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# **Emerging MOEMS Technology and Applications**

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This JM3 special section on emerging MOEMS comprises a collection of excellent papers emphasizing new technologies in MOEMS applications that have come to existence. The section includes outstanding new results in commercial research and development in photonics where micro-optics and MEMS are merged and innovative breakthrough devices come to light.

Recent demands for emerging miniature components for optical communication, digital imaging, sensors and actuators, wireless systems, and adaptive optics that are low cost with high performance and high reliability led researchers to consider batch processing in high clean room environments being the only solution. MEMS, MOEMS, and micro-optics have a foundation of integrated circuits (ICs) and involve batch processing in clean rooms facilities. MEMS is a micro-device that contains both electrical and mechanical elements. MOEMS is a microdevice that contains electrical, mechanical, and optical elements. Sometimes in literature, optical MEMS refer to MOEMS. However, by definition, optical components in MOEMS are always micro-optics, where in optical MEMS, optical components could be both micro-optics or bulk optics.

The field of micro-optics is now an important part of the photonics industry since it produces low cost components by batch processing and it has grown into a significant technology in the past three decades. SPIE's Photonics West convention has more than 80 conferences in the Opto and Bios symposiums, and most cover micro-optics. The development of a wide range of fabrication technologies, including diffractive optics, grayscale photolithography, and low cost replication techniques, has improved the precision, reliability, and quality of micro-optic devices that can be designed and fabricated using standard batch processing.

MOEMS components are compact and low weight, and can also provide unique functions or even a multiplicity of functions that are difficult or even impossible to achieve with convenient bulk optical processing. MOEMS is an enabling technology for application that cannot be addressed using micro-optics alone and is currently playing a significant role in numerous optical applications. The trend toward miniaturization and integration of conventional optical systems will accelerate the adoption of MOEMS technology in commercialization of many desirable elements of optical communication. MOEMS is a driver to move high tech to emerging technologies.

We present here a special selection of papers mostly presented at Photonics West 2013 at three conferences—Miniaturized Systems, Adaptive Optics, and Digital Micromirrors. Our goals for this special section were to collect recent top achievements of fundamental R&D and critically review them for readers to explain how close these works are to landing as emerging technologies.

The special section has 15 papers. Among them are four articles on digital micromirror devices, three on microscanning applications, three on adaptive optics, and others on three-dimensional profiling, focusing micromirrors, Fabry-Perot filters, and micromachined spectrum analyzers.

Blanche et al. from University of Arizona (USA) report a high speed diffractive optical switch with binary mirrors. It is a true emerging MOEMS device for telecommunication.

Mansur et al. from OPTRA Inc. (USA) report another emerging device for IR scene projector. The authors claim the system contrast is an order of magnitude better than existing IR scene projectors.

Kondiparthi et al. from Indian Institute of Science (India) report on extracting object profiles in 3D.

The method does not require full video projectors. The authors claim the system deals with noise reduction algorithms for fringe projection techniques.

Hofmann et al. from Fraunhofer Institute for Silicon Technology (Germany) report on a MOEMS device for an omnidirectional scanning system. This device is a true emerging MOEMS with a large size optical scanning mirror. The device is batch processed for low cost manufacturing.

Kronast et al. from Furtwangen University (Germany) report a true MOEMS focusing micromirror device built in SOI wafers. The scanning mirror is rather large in 6 mm in diameter scans by electrostatic actuation.

Mu et al. from National University of Singapore report a Polygonal Pyramidal Reflector for Bioimaging which is highly desired in some clinic applications.

Morley et al. from EPIR Technologies Inc. and six other research institutes all (USA) report design and fabrication of Fabry-Perot filters for infrared hyperspectral imagers. This work entertains readers for true understanding of hyperspectral infrared imagers, which are of great interest in applications requiring remote identification of complex chemical agents. The combination of HgCdTe detectors and Fabry Perot filters is highly desirable for hyperspectral detection over a broad wavelength range.

Sandner et al. from Fraunhofer Institute for Photonic Microsystems (Germany) report a gimbaled MEMS scanning mirror with quasi-static resonant actuation. The system is especially developed for adaptive raster scanning. The work is designated for the area of robotics, which is an innovative and growing industry.

Sandner et al. from Fraunhofer Institute for Photonic Microsystems (Germany) report a translator MOEMS actuator with an extraordinarily large stroke developed for fast optical path length modulation and used in miniaturized spectrometers. The system has a large 5 mm in diameter mirror. The system is CMOS compatible with SOI process. This device also has a good chance of being offered as a new upcoming emerging MOEMS system.

