultrasonic measurement, signal synthesize.

## **D-157 PMM13-MM100-226**

# **Design of scrap copper separation control system based eddy current sensor**

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### **ABSTRACT**

The detection and automatic separation of block scrap copper using eddy current sensor is beneficial to improve the level of recycling use of scrap copper. This paper introduces the working principle, overall structure, hardware circuit and software structure of scrap copper separation system based eddy current sensor.

**Keywords:** eddy current sensor, scrap copper, control system, automatic separation

## **F-159 PMM13-MM100-238**

# **Design and finite element analysis of the vibration isolation system of STM**

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### **ABSTRACT**

Vibration isolation system is a prerequisite to achieve high resolution picture using scanning tunnel microscope (STM). The principle of spring damping isolation, staked flat-elastomer isolation, pneumatic isolation, and sandbox damping isolation is introduced. The relationship between resonant frequency of the isolation and the effect is presented. The four resonant frequencies are calculated through Finite Element Analysis (FEA). The four vibration isolations is designed and optimized according to the analysis. The experimental results show that spring damping isolation has the best effect and a transfer ratio of 10<sup>-6</sup>(120dB) can be obtained.

**Keyword:** vibration isolation, STM, FEA, resonant frequency

## **H-166 PMM13-MM100-208**

# **Harmonic Distortion Analysis of a Mach-Zehnder Intensity Modulator**

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### **ABSTRACT**

With the aim to get harmonic distortion characteristics and frequency components of modulated output signals of a Mach-Zehnder (MZ) intensity modulator, this paper analyzes the optical intensity modulation transfer function by Taylor expansion method according with the working principle of modulator. From the viewpoint of spectrum, the output signal is mainly comprised of the fundamental harmonic, the second intermodulation harmonic and the third intermodulation harmonic of the input signal and their magnitudes are connected with the bias voltage and Eigen-phase of MZ modulator. The second harmonic distortion and the fundamental harmonic of the modulated output signal are closely related with the drift of the best bias point. When the modulator works at the best DC bias voltage point, the modulated output signals have the minimum second harmonic distortion. If the best bias point drifts, the second harmonic distortion increases and the fundamental harmonic decreases, which changes in proportion to the sine or cosine of the drift voltage. A 1GHz sine signal with 1V amplitude imposed on the modulator, the simulation results by MATLAB presents that the waveform starts distorting along with the drifting of the best bias voltage, which the fundamental wave component starts decreasing and the second harmonic component starts increasing. While at last the fundamental wave component is zero, the frequency of output modulated signal doubles as much the frequency of input

signal.

**Keywords:** Mach-Zehnder modulator, intensity modulation, DC bias, harmonic distortion

## **G-167 PMM13-MM100-203**

### **Design of High Current Voltage Conversion Circuit Based on LT3743**

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#### **ABSTRACT**

Laser diodes (LD) are used extensively in fiber lasers as pump sources. The operating characteristic of laser diodes determines a requirement of constant current regulation, high stability and high current in the drive circuit. This paper gives a design of constant current source aiming at the drive circuit of fiber laser pump sources with 24 volt power supply. It is made up of Buck module and constant current module. The synchronous Buck module consists of the chip LT3743, MOSFET Si7848BDP and RJK0330DPB, with the advantages of high-current output, low dissipation power and high power-supply efficiency. Circuit simulation results are given by the simulation software LTspice. It is shown that the Buck module satisfies the need of the circuit.

Keyword: DC-DC converter, soft switching, Buck converter, laser power supply.

## **G-168 PMM13-MM100-132**

### **Structure parameters optimization and system simulation of a double-triangulation probe**

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#### **ABSTRACT**

It would be very challenging for a designer to select desirable structure parameters for a laser triangulation probe, the parameters which have an appreciable or noticeable impact on probe's measuring range, resolution and accuracy. The challenge is aggravated by the trade-offs between the measuring range and resolution since there is interdependency and a delicate balance among them. Therefore, this paper focuses on building the relationship between the measuring range and resolution, and tries to optimize the structure parameters to improve measuring accuracy within a certain measuring range. In order to verify the validity and feasibility of this method, single-triangulation probe simulation experiments are also performed in 3dsmax platform. In addition, a double-triangulation probe simulation system is proposed and the experimental results confirm that the slope error can be compensated effectively. The conclusions presented in this paper provide useful guidance for designing a high-precision triangulation probe.

