

# MEMS REPORT

1 / 2016



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Dear Customers, Partners and Friends  
of Fraunhofer IPMS,

Institutions such as the Fraunhofer IPMS thrive on continuous conceptual development and new application fields. In this MEMS-Report, we are delighted to be able to highlight our annual participation at the Photonics West Conference in San Francisco in early February and a recently launched EU-project in which the Fraunhofer IPMS will take part. In addition, MESYS – the joint project group of Fraunhofer IPMS and BTU Cottbus-Senftenberg – has presented the results of their work on a new electrostatic drive principle for MEMS devices. The relevance of the results, also in regard to future applications, has been underscored with publication in the prestigious “Nature Communications” journal. MEMS sensors and actuators developed at the Institute have always been an essential part of the required hardware for “Industrie 4.0”. With the new “Smart Wireless Production” working group – in cooperation with the University of Applied Sciences (HTW) Dresden – we are further extending the competence of the institution in this field, particularly in the direction of necessary systems and software solutions. In Prof. Dirk Reichelt, we are pleased to have won an extremely competent group leader.

We wish you all an informative reading of the current MEMS report.



Prof. Dr. Harald Schenk

Prof. Dr. Hubert Lakner

## FRAUNHOFER IPMS RESEARCHER HONORED WITH HUGO GEIGER PRIZE

At the Munich Science Days 2015, the Fraunhofer-Gesellschaft, along with the Free State of Bavaria, is awarding three young scientists the Hugo Geiger Prize. The honored theses concerned energy-efficient semiconductors, powerful diode lasers and new substances for sharper displays. For his outstanding, application-oriented doctoral thesis, Dr. Johannes Müller from the Center Nanoelectronic Technologies of the Fraunhofer IPMS received the 1st Hugo Geiger Prize. Dr. Stefan Hengesbach of Fraunhofer ILT and Dr. Christian Ippen of Fraunhofer IAP were honored with the 2nd and 3rd Hugo Geiger Prizes.



*Award Ceremony Hugo Geiger Prize 2015 (l.t.r.: Prof. Dr. Hubert Lakner, Director of the Fraunhofer IPMS; Dr. Johannes Müller, Prize Winner; Prof. Dr. Alexander Kurz, Executive Vice President of the Fraunhofer-Gesellschaft).*

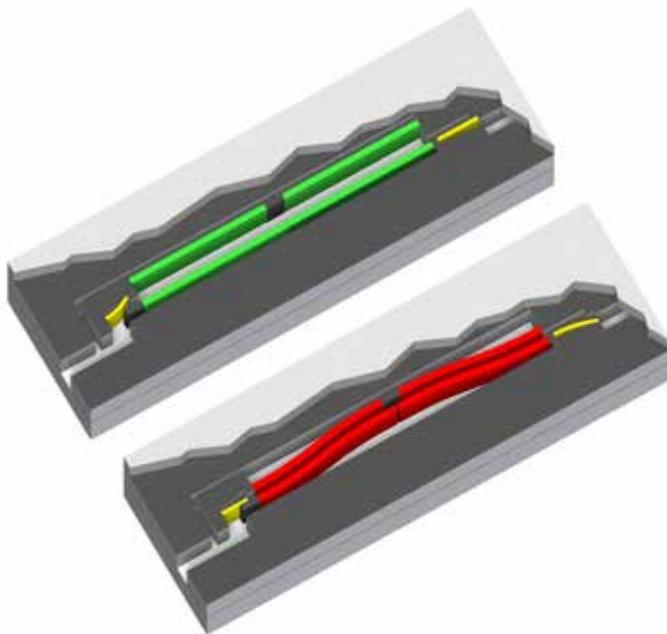
With the proliferation of complex mobile devices such as smartphones and tablets, the demand for high-performance and energy-efficient semiconductor storage increases. Existing materials and technologies, however, are hardly able to keep pace with developments. Silicon-doped hafnium dioxide has excellent ferroelectric properties and is, therefore, ideally suited for semiconductor storage. Dr. Johannes Müller from the Fraunhofer IPMS in Dresden has made decisive contribution to the study and understanding of this substance in his doctoral thesis. He has provided evidence that ferroelectricity may also occur in binary oxides – a phenomenon that has so far only been predicted theoretically. The researcher has thus succeeded in identifying a completely new class of materials – hafnium-based ferroelectrics – with more than 60 publications in scientific journals and at conferences internationally. Thanks to this, very energy-efficient, ultra-small and CMOS-compatible storage technologies have been placed within reach, which hadn't been possible before. Even piezoelectric actuators implemented in a chip or energy harvesters are thus conceivable.

