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2

PhotonicsViews

OPTICS • PHOTONICS • LASER TECHNOLOGY

Focus:

AKL '20

Laser Cutting
Analyzing the Dynamics of the Laser Beam Cutting Process

Laser Sources
Efficient and High-Brightness Broad Area Laser Diodes

published in media partnership with EPIC European Photonics Industry Consortium

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Imagine

Digitalization in photonic production

Photonics touches all areas of modern life, whether in communication, life sciences, medicine, power generation or production. It provides solutions and opens up new horizons. What makes photons and light such a unique tool? It's the ability to transmit and concentrate energy in time and space with unprecedented, high precision and the ease of delivering beams accurately to their target.

The next step to exploit the great potential of photonics is through systematic digitization and realizing synergies by combining photonics expertise with recent computational advancements. Intelligent automation allows robot-guided laser beams to be flexibly used for different parts in series production. Online process monitoring and control ensure high-quality production. However the next generation machine learning algorithms and artificial intelligence modules that reach back into expert know-how and process data libraries allow new performance levels, enhance adaptability and production flexibility, and can contribute to a reduction in time-to-market. It is a fast-progressing field with a need for targeted R&D developments.

Moreover, combining artificial intelligence, powerful computation and high quality data provide a plethora of opportunities in society and industry. While people shall retain their freedom of choice, digital companions can assist in analysis and charting a path through an increasingly complex world. They allow us humans to get back into the driving seat and make informed decisions while taking the hidden information in large amounts of data into account. Nonetheless, for AI to gain the necessary maturity and acceptance, we require access to high quality data, secure systems, clear responsibilities and a high degree of transparency and counter-checks of the methods and codes used. To achieve this, engineers, software developers as well as lawyers and ethicists will be in great demand. With digitalization, we are entering a new era for mankind.

I am excited about the new opportunities in production technology and that we are investing in the development of smart digital photonic solutions. The Fraunhofer ILT team is looking forward to a lively discussion among the attendees of the International Laser Technology Congress AKL´20 and all readers of this journal.

Sincerely yours

Constantin Häfner

Prof. Constantin Häfner

Prof. Constantin Häfner
Director
Fraunhofer Institute for Laser Technology ILT

AKL'20
postponed
please check
www.laserconfress.org and
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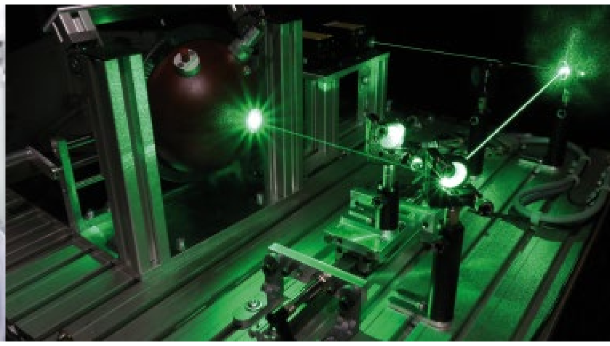
20 Lasers and Surface Functionalization

28 Laser's Future Will Be Smart

38 Digitization for Highly Accurate 3D Laser Processing

Contents

2/2020



Cover: One of the two dominating options of pre-assembled Fast Axis Collimators (FACs) is FACs on bottom tabs. Bottom tabs provide advantages such as better thermal conductivity between the FAC and the mechanical holder as well as a more mechanically robust design. (Source: Fisba)

The Path to a Digital Factory

Oerlikon AM, the additive manufacturing unit of technology group Oerlikon, and Siemens have announced a strategic agreement in which Siemens will provide Oerlikon AM with digital enterprise solutions that will help accelerate the industrialization of additive manufacturing.

The integration of Siemens' Digital Enterprise portfolio into Oerlikon's software landscape in its AM production and R&D sites will support Oerlikon in actively managing the AM engineering process from end to end using one interface. The technology includes software solutions in engineering, as well as product life cycle management.

The long-term objective is to create a digital factory in which Oerlikon AM can see the impact of change in any part of the process, from material selection to engineering design to printing and post-processing, and adapt accordingly. "At the moment we have a variety of special tools that we use for different steps of the value chain," said Dr. Sven Hicken, head of Oerlikon AM.

Dr. Sven Hicken, Oerlikon, and Dr. Karsten Heuser, Siemens (Source: Oerlikon)

The two companies will begin by focusing on tools used in the engineering part of the AM process.

http://siemens.com/plm
www.oerlikon.com/am

1,000th Employee Welcomed in Berlin

A very special event for Berliner Glas: the 1,000th employee, Michaela Gabriel, was among the 13 new arrivals in December.

Michaela Gabriel (center) is welcomed by CEO Andreas Nitze and HR manager Regina Draheim-Krieg (Source: Berliner Glas)

When the company started as a glasswork and glass wholesaler 68 years ago, nobody could have guessed that it would soon become one of the leading suppliers of optical key components, assemblies and systems, refined technical glass and glass touch assemblies.

The expansion and transformation into a high-tech company was accompanied by a steady increase in the number of employees – an increase that made Berliner Glas a major employer in the south-east of Berlin.

Not only has the number of employees increased, but also the diversity of professional groups. As late as the 1960s, employees were mainly involved in glass refining, while ten years later engineers were hired. In addition, over the years, precision opticians and, of course, commercial professions joined Berliner Glas, followed by physicists and other professional groups such as materials scientists, and software engineers. Today, all these experts work hand-in-hand and realize new achievements every day.

www.berlinerglas.com

A Production-Level Applications Center

A far-reaching collaboration agreement between Süss Microtec and BRIDG, a not-for-profit, public-private partnership focused on production process technologies, advanced system integration, and 200 mm microelectronics fabrication advancing next-generation nanoscale technology, puts an unprecedented array of Süss Microtec equipment and fabrication technologies at the doorstep of its American customer base, readily accessible for demonstrations and evaluations.

The Süss Imprint Excellence Center supports a fully equipped facility with a state-of-the-art ISO6 cleanroom and a secure work and office area for customers. (Source: Süss)

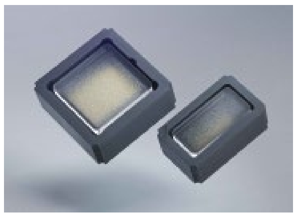
The Süss equipment spans a range of capabilities from advanced permanent bonding, temporary bonding and de-bonding to lithography and nano-imprinting, and fill needs in BRIDG's infrastructure for manufacturing and advanced R&D. Working within a manufacturing infrastructure enables customers to test new concepts in a real production environment, fully supported from concept to product commercialization.

"Access to high quality, advanced integration-enabling tools is a key component of the infrastructure BRIDG requires to unlock the next generation of speed, size, weight, and power optimization," stated Chester Kennedy, BRIDG CEO. "The unique tools manufactured by Süss Microtec will add capabilities to enable our customers to design systems at the absolute cutting edge of performance – faster, smaller, lighter, and using lower power – that allow customers to stay ahead of their competitors while having key systems components manufactured in the United States."

www.suss.com
http://gobridg.com

Trumpf Delivers One Billionth Mini Laser

The partnership between high-technology company Trumpf and the sensor manufacturer STMicroelectronics reached a new high when Trumpf delivered the one billionth vertical cavity surface emitting laser (VCSEL) to its European partner. VCSELs are fundamental components of sensors that feature prominently in modern smartphones to improve the camera autofocus, enable face recognition to unlock the device's display and switch off the display when the user raises the smartphone to their ear when taking a call. Trumpf's technology is now installed in more than 150 smartphones from a wide range of leading OEMs.



(Source: Trumpf)

"We see strong growth potential for our VCSELs in other markets including higher resolution time-of-flight cameras that flood an object or a room with infrared light, measure the round-trip travel time or the phase shift of the emitted light, and calculate three-dimensional models based on this data," says Joseph Pankert, the managing director in charge of the VCSEL line.

www.trumpf.com

Jenoptik Strengthens Its Position

Jenoptik has signed an agreement to acquire one hundred percent of the shares in the Spanish company Interob. The contract was signed on January 25th, closing is expected in the coming weeks. The purchase price was slightly less than twice the revenue in 2019.

The company in Valladolid was founded in 2001 and currently employs 54 staff. Interob specializes in tailor-made projects for plant planning, design, manufacture and integration of automation solutions and robotics applications with a focus on the automotive industry. The takeover strengthens the Jenoptik group's position as a full-service provider of automated manufacturing solutions, which Jenoptik has built up with the two recent acquisitions of Five Lakes Automation and Prodomax.

Similar to FLA and Prodomax, Interob designs automated production lines and sections and integrates them into the customer's production environment.

www.jenoptik.com
www.grupointerob.com

Fraunhofer and Additive Industries Co-operate in The Netherlands

Jan-Cees Santema, Kristian Arntz, Daan Kersten, Biba Visnjicki, Kai Winands, Ian Gibson, Maurice Herben, Harry Dirrigl and Harry Kleijnen (l.to r. Source: Fh. IPT)

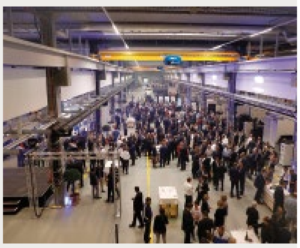
Fraunhofer is further expanding its activities in the Benelux countries through the co-operation of the Fraunhofer Project Center at the University of Twente (FPC@UT) and the Institute for Production Technology IPT with the Dutch supplier Additive Industries based in Eindhoven. Fraunhofer is further expanding its activities in the Benelux countries. Via the Fraunhofer Project Center, Dutch industry in particular will gain completely new access to current research and development in the field of additive manufacturing (AM).

The partners have joined forces and are working on key developments in the field of laser beam powder bed fusion (L-PBF) to accelerate the implementation of the L-PBF technology for industrial series production. They plan to qualify new materials, improve design guidelines, increase post-processing expertise and finally enable the integration of L-PBF into industrial process chains.

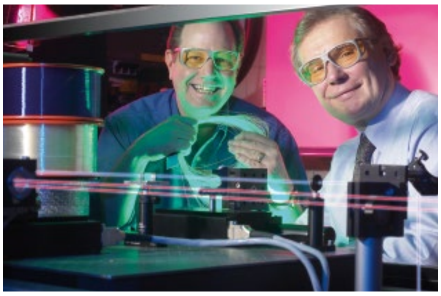
www.utwente.nl/en/fraunhofer
www.additiveindustries.com

Erratum

The picture above had been mistankenly used in issue 1/2020 on p. 6 in the news "Innovation and Production Center Inaugurated" instead of this photograph by +GF+:



SPI Celebrates 20 Years of Innovation



Don Spanlinger (left) & Sir David Payne were both involved in the start up. (Source: SPI Lasers)

In 2020, SPI Lasers, the UK-based designer and manufacturer of fiber lasers, will be celebrating its twentieth year, marking two decades of innovation and growth, cementing its position as one of the world's longest established fiber laser manufacturers.

Back in 2000, Southampton Photonics Inc. as it was originally known, was founded as a spin out company from Southampton University's Optoelectronics Research Centre, initially specializing in fiber optical components for the telecommunications industry but going on to develop both pulsed and cw fiber lasers under the redENERGY and redPOWER brands. These lasers that now enable a significant element of industrial manufacturing around the globe.

Over the last twenty years, the 50,000+ laser units deployed by SPI have been heavily involved in producing a myriad of everyday devices from some of the world's leading brands, all from lasers manufactured at their facilities located in Southampton and Rugby, England.

This year SPI is celebrating it's 20th anniversary by looking at how far it has come over the past two decades, from generating lasers with just a few watts capacity up to the 20 kW machines they produce today, but it is also looking forward to a future of continued innovation and development.

www.spilasers.com

Lumibird Acquires Laser and Ultrasound Business of Ellex

Lumibird has signed an agreement with the Australian company Ellex Medical Lasers to acquire Ellex's laser and ultrasound business for one hundred million Australian dollars (approx. 62 million euros). This acquisition aims at creating a world leader for laser and ultrasound technologies for the diagnosis and treatment of ocular diseases.

The combination of Lumibird's medical activities – through its subsidiary Quantel Medical – with those of Ellex offers strong potential for growth and value creation, thanks in particular to product synergies with complimentary features in terms of the pathologies addressed and comprehensive segmentation covering the various categories adapted for all markets. There are commercial synergies, with Ellex directly handling 75 % of its sales, while Quantel Medical sells primarily through its strong network of distributors.

Maria Maielli, CEO of Ellex Medical Lasers, said: "Lumibird will make an excellent strategic fit for Ellex's market leading range of lasers and ultrasound to treat a range of important eye diseases."

www.ellex.com
www.quantel-medical.com

New CEO in Scandinavia

Fredrik Wikfeldt took over as CEO of Laser Components Nordic AB. He holds a master's degree in engineering physics from the Royal Institute of Technology in Stockholm and brings more than twenty years of sales and management expertise in the electronics and manufacturing industry as well as a deep technical knowledge of industrial image processing and measurement technologies. Before joining Laser Components Nordic AB, he held positions of product manager, sales manager, and chief operating officer for local and international companies such as Stemmer Imaging and Carl Zeiss.

(Source: Laser Components)

Fredrik Wikfeldt

His core strategy is to focus on further growing the business of in-house developed products such as custom-made optics and fiber optic assemblies as well as standardized opto-electronic components. This portfolio will be complemented with high-end products from strategic suppliers.

Wikfeldt succeeds Mikael Winters who had led the company since it was established in August 2014 as a sales subsidiary of the Laser Components group. During his five-year tenure he helped the company achieve a leading position as a supplier of photonics components in the Nordic countries. Winters left the company at his own request.

www.lasercomponents.com

New COO at Plasmo Industrietechnik

Dr. Juergen Müller-Borhanian became chief operating officer at Plasmo Industrietechnik, responsible for the sales, marketing, operations, and customer success departments, as well as the worldwide branches.

Müller-Borhanian received his doctorate in camera-based in-process monitoring for laser beam welding from the Institut für Strahlwerkzeuge at the University of Stuttgart. He can look back on many years of experience in the various areas of automated production. Prior to this, he worked for eleven years at Precitec in several positions, most recently as a member of the management board responsible for global sales and marketing. The continuous growth of Plasmo in recent years requires structural adjustments.

(Source: Plasmo)

Dr. Jürgen Müller-Borhanian

Philipp Descovich, CEO at Plasmo, says: "With his extensive knowledge and his competence in specialist areas such as process monitoring and optimization as well as in change management and growth strategies, Plasmo also has Juergen Mueller-Borhanian at its disposal as an additional competent partner on an international level.

Plasmo is an innovative, globally operating technology company, specialized in quality assurance systems for automated metalworking production processes.

www.plasmo.eu

Lionix Appoints Arne Leinse as New CEO

With his long background in integrated photonics and cleanroom processing, combined with his extensive experience running large commercial projects, Arne Leinse will lead Lionix, a global provider of customized microsystem solutions, in particular integrated photonics-based, to the next level of growth.

(Source: LioniX International)

Arne Leinse

After successfully leading and growing the company from the start in 2001, the previous CEO Hans van den Vlekkert has decided to step down and take a new role as vice president strategic business development, in which he will stay involved in the companies roadmap and the strategic choices for the future. Van den Vlekkert introduced the company to the international ecosystem of high tech customers, which resulted in a strategic acquisition by Magic Micro (Korea) in 2016.

Leinse said: "I am honored to continue the work that Hans van den Vlekkert started. He built the company together with the other co-founder and current CTO René Heideman and I am looking forward to continue this work. The market of microsystem technology-based modules is growing and has a lot of potential. Exploiting this full potential is the goal for the coming years."

www.lionix-international.com

With a View to the Global Markets

LPKF Laser & Electronics is completing its management team with a new managing director for laser plastic welding: Simon Reiser has a strong professional background in the automotive industry and brings international expertise in sales, marketing, strategic development and business management.

(Source: LPKF)

Simon Reiser

The industrial engineer, who also has an MBA, started his professional career in sales at a major international automotive supplier. He has held various positions, from strategic development to divisional management. He spent five years in leading positions in China before returning to his native Franconia.

Reiser sees particular opportunities for the growth of the division through new technologies. He is convinced that the growing field of emobility, for example, will open up further applications for customers and new markets for LPKF. "As a reliable and safe joining process, laser plastic welding makes the use of plastics for many new applications possible and cost effective."

For CEO Götz Bendele, this appointment is another step forward, particularly in view of LPKF's business: "His deep understanding of our global customer base will strengthen our welding business in the long term."

www.lpkf.com

Torbay Hi Tech Forum Appoints New Chair

Following nine years of dedicated service as chair of the Torbay Hi Tech Forum by Martin Foulger, Dr. Andrew Robertson, senior vice president at Gooch & Housego, has been appointed. Robertson has been part of the Hi Tech Forum for four years and steps up from vice chair to chair. Andrew is also a member of the UK Photonics Leadership Group.

Foulger, division managing director for Spirent Communications, said: "It has been an honor to chair the Torbay Hi Tech Forum. My proudest achievements have been leading what started as a handful of tech businesses into the organization that is the influential, broad-reaching and respected forum of today, and working with the TDA in establishing a thriving tech sector in the Torbay and South Devon tech corridor."

In July 2019, the forum celebrated the opening of the brand new Electronics and Photonics Innovation Centre (EPIC) in Paignton and welcomed new tenants. The development of EPIC was born out of the demand for purpose-built facilities from the area's growing cluster of electech and photonics companies, and is now the home of the Hi Tech Forum.

(l. to r.) Martin Foulger (former Hi Tech Forum chair), Dr. Philip Mitchell (vice chair), Dr. Andrew Robertson (chair), and Wayne Loschi (EPIC center director. Source: TDA)

epic-centre.co.uk/hi-tech-forum

Sick Augments Executive Board

Sick has expanded its executive board with effect from 1 January 2020. The supervisory board has set course for growth in the rapidly developing technology and market environment, appointing Dr. Tosja Zywietz (48) for the operations portfolio in the sensor producer's executive board. The newly created portfolio consolidates production-relevant functions, including procurement and quality, at the executive board level.

Tosja Zywietz, a doctor in physics, has held responsible positions at the Bavarian technology company Rosenberger Hochfrequenztechnik since 2009, most recently as chairman of the management board. At Sick he augments the existing executive board of Dr. Robert Bauer, chairman, technology, Reinhard Bösl, systems & industries, Dr. Mats Gökstorp, sales & services, Dr. Martin Krämer, HR & legal, and Markus Vatter, controlling, finance & IT.

(Source: Sick)

Dr. Tosja Zywietz

www.sick.com

Chromacity with New Appointments

To respond to the global demand for its ultrafast laser systems, Chromacity announced the appointment of several senior positions.

Headquartered in Edinburgh, four senior positions will strengthen commercial and operational activities. Bill Handyside and Kerr Johnson bolster operations within manufacturing, research and development, with commercial duties supported by Melissa Crahan, responsible for finance, and Michael Dalgleish, leading the company's marketing activities.

The new recruits join as the ultrafast laser specialist is preparing to install its first system in Australasia. Senior management also returned from a tour of the Far East, where they secured new partnerships in Japan and China.

Shahida Imani, CEO, said: "Things are moving quickly for us on many fronts and finding the right people was absolutely critical to maintaining our momentum."

www.chromacitylasers.com

(Source: Chromacity)

New hires to support global growth

High-Speed Transimpedance Amplifier

Manufacturer: Gigahertz-Optik.
Product: New high-speed transimpedance amplifier "PLL-1701" for use with either external photodiodes or an internal integrating sphere and detector combination. This compact device incorporates both logarithmic and linear amplifiers and can provide an analogue voltage output or a digitized output of the input signal current. Application software is included and an SDK is available for full integration and automation.
Features: The device offers nine linear amplifier stages each with an identical rise time of 16 μs. The maximum input current is 1 mA and output signals can be up to ±5 V. Additionally, there is a single-range logarithmic amplifier which can be used for applications with very fast dynamic fluctuations such as fast positioning tasks or pulsed light sources with very wide dynamic ranges. The voltage output of the Analogue/Analogue mode (AA) is suitable for use with oscilloscopes and other data acquisition systems (e. g., datalogger). In the Analogue to Digital Conversion mode (ADC), the input current signals are digitized by the internal processor and output via RS 422 and USB 2.0 interfaces. Furthermore, the device has an internal integrating sphere with an extended range InGaAs photodiode. FC-terminated fibers can be directly connected allowing their power (A/W/nm) to be measured in the spectral range from 400 to 1550nm. The InGaAs photodiode signal is also output in both AA and ADC modes.

Data analysis is done with either the included application software or the available Software Development Kit (SDK). Evaluation routines for light flicker assessments (including PstLM, SVM, flicker frequency, flicker index) are already implemented in the software and also in the SDK and can thus be used directly. Therefore, the "PLL-1701" complies with international standards for temporal light modulation (TLM) applications including the EU Ecodesign Directive, CIE TN006:2016, and NEMA 77-2017.

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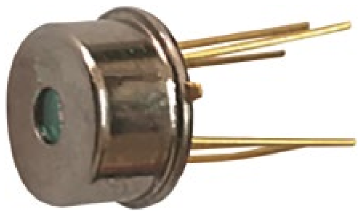
Website: www.gigahertz-optik.de

Single-Mode VCSELs

Supplier: Frankfurt Laser Company.
Product: Single-mode VCSELs (vertical-cavity surface-emitting laser) with perfect Gaussian beam shape. The emission is at a single optical wavelength, making it well suited for applications in gas and chemical sensing and coherent encoders.
Features: Specific wavelengths offered range from 760 nm to 1550 nm and the light is polarization stable. The VCSELs deliver wide wavelength tunability and wavelength accuracy as well as a fast performance for current modulation. They are offered in actively cooled free beam TO46 and TO39 housings, as well as in fiber-coupled coaxial cylinder shape and butterfly housing with single mode and polarization-maintaining fiber.



Applications: Tunable diode laser absorption spectroscopy TDLS; near-IR gas analysis; safety; environmental measurements; agriculture and food storage; industrial and production control; test and measurement; consumer applications; automotive.

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Website: www.frlaserco.com

New Solid-State Laser Light Sources for Advanced Imaging Applications

Manufacturer: Lumencor.
Distribution: AHF analysentechnik.
Product: Next generation light engines "CELESTA" and "ZIVA" that are equipped with seven individually addressable solid-state laser light sources.
Features: The "CELESTA" provides about 1 W and "ZIVA" about 100 mW output power from each laser source (total: 7 W and 700 mW). The laser outputs are allied to sophisticated control and monitoring systems to deliver the performance needed for advanced imaging applications. The control system of the light engines features an onboard computer with an embedded command library. These commands give access not only to the basic control functions of light source selection, on/off switching and output intensity adjustment, but also to an extensive panel of operating status reports and preference settings. A GUI

resident on the onboard computer, and viewed using a web browser via a LAN connection, provides convenient access to many of the command library functions. TTL trigger inputs are provided for all seven output lines for applications requiring fast (10 microseconds) switching. Long-term output stability is sustained by active stabilization. – AHF also provides laser filter sets which match perfectly to the new light sources.
Applications: "CELESTA" can be used for spinning disk confocal microscopy, optogenetics, MERFISH, super-resolution, FRAP, DNA-PAINT. The "ZIVA" is designed for structured illumination (SIM) and other super-resolution imaging techniques due to its optimized multimode laser array for coupling into narrow bore optical fibers.

AHF analysentechnik AG
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Fax: +49 (0)7071 970901-99
E-mail: info@ahf.de
Website: www.ahf.de

High Power Line Laser Diode Modules

Supplier: Frankfurt Laser Company.
Product: "ML2540" laser modules that deliver high output power up to 2 W and are ideal suited for the use in industrial applications with harsh environmental conditions.
Features: The offered wavelengths range from 405 nm to 1060 nm. Apart from round and line beam, other beam shapes like grids, circles, line and dot arrays are available. The line beam has sharp rectangular shape with homogenous power distribution along the line. The housing is electrically isolated and keeps the protection class IP65 (IP67 optional) conditions. TTL modulation up to 1 MHz and analogue modulation up to 100 kHz are available. The power stability is <1% over 24 h.
Applications include, but are not limited to, roof tile alignment, railway conditions control, steel parts production, subsea robotics, traffic control, long distance pointer in defense applications.

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Website: www.frlaserco.com

Biomedical High Stability Laser Module

Manufacturer: Vortran Laser Technology, Inc.
Distribution: Frankfurt Laser Company.
Product: The "Stradus" line of lasers is a fully CDRH-compliant series of high-performance, circularized laser diode modules for laser light in UV through the visible to the near IR.
Features: The highly integrated laser modules contain all the necessary optical power regulation, temperature regulation, communication interface, and protection circuitry. All "Stradus" lasers are single mode TEM_{00} lasers. The modules deliver unprecedented power stability (<0.5%/24 hours), light can be modu-

lated to 200 MHz digitally and 500 kHz analogue to 100% – complete turn ON/OFF. The lasers feature both USB and RS-232 connectivity for easy-to-use control and monitoring of the system. A PC user graphical interface software is provided to allow for easy setup of the system.
Applications: Flow cytometry, DNA sequencing, biomedical research.

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Multi-Wavelength Laser Diode Modules

Manufacturer: Akela Laser.
Distribution: Frankfurt Laser Company.
Product: Unique multi-wavelength fiber-coupled diode laser modules with individually addressable high-power diode lasers. They can deliver up to eight wavelengths in 450 nm to 1800 nm range and optical power from 3 W to 40 W via a common fiber, making it convenient for use in both the R&D and OEM markets.
Features: The module can easily be integrated in systems, and with the optional blast shield, fiber interlock, and the choice of red or green aiming beams, it meets stringent industrial or medical requirements. The laser diode modules

boast the broadest selection of operating wavelengths and the highest output power that meet the toughest challenges of machine vision applications
Applications: Due to the possibility to combine various wavelengths, these modules are useful for both the R&D and OEM markets. They can also serve as light engines for fluorescence microscopy, as well as RGB projectors for entertainment and advertising.