**Keywords:** triangulation probe; structure parameters optimization; system simulation; calibration; error compensation.

## **G-170 PMM13-MM100-147**

# **All-Fiber Q-Switched Ytterbium-Doped Fiber laser in MOPA Configurations**

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### **ABSTRACT**

An all fiber Q-switched Ytterbium-Doped Fiber (YDF) laser in Master Oscillator Power-Amplifier (MOPA) configuration is proposed theoretically and demonstrated experimentally, and the principle analysis and experimental verification are presented in details. Firstly, the system configuration is designed. The system is composed of the seed and the amplifier stage. Two 915nm LDs are used for pumping light, and the light is coupled into the gain medium of the seed and the amplifier stage by two combiners, respectively. Two Fiber Bragg Gratings (FBGs) are used as ends of the cavity of the seed. One Q-switch is used to modulate output laser of the seed, and the amplifier stage is adopted to amplify the light behind the seed. Then, 10m YDF with single mode is selected for the gain medium of the seed, and 8m YDF with multimode is used as the gain medium of the amplifier stage. The output laser of the seed with a 1.02W average power is realized when the seed pump power is 5.74W, the repetition rate is 20KHz and the action time of the Q-switch is 3.5 $\mu$ s. Meanwhile, a 7.58W pump power of the amplifier stage is used to amplify the seed laser. Finally, output laser with the pulse width of 90ns and the average output power of 4.93W are achieved.

**Keywords:** fiber laser, acousto-optic Q-switch, master oscillator power-amplifier, amplifier stage, all fiber, fiber Bragg grating, repetition rate, average power

## **G-171 PMM13-MM100-193**

# **Research on Amplification and Peak-holding Circuits of Nanosecond Light Pulse**

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### **ABSTRACT**

A kind of circuit characterized by sampling, amplifying and adjusting light pulse was introduced. It can be applied to the real-time monitoring of narrow light pulse. Theoretically, the paper analyses the relationship between the pulse

slewing rate and the selection of an amplifier, also the relationship between the bandwidth of the retainer and the selection of a hold-capacitance is deduced. The main performance of the peak holder is analyzed and the method of selecting amplifier and holding-capacitance is introduced. According to the theoretical analysis, high-speed, weak light-pulse signal sampling and peak-holding circuit is designed. PIN diode connected a 50 ohm resistor is used to convert electric current to voltage. The AD8009 voltage amplifier brings about amplifying voltage from 1V to 3V. Sampling and broadening peak can be achieved by OPA615. The excellent EP2C5T144 in the control field is qualified to provide a control signal, which is able to control the conversion of peak sampling or holding. Therefore, the amplification and broadening of narrow pulse signal are obtained. This light power signal pulse width is 100 ns, with 50 ns rising time and 50 ns falling time. Light power signal varies from 0.1w to 1w. The current signal from PIN diode is 1~10 mill ampere (mA). This circuit is effective for the signal of 100 ns pulse width and 50 ns rising time. It is proved that the scheme is feasible and this circuit-design can be used in practical application.

**Key words:** Narrow Pulse; PIN diode; AD8009; OPA615; Peak sampling and holding

## **G-172 PMM13-MM100-13**

# **Technique of Laser Confocal and Raman Spectroscopy for Living Cell Analysis**

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### **ABSTRACT**

Because of the shortcomings of the main methods used to analysis single cell, the need of single living cell analysis with no damage, unmarked and in situ dynamic multi-parameter measurement is urgent in the life sciences and biomedical advanced research field. And the method of for living cells analysis is proposed. The spectral pretreatment technology of living cell is the key work of laser confocal Raman spectroscopy. To study the spectrum processing methods for Raman spectrum on single living cell and develop the pre-process techniques to enhance the signal-to-noise ratio, sensitivity, and decrease the influence of fluorescence, elimination the cosmic rays was used to improve the spectrum. The classification, average and filtration of spectrum were applied to enhance signal-to-noise ratio. The fluorescence was depressed for quantity analysis or utilized for analysis by comparing the background and the spectrum. The results show that the proposed technique for laser confocal Raman spectrum of single cell can perform the sensitive and weak intensity peaks and reflect the information of molecules structures very well.

