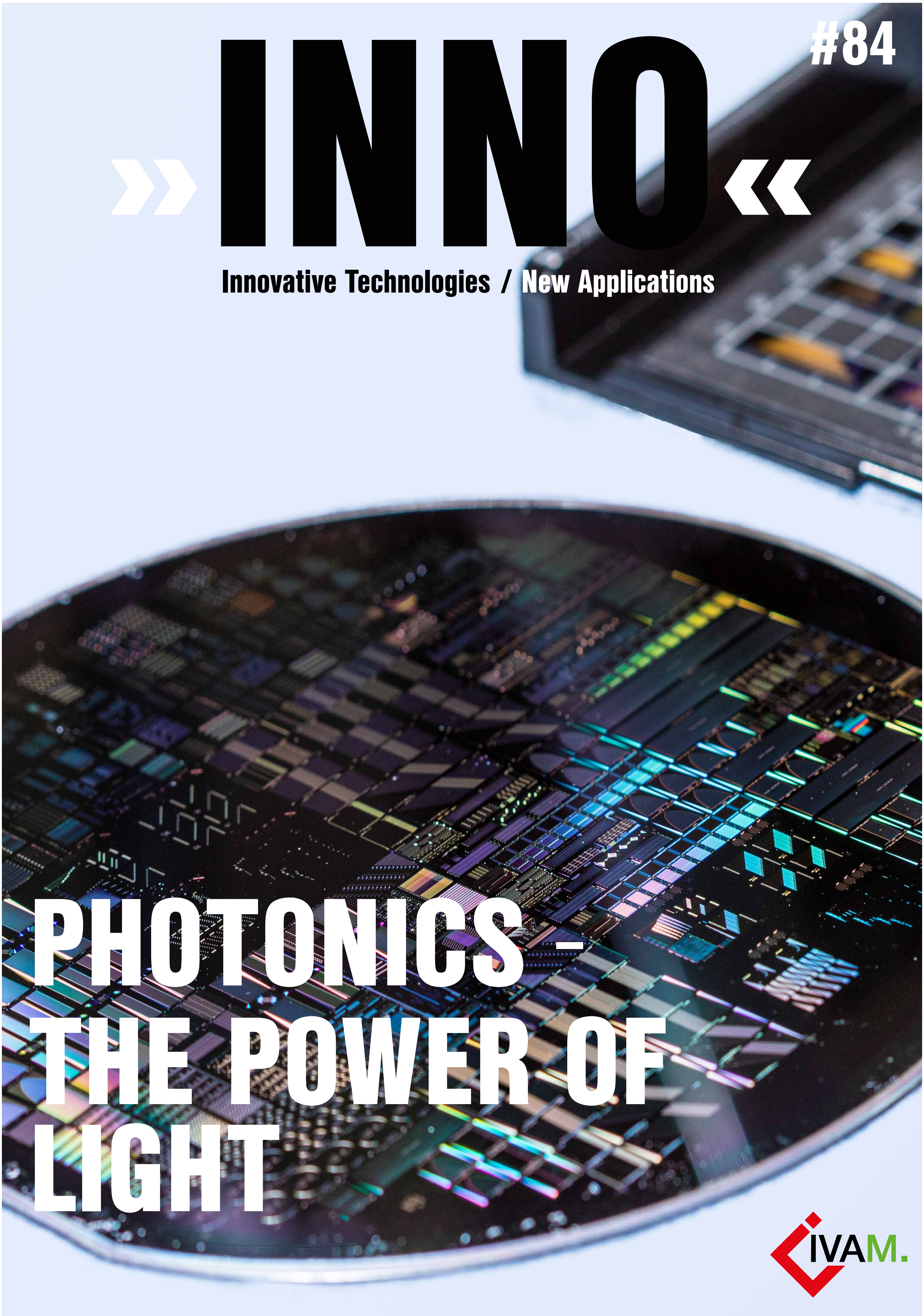
#84

»INNO«

Innovative Technologies / New Applications



PHOTONICS – THE POWER OF LIGHT

IVAM.

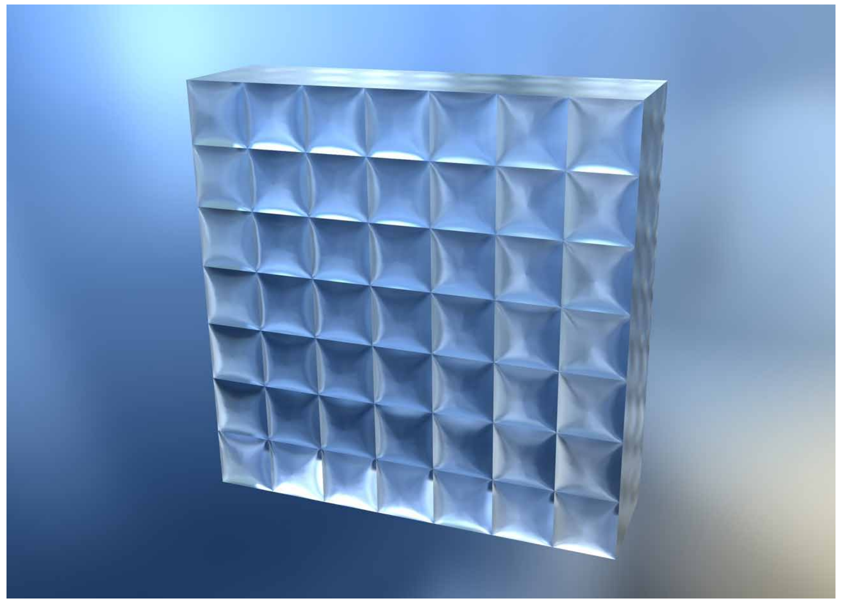
CONTENTS

INNO 84 I Spring 23

16

A Novel Multi-Project-Wafer Platform for Disruptive PIC Solutions

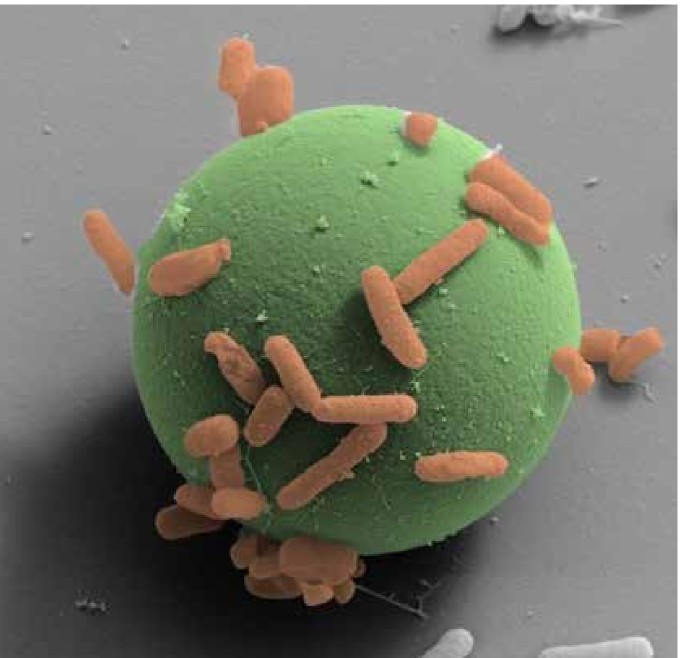
Photonic Integrated Circuits (PICs) are providing powerful new options to generate, route and process light for various applications.



20

Micro Optics as Key Components in Healthcare

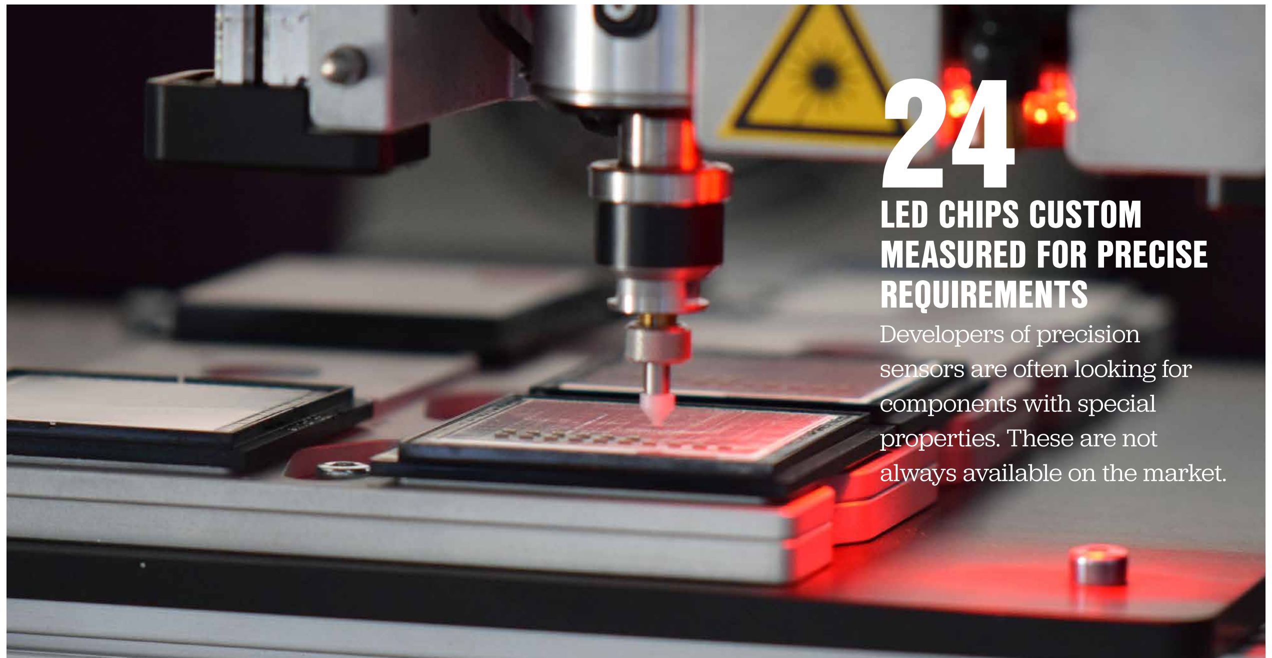
Micro optics and diffractive optics are highly innovative elements which have been instrumental in many areas of healthcare.



06

Ultrafast detection of microorganisms

To provide access to clean water and safe nutrition, it is essential to quickly identify pathogens in terms of their type and quantity.



24

LED CHIPS CUSTOM MEASURED FOR PRECISE REQUIREMENTS

Developers of precision sensors are often looking for components with special properties. These are not always available on the market.

»INNO 84« Photonics - the Power of Light

Photonics is becoming increasingly important due to its wide range of applications, including data communication, energy efficiency, medical applications as well as several industrial applications. As technology continues to advance, photonics is likely to play an even more critical role in shaping the future of many industries.

In this issue of INNO, IVAM members show how their technologies and products can best be used in the context of key technology photonics, or what contribution they make to photonic products.

On pages 12 and 20, the micro optics experts FISBA and SUSS show how their high-precision optical components are used in various industrie. How can photonics be used to support an ultrafast detection of microorganisms to provide clean water and safe nutrition? On Page 6 Society 6.0 together with FluiDect give an insight into this.

I wish you an exciting and entertaining reading. Best regards

Mona Okroy-Hellweg

IVAM.

Dr. Jörg Meinertz / Lukas Janos Richter / Dr. Jürgen Ihlemann

PHASE MASKS FOR LASER INTERFERENCE PROCESSING

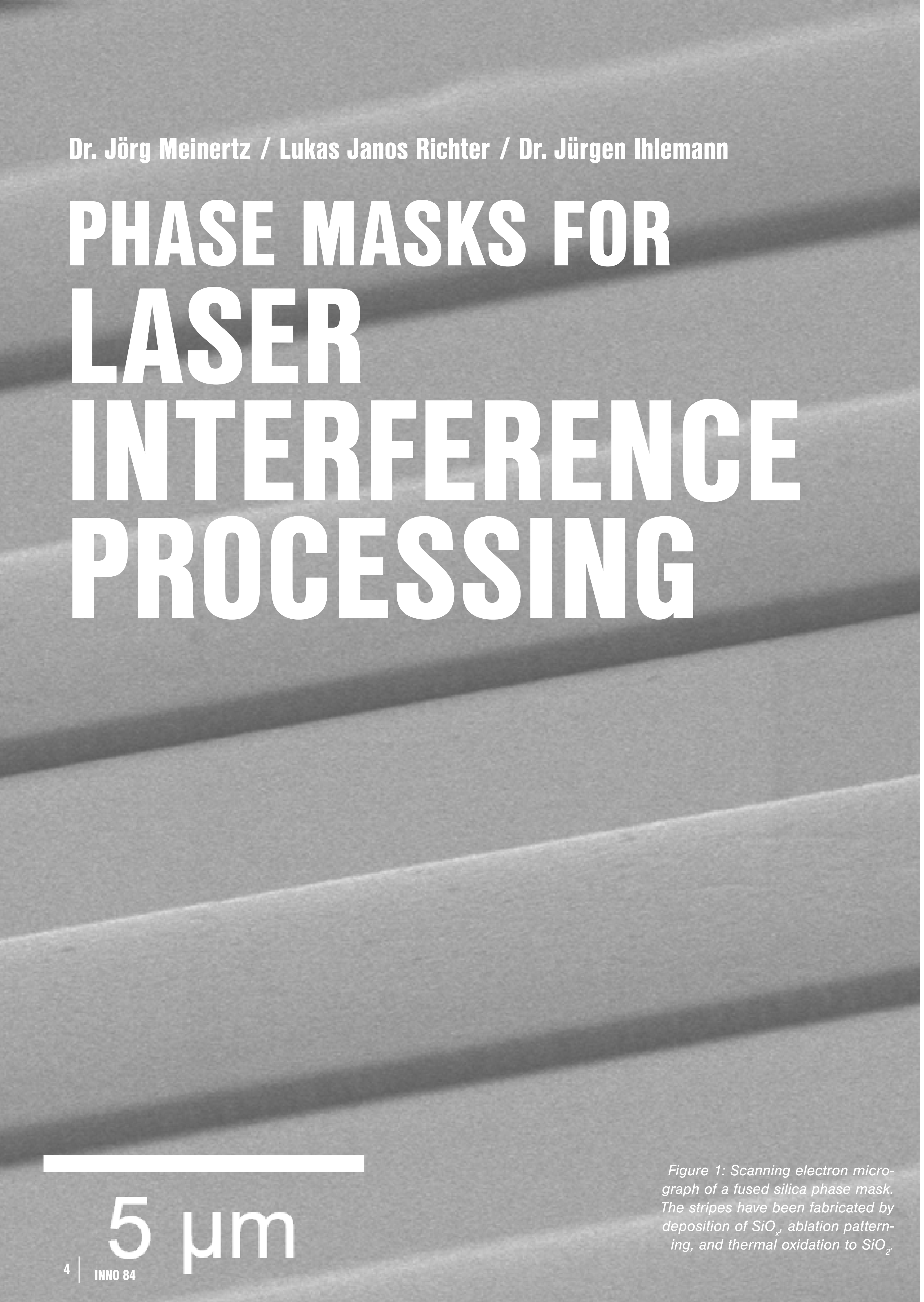


Figure 1: Scanning electron micrograph of a fused silica phase mask. The stripes have been fabricated by deposition of SiO_x, ablation patterning, and thermal oxidation to SiO_2.