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Mid-IR Quantum Cascade Laser Modules

Manufacturer: mirSense.
Distribution: Frankfurt Laser Company.
Product: Quantum Cascade Laser Modules (QCLs) for the mid-IR Region. The high-powered diodes with an output typically on watt-level emit in the main transmission bands of the atmosphere (4.0 µm, 4.6 µm, 4.8 µm, 9.x µm).
Features: The Fabry-Perot laser sources operate in the quasi-CW regime (pulsed operation down to few tens of nanoseconds and high frequency above MHz) at room temperature. Due to their high average power and wall-plug efficiency, they are perfectly suited for counter-measure and other defense applications. The

portfolio comprise a full range of ITAR-free products from chip on submount manufacturing to full turnkey systems. For OEM system integrators, mirSense manufactures a packaged diode plugged to a top-notch PCB driver that includes laser control, thermal management and security and safety. This packaged diode is the so-called "POEM" system (POEM stands for PowerMir OEM system).

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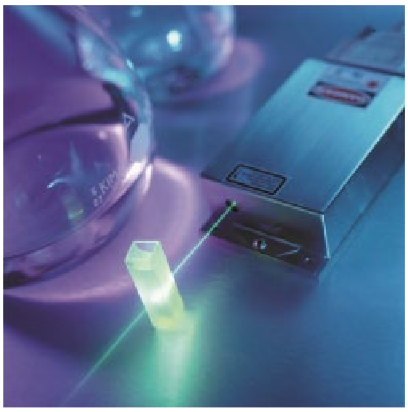
Coherent Passes 50,000 "Sapphire" Laser

Coherent has now passed the milestone of 50,000 units shipped for the company's "Sapphire" family of compact CW visible lasers. As the first solid-state alternative to bulky and energy inefficient gas lasers at the critical 488 nm wavelength, "Sapphire" lasers enjoyed early strong success mainly in life sciences and related instrumentation. However the unique power scaling and wavelength scaling inherent to the optically pumped semiconductor laser (OPSL) technology has enabled the company to continuously expand the product lineup with new wavelengths and power levels over the series' 20-plus year history to meet the demands of new and changing applications. For example, "Sapphire" is currently offered with a choice of nine different standard



wavelengths between deep blue (458 nm) and orange (594 nm) to support new applications in metrology and other techniques in diverse industries including semiconductors. Yet all of these compact lasers still feature exactly the same form and fit, which has proved a particularly popular advantage for OEM customers with products often tied to quite different life cycles. In addition to standard products, custom versions of "Sapphire" with unique wavelengths and other output properties continue to be developed for OEM customers.

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Electronic Autocollimator

Manufacturer: Möller-Wedel.
Product: "ELCOMAT vario N" series of electronic autocollimators for precise and fast measurements of straightness. The device is the logical further development of the "ELCOMAT vario D" series, which has proven itself worldwide.
Features: There are eight different models available, which differ in terms of measuring range and measuring uncertainty. This allows the potential user to choose the most suitable instrument for his task. The device consists of a sensor head and an intelligent display module. Thus the autocollimator can be operated independently of a PC/laptop.
The new hardware and software concept allows direct digital signal processing in the sensor head with a significantly improved signal-to-noise ratio. In addition, the sensor head is significantly more compact, so that the overall length of the individual models is shorter than that of their predecessors. With the additional alignment aid integrated in the measuring instrument, the autocollimator is adjusted easily, quickly and precisely. In addition, straightness can be measured on-the-fly with the integrated software. This saves valuable time when scraping guideways.
Applications: Electronic autocollimators are widely used in mechanical engineering to measure the straightness/parallelism of machine beds, to measure the pitch and yaw movements of machine axes and to determine the positional uncertainty of rotary and dividing tables.

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New Fiber Optic Fault Locator, Optionally With Battery Operation

Manufacturer: IMM Photonics.
Product: Different fiber test devices including adapters and fiber cleaners for the localization of fiber breaks, for continuity testing or for the identification of stressed fiber areas. The proven fiber optic fault locator "Fiberpoint ET" is now available in two further product variants. In addition to the conventional device with red laser light and battery power, it is now also available in a version with green and red laser light, both battery-powered and equipped with rechargeable batteries.
Features: Optically, the fiber testers differ in their clip color, allowing for quick and easy use of the tools. The "Fiberpoint ET G" with green clip operates at 520 nm (green light source), the "Fiberpoint ET" with red clip operates at 650 nm (red light source). The optical output power is < 400 µW.
Unlike the "Fiberpoint ET" with blue clip, the new continuity testers feature rechargeable batteries. As with all fiber optic fault locators of the series, customer-specific inscription is possible, e. g. with a company logo.
All three devices boast a laser class 1 certification, hence no laser protection measures are required. The production takes place exclusively in Germany.

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Machine-Learning Microscope Adapts Lighting

Prototype teaches itself the best illumination settings for diagnosing malaria

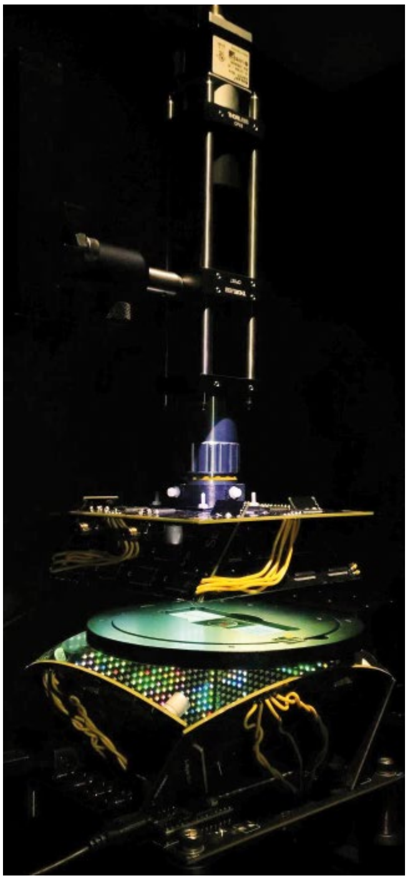
Engineers at Duke University have developed a microscope that adapts its lighting angles, colors and patterns while teaching itself the optimal settings needed to complete a given diagnostic task. In the initial proof-of-concept study, the microscope simultaneously developed a lighting pattern and classification system that allowed it to quickly identify red blood cells infected by the malaria parasite more accurately than trained physicians and other machine learning approaches.

"Computers can see things humans can't," Roarke Horstmeyer, assistant professor of biomedical engineering at Duke said. "So not only have we redesigned the hardware to provide a diverse range of lighting options, we've allowed the microscope to optimize the illumination for itself."

Rather than diffusing white light from below to evenly illuminate the slide, the engineers developed a bowl-shaped light source with LEDs embedded throughout its surface. This allows samples to be illuminated from different angles up to nearly ninety degrees with different colors, which essentially casts shadows and highlights different features of the sample depending on the pattern of LEDs used.

The researchers then fed the microscope hundreds of samples of malaria-infected red blood cells prepared as thin smears, in which the cell bodies remain whole and are ideally spread out in a single layer on a microscope slide. Using a type of machine learning algorithm called a convolutional neural network, the microscope learned which features of the sample were most important for diagnosing malaria and how best to highlight those features. (Source: Duke U.)

▪ *A. Muthumbi* et al.: Learned Sensing: Jointly Optimized Microscope Hardware for Accurate Image Classification, Biomed. Opt. Expr. 10(11), 1 November 2019; DOI: 10.1364/BOE.10.006351

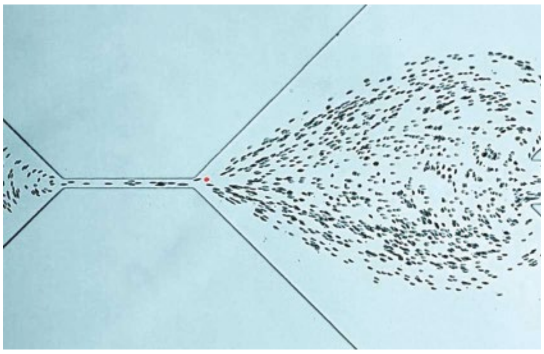


The new microscope, using a bowl studded with LED lights of various colors and lighting schemes produced by machine learning. (Source: R. Horstmeyer, Duke U.)

Cameras Help Accelerate Human Cell Analysis Process from Days to Minutes

Analysis sped up by factor of 10,000

Scientists at the Dresden University of Technology in Dresden, Germany, have developed an analytical procedure that allows the mechanical properties of 100,000 cells to be assessed in less than two minutes, or ten thousand times faster than conventional methods. Using advanced camera technology from Mikrotron, the research team was able to reach unprecedented cell analysis speeds.



Heart-shaped flow lines are formed, which are shown here by inverted superimposition of multiple individual images (Source: Zellmechanik Dresden)

During the process, a stream of deformed cells flows into the setup at a speed of 10 cm/s and passes the field of view of a microscope with 400× magnification. In principle, the system permits any inverse microscope to be connected; however, it is most frequently used with an Axioobserver from Zeiss. An Eosens CL high-speed camera from Mikrotron is connected to the microscope and captures each individual cell, with up to four thousand frames per second. The camera also controls the 1 µs short LED light impulse sent out for each image acquisition. The standard resolution of 250 × 80 pixels is automatically adjusted to the channel width. All images are transferred in real time to the computer unit via a Camera Link interface. A specifically designed program based on National Instruments Labview then analyzes the deformation of each particular cell. Analyzing a single image takes less than 250 µs.

"This process enables us to measure the mechanical properties of several hundred cells per second. In one minute, this permits us to carry out analysis that would take a week in the technologies we used before," says Dr. Oliver Otto, CEO of Zellmechanik Dresden. Within just fifteen minutes, a precise characterization of all blood cell types, including cell activation status, is analyzed. Due to the high throughput of cells, only one single drop of blood is needed for the analysis."

https://mikrotron.de

It’s a Sony!

Company presents concept car at CES featuring evolved imaging and sensing technologies

While only a prototype, Sony provided a spec sheet of its Vision S. (Source: Sony)

At the Comsumer Electronics Show in Las Vegas, Sony Corporation president & CEO Kenichiro Yoshida stated that, “It’s not an exaggeration to say that mobile has been the mega-trend of the last decade. I believe the next mega-trend will be mobility,” as he unveiled the prototype ‘Vision S’ prototype that incorporates imaging and sensing technologies. These contribute to safer and more reliable autonomous driving, and an array of highly-advanced electronics technologies deliver an unprecedented in-car entertainment experience.

The company showed a number of imaging and sensing technologies: CMOS image sensors, which achieve high sensitivity, high definition and high dynamic range while also suppressing LED flicker to deliver accurate object recognition, even in situations where conventionally detection has been difficult; solid-state lidar, which uses highly accurate distance measurement to gain a precise 3D grasp of real-life spaces; sensor fusion technology, which merges the capabilities of sensors with various attributes to enable early and accurate recognition, even in challenging conditions such as fog, backlight and night-time driving.

The ‘Vision S’ prototype that was shown [made in co-operation with European auto equipment companies Magna Steyr, Bosch, Continental, and ZF; ed.] incorporates Sony’s imaging and sensing technologies, as well as on-board software regulated using Sony’s AI, telecommunication and cloud technologies, in order to continuously update and evolve its features.

A total of 33 sensors – including CMOS image sensors and ToF sensors – are are embedded within the vehicle, to detect and recognize people and objects inside and outside the car and to provide highly advanced driving support.

www.sony.net/sonyinfo/vision-s

Laser Parameters for UDI Marking

Study provides manufacturers of medical instruments and implants with guideline for finding suitable parameters

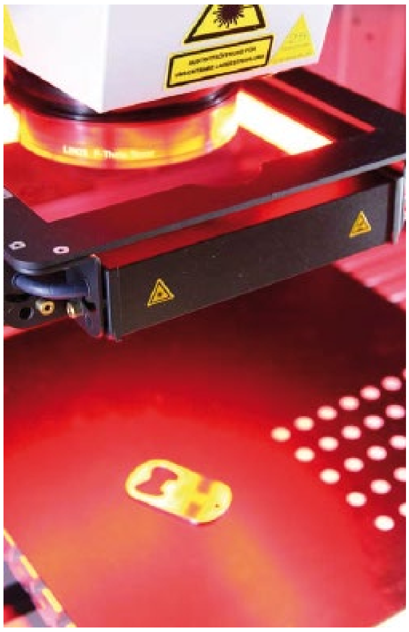
In March 2019, Foba provided the Innovation and Research Center (IFC) Tuttlingen at Furtwangen University (HFU) with a laser marking system. Since then, the system has proven itself in scientific research as well as for demonstration purposes in front of interested parties from the surrounding medical technology industry. The first study project, using Foba’s M2000-P laser marking system with a Y.0201 fiber laser, systematically dealt with the determination of the laser parameters for the marking of stainless steel instruments.

The purpose of the project thesis of Leonhard Bader, a student of the applied materials degree program, was to develop suitable laser parameter combinations for corrosion-resistant annealing marking on class 1.4021 / X20Crt13 type stainless steel. The resistance of the laser markings was verified using a cooking test in accordance with DIN EN ISO 13402. The effects of passivation, which is necessary in the context of instrument manufacturing but which can lead to fading of the laser-marked characters, were also taken into particular account.

The project was able to demonstrate that reproducible, corrosion-resistant marking of data matrix codes can be achieved using various parameter combinations. For this purpose, the data matrix codes were analyzed microscopically, macroscopically and using a code tester. After a corrosion test and passivation, the data matrix codes could be easily read by a blackness measuring device and a code-checking device.

▪ *L. Bader:* “Parameterstudie für korrosions- und sterilisationsbeständige Laserbeschriftungen in der Medizintechnik“, Fakult. Industrial Technologies, Hochschule Furtwangen University, Innovations- und Forschungs-Centrum (IFC) Tuttlingen

www.fobalaser.com



Laser head of Foba M2000 laser marking station with vision system and Mosaic software for automated mark alignment. (Source: Foba)

EU Pilot Lines: New, Expanded, Progressing

MULTIPLE, Phabuloμs, MedPhab, and Teraboard serving the photonics community

MULTIPLE aims at novel, cost-effective, multimodal monitoring solutions for breakthroughs in system optimization. (Source: EPIC)

The European MULTIPLE project was launched on December 16, 2019, at the Aimen technology center in O Porriño (Vigo) within the framework of the Horizon 2020 Information and Communication Technologies work program with a research volume of 7.4 million euros.

MedPhab Kick-off meeting in Brussels, 14 & 15 January 2020 (Source: EPIC)

It will bring together snapshot mosaic filters, organic electronic sensors, and state-of-the-art machine learning to deliver breakthrough and cost-effective snapshot hyperspectral imaging and spectrometric solutions covering a broad spectral range and suited to current industrial monitoring and control needs. Its multimodal monitoring systems will be IoT-native, exploiting open source cloud, big data, and deep learning technology. A fast-orchestrated deployment of data-driven AI-based models will foster production optimization in three different manufacturing scenarios: steelworking, woodworking, and food.

MULTIPLE project partners are Aimen Centro Tecnologico (co-ordinator), Abraia Software, Iris Technology Solutions, Imec, Airoptic, SCM Group, Royo, Photonfocus, Russula, LDL, EPIC, Tematys, Yiotis, MRA, Senorics and TiO_2.

Kick-off meeting Phabuloμs EU Project in Neuchatel 15 & 16 January 2020. (Source: EPIC)

"New Era for Free-Form Micro-Optics"

The EU 'Phabuloμs' project - a "pilot line providing highly advanced and robust manufacturing technology for optical free-form μ-structures" – was launched on January 15, 2020 at CSEM in Switzerland. This follows the need to provide miniaturized optical components due to the exponential growth of the micro-optics market over the last decade. This is in tandem with an increasing need for free-form micro-optics that can address the challenges set by the photonics market over the next five to ten years. Industrial demand for free-form micro-optics is a current market reality. However, the high access barriers to pre-commercial production capabilities in Europe prevent companies, especially SMEs, from commercially exploiting this technology.

Among the objectives of the project are: the general increase of the current technology and manufacturing readiness levels of free-form micro-optics; the implementation of six industrial user cases demonstrating pilot manufacturing in operational environments for a broad range of applications.

The Phabuloμs consortium consists of 19 Companies and RTOs along the whole manufacturing value chain, namely: CSEM as co-ordinator, Johanneum Research, VTT, Fraunhofer Gesellschaft, CEA, Suss MicroOptics, Morphotonics, Nanocomp, Wielandts UPMT, Lasea, PowerPhotonic, Limbak, MicroOled, Seisenbacher, Swarovski, Hella, Zumtobel Lighting, EPIC, and Amires.

Pilot-Line for Medical Diagnostics

The European Commission decided to expand the existing photonics pilot-line offering by funding the establishment of the MedPhab pilot line. Its purpose is to accelerate the commercialization of diagnostic devices and instruments for treatment based on photonics, and to reduce the R&D costs, focusing on three application areas intended for hospital use, home care devices and equipment for chemical diagnostics. The pilot production line is being developed by a consortium involving research institutes and companies from various parts of Europe. The role of research institutes is to develop new production technologies.

The project is coordinated by research professor Jussi Hiltunen, VTT. The consortium comprises: VTT, Tyndall, Joanneum Research, IMEC, CSEM, Philips Electronics, Jabil Circuit Austria, Screentec, III-V Lab, Stryker, Polar Electro, Radisens Diagnostics, Antelope Dx, Genspeed Biotech, ViennaLab Diagnostics, Stichting Het Nederlands Kanker Instituut, EPIC, and Amires.

Integrated Photonic Interconnect

The EU "High bandwidth density and scalable optically interconnected Terabit/s Board" project, initiated in 2015 and dubbed "Teraboard", has solved a number of challenges during 48 months of development. These concern regarding high bandwidth density communications in a high confinement scenario, such as advanced datacom systems in data centers, as required by Ericsson, STM, and Nokia.

Silicon photonics active devices, developed by IMEC, were co-integrated with 3D-IC modules such as through-silicon vias (TSVs) of 10 μm diameter and 100 μm depth and 50 μm-pitch microbumps at wafer scale. These opened the path for high density and low parasitic stacking of electrical and silicon photonics dies to enable significantly improved high-speed interconnections compared to wire-bonding. Teraboard has found immediate development demand at one of the partner companies. The project comprises the following partners: CNIT (coordinator), Fondazione Inphotec, Ericsson Research, STMicroelectronics, Nokia System Networks and CNR from Italy, IMEC from Belgium, UPV from Spain and EPIC from France, among others. (Source: EPIC)

www.phabulous.eu
https://medphab.eu
www.teraboard.eu

Amazing February 2020 in San Francisco at EPIC

European Photonics Industry Consortium alongside Photonics West conferences and exhibition

EPIC had a blast the first week of February in San Francisco. The association organized a lot of networking and technology events to foster a vibrant ecosystem among its members.

For the first time, the EPIC World Photonics Technology Summit on February 3 was also held in San Francisco. This is EPIC's highest-level technology meeting. The event gathered more than 120 experts and leaders from industrial companies around the world to discuss photonics technology developments, applications, and challenges. The event was very oriented towards networking opportunities, with many occasions to meet other participants for further discussions and collaborations.

EPIC also exhibited at the Photonics West exhibition. (Source: EPIC)

The association also organized exclusive networking sessions during the week, held at an exceptional location, in order that its members and VIP friends could spend their breaks at the exhibition effectively. These events stimulate networking and help to build relations and memories with experts and leaders from the photonics industry.

On the morning of the February 4, EPIC organized the Pilot Lines Executive Breakfast, a technology networking breakfast with more than sixty participants, where the EU-funded pilot lines in photonics were presented (PIXAPP, MIRPHAB, JePPIX Pilot Line, PIX-4life, PHABULOuS and MedPhab, EU-funded projects in public-private partnership with Photonics21). The event generated good discussions and business opportunities and raised the interest of the participants in the European manufacturing capabilities for photonic integrated circuits-based products.

For the early birds the already traditional EPIC 5 Miles Executive Run took place on the morning of February 5. We gathered seventy CEOs, CTOs, presidents, and managing directors of photonic companies at San Francisco pier to run and walk together, stimulating networking, relations, and friendships. After the running, the participants shared a recovering breakfast together.

Upcoming EPIC events:

EPIC events are now also going online with some great online technology meetings. These technology meetings will be small groups of system integrators, component suppliers and end-users discussing opportunities for new business. A great new way of connecting people! The online meetings will cover different topics such as microwave optics, photonics packaging, hyperspectral imaging, surface structuring, quantum computing, lidar technology, biosensors, and many more.

On our site you can also apply to be part of this, so be sure to check our website for all upcoming events:

www.epic-assoc.com/epic-events

The Photonics Industry is Growing and so is EPIC

Association hires additional staff to answer increasing number of activities and responsibilities

The European Photonics Industry Consortium is constantly growing and now has more than five hundred members impacting the photonics industry. EPIC has recently added three new staff members in order to sustain its growth strategy. Last November, Dr. Francesca Moglia joined as project leader. She has a background in crystal growth, spectroscopy, optics and laser development for research and large research facilities. She is taking part in the European project LAMpAS, dealing with laser-based surface functionalization (cf. Tech Report, p. 20), and MULTIPLE (cf. Communications, p. 14), which is focused on the development of a multimodal monitoring system based on hyperspectral imaging. Then, early this year, Jessica van Heck joined as marketing manager at EPIC. She has a bachelor's degree in engineering and over fifteen years of experience in marketing of which five were with a photonics company. She will take care of the marketing for the EU projects and provide support with overall EPIC marketing activities. Mid-January, Dr. Sana Amairi Pyka joined EPIC, also as a project leader. She is an experimental physicist specialized in the field of quantum optical metrology and will be mainly focusing on the innovations in the optical technologies and quantum photonics industries. She will also be responsible for the Horizon 2020 funded European project PHABULOμS (cf. Communications, p. 14), the new pilot line providing highly advanced and robust manufacturing technology for optical freeform and microstructures.

From left to right: Dr. Francesca Moglia, Dr. Sana Amairi Pyka and Jessica van Heck (Source: EPIC)

www.epic-assoc.com

EMVA Elects New President

Chris Yates succeeds Jochem Herrmann effective January 2020

The European Machine Vision Association EMVA announced that Chris Yates will adopt the role of president of the EMVA effective January 1, 2020. Chris will succeed Jochem Herrmann, the current president of the EMVA, who has held the role since 2015 and now decided to step down to be able to spend more time with his family. According to the association statutes, the decision to elect the new president was agreed by the board of directors of the EMVA during a recent board meeting in Berlin where Yates was elected unanimously.

The change of president comes after an outstanding term in office, during which Jochem has provided strong leadership and guidance over a period of significant growth for the association and rapid change in the industry. Jochem Herrmann is co-founder and chief scientist of Adimec, which specializes in the development and manufacture of advanced industrial cameras for demanding applications. During an eminent tenure as president, Jochem has overseen the continued growth of the association each year, whilst also providing important guidance in the area of standardization, where his expertise and insight has been widely recognized. Jochem will continue to be a member of the board of directors into 2020 to help ensure a smooth transition of responsibilities.

Chris Yates is the director of advanced technology within the safety, sensing, & connectivity business of Rockwell Automation, having previously been the CEO and founder of Odos Imaging prior to the company's acquisition by Rockwell during 2017. He was elected to the EMVA board of directors during the 2018 Business Conference in Dubrovnik, Croatia, and has focused on greater engagement with startup companies together with operational direction of the association. He earned a degree and PhD from Imperial College London and has held a number of senior roles in early stage companies, concentrating on the effective translation of novel technology to products in the market.


Dr Chris Yates (Source: EMVA)

In accepting the role of president, Yates commented: "I believe that the EMVA is well placed to provide a focal point for dissemination, education, and collaboration within the market." He continued: "I must also thank Jochem, leaving behind a legacy which places the association on an excellent foundation for the future."

www.emva.org

"Understanding What Customers Value"

A portrait of Mary Hibbs-Brenner, co-founder and CEO of Vixar

Jose Pozo

In this article, we portrait Mary Hibbs-Brenner, co-founder and CEO of Vixar, a world-renowned manufacturer of VCSEL-based optical components and subassemblies for sensor and device applications, part of the German photonics specialist Osram.

Mary Hibbs-Brenner, co-founder and CEO of Vixar, meeting Jose Pozo, EPIC's director of technology. (Source: EPIC)

Early research

After obtaining a degree in Physics from Carleton College and a PhD in materials science from Stanford University, Mary spent two years doing postdoctoral research at the University of Linkoping, Sweden.

In 1984, she joined Honeywell's R&D division and in the mid-90s, she began to work on a new laser technology, vertical cavity surface emitting lasers, or VCSELs per short. Compared to edge-emitting semiconductor CD lasers, VCSELs were more reliable, and compared to longer distance telecom lasers, VCSELs were cheaper to manufacture, and allowed data communication at much higher rates over short distances – features which gave VCSELs the potential to completely transform the data communication industry. Over the next five years, Mary and her team turned VCSEL technology into marketable products that helped to fuel the growth of the Internet by becoming the laser source of choice for local area networks (LANs) and storage area networks (SANs).

Vixar

But in 2000, the telecom bubble burst and the bottom dropped out of the market. Revenues began to fall although there was still a market. In 2004, Honeywell decided to move out of the market and sell their VCSEL business to Finisar. Mary's work with VCSELs had given her insights into their market potential for a range of non-telecom commercial applications that she knew could not be pursued as part of Honeywell.

As a result, in 2005, Mary and her colleague, Klein Johnson, decided to start their own company, Vixar, with Klein as CTO and Mary as CEO.

Knowing that there were already more than enough suppliers in the telecom data field, their plan was to focus Vixar on developing variations of VCSEL technology that could address different kinds of applications and to secure new IPs around those applications.

