FRAUNHOFER INSTITUTE FOR PHOTONIC MICROSYSTEMS IPMS

# MEMS REPORT

2 / 2014

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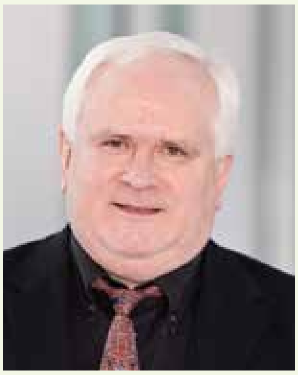
◄ Cover picture: Fraunhofer IPMS clean room for microsystems



Prof. Dr. Hubert Lakner
Director of Institute

Dear Customers, Partners and Friends
of Fraunhofer IPMS,

photonics is regarded as one of the key technologies for dealing with the current global social challenges and for ensuring the continued existence of an industrially successful Europe. An even stronger growth than in other KETs (Key Enabling Technologies) such as micro-/nanoelectronics, nanotechnology, advanced materials and biotechnology is predicted for photonics over the coming years.

This MEMS Report makes it very clear that the Fraunhofer IPMS with its manifold research and development activities perfectly represents the cross-sectional character of photonics. Learn how our spatial light modulators contribute to new light microscopes with improved properties. We report on developments of components based on electro-optically active materials that open up new possibilities in optical telecommunications and fiber optic sensor systems. We present the results of an EU-funded project in which very economically advantageous optical test technologies for the automotive industry and beyond were developed with the participation of the Fraunhofer IPMS. I believe that the sheer scope of these topics demonstrates the institute's appeal for its customers. I wish you an informative read of the latest MEMS Report.

Prof. Dr. Hubert Lakner

# QUICK NOTES

**Trade fair participation "Photonix EXPO & CONFERENCE"**

From 16 to 18 April the Fraunhofer IPMS will, for the first time, participate in the "Photonix EXPO & CONFERENCE" trade fair in Tokyo, Japan, where it will be exhibiting demonstrators from the fields of spatial light modulators (SLM), MEMS scanners and optical wireless data transmission by means of infrared light.

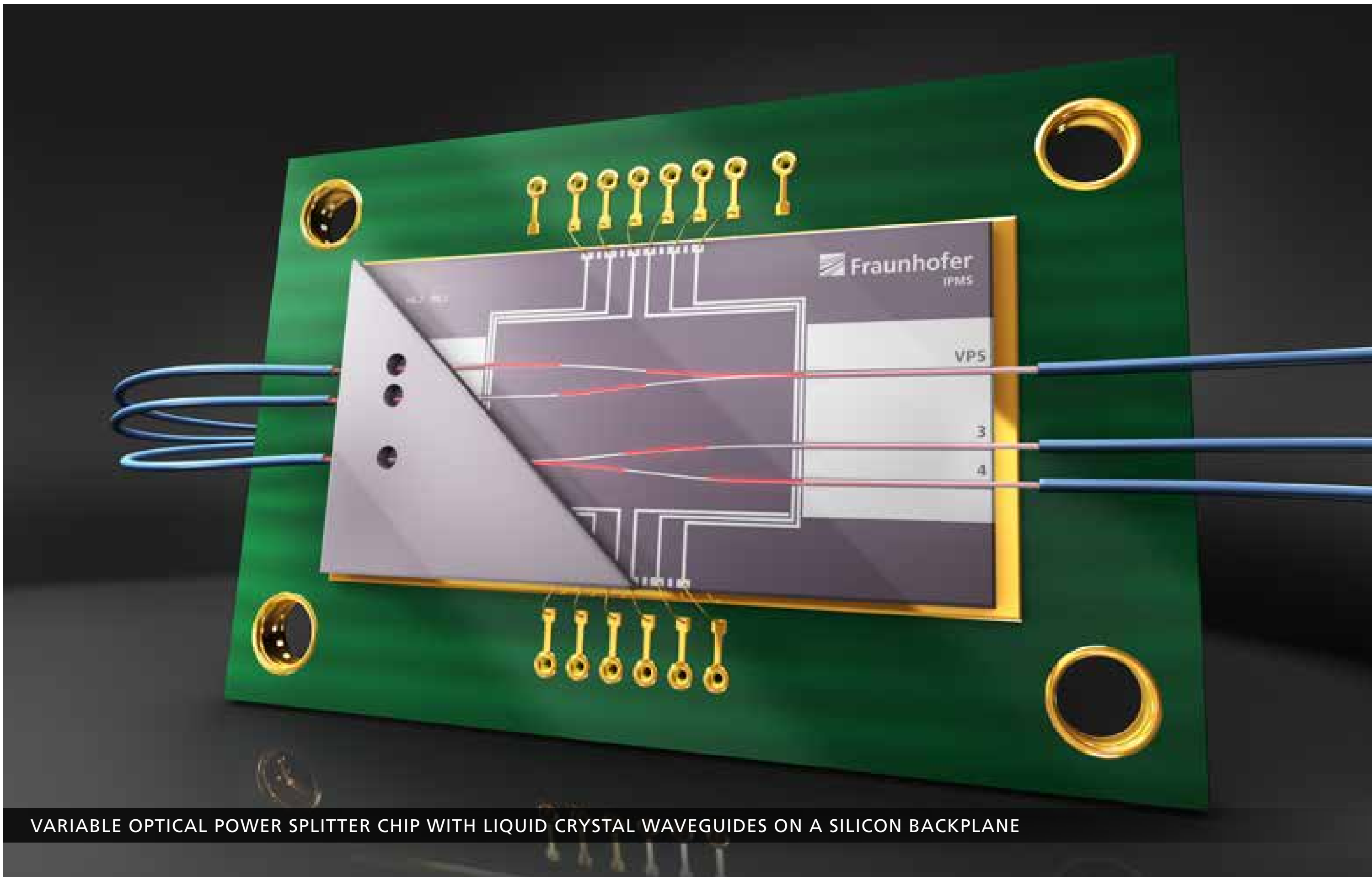
**Fraunhofer Bessel award-winner working on research at the Fraunhofer IPMS**

