

36th ASPE Annual Meeting 2021

Minneapolis, Minnesota, USA
1 – 5 November 2021

ISBN: 978-1-7138-4256-9

Printed from e-media with permission by:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571



Some format issues inherent in the e-media version may also appear in this print version.

Copyright© (2021) by American Society for Precision Engineering (ASPE)
All rights reserved.

Printed with permission by Curran Associates, Inc. (2022)

For permission requests, please contact American Society for Precision Engineering (ASPE)
at the address below.

American Society for Precision Engineering (ASPE)
230 Washington Ave. Ext., Suite 101
Albany, NY
12203

Phone: (518) 463-8687
Fax: (518) 463-8656

www.aspe.net

Additional copies of this publication are available from:

Curran Associates, Inc.
57 Morehouse Lane
Red Hook, NY 12571 USA
Phone: 845-758-0400
Fax: 845-758-2633
Email: curran@proceedings.com
Web: www.proceedings.com

ASPE 2021 Annual Meeting

Oral Sessions

Session 1 – Optomechanical Sensing for Gravity, Acceleration, and Optical Power

Wednesday, November 3, 2021, 8:30 AM – 10:00 AM

Session Chairs:

Felipe Guzman, Texas A&M University

Jon Pratt, National Institute of Standards and Technology

- Four Challenges Met in the Development of Laser Metrology for the LISA Gravitational Wave Detector***

Spero, R. (California Institute of Technology)

- An Electrostatic Force Balance as a Primary Standard to Measure High Laser Power by a Multiple Reflection System**

Schulze, S.; Keck, L.; Rogers, K.; Simonds, B.; Artusio-Glimpse, A.; Williams, P.; Lehman, J. (National Institute of Standards and Technology); Seifert, F. (National Institute of Standards and Technology; University of Maryland); Newell, D. (National Institute of Standards and Technology); Theska, R. (Technische Universität Ilmenau); Schlamming, S.; Shaw, G. (National Institute of Standards and Technology)11

- Membrane-based Optomechanical Accelerometry by a Multiple Reflection System**

Chowdhury, M.D.; Agrawal, A.R.; Pluchar, C.M.; Wilson, D.J. (University of Arizona)

.....16

- An Experiment to Test the Mechanical Losses of Different Bonding Techniques in Fused Silica**

Carter, J.J. (Max Planck Institute for Gravitational Physics (Albert Einstein Institute); Institut für Gravitationsphysik der Leibniz Universität Hannover); Birckigt, P. (Fraunhofer Institute for Applied Optics and Precision Engineering; Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Albert-Einstein-Str.) Gerberding, O. (Institut für Experimentalphysik); Li, Q. (Institute of Applied Physics, Abbe Center of Photonics, Friedrich-Schiller-Universität Jena, Albert-Einstein-Str.); Strüning, R. (Institut für Gravitationsphysik der Leibniz Universität Hannover); Ullsperger, T. (Max Planck Institute for Gravitational Physics (Albert Einstein Institute); Koehlenbeck, S.M. (Albert Einstein Institute); Institut für Gravitationsphysik der Leibniz Universität Hannover)21

*No Abstract Available

5. **A New Spin on Kibble: A Self-Calibrating Torque Realization Device**
 Comden, Z. (National Institute of Standards and Technology; University of Maryland);
 Schlamming, S. (National Institute of Standards and Technology) Perera, C.W.;
 Seifert, F.; (National Institute of Standards and Technology; University of Maryland);
 Newell, D.; Hendricks, J.; Goldstein, B.; Chao, L. (National Institute of Standards and
 Technology)27

Session 2 – Precision Design

Wednesday, November 3, 2021, 10:30 AM - 12:00 PM

Session Chair:

Adam Jaycox, Lawrence Livermore National Laboratory

1. **Internal Feature Design for Increased Damping by Captured Powder**
 Schmitz, T.L. (The University of Tennessee, Knoxville; Oak Ridge National
 Laboratory); Corson, G.; Compton, B. (The University of Tennessee, Knoxville);
 Gomez, M. (Oak Ridge National Laboratory)32
2. **Characteristics of Additively Manufactured Auxetic Materials for Spindle Vibration
 Mitigation**
 Kim, J.; Hegde, H. (Texas A&M University); Kim, H. (Korea Institute of Industrial
 Technology; Korea Polytechnic University); Lee, C. (Texas A&M University)37
3. **High-speed Large-range Flexure-based Six-Axis Positioner**
 Yang, Z.; Hopkins, J. (University of California, Los Angeles)41
4. **Improving Support Stiffness of Flexure Mechanisms by Statically Balancing**
 de Jong, J.J.; Theans, S.; Epping, L.J.; Brouwer, D.M. (University of Twente)45
5. **Multi-Material Component Optimization via Hybrid Manufacturing**
 Jared, B.H.; Miramontes, E.; Hamel, W.R.; Penney, J.; Schmitz, T.L. (The University of
 Tennessee, Knoxville); Robbins, J. (Sandia National Laboratories)49
6. **Design of the Mechanical System for the Quantum Electro-mechanical Metrology
 Suite**
 Keck, L. (National Institute of Standards and Technology; Technische Universität
 Ilmenau); Schlamming, S. (National Institute of Standards and Technology);
 Seifert, F. (National Institute of Standards and Technology; University of Maryland);
 Newell, D. (National Institute of Standards and Technology); Theska, R. (Technische
 Universität Ilmenau); Haddad, D. (National Institute of Standards and Technology)
53

*No Abstract Available

2021 ANNUAL MEETING VOLUME 75

Session 3 – Micro Nano

Thursday, November 4, 2021, 8:30 AM - 10:00 AM

Session Chair:

Michael A. Cullinan, The University of Texas at Austin

1. **Integrated Approach for Parametric Design and Fabrication of V-groove-based Functional Structures**
Churchill-Baird, J.T.; Tutunca-Fatan, O.R. (Western University); Bordatchev, E.V. (National Research Council of Canada)**57**
2. **Design and Verification of a Lens Focus Module Based on a Bi-directional Thermoelectric Actuator**
van den Buecken, N. (NTS-Group, Eindhoven University of Technology)**63**
3. **Large-Area Stitch-Free 3D Nano-Printing Based on Two-Photon Polymerization**
Lu, W.; Shao, Q. (The Chinese University of Hong Kong); Chen, S. (The Chinese University of Hong Kong; Oxford-CityU Centre for Cerebro-Cardiovascular Health Engineering (CoCHE))**67**
4. **Testing for Torsion During Nanoindentation**
Fan, C.; Smith, S.T. (The University of North Carolina at Charlotte)**72**
5. **Experimental Characterization of Heat Affected Zones for Fabricating Near-net Shaped Microscale Features**
Behera, D.; Liao, A.; Cullinan, M.A. (The University of Texas Austin)**78**
6. **Precision Systems for a Conformable, Capillary-Driven, Continuous Roll-to-Roll Nanoimprint Lithography Process**
Pandya, P.N.; Jain, A. (The University of Texas at Austin); Gilpin, R.; Baines, J. (E+R Group); Sreenivasan, S.V. (The University of Texas at Austin).....**83**

Session 4 – Controls & Mechatronics

Thursday, November 4, 2021, 10:15 AM - 12:00 PM

Session Chair:

David L. Trumper, Massachusetts Institute of Technology

1. **Piezoelectric Shunt Damping in Cryogenic Conditions: Application to a Flexure-based Mechanism**
Ambaum, N.; Vermeulen, J.P.M.B. (Eindhoven University of Technology); Mokrani, B. (ASML Netherlands)**89**