However, while Mary had acquired a good grasp of the business side – from her experience with Honeywell and receiving an MBA at the University of Minnesota – the motivation to set up Vixar was not all commercial: what she wanted most was to recapture the

Company

Vixar

Vixar is a wholly owned subsidiary of Osram Opto Semiconductors and is located in Plymouth, Minnesota, USA. Vixar was acquired by Osram OS in 2018 and was founded in 2005 to develop VCSEL device and subassembly technology for the consumer, industrial and medical industries. Osram OS is a global high-tech company and photonics leader. Primarily focused on semiconductor-based technologies, its products are used in highly diverse applications ranging from virtual reality to autonomous driving and from smartphones to networked, intelligent lighting solutions in buildings and cities. The product portfolio is comprised of high-performance light-emitting diodes (LEDs); infrared LEDs (IREDs); semiconductor lasers, including VCSELs, and detectors. Osram utilizes the infinite possibilities of light to improve the quality of life for individuals and communities.

www.osram-os.com
www.vixarinc.com

VCSELs can be used in mobile devices as a light source for facial recognition, providing uniform illumination of the entire face. (Source: Osram OS)

element of fun – the fun of developing a technology that people valued, being able to interact directly with customers and solve their problems. And she also wanted the challenge of figuring out how to get all the pieces into place to make Vixar a viable company.

Challenges

Funding: As Mary recalls, the first headache was money: "It's a chicken and egg situation: you need money to demonstrate something but to demonstrate something, you need money."

Fortunately, they were able to obtain funding from the US government for innovative research projects. They also had some good advice from Frank Levinson who encouraged them to find customers who were willing to pay up front for the development of the applications they wanted. Frank also provided invaluable help by helping them find angel investors, and later, through his involvement with a venture capital firm, Phoenix Venture Partners.

Building a team: Another challenge was recruiting the right team. It goes without saying that a company needs human resources to accomplish its goals. This requires money and for a company based in the Midwest of the United States, there is the added difficulty of finding employees with the right experience in opto-electronics. As it turned out, recruitment proved relatively easy as there were enough people with the right experience who were happy to come back from California to the Midwest. They were also able to recruit non-technical people locally and learned that the best quality to look for in an employee was the belief that being part of a small company would be fun.

Cash flow: In the early days, the thing that gave Mary the most sleepless nights was making sure there was enough money to pay the employees. It was an anxious time, but they somehow always managed to pay on time.

Vixar development

In the beginning, business was slow: many of their potential customers had never heard of VCSELs and a lot time was spent explaining the technology and the advantages of integrating VCSELs into their products. But gradually, as knowledge of the technology spread, they started to take on customers.

Originally, they had intended to exploit VCSEL features i.e., low power, easy to test narrow spectrum and narrow beam convergence in a variety of applications, but as it turned out, none of these applications were successful. Instead, customers would show up asking for VCSEL applications they had never imagined, and these were the markets they started to sell into.

As Mary says, "it's just a question of persistence. Yes, you need to be flexible and willing to change your plans if they're not working out, but the thing you need most is regular income to keep you going until you find the big thing that will make the company a success."

Osram acquisition

By 2018, Vixar had gone as far as it could as a medium-sized company. Their customers were demanding increasing volumes and Vixar needed to find a type of funding that would enable them to scale up. After considering various options, they decided on an acquisition by the German company, Osram, which had the manufacturing capability, quality infrastructure, and distribution channels that Vixar needed.

As Mary explains: "It was a very good combination: our companies shared the same culture and Osram was a very well-known and respected volume manufacturer of optoelectronic components that needed VCSELs to fill a gap in their portfolio."

Like all good mergers, the two companies have been able to do things together that neither would have been able to do on their own since the acquisition. Vixar have continued to provide cost-efficient VCSEL solutions in standard and more custom packages at a higher level of integration than are typical of emerging and niche markets. But where they had previously contracted out a large part of the manufacturing and packaging, they could now take advantage of Osram's extensive, large volume manufacturing and packaging facilities.

Markets

Coming under the umbrella of Osram has also enabled Vixar to expand its range of VCSEL applications and it now sells short wavelength (670 nm to 940 nm) VCSEL-based optical components and subassemblies into the following markets:

Consumer: The most important development for the photonics industry in recent years has been the deployment of VCSELs in mass consumer products, particularly for cameras and smartphones. Major technology companies now use them for time-of-flight analysis as part of 3D imaging: objects in front of the phone's screen can be tracked and the information deployed in 3D facial identification, portrait selfie photographs, and animated emojis. World-facing 3D imaging technology can enhance camera functions and enable a whole range of future applications utilizing 3D imaging data taken with your smartphone.

All smartphone manufacturers are beginning to incorporate VCSELs in their devices and in future, they will be used for more complicated 3D mapping and imaging to enable true augmented reality. VCSELs are predicted to become a 3.6 billion dollar business by 2020 with the lion's share of volumes going into smartphones. Being part of Osram's extensive manufacturing infrastructure has enabled Vixar to scale up and to take advantage of this lucrative market.

Medical: the medical market is a much more diverse market and includes applications such as oximetry/absorption, fluorescence spectroscopy, imaging illumination sources and low light laser therapy, which allow real-time biometric monitoring. There is also demand for 3D sensing applications.

Atomic sensors (communication/sensing/military): applications in this sector include magnetometers and atomic clocks. This is interesting for Vixar because although the market is likely to remain small, the small size and power dissipation of VCSELs allow miniaturization that is transforming the way these applications are used. For example, portable microatomic clocks, including the power source, are light enough to carry and provide very accurate GPS so that signals can be coded in a much more complex way.

Automotive and lidar: Another rising application for VCSEL lasers is lidar and advanced driver assistance systems for the next generation of automated vehicles. Although not widely used at this point on account of cost and physical bulkiness, Vixar, together with the automotive prowess of Osram in lighting and optoelectronic sensing, is making inroads for lidar applications such as object detection and occupant monitoring systems that enable the vehicle to understand the positions, sizes, and activities of driver and passengers.

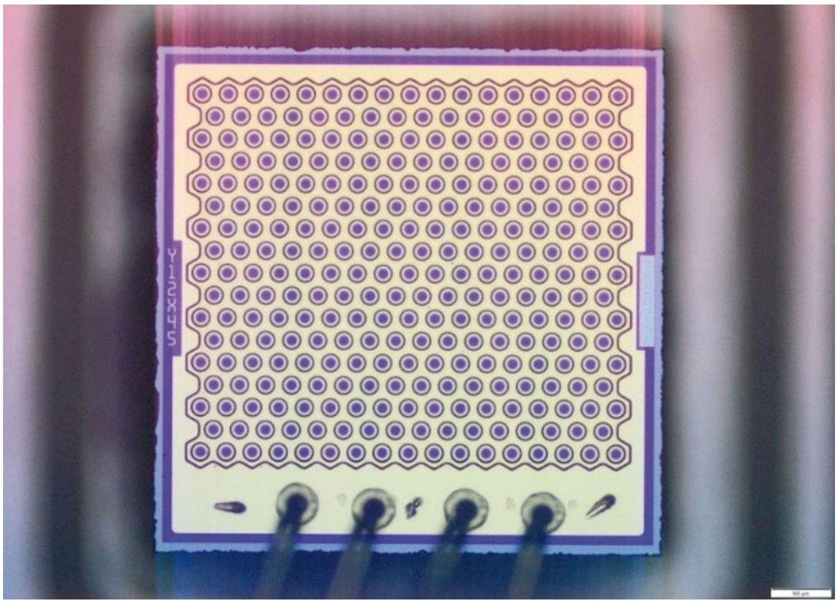
Industry: Vixar also sells into the industrial market providing proximity sensing, motion control and range and interferometric sensing.

Future applications

As Mary says: "There is a lot of potential for new things to happen with VCSELs; some we can guess but others will be things we haven't thought of yet."

But even with things we already know, Mary sounds a note of caution. For example, although a lot has been said about the Internet of Things, the phenomenon it is not yet a reality and while there will be a lot more sensors around in our daily lives, the role of VCSELs is uncertain.

For instance, in the case of lidar, the question is one of distance: VCSELs are good for short distances but edge-emitting lasers are better for longer distances. A similar uncertainty applies to penetration of VCSELs in virtual reality



Vixar and Osram present their first VCSEL in the new Bidos family. VCSELs combine the outstanding technical properties of an LED with those of a laser. (Source: Osram OS)

and ultimately, the dividing line will be determined by the customer.

If you could start over again what would you do differently?
"I've really enjoyed the things I've done in my career so I'm not sure I would change much. One thing I would do differently is to try to find ways to speed up the process of getting information about markets and applications. This is particularly important for young scientists, because exposure to the marketplace and understanding what customers value makes your research more effective and more useful."

"It's also important when you're planning a start-up. When we started Vixar, we found it really hard to gather market and application information to guide us in the right direction."

What are your words of wisdom for the next generation of entrepreneurs?

"First, look for ways to learn as much as you can about a business. This can involve being part of another company and paying really close attention to what decisions are being made and how success is evaluated. You can also do an MBA and find advisors, but whatever you do, the key thing is to be super curious and try and understand as much as you can."

"Second, be aware that you're going to have to be flexible and you're going to change your mind: you also need to recognize when you've made a mistake and move on quickly."

"Third, and this is from a book, 'The Lean Start Up', think about the biggest risks you're taking when you start a company, whether they are market risks, technology risks, or manufacturing risks, and then figure out how you can test out your assumptions around those risks as fast as possible."

Author

Jose Pozo is director of technology and innovation at EPIC, and as such he represents more than four hundred leading corporate members active in the field of photonics. His work consists of actively engaging with them and providing them with the tools to strengthen their position in the supply chain. He has twenty years' background in photonics technology, market knowledge, and a large network within the industrial and academic photonics landscape. Jose holds a PhD in electrical engineering from the University of Bristol, UK, and a MSc and BEng in telecom engineering from Spain and Belgium.

Dr. Jose Pozo, European Photonics Industry Consortium EPIC, 17 Rue Hamelin, Paris, France; e-mail: jose.pozo@epic-assoc.com, Web: www.epic-assoc.com

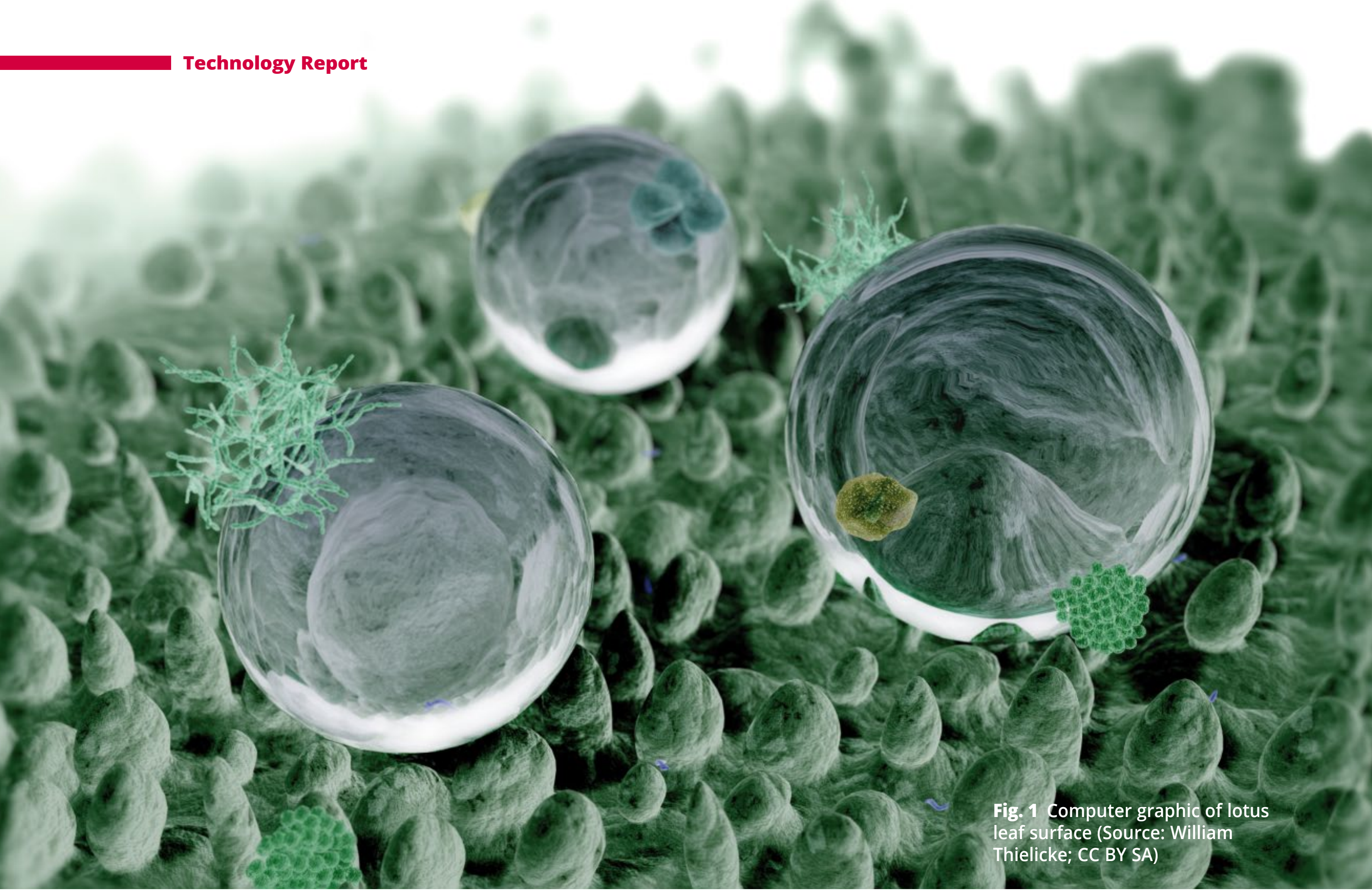


Fig. 1 Computer graphic of lotus leaf surface (Source: William Thielicke; CC BY SA)

Lasers and Surface Functionalization

How a technology aiming at sustainability is spreading and supporting laser development in Europe

Francesca Moglia, Jose Pozo and Andrés F. Lasagni

Nature shows how special nano- and micrometer-sized features can render surfaces hydrophobic or anti-bacterial. Laser-based texturing is a technique capable of imitating this and functionalizing surfaces without the use of additives. EU-funded projects, such as LAMpAS, aim at achieving high throughputs with systems based on kW-level, short and ultrashort-pulsed lasers, enabling this technology for the competitive manufacturing and commercialization of domestic appliances with new features and fast-moving consumer products.

Laser-based surface treatment as defined spans a wide range of specific applications and the appropriate laser technologies. For example, if required just for marking, only relatively low power is needed (typically below 20 W). Nevertheless, it can approach the kilowatt power level, depending on the material and type of treatment to be carried out. The same applies to the nature and the operation of the lasers: depending on the specific application, they can be CO_2, solid-state, excimer or diode lasers and can operate in cw or pulsed mode with different pulse durations and repetition rates.

This flexibility of the market as well as the reliability and development potential of laser technology have motivated various groups to exploit it further to support sustainable solutions for the global market.

Currently, industry demands highly value-added products offering new features at a low-cost. Some of these can allow for direction-dependent fluid transport, antibacterial/antifouling effects, anti-reflectance, friction reduction, self-cleaning and water repellency. Often, to obtain these features, only the surface of the object is affected, being treated with external composites or spread with coatings. In addition, this

Fig. 2 Image of a lotus leaf, which is naturally superhydrophobic due to the combination of micro- and nano-structures on its surface (left) and SEM picture of the same surface (right, source: W. Barthlott, lotus-salvinia.de)

process usually needs to be periodically renewed and implies the use of chemicals and additives.

The capability of nature

Observing nature, it is possible to find many different examples in which characteristics of certain surfaces result from intrinsic features in the nano/micrometer scale. For example, the hydrophobic properties, which minimize adhesion of water droplets to some leaves and the wings of certain insects, are caused by surface micro- and nano-patterns resembling those shown in Fig. 1 and 2. The surface of a lotus leaf is full of micro-meter sized pillars, which contain hundreds of nanometer-sized ripples and the combination of these structures prevents water from reaching the surface. The geometry of the surface is the only origin of these characteristics. The same is valid for the butterfly shown in Fig. 3. In this case, no pigmentation is present on its wings surface, just its special topography allows for reflectance of only blue light.

Commercializing natural properties

Imitating these and other similar natural examples, surfaces of industrial products can be directly functionalized obtaining the same characteristics in a more environmentally friendly way then adding external composites. With this respect, laser surface texturing has shown to be capable of obtaining such advanced functionalities and the best results come from laser sources operating at short and ultrashort pulse durations, i.e. at nano- down to pico- and femtosecond. Furthermore, for commercialization of a complete laser-surface texturing system, the whole process needs to undergo an enhancement of efficiency, flexibility and productivity resulting in high throughput.

Recognition by the European Commission and the potential of the LAMpAS project

In recent years, the potential of laser technology has been recognized also by the European Commission within the Horizon 2020 Framework Program and, jointly through a Public Private Partnership (PPP) with the European Technology Platform Photonics21, substantial investments have been made. Together with the environmentally sustainable aim of structure functionalization, laser technology is at the heart of many current EU-funded projects.

One of these projects is called LAMpAS, which is currently running under Grant Agreement 825132 and the co-ordination of the Technische Universität Dresden. With eight partners, among them Next Scan Technology, New Infrared Technologies and Lasea, this project has the challenging aim of building a complete laser-based surface-texturing system reaching both high resolution (feature sizes 200 nm – 200 µm) and high throughput (up to 1 – 5 m^2/min), to address both the functionality and the commercialization purposes, respectively. This is possible thanks to a multi-beam processing technique with interference patterns on large spots, called direct laser interference patterning (DLIP), delivered to the material by high-speed polygon scanners. These technologies, if thoroughly applied in controlling the interaction between laser light and the substrate, can also stimulate self-organization processes generating laser-induced periodic surface structures (LIPSS) in a homogeneous way. These result in a three-level hierarchical surface pattern: a micrometer-scaled structure, derived directly by DLIP, plus two distinct, overlapped, sub-micrometer sized LIPSS patterns called high and low spatial frequency LIPSS (HSFLs and LSFLs, respectively), making artificial surfaces resembling natural ones and mirroring their fascinating properties, as mentioned at the beginning of this text. Two examples of such artificially generated patterns are shown in Fig. 4.

All this is applicable to different kinds of surfaces (polymers, metals, ceramics, …) and obtainable in LAMpAS thanks to the efforts of Trumpf Laser, a project partner that is concentrating on the development of a think-disk based, ps-laser, delivering up to 1.5 kW at MHz-level repetition rate. These parameters are the result of a tested ideal scenario whereby a high pulse energy in the millijoule range at a moderate repetition rate of 10 MHz or less, combined with a scan speed of 100 m/s or more, enables large spot sizes with an interference pattern, giving a high feature size resolution.

Two end-users, and partners of the projects, are Bosch for pharmaceutical

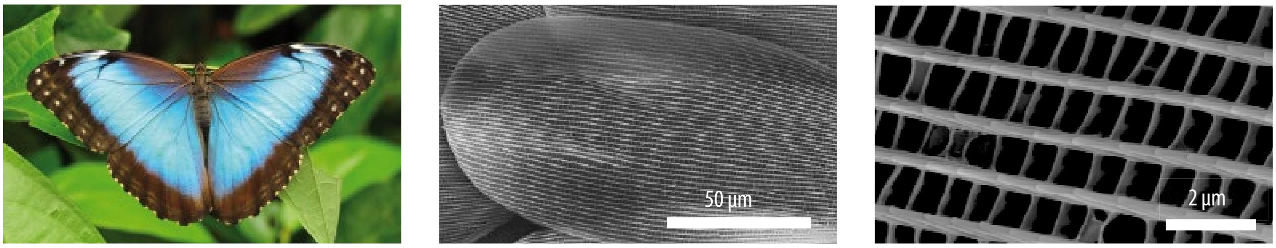


Fig. 3 Image of the Morpho Peleides butterfly, whose color is due to a periodic variation of the surface topography on the micrometer scale that reflects only blue light (Source: Zoe Schnepp; CC BY-SA 4.0).

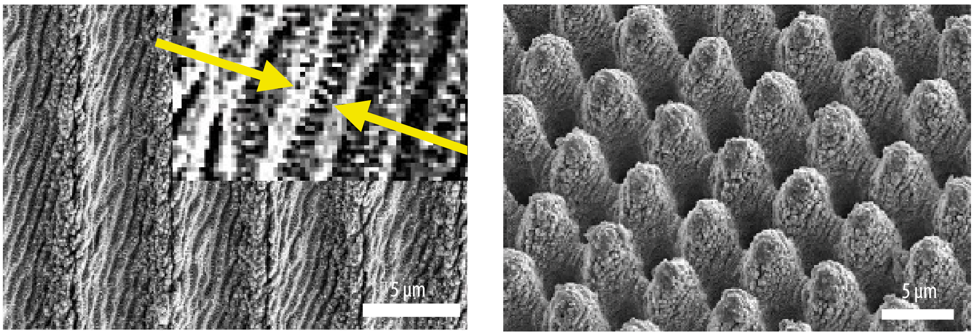


Fig. 4 Three-level hierarchical surface pattern induced by direct laser interference patterning (DLIP) with µm-scaled features (left main picture) overlapped with two different orders of laser-induced periodic surface structures (LIPSS) in the order of 800 nm and less than 150 nm (visible in the left inset). The pillar-like structure (right) was also generated with DLIP. A ps-laser was used for both. (Source: S. Aguilar-Morales et al., Mater. Process. Technol. **252** (2018) 313–321; CC BY-NC-ND 4.0).

packaging and BSH for domestic appliance products. One of their aims is to test a robust industry-oriented prototype, able to functionalize surfaces in real time and increase the value of their products by adding anti-fingerprint, easy-to-clean and antibacterial features and new decoration finishes.

One of the overall aims of the project is to have a total improvement in product performance greater than 20 %, based on the deployed surface functionalities.

Other EU-funded projects in laser-based surface functionalization

The potential of a mature technology running at longer pulse duration is the one exploited by other EU-funded projects such as PROMETHEUS. It is coordinated by EWF (European Federation for Welding, Joining and Cutting) and counts on partners such as Prima Power, Photonics Bretagne, HOLO/OR, AIMEN Centro Tecnologico and the Fraunhofer IWS. They aim at applying DLIP with a pulsed-laser architecture working in the nanosecond-regime, with average power > 1 kW and repetition rates > 500 Hz to serve end users in different areas, such as automotive and fast-moving consumer goods markets.

Other projects besides LAMpAS aim at exploiting the technology of ultra-fast lasers in the ps-range. Two of them are called TresClean and Laser4Surf. The first is coordinated by the Universitá degli Studi di Parma, which is supported by partners such as as Alphanov and University of Stuttgart, and pursues a similar strategy to LAMpAS in employing thin-disk based ps-lasers for DLIP and LIPPS. These are more oriented in testing different laser wavelengths and parameters, which the LAMpAS community has already tested experimentally and numerically in previous projects (e.g. LASER4FUN). Laser4Surf is co-ordinated by Ceit-IK4is supported, among others, by Multitel, and also bases its future platform for laser surface texturing on similar laser systems. Nevertheless, they focusing on other end-user fields such as the increase of product performance of advanced batteries, linear encoders and medical components.

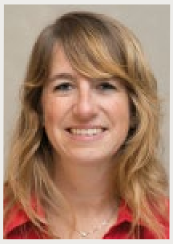
When the pulse duration is shortened further to the femtosecond level, the multi-beam processing techniques described above can still be used if the parameters of the lasers are adjusted accordingly. The EU-funded FEMTOSURF project is coordinated by Femtika and is investigating this alternative with the support of Amphos, who is developing a laser with a duration of a few hundreds of femtoseconds, based on their InnoSlab amplification technology, reaching a 2 – 3 kW laser power level, with a similar aim of reaching a throughput higher than 1 m²/min. Among others, end-users in the fields of healthcare, ship building and aerospace wish to profit from a final product providing laser-structured surfaces with anti-bacterial, self-cleaning, friction-reduced and anti-icing properties.

*

LAMpAS has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No [825132) and is an initiative of the Photonics Public Private Partnership.

PHOTONICS PUBLIC PRIVATE PARTNERSHIP

Authors



Francesca Moglia is a project leader at EPIC, the European Photonics Industry Consortium. She has a background in crystal growth, spectroscopy, optics and laser development for research and large research facilities. Before joining EPIC, she moved from R&D to scientific management for the coordination of a consortium of funding agencies in the field of astroparticle physics. She graduated in Physics from the University of Pisa in Italy, acquired her PhD (Dr. rer. nat.) at the Universität Hamburg in the field of Laser Physics and pursued her post-doctoral activities at DESY, Deutsches Elektronen-Synchrotron in Hamburg, Germany.

Jose Pozo is director of technology and innovation at EPIC, and as such he represents more than four hundred leading corporate members active in the field of photonics. His work consists of actively engaging with them and providing them with the tools to strengthen their position in the supply chain. He has twenty years' background in photonics technology and market knowledge, and a large network within the industrial and academic photonics landscape. Jose holds a PhD in electrical engineering from the University of Bristol, UK, and a MSc and BEng in telecom engineering from Spain and Belgium.