**Keywords:** LASER CONFOCAL, Raman SPECTROSCOPY, LIVING CELL, SPECTRAL IMAGING

## **G-173 PMM13-MM100-137**

# **An improved centroid location algorithm for infrared LED feature points**

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## ABSTRACT

The precision of centroid location for infrared LED point images is an important factor, which affects the precision of the light-pen Coordinate Measuring Machining (CMM). In this paper, the error model using the traditional center of mass (COM) algorithm is analyzed and it is shown that there are systematic error and random error. This paper analyzes the systematic error and random error, and then adopts the Gaussian surface fitting (GSF) algorithm and weighted centre-of-gravity (WCOG) algorithm to compensate systematic errors, meanwhile it analyzes how to reduce random error. The simulation results show that the accuracy of the infrared LED point position can be enhanced from 1/20 pixel to 1/100 pixel using the new algorithm.

**Key words:** image processing; two-dimensional Gaussian distribution; centroid location

## I-174 PMM13-MM100-160

### Simulation research of acousto optic modulator drive based on Multisim

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## ABSTRACT

The acousto optic modulator drive is mainly made with 2 amplitude shift keying (2ASK) circuit, pre-amplifier circuit and power operational amplifier circuit, and the simulation of the acousto optic modulator drive is realized. Firstly, the acousto optic modulator drive works as follows. The modulation function is realized by the analog switch circuit, and the on-off of the analog switch chip (CD4066) are controlled by the pulse signal generated by the electronic conversion circuit. The voltage amplification of the modulated signal is achieved by two reverse proportional operation implements voltage amplifier circuit, and the circuit is mainly made with the AD8001 chip. Then the amplified signal is transferred into a two-stage power operational amplifier circuit of class C which is mainly made with the chip of MRF158. Secondly, both of the simulating structures and the union debugging based on the designed system are realized by Multisim. Finally, obtaining the modulation signal of 150(MHz) frequency and 5( $\mu$ s) pulse width illustrates that a 2ASK modulation of the 150 (MHz) carrier signal and the 20(kHz) modulation signal is achieved. Besides, as the frequency of input signal and amplitude of voltage change, the output power of the power operational amplifier circuit also changes, and the conclusion is drawn that the output power increases when the frequency of input signal decreases and the amplitude of voltage increases. The component selection of the drive's PCB design, the performance parameter and of the actual circuit and the debugging of the actual circuit are based on the simulation results

**Keywords:** ACOUSTO OPTIC Modulator DRIVE, MULTISIM, POWER AMPLIFICATION, 2 AMPLITUDE SHIFT KEYING

## **G-175 PMM13-MM100-124**

# **An accuracy evaluating method for image point location based on linear fitting**

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### **ABSTRACT**

Determination of image point coordinates has a strong influence on the accuracy of photogrammetry. It will be helpful if we could choose a kind of locating method with highest accuracy in specific environment. As it is difficult to measure the image point location accuracy directly, researchers generally acquire this accuracy by simulation which may deviate greatly from real environment. This paper proposes a more practical method - to evaluate the accuracy of image point center location from practical scenario based on linear fitting. This method promises to evaluate a higher accuracy in the image space via a lower accuracy in the object space through projection rules. In this paper we perform an experiment with retro-reflective targets (RRT), a coordinate measuring machine (CMM) and a CCD camera. The target locations are centroid, squared centroid and ellipse fitted center. Their accuracy, in descending order, is: squared centroid, centroid, and ellipse fitted center.

**Keywords:** target location; accuracy evaluation; linear fitting; practical scenario; image point coordinates; RRT

## **G-177 PMM13-MM100-169**

# **Optical tweezers based on cylindrical vector beams**

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### **Abstract**

Optical tweezers based on cylindrical vector beams are studied theoretically and experimentally. First, we present the basic concept of a cylindrical vector beam (CVB), whose polarization is axially symmetric to the optical axis. Second, two theoretical modes to analyze the interaction between the light beam and the particle are introduced, respectively, and some simulations have been shown. Then, the system structure and its operation principle are introduced in details, where a spatial light modulator (SLM) is used to flexibly generate the CVBs, and experimental results are also demonstrated, which show some advantages for optical manipulation of particles using CVBs.