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## JOURNAL "NATURE" TO FEATURE FRAUNHOFER IPMS AND BTU COTTBUS-SENFTENBERG REVIEW OF NEW ACTUATOR PRINCIPLE

Researchers at the Fraunhofer Institute for Photonic Microsystems IPMS and the Brandenburg Technical University Cottbus-Senftenberg (BTU) introduce a novel class of electrostatic micro actuators in the current issue of the "Nature Communications" professional journal.

In 2012, the mesoscopic actuators and systems (MESYS) project group was launched in close cooperation between Fraunhofer IPMS and BTU. The researchers have been developing novel electrostatic microactuators, so-called nanoscopic electrostatic drives (NED), for three years. Now, this highly interesting scientific approach is being introduced to the public for the first time in an article appearing in the respected "Nature Communications" journal. Prof. Dr. Harald Schenk, Director of the Fraunhofer IPMS and Professor of Micro and Nanosystems at BTU, is delighted, "We are very proud of the appreciation of our work and our results being published in this prestigious professional journal. After three years of basic research, we were able to demonstrate a completely new actuator principle."



*Simplified representation of a MEMS-based micro-pump based on the NED approach. The picture shows undeflected bender actuators (green), NED-deflected bender actuators (red) as well as input and output valves (yellow).*

The CMOS compatible actuator technology developed by MESYS solves fundamental problems of electrostatic actuators. Previously, deflection was very limited due to the so-called pull-in-effects and the movement of conventional actuators was restricted to approximately 33 percent of the electrode spacing. This problem has now been solved. Group Leader Holger Conrad explains, "By means of suitable lever mechanisms, deflections which are much greater than the electrode separations are now possible. Therefore, nanometer-small electrode spacings can be deployed, enabling actuators to make use of the enormous force of electrostatic fields."

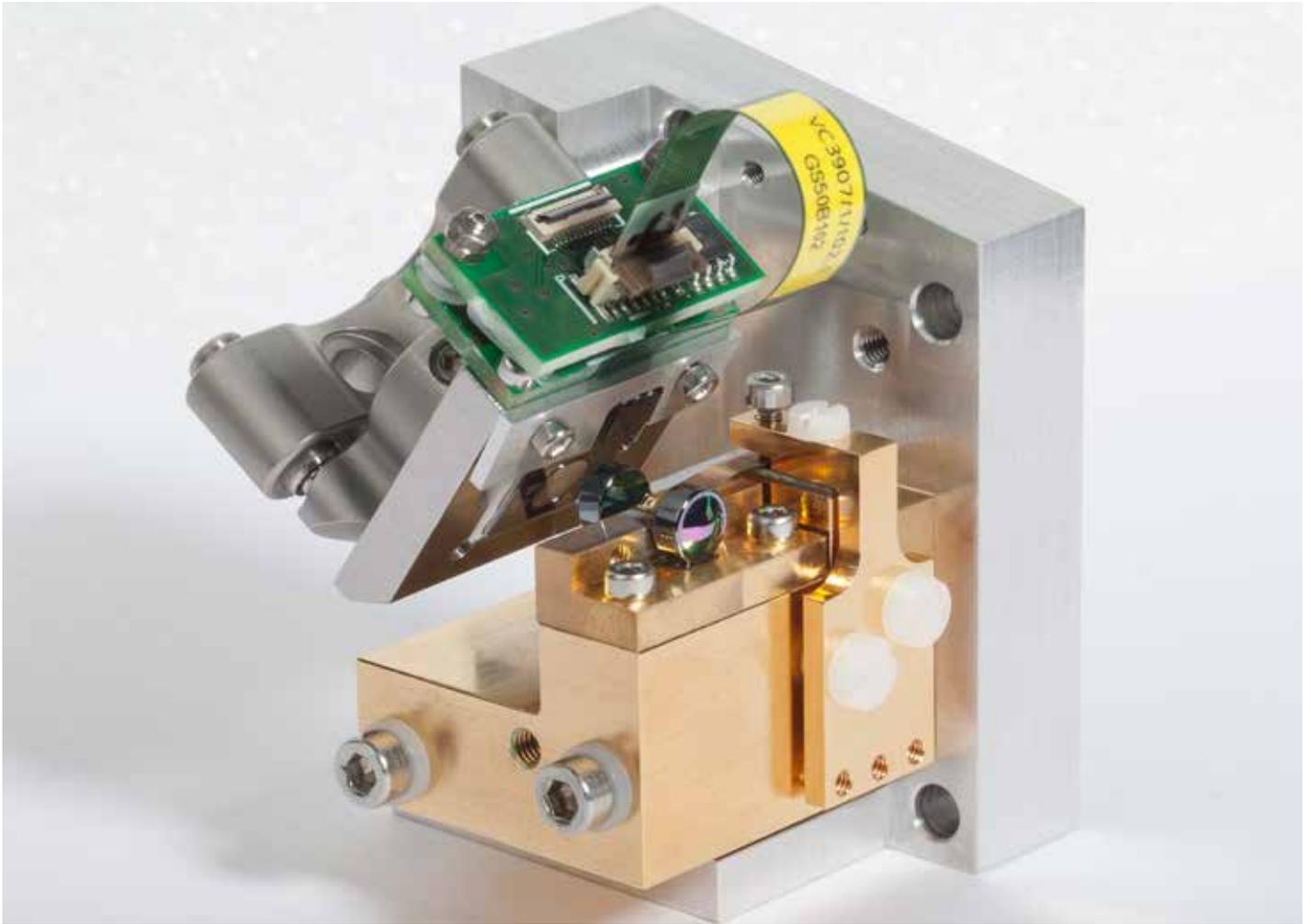
The patented actuator class can greatly improve the performance of microsystems such as capacitive ultrasonic transducers, tilting micro-mirrors and microvalves in the future. In addition, the actuator class provides completely new design solutions for microsystems such as micropumps, MEMS loud speakers or micro positioning systems. Conrad concludes, "Our vision is to develop electrostatic actuators with extremely small gap distances for high deflections at moderate control voltages. We want to extend the developed principle to enable in-plane movement and believe that the new electrostatic bender actuators could possibly replace or supplement piezoelectric or electrostrictive materials in the future. This would then allow for RoHS-compliant bender actuators."

