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FRAUNHOFER INSTITUTE FOR PHOTONIC MICROSYSTEMS IPMS

MEMS REPORT

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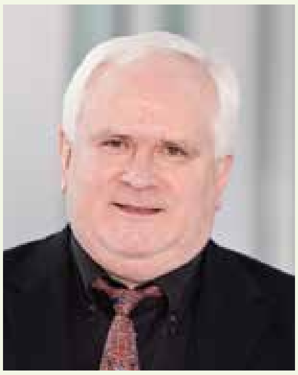


Prof. Dr. Hubert Lakner
Director of Institute

Dear Customers, Partners and Friends
of Fraunhofer IPMS,

together with our employees, I can look back over a very successful 2013. Both the original part of the Fraunhofer IPMS as well as the new business unit IPMS-CNT were able to achieve the goals they had set themselves from a commercial and technical-scientific point of view. The high share of direct revenue from industry to cover the institute's budget confirmed that we have judged our customers' needs correctly with our research and development topics and are an attractive partner for them. We will be presenting the results of a long-term strategic partnership in the business unit “Spatial Light Modulators” in more detail in this edition of the MEMS Report.

One important way to nurture existing customer relations and to make new contacts are our attendances at trade fairs. The “Photonics West” in San Francisco has been a good opportunity for us to present new developments in the field of MOEMS to the public for many years. The “OFC”, which is also held in the USA and where we will be presenting new developments and products in optical communication technology, is relatively new in the trade fair portfolio of the Fraunhofer IPMS. Some of the trade fair highlights will be presented in advance in this MEMS Report, which I hope you will enjoy reading and from which you will learn a lot of new things.

Prof. Dr. Hubert Lakner

QUICK NOTES

Hands-on science: 3-day Fraunhofer Talent School in Dresden

During the 5th Fraunhofer Talent School in Dresden, 28 pupils from grades 9 to 13 were once again able to experience science close up. Between November 15 and 17, 2013, they had the chance to take a peek over the shoulders of our researchers and help out in some exciting projects. During this 3-day event the adolescents were able to grapple with problems of applied research and development in various workshops and demonstrate their knowledge in the fields of medical technology, microelectronics and nanotechnology.

The Dresden Talent School was organized by the Fraunhofer IPMS. This year, the Fraunhofer IPMS-CNT, Center for Nanoelectronic Technologies, took part for the first time and also organized a workshop.

FRAUNHOFER TALENT SCHOOL DRESDEN PARTICIPANTS

Julia Schröder receives Fraunhofer support “TALENTA speed up”

“Fraunhofer TALENTA” is a systematic and integrated support and development program of the Fraunhofer Gesellschaft that is specially construed to attract scientists for applied research and to encourage these accordingly in their career development. We would like to congratulate Julia Schröder, a graduate physicist specializing in applied optics and PhD student at Fraunhofer IPMS, who was able to secure one of the 30 places on the “TALENTA speed up” support program. Within the scope of her doctorate she will be in charge of developing a portable, multi-spectral optical sensor system.

HIGH SPEED 1D SPATIAL LIGHT MODULATOR FOR LASER DIRECT IMAGING AND OTHER APPLICATIONS IN THE ULTRAVIOLET SPECTRAL RANGE

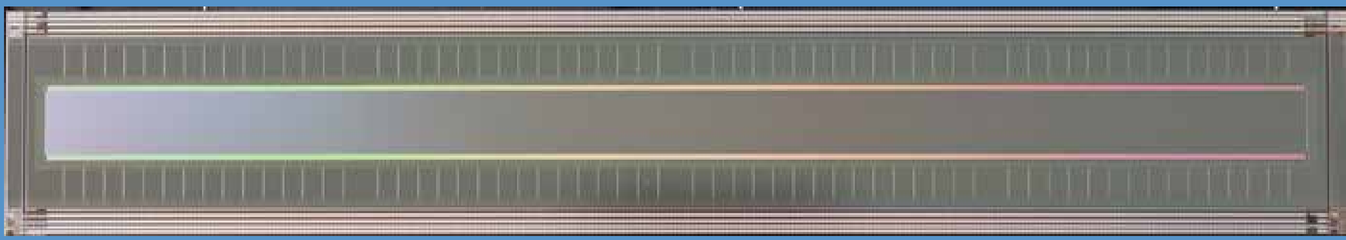


Figure 1: Photograph of the new Fraunhofer IPMS light modulator with chip dimensions of 14.9 mm × 87.5 mm