**Keywords:** Optical tweezers; cylindrical vector beam; spatial light modulator

## **G-178 PMM13-MM100-103**

# **A variable weighted centroid method for Retro Reflective Target locating**

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### **ABSTRACT**

This paper proposes a new method which is called variable weighted centroid method for locating the center of retro reflective target. It is based on centroid method. This method adapts itself to different measurement environments by varying the weight coefficients  $\alpha$ , which is determined by different factors associated with measuring environment. The coefficient  $\alpha$  is optimized by experiment. The evaluation criterion (lower is better) under the proposed method is reduced by at least 25% compared with the traditional method. Experiment results show that this variable weighted centroid method provides higher locating accuracy than old methods.

**Keywords:** photogrammetry; sub-pixel location; retro reflective target

## **E-182 PMM13-MM100-98**

# **A study on the fabrication of main scale of linear encoder using continuous roller imprint method**

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### **ABSTRACT**

Linear encoder composed of main and index scales has an extensive application in the field of modern precision measurement. The main scale is the key component of linear encoder as measuring basis. In this article, the continuous roller imprint technology is applied to the manufacturing of the main scale, this method can realize the high efficiency and low cost manufacturing of the ultra-long main scale. By means of the plastic deformation of the soft metal film substrate, the grating microstructure on the surface of the cylinder mold is replicated to the soft metal film substrate directly. Through the high precision control of continuous rotational motion of the mold, ultra-long high precision grating microstructure is obtained. This paper mainly discusses the manufacturing process of the high precision cylinder mold and the effects of the roller imprint pressure and roller rotation speed on the imprint replication quality. The above process parameters were optimized to manufacture the high quality main scale. At last, the reading test of a linear encoder contains the main scale made by the above method was conducted to evaluate its measurement accuracy, the result demonstrated the feasibility of the continuous roller imprint method.

**Keywords:** linear encoder, main scale, roller imprint, cylinder mold, grating microstructure, imprint replication

**B-183 PMM13-MM100-207**

## **Study on Technology of Double Parallel-joints Coordinate Measuring Machine**

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### **ABSTRACT**

The research of the high accuracy coordinate measuring machine is now playing a more and more considerable role in heightening the technical level of equipment manufacturing industry. With reference to the characteristics of foreign ScanMax coordinate measuring machine, this paper introduces the development of a double parallel-joint coordinate measuring machine with our own dependent intellectual property. This paper details the structural design, the calibration method and the evaluation for the uncertainty measurement of a prototype. The prototype has several advantages when compared with foreign instruments: first, decrease of Abbe error; second, enlargement of the measuring range; third, improvement of the rigidity of the instrument. The measurement test indicates that the measurement uncertainty (when  $K=2$ ) of special random distance is  $10.2\ \mu\text{m}$ . The double parallel-joint coordinate measuring machine studied by this paper is of great academic value and the developed prototype is highly practical and worthy of being popularized.

**Keywords:** double parallel-joint, measurement coordinator, Abbe error, uncertainty, field measurement

**G-184 PMM13-MM100-66**

## **Three-dimensional shape measurement based on a combination of gray-code and phase-shift light projection**

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### **ABSTRACT**

Blade is the key component of the aero-engine. In generally, it requires precise size and accurate shape, so the three-dimensional shape measurement of the blade is very important. Fringe projection profilometry is generally used to measure the 3D shape of an object, because of the advantages of non-contact operation, full-field acquisition, high resolution, and fast data processing. In this paper, 3D shape measurement method based on surface structured light that combination of gray-code and phase-shift projection is proposed. The wrapped phase of the blade is got by the four-step phase-shift method. In the projection process of the gray-code, due to the ambient light, different surface reflectance and surface physical discontinuous, the edge of gray-code becomes smooth, leading to decode error, so that the gray-code pattern must be binaried before decode. Through the accurate binarization of the blade gray-code pattern, the decoding cycle of the blade is achieved, and the unwrapped phase is achieved by phase unwrapping. Then the unwrapped phase difference between the blade and reference plane is got, the height of the blade can be obtained by the relationship

between the phase difference and the height. The experimental and simulation results show that the proposed method can achieve a high precision, high speed and low cost 3D shape measurement of the blade. The measurement accuracy reaches 0.03 mm. The proposed method extends the reliability and practicality of the fringe projection profilometry.