Further author: Prof. Dr. Andrés F. Lasagni, Technische Universität Dresden and Fraunhofer-Institut für Werkstoff- und Strahltechnik – IWS

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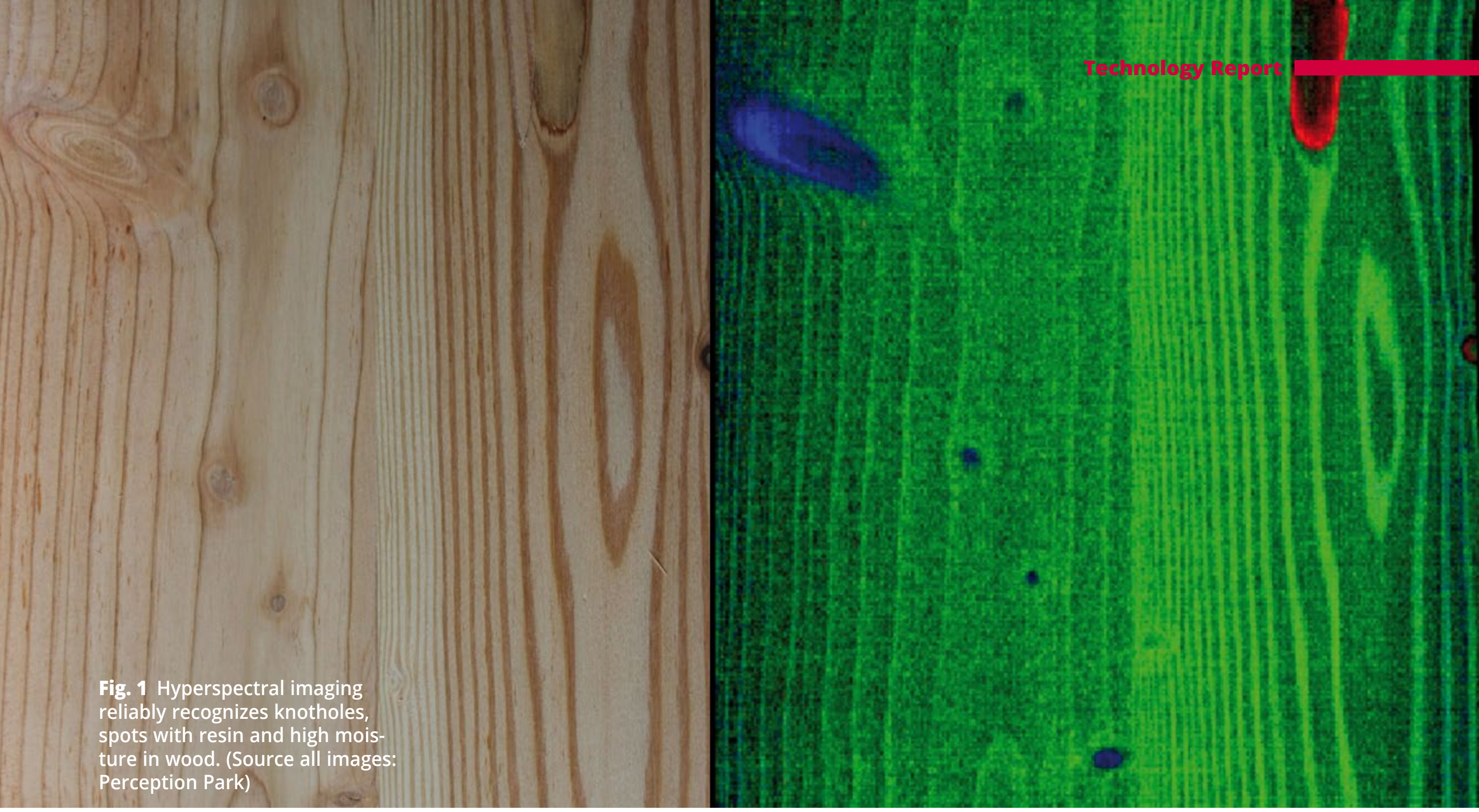

Fig. 1 Hyperspectral imaging reliably recognizes knotholes, spots with resin and high moisture in wood. (Source all images: Perception Park)

Hyperspectral Imaging is Conquering the Industry

Hyperspectral-based imaging is establishing itself in ever new industrial fields of application. How does this technology work and where can it be used?

Peter Stiefenhöfer

Conventional image processing systems have become established in automation in industrial applications in recent years. Machines that can 'see' can do more than systems without image processing, and this knowledge has now become established among developers and designers. While conventional 2D and 3D vision systems check the quality of objects by recognizing certain error features on the surface, hyperspectral imaging (HSI) goes one step further: with the help of this technology, spectroscopic analysis of objects can be carried out in order to determine organic or inorganic impurities – not only on the surface, but also partly inside the inspected materials.

Hyperspectral imaging systems usually utilize one hundred or more different wavelengths and a spectrograph that splits the light reflected from the object into its spectrum and reproduces it on the camera sensor. An HSI system assembles the resulting images into a three-dimensional hyperspectral data cube that can contain very large amounts of data. The result is a "chemical fingerprint" of the object under consideration, which enables the analyzed material properties to be precisely determined. With the help of special evaluation software, each identified chemical component can then be flagged with its own color in the images taken in order to visualize the substances that are present in a simple way for the user. This technology is called chemical color imaging (CCI).

Diverse applications

"Hyperspectral imaging can be used in a wide variety of industrial application areas and in certain cases offers solutions for tasks where conventional image processing systems fail," explains Markus Burgstaller, managing director of the Graz-based company Perception Park that specialized in that innovative technology a few years ago. As an example of an application, Burgstaller mentions the classification of substances that have no visual differences, but are not chemically identical: "Plastics of various compositions can look very similar and can therefore hardly be distinguished by conventional image processing. On the other hand, HSI systems are able to analyze chemical properties and therefore recognize materials very reliably. With this technology, the concentration and distribution of ingredients can largely be recorded in real time."

A special feature of hyperspectral imaging systems makes them particularly attractive for certain applications: some substances are not transparent to visible light, but can be penetrated by infrared light. This makes it possible to check the chemical composition of packaged content even through suitably designed packaging. According to Burgstaller, applications in which this property comes into play are found primarily in the pharmaceutical and food industries, but also in numerous other industrial segments.

Fault detection in the pharmaceutical industry

As in many other areas, production speeds in the pharmaceutical industry are increasing rapidly worldwide. Particularly strict safety regulations apply in this industry to reduce the risk of product recalls and to protect consumers from contaminated drugs. Image processing systems have therefore been state-of-the-art in the manufacturing processes of pharmaceutical products for some time to evaluate products in real time according to criteria such as shape, size or weight. However, the use of hyperspectral imaging and CCI systems can further optimize the monitoring of pharmaceutical production processes: pharmaceuticals can be 100 % examined for their molecular properties.

A typical application of HSI systems in the pharmaceutical industry is the checking of retard tablets for correct coating. This form of medication releases the active ingredient after its administration over a longer period of time or to a specific target in the body. The sustained release coating of the tablet is decisive for this controlled release of the active ingredient: if it is damaged or missing completely, the medication gets into the body faster than desired and fails to deliver its long-term effect.

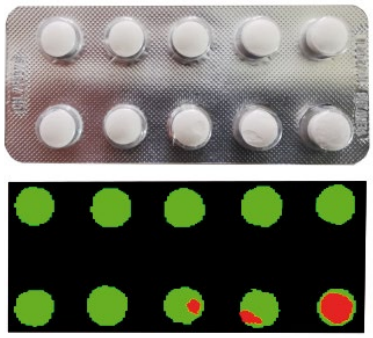

Fig. 2 The correct filling of blisters and errors e.g. of the retard coating of medication can be checked with HSI and CCI technology in real time even at high production speeds.

The quality of retard-based medication can be reliably checked by using a combination of HSO and CCI technology explains Markus Burgstaller: "With a hyperspectral camera working in the NIR area and the use of chemical color imaging technology with our Perception Studio software suite, we were able to clearly demonstrate that previously artificially generated coating defects can be recognized with 100 % certainty and also in real time in high-speed production." This quality check is possible even through blister packs, provided the blister material is not made of aluminum, which would reflect the NIR radiation.

According to Burgstaller, testing retard coatings is just one of many possible use cases for HSI technology in the pharmaceutical industry. It can also be used to reliably check whether the correct number of tablets are packed in blisters, whether they are undamaged and free from any contamination, whether the correct ingredients are contained in drug capsules or whether they are completely sealed. "Hyperspectral imaging offers numerous application options in the pharmaceutical sector and increases safety for patients and manufacturers."

More security in food production

Similar guidelines as in the pharmaceutical industry apply in the production of food: no contamination must remain undetected to eliminate health risks to consumers. The food must also contain exactly the ingredients that the manufacturer wants to and that are defined in the product descriptions for the consumer.

HSI and CCI also offer numerous application options for this industry. These techniques make it easier to find any contamination in food and identify unwanted objects such as stones or earth when sorting potatoes, carrots or other vegetables, as well as shell parts or other substances in the production of nuts, even in high-speed production lines. If food is stored for too long, maggots can also nest or fresh fruit can start to rot. According to Burgstaller: "In food production, the task is often not just detecting any contamination, but also identifying rotten, immature or pest or mold infected goods. These and many other quality defects can be safely ruled out by the use of hyperspectral imaging systems."

Industrially manufactured food such as sausage and cheese are usually offered for sale in a shrink-wrap form. Similar to the pharmaceutical industry, HSI systems also allow quality checks through the packaging in many cases. A special task here is the inspection of heat-sealed joints, which are supposed to guarantee absolutely airtight packaging of the food. Even the smallest contamination or damage to these sealed joints can lead to leaky packaging and spoilage of the goods before the calculated best before date. Unsellable products or expensive product recalls would then be possible consequences for manufacturers, which can be avoided in many cases by using hyperspectral imaging.

HSI in wood processing

In recent decades, woodworking technologies have made extraordinary strides. There are also many options in this field of application to check the quality of products such as sawn timber, wood-based materials, wood chips and paper and paper products by using HSI systems. Even features or possible defects that are invisible to humans can be reliably detected.

Company

Perception Park

Perception Park is a company with a passion for hyperspectral imaging and a focus on generic and configurable hyperspectral data processing solutions for industrial inline applications. Hyperspectral imaging systems combined with our generic, intuitive configurable data processing platform, Perception System, make the scientific methods of hyperspectral analysis accessible for everyone and open up new application areas.

www.perception-park.com

The detection of defects such as resin pockets or knotholes is a common task in this industry, which can be reliably solved with the help of a hyperspectral system in combination with a near-infrared hyperspectral camera. Resin in wood can be identified reliably even if it is covered by a thin layer of wood. Even adhesives that are often used in the production process to compensate for small holes with fillers can be easily recognized by using chemical color imaging – a task where conventional image processing cameras often fail because the adhesive is usually transparent.

Another important characteristic of wood is its moisture. Damp spots in wood can be clearly identified and displayed as a CCI image by using HSI analysis. It is even possible to calibrate a perception system to measure the fraction of water. By adapting a hyperspectral camera to such a calibrated perception system, chemical color imaging transforms the camera system into an easy-to-understand 'moisture camera' for wood and can be implemented into any image processing system.

"The reliable detection of such defects is imperative for high-quality wood products," emphasizes Burgstaller. "HSI systems offer a powerful tool for this industry to detect undesirable quality defects in time."

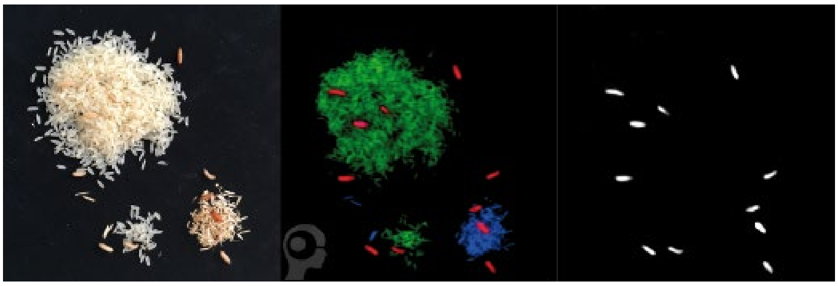

Fig. 2 An image processing solution based on hyperspectral imaging detects contamination such as maggots and pieces of wood between rice. The right partial image shows a segmentation image with recognized maggots.

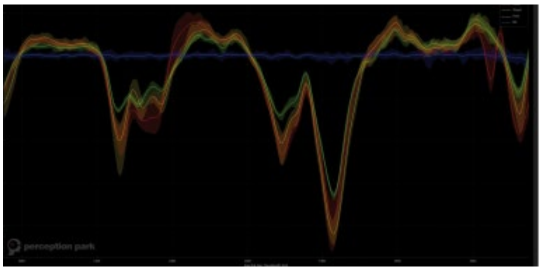

Fig. 3 Differentiating knotholes, spots with resin or high moisture in wood with Perception Studio is based on the spectral curves of the materials.

HSI systems for plastics sorting

Even at the end of their first application, plastics are still too valuable to simply throw away. If the full potential of the currently dumped plastic waste were used in an environmentally friendly way, by applying the best recycling and energy recovery methods and technologies, many millions of tons of plastic could be recycled. This would also make it possible to save large amounts of heat and electricity spent in current recycling processes.

Appropriate measures are required to stop the disposal of plastics and to set up recovery-oriented collection systems. These must be reconciled with modern sorting infrastructure and improved recycling and recovery processes in order to exploit the full potential of this valuable resource. Recycled plastics can be reused in many everyday products, e.g. in clothing, in vehicle parts, in packaging products and for many other purposes. However, too little plastic is currently being recycled, although innovative technology such as Perception Park's software suite would help to capitalize on this potential.

"Hyperspectral imaging makes it very easy to distinguish between polypropylene and polythene, for example, that look very similar at first glance. With our Perception Studio, appropriate systems can be developed even by people who have little or no experience with the subject of spectroscopy. The technical possibilities for a significant expansion of the recycling quotas of plastics are therefore already available and should be increasingly applied for environmental reasons", Burgstaller expresses his hopes for the future.

Infobox

Experience hyperspectral technology live

On May 27 and 28, 2020, representatives of the manufacturing industry will have the opportunity to learn about the latest trends in hyperspectral imaging during the fourth conference on Hyperspectral Imaging in Industry (chii) in Graz, Austria (cf. p. 76). The focus of this international industry meeting is the use and application of hyperspectral systems, which will be presented in numerous short lectures by leading technology providers and in the context of an exhibition. Matchmaking meetings will provide the opportunity for individual questions to be answered. Details on the program and registration for chii2020 can be found at **www.chii2020.com**

The fourth Conference on Hyperspectral Imaging in Industry (chii) will take place in Graz, Austria, on May 27 and 28, 2020.

Author

Peter Stiefenhöfer completed his studies in manufacturing engineering in Erlangen in 1994. He had been working as an editor for more than five years before joining Stemmer Imaging in 1999, where he was responsible for the company's marketing and PR activities until December 2016. In January 2017, he founded his own company PS Marcom Services, a PR agency focusing on machine vision technology.

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Program of the Technological Conference AKL'20

AKL'20

Day 1*)

Gerd Herziger Session, Room Berlin

Chairman: *Prof. Constantin Häfner*, Fraunhofer ILT, Aachen (D)

from 8:00 Check-in and Coffee Reception

8:30 Welcome
Prof. Constantin Häfner, Fraunhofer ILT, Aachen (D)

8:45 Perspectives for the Laser Source Development
- *Dr. Christian Schmitz*, CEO for Laser Technology, Member of the Managing Board, TRUMPF GmbH + Co. KG, Ditzingen (D)
- *Magnus Bengtsson*, Vice President Strategic Marketing, Coherent Inc., Santa Clara (US)
- *Volker Krause*, Managing Director, Laserline GmbH, Mülheim-Kärlich (D)

9:30 Panel Discussion with the Speakers

10:30 Coffee Break – Visit of the Sponsors' Exhibition

Digitization in Photonic Production, Room Berlin

Chairman: *Prof. Constantin Häfner,* Fraunhofer ILT, Aachen (D)

11:00 The Future of Manufacturing
Dr. Hans-Jürgen Braun, Head of Operations, Vitesco Technologies GmbH, Regensburg (D)

11:30 Digital Photonic Production – the Case of Additive Manufacturing
Prof. Johannes Henrich Schleifenbaum, Chair Holder of RWTH Aachen University – DAP and Competence Area Manager Additive Manufacturing and Functional Layers at Fraunhofer ILT, Aachen (D)

12:00 Perspectives of Production Technology with Artificial Intelligence
Ansgar Heinen, Sales Team Manager Azure & *Marcel Franke*, Cloud Solution Architect for Data & AI, Microsoft Deutschland GmbH, Köln (D)

12:30 Lunch – Visit of the Sponsors' Exhibition

Session 1: Laser Material Processing – Macro, Room Berlin

Laser Powder Bed Fusion LPBF

Chairman: *Prof. Sebastian Bremen*, Fraunhofer ILT, Aachen (D)

14:00 Process Analysis and Control in Metal 3D Printing
Dr. Florian Bechmann, GE Additive, Lichtenfels (D)

14:30 Modelling Laser Powder Bed Fusion Processes – Goals, Achievements and Gaps
Dr. Mustafa Megahed, ESI Software Germany GmbH, Essen (D)

15:00 Scalable Laser Powder Bed Fusion Concept
Christian Tenbrock, Fraunhofer ILT, Aachen (D)

15:30 Coffee Break – Visit of the Sponsors' Exhibition

16:00 Shuttle Transfer to Fraunhofer ILT

Laser Technology Live

16:30 Laser Technology Live at Fraunhofer ILT

19:30 Shuttle Transfer to Research Campus DPP

*) originally planned for May 7 and 8, 2020 – postponed until further notice, please check www.laserconfress.org and www.photonics-views.com for updates

Evening Event

20:00 – 23:00 (Doors open 19:30)
Networking with Snacks at Research Campus DPP
22:00 – 23:30 Shuttle Transfer to City Center

Session 2: Laser Material Processing – Micro, Room Brüssel

Micro Structuring

Chairman: *Martin Reininghaus*, Fraunhofer ILT, Aachen (D)

14:00 Hightech Mastering for Endless Structuring for Micro- and Nanofunctionalized Foils
Wilfried Schipper, temicon GmbH, Dortmund (D)

14:30 Flexible Beam Shaping in Materials Processing with Ultrashort Pulse Lasers
Dr. Jens Holtkamp, Pulsar Photonics GmbH, Herzogenrath (D)

15:00 New Perspectives in Micro Processing with GHz Ultrashort Pulse Lasers
Dr. Clemens Hönninger, Amplitude Laser Group, Pessac (F)

16:00 Shuttle Transfer to Fraunhofer ILT

Laser Technology Live

16:30 Laser Technology Live at Fraunhofer ILT

19:30 Shuttle Transfer to Research Campus DPP

Evening Event

20:00 – 23:00 (Doors open 19:30)
Networking with Snacks at Research Campus DPP
22:00 – 23:30 Shuttle Transfer to City Center

Session 3: Laser Beam Sources, Room Lissabon

Solid State and Fiber Lasers

Chairman: *Hans-Dieter Hoffmann*, Fraunhofer ILT, Aachen (D)

14:00 High Efficiency Converter Laser
Volker Krause, Laserline GmbH, Mülheim-Kärlich (D)

14:30 High Average Power Ultrafast Lasers with High Flexibility for Materials Processing
Dr. Dirk Sutter, TRUMPF Laser GmbH, Schramberg (D)

15:00 Scalable Short Pulse Fiber Lasers
Michael Lee, IPG Laser GmbH, Burbach (D)

16:00 Shuttle Transfer to Fraunhofer ILT

Laser Technology Live

16:30 Laser Technology Live at Fraunhofer ILT

19:30 Shuttle Transfer to Research Campus DPP

Evening Event

20:00 – 23:00 (Doors open 19:30)
Networking with Snacks at Research Campus DPP
22:00 – 23:30 Shuttle Transfer to City Center

Day 2*)

Session 1: Laser Material Processing – Macro, Room Berlin

Cutting

Chairman: *Dr. Dirk Petring*, Fraunhofer ILT, Aachen (D)

8:30 Enhancing Cutting Performance with an Oscillating Laser Beam
Takaaki Yamanashi, AMADA Co. Ltd., Kanagawa (JP)

9:00 Analyzing the Dynamics of the Laser Beam Cutting Process
Dennis Arntz-Schröder, Fraunhofer ILT, Aachen (D)
article → page 43

9:30 The Rise and Rise of the Fiber and Disk Laser
Prof. John Powell, Lulea University of Technology, Lulea (SE) / Laser Expertise Ltd., Nottingham (UK)

10:00 Coffee Break – Visit of the Sponsors' Exhibition

Laser Welding

Chairman: *Dr. Dirk Petring*, Fraunhofer ILT, Aachen (D)

11:00 Fundamental Effects on Critical Welding Processes and their Performance by Adapted Laser Beam Shaping
Dr. Jens Schüttler, Coherent-ROFIN, Hamburg (D)

11:30 Laser Beam Processing of XXL Assemblies for Ship and Railcar Manufacturing
Holger Alder, Photon AG, Berlin (D)

12:00 Improving the Manufacturing Process and Product Design with Laser Beam Welding
Harald Strauß, STIWA Automation GmbH, Attnang-Puchheim (AT)

12:30 Lunch – Visit of the Sponsors' Exhibition

Laser Material Deposition

Chairman: *Dr. Andres Gasser*, Fraunhofer ILT, Aachen (D)

14:30 Requirements of Brake Disc Coatings from an OEM View Point
Dr. Sebastian Gramstat, Audi AG, Ingolstadt (D)

15:00 New Developments for the Repair of Structural Engine Components with Laser Material Deposition
Bernd Müller, Rolls-Royce Deutschland Ltd. & Co. KG, Blankenfelde-Mahlow (D) article → page 48

15:30 Industrie 4.0 Approaches for Process and Condition Monitoring in Laser Material Deposition
Talu Ünal-Saewe, Fraunhofer ILT, Aachen (D)

16:00 Outlook (Room Berlin)
Prof. Constantin Häfner, Fraunhofer ILT, Aachen (D)

16:30 End of the Lectures

Session 2: Laser Material Processing – Micro, Room Brüssel

Micro Joining

Chairman: *Dr. Alexander Olowinsky*, Fraunhofer ILT, Aachen (D)

8:30 Micro Welding with Temporal and Spatial Beam Modulation
André Häusler, Fraunhofer ILT, Aachen (D)

9:00 Laser Beam Micro Welding for Electronic Packaging
Georg Haselhorst, SCHOTT AG, Mainz (D)

9:30 Flexible Use of Laser Beam Technology for E-Mobility
Dr. Jan-Philipp Weberpals, Audi AG, Neckarsulm (D)

10:00 Coffee Break – Visit of the Sponsors' Exhibition

Ultrafast Lasers – Applications

Chairman: *Dr. Arnold Gillner*, Fraunhofer ILT, Aachen (D)

11:00 Digitalization for Highly Accurate 3D Laser Processing of Customer-Specific Tools
Dr. Claus Alexander Dold, EWAG AG, Etziken (CH)
article → page 38

11:30 Machining of Ceramic Materials using Ultrashort Pulsed Laser Radiation
Dr. Christian Kalupka, Fraunhofer ILT, Aachen (D)

12:00 Next Level Laser Processes for Gasturbine Manufacturing
Marcel Vollgold, Siemens AG, Berlin (D)

12:30 Lunch – Visit of the Sponsors' Exhibition

Polishing and Thin Film Processing

Chairman: *Dr. Edgar Willenborg*, Fraunhofer ILT, Aachen (D)

14:30 Process Chain with Laser Ablation and Laser Polishing for the Manufacturing of Intraocular Lenses
Axel von Wallfeld, AIXLens GmbH, Alsdorf (D)

15:00 Laser Vitrification and Polishing of Ore Samples for X-Ray Fluorescence Spectroscopy
Reinhard Teutenberg, thyssenkrupp Industrial Solutions AG, Beckum (D)

15:30 Smart Products through Functional Layers
Dr. Christian Vedder, Fraunhofer ILT, Aachen (D)

16:00 Outlook (Room Berlin)
Prof. Constantin Häfner, Fraunhofer ILT, Aachen (D)

16:30 End of the Lectures

Session 3: Laser Beam Sources, Room Lissabon

Ultrafast Lasers – Beam Sources

Chairman: *Dr. Peter Rußbüldt*, Fraunhofer ILT, Aachen (D)

8:30 Advanced Photon Sources – Extending the Parameter Range of Ultrafast Lasers
Hans-Dieter Hoffmann, Fraunhofer CAPS, Aachen/Jena (D)

9:00 High Power and High Energy Ultrashort Pulsed Laser Sources at 2 µm and Beyond – Results from the NUCLEUS Project
Dr. Maik Frede, neoLASE GmbH, Hannover (D)

9:30 Ultrafast Industrial Thin-Disk Amplifiers
Dr. Thomas Metzger, TRUMPF Scientific Lasers GmbH + Co. KG, Munich (D)

10:00 Coffee Break – Visit of the Sponsors' Exhibition

Lasers with Tailored Wavelengths

Chairman: *Dr. Bernd Jungbluth*, Fraunhofer ILT, Aachen (D)

11:00 Green High-Power Disk Lasers and Industrial Applications
Dr. Thomas Rettich, TRUMPF GmbH + Co. KG, Ditzingen (D) article → page 57

11:30 Mid-Infrared Short and Ultrashort Pulse Lasers for Materials Processing
Dr. Sebastian Nyga, Fraunhofer ILT, Aachen (D)

12:00 2 µm Fiber Lasers for Industrial Use
Dr. Peter Fuhrberg, Futonics Laser GmbH, Göttingen (D)
article → page 64

12:30 Lunch – Visit of the Sponsor's Exhibition

Diode Lasers

Chairman: *Martin Traub*, Fraunhofer ILT, Aachen (D)

14:30 Blue High Power Laser Diodes – Beam Sources for Novel Applications
Dr. Martin Behringer, OSRAM Opto Semiconductors GmbH, Regensburg (D) article → page 60

15:00 Efficient High Brightness Laser Diodes designed for High Temperature Operation
Dr. Ralf Hülsewede, JENOPTIK Diode Lab GmbH, Berlin (D) article → page 52

15:30 Lasers for 3D Sensing and LIDAR Applications
Dr. Holger Mönch, TRUMPF Photonic Components, Aachen (D)

16:00 Outlook (Room Berlin)
Prof. Constantin Häfner, Fraunhofer ILT, Aachen (D)

16:30 End of the Lectures

Laser's Future Will Be Smart

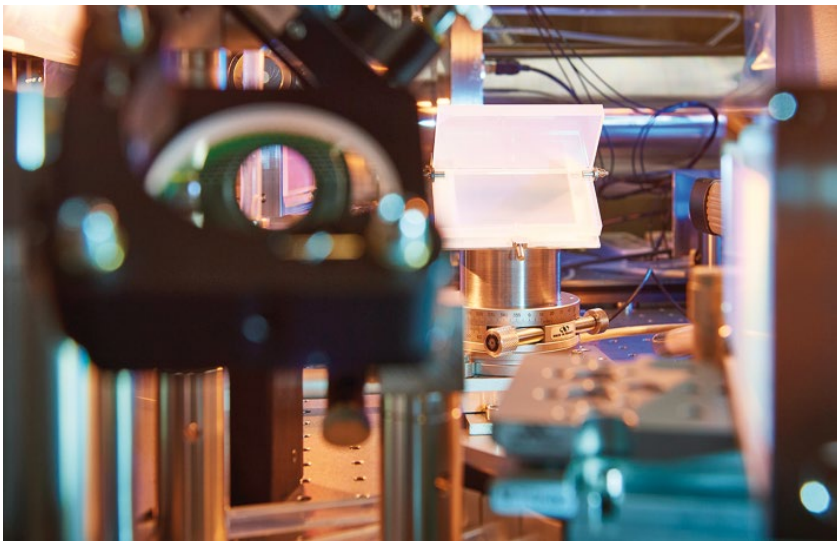
12 laser experts working in research and industry reveal their views on the future of laser technology: artificial intelligence will clearly have a significant role to play

Hilde-Josephine Post

This year the laser is celebrating its 60th birthday, but it can by no means be regarded as anachronistic. On the contrary, the more mature laser technology becomes the more exciting and dynamic its development is. The future of the laser promises above all to be smarter, even more efficient, more powerful, more flexible and more productive. This coincides with the vision put forward by this year's top-class International Laser Technology Congress in Aachen (AKL'20). Under the auspices of the Fraunhofer Institute for Laser Technology (ILT), laser developers, manufacturers and users will meet for the 13th time from May 6 to 8, 2020, to share their experiences. Looking forward to the conference, ILT's head of communication, Axel Bauer, reveals that "the conference agenda will include practice-oriented research, new applications and an outlook on pioneering developments such as additive manufacturing and artificial intelligence." For PhotonicsViews, in the run-up to the congress, experts from research and industry have taken a look into the crystal ball of the laser's future.