As one of three award-winners, Dr. Wibool Piyawattanametha received the "Fraunhofer Bessel Research Prize" worth 45,000 euros. This prize honors internationally outstanding foreign scientists from all fields of applied research and gives them the opportunity to conduct a research project at a Fraunhofer institute of their choice.

PROF. DR. SCHENK AND DR. PIYAWATTANAMETHA (RIGHT)

Dr. Piyawattanametha works in Thailand at the Chulalongkorn University Medical School, where he is in charge of the Center for Imaging, and is also the Director of the Laboratory for Integrated Biosensors at the National Electronics and Computer Technologies Center and head of a study group at Stanford University. He works in the field of diagnostic cancer research and develops compact, confocal microscopes that allow an in-vivo optical assessment of cells and that can also be integrated in endoscopes on account of their small size. These systems use scanner mirrors for the optical deflection of the laser beam. In order to further advance his research in this field, we will be welcoming Mr Piyawattanametha as a guest scientist in our institute later this year to establish a field of application for imaging systems in cancer diagnosis at the Fraunhofer IPMS.

## LIGHT PATH CONTROLLER IN FIBER OPTIC NETWORKS

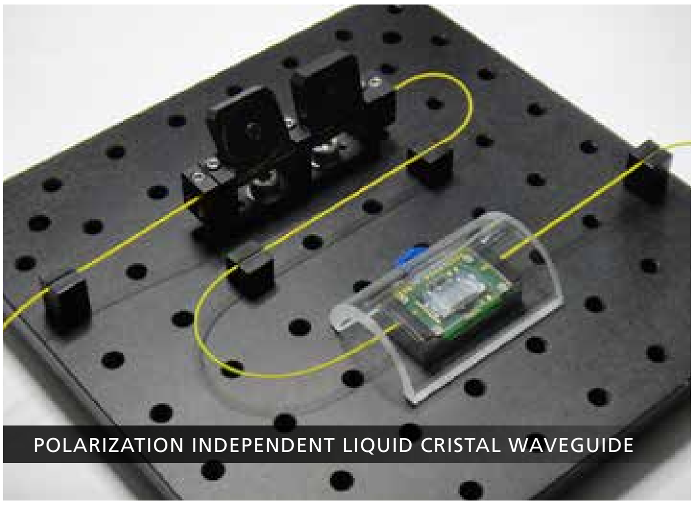



VARIABLE OPTICAL POWER SPLITTER CHIP WITH LIQUID CRYSTAL WAVEGUIDES ON A SILICON BACKPLANE

Fraunhofer IPMS has developed an optical switch / variable optical power splitter device (OS / VOPS), which can enable fast and almost wear-free distribution of light signals in fiber optic networks. The technology is based on waveguides with liquid crystals integrated on a silicon backplane. This OS / VOPS device could have a wide range of applications. Both the optical switching function and the power split ratio are controlled by actively adjusting the transmitted optical power on output channels. In this way optical resources in fiber optic networks can be used efficiently. Further measurement techniques based on multiplexed fiber optic sensors can benefit directly from the Fraunhofer IPMS integrated optical switching solution. Light signals from sensor networks can now be monitored faster (MHz) and more economically.