The work of the project group MESYS based at the BTU Cottbus-Senftenberg and at the Fraunhofer IPMS is supported through the Brandenburg Ministry of Science, Research and Culture (MWFK) and the Federal Ministry of Education and Research (BMBF) (grant number: 16V0297).

The article was published on December 11, 2015 and is freely available as Open Access at the following:



## START OF THE NEW EU PROJECT "MIRPHAB"



*QCL module with integrated MEMS diffraction grating.*

**The MIRPHAB (Mid InfraRed PHotonics devices fABrication for chemical sensing and spectroscopic applications) consortium will establish a pilot line to serve the growing needs of the European industry in the field of analytical micro-sensors. Grant-No.: 688265**

Its main objectives are to provide a reliable supply of mid-infrared (MIR) photonic components for companies, in particular SMEs already active in analytical MIR sensing, to reduce investment costs for access to innovative MIR solutions for companies already active in the field of analytical sensors, but new to MIR photonics based sensing and to attract companies new to the field of analytical sensors, aiming to integrate  $\mu$ -sensors into their products. To fulfil those objectives, MIRPHAB is organized as a distributed pilot line formed by leading European industrial suppliers of MIR photonic components, complemented by first class European R&D institutes with processing facilities capable of carrying out pilot line production.

MIRPHAB provides access to MIR photonic devices via mounted/packaged devices for laser-based analytical MIR sensors and expert design for sensor components to be fabricated in the pilot line plus training services to its customers. The platform will be organized in such a way that new developments in MIR micro- and integrated optic components and modules can be adopted and incorporated into the MIRPHAB portfolio. MIRPHAB will work on a convincing scheme for the flow of hardware and information, suitable to operate a distributed pilot line efficiently. MIRPHAB will develop sound business cases and a compelling business plan. Potential cost-performance breakthroughs will be shown for reliable MIR sensing products based on building blocks provided by MIRPHAB.

MIRPHAB will become a sustainable source of key components for new and highly competitive MIR sensors, facilitating their effective market introduction and thus significantly strengthening the position and competitiveness of the respective European industry sector.