High-performance USP lasers on their way to industrial maturity

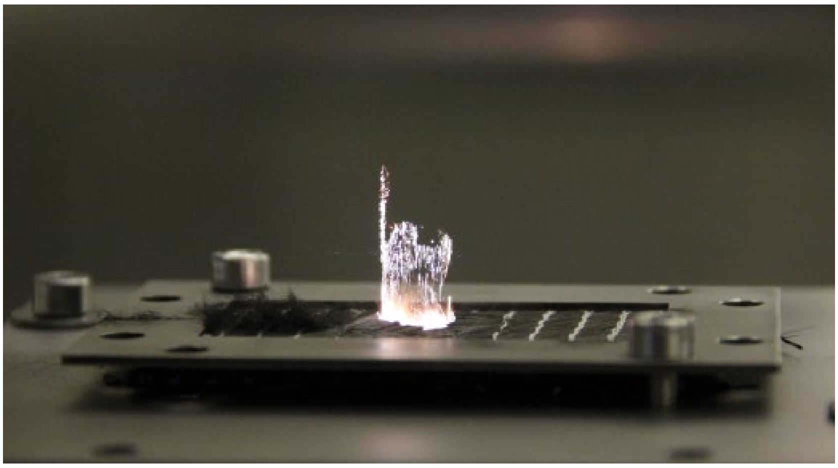
The ultrashort pulse (USP) laser is considered the precision tool of the future. There are good reasons for this, as it offers decisive advantages, especially in micromaterial processing: ultrashort light pulses lasting only a few pico or femtoseconds result in multiphoton absorption processes due to extremely high pulse peak powers. This means that almost any material can be processed, regardless of its absorption properties. Accordingly, even transparent, hard or brittle materials can be modified excellently with industrial USP laser systems. What's more, the materials evaporate directly without producing any significant melt. Thanks to this vaporization-based ablation, material-friendly and high-precision processing methods are possible. "USP laser technology holds great potential. Given the low average power of USP laser systems available so far, it has not yet been possible to implement many applications with high throughput requirements. This is now changing. We intend to combine the precision of the USP laser with the area throughput of modern cutting and welding lasers," says Hans-Dieter Hoffmann, head of the Laser and Optics technology field at Fraunhofer ILT. So within the framework of the Fraunhofer Cluster of Excellence Advanced Photon Sources (CAPS), over the next two years, 13 Fraunhofer Institutes will be developing and using a new generation of high-repeating, high-power USP fiber laser systems. These will have average powers up to 20 kW at around 80 MHz as well as InnoSlab and disk laser systems with pulse powers in the 10 GW range and 10 kW average power at a repeti-



Scaling of ultrafast laser radiation in the multi-kW range. (Source: Fh. ILT)

Source: Amphos

Dr. Claus Schnitzler, CEO of Amphos, a subsidiary of Trumpf



Almost any material can be processed with a USP laser, including carbon fiber components, as shown here, modified with a 200 W USP laser. (Source: Amphos)

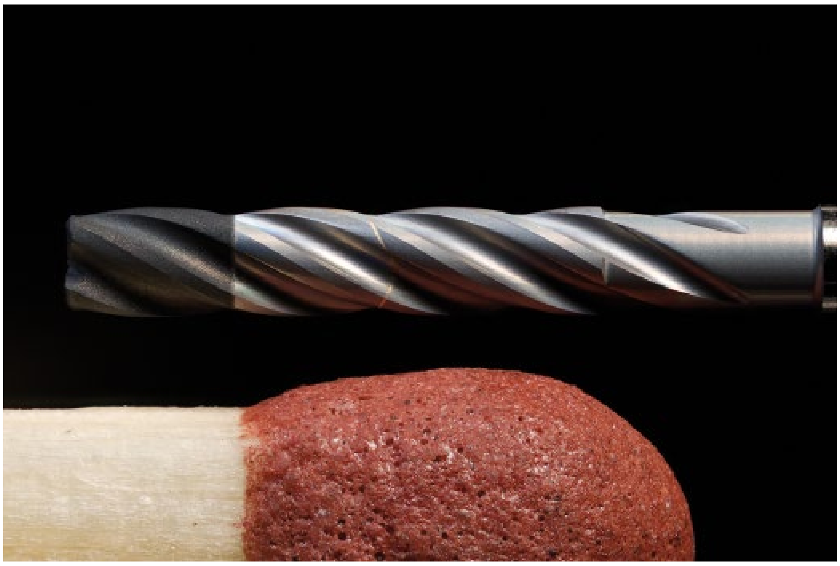
tion rate of some 100 kHz. Hoffmann explains further: "We also focus on highly efficient compression-to-pulse durations below 50 fs and pulse energies above 5 mJ at average laser powers in the kilowatt range. These beam parameters make it possible to generate coherent USP radiation in the EUV (extreme ultraviolet) spectral range for metrology applications."

Amphos, a spin-off of Fraunhofer ILT and now a subsidiary of Trumpf, supplies USP slab lasers with a current output power of 1 kW for the laboratory tests conducted by the Fraunhofer Institutes. "In general, the aim over the next few years is to make USP laser sources in the higher power range suitable for industrial use," says Dr. Claus Schnitzler, chief executive officer of Amphos. In his view, disk, fiber and slab laser concepts have all shown in laboratory-scale applications that they can achieve high output powers in the kilowatt range. Dr. Schnitzler reports: "In our experience, the InnoSlab concept is currently the most suitable for industrial application, as this is the most compact and cost-efficient way of building the USP laser. This was one of the reasons why Trumpf invested in the Fraunhofer patent for InnoSlab technology." In InnoSlab technology, pulses are amplified in cuboidal laser crystals. "We currently achieve up to 2 kW average power," the Amphos CEO continues, "and will certainly be able to increase this to 5 kW over the next three years. If we want to go beyond that, the disk laser will become interesting." Dr. Schnitzler ascribes great benefits to the powerful USP lasers: "Glass-cutting processes can be carried out faster, and thick glass plates in particular can be cut using laser radiation. In future, glass manufacturers will be able to cut contours that were previously impossible, and with little glass waste. In addition, high-quality glass-joining processes will also become possible. In the future, USP lasers will leverage their strength in the fast cutting of ceramics, industrial diamonds, fiber composites and material combinations like those found in printed circuit boards."

Productivity leaps in laser micromachining

"USP laser technology already offers very high accuracy in the nanometer range (< 100 nm) for laser ablation in microtechnology. With a power increase into the kilowatt range and corresponding system technology, today's qualities can be transferred to high production rates and large components in the future," predicts Dr. Arnold Gillner, head of the Ablation and Joining technology field at Fraunhofer ILT. "This is why at CAPS," adds Hoffmann, "in addition to developing the laser sources, we are also focusing on refining the system-technological concepts for beam shaping and rapid deflection as well as applications in industrial production processes." Experts from industrial practice such as Dr. Claus Alexander Dold, head of process innovations and head of product management at machine manufacturer Ewag, welcome powerful, reliable laser sources: "We can see that the USP laser-beam sources are becoming increasingly available on an industrial scale. In our machine tools, we currently use USP industrial lasers with 50 to 100 watts average power. When manufacturing micro-tools such as drills with diameters of 0.4 to 3 mm, the laser beam works the full drill geometry directly into the cylindrical shank of the metal blank. We achieve this competitively, as material ablation is low here. For drills with diameters larger than 3 mm, however, a great deal of material must be removed. Here grinding is still by far the most efficient method today. This could change in the future with more powerful USP lasers." "Today's USP laser processing methods often compete with more conventional methods such as micro-milling, mechanical drilling or electrical discharge machining (EDM) technologies," says Dr. Gillner. He therefore sees the main challenge in USP laser processing in further increasing productivity: "This can only be achieved by dynamically controlling the energy deposition in order to always work at the optimum energy density for all geometries and materials. We need ultra-fast modu-

Cutting of thin glass with ultrashort pulsed laser beams. (Source: Fh. ILT)



USP laser machines from EWAG efficiently produce high-precision end mills with diameters ranging from 0.5 to 3.0 mm. (Source: Ewag)

lation and scanning technology with variable beam geometries and adapted ablation strategies that can be dynamically adjusted to the respective process." Dr. Dold can only agree: "We, too, regard control as a major challenge. Machine control and the control of the optical system are still separate today. This will also have to change in the future. Initial steps have already been made. In our opinion, in the near future, USP laser technology will leverage its advantages above all where very small geometries are required. It will be possible to produce intricate geometries in greatly improved quality, with better properties and with less effort. We also see a major advantage of USP laser technology in the ability to create free-form geometries that previously could not be produced conventionally, especially in ultra-hard materials such as diamonds. For the future, we are also thinking about self-learning systems that use wear data they have collected to autonomously optimize tool geometries." The involvement of Artificial Intelligence (AI) is also foreseen by Dr. Gillner: "In the future, high ablation accuracy will be achieved by integrating sensors that monitor ablation geometry, whose data is evaluated by AI." The ILT expert forecasts further: "In five years, the USP laser will have become an important tool for precision machining and in ten years' time we will be using it across the board, just as electro-erosive machining is used today. The user will enter the data according to the technical drawing and the machine will ablate the desired structure exactly, without test runs. USP technology will then have largely replaced today's milling and EDM."

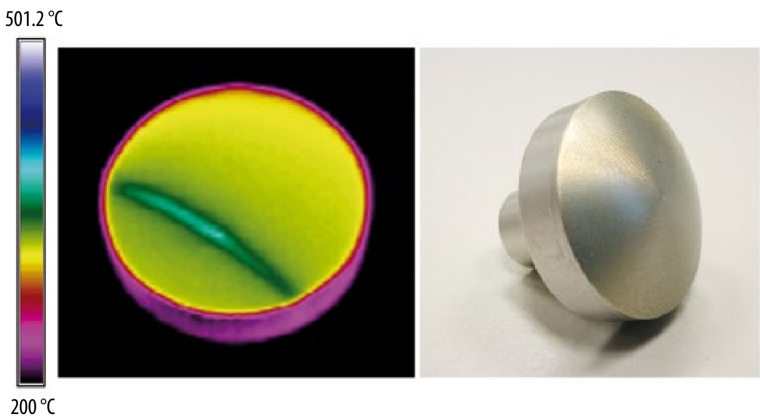
Dr. Claus Dold, head of process innovations and head of product management at Ewag

Source: Ewag

Pioneering: laser processing creates functionally optimized surfaces

Surface structuring is currently at the forefront of developments, as functional surfaces are considered a trend topic. "USP laser structuring can change the optical or thermal properties of metal or glass surfaces," reports Amphos' managing director Dr. Schnitzler. In his opinion, however, a future challenge lies in implementing the laser processing of large surfaces. He explains: "To achieve this, we definitely have to further accelerate and optimize the laser processes. Once we have a powerful USP laser capable of processing a two-square-meter surface within one second, it can be used to structure complete fronts of glazed houses, entire ship hulls or the wings of airplanes and wind turbines. This would give us enormous leverage in terms of energy and cost savings. We expect industrial applications like this to be available in the next three to five years."

The laser is predestined not only to ablate material from surfaces precisely and quickly, but also to modify surfaces or coat them. For Dr. Christian Vedder, group leader thin film processing at Fraunhofer ILT, the focus is on the development of new multifunctional coatings and smart surfaces: "They enable a component to increase its load limit, fulfill additional thermal, mechanical, chemical and electrical functions and even communicate with its environment." As a current example, Dr. Vedder cites the additive, laser-based insertion of integrated sensors into metallic components or fiber-reinforced plastic parts. "These sensors inform the machine about the component status, thereby preventing critical operating states or enabling a more efficient operating mode," continues the group leader. According to Dr. Vedder, laser processes offer the advantage of gently coating temperature-sensitive components. The challenges here are the precise measurement and control



The ELB-Eloxalwerk Ludwigsburg Helmut Zerrer company is making pioneering progress and using laser technology for innovative coating processes. High-performance polymer coatings make light metal surfaces particularly wear-resistant. Pictured is the laser process for coating a 3D component. (Source: ELB-Eloxalwerk)

Integrated functionalities: electrical functional layers can be applied directly to metal, glass and polymer parts thanks to a combination of printing and laser technology. Applied to glass fiber fabrics which will be used to manufacture fiber composite components, sensors or heating elements could also be integrated into aircraft wings. (Source: Fh. ILT)

Source: ELB Eloxalwerk

Dr. Anna Buling, head of research and development at ELB-Eloxalwerk Ludwigsburg Helmut Zerrer

of this fast material processing, the mastery of the adhesion process (interface) between layer and component, and the integration of the new laser processes into existing production chains. Component coating with powders, sol gels, pastes or inks and subsequent laser-based thermal post-treatment such as drying, cross-linking, sintering or melting make it possible to add new functions to surfaces and thus immensely increase a component's range of possible applications. "This means that in some areas, manufacturers can replace energy and cost-intensive electroplating, high-vacuum or furnace processes," Dr. Vedder concludes.

Laser surface processing is already being used in many different ways today and will enter new industries in the future. ELB-Eloxalwerk Ludwigsburg Helmut Zerrer is making impressive progress here: "We are pioneers in innovative surface solutions. Since we are passionate about lightweight construction, we see our contribution to a positive energy balance in functionalizing light metals in such a way that their full potential can be exploited. We are already using laser technology for innovative coating processes. Using high-performance polymer coatings, we are able to make light metal surfaces particularly wear-resistant," explains Dr. Anna Buling, head of research and development at ELB. As a result, light metals can now be used in areas where this was previously not possible due to high wear. Reduced friction also means systems consume less energy. The automotive industry and e-mobility, for example, are already enjoying the benefits of light metal coatings. "Our development work is also focused on solutions for corrosion protection. But we are only at the beginning of functional optimization by means of laser technology," the research manager continues. She expects laser technology to play an increasingly important role at ELB in the next five to ten years: "Laser surface treatment offers greater flexibility, energy efficiency and shorter process times compared to conventional methods. A key advantage is the fact that a single component can be equipped with a variety of functional properties in different places. One part of the component may be particularly wear-resistant, another highly corrosion-resistant and a third resistant to chemicals." Dr. Buling's future scenario: "ELB will offer highly automated surface optimizations and therefore be in a position to process large quantities particularly efficiently. The high spatial resolution and the range of freedom offered by laser technology facilitate the development of smart mixed-construction methods so that materials can be used and functionalized specifically where they are most effective. Our vision is that we will rely

Hans-Dieter Hoffmann, head of competence field laser and laser optics at ILT

Dr. Arnold Gillner, head of competence field laser ablation and welding at ILT

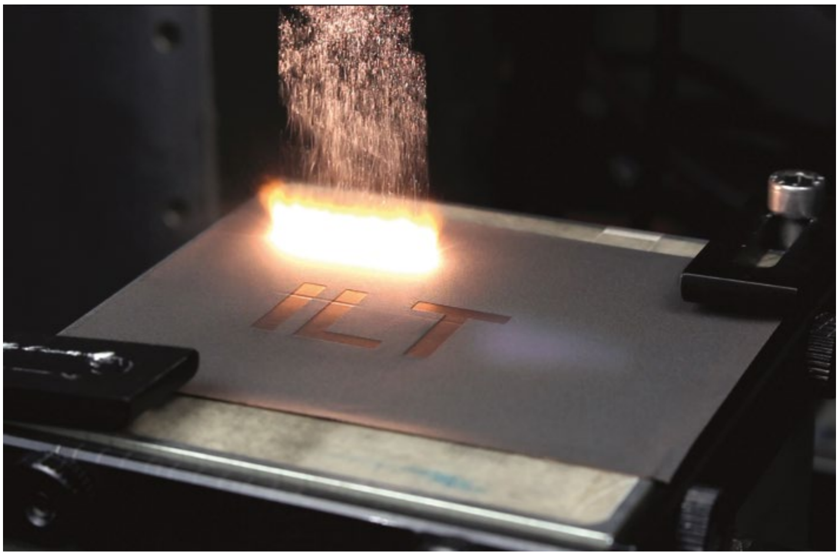
Dr. Christian Vedder, group leader of thin film processing at ILT

Dr. Alexander Olowinsky, group leader of micro welding at ILT

Dr. Dirk Petring, group leader of macro welding and cutting at ILT

Prof. Dr. Johannes Henrich Schleifenbaum, head of competence field additive manufacturing and functional layers at ILT

Source all images: Fh. ILT



In addition to classic materials such as aluminum and steel from automotive engineering, laser processing of copper will be the focus of further developments in future. (Source: Fh. ILT)

on AI, allowing processes to be adjusted to new requirements and materials in the shortest possible time by detecting and analyzing the process data and the resulting surface properties."

E-mobility: with lasers & AI for zero-defect production of energy storage systems

A decisive factor for the future success of e-mobility is the introduction of competitive electrical energy storage systems into the mass market. Car manufacturers are faced with the challenge of reducing the production costs for battery cells. "A large number of external factors are shaping the new product requirements for battery systems," says Dr. Jan-Philipp Weberpals, strategic overall planning of laser-beam technology at Audi. He continues: "In addition to aluminum and steel as the traditional automotive engineering materials, copper will be the focus of future developments. The great variety of materials and thicknesses, as well as the number of welded seams and costs per component lead to a sharp increase in complexity. Here, laser-beam technology as a highly flexible production technology offers a wide range of solutions for e-mobility requirements."

Dr. Jan-Philipp Weberpals, strategic overall planning laser-beam technology at Audi

Source: Audi

Laser-based processes are already used today in the production of conventional batteries. Dr. Alexander Olowinsky, head of the micro joining group at Fraunhofer ILT, gives some examples: "Lasers cut electrode foils, structure active materials and weld cell casings. In addition, lasers are increasingly used to weld electrical connectors to combine individual cells into modules. For the next generation of cells, we will focus our research on new processes such as drying and structuring active materials." Especially in terms of drying, Dr. Olowinsky sees the laser-based process as an energetically favorable alternative to oven-based drying, and one which also requires less space. He emphasizes: "Improved laser technology has significantly reduced the cost of beam sources, which in turn increases the economic efficiency of the processes in terms of overall costs."

Quality and reliability are essential in the production of energy storage systems for e-mobility. "In addition to fundamental product requirements such as chargeability, storage capacity and output, development work at Audi focuses on the quality of the connections and their operational stability," reports Dr. Weberpals. Rework on battery systems is not yet possible. "That's why stable and robust laser-beam processes have to reliably generate seam patterns, thus minimizing contact resistance in the weld width," the Audi expert explains. "Given the risk of short-circuits in high-voltage storage systems, instabilities, such as splashes during laser joining, must also be avoided in cost-efficient series production." Dr. Olowinsky agrees that the interconnection of individual battery cells by means of laser-beam welding represents a particular challenge in terms of process stability and quality: "Only numerous cells electrically interconnected can provide the output parameters required of a battery module. Online process control is therefore of great importance. Every bad or faulty weld impacts performance and must therefore be detected during the production process if possible." Dr. Weberpals is convinced: "Artificial intelligence will play a very important role in battery-system production. The desired zero-defect production requires intelligent algorithms to ensure cost-efficient series production through real-time quality assurance." ILT teams are currently researching AI methods for evaluating signals in process control. "Initial results indicate great potential, far beyond conventional signal evaluation, especially for assessing weld-seam quality," reports Dr. Olowinsky. He predicts: "Machine learning methods will be successively transferred to other processes, and the knowledge gained will speed up future process development."

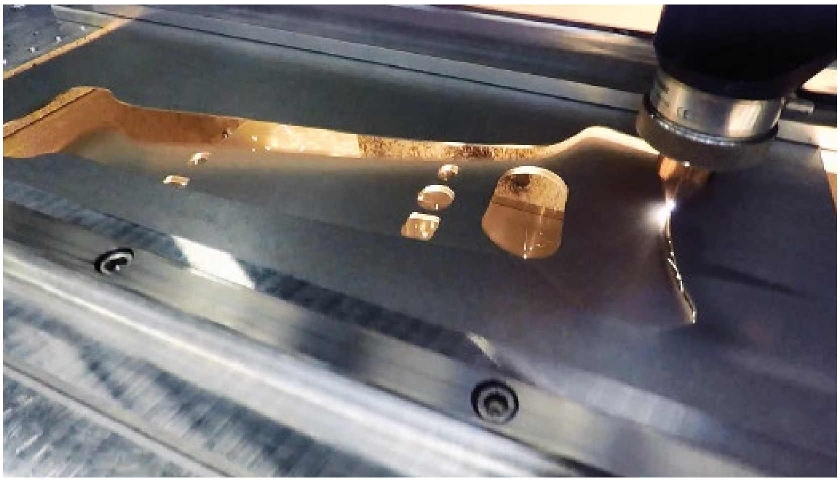
Excellent perspectives for high-speed laser cutting

Cutting was one of the first tasks with which the laser firmly established itself in the field of industrial production. Laser cutting today accounts for more than forty percent of global laser sales in materials processing. In the future, the focus will be on even higher cutting speeds. "High-speed cutting using laser beams," says Alexander Knittel, head of strategy planning for press plants at

Mercedes-Benz, “has become an integral part of modern production plants and has been successfully implemented in automotive production over a period of four years. At Mercedes-Benz, this innovative technology is being continuously optimized by enhancing system performance and reducing non-productive times.” He adds: “We use high-speed laser cutting to produce high-quality blanks in outer skin quality (body in white, visible surfaces of the body). This means that two laser blanking lines now generate a higher output than comparable modern blank cutting lines with presses. At Technologiefabrik Sindelfingen (TECFABRIK) we have refined high-speed laser cutting for use in automotive series production. The aim there was to be able to flexibly process materials such as aluminum or steel metal strip in one facility. The challenges were to accommodate the different material and surface properties as well as the subsequent forming and painting processes. The aluminum and steel sheets can now be flexibly processed on a single laser blanking line with short changeover times and without intermediate cleaning.” Knittel points out some of the advantages: “High-speed laser cutting is extremely flexible as regards blank geometries and quantities. This means that small series or different car variants can be produced cost-efficiently without integrating additional cutting tools.”

> Higher performance in the field of fiber lasers will allow even higher cutting speeds.
>
> Alexander Knittel, Mercedes Benz

But what are the future prospects of achieving even faster cutting processes and where are the hurdles? Dr. Dirk Petring, head of the macro joining and cutting group at Fraunhofer ILT, notes: “Thanks to its controllable scalability, the laser process itself will not be the limiting factor on the way to even higher speed and output in the next five to ten years. High-speed laser cutting thrives on the synthesis of dynamics and rigidity in the machine system. There is still plenty of optimization potential with regard to the lightweight construction of the moving parts (cutting heads, gantry) and the efficiency of the drive motors as well as the real-time capability of the control system.” According to Dr. Petring, the systems also require much more flexible and faster techniques for the removal of cut parts. “Especially in systems where several laser cutting heads cut sheet-metal parts from the running coil, the degree of automation will be a key success factor,” states the group leader. This is one of the reasons why AI-supported process monitoring and control systems that autonomously adapt the laser parameters to current process requirements have priority in current ILT research projects.



The degree of automation will be a key success factor in the future, especially if several laser cutting heads are involved. Here: high-speed cutting with laser beam. (Source Fh. ILT)

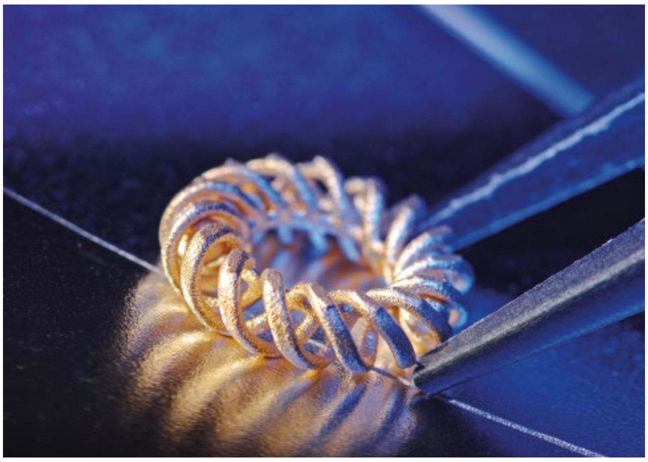
Alexander Knittel’s preview of the future reveals: “Higher performance in the field of fiber lasers will allow even higher cutting speeds. This will have a particularly positive effect, especially when processing steel sheet strip. In the softer aluminum sheet strip, we already achieve remarkably high cutting speeds today.” The exciting question for the automotive expert is: how can the flexibility provided by the laser cutting process be used most economically? According to Knittel, higher laser cutting performance will also allow more cost-efficient facility concepts to become reality in the future – instead of three laser cutting heads working in parallel, one will be sufficient in the ideal case. “Especially in the areas of tool testing, prototype construction and small series – such as cabrio models – a cost-reduced facility concept with one laser cutting head could be more target-oriented,” says Knittel. ILT expert Dr. Petring further elaborates on the future potential of lasers: “In about ten years’ time, lasers will even be able to cut three-dimensional parts at high speed – then perhaps with flexibly pulsable lasers, smart beam-shaping and deflection systems, integrated into a multifunctional laser process chain of cutting and joining operations.” He is confident: “In the course of the progressive digitalization of business and production processes, high-speed laser cutting will increasingly replace contour-bound cutting tools with flexibly programmable laser machines, not only in the automotive sector. Instead of producing, adapting, storing and transporting countless rigid tools, we will only generate data – as has long been the case in other areas – and send it to the place where it is needed at the time. Short adaptation and response times will facilitate the much-vaunted agile production in volatile markets.”