Keywords: Three-dimensional shape measurement, structured light, gray-code, phase-shift, blade, unwrapped phase, non-contact, gray-code

## **G-185 PMM13-MM100-200**

### **A Designed Circuit for Sintering Optical Fiber Probe**

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#### **ABSTRACT**

In order to meet the needs of sintering optical fiber probe, a discharging device based on CA1524 is presented in this paper. First the direct current (DC) is converted into the high-voltage alternating current by push-pull power amplifier circuit. Then we can get more than 2000 V DC by voltage doubling and rectifying, and it is connected to the electrode rod for high-voltage discharge. LPC1768 is used to control the duty cycle of CA1524, which can regulate the discharge intensity; the discharge time is controlled by the LPC1764 and CA1524.

Keywords: Pulse Width Modulation; CA1524; Push-pull amplifier

## **D-187 PMM13-MM100-205**

### **An Improving Demodulation of Interferometric Fiber Optic Sensor Technology**

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#### **ABSTRACT**

Commonly used in Interferometric fiber optic sensor signal demodulating methods: passive homodyne method, phase tracking method, heterodyne method and the heterodyne method and so on. Based on the principle of phase generated carrier demodulation techniques for error analysis, Research proposed an improved carrier phase demodulation method and established a complete relatively interferometric fiber-optic sensing system. Experiments demonstrated that it improved amplitude-frequency characteristics of the original system, and obtained higher detection sensitivity.

**Keywords:** Interferometric Fiber Optic Sensor, Demodulation, Phase Carrier, Locating

# **G-190 PMM13-MM100-116**

## **Digital Optimeter Based on Linear CCD**

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### **ABSTRACT**

In this paper, the development of a new type of digital optimeter based on linear CCD is introduced and discussed. It is based on traditional autocollimation optical system and optical lever motion, with linear CCD as measuring element. A light band generated by slit is captured by linear CCD after passing through an autocollimation optical system. A piece of mirror placed in the optical path of this system is controlled by displacement of a measuring slide in order to adjust the light band imaging position. The displacement of light band is detected by CCD and is then displayed in digital format. Such a design successfully eliminates the existing issues of signal quality and signal overspeed in digital optimeters using grating as the measuring element. The final product based on this technique has been released, offering a resolution of 0.1 $\mu$ m and 0.02 $\mu$ m.

**Keywords:** optimeter, digital optimeter, Linear CCD, length measuring instrument, digital image processing, autocollimation, optical level

# **D-191 PMM13-MM100-213**

## **Research on Working Clearance Optimization for Non-contact Stress Detection with Magneto-elastic Stress Sensor**

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### **ABSTRACT**

In order to acquire the optimal working clearance for non-contact detecting stress of steel members with magneto-elastic stress sensor, a magneto-elastic sensor probe with E-shaped structure is adopted for carrying out the relevant research. Firstly, the principle of non-contact stress detection is discussed based on magneto-elastic effect, and the magnetic circuit of the magneto-elastic stress sensor is analyzed for deducing the basic output voltage equation of sensor when tested pieces (low carbon steel Q235) is loaded with uniaxial stress, on the basis of ferromagnetism and presented references, the technical parameter of sensor is determined for designing non-contact stress detection system. After that, focusing on the design of the testing program with different excitation frequencies and air gap, actual experiments are carried out to optimize working clearance when tested pieces are loaded with uniaxial stress. Results of the test show that this kind of sensor is not only simple in structure but also valuable with non-destructive, convenient and fast measurement of stress in application.