*No Abstract Available

AMERICAN SOCIETY FOR PRECISION ENGINEERING

2. Intelligent Online Scan Sequence Optimization for Uniform Temperature Distribution in Laser Powder Bed Fusion	Okwudire, C.E.; Ramani, K.S.; He, C. (The University of Michigan)	97
3. Thermal Error Compensation for Large Machine Tools	Ibabe, B.I.; Colinas-Armijo, N. (IDEKO); López de Lacalle, L.N. (EHU-UPV); Aguirre, G. (IDEKO)	102
4. Magnetically Levitated XYZ-Nanopositioning Sample for X-Ray Microscopy	Heyman, I.; Ibrahim, M.; Zhou, L. (University of Texas at Austin)	108
5. Frequency-dependency and Coupled Dynamics of Near Field Acoustic Levitation Bearing	Guo, P.; Wang, Y. (Northwestern University)	114
6. Contact-free, Electrostatically-levitated Reticle Handoff in Photolithography Tools*	Bhushan, B.M.; Trumper, D.L. (Massachusetts Institute of Technology)	
7. Active Control of High Frequency Regenerative Chatter Vibrations with Machine Tool Feed Drives	Sencer, B.; Dumanli, A. (Oregon State University)	120

Session 5 – Replicated Optics

Thursday, November 4, 2021, 1:30 PM – 3:00 PM

Session Chair:

Jim Nelson, 3M Company

1. Single Point Diamond Turning of CVC SiC Using the Micro-LAM Process	Shahinian, H.; Zhong, Y.; Turnbull, R.; Bodlapati, C.; Navare, J.; Mohammadi, H. (Micro-LAM, Inc.)	125
2. Simulation and Comparative Metrology of Diamond Dies, Metal Molds, and Replicated Microlens Arrays for Mass Fabrication	Eaton, P. (North Carolina State University); Furst, S.J.; Cates, N.; Micklow, L. (Smart Material Solutions, Inc.); Pankow, M. (North Carolina State University)	130
3. Metrology of Ultra-High Precision Stamped Metallic Optical Mirrors for Photonics Packaging and Ultraviolet LED Applications	Chen, Y.; Johnstone, R.; Hii, K.; Vallance R.R. (CudoForm, Inc.)	136

*No Abstract Available

4. Precision in Roll-2-Roll Printed Electronics: Keynote	
Spaan-Burke, T.M.; van der Nolle, R.; de Vries, J.; Daneshkhah, B.; Felius, M.; Overschie, P.; Hannot S. (IBS Precision Engineering)	142
5. Single-Point Diamond Turning of Features with Large Azimuthal Slope	
Sohn, A.; Naples, N. (Facebook Reality Labs).....	146

Session 6 – Replicated Optics

Friday, November 5, 2021, 8:30 AM – 10:00 AM

Session Chairs:

Jonathan D. Ellis, Clerio Vision, Inc.

Richard K. Leach, University of Nottingham

1. Qualitative Edge Topology Inspection and Interpretation by Enhanced Knife-Edge Interferometry	
Lee, C.; Wang, Z. (Texas A&M University).....	152
2. The Effect of Motion Blur on Photogrammetric Measurements of a Robotic Moving Target	
Isa, M.A. (University of Nottingham); Leach, R.K. (University of Nottingham; Taraz Metrology); Branson, D.; Piano, S. (University of Nottingham)	155
3. Preliminary Study on Fluorescence Strobo-Stereoscopy for 3D Surface Imaging	
Guo, X.; Lee, C. (Texas A&M University)	161
4. Ultra-High-Speed Micromachining Spindle Metrology under Radial Loading Conditions	
Nahata, S.; Ozdoganlar, O.B. (Carnegie Mellon University)	165
5. Lateral Shift Mapping for Absolute Metrology of Acylindrical X-ray Telescope Mirrors	
Wisniewski, H.J. (The University of Arizona); Whalen, M.M; Heilmann, R.K.; Shattenburg, M.L. (Massachusetts Institute of Technology); Chalifoux, B.D. (The University of Arizona)	171
6. A Pilot Study on Uncertainty Analysis for Stereo-vision Photogrammetry	
Lifei, R. (The Hong Kong Polytechnic University; Zhejian University); Fai, C.C. (The Hong Kong Polytechnic University); Yanlong, C. (Zhejian University) Da, L. (The Hong Kong Polytechnic University); Jiangxin, Y.; Yanpeng, C. (Zhejian University)	178

***No Abstract Available**

AMERICAN SOCIETY FOR PRECISION ENGINEERING

Session 7 – Precision Manufacturing
Friday, November 5, 2021, 10:30 AM – 12:00 PM
Session Chair:
Stephen J. Furst, Smart Material Solutions, Inc.