Source: Mercedes Benz

Alexander Knittel, head of strategy planning for press plants at Mercedes Benz

Smart series production using 3D printing holds great potential

Additive manufacturing (AM) using laser technology is also about sending data, not goods. “For me, smart production means that we produce exactly what is really needed – in other words, produce less and less as stock. To do this, we need production processes that can



Processing high carbon steels by Laser Powder Bed Fusion (LPBF). (Source: Fh. ILT)

Demonstrator with flexible hinges manufactured using μ-PBF. (Source: Fh. ILT)

quickly and easily handle even small quantities. Additive manufacturing is virtually predestined for this, as only data and no components need to be kept in stock. This is a smart approach and highly cost-effective," explains Prof. Johannes Henrich Schleifenbaum, head of the additive manufacturing and functional layers technology field at ILT. According to the professor, additive manufacturing will only develop successfully if it is addressed using an integrative approach combining product design, materials and production. Interdisciplinary collaboration is urgently required. Schleifenbaum sees the current development priorities first of all in the interaction of the laser beam with the material: "We expect completely new effects here, as we are dealing with an entirely new type of material genesis in the component. Multimaterial construction will also be a key topic." The professor adds: "So far, research has mainly focused on metals. Now we are making remarkable progress with multimaterial combinations in the field of plastics as well." A second and equally important priority, he says, will be training and further education. Designers and engineers must first become aware of the exciting new possibilities additive manufacturing has to offer. Schleifenbaum forsees: "The design approach will be completely different. For instance, components will no longer be designed as blocks, but with different properties along their geometry."

*Voxel = 3D pixel, volume element

Source: Materialise

Dr. Bart Van Der Schueren, chief technology officer at Materialise

> The biggest challenge is to increase the overall productivity of AM.
>
> Bart Van Der Schueren, Materialise

A pioneer in the industrial application of additive manufacturing, Materialise, already has a wealth of experience. "There are still quite a number of challenges that we, as an industry, must solve if we want to use additive manufacturing (AM) for the production of larger series," says Materialise CTO Dr. Bart Van Der Schueren. In his view, the biggest challenge is to increase the overall productivity of AM. His solution: "A greater number of lasers within one system will be able to handle this in the future." But this also presents additional challenges – for example, with regard to process control and the complexity of data preparation. "We consider the laser a very suitable energy tool in AM machines," explains the CTO, "because it applies the precise amount of energy in a controlled manner on a voxel-to-voxel* basis during the printing process. In the future, with new technologies such as artificial intelligence, it will be possible to achieve even better process control, enhance the quality of the printed parts, improve repeatability and reduce printing failures. This will also increase productivity." Another element the Materialise expert considers to be important: "The software for data preparation must become even more intelligent in order to support the operator in reaching the desired results faster. Artificial intelligence helps achieve these goals and from a print perspective, it is becoming increasingly easier to obtain design variations with predictable performance." Prof. Schleifenbaum already mentioned product development, which must be approached differently in the future. Van Der Schueren adds: "AI helps design products in such a way that they exhibit better performance and are ideally suited for AM production. This leads to higher-quality components while using less material." Schleifenbaum is also convinced: "Within the next five years, designers will increasingly use AI tools to create intelligent solutions. Generic algorithms implemented in a cloud will then compute component designs that are not necessarily symmetrical, but inspired by nature." Both experts see a very positive future for AM: multimaterial technologies and the integration of electronics in printed 3D-components are gaining ground. This opens up new possibilities for innovative products. A large number of the objects produced by AM machines are customized. AM processes are increasingly used to extend the life of products or improve their performance with advanced upgrade parts. "After all, AM is developing into a mainstream production method, just like CNC, casting or moulding," Van Der Schueren concludes. "These new technologies will drive the ever-growing share of AM in the overall manufacturing paradigm."

Hilde-Josephine Post

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Translation: K. Vinz & D. Gough

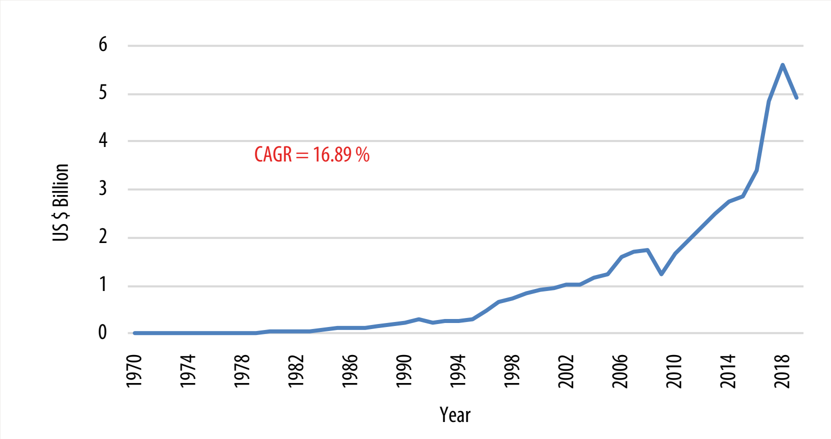

Fig. 1 Industrial laser revenues 1970 – 2019 (Source: Belforte Assoc.)

The Global Market for Industrial Laser Processing

Fiber laser revenues dictate total-industry negative performance in 2019

David A. Belforte

Global industrial laser revenues, over the period 2010 – 19, show a period of strong CAGR growth (11.5 %) led by the dynamic markets for high-power fiber lasers used in sheet metal cutting and a significant application for excimer lasers (smart phones). In 2019, global laser revenues decreased for only the first time since the recession of 2009, mainly for two reasons: unconstrained fiber laser selling price decreases and the maturation of the application for excimer lasers. Strong competition in the Chinese market – now more than 40 % of the world market – drove down the average selling price of industrial lasers by 17.5 % in 2019 while unit sales were up 6.5 % in the same period.

The global industrial laser market in 2019 experienced its first decline in revenue growth since the recession of 2009. In fact, since I started collecting industry data in 1970 (Fig. 1), industrial laser revenues declined in only one other general economic recession, 1992, and barely squeezed out positive numbers in the recessions of 1975 and 1982. What made the 2009 recession notable was the steepness of the decline, –40 %. The 2019 revenue drop had two major causes: a sudden drop in average fiber laser selling prices (ASP) promulgated by suppliers in China and the expected reduction in machine sales for one large excimer laser application used in the manufacture of smart phones and other hand-held display screens.

So, 2019 was not a great year for industrial lasers (Fig. 2). Wait a minute: factor out the excimer laser bubble and you are left with the revenue gap in fiber laser revenues, perhaps as much as 12 % below 2018 revenues. True but, with ASP down, China's OEM suppliers flocked to lower-priced lasers, and unit sales were up about 6 % in 2019. Keep in mind that China is acknowledged as the single largest market for industrial lasers, and fiber lasers represent more than 60 % of the laser processing market in that country [1].

Put another way, the decline in 2019 of fiber laser sales of more than $300,000 due to short term ASP problems makes up about half the loss in total 2019 laser revenues. The scheduled reduction (more than 30 %) in excimer laser revenues makes up another 25 %. Between them, these two factors – one planned, one unexpected – account for most of the shortfall in 2019 revenues. Some might say, salve for a wound, making the remainder of this article more palatable.

The 2019 market in review

The decade following the disastrous 2008-9 recession was, in reflection, one of the best for growth in industrial laser revenues. Foresighted R&D investment during the recession in advancing laser technology and applications capabilities by suppliers realizing the pent-up buying demand, once the sales downturn ended, would likely call for new processing needs served by automation solutions featuring a new generation of lasers. Consequently as shown in Fig. 3, the CAGR for these product revenues was in excess of 13 % for the decade, approaching $ 6 B before the 2019 decline.

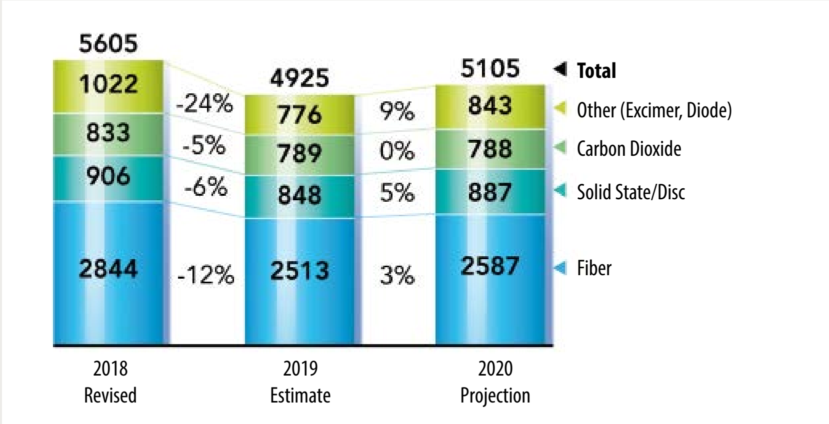

Fig. 2 Global industrial laser revenues (US $ M) (Source: Strategies Unlimited)

This led to speculation that 2019 could be a modest growth year, tempered by very cautious optimism by the world's manufacturing industries causing us to project very modest 2 % total revenue growth in 2019. Factored into our thinking was the pending slowdown in excimer laser system deliveries. We frankly were not prepared for the first half buying onslaught in China for fiber laser processing equipment with attractive reduced investment enabled by lower ASP lasers. One domestic fiber laser manufacturer experienced a 35 % increase in first half revenues over the previous year, with most of it driven by high-power fiber lasers [2]. As a consequence the total industrial laser revenues in 2019 (Fig. 2) dropped 12.1 % in 2019.

Fiber remains king

As in the past, fiber lasers led all types in 2019 revenues (51 %), with solid-state a far second at 17 %, followed by CO_2 (16 %) and diode/excimer (16 %). All laser types showed a decline in 2019 revenues, with excimer taking the biggest hit with the display application winddown (Fig. 2). Fiber lasers succeed with output powers from a few watts to many kilowatts, with revenue strength in the metal cutting and welding sectors where power counts [2].

Solid-state lasers, buoyed by fast-growing sales of ultra-short pulse USP lasers, came close to matching 2018 performance. This technology, geared to microprocessing applications, set the table for 2020 growth. CO_2 laser usage continued an inexorable revenue decline as high-power versions continue to lose market share to fiber lasers, although lower-power units carved out a solid niche in the low-power engraving sector.

Cutting produces the revenues

Thirty-five years ago, when laser revenues were $ 268,000 (in 2020 dollars), metal cutting was the leading application and remains so today (Fig. 4). Then, the market was dominated by Japanese suppliers and users. Today, along with laser marking, it is a global application found in countries around the world, from emerging economies to the worlds' largest, but uniquely, in each, all the technology is the same, whether it be Thailand, Botswana, Japan or Germany. Sheet metal cutting with fiber lasers ranging in output power from 1 to 15 kW are processing ferrous and non-ferrous metals, faster, more precisely and in higher quality than those 1986 units.

And just when questions about market saturation appeared, the suppliers of laser cutting systems introduced a new technology, adjustable beam mode, that allows users to alter, in real time, the laser beam's characteristics as it impinges on the workpiece. Depending on the supplier, this resulted in optimized performance on all metals and thicknesses, extended job-shop competitiveness, significantly increased productivity, improved cut quality, stable automated processing, reduced process costs, reduced or eliminated weld spatter and reduced laser power consumption – to name some advantages [3]. All these are important – but what about the laser systems suppliers? If output power can be reduced for increased productivity does not that imply unit sales of higher power lasers may slow revenue growth over time?

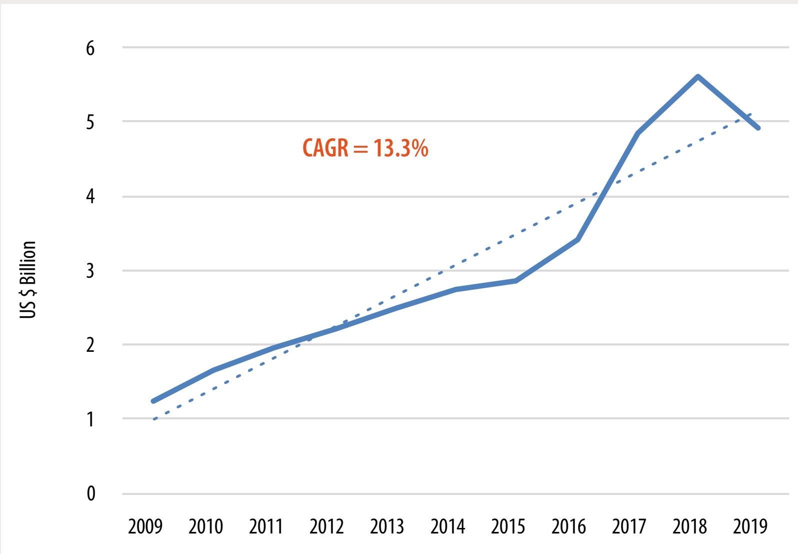

Fig. 3 Industrial laser revenues since recession (Source: Belforte Assoc.)

Microprocessing takes up the slack

Many within the laser industry speculate on the rise of USP lasers as a widespread microfabrication tool. Increasing cost-effective applications lends credence to this and numerous USP laser and system suppliers now offer equipment at cost-justifiable selling prices that have led to substantive double digit revenue growth [4], It will not be easy, as evidenced by the introduction of industrial femtosecond laser micromachining in 1997 and the lengthy acceptance curve which began exponential growth 15 years later [5]. Expansion of USP laser suppliers leads to more cost-justifiable equipment which leads to new markets with multiple customers. Among these are a fairly large number of OEMs and most importantly a growing number of contract manufacturers' providing the process certification necessary to broaden the markets [6].

The microprocessing sector showed an 18 % decline in 2019 primarily attributed to cyclical slowdown in the semiconductor industry and the aforementioned wind-down of excimer laser display processing systems. Solid-state (USP), fiber and CO_2 lasers for microprocessing applications posted single digit losses versus a strong double digit loss for excimer (Fig. 4). Investment in technology to develop USP lasers with kilowatt output power further supports the import of USP revenue growth in the coming years [7].

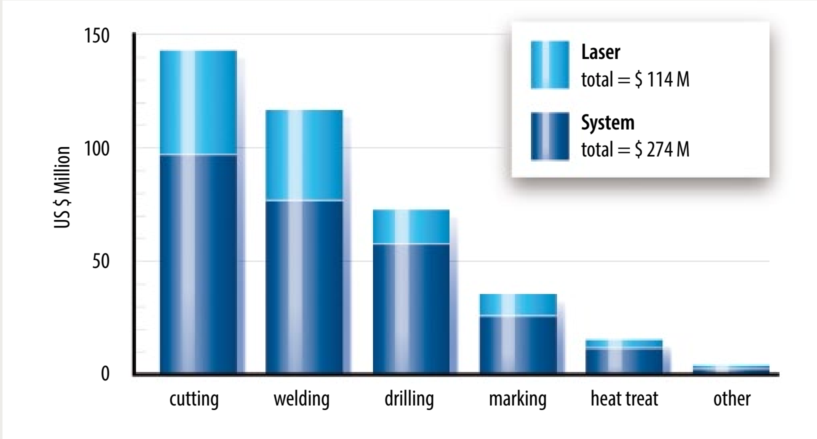

Fig. 4 Industrial laser revenues – 1986 (Source: Industrial Laser Review)

Macro processing rules revenues

Applications in the macro category are metal cutting (71 %), welding / brazing (25 %) and additive manufacturing (4 %). Cutting at 40 % of all 2019 industrial laser revenues sets the tone for total marketplace performance and as revenues decline (15 %), predicated by the China ASP situation for high-power fiber lasers that power the domestic OEMS, altered the economics performance of several international suppliers.

As laser metal cutting matures globally, suppliers of high power lasers look to the second largest Macro application, welding, for increasing revenues, which was the only sector to sustain growth in 2019. Revenues in 2019 were slightly ahead of 2018 but not enough to move metal joining off the low teens, a position it has occupied for years. Because welding is a part-specific application, the time from feasibility to installation sign-off can be lengthy so revenue flow in a given year can be elusive.

Additive manufacturing has also been suggested as a laser revenue generator, and rightly so because the transition of laser metal deposition from prototype to serial production, with the attendant need for quantities of laserassist machines needed, is happening. Growth in 2019 was hampered (−14.8 %) by a temporary surplus of capacity which is expected to adjust upward in 2020. Interestingly, laser 3D printing is also finding a home in microfabrication applications, a diverse but less competitive market [8].

Marking / engraving revenues cruise

This sector has not made significant revenue gains in recent years as extreme competition in the major market, China, has driven down system selling prices, forcing laser suppliers to drop OEM selling prices to the bare bones, relying on volume orders to generate profits. Unit sales increased while ASP decreased, a situation complicated in 2019 by the slowdown in the overall Chinese market, leading to a 6 % revenue loss in 2019, the first in many years.

Summing up 2019

A sarcastic phrase used in the USA to ease the pain of an unfortunate situation is appropriate for laser revenue performance in 2019 – "Other than that Mrs. Lincoln – how did you enjoy the play". Revenues went down 12 % while unit sales were up 5.6 %. Except for welding, up 6 %, all other application sectors experienced a decline. It will not bring comfort to three of the four laser companies in the billon dollar club [9] that saw substantive revenue losses in the second half of the year, but the causes appear to be temporary and correctable.

Projections for 2020

Based on public companies' guidance and generally more positive first quarter thinking about the health of the global laser market, we are projecting all application sectors except for marking (-1 %) and semiconductor (-3 %) to experience 1 – 9 % revenue growth in 2020 and all laser products revenues should see increases from 2 – 10 % except for CO_2 (0 %). This may return microprocessing to 5 % growth and macro processing to 4 % growth for 2020. If the forecast holds, total industrial laser revenues could reach 4 %.

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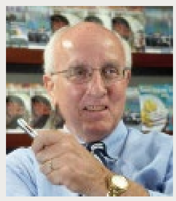

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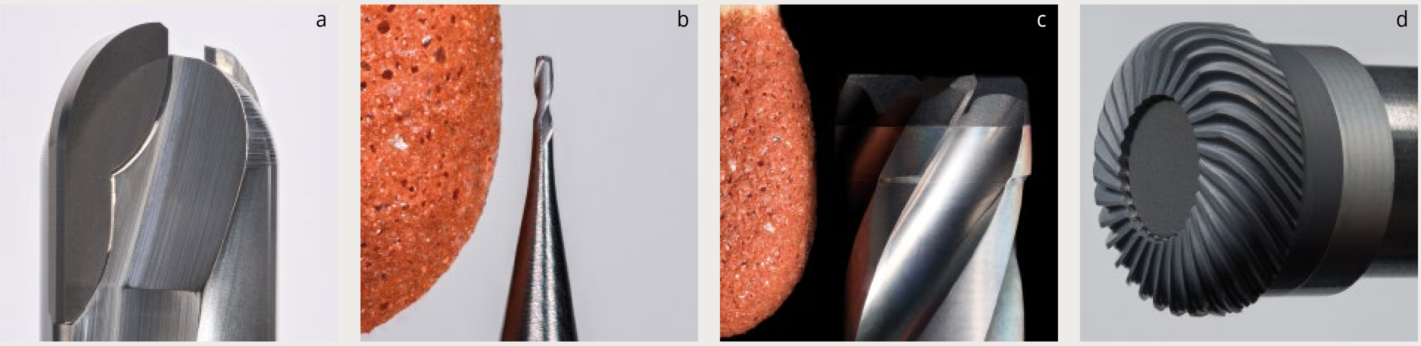

Fig. 1 Typical examples of tool geometries. Brazed PCD ball nose end mill (a), micro tungsten carbide 2-flute end mill (Ø = 0.2 mm) (b), micro PCD 4-flute end mill (Ø = 3 mm) (c), PCD torus end mill used for milling graphite molds for mobile phone displays (d; sources: Ewag AG)

Digitization for Highly Accurate 3D Laser Processing of Customer-specific Tools

Digital generation of micro tools in coatable carbide and ultra-hard materials and aspects of autonomous production.

Claus Alexander Dold, Gregory Eberle, and Christian Heger

Cutting tool manufacturing by laser technology has developed quickly during the past fifteen years. Compared to conventional machining methods such as grinding or eroding, laser processing does not require any additional elements such as coolant, grinding wheels, erosion wire, discs, etc. If ultrashort laser pulses are used together with optimized laser parameters, heat input into the material can be negligible. Additionally, there are no processing forces or tool wear present during laser manufacturing. For these many reasons, autonomous production of metallic or diamond tools is feasible and highly interesting.

Tool manufacturing covers many tool types, from rotary tools such as drills or end mills, inserts and reamers to special form tools for a multitude of applications. Tool production steps start with the generation of the cutting edge followed by adding additional features such as chamfers, pockets or chip breaker geometries. The cutting edge itself contains a rake and a flank face, the latter providing clearance to the workpiece that is supposed to be machined with the tool. This clearance geometry typically consists of one to three progressive surfaces, each exhibiting a different clearance angle over the entire contour of the tool. These surfaces are often planar in their projection profile but not planar in 3D space. Typical tool accuracies, for instance in the automotive industry, are three to five micrometers with respect to runout and profile form. Tool diameters up to 200 mm and up to 250 mm in length can be processed in our laser machining centers.

Processing of large tools typically requires the removal of large material volumes. In many cases, laser processing cannot match the volume removal rates that can be achieved by conventional technologies such as grinding. This holds true especially for the manufacturing of carbide or high-speed steel tools. If the tools are small, then this disadvantage is quickly transformed into a strength, since, for micro tool dimensions, volume removal is not dominant, however, processing forces and vibrations play a strong role in the ability to process the tool. Therefore, this article concentrates on small and micro tools. These range from Ø = 0.2 mm to Ø = 10 mm. Some sample geometries are shown in Fig. 1.

Laser processing using ultra-short laser pulses is especially well suited for metallic based tool materials due to their cold ablation characteristics, which lead to good coatability of the tool.

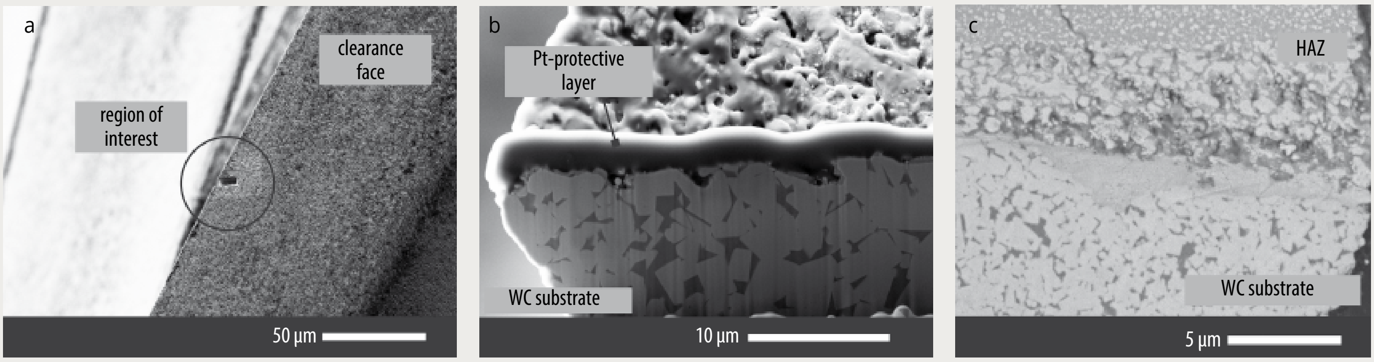

Fig. 2 Analysis of the HAZ after ultra-short laser processing by FIB cross-sections [1]: overview of FIB region of interest at an uncoated micro cutting tool cutting edge (a), magnified cross-section of FIB region of interest from Fig. 2a showing no observable HAZ (b), typical magnified cross-section of tungsten carbide showing an observable HAZ when using improper laser irradiation conditions (c); sources: Institute of machine tools and manufacturing, ETH Zurich)

Material choice in tools and optimization of carbide tools by coating

Most tools are fabricated from metallic based materials such as tungsten carbide or HSS (high-speed steel) due to their ease of machinability by grinding. To improve upon their mechanical, thermal and chemical properties, metallic-based tools are almost always coated single or multilayer by chemical vapor deposition or physical vapor deposition (CVD or PVD). With the advent of erosion in the last decades, polycrystalline diamond (PCD) could also be processed. However, since neither grinding nor erosion can process the diamond grain directly, coarse diamond grains, CVD-D (chemical vapor deposition diamond) monocrystalline diamond (MCD) cannot be processed.