Figure 2: Micronic Mydata's LDI 5sp system

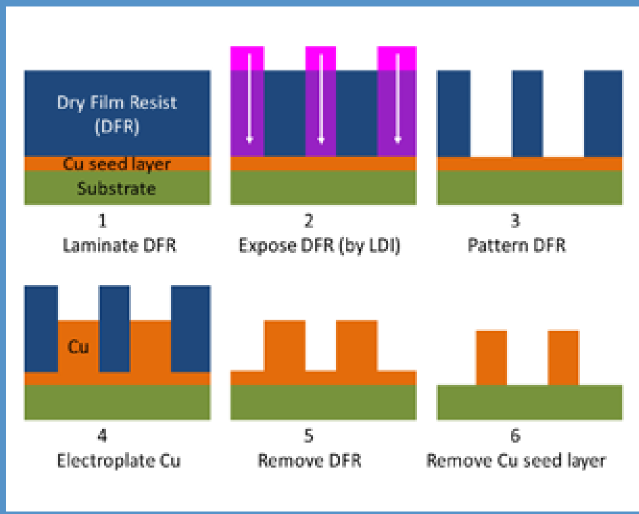


Figure 3: Semi-additive metallization scheme

Fraunhofer IPMS has developed a one-dimensional high speed spatial light modulator (Figure 1) in cooperation with Micronic Mydata. This SLM is the core element of the Swedish company's new LDI 5sp series of laser direct imaging systems that are optimized for processing of substrates for semiconductor packaging (Figure 2).

Application challenges

Modern electronics packaging increasingly makes use of special, high-end forms of printed circuit boards called "substrates" and "interposers". These provide a mechanical support and an electrical interface between integrated circuits and the outside world, or act as an intermediate layer used for interconnection routing or as a ground/power plane. Advanced packages, e.g. "system-in-package" (SIP) for mobile applications, require substrates with a high density of interconnects with minimum line widths and spaces of about 10 µm, and in a few years even less.
Such high density substrates are produced in form of large panels (e.g. 510 mm × 515 mm) using the "semi-additive metalization" process (Figure 3). As part of this process, the whole panel is exposed to ultraviolet (UV) light, in order to pattern laminated layers of dry film resist (DFR).
The spaces in the patterned DFR act as template for the deposition of copper by electroplating. As feature size decreases, several wiring layers and their vertical connections (vias) have to be aligned within smaller tolerances to avoid functional errors.
"Laser direct imaging" (LDI) techniques provide an improvement to conventional mask-based steppers. They use a programmable micromechanical element, a so-called "spatial light modulator" (SLM) to print dose-patterns into the resist, and have the potential to combine high resolution, high precision of alignment and high throughput. In addition, variations in the pitch of existing structures induced by strain in the substrates can be measured for each panel and compensated by appropriate algorithms, such that new layers perfectly match the preceding ones.
Addressing this field of application, the Swedish high-tech company Micronic Mydata AB has developed a novel LDI 5sp laser direct imaging system.
As a cooperation partner, Fraunhofer IPMS contributed to this system a novel fast one-dimensional diffractive light modulator for the ultraviolet spectral range. Integrated into the new LDI 5sp system, the new SLM has successfully proven its excellent performance.