Stuerwald et al. from Fraunhofer Institute for Production Technology (Germany) report a new technique for measuring diffraction errors in testing aspheric optics using DMDs.

Love et al. from Los Alamos National Laboratory report a spectral filter based on micromirror arrays. The device is created by placing a DMD at the spectral plane of an imaging spectrometer and using it as a spectral selector device.

Goy et al. from the University of Jena (Germany) report the testing of a lightweight unimorph-type deformable mirror (DM) for wavefront correction in cryogenic instruments. The presented mirror manufactured from the titanium alloy with a piezoelectric disk actuator was cooled to 86 K and characterized for thermally induced deformation and the achievable piezoelectric stroke between room temperature and 86.

Cahoy et al. from the Department of Aeronautics and Astronautics, MIT (USA), report an excellent study to meet the high contrast requirement to image an Earth-like planet around a sun-like star. Such contrasts can be obtained through the use of active optics systems operated on space telescopes. High actuator count deformable mirrors are a key technology for this application. Readers interested

in space exploration could enjoy this scientific article. The paper is chosen for open access.

Graff et al. from Los Alamos National Laboratory report on hyperspectral imaging sensors to be powerful tools for highly selective and sensitive chemical detection applications, but they have significant operational drawbacks. The authors claim they have recently developed and demonstrated a high-speed, high-resolution, programmable spectral filter based on the Texas Instruments DLP and DMD that is capable of performing matched-filter image processing across a 2D field of view directly in the optical hardware, and will enable real-time chemical detection without scanning, large data volumes, or expensive post-processing requirements.

Sabry et al. from Paris University report on an in-plane external fiber Fabry-Perot cavity with a silicon micromachined concave mirror. The authors claim that replacing the standard flat mirror with a concave one will reduce expenses due to wave processing to overcome losses due to diffraction.

We hope this collection of papers demonstrates how MOEMS can revolutionize the photonics industry to bring innovative ideas to the high-tech market.

**Ed Motamedi** is an executive at Revoltech Microsystems. He received his PhD in EE from Northwestern University, Evanston, Illinois, and an MBA from Pepperdine University, Malibu, California. Before founding Revoltech, he worked at Rockwell International for 18 years as program manager, where he was named MEMS champion. At Rockwell, he was also leading development of commercial micro-optics. His current responsibilities at Revoltech are to commercialize biomedical and life sciences devices and promote them to emerge into global markets. He has been an active contributor to IEEE for 10 years and to SPIE for 20 years. He is the founder of MOEMS-MEMS symposium and author/editor of a SPIE MOEMS book. He has more than 20 inventions and 100 publications. He is nominated as IEEE fellow and is a fellow of SPIE.

**Joel Kubby** is the Department Chair of Electrical Engineering at the University of California, Santa Cruz. His research is in the area of micro-electro-mechanical systems (MEMS) with applications in optics, fluidics, and bio-MEMS. Prior to joining the University of California, Santa Cruz, in 2005, he was a manager with the Wilson Center for Research and Technology and a member of technical staff in the Webster Research Center in Rochester New York (1987 to 2005). Prior to Xerox he was at the Bell Telephone Laboratories in Murray Hill, New Jersey, working in the area of scanning tunneling microscopy (STM). He has a PhD in applied physics from Cornell University and a BA in physics from the University of California, Berkeley. He is a co-chair of the SPIE Silicon Photonics conference and the MEMS Adaptive Optics conference.

**Patrick Oden** received his PhD and BS degrees in physics from Arizona University and Montana State University, respectively. After a postdoctoral fellowship at the Universität Berne, Switzerland, and a five-year appointment as a staff scientist at Oak Ridge National Laboratory, he has spent the last 15 years at Texas Instruments Inc. At TI he spends his time working on massively paralleled, digital-micro-mirror MEMS technology and associated business opportunities around this technology. For his contributions, he has been appointed technical fellow of Texas Instruments.

**Wilbool Piyawattanametha** received PhD degree in electrical engineering from the University of California, Los Angeles, in 2004. From 2005 to 2009, he was with the Bio-X Program at Stanford University, Stanford, California. Currently, he is with the National Electronics and Computer Technology Center, the Faculty of Medicine, Chulalongkorn University, and the King Mongkut's Institute of Technology Ladkrabang. He has co-authored over 90 peer-reviewed publications in areas of microelectromechanical systems (MEMS), photonics, and biomedical imaging.