Telecommunications, environmental monitoring and industrial process control are high-demand applications, which currently benefit from the fast transfer and distribution of data over fiber optic networks. In particular, communications systems increasingly rely on optical fibers to carry information between locations encoded in a beam of light. Routers and switches are used to channel this information on a best path over intricate networks of optical fibers so that the information reaches the user quickly. Optical power splitters (OPS) are used for optical power management in telecommunications networks. OPSs ensure the important functions of splitting and combining optical signals in optical communications networks. By employing OPSs with variable power split ratio, the optical power can be redistributed in the network dynamically and in real-time, providing advantages such as improvement in network flexibility while maintaining the quality of transmission.

On the other hand, optical fibers can have sensors placed on them, the fiber serving in this case as transport medium for the sensor signal to the signal processing (interrogation) instrument. Fiber optic sensors are increasingly used for structural health monitoring, i.e. to measure changes in strain, temperature, pressure or displacement, as well as for controlling and monitoring changes in the environment. In comparison with conventional electrical sensors, they provide increased sensitivity and capability to process data harvested from sensors placed far away and in dangerous or inaccessible areas. Signals collected from sensors are processed by means of spectrometric methods in interrogation instruments. The challenge is to provide portable, rugged, cost-effective instruments, able to monitor data acquired from large networks of multiplexed fiber optic sensors over prolonged periods of time. Making use of reliable switches able to facilitate fast transmission of sensor signals to the processing unit is essential here. To date, signals detected by the optical sensors placed on the fibers can be directed into the processing unit at a maximum rate of a few kHz, which means that about 1000 measurements in a second and about 30 billion measurements in a year can be processed in theory. However, existing technologies such as opto-mechanical switches suffer from limited performance in terms of switching speed, restricted reliability and lifetime due to their mechanical parts as well as high costs.



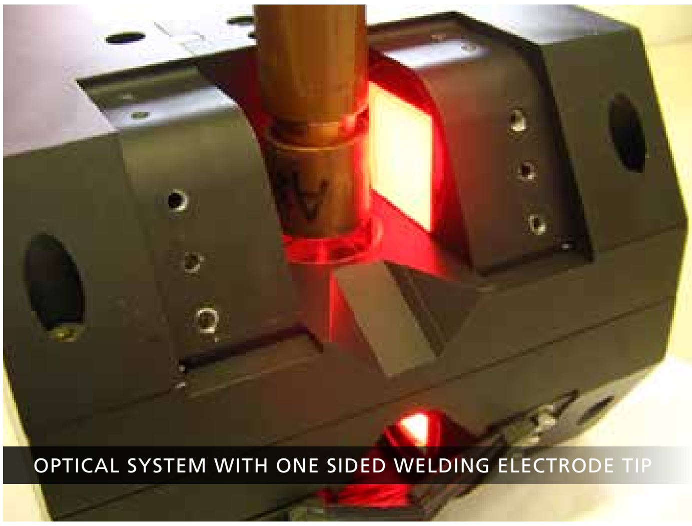
POLARIZATION INDEPENDENT LIQUID CRISTAL WAVEGUIDE

As an alternative, Fraunhofer IPMS offers an integrated optical switching/variable power splitting (OS/VOPS) solution with no mechanical parts, which is promising for both optical telecommunications and remote fiber optic sensing applications.
The key features provided by this technology are: fast switching speeds, good reliability and stability of the switching process, scalability towards high channel count and integrability with other devices, large number of switching cycles as well as low insertion loss and low crosstalk. Referring to the range of applications, technology manager Dr. Florenta Costache states: "For fiber optic sensor network monitoring, our device can ensure switching between channels at frequencies in the MHz range. This means that up to one million measurements can be processed per second. Moreover due to the absence of mechanical parts, the device operates nearly wear-free and can therefore be the technology of choice for long-term monitoring applications. In optical telecommunications networks, this device can provide dynamic switching between different channels, control of power allocated to network nodes and increased efficiency by utilizing optical resources effectively."