HIGH SPEED 1D SPATIAL LIGHT MODULATOR FOR LASER DIRECT IMAGING AND OTHER APPLICATIONS IN THE ULTRAVIOLET SPECTRAL RANGE

SLM function and features

The SLM has been designed as an array of electrostatically addressed micro mirrors with analogue tilting deflection. Figure 4 shows a scanning electron microscopy (SEM) image of mirrors in the optically active area. Colours (added manually) indicate that mirrors belonging to the same row are addressed with the same voltage, and move synchronously. Each of the 8192 mirror rows acts as one "optical pixel" of the SLM. When used with a coherent narrow-band light source (e.g. a laser), the SLM can be considered as a variable-blaze grating. The positions of diffraction orders in space are defined by the pitch of mirrors and the angle of incidence. For perfectly flat mirrors and negligibly small slits the SLM will reflect light specularly, or in different words, into the 0 th diffraction order. A small tilt of mirrors modulates the phase of the reflected wave-fronts such, that intensity is redirected from the 0 th diffraction order into higher diffraction orders. A mirror edge deflection on the order of a quarter wavelength fully depletes the 0 th diffraction order of intensity. In the LDI system, a laser beam with rectangular cross-section is reflected by the SLM, and imaged to a line-focus which in turn is scanned across the substrate. An aperture in the Fourier plane of the optics blocks the higher diffraction orders. Only the 0 th diffraction order contributes intensity to the line-like image of the laser beam at the substrate. The 8192 optical pixels of the SLM control the intensity within the image. Bright features are generated by zero deflection of the corresponding SLM pixels, dark regions are generated by deflected pixels, and by using intermediate deflection states at a border pixel between bright and dark, the feature edge can be positioned with sub-pixel accuracy. The SLM contains no electronics for signal processing: the 8192 data channels controlling the pixel deflections are hard-wired to the output channels of an external addressing unit. All pixels can be updated in parallel at MHz rates, which enables a continuous exposure process end an efficient utilization of the light source.

SLM Parameter	Value
Number of pixels	8192
Dimensions of chip	14.9 mm × 87.5 mm
Dimensions of active area	3.9 mm × 81.9 mm
Target wavelength	355 nm
Mirror deflection range	>110 nm
Fill grade (active area)	> 90 %
Mirror material reflectance	> 85 %
Mirror RMS planarity	< 7 nm

Table 1: Summary of SLM parameters

SLM performance

During the development phase of Micronic Mydata´s LDI 5sp systems, the new SLM device has successfully mastered various performance tests. Meanwhile, the first LDI 5sp systems are operated commercially. As an example, Figure 5 shows a close-up SEM image of a substrate panel on which a 25 µm thick layer of dry film resist on top of a copper layer has been patterned. The image shows well-defined resist lines with vertical sidewalls. At image centre the lines are 10 µm wide.

More details on this SLM, its application and performance will be presented at "Photonics West" in San Francisco, USA (paper 8977-21).

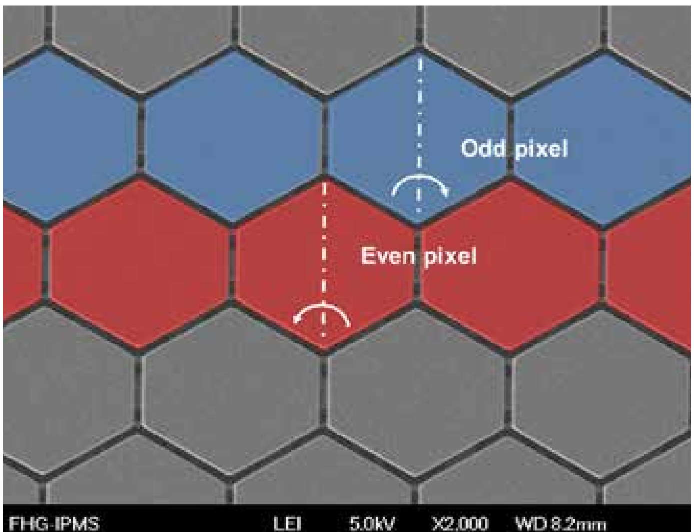


Figure 4: Top view on mirrors in active area of SLM (colors added manually)