Here, laser manufacturing using ultrashort pulses is a highly suitable alternative. It is able to cut the diamond grain into any desired shape and does not encounter mechanical limitations or residual thermal problems. By being independent of a material's mechanical properties, ultrashort laser pulses can extend the product portfolio of tooling manufacturers by being able to process any type of ultrahard material from PCD of all grain sizes, CVD-D, MCD or even ceramics. For this reason, there is a growing trend by the automotive, aerospace and electronics industries to

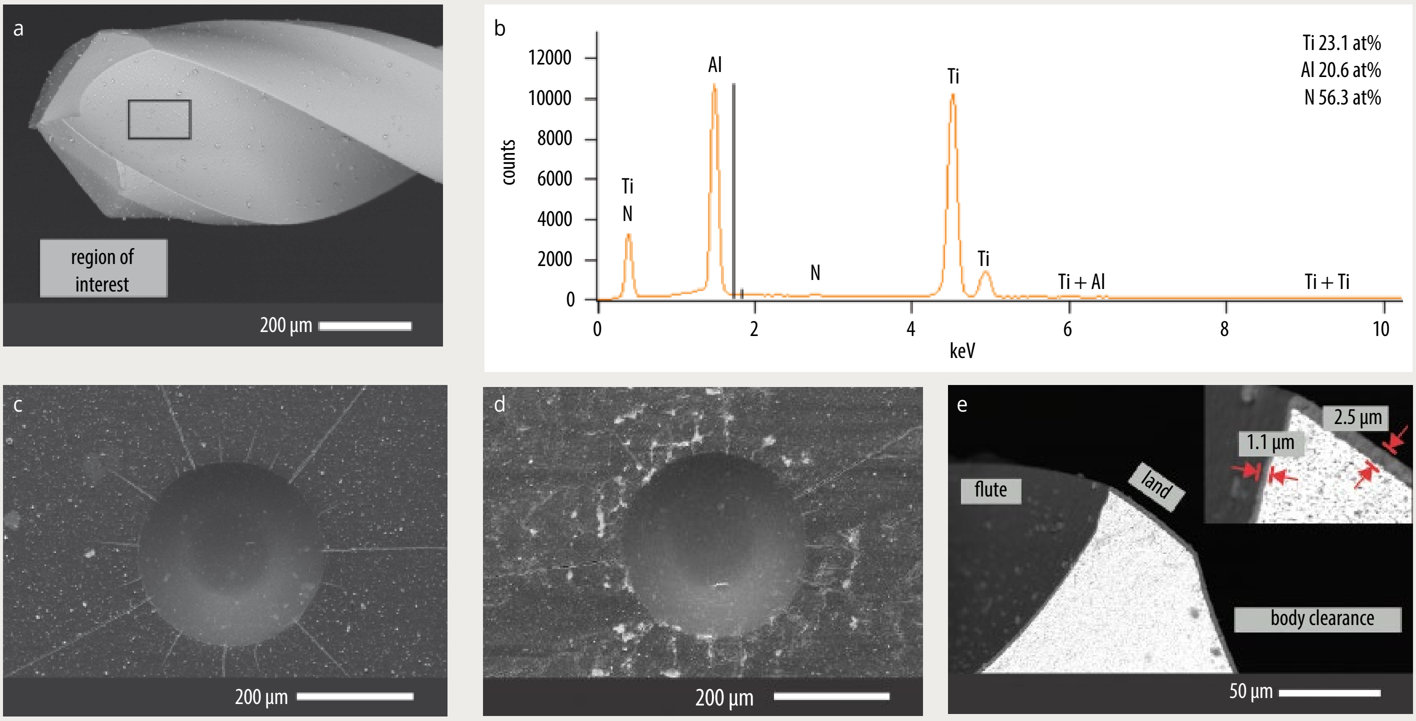

Fig. 3 Summary of results used to investigate the coatability of lasered tungsten carbide tools: SEM image of a drill bit after TiAlN coating [2] (a) EDX area scan of helix flute indicated in Fig. 3a [2] (b) hardness indentation test on an AlTiN-coated lasered surface given optimized irradiation conditions [1] (c) hardness indentation test on an AlTiN-coated lasered surface given improper irradiation conditions [1] (d) cross-section and magnified outset of an TiAlN-coated drill bit following destructive break tests [3] (e) sources (a), (b), (e): Platit AG (www.platit.com); sources (c), (d): Institute of machine tools and manufacturing, ETH Zurich)

implement ultrahard cutting tools into their machining processes.

Nevertheless, due to the cost of ultrahard materials and their processing, the majority of cutting tools are still metallic based. Ultrashort laser pulses can still play a role by either re-sharpening the already coated tool by eliminating edge rounding caused by the coating thickness, or by fabricating the tool itself in such a way that it is suitable for coating. The latter shall be discussed in greater detail. A study was carried out in which Ø < 0.5 mm micro cutting tools were manufactured from solid cylindrical tungsten carbide blanks. In the first step, the laser-fabricated tools were analyzed for the presence of a heat-affected zone (HAZ) by observing cross-sections made by a focused-ion beam (FIB). A summary of these results is shown in Fig. 2.

Fig. 2a shows the region of interest where the FIB cross-section is generated. This is the circumferential clearance face of a micro end mill. Fig. 2b shows this FIB cross-section at a significantly higher magnification and it can be observed that by using ultrashort laser pulses, an HAZ between the tungsten carbide substrate and the platinum FIB protective layer cannot be distinguished. Fig. 2c serves as an example of what a typical cross-section would look like given the presence of an HAZ. In this case, defects in the form of cobalt binder migration, gas entrapment, cracking and evidence of melting would be observed. This typically occurs when using short or long laser pulses, or improper processing strategies.

Given promising FIB results, a second step was carried out in which the laser-fabricated tools were subsequently coated by a single layer of either titanium aluminum nitride (TiAlN) or aluminum titanium nitride (AlTiN) by the PVD coating process. After coating, a number of techniques were used to analyze adhesion, including visual inspection by scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDX), hardness indentation tests and destructive break tests. The results are summarized in Fig. 3.

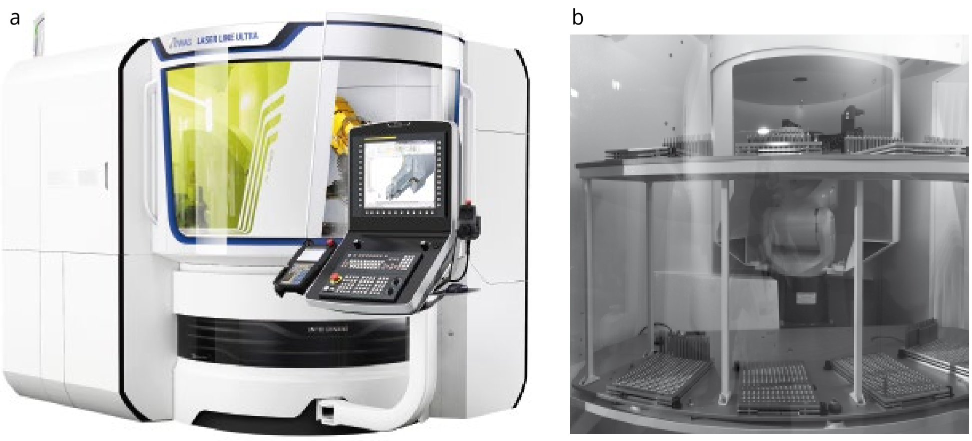

Fig. 4 The EWAG LASER LINE ULTRA machine is an ideal base for highly accurate tool machining, with an integrated automation cell that can be configured as a tool blank storage unit (a). Tool storage within the machine, housing eight pallets: six pallets are used for blank storage of Ø = 0.5 – 3 mm blanks and two pallets are used for finished tools (b);
sources: Ewag AG)

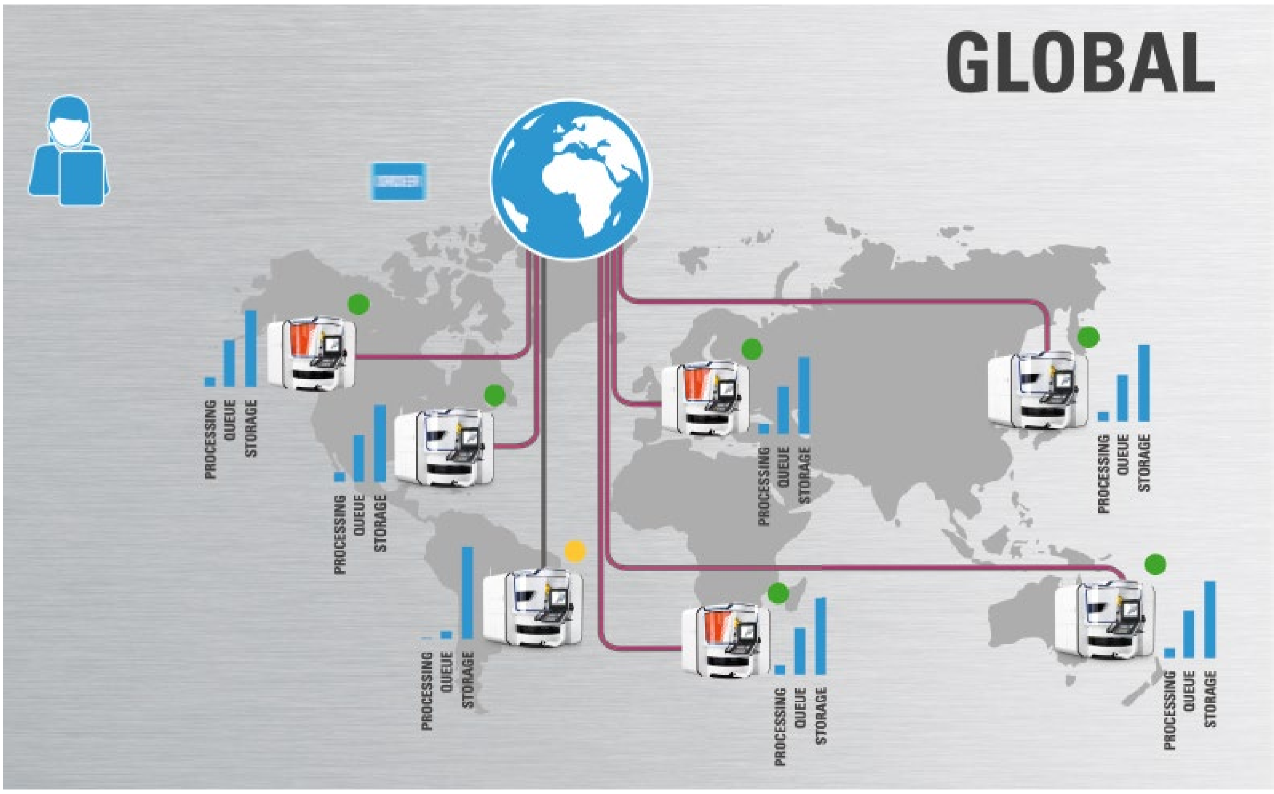

Fig. 5 Autonomous manufacturing example. Each EWAG LASER LINE machine has access to its built-in tool blank storage space. Once a customer uploads an order to the server, the closest available machine will produce the tool. (Source: Ewag AG)

Following coating, acceptable coating adhesion can be ascertained when inspecting Fig. 3a. The cutting edges are coated uniformly and there is no local flaking of the coating. The droplets that are clearly visible are normal and are a typical feature of the standard arc PVD coating process. An EDX area scan was carried out for the region of interest illustrated in Fig. 3a.

Fig. 3b shows the spectrum of this EDX scan in which expected results of a 50:50 Ti/Al ratio for a TiAlN-alloy coating was achieved. Fig. 3c depicts a coated lasered surface in which radially propagating cracks can be observed after a hardness indentation test. This is expected and arises because there is a residual stress mismatch between the lasered surface and the coating. For this reason, cracking will result after the indentation as a measure to relieve the stresses. This impression behavior is comparable to a coated ground surface indicating good coating adhesion. When using improper laser irradiation conditions, both cracking and flaking (coating delamination) can be clearly observed in Fig. 3d. Through excessive heat input, several phenomena such as material transformations and severe cobalt leeching will cause poor coating adhesion. The final analysis involves mechanically breaking a coated sample, in this case a drill bit, and the cross-section is observed as shown in Fig. 3e. This image reveals good coating coverage for all features of the carbide drill bit without any observable defects. Upon closer inspection, the coating thickness of the land is double that of the flute, which is expected. This is a typical behavior of the PVD process due to shadowing of the sputtered ions during coating.

Autonomous manufacturing using ultrashort pulsed lasers

There is a strong trend towards automation and in reducing headcounts in production environments. Conventional machining technologies such as grinding, milling, turning, etc. depend on tools that suffer wear through mechanical interaction with the workpiece. Very often, additional coolant or other liquids are also necessary for the process to work. Auxillary systems and wear are eliminated by the use of laser technology, and the beam alone is responsible for the manufacturing process. The EWAG LASER LINE Series machine operates with a kinematik layout of five mechanical and three optical axes. The machine is depicted in Fig. 4. In addition, an integrated automation cell enables the machine to host an internal storage compartment for tool blanks.

Typical tool geometries, such as drills or end mills, are developed in terms of laser processing using a parametric model. Within this model, only tool geometry information is needed and the automatic process calculation is carried out by EWAG LaserSoft software. The automation cell is configured into a defined layout of blank storage pallets, providing different blank diameters and finish tool pallets for finished products. In a first autonomous production study [4], such configured machines are connected to a customer web shop, within which the customer can define and order the desired tool based on the parametric tool calculation. After the customer confirms the order, the job is sent to a cloud service. This evaluates the job with respect to machine availability and sends out a request to the machine park. As soon as a machine is available and has a suitable cylindrical blank available (made out of tungsten carbide or brazed with PCD), the job is automatically drafted and is produced directly without human interaction. This scenario requires multiple machines being introduced to the tool producer's machine shop. The virtual shop can also span over multiple machine shops worldwide. This is depicted in Fig. 5.

After production, the tool is scrutinized by a suitable measuring machine, e.g. a WALTER HELICHECK series machine, packaged and shipped to the final customer. As soon as the machine finalizes the job, it reverts automatically to its "ready to produce" state and waits for another production job from the server.

By using laser processing techniques, each order can have a lot size of one, and every tool can have varying geometries, for example after a drill, an end mill can be produced. Even tools made of different materials, such as carbide and PCD, can be manufactured without human interaction. The tool storage compartment holds up to 1,800 blank tools if a standard palette is used and up to six diameters are present with a shaft diameter of Ø = 6 mm. In this case, tip diameters from 0.5 mm to 3 mm are used. If a dimension in between is necessary, for example if a tool with Ø = 0.9 mm should be produced, a Ø = 1 mm blank will be picked and automatically laser-turned down to the desired diameter before tool geometry production begins. This approach leads to a high degree of independence from human interaction. We believe this is a highly interesting path into a digital manufacturing world which does not stop at the manufacturing process.

Summary

There are many different tool types used in tool manufacturing, and a large variety of geometrical elements such as cutting edge geometries. Typical tolerance ranges are in the range of a few micrometers for profile form and runout. Conventional machining holds an advantage when a lot of material needs to be removed, especially from metallic materials. If the tool is small (e.g. Ø < 1 mm) however, other aspects such as vibration or process forces on the small tool become more relevant. Laser technology is able to produce highly accurate tools in these small dimensions due to cold ablation when ultrashort laser pulses are used.

In terms of material choice, tungsten carbide and high-speed steel but also ultrahard materials can be laser processed. If metallic substrates are used, these tools are most likely to be coated after production. Investigations through scanning electron microscopy, hardness indentation tests and destructive break tests have shown that laser-processed carbide micro tools can be successfully coated with AlTiN or TiAlN by standard PVD coating methods.

When processing tools by laser only, the laser beam itself is the tool and no additional liquids, coolants or other equipment are necessary. If a laser machining center has a built-in storage space for blanks and if laser processing of the tool is into a solid cylinder, then an autonomous manufacturing environment can be built. The customer of the tool manufacturer orders the desired tool within a web shop. The order is then sent to a cloud service to which each machine is connected. Once a machine is available and the cloud has a machining job, one machine automatically takes the job, manufactures the tool and returns the final tool to the storage unit.

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Analyzing the Dynamics of the Laser Beam Cutting Process

An explanation of characteristic frequencies of melt film dynamics

Dennis Arntz-Schroeder and Dirk Petring

Source: Fh. ILT

Instabilities of the melt flow dynamics at the laser cutting front lead to quality losses, due to the formation of striations at the resulting cut flank. The application of high-speed video diagnosis has turned out to be very instructive for a well-founded process analysis. In this way, it was found out for the first time that the melt film dynamics at the cutting front reveal characteristic frequencies that are nearly independent of process parameters. Interestingly, their local appearance correlates with the area of lowest roughness on the resulting cut flanks. This observation suggests the amplification of the characteristic frequencies in order to obtain a reduced roughness over the complete cut depth. Comprehensible rules for optimized laser beam and gas flow parameters can be determined based on the physical understanding of the origin of the characteristic frequencies.

High-performance laser cutting systems for macro processing are mainly equipped with CO_2 and fiber or disk lasers. The achievable cutting quality is constantly being improved, but the achievable cutting quality in thick sheet cutting with fiber or disk lasers is still significantly lower than with CO_2 lasers. Instabilities of the laser cutting front lead to quality losses in the form of striations on the resulting cut flank and can even lead to burr formation. Only individual aspects of mechanisms of striation generation during laser cutting are understood. In recent years, Hirano and Fabbro [1], Ermolaev et al. [2] and Pocorni et al. [3] have pushed important work on in-situ high-speed visualization of the melting and solidification dynamics during the cutting process. Hirano and Fabbro were able to observe the formation of melting plateaus, which they describe as „humps“, in the upper area of wide kerfs (width >1.7 mm) at low assist gas pressures ($p = 2.5$ bar). They used 3 mm thick stainless-steel samples and determined a melt flow velocity of ≈3.2 m/s and a hump velocity of ≈0.2 m/s. For 6 mm thick stainless-steel samples, Ermolaev et al. reported velocities of melt transport along narrow tracks of up to 10 m/s. Pocorni et al. describe

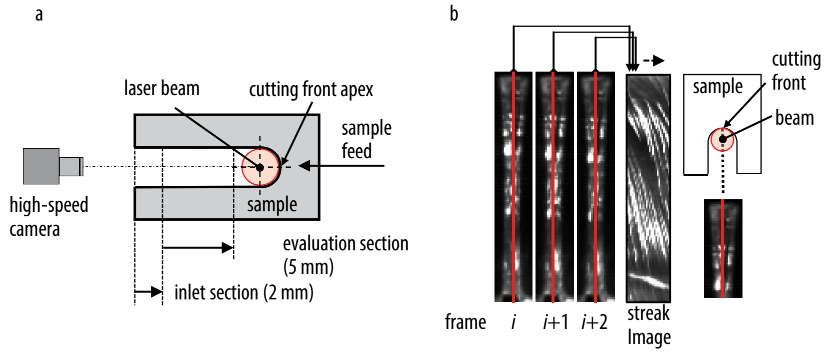

Fig. 1 Principle of in-situ diagnosis setup for incisions (a); principle of streak image procedure (b). (Source: Fh. ILT)

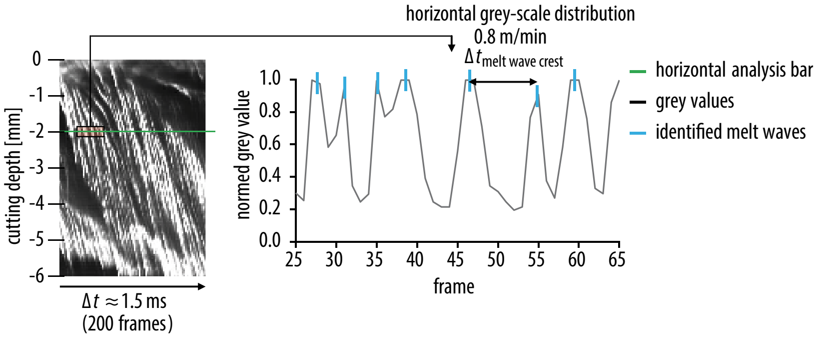

Fig. 2 Principle of cutting depth-dependent melt wave identification procedure for a cutting depth of 2 mm and a selection of 40 frames. (Source: Fh. ILT)

velocities of melt accumulations, which they called "bumps", with an average velocity of ≈0.4 m/s and an average melt flow velocity of ≈1.1 m/s for 10 mm thick stainless-steel samples. By using in-situ high-speed recordings and an advanced algorithm [4] we were able to quantitatively evaluate the melt flow dynamics and velocity distribution of melt waves on the cutting front apex superposing the melt accumulations. With this method it could be shown that a dominant amount of the melt waves reaches velocities of ≈15 m/s. The findings revealed that a stable melt film with fast melt waves is beneficial to achieve good cut flank quality with low surface roughness.

Beside this, further evaluations regarding characteristic temporal and spatial variables of the cutting process and their dependences are necessary. The main objective of this work is to investigate and correlate the frequencies of melt waves sliding down along the cutting front apex with the striation pattern on the resulting cut flank for a variation of cutting velocity, focus position as well as assist gas pressure.

Experimental setup and evaluation method

The experiments were carried out using a 12 kW disk laser (Trumpf, TruDisk 12002) with a wavelength of 1030 nm at an output power of 5 kW. A Precitec HP SSL cutting head was used and the fiber (Ø 200 µm) guided laser beam was collimated and focused with focal lengths of 100 mm and 250 mm, respectively. This configuration provides a focal diameter of 500 µm. A conical-cylindrical nozzle with a diameter of 5 mm was mounted and a stand-off distance of 0.7 mm was adjusted. Different combinations of focus position (z), cutting velocity (v), and nitrogen assist gas pressure (p) were used to cut 6 mm thick stainless-steel samples.

In order to visualize and analyse the melt flow dynamics at the cutting front apex, incisions were made, and the direction of observation was aligned through the evolving cut kerf (Fig. 1a). The region of interest of the high-speed camera (Photron SA 5) was set to 64 × 376 px, to facilitate a recording frame rate of 140,000 fps. By using a Nikon 200 mm macro lens a spatial resolution of 20 µm/px was enabled. To eliminate artefacts from the start of the cut and to ensure a sufficient statistical evaluation of the velocity distribution, the evaluation start was placed 2 mm behind the start of the cut and a cutting section of 5 mm was used for each evaluation. (Fig. 1a)

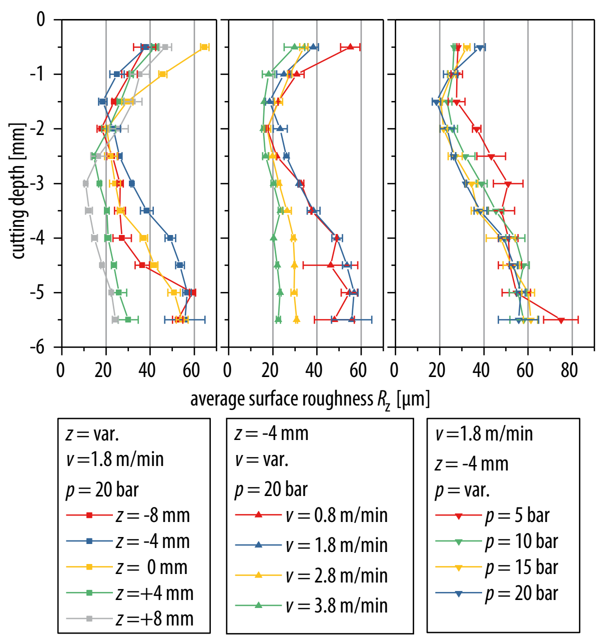

Fig. 3 Average surface roughness measurements for different focus positions z (left), cutting velocities v (middle), and assist gas pressures p (right). (Source: Fh. ILT)

To evaluate the melt flow dynamics, an algorithm was developed to detect the occurring brightly shining melt wave crests on the cutting front out of the high-speed video-recordings. Streak images were generated (Fig. 1b) and a "Peak-Finder" programmed by S. Bergman [5] was adapted to analyze the horizontal (temporal) distribution of the gray-scale values from streak images in each cutting depth. To do this, horizontal analysis bars were placed in each single horizontal pixel line of the streak image (Fig. 2).

The dynamics of the peaks and thus the melt wave crests was assigned to the temporal development of the process and the cutting depth. To consider different lengths of process durations due to the different cutting velocities, the number of melt wave crests was normalized over time. By knowing the time-dependent location of each melt crest, a cutting depth-dependent analysis of the temporal distance between the melt wave crests ($\Delta t_{\text{melt wave crest}}$) or the frequencies of the melt waves ($f_{mw} = 1/t_{\text{melt wave crest}}$) becomes possible (cf. Fig. 4).

Surface roughness

An increase of the cutting velocity (v) while maintaining focus position and assist gas pressure leads to an overall reduction in the surface roughness, whereby the reduction varies greatly versus cutting depth (Fig. 3, middle). The lowest average surface roughness ($R_z \approx 20$ µm) and the lowest dependence on cutting velocity is achieved around 1/3 to 1/2 of the cutting depth. At larger cutting depths, the average surface roughness increases for all four examined cutting velocities. The analysis of the roughness depth with variation of focus position and assist gas pressure leads to a similar profile over the cutting depth (Fig. 3a and 3c). From the top edge of the sheet, the average surface roughness decreases up to the first third to half of the sample thickness and increases to the bottom edge of the sheet. The course of the surface roughness over the cutting depth is roughly S-shaped for all investigated cutting parameters (Fig. 3).