The OS/VOPS principle developed by Fraunhofer IPMS makes use of an actively controllable guiding effect in electro-optical waveguides. Dr. Costache describes the effect: "The OS/VOPS device is based on a specially developed electro-optical waveguide structure. Light is guided inside an electro-optical layer along pathways defined by structured electrodes placed on both sides of this layer. Unique features stem from employing highly transparent isotropic liquid crystal blends as waveguide core layer element. Specifically, the optical power transmitted along the waveguide structure is controlled by adjusting the electro-optical Kerr response strength in the liquid crystal layer by an applied electrical field. With this device we could demonstrate sub-microsecond switching, and continuously voltage adjustable, full variable range power splitting at low optical loss. The device has been developed for the telecommunication C-band centered around 1550 nm. Yet, if preferred, the device can be optimized to operate at any other wavelength between 400 nm and 1600 nm. We fabricate this device at the Fraunhofer IPMS using precision silicon wafer level technology. This fulfills the prerequisites for high quality, high volume and cost efficient manufacturing."

Nowadays, many applications are sensitive to light polarization and require polarization maintaining components. Equally there are applications which demand polarization independent components, for instance when reducing fiber optic network complexity and costs is an issue. Due to the underlying electro-optical effect the propagation behavior of a light wave along the Fraunhofer IPMS liquid crystal waveguide is dependent on its polarization state. This renders firstly the OS/VOPS polarization sensitive. Dr. Costache's team has recently solved this limitation in their technology as well: the team currently finalizes a solution for a polarization independent OS/VOPS. The development has been possible within the framework of the project "Electro-Optical Waveguides based on Liquid Crystals for Integrated Optical Switching" (EOF-IOS), contract No. 13N12442, funded by the German Federal Ministry of Education and Research. The project, which will end in Sept 2014, is part of the research initiative "Wissenschaftliche Vorprojekte" (WiVorPro) within the program "Photonic Research in Germany". Future developments in the project are focused on the usage of the polarization insensitive optical switch to transmit periodic signals in signal-processing instruments. These signals will be acquired from multiplexed fiber optic sensors.

# OPTICAL SENSOR INCREASES SPOT WELDING EFFICIENCY IN THE AUTOMOTIVE INDUSTRY


OPTICAL SYSTEM WITH ONE SIDED WELDING ELECTRODE TIP

Three research institutes and four industrial companies have worked for two years within the framework of the “SmartDress” European joint research project on the development of a fully automated system for the monitoring, optimization and post processing of electrode tips for resistance spot welding in the automotive industry. Hereby, Fraunhofer IPMS provided the optical measuring system with which the wear on the welding electrodes can be measured rapidly and precisely. This knowledge helps to preserve the quality of welded joints, increase the life cycle of electrode tips and thereby make it possible to use spot welding economically even for sophisticated materials such as aluminum.