**Keywords:** magneto-elastic stress sensor, working clearance, E-shaped probe, non-contact detection

## **G-196 PMM13-MM100-24**

# **The accuracy analysis of the intersection measurement on the moving ships**

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### **ABSTRACT**

Based on the principle of the intersection measurement, the mathematical model of measuring the position and dimension of the moving ships was established, and the formula of the metrical accuracy was deduced. The Matlab software was utilized to simulate and emulate the metrical accuracy, and analysed the primary errors of the system measurement accuracy; the measurement model is validated, combined with the examination. The result indicated that the method is feasible which utilized the measurement principle to measure the position and dimension of the moving ships, and establish the basical for further project application.

**Keywords:** intersection measurement, moving ships, accuracy analysis, simulate and emulate, position measurement, dimension measurement, measurement model, metrical accuracy

## **D-199 PMM13-MM100-110**

# **Extending the measuring range of fiber optic displacement sensor with differential evolution optimized extreme learning machine**

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### **ABSTRACT**

A signal processing method for reflective fiber optic displacement sensor is presented by means of a differential evolution optimized extreme learning machine (DE-ELM). The sensing head of the sensor is a combination of an illuminating fiber bundle transmitting incoming light beam and two receiving fiber bundles employed to collect the reflected beam from the reflector. Three fiber bundles with same type are put together and arranged side by side, but the two receiving fiber bundles enfaces have different distances from the reflector surface. The DE-ELM is used for extending the measuring the range of reflective fiber optic displacement sensor. A simulation experiment has been illustrated. The experimental results show that the measuring range can be extended to the whole response characteristics of the fiber optics displacement sensor and a high measuring accuracy can be obtained by the proposed method.

**Keywords:** Fiber optic sensors, displacement, differential evolution, extreme learning machine

## **PMM13-MM100-228**

# **Study on Detection Method of Inner Wall of Small-diameter Workpiece Based on Cone Reflector**

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## **ABSTRACT**

The image detection of the inner wall of the small-diameter workpiece is a difficult problem all along. The industrial endoscope is a common solution of this problem, but its measuring repeatability cannot be guaranteed and it results a large image distortion. In this paper, for this problem, a new method based on the cone reflector has been presented. Firstly, this method introduces a 45-degree cone reflector innovatively, which is placed within the workpiece. Secondly, the optical devices are placed outside, which simplifies the measuring structure and make the adjustment of the optical system easier. Finally, an image conversion method is proposed, making the image observation more intuitive. Though analyses and experiments, the resolution of images obtained from the inner wall can be achieved 10 $\mu$ m/pixel. Meanwhile, the efficiency of measurement has been greatly improved.

**Keywords:** small-diameter, image detection, cone reflector, image conversion

## **A-162 PMM13-MM100-246**

# **A Verification Device for the Stylus Profilometer Sensor**

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## **ABSTRACT**

The accuracy of stylus profilometer sensor directly affects the performance of the profilometer. To ensure good status of the profilometer, the accuracy features of the profilometer sensor should be verified regularly. However by now, only standard samples with comprehensive parameters are adopted for verification of the total profilometer, and there is no verification device for stylus profilometer sensor, especially for that with large range and high resolution. In this paper, a special verification device for stylus profilometer sensor is introduced. The device consists of displacement generation unit, displacement measurement unit and data acquisition and feature analysis software unit. A motor and PZT are combined to be a large range and high resolution displacement generator in the displacement generation unit, and a grating interference displacement measurement unit gives standard value of the displacement. When a sensor should be verified, the displacement generation unit generates displacement within the measuring range of the stylus sensor, and the displacement is input to the sensor, the output of the sensor is compared with the data measured by the grating interference displacement measurement unit, and the acquisition and feature analysis software unit shows the accuracy features of the stylus sensor. A double frequency laser interferometer is applied to the verification device for experimental testing, its high accuracy, stability, reliability and wide range is verified, which satisfies the large-scale



verification requirement of stylus profilometer sensor.

**Keywords:** Stylus Profilometer Sensor, large scale, high resolution, verification

## **D-181 PMM13-MM100-247**

### **A Small Angle Dynamic Measuring Device**

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#### **ABSTRACT**

Small angle measurement has been widely use for the alignment or error compensation of a mechanical system. In this paper a small angle dynamic measurement device based on laser interference technique is introduced, which consists of a reference module and a measuring module. The measuring module is fixed on the measured object. With the variation of the small tilt angle of the measured object, the phase difference between the two beams from prism1 and prism2 changes according to it. By analyzing the interference patterns, the variation of the small tilt angle can be obtained dynamically. Experimental setup has been established and the results show that the measurement range is 15' with the resolution of 0.08", the measurement error is less than 8".