1. **Single Point Diamond Cutting of High-Aspect Ratio V-Grooves: Alternative Flank Cutting Strategy and Preliminary Burr Formation Analysis**
Rangel, O.F.; Tutunea-Fatan, R. (Western University); Bordatchev, E.V. (National Research Council of Canada)183
2. **Tool Wear Evaluation Using a Constrained-motion Dynamometer**
Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (Oak Ridge National Laboratory; University of Tennessee, Knoxville)189
3. **Integral Blade Rotor Milling Improvement by Physics-guided Machine Learning**
Corson, G. (University of Tennessee, Knoxville); Karandikar, J. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)193
4. **A New Diamond Turning Model for Generating a Scratch-Free Surfaces in AL 6061 with Embedded Hard Particles**
Ding, X.; Roblee, J. (AMETEK Precitech Inc.)199
5. **Ductile Cutting Regime in Diamond Milling of Monocrystalline Silicon**
Groeb, M. (Kern Microtechnik GmbH; Technical University of Darmstadt); Fritz, M. (Kern Microtechnik GmbH); Groeb, J. (Independent Researcher); Ensinger, W. (Technical University of Darmstadt)205
6. **Ultrafast Laser Stress Figuring of Fused Silica Mirrors**
Laverty, K.A.; Arnold, I.J.; Chalifoux, B.D. (University of Arizona)211

*No Abstract Available

2021 ANNUAL MEETING VOLUME 75

ASPE 2021 Annual Meeting

Poster Sessions

Wednesday, November 3, 2021, 3:30 PM – 5:00 PM

Thursday, November 4, 2021, 3:30 PM – 5:00 PM

1. **Fundamental Precision Limit of Frequency Measurement of Linear Harmonic Oscillators**
Wang, M. (National Institute of Standards and Technology; University of Maryland); Zhang, R. (Worcester Polytechnic Institute); Illic, R. (National Institute of Standards and Technology); Liu, Y. (Worcester Polytechnic Institute); Aksyuk, V.A. (National Institute of Standards and Technology).....**215**
2. **CNC Machining and Metrology Training: ACE Program Update**
Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory); Cornelius, A.; Dvorak, J.; Nazario, J. (University of Tennessee, Knoxville); Betters, E. (University of Tennessee, Knoxville; Oak Ridge National Laboratory); Smith, S.; Blue, C. (Oak Ridge National Laboratory); Harmon, J.; Morrison, M.; Blevins, T.; Hopkins, J. (IACMI – The Composites Institute)**220**
3. **Optical Knife-edge Displacement Sensor Modeling**
Zameroski, R. (University of Tennessee, Knoxville); Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)**22□**
4. **Stability Analysis of a Constrained-motion Dynamometer**
Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)**232**
5. **Tool Wear Evaluation Using a Constrained-motion Dynamometer**
Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)**238**
6. **CNC Machining Considerations for WAAM Preforms**
Dvorak, J.; Cornelius, A.; Corson, G.; Zameroski, R.; Jacobs, L.; Penney, J. (University of Tennessee, Knoxville); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)**242**
7. **Surface Metrology of a DED Lens AM Part: Optical Microscope***
Morgan, W.; Yazzie, J.; Wilson, W. (Navajo Technical University); Valdez, M.O.; Montano, J.D. (V&M Global Solutions LLC), Haliday, H.S.; Shanmugam, R.; Romani, M. (Navajo Technical University)