Laser interference patterning has become an attractive method for functionalizing surfaces by creating periodic patterns. Eye-catching labeling or marking, changing the properties for wetting and cell adhesion, or modifying tribological behavior are examples of possible applications. Radiation resistant fused silica phase masks enable efficient implementation of such laser processes.

In many cases, surface relief patterns are required with periods and height amplitudes in the micron or sub-micron range, which are preferentially generated by direct laser ablation without laborious and time consuming etching processes. Laser interference ablation utilizes the superposition of two or more coherent beams on the surface of the work piece in order to generate an intensity profile which is periodic in one or two dimensions. This results in the ablation of line or hole arrays or more complex patterns, if sufficient laser fluence is provided. This is generally accomplished by splitting one laser beam into the required number of partial beams. For this, diffractive beam splitters offer the advantage that they can be easily used in the mask plane of a laser projector, which projects a demagnified image of the mask onto the target, providing at the same time high fluence and good interference contrast - even in case of only partially coherent laser light such as that of excimer lasers. Transmission phase masks are diffractive beam splitters without substantial losses by absorption or reflection, as they influence only the phase of the transmitted light.

For high power applications, especially in the UV, they have to be made of fused silica. They can be optimized for specific properties of the diffracted partial beams. In the simplest case, an incident beam is split into two beams of equal intensity, which can be accomplished with a phase grating having a step height d = λ / (2 (n-1)) (λ operation wavelength, n refractive index of SiO_2) and a duty cycle of 0.5 (lines and spaces of equal width). This suppresses the zero order beam and diffracts most light into the +/- first diffraction orders which are subsequently selected for interference. Line periods of typically 20 to 200 µm (Fig. 1) and demagnification factors of typically 10x to 25x of the mask imaging optics then lead to µm- or sub-µm pitch interference patterns.

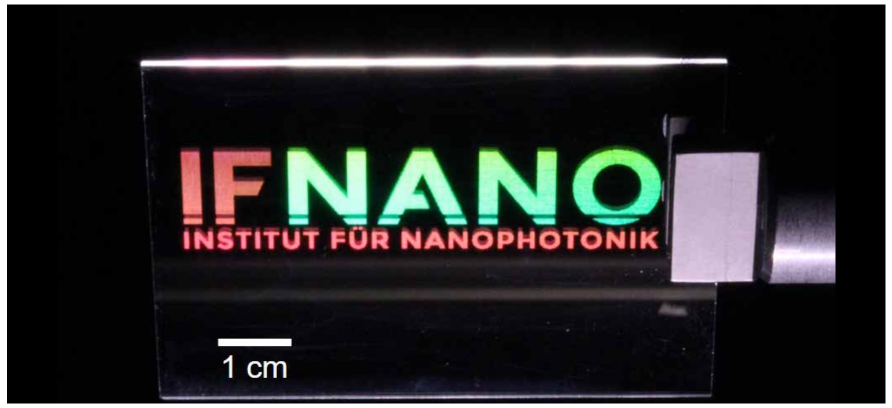


Figure 2: Diffractive mark on glass made by phase mask projection. The area appearing red has a structure period of 2 µm, the area looking green a period of 3 µm.

Fabrication Process

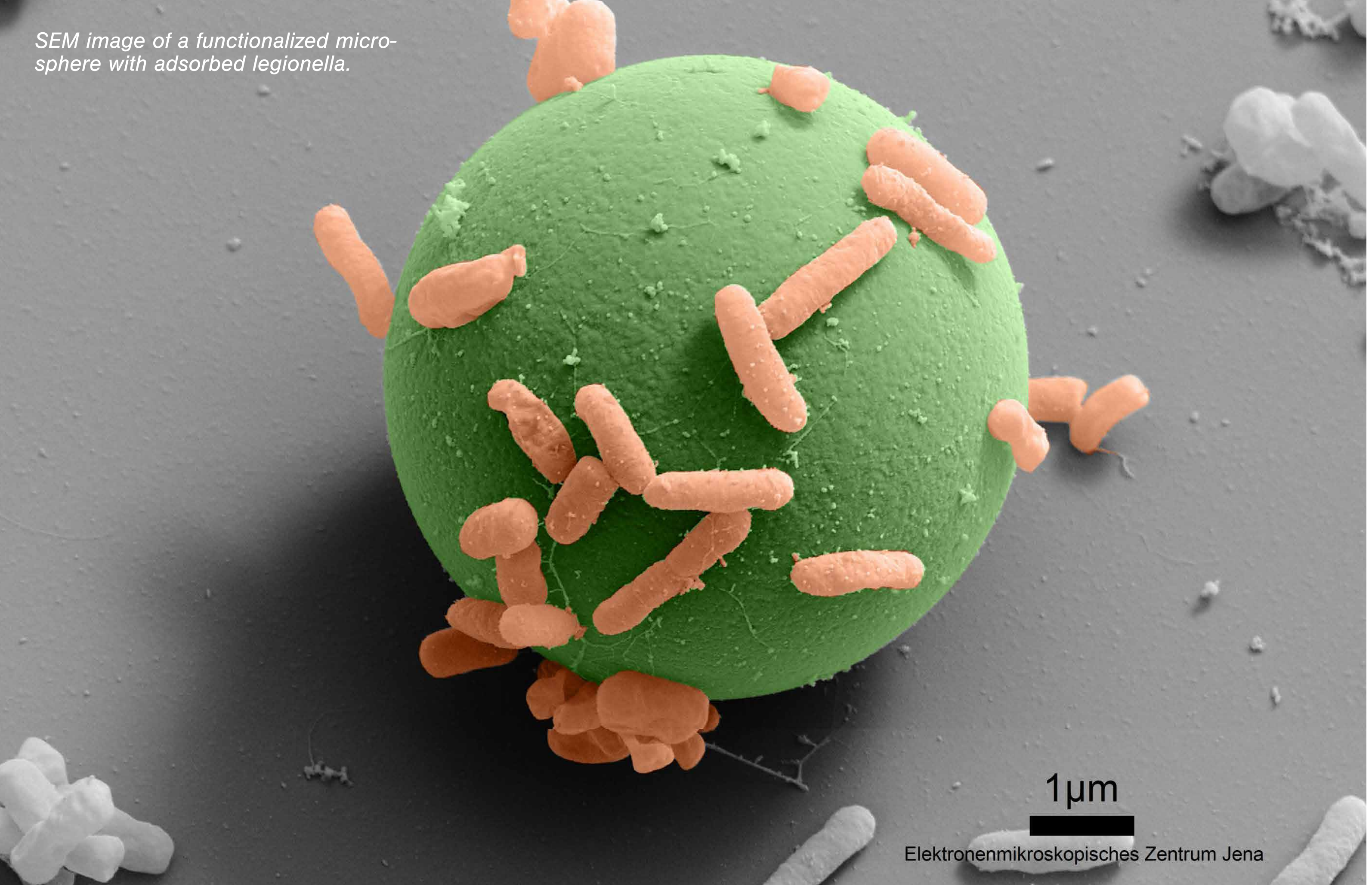
Custom made phase masks are fabricated according to the following procedure. A SiO_x-coating is deposited on a SiO_2 (fused silica) substrate. The desired pattern is created by removing the coating in defined areas by excimer laser ablation. In the case of a line grating for example, stripes of this coating are removed. SiO_x exhibits a strong UV absorbance, so that the ablation is far more precise compared to the alternative ablation patterning of the weakly absorbing SiO_2 substrate itself. As the excimer laser beam can be shaped easily to a line beam profile, complete stripes can be ablated with a single laser pulse, rendering time consuming 2D scanning of the laser spot unnecessary. The remaining SiO_x material is then oxidised to SiO_2 by a thermal annealing process, so that finally a monolithic SiO_2 phase mask with the specified height profile (determined by the coating thickness) is obtained (Fig. 1). By repeated deposition and ablation processes, multilevel phase masks can be fabricated.

Applications

The application of phase masks for high contrast labelling of surfaces is demonstrated in Fig. 2. a glass slide has been patterned by laser interference processing using a deep UV excimer laser at 193 nm wavelength in combination with a fused silica phase mask. This wavelength is the best choice for ablating glass materials, as at longer wavelengths the absorbance of standard glasses is not sufficient for high resolution ablation. In the case of metals, to obtain high spatial resolution in spite of the high thermal diffusivity, the use of ultrashort laser pulses is recommended instead. The color gradient can be adjusted by the choice of the structure period. In Fig. 2, the use of two different structure periods leads to the two-colored appearance. Besides interference ablation, further applications of phase masks are in the fields of microscopy (structured illumination, focus shaping) or the generation of Bessel beams.

Institut für Nanophotonik Göttingen e.V., Göttingen, DE

https://www.ifnano.de



SEM image of a functionalized microsphere with adsorbed legionella.

ULTRAFAST DETECTION OF MICROORGANISMS

Tobias Schröter/ Michael Himmelhaus / Klaus Schindlbeck / Ruth Houbertz

According to the United Nations , about three billion people depend on water of unknown quality with high risk to their well-being and health. One of the reasons for such unacceptable living condition is related to the lack of tools for point-of-issue (POI) testing, providing high sensitivity and fast response. Certainly, such tools need to be robust, reliable and low cost.

Microbes, such as bacteria or fungi, are ubiquitous and may cause serious threats such as water and food poisoning. To provide access to clean water and safe nutrition, it is essential to quickly identify pathogens in terms of their type and quantity. Depending on the type of pathogen such as, e.g., legionella in drinking water, present analytical methods require several hours (e.g., for E. coli) to up to more than a week for their identification.

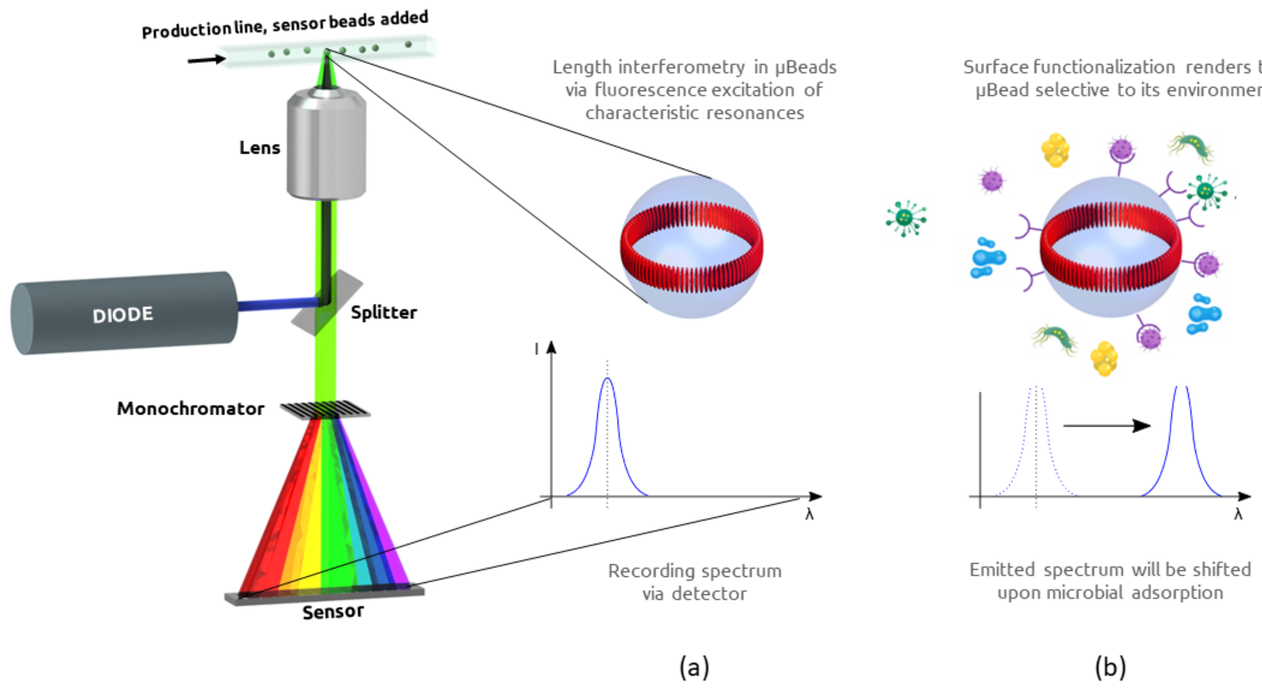


Figure 1. Principle of FRS. (a) Optical setup for excitation and readout of FRS from functionalized µBeads. (b) Illustration of the change in FRS due to specific binding of target pathogens to the µBeads.

Additionally, most methods are laboratory-based and thus costly.

Consequently, process monitoring in production plants or at water works is not feasible, resulting in contaminated food, outbreaks of legionella or E. coli in drinking water. These lead to numerous infection cases and, as an economic impact, to losses of over $110 billion for food-borne infections in low- and middle-income countries. Diseases like diarrhea, cholera, dysentery, typhoid and polio transferred by contaminated water were identified by the WHO to cause 485,000 deaths each year just for diarrhea .

It is our vision to provide a microbial sensor that can be used right at the point-of-issue (POI), e.g., in fresh water supply, in water treatment, in food industry, and in animal husbandry to monitor process chains seamlessly, thereby reducing the number of infections caused by pathogens, thus also minimizing the related economic damage.

State of the Art

The analytical tools currently used for the detection and analysis of pathogens are well-established, however, are most likely not suited for becoming an integral part of water processing and food production plants in industrial processes for in situ detection of pathogens. Most common methods, such as PCR, Maldi-TOF, ELISA, flow cytometry or microbial plating, are laboratory-based, labor-intensive, and therefore expensive.

Biosensors that do not require prior labeling of the microorganisms, such as surface plasmon resonance , quartz microbalance, or high-Q whispering gallery mode systems, employ elaborate fluidics with the channel walls also containing the sensor surface. The latter can be regenerated only to limited extent and has to be replaced regularly - usually after only a few measurements. Thus, also here automated use in a continuous production process is hindered.