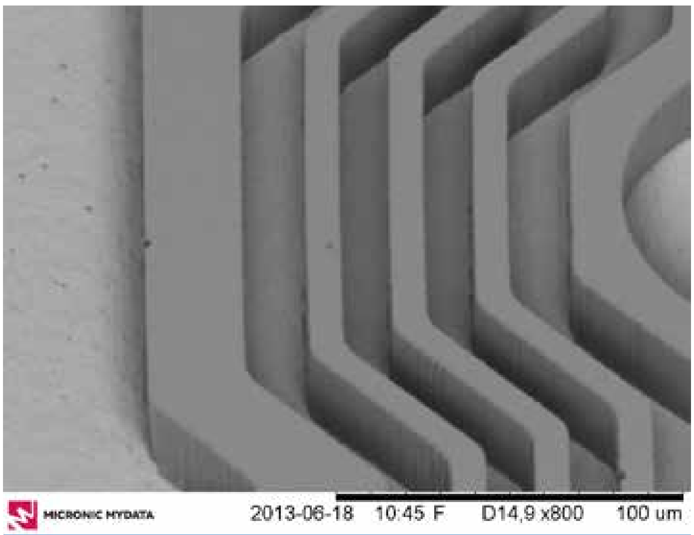


Figure 5: 10 µm lines formed in 25 µm thick dry film resist on a substrate panel using the LDI 5sp system

INTERVIEW WITH DR. JAN-UWE SCHMIDT

Dr. Jan-Uwe Schmidt is the current project manager for the LDI-SLM development project at Fraunhofer IPMS. After he received his doctorate in physics in 2004 he joint Fraunhofer IPMS to work as scientist and project manager in the field of new MEMS technologies.

What was the reason to start the development of a one-dimensional (1D) modulator – why not stick to the two-dimensional (2D) devices the Fraunhofer IPMS had developed earlier?

Jan-Uwe Schmidt: "1D and 2D SLM are not replacements for each other, they are used in different types of setups. Two-dimensional SLMs require some time to refresh the image information. They are typically used in combination with a pulsed laser at several kHz repetition rate. A 1D SLM is typically used in a scanning mode, in combination with a continuous or quasi-continuous (high frequency pulsing, e.g. mode-locked) laser. This way, the peak power density at the SLM and thus surface damage to mirrors can be minimized, resulting in a long SLM lifetime."

How did you experience the collaboration with your customer Micronic Mydata during this development project?

Jan-Uwe Schmidt: "It was a great experience to watch an idea of a system grow into a clearly defined concept, finally materializing in a complex functional product. During the SLM development project, experts of very different functional areas at Fraunhofer IPMS and at Micronic Mydata worked hand in hand to define the best strategies or to solve technical challenges. Based on a cooperation agreement, both parties decided to trustfully exchange knowledge, which helped a lot to find the optimal solutions. The project has benefited a lot from this very close collaboration."

What were the most challenging aspects of the development of this new SLM?

Jan-Uwe Schmidt: "In the last decade Fraunhofer IPMS has collected valuable experience in the processing of two-dimensional SLM with analog deflection control by monolithically integrated CMOS electronics. New products benefit from existing MEMS technologies. The SLM presented here is the first Fraunhofer IPMS SLM without integrated driver electronics. For the large number of external connections needed here new concepts had to be implemented for assembly and testing. And as actuators are 'always on' (no idle time or dead-time), highly stable deflection characteristics were needed – and achieved."

How would you describe the most beneficial features of the developed SLM?

Jan-Uwe Schmidt: "The fundamental resonance of actuators in the MHz range enables high data rates on the order of several billion grey-scale pixels per second. Due to the continuous deflection and the diffractive intensity modulation principle the SLM is optimally suited to generate patterns with sub-pixel edge placement accuracy. The very high fill-grade of the mirror array in combination with the continuous writing process without dead-times enables a highly efficient exposure process with minimal losses of laser power. "