**Key words:** Small angle; dynamic measurement; laser interference technique

## **PMM13-MM100-248**

### **Comprehensive evaluation of surface topography in running-in wear process**

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#### **ABSTRACT**

Running-in is the initial phase of the entire wear process and significantly influences the performance and service life of wear components. Surface profile is an important feature of wear components, and researchers have made a lot of effort in investigation of running-in based on surface profile. However, surface profile merely contains the two-dimensional information about surface, which cannot represent the three-dimensional information. Due to the technology development of surface measurement and analysis, three-dimensional evaluation of surface topography can effectively extract comprehensive information about surface. Therefore, it is necessary to update the conclusions about running-in wear based on surface profile. This paper adopted areal surface evaluation parameters derived from surface topography instead of surface roughness parameters derived from surface profile to investigate a common phenomenon of running-in, which illustrates that the surface roughness after running-in is independent of the nature of initial roughness. The analysis of experiment result revealed that some properties of surface topography before running-in process are

reserved after running-in.

**Keywords:** Surfaces; Wear and tribology; Parameter; Running-in

**PMM13-MM100-250**  
**Research on Pre-processing of QR Code**

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**ABSTRACT**

QR code encodes many kinds of information because of its advantages: large storage capacity, high reliability, full arrange of utter-high-speed reading, small printing size and high-efficient representation of Chinese characters, etc. In order to obtain the clearer binarization image from complex background, and improve the recognition rate of QR code, this paper researches on pre-processing methods of QR code (Quick Response Code), and shows algorithms and results of image pre-processing for QR code recognition. Improve the conventional method by changing the Souvola's adaptive text recognition method. Additionally, introduce the QR code Extraction which adapts to different image size, flexible image correction approach, and improve the efficiency and accuracy of QR code image processing.

Keywords: digital image process, QR code, recognition algorithm, pre-processing

**G-033 PMM13-MM100-174**  
**3D Measurement Method Based on Combined Temporal Encoding Structured Light**

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**ABSTRACT**

Three-dimensional (3D) vision measurement technology based on encoding structured light plays an important role and has become the main development trend in the field of 3D non-contact measurement. However, how to synthetically improve measurement speed, accuracy and sampling density is still a difficult problem. Thus in the present work, a novel 3D measurement method based on temporal encoding structured light by combining trapezoidal phase-shifting pattern and cyclic code pattern is proposed. Due to trapezoidal phase-shifting has the advantages of high sampling density and high-speed, the proposed method can maintain these advantages by using cyclic code to expand the range of trapezoidal phase-shifting. In addition, the correction scheme is designed to solve the problem of cycle dislocation. Finally, simulation experimental platform is built with 3ds max and MATLAB. Experimental analyses and results show that, the maximal error is less than 3 mm in the range from 400 mm to 1100 mm, cycle dislocation correction has a good effect.

**Keywords:** Three-dimensional vision measurement; cyclic code; trapezoidal phase-shifting; cycle dislocation correction; simulation

## **I-123 PMM13-MM100-63**

# **Error Analysis and Modeling for the Time Grating Length Measurement System**

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### **ABSTRACT**

Through analyzing errors of the length measurement system in which a linear time grating was the principal measuring component, we found that the study on the error law was very important to reduce system errors and optimize the system structure. Mainly error sources in the length measuring system, including the time grating sensor, slide way, and cantilever, were studied; and therefore total errors were obtained. Meanwhile we erected the mathematic model of errors of the length measurement system. Using the error model, we calibrated system errors being in the length measurement system. Also, we developed a set of experimental devices in which a laser interferometer was used to calibrate the length measurement system errors. After error calibrating, the accuracy of the measurement system was improved from original 36um/m to 14um/m. The fact that experiment results are consistent with the simulation results shows that the error mathematic model is suitable for the length measuring system.

**Keywords:** length measurement system, error analysis, error modeling, time grating