None of the analytical methods has yet been developed into a fully automated sensor and established in industrial production plants. Up to now, indirect parameters, which are assessed by commercially available physical and chemical sensors (temperature, turbidity, pH value, etc.) in order to gain information about the occurrence of relevant targets, are monitored. Recently, attempts have also been made to combine these summary parameters with numerical algorithms

“Three billion people depend on water of unknown quality with high risk to their well-being and health - related to the lack of tools for point-of-issue (POI) testing”

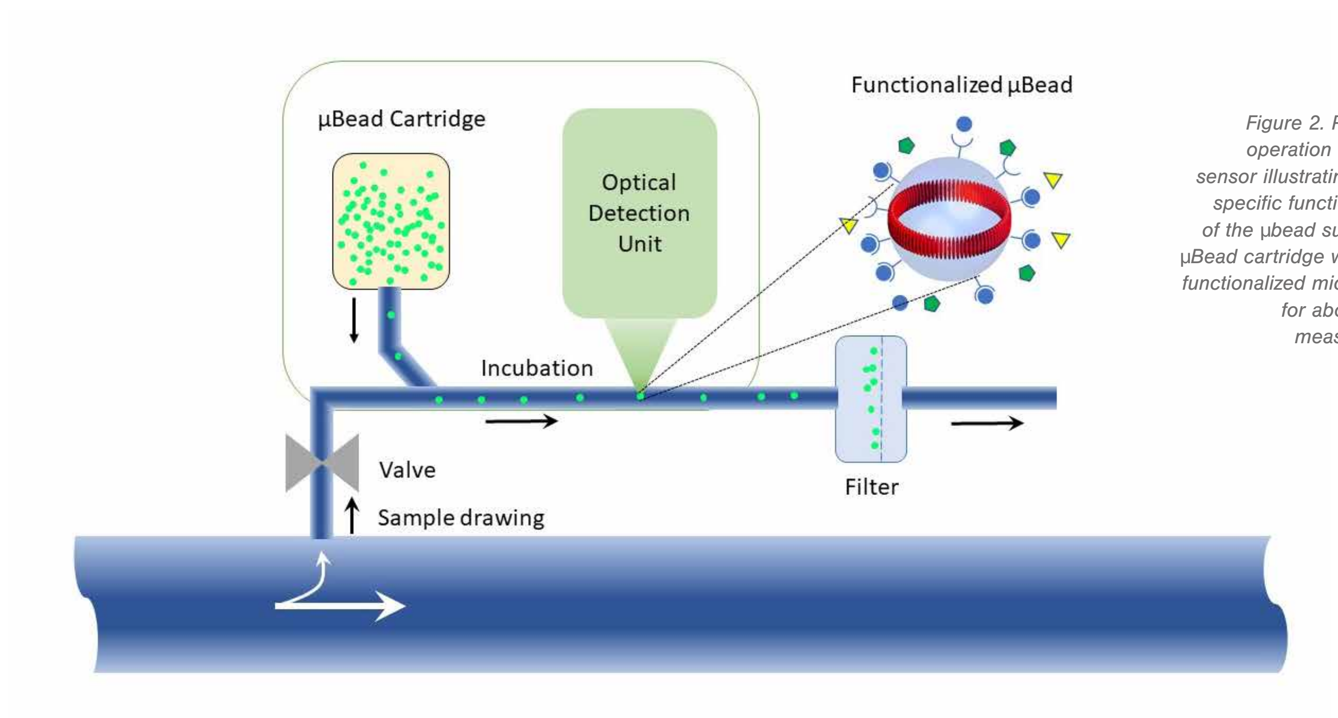


Figure 2. Principle of operation of the FSR sensor illustrating also the specific functionalization of the µbead surface. The µBead cartridge will provide functionalized microsensors for about 10,000 measurements.

or AI methods to gain more reliable information. However, the accuracy of the predictions is still severely limited.

Fluorescent Resonator Signature Technology

To overcome present constraints and limitations, FluIDect is developing the world's first sensor based on Fluorescent Resonator Signature (FRS) technology that continuously analyzes process media in industrial plants 24/7 for specific pathogens. For the first time, this will enable seamless quality control of products and optimal control of production processes. The FRS technology provides a platform which allows direct specific and quantitative measurements of microbial contamination of liquids and is suitable for fully automated execution due to a non-intrusive sample preparation.

The in-line process sensor is based on fluorescent, specifically functionalized polymer microspheres (µBeads), which bind to their target organism while floating in an analyte. Sensor readout is performed by optical means, i.e., by fluorescence excitation of the organic dye embedded in the µBeads and recording of its fluorescence emission (Fig. 1 (a), Fig. 2). A numerical algorithm is then applied to evaluate potential binding events on the sensor surface. The number of sensors can be chosen high enough to provide reliable statistics on the concentration of the target pathogen in the analyte.

A sketch of the basic implementation of an FSR sensor is shown in Fig. 1. The µBeads are added to a reactor line containing the medium to be screened for pathogens. To avoid its contamination with µBeads, the detection line bypasses the main line (cf. Fig. 2). The µBeads are optically interrogated, generating the FRS. The beads' functionalization can be chosen specifically for a certain pathogen, which then will bind to the µBead sensor, thus resulting in changes of the FRS signal (wavelength shift). These events can be detected with high spectral resolution of as small as 50 pm (Fig. 1 (b)). Continuous or random sampling will be possible on demand. About 4 ml sample volume per measurement are presently required. As shown in Fig. 2, the µBeads are filtered off the sample solution at the end of the measurement. The filters can be disposed as household waste according to local regulations. This sensing scheme can be easily extended to detect more than one microbial species at a time by varying the specific biofunctionalization of the µBeads.

Analysis of Legionella in Water

The state of the art is significantly advanced by the real-time acquisition of the resonance spectra emitted by the microsensors, which allows to detect the FRS signal of the µBeads in free suspension directly in the analyte. This not only minimizes the reaction time with potentially present pathogens, but also the effort required to operate the sensor. The typical time for analysis of legionella in water is reduced to presently less than 60 min. compared to roughly a week with nowadays employed methods. For demonstration, the title grafic shows an SEM image of a functionalized µBead with adsorbed legionella from a contaminated water sample.

FluIDect is currently working on the first prototype for use in an industrial environment. The goal is to be able to operate the first pilot applications in the drinking water sector before the end of 2023.

Society6.0 Bewegung für Menschen und Umwelt eG, Würzburg DE/ FluiDect GmbH, Jena, DE

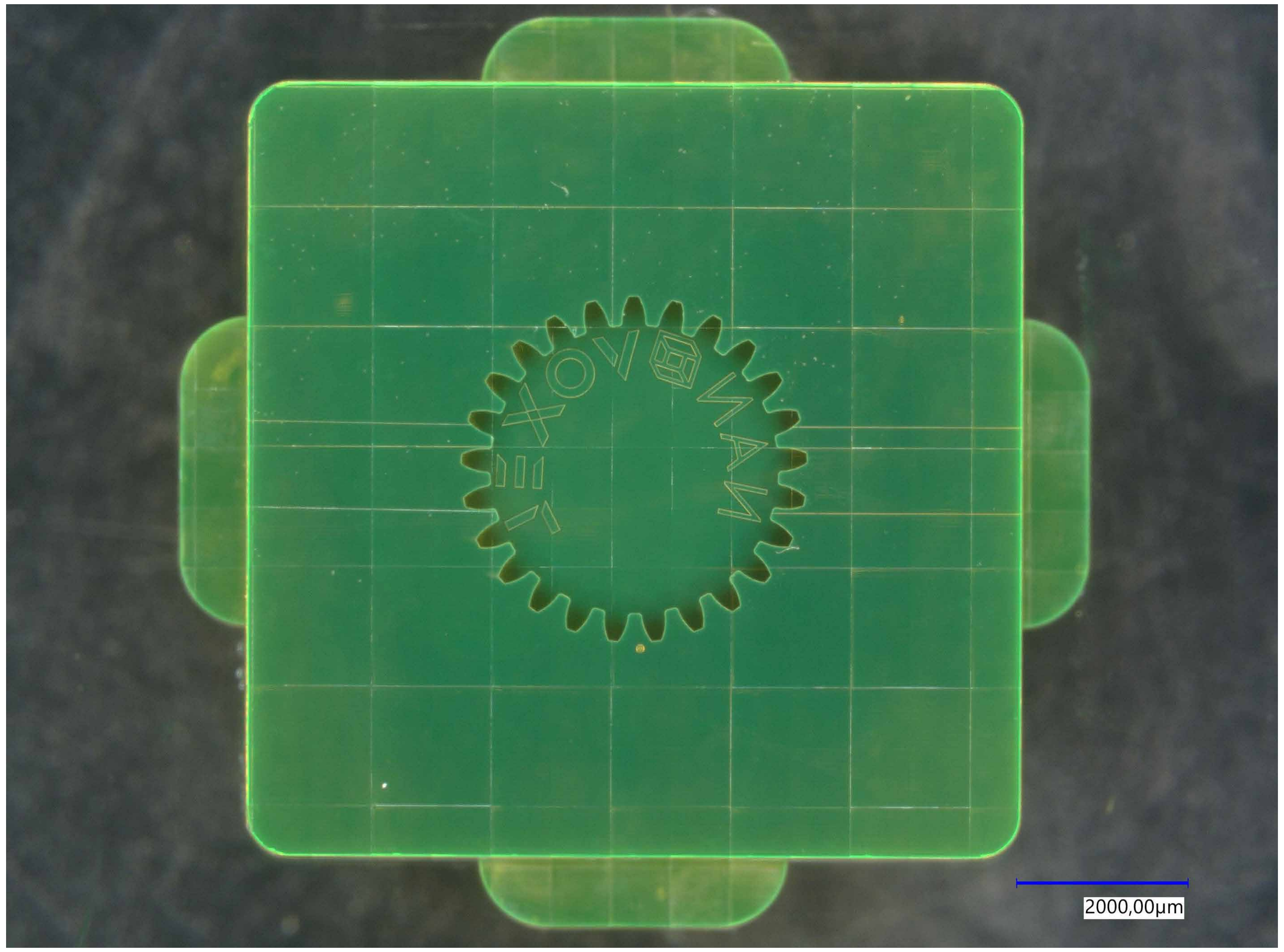
https://society-6.org/en
https://fluidect.com/en

Domenico Foglia

2PP MICRO 3D PRINTING

Two-photon polymerization (2PP) is a micro 3D printing technology that uses ultrafast (femtosecond) lasers to selectively polymerize photosensitive resin to create complex structures with high precision and resolution. This is achieved by two-photon absorption at the focal point of the laser beam, which allows for high-resolution printing with voxel sizes as small as 200 nm. Compared to other micro 3D printing methods such as μ-DLP, 2PP is the only one capable of preserving single-digit micron features, avoiding post-curing processes, achieving nanometric precision and smooth surface finish down to 10 nm of roughness. This technology is already known to produce microstructures such as photonic crystals, microfluidic devices, tissue scaffolds, and advanced optical components such as lenses and waveguides.

2PP 3D- printed cavity



New Generation of 2PP Printers has Arrived on the Market

Since the company UpNano entered the market, the new generation of 2PP printers has achieved print speeds up to 100 times faster than before, approaching μ-DLP throughput while maintaining higher resolutions and precision. Depending on the resolution and material used, advanced 2PP technology can achieve print speeds of up to 0.5 cc/hr. This makes it economically feasible to produce larger centimeter-scale parts requiring micro features or the highest precision (±5 μm), which is more convenient than standard subtractive manufacturing methods.

2PP as New Solution to Produce Highest Precision Polymer Softtools

In addition to final parts printing, 2PP has great potential for the development of high-precision soft tooling for mass production techniques. Standard production of hard steel tools using subtractive methods such as CNC and EDM can take up to 20 weeks, which impacts prototyping iterations and development builds in fast-paced industries. In contrast, 2PP printing technology can produce a polymer tool with tolerances of less than 10 microns overnight instead of four months, enabling multiple iterations of part production and design corrections down to single microns in a short period of time to achieve perfectly dimensioned parts (±3 microns).

NanoVoxel is the first company in the world to offer a high-speed 2PP 3D printing service, integrating in-house 2PP with other manufacturing processes such as μ-injection molding, thermoforming, hot stamping and vacuum casting to provide a one-stop-shop for micro parts.

Initially, NanoVoxel focused on developing a direct tooling process for μ-injection molding, using a 4 mm diameter micro gear as a sample geometry. After several iterations, the polymer cavity was designed with high-precision and very narrow venting channels that would be nearly impossible and economically unfeasible to produce using conventional subtractive methods. These complex venting channels have greatly reduced the clamping and injection forces required during molding, increased mold life, and enabled the production of more than 50 POM parts from each cavity with high repeatability (± 3 μm) and clearly sharp edges.

2PP 3D printed gear

Exact Masters Allows High Precision Indirect Tooling

The ability of 2PP to produce high definition masters opens up the possibility of using secondary processes for indirect tooling, allowing the creation of multiple molds from a single master and the creation of cavities with a wider range of materials than those available for 2PP printing like metals, glass, ceramics, thermosets, etc.
By utilizing this method, NanoVoxel will be able to reduce the turnaround time of robust micro molds, increase throughput and the durability of the cavities, allowing this technique to be used for medium to high volume production.

The ultimate goal of is to simplify the miniaturization challenge for innovative companies by disrupting the current manufacturing of small and micro parts, offering different materials - mostly polymers - and highest precision, from early development to mass production.

NanoVoxel GmbH, Wien AT
https://www.nanovoxel.com

Dr. Martin Forrer / Andreas Kunz

MICRO OPTICS DRIVING HIGH POWER DIODE LASER APPLICATIONS

FISBA is a pioneering supplier in the diode laser market, specializing in the development and production of precision micro optics solutions for beam shaping.
The need for outstanding collimation performance in diode lasers motivates to strive for excellence in creating solutions that cover every aspect of the development process, from requirements to design solution, testing, and validation to product delivery.

Crafting collimation design for diode laser beam shaping requires respecting miniaturized dimensional and other system requirements for delivering a stable beam to the application via free-beam or fiber-optics. A core competence is manufacturing collimation optics using precision optical glasses, integrated, and tested to the highest quality requirements in the industry by the operational excellence made available in the production teams.