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## INDUSTRIE 4.0: FRAUNHOFER IPMS AND HTW DRESDEN COOPERATE

Pooling their expertise in "Industrie 4.0", the Fraunhofer Institute for Photonic Microsystems IPMS and the University of Applied Sciences (HTW) Dresden have come together to form the newly created working group "Smart Wireless Production" (SWP). The collaboration between the two research institutions was officially inaugurated with guests from politics, industry and science on January 14, 2016.

With the SWP working group, Fraunhofer IPMS and the HTW Dresden aim to develop new solutions for digital transformation in industrial production. Through the combination of their competencies in hardware and software development, both Dresden research institutions aim to make future concepts and solutions for the data integration as well as the simple and efficient analysis of business information systems available. The goal is the realization of an intelligent factory in terms of Industrie 4.0 and to establish a sustainable joint research line.

Small and medium-sized businesses in particular face new challenges in international competition. Due to the ever-increasing

presence of electronic systems in all areas of life, networking these systems plays a central role. Quick access to information on the latest technological progress is essential for product development and manufacturing to safeguard company effectiveness and innovativeness. Prof. Dr. Dirk Reichelt, Professor of Information Management at the HTW Dresden and head of the SWP working group at Fraunhofer IPMS says: "It is an important goal of the working group to regionally expand research services provided by the Fraunhofer IPMS and the HTW Dresden to businesses, especially small and medium-sized enterprises. With this cooperation, we would like to contribute to strengthening the capability and competitiveness of our domestic industry by providing innovative solutions in the context of Industrie 4.0." This cooperation offers both the Fraunhofer IPMS and the HTW Dresden the opportunity to address new tenders, customers and markets which have not been fully served yet and to provide complete "one-stop-shop" solutions.

Supported in a three-year initial phase with a total of 1.2 million Euro, the SWP working group is part of the internal Fraunhofer "Colleges Cooperation Program".



*Prof. Dr. Frank Schönefeld, Prof. Dr. Dirk Reichelt, Prof. Dr. Harald Schenk, Dr. Hans-Otto Feldhütter, Prof. Dr. Hubert Lakner, Dr. Eva-Maria Stange, Prof. Dr. Roland Stenzel (f. l. t. r.).*

## FRAUNHOFER IPMS AT SPIE PHOTONICS WEST 2016

The Fraunhofer IPMS presents its latest research and development activities at this year's SPIE Photonics West from February 13 to 18, 2016. We will be more than happy to welcome you at our booth No. 4636 or in one of the lectures held by scientists of our institute.

### Eye safety analysis for non-uniform retinal scanning laser trajectories – Paper 9700-10

13 February 2016 • 1:30 - 1:50 PM | Part of SPIE BiOS

Conference 9700: Design and Quality for Biomedical Technologies IX  
Session 3: Quality of Biomedical Technologies

Authors: Uwe Schelinski, Hans-Georg Dallmann, Heinrich Grüger, Jens Knobbe, Tino Pügner, Peter Reinig, Franziska Woittennek

Laser-scanning the human retina is an approved method in ophthalmology and may also be used for biometric identification. The latter application can emerge if less expensive MEMS-based retina scanners are available. MEMS operate preferably in resonant mode causing non-uniform radiation exposures within the scanned retinal area. Retina-safe Class-1 laser devices must not cause any hazard. Therefore, the laser safety standard requires that all particular impacts are analyzed under different criteria and the strongest limitation must not be exceeded. For exemplary scanning conditions, simulation results are reported to assess the radiation and to identify critical impacts. Generalized approaches are discussed.



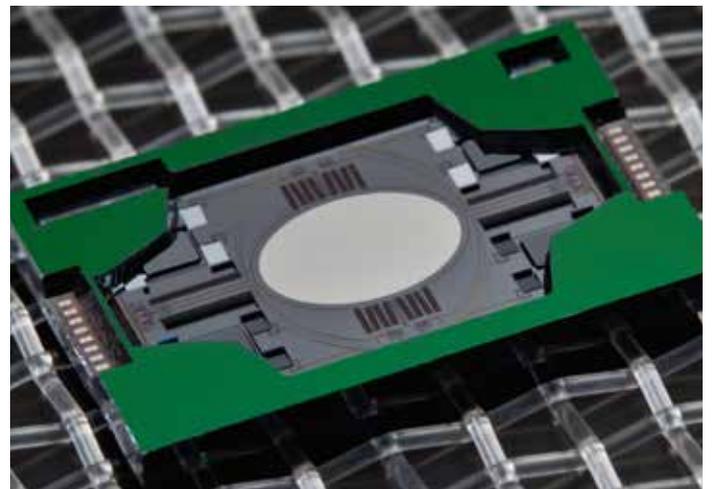
### Real-time control for micro mirrors with quasistatic comb drives – Paper 9760-8