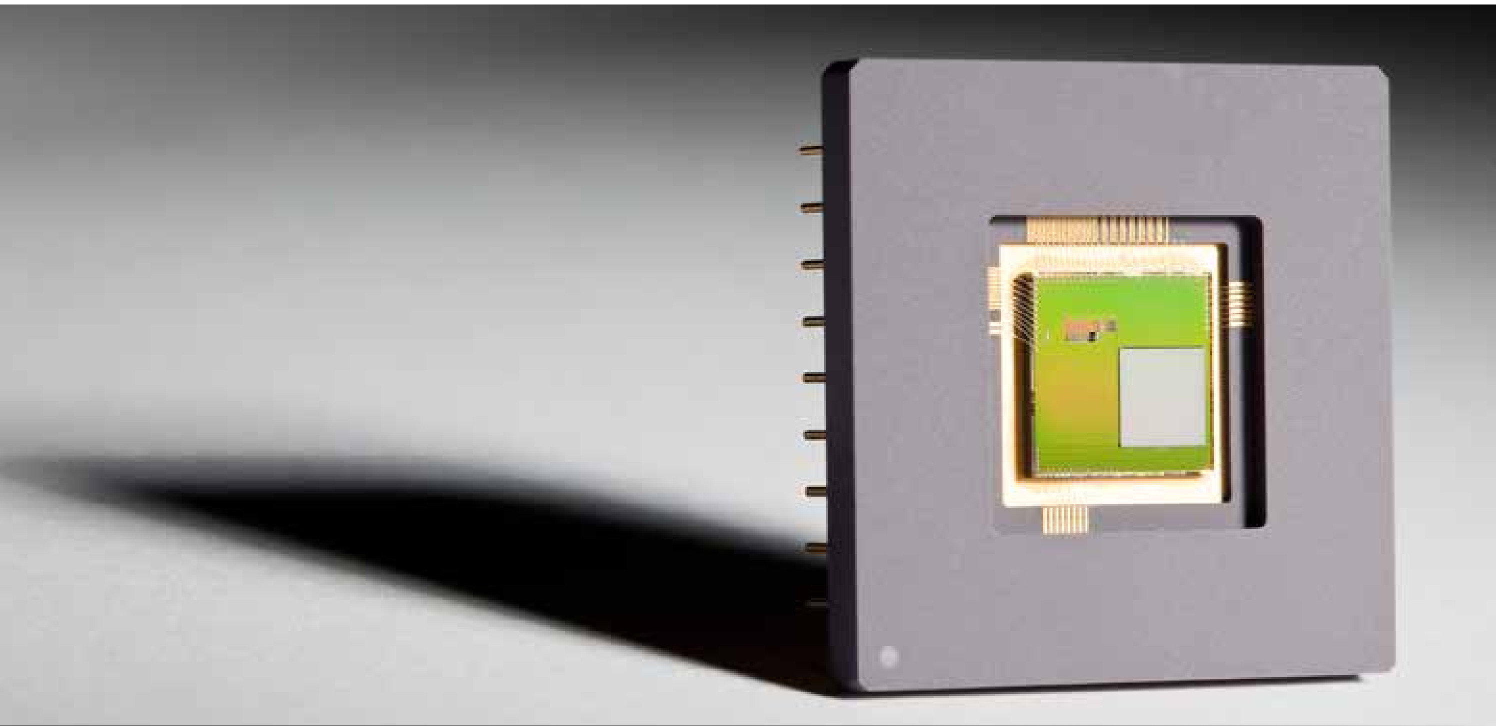
Nowadays, an average family car is held together by approximately 5000 spot welds. For many years, the welding process used for this purpose, resistance spot welding, has been the undisputed top technique for the long term joining of steel plates in the automotive industry, in bodywork and vehicle construction and in the sheet steel processing industries in general. This process is economical, efficient and robust and the significant welding parameters such as the type, thickness, number of components to be welded, their compatibility and surface finish and the cooling of the welding electrode can be efficiently controlled and planned. However, to date one essential quality characteristic has not been systematically recorded – the wear on the welding electrode. An increasing number of welding processes leads to the electrodes wearing out and consequently the cross section of the contact areas increases in size due to thermal and mechanical influences. This leads to the spot weld becoming ever larger and the melting area between the plates becoming irregular to the extent that they no longer bond. This is prevented by regularly dressing or reworking the electrode tips in order to maintain their original cross section. In case of galvanized steel, the wear is moderate and can be corrected on the basis of past experience. However the welding of aluminum components leads to such excessive wear that most body manufacturers consider aluminum spot welding to be totally unsuitable. For some assemblies the electrodes are already worn out before one part has been completed. To date the intervals between the reworking of electrode tips are usually determined according to experience. This practice results in: avoidable production line down times, unnecessary consumption of the copper electrodes and time and material intensive optimizing of the maintenance intervals during the set-up phase for new production lines.

It is not necessary to put up with these disadvantages, thought the designers at the Fraunhofer IPMS. So, Fraunhofer IPMS collaborated with two additional research institutes and four industrial companies within the framework of the European joint research project “SmartDress” to design a fully automated system regulating the maintenance of electrode tips for resistance spot welding. At the core of the system is an optical sensor which records the condition of the welding electrode and thereby calculates the time and extent of cleaning or mechanical post processing required. Michael Leuckefeld, project manager at Fraunhofer IPMS, explains the operation as follows: “Our system monitors both welding electrodes simultaneously from various perspectives. We use diffuse monochrome LED lighting generated by opal glass for this purpose. The light is sent to the electrode via a mirror arrangement and beam splitter and then back to the photo detector. Lighting and image recording thus use the same optical elements”. The first prototype is based on a passive camera system which is controlled by an external computer via a USB interface. Later, the control is to be integrated into the sensor system. The first tests under live production conditions are scheduled to take place during the current year.

### About “SmartDress”

“SmartDress” is an EU funded project under Framework 7, research for SME's [EU Project No. 286598]. Within the project a fully adaptive system for spot welding electrode maintenance has been created. The “SmartDress” system represents a significant step forward in electrode tip dressing technology, offering a functionality and performance beyond the scope of any system presently on the market. The “SmartDress” project was recently concluded with a series of successful tests.