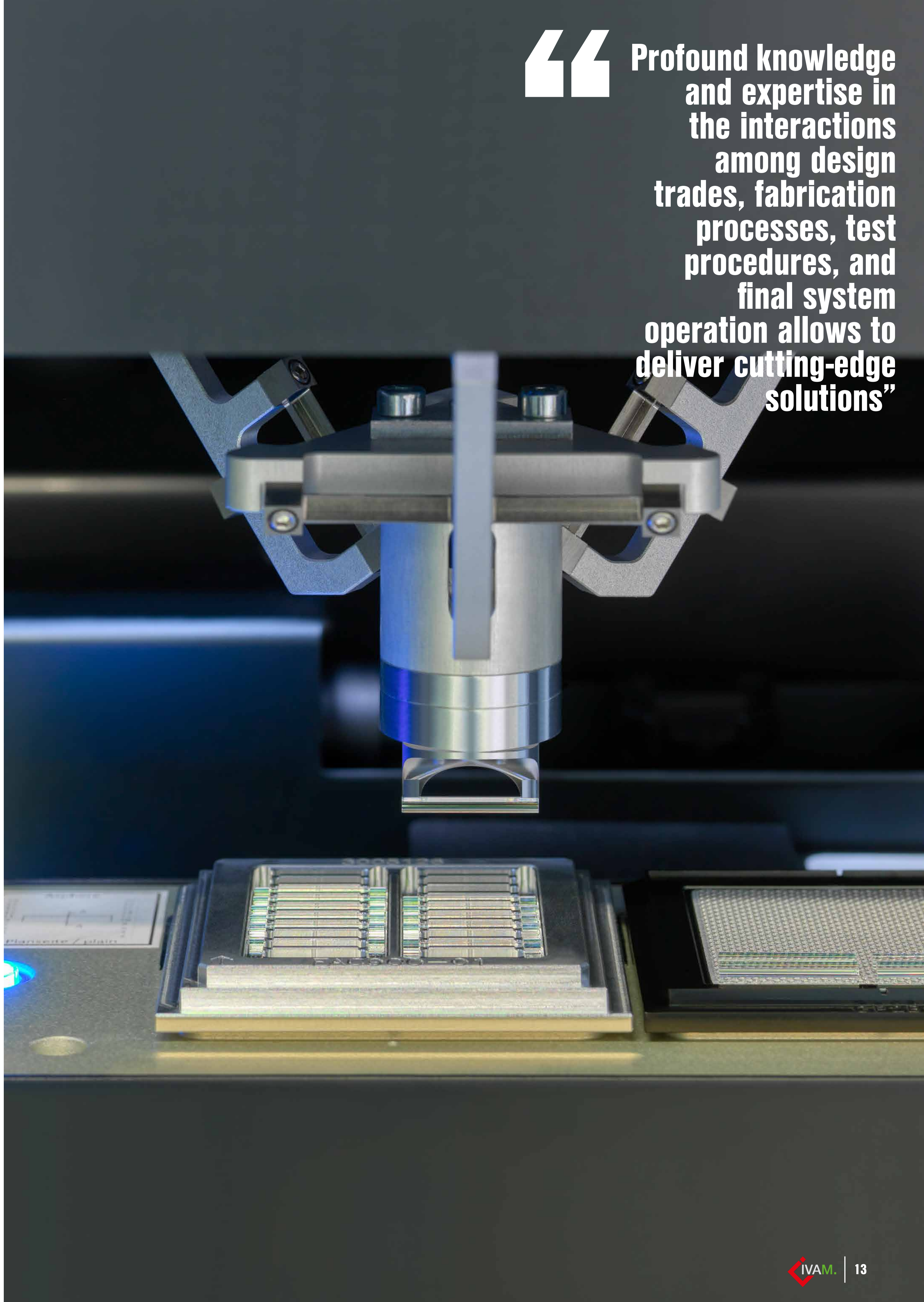
Fiber Laser Pump Modules Collimated in Fast and Slow Axis with FAC and SAC Micro Optics

The drive towards higher power fiber lasers in advanced manufacturing applications is gaining momentum due to the increasing pump power available from high power diode lasers. A multitude of single edge-emitting high-power laser chips emit light that is coupled to fiber pump modules, using specific micro optics to collimate the fast and slow axis (FAC/SAC). To meet the growing demand for increased collimation performance, highly reproducible processes are used to produce higher quality miniaturized optics. FISBA offers a broad range of standard components, and also quick to customize to meet specific customer needs and ramp up production of these customized parts promptly. Continuous innovation and improvement in these components enable FISBA to offer the highest levels of optical performance, especially with coatings designed for the specific diode laser wavelength.

High Power Blue Laser Direct Diode Welding and 3D Advanced Manufacturing

There are growing demands for high-power industrial blue diode lasers in direct diode laser processing applications, such as laser welding and additive manufacturing of copper, gold, aluminum, and other materials. These diode lasers have unique physical features that make them ideal for material processing applications, which all rely on high-power edge-emitting diode lasers.

Optimal collimation performance with fast-axis collimation (FAC) and slow-axis collimation (SAC) combinations is crucial for achieving exceptional power-scaling in these applications. Aspherical correction for FACs is already an industry standard and FISBA provides the same feature for SACs improving system performance, especially for blue laser diodes, which



typically have lower emitter width and higher SA divergence. Both FACs and SACs are designed and manufactured using optimized material selection and coatings. FISBA also offers pre-assembled micro optics, such as FACs on the bottom tabs, with high precision alignment.

Printing with Individually Addressable Single Mode Diode Laser Arrays Integrated with Micro Optics

CTP printing is a prepress digital printing technology that directly creates printing plates from digital files, eliminating the need for film-based processes. A technology in CTP printing is individually addressable single diode laser arrays integrated with micro optics.

These lasers selectively expose the printing plate to create the image that will be printed. The individually addressable lasers offer greater precision and control in the imaging process, allowing for precise energy delivery to each point on the plate. This results in sharper, more accurate images, and greater consistency between different plates. Micro optics integration further enhances precision by shaping and controlling the laser beams for focused and accurate exposure. The use of FISBA micro optics in CTP printing produces higher quality printed materials.

Cytometry Imaging Powell Lenses with Micro Laser Module Platforms

Cytometry imaging is a powerful tool used in a wide range of applications, including medical diagnostics, research, and drug development. By using Powell lenses and micro laser modules researchers can improve the accuracy and precision of their analyses leading to more reliable results.

Powell lenses can transform Gaussian laser beam profiles into top-hat profiles, providing precise and homogeneous laser illumination. This is particularly important in cytometry imaging, where even and consistent illumination is crucial for accurate analysis. The use of Powell lenses can also improve resolution and reduce background noise, enabling researchers to identify and analyze individual cells or particles more easily.

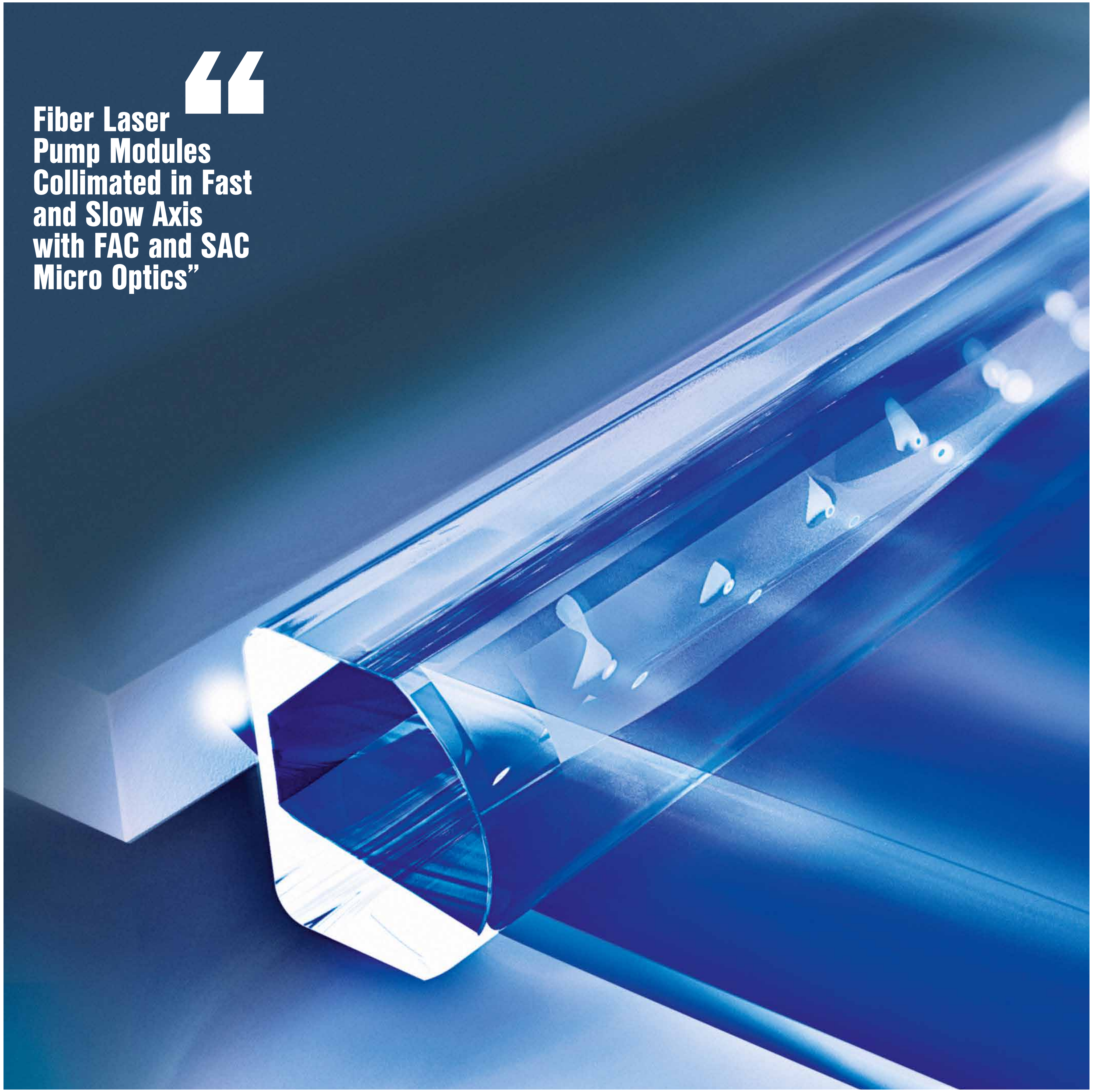
Micro laser modules are compact and highly integrated laser units that provide high-quality laser output in Gaussian beams. These modules can be easily integrated into imaging systems, making them ideal for use in cytometry imaging. By providing precise and high-quality laser output, micro laser modules can improve the accuracy and resolution of cytometry imaging, allowing researchers to identify and analyze individual cells or particles more accurately.

FISBA is developing custom-specific Powell lenses combined within their micro laser module platform to enhance the precision and accuracy of cytometry imaging. This combination of technologies can provide researchers with a powerful tool for analyzing individual cells or particles with high accuracy and precision, leading to better results in a wide range of applications.

FISBA's expertise in designing and manufacturing diode laser solutions with micro optical and opto mechanical systems makes them a global leader in the markets of Life Sciences, Industrial Applications and Aerospace & Defense. With the increasing demand for high power diode laser devices, it has become critical to get these devices to market with the right solution.

FISBA AG, St. Gallen CH

https://www.fisba.com



Amir Ghadimi / Davide Grassani / Steve Lecomte / Andreas Voelker

A NOVEL MULTI-PROJECT-WAFER PLATFORM FOR DISRUPTIVE PIC SOLUTIONS

Photonic Integrated Circuits (PICs) are providing powerful new options to generate, route and process light for applications in metrology, sensing, telecommunication, or quantum computing. Silicon based PICs are already today a core component of our telecommunication infrastructure, specifically in the form or transceivers which are used in the millions in data center around the world. Silicon has been the obvious choice of material, because of its availability and the wide-spread and established know-how in classic semiconductor industry that could easily be adopted to manufacture Silicon PICs in large volume. While Silicon has proven its advantages for the semiconductor industry, it is by far not the only option regarding PICs. Materials such as Silicon Nitride (SiN), Barium Titanate (BTO) or Indium Phosphide (InP) all offer their specific advantages for PICs. One of the most promising materials for integrated photonics however, is thin film Lithium Niobate on Insulator (LNOI). It offers a variety of unique optical properties, including a high electro-optic (EO) coefficient, high intrinsic 2nd and 3rd order nonlinearities, and a large transparency window (350 to 5500 nm). These properties enable precise control of the temporal and spectral profiles of photons, efficient frequency up- and down conversion, quantum transduction, and entangled photon pair generation, which makes LNOI perfectly suited for quantum applications.

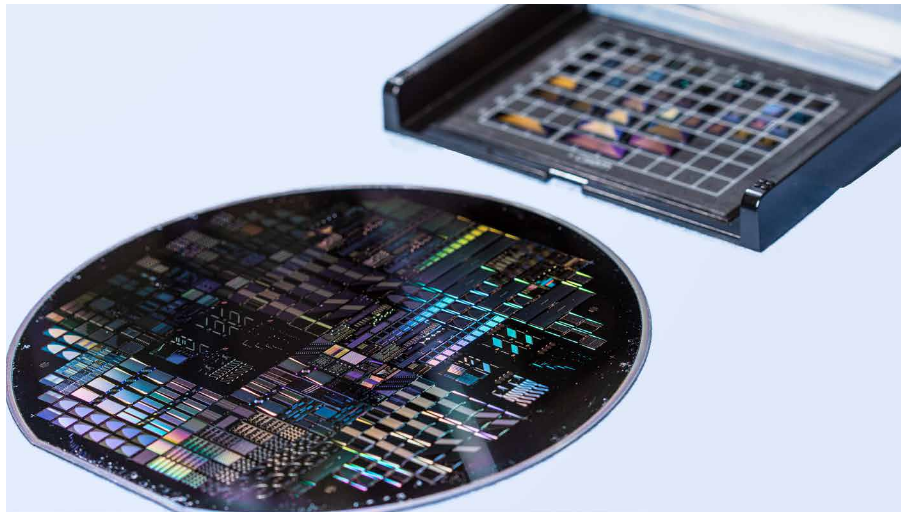


Figure 1: Lithium Niobate on Insulator Multi-Project-Wafer (LNOI MPW) produced at CSEM, Switzerland

For this reason, CSEM has been building expertise in design, simulation, fabrication, and testing of PICs based on its in-house LNOI platform. Despite the significant advantage of the LNOI technology for many applications, as of today there is still no industrial foundry that can offer standardized production of LNOI PICs. CSEM is set to change this by establishing an open access PIC foundry for LNOI platform based on a well-tested process design kit (PDK) library. Such PDK library includes standardized essential components which can be used to design and fabricate more complex systems on a chip. CSEM is developing PDK library for both passive (waveguides, couplers, grating etc..) and active electro-optic and nonlinear structures (modulators and frequency converters). This endeavor has been strongly supported by several ongoing European and national projects to further develop both the wafer scale fabrication technology and the PDK. Since 2022 CSEM has been offering first multi-project wafer (MPW) fabrication services to selected external customers (Fig. 1).