***No Abstract Available**

AMERICAN SOCIETY FOR PRECISION ENGINEERING

- 8. Surface Metrology of a DED Lens AM Part: Contact Surface Profilometer***
Yazzie, J.; Morgan, W.; Wilson, W. (Navajo Technical University); Valdez, M.O.;
Montano, J.D. (V&M Global Solutions LLC), Haliday, H.S.; Shanmugam, R.; Romani, M.
(Navajo Technical University)
- 9. Effects of Surface Treatments on ABS Mechanical Properties for Fused Filament Fabrication**
Shen, J.; Patterson, M.R.; Marshall, E.; Dvorak, J.; Romberg, S.; Compton, B.
(University of Tennessee, Knoxville) Schmitz, T.L. (University of Tennessee,
Knoxville; Oak Ridge National Laboratory) **248**
- 10. A Prototype Contamination Inspection System for DUV/EUV Reticles**
Papadakis Ktistakis, I.; Pawlowski, M.E.; Walsh, J.; Loke, C.; Bendiksen, A.; Munden,
R.; Roux, S. (ASML) **254**
- 11. A Torsion Pendulum for Chip-scale Relative Gravimetry**
Pratt, J.R.; Schlamminger, S. (National Institute of Standards and Technology);
Agrawal, A.R.; Wilson, D.J. (University of Arizona) **260**
- 12. Optomechanical Inertial Sensors***
Guzman, F. (Texas A&M University)
- 13. Remote Bayesian Updating for Milling Stability**
Karandikar, J. (Oak Ridge National Laboratory); Ramsauer, C.; Leitner, D. (University
of Tennessee, Knoxville); Schmitz, T.L. (Oak Ridge National Laboratory; University
of Tennessee, Knoxville); Bleicher, F. (University of Tennessee, Knoxville) **266**
- 14. Accounting for Shrinkage in Functional Ceramic Structures Printed through Two-photon Polymerization**
Cortes, J.; Mettry, M.; Worthington, M.; Chandrasekaran, S.; Panas, R.M. (Lawrence
Livermore National Laboratory) **271**
- 15. Precision Stamp-based Thin-film Material Transfer System Using Soft-robotic Manipulation**
Ahn, S.; Zhou, L. (University of Texas at Austin) **276**
- 16. Ductile Cutting Regime in Diamond Milling of Monocrystalline Silicon**
Groeb, M. (Kern Microtechnik GmbH; Technical University of Darmstadt); Fritz, M.
(Kern Microtechnik GmbH); Groeb, J. (Independent Researcher); Ensinger, W.
(Technical University of Darmstadt) **282**

*No Abstract Available

2021 ANNUAL MEETING VOLUME 75

17. Milling Force Prediction Case Study for Non-standard Geometry Endmill Using Structured Light Scanning	No, T. (University of Tennessee, Knoxville); Gomez, M. (Oak Ridge National Laboratory); Schmitz, T.L. (University of Tennessee, Knoxville; Oak Ridge National Laboratory)	288
18. Force-controlled Electrode Holder for Lathe-type Electrochemical Discharge Machine	Furutani, K.; Tsuchiya, T. (Toyota Technological Institute)	294
19. In-process Machining Process Monitoring Based on Impedance Model of Dielectric Coating Layer at Tool-chip Interface	Chun, H.; Kim, J.; Lee, C. (Texas A&M University)	298
20. Microfabrication and Experimental Investigation of Drag Reduction and Fouling Resistance Potential of Asymmetric Triangular Riblets	Hamilton, B.W.; Tutunea-Fatan, R. (Western University); Bordatchev, E.V. (National Research Council of Canada)	302
21. A set of Turing Complete Mechanical Logic Elements and a Simple Logic Circuit	Sun, F.; Panas, R.M.; Bekker, L.; Pascall, A.J. (Lawrence Livermore National Laboratory)	308
22. A Dynamic Athermalization Approach for Precision Machine Designs*	Hijkoop, E.G.; Verbaan, K.; van Swaaij, S. (NTS-Group)	
23. Self-Sensing Hysteresis-Type Bearingless Motor	Homiller, L.; Zhou, L. (University of Texas at Austin)	312
24. Time-domain Based Early Detection of Chatter Vibrations	Bahtiyar, K.; Sencer, B. (Oregon State University)	317
25. Volumetric Two-Photon Polymerization Based on Computer-Generated Holograms	Fu, Z. (The Chinese University of Hong Kong); Liu, K. (Tsinghua University); Wang, Y. (The Chinese University of Hong Kong; Centre for Perceptual and Interactive Illetelligence Ltd.); Chen, S. (The Chinese University of Hong Kong; Tsinghua University)	322
26. Parallel 3D Nanofabrication Using 1000 Programmable Laser Foci	Ouyang, W. (The Chinese University of Hong Kong); Han, F.; Chen, C. (The Chinese University of Hong Kong; Tsinghua University)	327
27. Control Co-design for Magnetically-suspended Stages with Light Weight and Flexible Structure	Wu, J.; Zhou, L (University of Texas at Austin)	332