16 February 2016 • 2:40 - 3:00 PM | Part of SPIE OPTO

Conference 9760: MOEMS and Miniaturized Systems XV  
Session 3: Microscanner

Authors: Richard Schroedter, Thilo Sandner, Klaus Janschek

In this paper we demonstrate the closed-loop control of a quasistatic micro mirror with an electrostatic staggered vertical comb drive using a real-time controller and optical feedback. Based on a nonlinear mechatronic system model we apply nonlinear closed-loop control methods with observer based feedback showing the considerable improvements in linearity and repeatability of the control error compared to open-loop control. The application of optimized jerk-limited trajectories improves the avoidance of unfavorable residual oscillation for trajectory frequencies up to two third of the mirror's eigenfrequency. The control concepts have been verified in a simulation with Matlab/Simulink and proved experimentally on a real micro mirror device by Fraunhofer IPMS.



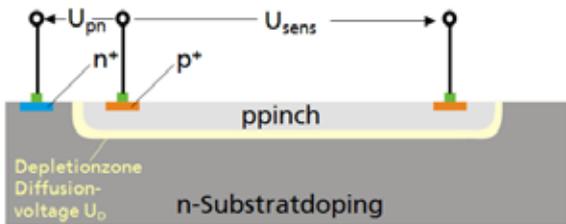
### MEMS-mirror based trajectory resolution and precision enabled by two different piezoresistive sensor technologies – Paper 9760-5

16 February 2016 • 1:30 - 2:00 PM | Part of SPIE OPTO

Conference 9760: MOEMS and Miniaturized Systems XV  
Session 3: Microscanner

Authors: Jan Grahmann, André Dreyhaupt, Christian Drabe, Richard Schrödter, Jörg Kamenz, Andreas Herrmann, Thilo Sandner

Two new technological process flows for the piezoresistive position detection of resonant and quasistatic micro scanning mirrors were developed to increase sensitivities by a factor >10 compared to former sensors, to improve signal to noise ratio of the sensor signal and to allow controlled feedback loop operation. The sensor types use differently doped and deposited silicon. One is based on single crystal silicon with a pn-junction to isolate the active sensor area from the device layer silicon, the other one is based on a deposited and structured polysilicon. The sensor characteristics are compared including light, temperature dependence and reliability results.



SCS-Sensor pn-diode



Polysilicon-Sensor

### Two-fluid variable focus micro-lens with a large deflection polymer actuator – Paper 9760-30

17 February 2016 • 2:30 - 2:50 PM | Part of SPIE OPTO

Conference 9760: MOEMS and Miniaturized Systems XV

Session 7: MOEMS for Sensing and Imaging Applications II

Authors: Florenta A. Costache, Boscij Pawlik, Christian Schirrmann, Kirstin Bornhorst, Andreas Rieck



An electromechanically driven variable focus lens concept with a multilayer polymer actuator was designed and fabricated. The lens consists of two fluidic chambers structured on silicon wafers, bonded together and sealed by an elastic membrane with the polymer actuator attached to it. The lens was designed and optimized using FEM simulations. A ring-shaped actuator ensured a large lens curvature change. Fluids of different refractive indices and low membrane permeability were used to optimize the focus variation and membrane deformation stability. For a 3 mm lens aperture, a focus variation-range of up to 10 dpt was achieved for moderate driving voltages.

## UPCOMING EVENTS

### SPIE Photonics West

San Francisco, USA February 16 - 18, 2016  
Moscone Center, Booth 4636

### Embedded World

Nuremberg, Germany February 23 - 25, 2016  
Nuremberg Exhibition Center, Hall 4, Booth 4-583

### Smart Systems Integration

Munich, Germany March 9 - 10, 2016  
Holiday Inn Munich – City Center, Booth 35

### OFC

Anaheim, USA March 22 - 24, 2016  
Anaheim Convention Center, Booth 2562

### Photonix

Tokyo, Japan April 6 - 8, 2016  
Tokyo Big Sight

[www.ipms.fraunhofer.de/en/events.html](http://www.ipms.fraunhofer.de/en/events.html)

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