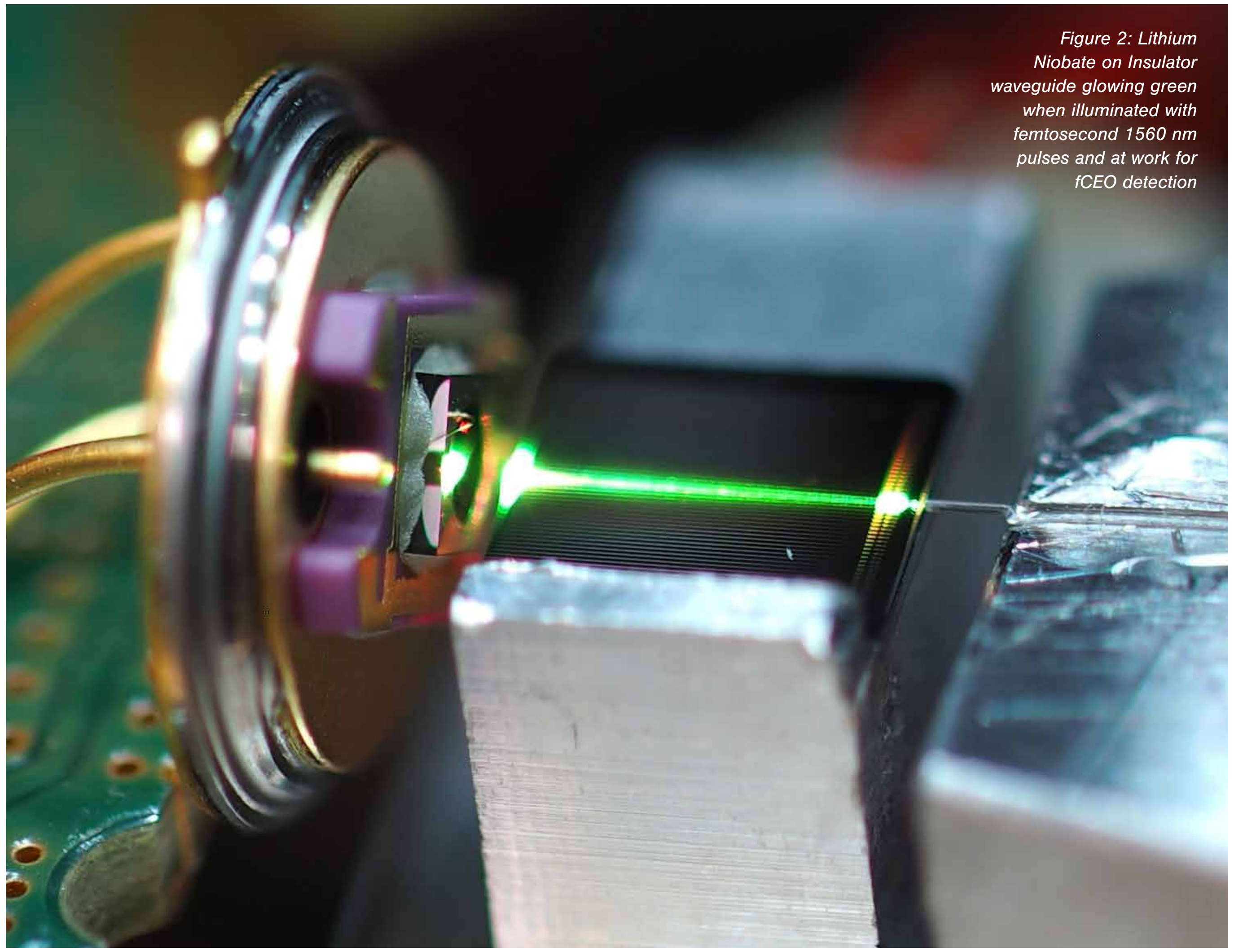


Figure 2: Lithium Niobate on Insulator waveguide glowing green when illuminated with femtosecond 1560 nm pulses and at work for fCEO detection

PDK development has so far focused on components suited for telecom wavelength, since one of the most important previewed applications will certainly be data transceivers, as well as data switches for next generation of data centers. But component design is now also expanding to other wavelength that will be more relevant in the field of quantum technologies for applications such as geo-localization, quantum computing or medical diagnostics.

With respect to laser technology, LNOI PICs are game changers in femtosecond laser self-referencing (to obtain an optical frequency comb), because they can drastically reduce the laser pulse peak power (and hence average power) requirement, while, at the same time, occupying a much smaller volume than the traditional approach, based on nonlinear fibers and frequency doubling crystals. LNOI PICs will thus make optical frequency combs more affordable, compacter and more energy efficient, which will significantly increase the range of potential commercial applications. One example developed at CSEM is a carrier-envelope-offset frequency (fCEO) detection unit (Fig. 2) based on LNOI waveguide technology.

These promising results confirm that the rapidly maturing LNOI PIC technology, with its unique capabilities, offers a tremendous potential to impact many fields of application in the coming years.

CSEM Centre Suisse d'Electronique et de Microtechnique SA, Neuchâtel CH

https://www.csem.ch

Julia Wecker / Prof. Karla Hiller

SILICON INFRARED WAVEGUIDE TECHNOLOGY
WITH TUNABLE COMPONENTS

Based on a proven cavity-SOI-technology, an optical platform on-chip for the MIR range developed at Fraunhofer ENAS combines modular building blocks such as edge and grating couplers, optical resonators and waveguides with built-in optical filters. Integrated MEMS actuators allow for tuning of the optical components, as demonstrated here for an embedded tunable Fabry-Pérot interferometer.

On-chip integrated Spectrometers

One of the first application examples of the novel platform on-chip aims for very small size and low-cost MIR spectrometers with possible applications in (hand-held) devices e.g. for gas and environmental sensing. For gas sensing, e.g. a “free-space” approach utilizing optical cavities for facilitating the light-gas interaction or the evanescent field of waveguides or resonators in the mid and long infrared wavelength range are used as “gas-sensitive” elements. In general, spectrometers can be distinguished according to their wavelength selecting principle in grating-based diffraction spectrometers (e.g. supplied by Hamamatsu), Hadamard transform spectrometers, MEMS-based Fourier transform spectrometers, Fabry-Pérot interferometer (FPI) based spectrometers, and spectrometers with linear optical filters and multi spectral sensors. Modular approaches with the integration of components like waveguides, bends and couplers on one single chip have been already reported in the literature, mainly for the NIR range. In the development towards single chip spectrometers, in-plane FPI filters are of particular interest because of their high integration potential.

Tunable Optical Filter as Key Component

As part of the optical platform on-chip, we present a waveguide integrated tunable Fabry-Pérot interferometer for the long infrared wavelength range. The development goals for such kind of electrically tunable wavelength filters are high passband transmittance, sufficiently high wavelength selectivity and wavelength tuning range, excellent (digital) control of the filter wavelength, small outline and affordable cost and low complexity of the fabrication technology. To meet these requirements, our FPI consists of two parallel Bragg reflectors that are located at the ends of two waveguides facing each other. The (multimode) waveguides are made of low doped silicon and are suspended in air. The reflectors are realized as an alternating stack of silicon and air layers with high (H) and low (L) refractive index. The filter transmittance is evaluated by analytic calculations and electromagnetic finite difference time domain simulations. Filters with $(HL)^2$ layer stack show a full width half maximum of 270 nm and a peak transmittance of more than 25 % at a wavelength of 9.4 µm at the first interference order in the simulation. A MEMS actuator is used to tune the filter wavelength by changing the distance between both reflectors. A digital electrostatic actuator concept with a linear drive characteristic, designed for a large travel range up to 4 µm with a driving voltage of less than 30 V has been realized and evaluated together with the filter. The tuning characteristics of the filter is visualized in Fig. 1. The MEMS fabrication process for the Si structures is based on bonding and deep reactive ion etching (BDRIE). The DRIE etch process was optimized, hereafter achieving a reduced roughness of less than 3 nm of the waveguide and reflector sidewalls for low optical loss. For transmission measurements, the FPI was coupled into the optical measurement setup using grating couplers and edge couplers. It was successfully tested with a 9.0 µm to 9.4 µm laser source (from Thorlabs) and a MCT detector (Bruker Optics).

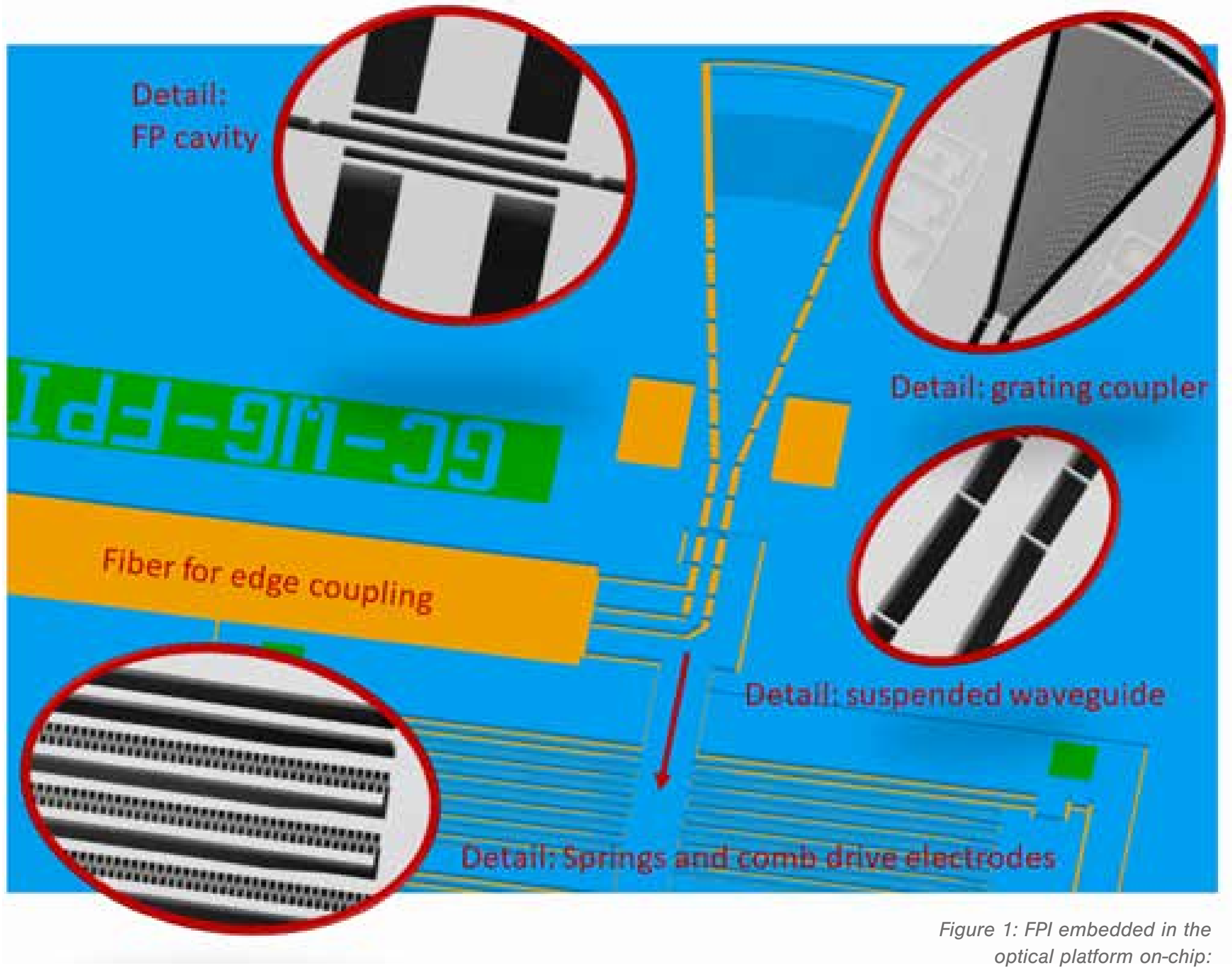


Figure 1: FPI embedded in the optical platform on-chip: Schematics and SEM details of fabricated devices.

Outlook

While presently designed and demonstrated for a wavelength range around 9 µm, the concept is not limited to this range. Relying on the well-established Si waveguide and MEMS material, the working range can be extended both to the NIR range and to the long IR range; up to 12 µm extension is already planned. The filter design can be easily adopted by adjusting the Bragg reflector and resonator cavity respectively. Furthermore, the IP building blocks can be arranged to form flexible and even more complex optical systems. Looking on the technology prospective, we also aim for a double-layer “waveguide-on-MEMS” concept, which may as well enable the integration of other waveguide materials, such as SiN or AlN, and hereby the extension of the concept to the VIS range. In a future perspective, the hybrid or even direct integration of light source (e.g. thermal emitter) and detector is feasible. Due to the established optomechanical coupling, the MEMS components can also be used e.g. as inertial sensing elements, since the integrated photonic resonator components enable a highly sensitive detection of tiny mechanical deflections.