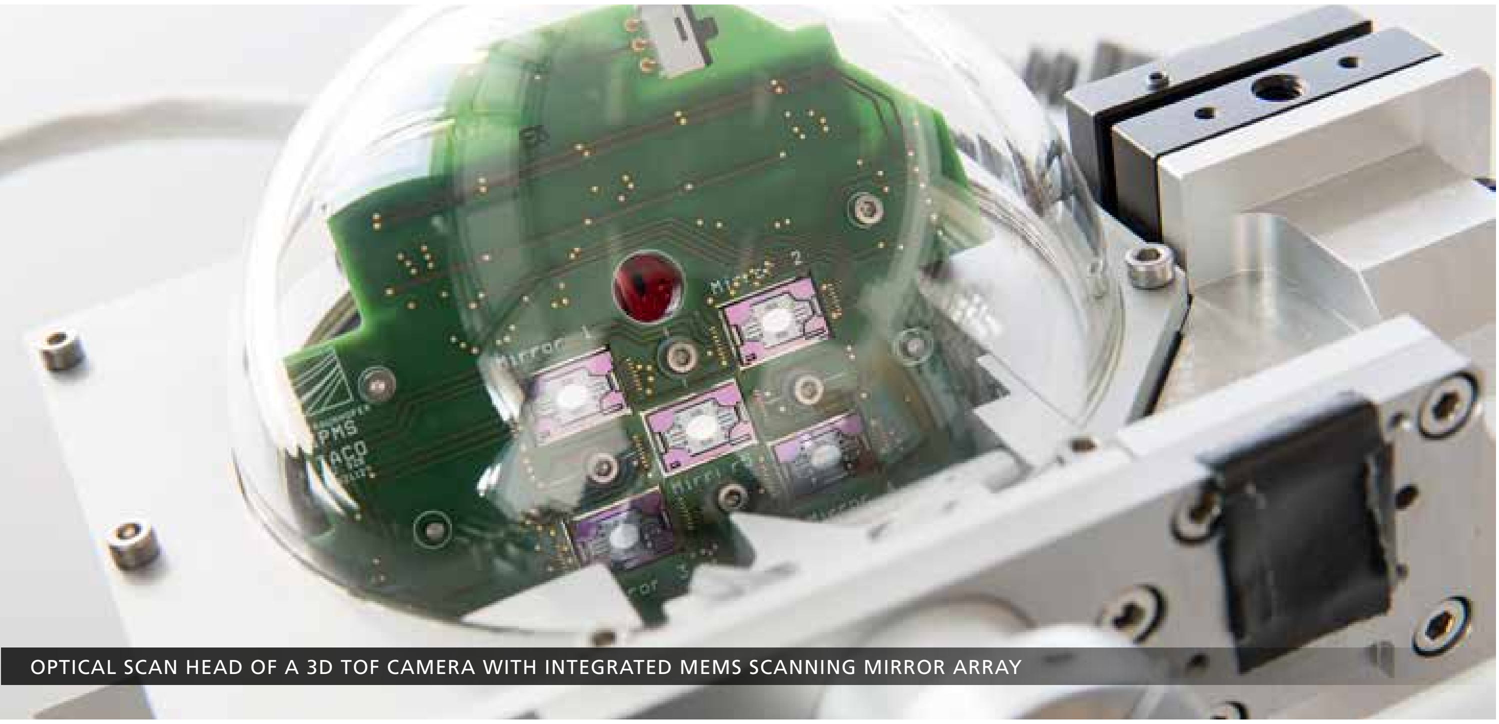
Does the SLM have potential to be utilized for other fields of applications?

Jan-Uwe Schmidt: "Yes! Laser direct imaging techniques can be used in many other application areas, wherever UV modulation with high throughput and high precision is required."

Are there other Fraunhofer IPMS SLMs that one might want to consider for new applications?

Jan-Uwe Schmidt: "Fraunhofer IPMS has developed a 'customer evaluation kit', which may be purchased to potential project partners in order to stimulate new development projects. The SLM used in the current kit has 256 × 256 pixels with integrated CMOS circuitry. With a driver electronics board and control software the kit includes everything required to operate the SLM in an optical setup. A large tilt angle of mirrors enables the use of this device from the deep ultraviolet to the near infrared spectral range. Currently this evaluation kit is also used in an European project to explore applications in microscopy."