*No Abstract Available

AMERICAN SOCIETY FOR PRECISION ENGINEERING

28. Study on Non-Axisymmetric 3D Curved Surface Turning by Driven-Type Rotary Tool Synchronized with Sprindle Ishizuka, A.; Morimoto, Y.; Hayashi, A.; Kaneko, Y.; Suzuki, N. (Kanazawa Institute of Technology)	338
29. Scaleable Positioning System for Minimal Time to Market and Low Cost* van den Braber, R.; Verbaan, K. (NTS-Group)	
30. Innovation in Nanopositioning* Raby, A.; Bartlett, G. (Prior Scientific Instruments Ltd.)	
31. Deep Learning Workflows for Dimensional Metrology with High-Resolution X-ray Computed Tomography Tekawade, A. (Argonne National Laboratory); Villarraga-Gomez, H. (Carl Zeiss Industrial Metrology, LLC); Andrew, M. (Carl Zeiss X-ray Microscopy, Inc.) Sforzo, B.A.; Kastengren, A.L.; Powell, C.F. (Argonne National Laboratory)	344
32. Design and Verification of a Planar, Flux-Steering Magnetic Actuator* Anthis, A.F.; Trumper, D.L.; Hamer, T.T. (Massachusetts Institute of Technology)	
33. Advancing Throughput and Image Quality in 3D X-ray Microscopy by Deep Learning Reconstruction Techniques Villarraga-Gomez, H. (Carl Zeiss Industrial Metrology, LLC); Andreyev, A.; Andrew, M.; Bale, H.; Sanapala, R.; Terada, M.; Gu, A.; Johnson, B. (Carl Zeiss X-ray Microscopy, Inc.); Omlor, L. (Carl Zeiss, Inc.); Graf vom Hagen, C. (Carl Zeiss X-ray Microscopy, Inc.)	347
34. Design of a Polariscope Tool for the Evaluation of Strain in Roll-to-roll Nanofabrication Groh, B.T.; Connolly, L.G.; Cullinan, M.A. (University of Texas at Austin)	353
35. Optical Fiber Surface Probe Using Mechanically Modulated Fabry Perot Interferometer Shabahang, F.; Smith, S.T. (University of North Carolina at Charlotte)	355
36. Relaxed Uncertainty Dimensional Metrology for Assembly via Photogrammetry Using Open-Source Libraries Nawab, R.; Allen, A.D. (University of North Carolina at Charlotte); Lee, N. (Caterpillar Inc.)	360
37. Precision Design and Error Analysis of a Pump Variable Volute Mechanism Johnson, H.A.; Slocum, A.H. (Massachusetts Institute of Technology)	365
38. Interference Fit, Sub-Micron Piloted Tool Holder Arneson, D. (Professional Instruments Company)	370
39. Effect of Squeeze Film on Dynamics of an Air Bearing* Knapp, B.; Arneson, D.; Oss, D. (Professional Instruments Company)	

*No Abstract Available

2021 ANNUAL MEETING VOLUME 75