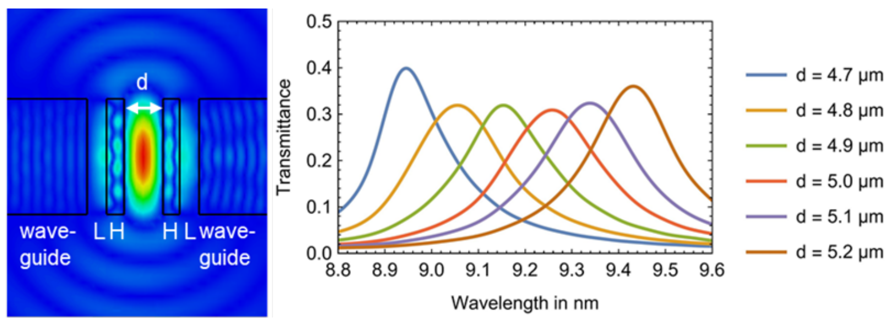
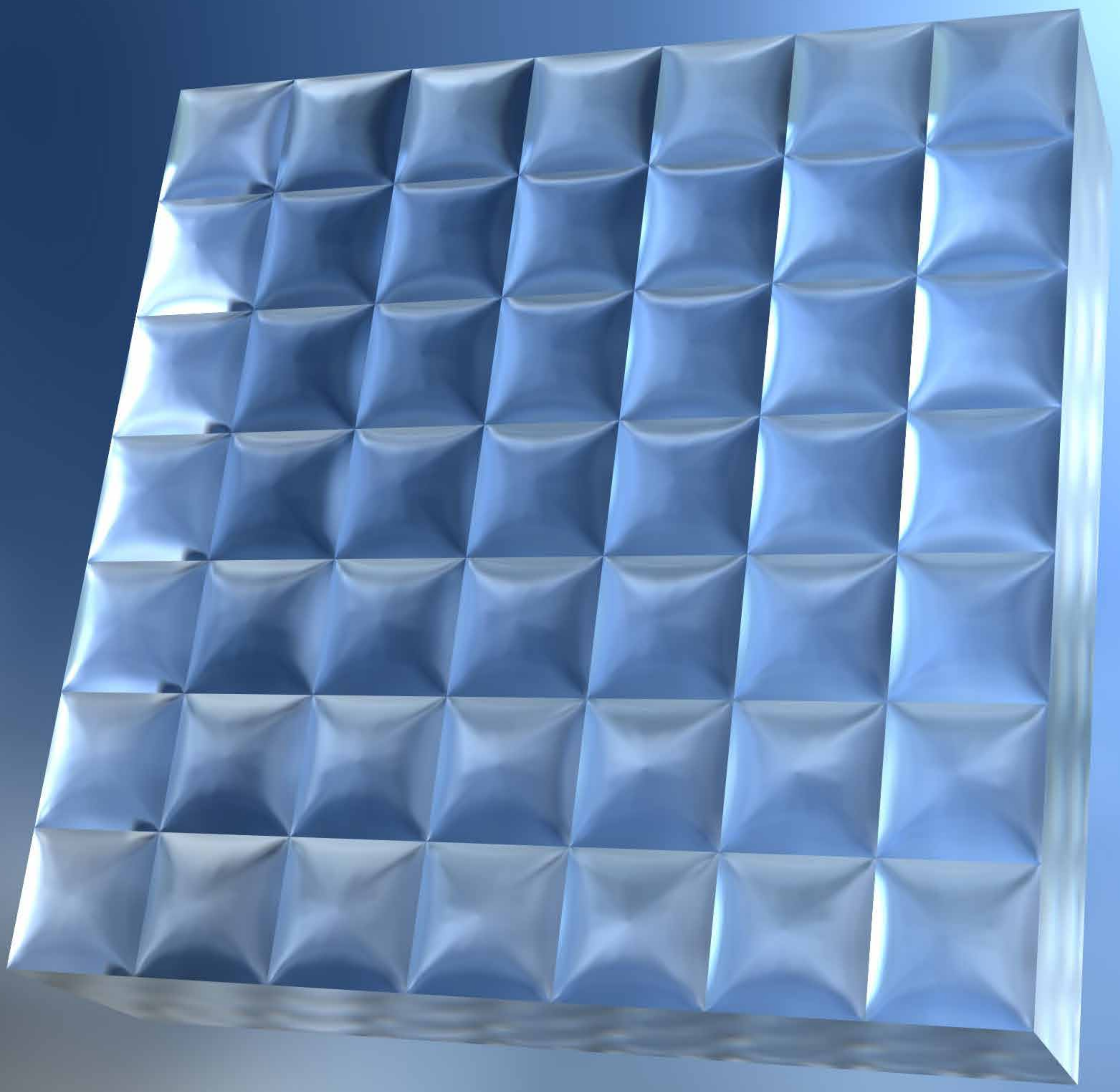


Figure 2: Electric field and transmittance of first order FPI for different resonator distances d between the reflectors.

Fraunhofer Institute for Electronic Nano Systems ENAS, Chemnitz, DE

https://www.enas.fraunhofer.de

Shack Hartman array by SUSS MicroOptics, typically used in ophthalmology and microscopy



Giorgio Quaranta

MICRO OPTICS AS KEY COMPONENTS IN HEALTHCARE

Micro optics and diffractive optics are highly innovative elements which have been instrumental in many areas of healthcare. They offer a wide range of benefits, from unique functionalities to enhanced precision, miniaturization and performance, which translate into practical and economic advantages for users in the healthcare industry.

Micro Optics for Precision Laser-based Procedures in Dermatology and Ophthalmology

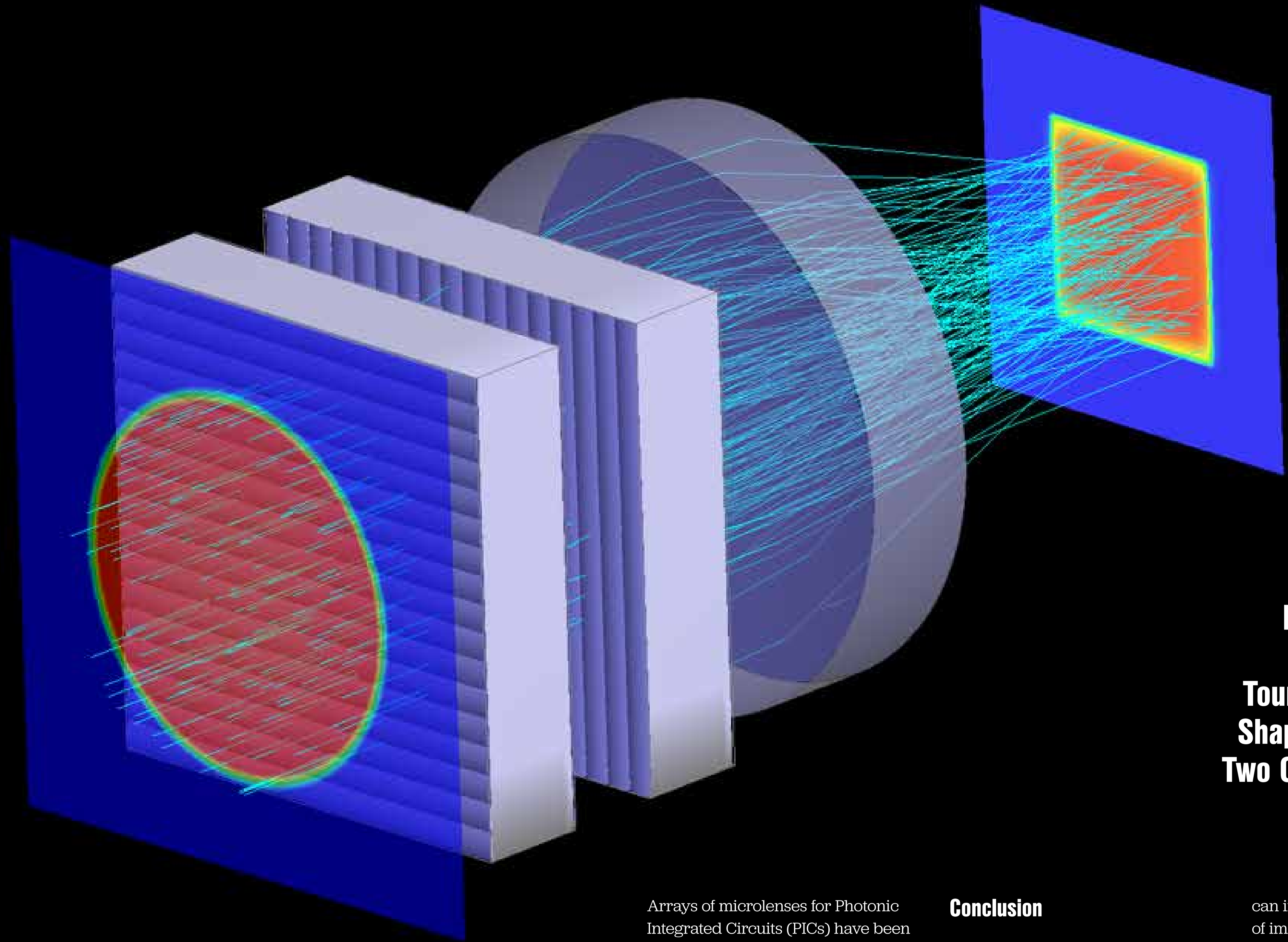
Most medical laser-based applications require a uniform light distribution in order to achieve the best possible results. The integration of micro optics within these medical procedures enhances the precision of the laser-based techniques, reaching a high efficient homogeneous working plane, increasing the treatment performance and minimizing side effects for the patient. For instance, in dermatology, the microlense arrays (MLAs) or diffractive optical elements (DOEs) are used to improve the accuracy of laser skin treatments, such as tattoo or hair removal as well as skin rejuvenation. In particular, laser tattoo removal utilizes high-power laser radiation that penetrates deep into the skin to permanently remove the ink particles. MLAs or DOEs are compatible with high power laser applications and therefore enable the focus of the beam into the smallest, uniform point, in order to target the minuscule-inked areas whilst avoiding damage to the surrounding tissue. The tailored micro optics also improves the performance of laser-based skin rejuvenation treatments, by generating a homogenous point pattern on the skin resulting in refined skin tone and complexity.

In ophthalmology, micro optics also plays a crucial role in strengthening the precision of laser eye surgery (LASIK). Specific tailored microlenses can advance the performance of the laser beam, enabling precise modification of the cornea's shape with minimal risk of adverse effects.
The integration of micro optics in laser-based procedures in dermatology and ophthalmology has greatly increased the precision of these treatments, providing better outcomes and reducing the risk of complications.

Micro Optics as Enabling Technology in Odontology and Endoscopy

Micro optical components are essential elements for imaging systems, and can be easily integrated into the optical assemblies of imaging diagnostics devices, such as endoscopes or 3D dental scanners.
In both odontology and endoscopy, micro optics plays a central role in improving the efficiency and precision of imaging systems, enhancing their optical performance and reducing their size. The integration of micro optics in odontology allows the facilitation of 3D dental imaging, with less invasive procedure for the patient and more accurate imaging of the oral cavity. Similarly, in endoscopy, micro optics components are key elements of the device optical system and play an essential role in improving the image quality.

By using MLA-based illumination optics, endoscopy and intraoral scanner systems can highly improve efficiency, resulting in better diagnostic accuracy and shorter procedure time, also reducing the patient discomfort. The use of micro optics in health imaging systems enhances efficiency but also reduces patient´s discomfort and procedure time, making these procedures less invasive and more accurate.



Beam Homogenizer Simulation: Tound-to-Square Beam Shape Conversion with Two Crossed Cylindrical Lens Arrays

“MICRO OPTICS SOLUTIONS FOR NON-INVASIVE METABOLIC SCREENING”

Arrays of microlenses for Photonic Integrated Circuits (PICs) have been integrated into intelligent wearables to monitor heart rate, blood pressure, and sleep. Non-invasive point-of-care wearable devices incorporate these microlenses to accurately measure various metabolic parameters, such as glucose and oxygen levels. This enables a real-time, label-free monitoring and miniaturization of the device, making it more portable and convenient for users. This contributed to making metabolic screening easier and more accessible for both healthcare professionals and patients.

Conclusion

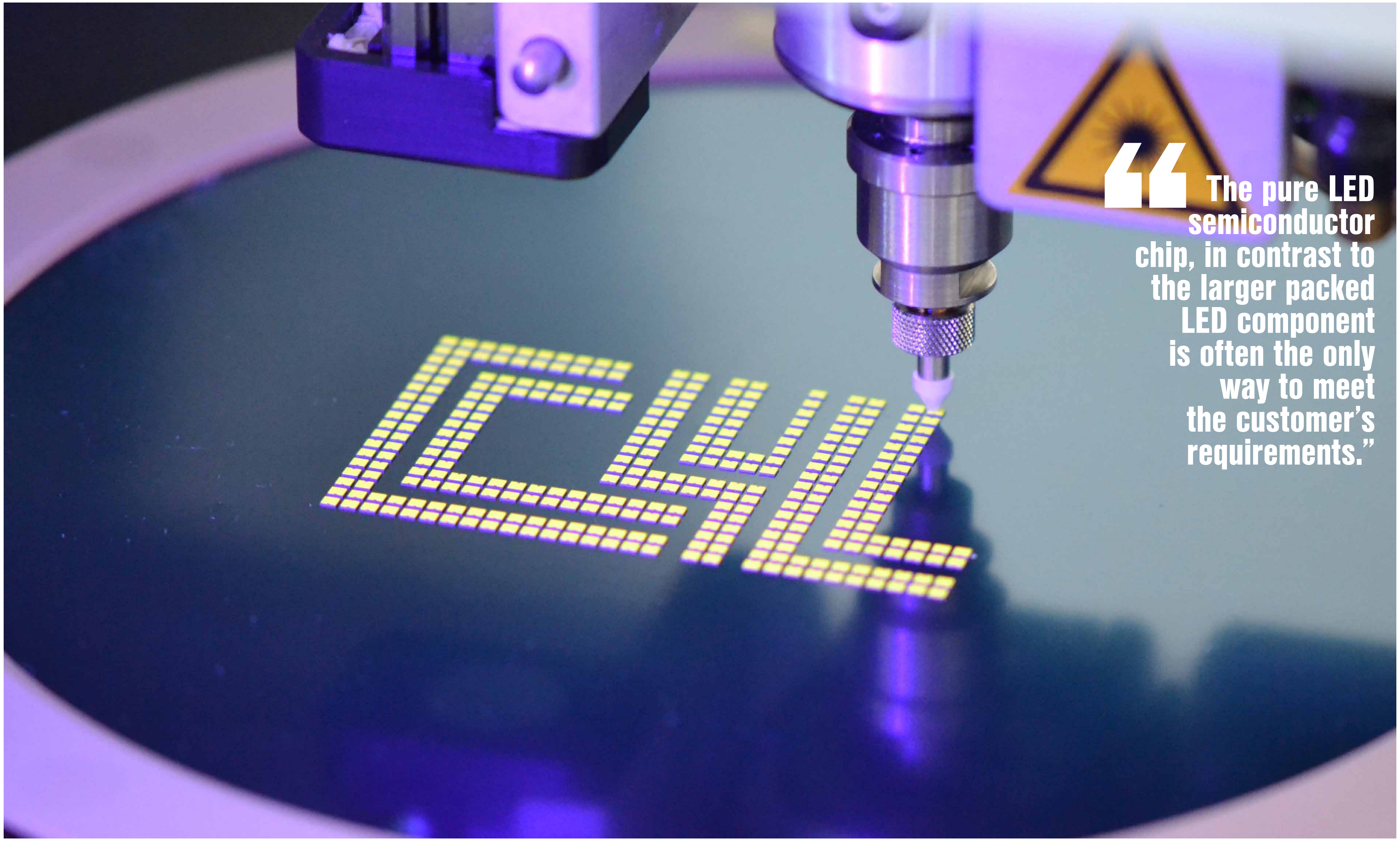
Micro optics has proved to provide a variety of practical, economical and benefits in the field of healthcare. With its unique functionalities, precise targeting and delivery of treatments, micro optics can lead to more effective treatments with fewer side effects. This increased precision can also reduce the need for multiple treatments, ultimately lowering healthcare costs. Additionally, the small size of micro optics allows the development of smaller and miniaturized medical devices. Furthermore, the use of micro optics can improve the optical performance of imaging systems, by increasing the resolution and contrast of images. This enhanced imaging can lead to earlier detection of diseases and more accurate diagnosis, ultimately exceeding health results. Overall, the integration of micro optics into healthcare devices and procedures, has the potential to significantly impact the field, providing improved treatments and outcomes for patients, while also lowering costs and increasing accessibility.