# MEMS MIRRORS FOR GENETIC RESEARCH



EXAMPLE OF MICRO MIRROR ARRAY IN PGA PACKAGE

Researchers at the Fraunhofer IPMS have developed a programmable microelectromechanical (MEMS) chip which can divert light of varying wavelengths at ultra-high speed and with micrometer-accuracy. Installed in an optical microscope, this technology can be used to illuminate multiple targeted areas, which can be smaller than single cells and thereby stimulate specific light sensitive molecules as ensemble . In addition it is possible, by using a second chip, not only to select specific areas precisely but also the angle at which these are illuminated. This technique  is able to reach objects that appear as structures to be highlighted with even greater precision and to significantly reduce the many undesired environmental influences.

A single MEMS chip consists of an array of 65,536 separate micro mirrors which can each be tilted separately and virtually in a continuous way . By controlling the deflection of all mirrors it is possible to distribute the angle of incidence and the intensity of the light with up to 1,000 changes per second over the entire matrix area. In order to make the benefits of this MEMS technology amenable for optical microscopes, researchers at Fraunhofer IPMS team up with the manufacturer of optical systems, IN-VISION Digital Imaging Optics GmbH in Austria, and scientists of the plateforme d'imagerie dynamique (PFID) at the Institut Pasteur, in France. The aim of the French consortium's leader is to apply this new combination of optics and genetics to influence the expression of individual genes in cells or organs of zebrafish embryos and fruit fly larvae. Such an intervention will make it possible to study the influence of specific genes on the development of organisms with far greater precision than before. The system is also intended to be used to activate neurons by means of genetically modified, light sensitive ion channels and thereby explore the function of individual neural networks in cerebral tissue.

MICRO MIRROR ARRAY AND DRIVING ELECTRONICS

This research collaboration between Fraunhofer and the Institut Pasteur is being supported by the German Federal Ministry for Education and Research and the French National Research Agency within the framework of the Inter Carnot Fraunhofer Programme.

## RESEARCH MEETS INDUSTRY: 4TH INDUSTRY PARTNER DAY AT THE FRAUNHOFER IPMS-CNT

Under the motto "Nanoelectronic Technologies for Future Smart Systems", around 100 representatives from the semiconductor industry and political decision-makers came together on February 6, 2014 in the Königsbrücker Straße office for an academic exchange between applied research and industry.

The program was opened by Dr. Manfred Horstmann from Globalfoundries with a paper on "Cooperation is Key – R&D Perspectives at Globalfoundries Dresden". International speakers such as Martin M. Frank (IBM USA) or Malgorzata Jurczak (IMEC Belgium) then continued the agenda. The program was completed by speakers from the Fraunhofer IPMS and was rounded off by a guided tour of the clean rooms and laboratories of the Center for Nanoelectrical Technologies (CNT) on the premises of Infineon Dresden.

"The Industry Partner Day is a good opportunity for our business unit to get together with cooperation partners once a year in a relaxed atmosphere and to discuss future developments and potentials.", says Dr. Jonas Sundqvist, group manager for High-k Devices at the Fraunhofer IPMS-CNT.

THE EVENT WAS OPENED BY PROF. LAKNER

The event, which was held for the fourth time at the Fraunhofer IPMS-CNT, was well received by all of the guests, who took the chance offered after the papers and during the breaks for lively discussions about processes in the fields of copper metallizing, nanopatterning, MEMS and sub-nanometer characterization.

The next Industry Partner Day has been scheduled for February 2015.

## UPCOMING EVENTS

**Photonix**
Tokyo, Japan — April 16 - 18, 2014
Tokyo Big Sight, Booth 19-37

**Semicon Russia**
Moscow, Russia — May 14 - 15, 2014
Expocentre Moscow

**Optatec**
Frankfurt, Germany — May 20 - 22, 2014
Exhibition Center Frankfurt, Hall 3/Booth D50

**Sensor und Test**
Nuremberg, Germany — June 3 - 5, 2014
Nuremberg Exhibition Centre, Hall 12/Booth 537

**Sensors Expo**
Rosemont, USA — June 24 - 26, 2014
Donald E. Stephens Convention Center, Booth 421

**www.ipms.fraunhofer.de/en/events.html**

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**Further Information:**

Dr. Michael Scholles, Head of Business Development
Phone +49 351 88 23 201
E-Mail info@ipms.fraunhofer.de

**PUBLISHING NOTES**

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Phone +49 351 88 23-0, Fax +49 351 88 23-266, www.ipms.fraunhofer.de

Editor: Moritz Fleischer, Romy Zschiedrich, info@ipms.fraunhofer.de



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