NEW EYES FOR ROBOTS: FRAUNHOFER IPMS PRESENTS 3D CAMERA SYSTEM AT PHOTONICS WEST 2014



OPTICAL SCAN HEAD OF A 3D TOF CAMERA WITH INTEGRATED MEMS SCANNING MIRROR ARRAY

Differentiate between colors and brightnesses, judge distances, identify objects and movements in our surroundings in 3D and in a matter of seconds: Things that are easy for humans thanks to our eyes and brain pose a big problem for machines. Because robots lack either spatial information that is resolved in real-time or the necessary focus for three-dimensional seeing, or because too much image information is recorded to be processed quickly, it has only been possible to develop robots up to now that are only able to perform services such as cleaning, building, servicing, security or personal care tasks in a relatively rudimentary way. But things don't have to stay that way, researchers at the Fraunhofer IPMS believe. The scientists have developed a compact scanning technology (“LinScan”) for ToF (time of flight) telemetry systems that allows three-dimensional image acquisition with a flexible scanning rate and thus scanning with an adapted resolution. 3D camera systems equipped with LinScan could enable future generations of robots to roughly search their surroundings for objects that appear in their visual field and to only resolve the objects they are looking for at a higher accuracy. This way the robot would work with a relatively small volume of data.

A precondition for the realization of this so-called principle of foveation is, however, that the robot knows what it is looking for and that it is also able to identify and interpret the objects being sought in a matter of seconds. Apart from the hardware (eye) it also needs corresponding image analysis software algorithms (brain). What's more, the robot should also be equipped with image sensors and software for three-dimensional seeing to gain a spatial idea of its surroundings and thus be able to navigate to objects precisely. In order to satisfy all of these requirements, the Fraunhofer IPMS worked within the scope of the European joint research project “TACO” (Three-dimensional Adaptive Camera with Object Detection and Foveation; www.taco-project.eu) together with four other research institutions and two industrial companies on the development of a novel adaptive camera system. The heart of the system is an optical scanner with five synchronously operated LinScan mirrors from the Fraunhofer IPMS. The TACO project was recently concluded with the development of a fully-functional complete system. This prototype will be presented to a professional public for the first time at the trade fair booth of the Fraunhofer IPMS at the Photonics West trade fair in San Francisco between the fourth and sixth of February 2014.


QUASI-STATIC / RESONANT 2D LINSCAN MIKROSCANNER

OPTICAL WIRELESS DATA TRANSMISSION VIA INFRARED LIGHT

Since the technical equipment in portable devices is getting better and better, the amount of data being produced is constantly growing, often in the gigabyte range. It takes not only time but also patience to transmit large image files or full-HD film sequences from one terminal device to another. A wired data transfer can thus sometimes take several minutes.

Dr. Frank Deicke from the Fraunhofer IPMS has set himself the goal of accelerating the transfer of large amounts of data and uses optical wireless data transmissions by means of infrared light. As an alternative to the common USB 3.0 standard, he has thus developed a communication module that enables a data transfer rate of up to 5 gigabits per second (Gbit/s). "The use of infrared light as a wireless transmission medium means that signal processing is up to 100-times faster than currently available solutions because the information does not have to be specially coded for radio transmission beforehand. What's more, the bit error rates in the optical link are exceptionally low so that net data rates of up to 95 percent of what is theoretically possible can be achieved; the percentage for WLAN is much lower," explains Deicke, who goes on to point out another advantage of infrared technology: "The path via light needs only 15 percent of the energy per byte – something that particularly benefits mobile, battery-operated devices such as mobile phones or digital cameras".

INFRARED BASED OPTICAL WIRELESS DATA TRANSMISSION

The only condition: there has to be a so-called "Line-of-Sight" connection, just like a remote control that works with IR. This assumes an unobstructed view between the transmitter and recipient. The Fraunhofer IPMS offers an evaluation kit that gives interested parties the chance to evaluate an optical, wireless data transmission with data rates of up to several gigabits in their target system.

UPCOMING EVENTS

Photonics West
San Franscisco, USA — February 4 - 6, 2014
Moscone Center, Hall D, Booth 4407

OFC
San Franscisco, USA — March 11 - 13, 2014
Moscone Center, Booth 4377

Smart Systems Integration
Vienna, Austria — March 26 - 27, 2014
Austria Trend Hotel Savoyen, Booth A-02

Photonics Europe
Brussels, Belgium — April 14 - 17, 2014
SQUARE Brussels Meeting Centre

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

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