SUSS MicroOptics SA, Hauterive CH
https://www.suss-microoptics.com

Dr. Wolfgang Huber

LED CHIPS CUSTOM MEASURED FOR PRECISE REQUIREMENTS

Chips 4 Light supports companies that have special requirements for optoelectronic components and are looking for specific solutions for small and medium quantities. The company is primarily a distributor for LED chips, detectors and laser products, but also develops LEDs and LED modules outside the usual market standards or manufactures prototypes on customer request.



"The pure LED semiconductor chip, in contrast to the larger packed LED component is often the only way to meet the customer's requirements."

LED Chips as Miniaturized Light Source in Sensor Technology

Developers of precision sensors are often looking for components with special properties. These are not always available on the market. Specific conditions, such as limited space and high ambient temperatures, make it difficult to use standard LED components. The pure LED semiconductor chip, in contrast to the larger packed LED component is often the only way to meet the customer's requirements. LED chips have a number of advantages in the development of for example sensors, especially when it comes to addressing specific requirements. Because they are very small, unlike larger LED components, they can be used in applications where available space is limited. Among other things, the bare die allows the design to realize different functions on one board, for example several wavelengths on a very small area or integration of LED chips and photodiodes in a common, tiny package as well as the highly precise placement of optical components like lenses relative to the die to establish a special viewing angle.

Chips 4 Light meets exactly these challenges with an extensive LED and detector chip portfolio (synonymous are dice or die). In addition to the opto-semiconductors components, the company has equipment to meet customer-specific requirements.

Services for Storage, Die Sorting and Measuring

Chips 4 Light has therefore also invested in "die sorters", which are used to sort the single LED chip off the wafer and place on different carriers as blue foil, UV foil, gel or waffle pack, which is necessary to create small quantity sample wafers for initial customer evaluation. Additionally the company also offers its customers long-term storage of LED chips in waffle or gel packs for the complete

“Die sorters” are used to sort the single LED chip off the wafer and place on different carriers as blue foil, UV foil, gel or waffle pack.”

project duration by using special dry storage cabinets. This protects the LED chips from external influences such as moisture and dust and enables easy and safe handling, while getting rid of the blue foil, which is normally limiting the storage time of the chips.

Furthermore Chips 4 Light is able to perform a wavelength, brightness and voltage measurement of individual vertical dice according to customer specification. Even in case the customer needs support in the processing and packaging of bare dice, the company offers the development and production of customized LEDs as well as optical and thermal simulations upfront. Such precise detail work is delivered by the company not only in the field of LED and detector chips, but also for TO38 and TO56 semiconductor laser diodes in the visible and infrared spectral range. Chips 4 Light has developed a special measuring station, where individual laser diodes can be classified according to brightness, wavelength and viewing angle. Thus customers receive precisely measured laser diodes according to the desired specification.

Chips 4 Light GmbH, Sinzing DE
https://www.chips4light.com

Dr. Max K. Körner

STANDARDIZATION ENABLES PHOTONICS INDUSTRIAL PRODUCTION

Production equipment with high standardization levels and open interfaces provide an easy access to industrial automation of photonic product assembly. By encapsulating highly individual systems within a plug-&-produce system provides the opportunity to manufacturers to focus on their core applications as a unique quality factor of their product.

Industrialized Production of Photonic Products is Going to be a Game Changer

Light-based technologies have become a major aspect in modern world. Our highly evolved societies rely on it within communication and computing systems, use light as a fabrication tool or use it for measurement systems. Due to the broad range of applications, the availability of high quality and complex products at low costs are a more and more demand, which will be the major challenge for the near future. One answer to face this challenge is the fully automated production of photonics assembling. Confronted with such a challenge, the question arises: How to get from a mostly manufactory-like production to a highly industrialized automatic production solution for assembling photonic products in a growing and volatile market? This issue is even more relevant because most of the current companies in the photonics market are small or medium-sized ones.

The Answer is an Open and Standardized Plug-&-Produce Production Platform.

Today's production systems for the full automation of photonic product manufacturing are still associated with very high investment costs. In addition, it is difficult to find the manufacturing technology or appropriate combinations required for one's own product. It is even more difficult to commit to a system, although the own product to be automated is not yet fully defined but the market opportunity could already be huge. Access is thus hampered by a highly volatile market, high investment costs and low availability of required technologies integrated in fully automated production equipment.

The most suitable answer to the aforementioned challenges of full automation is a platform that offers established basic production skills combined with open, standardized interfaces to adapt almost any required technology. Häcker Automation has developed such a production equipment platform over the last 20 years to realize complex automation tasks in micro assembly.

The platform makes it easy to get started by providing basic machines of different sizes and purposes. All basic machines have highly standardized mechanical, electrical and software interfaces. This means that all machines can be equipped with the same modules. By using standardized main control software, the production process can be transferred very easily from laboratory scale to large-scale systems by the user itself. Another way of scaling up is to start production on a single machine with low throughput and to increase the yield considerably by dividing the sub-processes among individual machines. So, the ramp up of a newly developed product can start small and grow fast. Due to the standardized interfaces and the small-scale modularity of the platform it is quite easy to adapt new production technologies. This is a major benefit to survive in the volatile, innovative and growing photonics market as a manufacturer.

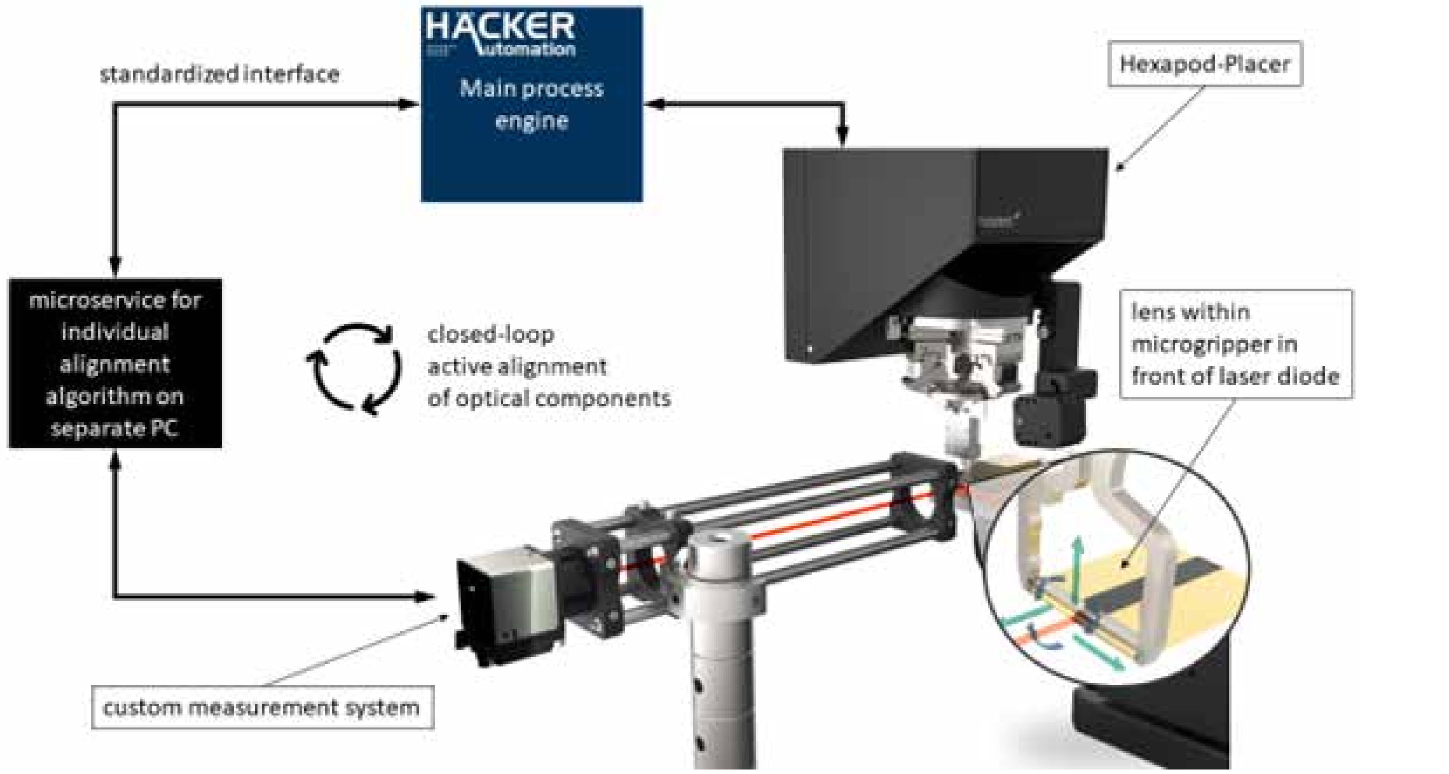
Encapsulating Individual Production Equipment in a Standardized Framework Enables Nearly Infinite Possibilities

The platform includes a variety of production modules for inspection, die bonding or dispensing that are already proven in electronics micro assembly. In addition, Häcker Automation has recently expanded the platform with new modules and standardized frameworks that are particularly suitable for photonics production. For instance, a hexapod module combined with microgrippers can be used as a placing system in alignment processes. To implement the possibility of active alignments into the platform a generic contacting system has been created. Further, the standardized and open microservice framework gives the possibility to adopt arbitrary measurement systems and adds the possibility of individual alignment algorithms to the platform.

The common closed-loop alignments of optical components are mostly combined with individual measurement techniques, e.g. characterizing laser beams or measuring relative positions in sub-micrometer range. The production platform provides a standardized interface to adapt any measurement system into the equipment and communicate the results of the evaluation algorithm to the main process engine. From there, any motion system of the platform can react on the new results and creates the closed-loop alignment.

Common integrations of measurement systems can reach from beam profiling cameras for active alignment

> **"Industrialized production of photonic products is going to be a game changer soon."**



of FAC and SAC lenses of high-power laser diodes (CoS-Systems) to white light interferometry for passive alignment of laser bars in the sub-micrometer range. In simpler contexts it could be more efficient to integrate scalar measurement systems like power meter or photodiodes to determine the control value of the active or passive alignment.

The complete microservice framework can be manipulated or even completely setup by the manufacturer itself. That means that the microservice encapsulates the individuality of the product within a standardized framework. Doing so, the manufacturer gets the possibility to combine its unique, validated processes with a versatile and standardized production platform.

Due to the standardized interfaces and the easy possibility to combine standard equipment with custom systems, the entry level to full-automation can be easily adopted to nearly every situation: From laboratory setups to high volume production. Starting from open-source systems to turnkey production equipment, the platform provides an all-in-one solution to face a large variety of photonics production challenges.

Häcker Automation GmbH
https://haecker-automation.de/en/

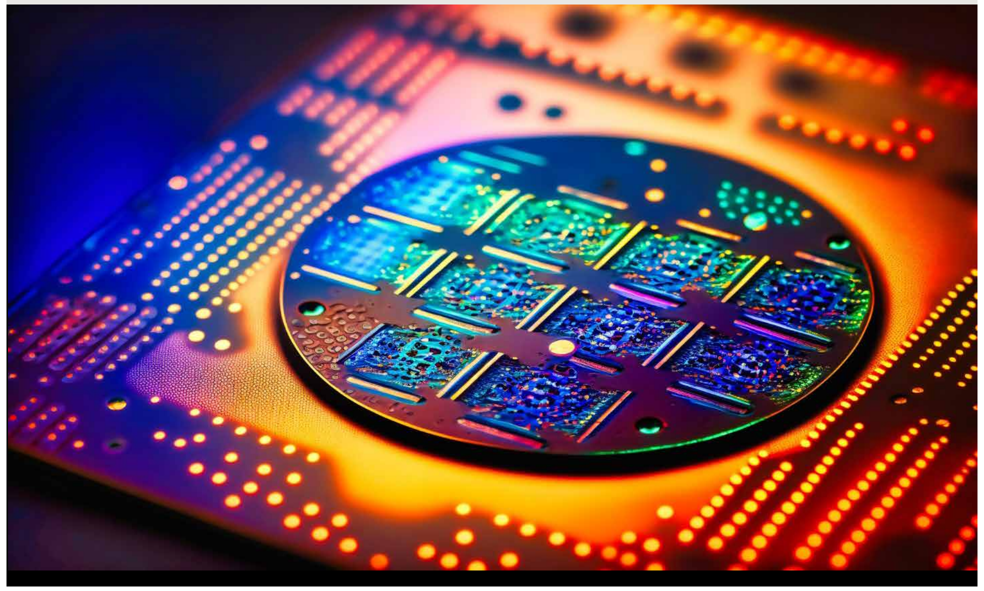
FASTER MARKET INTRODUCTION OF QUANTUM TECHNOLOGIES

Despite in scientific research in multiple technologies, European industry faces challenges in translating quantum technology innovation into robust and scalable hardware processes and products. Project Qu-Pilot will change this by leveraging the existing piloting infrastructure predominantly distributed across the European research and technology organizations (RTOs). The end goal is to accelerate the time-to-market of European industrial innovation in quantum technology and help establishing a trusted supply chain. Fraunhofer IPMS contributes its expertise in state-of-the-art, industry-compatible CMOS semiconductor fabrication in 300 mm wafer standard.

Success of the European start-ups and small and medium enterprises (SMEs) depends greatly on the efficient conversion of prototypes to pilots to production. Piloting, however, requires time and, in many cases, significant investments in infrastructure. These high costs represent a significant barrier for start-ups and SMEs to enter the very competitive quantum technology market early enough with their product. Project Qu- Pilot wants to change this. The aim is be to upgrade the existing pilot line infrastructures in Europe, predominantly distributed across the research and technology organizations (RTOs), and to enable product development loops together with the quantum technology hardware industry in Europe. The end goal is to accelerate the time-tomarket of European industrial innovation in quantum technology and help establishing a trusted supply chain.

https://www.ipms.fraunhofer.de

Silicon wafer. Source: Fraunhofer IPMS



GET TO KNOW IVAM MICROTECHNOLOGY NETWORK - JOIN A Q&A SESSION

Have you ever thought about whether your company could benefit from a membership in a network? Perhaps an IVAM membership may be the right solution for current challenges in your microtech-, biotech- oder deeptech-company! We cordially invite you to get to know the network better. You are welcome to bring specific questions, which we will then answer personally. Additionally you have the possibility to arrange an individual appointment.

sh@ivam.de

IMPRINT »INNO«

published by:
IVAM e.V.
Joseph-von-Fraunhofer Straße 13
DE - 44227 Dortmund

Editors:
Mona Okroy-Hellweg
Dr. Thomas R. Dietrich

Contact:
Mona Okroy-Hellweg
Phone.: +49 231 9742 7089
E-Mail: mo@ivam.de

PLAN OPTIK AND 4JET COOPERATE

Plan Optik AG and 4JET microtech have jointly developed a process chain for the highly productive production of metallized through-glass vias. The new VLIS process (short for Volume Laser Induced Structuring) enables the production of high-precision TGV („Through Glass Vias") for advanced packaging in glass wafers, or substrates for displays. TGV are micro-holes with a diameter of typically 10 µm to 100 µm. For various applications in the advanced packaging sector, tens of thousands of these vias are applied per wafer and metallized to produce the required conductivity. TGVs are also used in the manufacture of displays, for example based on µLED. Previous methods for manufacturing have been slow, associated with high reject rates, and difficult to match to the metallization process.

The teams from both companies have now developed a solution that can prepare several 10,000 vias per minute, which are etched in a batch process for subsequent plating. The resulting channels are positioned with a hole-to-hole accuracy better than +/- 2µm, the substrates are free of microcracks, and the insides of the channels are smooth-walled and can be homogeneously metallized. The process is suitable for glass types typical in the semiconductor and display industry. In addition to glass starting thicknesses of 100 µm, various copper layers down to 25 µm thickness can be realized. The two partners have agreed on a cooperation that provides users with a high degree of flexibility: Customers can either purchase components produced with VLIS from Plan Optik, or purchase qualified total solutions for system technology including laser systems, wet chemistry and metallization from 4JET and partners.

https://planoptik.com

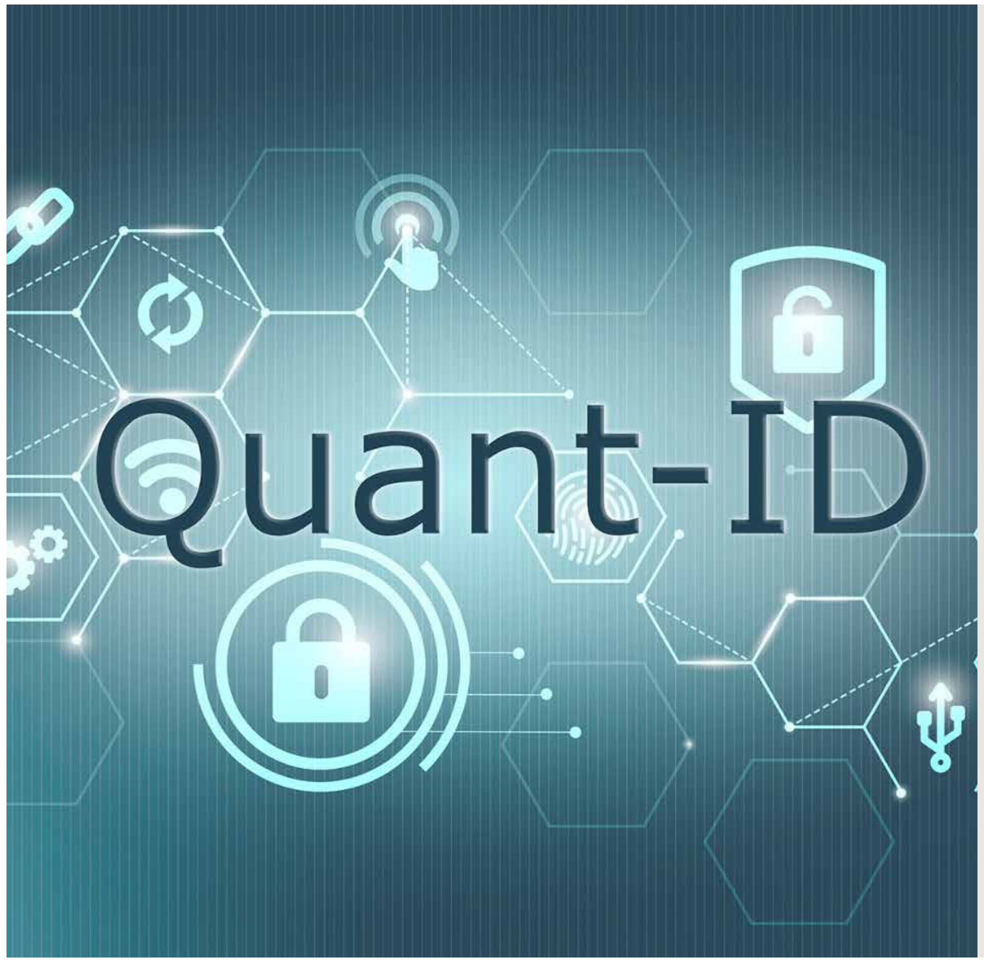
FLOW SENSOR FOR FLOW RATES UP TO 1 LITER PER MINUTE

Sensirion expands the possibilities of thermal flow measurement in laboratory analytics and industry. With the help of a new design, engineers have succeeded in developing a high-flow sensor with significantly higher liquid flow rates of up to 1 liter per minute. The Swiss manufacturer is thus advancing into a new dimension of accurate flow measurement and expanding their portfolio. Sensirion closes the gap of flow sensors for high flow rates in laboratory analysis and industry with the cost-effective SLF3S-4000B liquid flow sensor. It accurately measures flow rates up to 1 l/min with the usual quality, while measuring just 5 cm in length and weighing 7 g.

To accurately measure high flow rates, either higher flow velocities or larger channel cross-sections are required; both factors, however, increase the likelihood of turbulence. To overcome this hydrodynamic limitation, Sensirion's engineers employed a design trick when developing the new high-flow sensor: they laid out the new channel profile in a W-shape. This allows the MEMS chip to be positioned along the narrower side stream (with laminar flow), where it can really demonstrate its measurement performance.

With the new SLF3S-4000B high-flow sensor, Sensirion is moving into a new measurement dimension and now covers a much wider measurement range: from microliters per minute to 1 liter per minute. With the same look and feel as the three existing flow sensors in the SLF3x family, the SLF3S-4000B offers several advantages: users can continue to use existing cables or software for readout without customization, thus eliminating the need to reprogram software.

https://www.sensirion.com



QUANTUM-SAFE IDENTITIES

The security of digital identities is threatened by future quantum technologies. In the hands of attackers, quantum computers will be able to break classical encryption methods. To fend off such attacks, four partners - Quant-X Security & Coding GmbH, the Fraunhofer Institute for Photonic Microsystems IPMS, MTG AG and the University of Regensburg - launched the Quant-ID project. In this project, they are researching the development of novel methods and systems that guarantee cryptographic security in the long term based on quantum random numbers and post-quantum cryptography. The BMBF-funded project started in September 2022 and will run for three years.

https://www.ipms.fraunhofer.de

SWIR TO MIR, SUITABLE LIGHT SOURCES AND APPLICATIONS

PHOTONICS IVAM.

SWIR to MIR, suitable light sources and applications

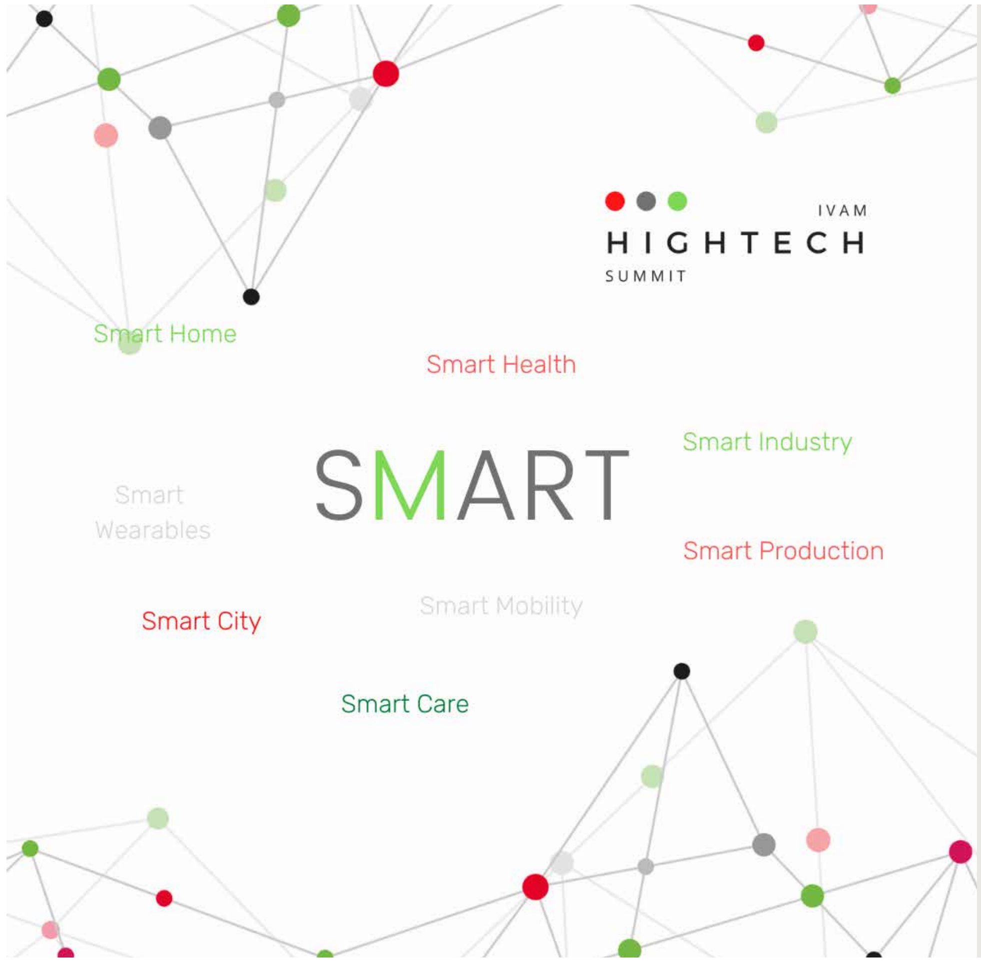
The sixth digital meeting of the IVAM Photonics Focus Group will take place on Tuesday, May 30, 2023 from 12:00 p.m. to 1:30 p.m. (CEST).

In the first part, Kristijonas Vizbaras from Brolis Sensor will present widely tunable III-V/silicon lasers for spectroscopy in the shortwave infrared range. The availability of such lasers, which operate in the short-wave range of 2-2.5 µm, is very valuable for spectroscopic measurement, as many important industrial gases and blood sugars have absorption bands there.

Integrated silicon photonic circuits (ICs) in the 2-4 µm wavelength range thus enable the development of miniature optical sensors for the detection of trace gases and biomolecules. Christian Rosenberg Petersen from Norblis will then provide insights into broadband mid-infrared laser technologies and their applications, e.g. in the automotive industry.

What are the benefits of these systems, where can they be used, and what are the challenges of using them? These and further questions will be discussed at the next Photonics Focus Group meeting. This will provide a basis for discussion on opportunities and trend directions for photonics companies. In addition to the talks, the discussion round will provide the opportunity for networking and the exchange of knowledge and experience. In the second part of the meeting, further activities of the Focus Group will be coordinated.

https://www.ivam.de/events/ivam_focus_group_photonics



IVAM HIGHTECH SUMMIT SHOWS INNOVATIONS FOR DIGITALIZATION

At the IVAM Hightech Summit 2023 "Microtechnologies for a Smart World", a total of nine sessions, two workshops and exciting keynote presentations will address technological innovations that make the world smarter. The conference event with networking meeting will bring together leading experts from the high-tech industries in Bochum on May 3 and 4, 2023.

https://www.ivam-hightech-summit.com

HIGH-TECH SENSOR TECHNOLOGY FOR INNOVATIVE PREVENTION AND PERSONALIZED THERAPY

The healthcare system is facing major challenges: The costs continue to rise; at the same time, there is a shortage of trained personnel. Modern technologies can make an important contribution to the solution here.

This year's COMPAMED Innovation Forum will therefore focus on sensors for prevention and diagnostics. Preventive measures help detect abnormalities in order to avoid diseases in the best possible way or detect them at a very early stage. Chronic diseases such as diabetes, cardiovascular diseases and asthma can be effectively monitored by means of modern sensors so that deviations can be detected quickly and therapy can be adapted in a targeted manner.

The international expert forum will take place on June 12, 2023, as a digital event on the topic of "Sensor Technology for Prevention and Diagnostics." Leading international experts will show what modern sensor technology can do for the healthcare sector and how the integration of sensors into medical aids, such as diagnostic or treatment devices, can succeed. Furthermore, questions around reliability and long-term stability will be addressed and discussed. Following the presentations, there will be an opportunity to discuss chances and challenges for modern sensor technology in the healthcare system with manufacturers and users.

COMPAMED Innovation Forum

EVENTS

IVAM HIGHTECH SUMMIT — **MAY 03-04/2023**
Annual Micro- and Nanotechnology Conference
Bochum, DE

Mid-Week Coffee Break - May @ — **MAY 17/2023**
Virtual technology talk between IVAM Members

Get to know IVAM @ — **MAY 17/2023**
Information event about the benefits of membership

IVAM Focus Group Photonics @ — **MAY 30/2023**
SWIR to MIR, suitable light sources and applications

COMPAMED Innovation Forum 2023 @ — **JUNE 12/2023**
Sensor Technology for Prevention and Diagnostics

Mid-Week Coffee Break - July @ — **JULY 19/2023**
Virtual technology talk between IVAM Members

IVAM Focus Group Marketing — **AUGUST 16/2023**
AI-based Contentmarketing for SME
Dortmund, DE

Medical Fair Thailand 2023 — **SEPTEMBER 13-15/2023**
Special Exhibiting Area "Manufacturing Processes and Components for Medical Technology"

COMPAMED 2023 — **NOVEMBER 13-16/2023**
Product Market "High-tech for Medical Devices" and "COMPAMED HIGH-TECH FORUM" in Hall 8a

MD&M West 2024 — **FEBRUARY 06-08/2024**
Medical Design & Manufacturing -
IVAM presents Micro Nanotech Area in Hall C

Medical Manufacturing Asia 2024 — **SEPTEMBER 11-13/2024**
Manufacturing Processes for Medical Technology
IVAM presents joint area & IVAM Marketing Award Asia

https://www.ivam.de/events

IVAM Microtechnology at COMPAMED/MEDICA

COMPAMED, the leading international marketplace for medical manufacturing suppliers, which takes place parallel to MEDICA in Duesseldorf from November 13-16, 2023. If you are interested in one of the last free booths for 2023, please contact b2b@ivam.de.

https://www.ivam.de/events/compamed_2023

JOIN OUR COMMUNITY OF HIGH-TECH EXPERTS AND ACCELERATE YOUR MARKET ACCESS!

IVAM.
Microtechnology Network

GET IN TOUCH!

www.ivam.com

membership@ivam.com

SCAN ME