Melt wave frequencies

In order to discuss the frequencies of the melt waves sliding downwards at the cutting front apex, the rate of occurrence over different cutting depths was plotted for all investigated cutting

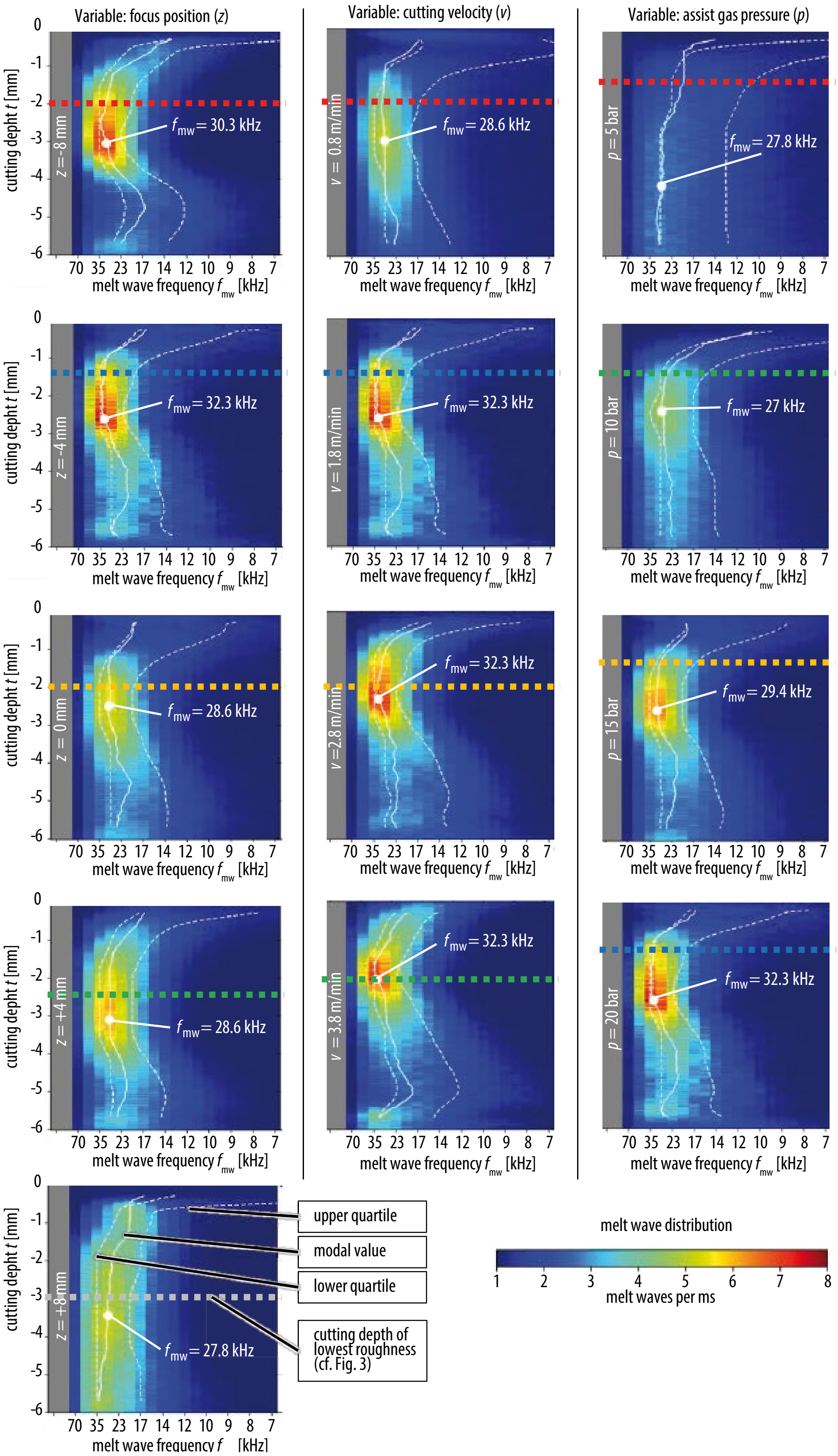

Fig. 4 Cutting depth-dependent analysis of the melt wave frequencies (f_{mw}) for different cutting parameters. (Source: Fh. ILT)

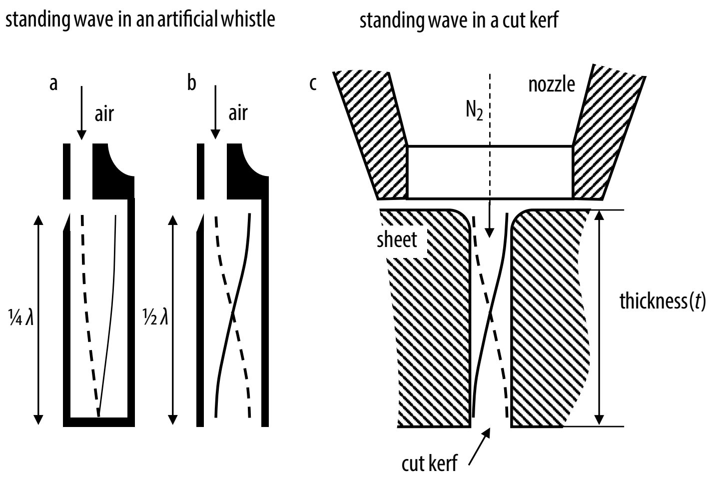

Fig. 5 Principle of a longitudinal oscillation i.e. standing wave of an air or gas column in a closed (a) or open artificial whistle (b) and a cut kerf (c). (Source: Fh. ILT)

parameters (Fig. 4). In addition to the distribution, the cutting depth-dependent modal value, lower and upper quartile and the global maximum of occurring frequencies are marked.

For all investigated cutting parameters, characteristic frequency distributions of the cutting depth-dependent time distance of the melt waves can be identified (Fig. 4). The modal values (Fig. 4; white line) plotted over the cutting depth show a relatively similar S-shaped profile from the top to the bottom of the sheet for all investigated cutting parameters. From the kerf entry to a cutting depth of 1/3 to 1/2 of the cutting depth, the modal value of the temporal melting wave frequency is increased to the highest values of 27 – 33 kHz with only minor exceptions. The frequency then decreases slightly to about 2/3 of the cutting depth and partly increases again until the kerf exit is reached.

Since the highest temporal melt wave frequency and the smallest surface roughness of the cut flank can be determined in a cutting depth of approximately 1/3 to 1/2 of the cutting depth, a small temporal melt wave distance seems to be beneficial for a reduction of the surface roughness. This is in accordance with the earlier observation that fast melt waves are beneficial to achieve smooth cut flanks [4].

Explanation and utilization of characteristic melt wave dynamics

It is interesting that the cutting depth-dependent analysis of the melt wave frequency i.e. the temporal distance between the melt waves only reveals a low dependence on the process parameters. Apparently, the frequencies of 27 – 33 kHz, which correspond to a time interval of the melt waves between 30 – 35 µs, are characteristic for the investigated process parameter field.

Our explanation approach is based on the longitudinal oscillation of the air or gas column in the cutting kerf (Fig. 5c). The principle can be explained by means of artificial whistles. In artificial whistles a sound is basically produced by splitting an air stream through a sharp edge or similar obstacle (Fig. 5a, b). In this way, vortices are created which, in interaction with a resonance chamber, produce a sound wave and thus a tone of corresponding frequency. The frequency depends on the length and shape of the resonance chamber, the property of whether the ends are closed or open and the sound velocity in the air or gas column.

For a resonance chamber open on both sides the n-th harmonic frequency is well known to be

$$f_n = n \cdot c_{N_2}/(2 \cdot t) \qquad (1)$$

By specifying the sheet thickness ($t = 6$ mm) and the sound velocity of nitrogen at room temperature ($c_{N_2} = 333.6$ m/s) the fundamental frequency or first harmonic ($n = 1$) is $f_1 = 27.8$ kHz. This frequency is a very good approximation of the experimentally determined characteristic frequencies.

We hypothesize that as a consequence of the whistle approach described above, a resonant melt wave formation can be induced on the melt film. As a result, the frictional forces of the gas flow on the melt film are locally increased and the melt transport is improved, resulting in a locally reduced roughness depth.

This physical understanding reveals a promising approach to increase the quality of the cut flanks. We assume that by modulating process parameters with the resonance frequency explicitly described by Eq. 1, it is possible to stimulate this whistle effect. In this manner, a resonant melt wave formation with a high efficiency shall be induced, which in turn significantly stabilizes the friction forces on the melt over the entire sheet thickness.

The temporal modulation of laser beam parameters, such as beam power and power density distribution, as well as spatial beam oscillation, are self-evident methods to stimulate the acoustic resonance. Another possibility is to generate a gas flow already oscillating at the resonance frequency above the kerf. For this purpose, a special design of a resonance chamber in the nozzle geometry with a length adapted to the thickness of the sheet to be cut is conceivable.

Institute

Fraunhofer Institute for Laser Technology ILT

With more than 540 employees and more than 19,500 m² net floor space, the Fraunhofer Institute for Laser Technology ILT is one of the most important contracting research and development institutes of its sector worldwide. Its experts develop and optimize laser beam sources and laser processes. In close cooperation with its clients, it uses laser technology to solve tasks for production, measurement technology, environment, energy, medical technology and biotechnology.

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Conclusion and further outlook

The presented approach for the analysis of frequencies of melt waves sliding down on the cutting front apex and the physical interpretation of the results allows the following statements:

- A small temporal melt wave distance or a high melt wave frequency is beneficial for a low surface roughness.
- Characteristic melt wave frequencies of 27 – 33 kHz can be found for the investigated process parameter field.
- The characteristic frequencies can be explained by the resonant frequency of the oscillating gas column in the cut kerf as a function of sheet thickness and the velocity of sound according to the principle of artificial whistles.
- It is assumed that the resonant wave frequency of the gas column is transmitted to the melt film and thus leads to a low roughness of the resulting cut flanks.

The results provide a new basis for the development of optimization strategies for the reduction of the cut flank roughness depth. We assume that by modulating process parameters with the process inherent resonant frequency, the generation of the smoothest possible cut flanks and thus an efficient ejection of the melt from the kerf is possible.

*

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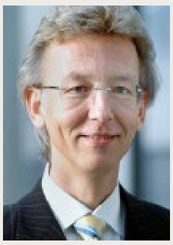

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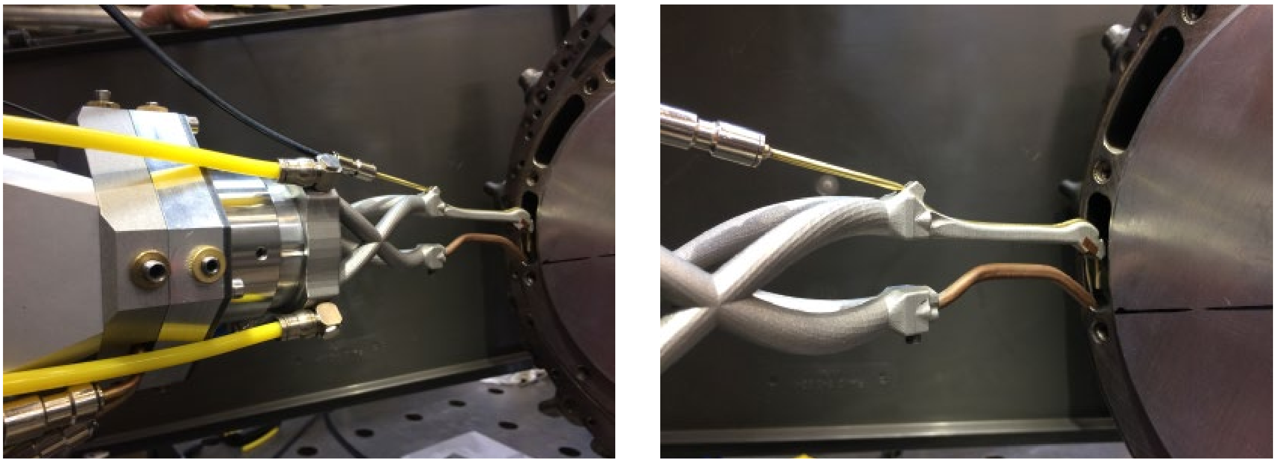

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New Developments for the Repair of Structural Engine Components with Laser Material Deposition

In-situ repair by combining LMD and endoscopic devices

Bernd Müller

Driven by today's typical "power by the hour" type aftermarket support contracts (e.g. Corporate Care and Total Care) the demands for continuous operation of aircraft engines have increased significantly. For this reason, any disruption caused by heavy maintenance needs to be avoided. Where needed, repair operations should be as time, cost and material efficient as possible. However, service disruptions will still occur and wherever possible, the resulting maintenance intervention activities should take place either "on-wing" or "near-wing". Consequently, it is the intention of Rolls-Royce to introduce more and more in-situ and minimal invasive maintenance capabilities, such as endoscopic laser material deposition (LMD), for the repair of structural engine components.

This article describes the challenges of the minimal invasive LMD process inside cavities and the continued development requirements over and above today's state-of-the-art repair capability. It also provides further insight concerning the ongoing development of equipment that combines viewing and LMD capability and an outlook on the application of the developed technology.

Due to their very nature, engine components will be exposed to severe operating conditions within the engine and as a result will suffer and deteriorate from environmental influences like foreign object damage (FOD), erosion or fatigue. Structural components are specifically designed in a way that enables them to survive throughout the complete lifecycle of an engine. This comes at a cost and is directly reflected within the high retail prices of such parts. Any additional required maintenance activity directly influences the lifecycle cost strategy and therefore any such activity is prevented where possible or reduced to an absolute minimum. A total focus is therefore necessary to ensure the maintenance repair & overhaul (MRO) processes are as lean as possible.

The part concerned for the development described in this article is a rear bearing support structure shown in Fig. 5. The part is manufactured from a complex precision casting, which pushed the boundaries of existing technologies to their limit. In the case described, multiple locations inside a cavity were chosen to demonstrate the general feasibility of a material build-up. Several techniques were considered and possible concepts like laser material deposition using an inside cladding system (ICS) were evaluated.

Currently available ICSs cannot be applied as suitable access is required – i.e. it is not useable in confined spaces or small crevices and further complicated by the inability to accurately monitor the process. With the aforementioned in mind, a technology and repair develop-


Fig. 1 Cavity

ment project was initiated in close collaboration with the Fraunhofer Institute for Laser Technology ILT to develop and set up a suitable technique and capability to address this challenge.

Development for endoscopic LMD repair – the basics

Laser material deposition can be classified as cladding (DIN 8580) of a component by the process of welding. The process enables the application of functional layers to components of various kinds, as well as the generation of components using wire and powder filler materials. However, only processes in which powder filler materials are used will be described further within the article. The layers applied have both wear-resistant and corrosion-resistant properties. In the process of laser material deposition welding, a powdery filler material is introduced through a powder nozzle into the melt pool induced by a laser beam on the surface of the component. The filler material is melted, and a layer is generated on the workpiece surface by the continuous relative movement between the component and the laser beam [1].

The currently available inside cladding systems are used, for example, in the off-shore sector or for toolings to apply corrosion and wear resistant layers during manufacture or repair. The application is limited to cylindrical parts with a diameter of at least 25 mm [2].

Equipment development

Depending on the location of the area for the material build-up, specially-tailored endoscopic LMD equipment needs to be designed, manufactured, assembled and tested to fulfill the requirements for the repair development described above. The repair area of the rear bearing support structure at a separation wall is inside a cavity (Fig. 1) and access can be gained through a kidney-shaped orifice with a width of approximately 10 mm and a depth of 70 mm.

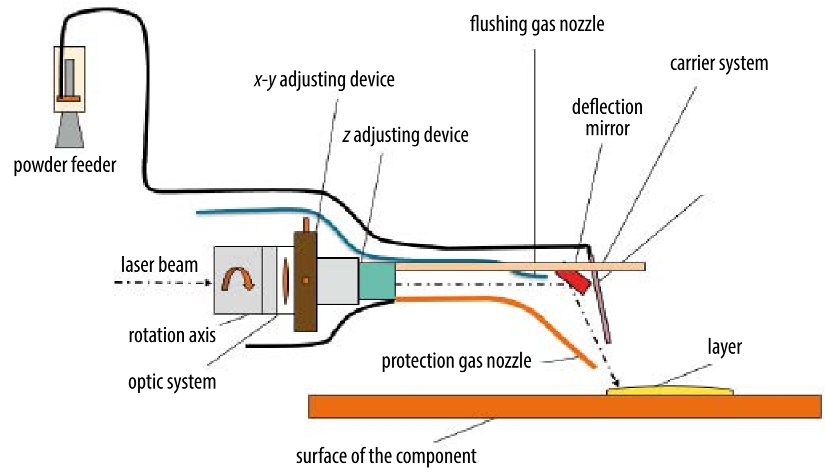


Fig. 2 Conceptional design of the endoscopic LMD equipment.

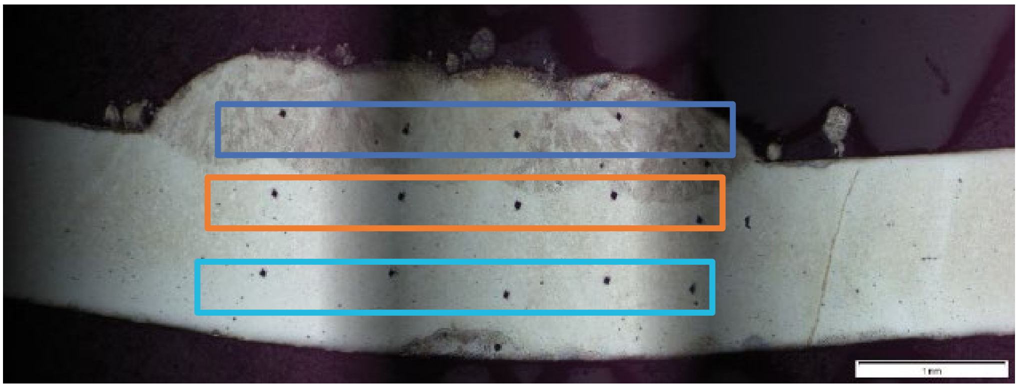


Fig. 3 Cross section of weld trial

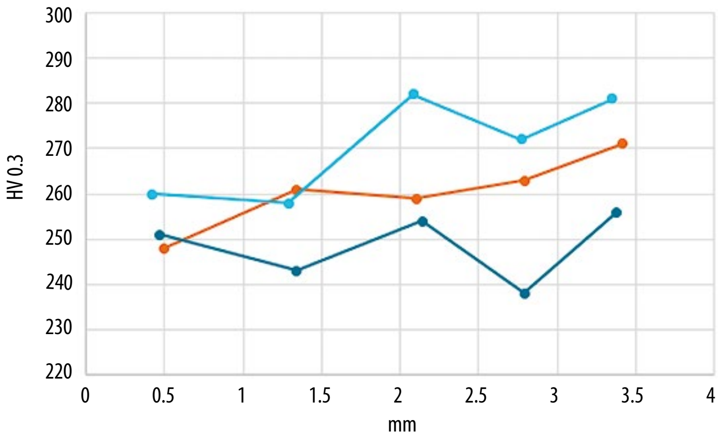


Fig. 4 Hardness profile in HV

The initial design concept is shown in Fig. 2. The equipment needs to be designed in a manner that, by tipping it, it is then possible to increase the width of the repair area in the given environment. Therefore, a carrier system is mounted on an adjustment unit that allows positioning in the *x*, *y*, and *z* planes. The rotation axis describes the interface to the robot. The endoscopic carrier system holds a deflection mirror which guides the laser beam to the surface of the component to be repaired and where the powder nozzle injects the powder into the created melt pool. Due to the high energy density on the optical components, the deflection mirror has an integrated direct water cooling system. And because of the short distance from the deflection mirror to the melt pool, a flushing gas nozzle is also integrated to prevent the deflection mirror from strayed powder particles. An additional protection gas nozzle is connected to the *x*-*y*-*z* adjusting device to protect the repair area from the surrounding atmosphere. The whole system has a length of 120 mm, a height of 30 mm and a width of 7 mm. The powder nozzle itself is made from copper and the powder canal has a specially polished surface to minimize the divergence angle of the powder gas stream. The powder efficiency can be optimized through a powder gas stream with a minimized divergent angle, and with a minimized amount of straying powder particles, which is necessary to achieve a stable and reliable deposition process. In a later stage of the development, the carrier system was manufactured using laser powder bed fusion (LPBF) as shown in the title image.

Process development

The two challenges which needed to be addressed during the development stages of the process were on one hand the dimensions of the area intended for the material deposition and the base material thickness. On the other hand the need to avoid powder accumulation from taking place within the cavity to ensure a sound weld metallurgical bonding takes place whilst avoiding sintering of powder to the parts surface.

The first process trials focused on the base material thickness, which is in the range of 0.5 mm to 1 mm. The parameters were adjusted to achieve sufficient melting of the base material while avoiding a complete weld through which would later lead to damage of the component. During the first trials

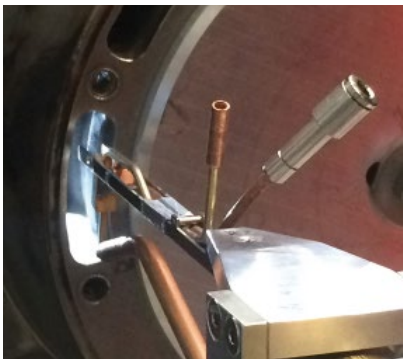
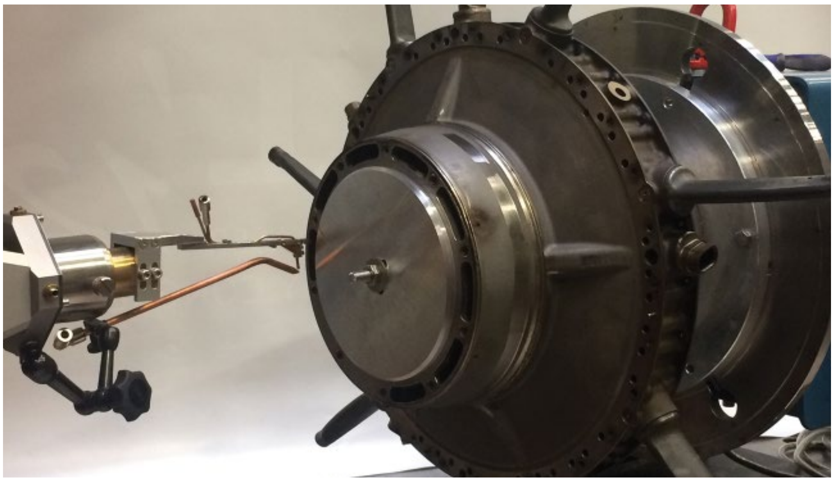


Fig. 5 Test repair set up



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it was obvious that, in the time between switching the laser on and off before and after each layer of applied material, powder had accumulated on the component surface. For a later application inside a cavity this would have an adverse effect on the weld and therefore needed to be avoided. For that reason, the laboratory setup was amended and a rapid powder switch introduced to ensure that powder is only fed while the laser is switched on.

A cross-section of one of the first trials is shown in Fig. 3. It is obvious that a sound metallurgical bond without pores, cracks, joint defects or lack of fusion was achieved.

The hardness profile (Fig. 4) shows a reasonable and acceptable distribution of hardness in the applied Inconel 718 filler (dark blue) the mixed zone (orange) and the Inconel 718 base material (light blue).

Application

After the initial trial phase, the equipment was brought into test using a repair part to demonstrate the capability of the equipment and the process.

The first application showed that the defined repair areas are reachable with the endoscopic device, with good positioning via the embedded viewing capability. The endoscopic equipment and process function in a manner that a material build up according to the defined scope of performance is possible.

Forecast

The development work showed the feasibility of repairing structural engine components using powder-based endoscopic LMD. Usage as in-situ technology for the repair of components in an assembled or sub-assembled condition is under consideration for multiple applications in future developments.

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Efficient and High-Brightness Broad Area Laser Diodes Designed for High-Temperature Operation

Advantages of semiconductor laser diodes as efficient high-power laser light sources applicable at elevated ambient temperatures

Ralf Hülsewede and Martin Zorn

Semiconductor laser diodes, manufactured as single emitters or laser bars, are highly desired light sources for direct material processing as well as optical pumping of fiber and solid-state lasers. Laser diodes feature high optical output power and efficiency, long lifetimes, low maintenance and consequently low cost of ownership. To improve the usability and extend the application spectrum of high-power laser diodes, relaxed cooling requirements – without compromise in laser performance and lifetime – are required. Therefore, great development efforts are made, both in externally and internally funded research projects, to push the maximum permissible operating temperature of such semiconductor laser diodes to higher levels.

Global market surveys expect an increase in the application of semiconductor laser diodes used as pump sources for fiber and solid-state lasers, as well as high-power applications such as material processing and diode direct applications within the next couple of years.

Pumping of fiber lasers in low-cost pump modules is realized using single emitter laser diodes, while laser bars (i.e. arrays of single emitters) are used for high-power applications. The wavelength range most often applied lies between 900 nm and 1000 nm (often described as the "9xx nm" range).

Several features make diode lasers more advantageous than other types of lasers. They can be pumped and directly modulated electrically which means that no external light source is required. The emission wavelength can be tuned over a wide spectral range with accuracy better than 1 nm by adjusting the material composition of the light-emitting semiconductor material. Another advantage of laser diodes is their high efficiency of converting electrical into optical power. Typical values are above 60 % significantly higher than for most other types of lasers. The diode laser is only about several hundreds of micrometer wide, several millimeters long and around 150 µm thick. Mounted on a heat sink, the typical footprint of the packaged laser does not exceed 2.5 × 2.5 cm^2. The small size makes this kind of laser very flexible and easy to handle. The main purpose of the heat sink is to remove waste heat which is dissipated from the small semiconductor chip during operation. Depending on the output power, a costly active cooling might be necessary. In order to relax cooling requirements imposed on the heat sink, the maximum permissible operating temperature of the laser diode chip itself has to be elevated by virtue of chip design.

The edge emitting laser consists of a stack of semiconductor layers forming a p-n junction with an active region in the middle, which generates the light by converting electric current to photons (Fig. 1a). The active region is embedded in a waveguide within which the generated light propagates. The waveguide is enclosed between cladding layers which confine the light within the waveguide via total internal reflection. The p-n or p-i-n junction is created by an appropriate doping of the different layers to ensure electrical transport of carriers through the structure. The careful design of this layer stack directly determines the optical, electrical and the thermal properties of the final laser diode. Therefore, the first steps to enable high-temperature operation of the laser diode are simulation and design of the semiconductor layer stack with respect to high thermal efficiency.

For laser diodes emitting in the 9xx nm wavelength range, compound semiconductor layers made from gallium, aluminum, indium, and arsenic are deposited by an epitaxial growth process on gallium arsenide substrates (wafers). The wafer is processed using standard technological processes such as lithography, wet or dry etching and metal contact deposition (Fig. 1b). After cleaving the laser device out of the wafer, both ends of the laser resonator, called laser facets, are coated with dielectric layers in order to create a highly reflecting mirror on one end of the resonator

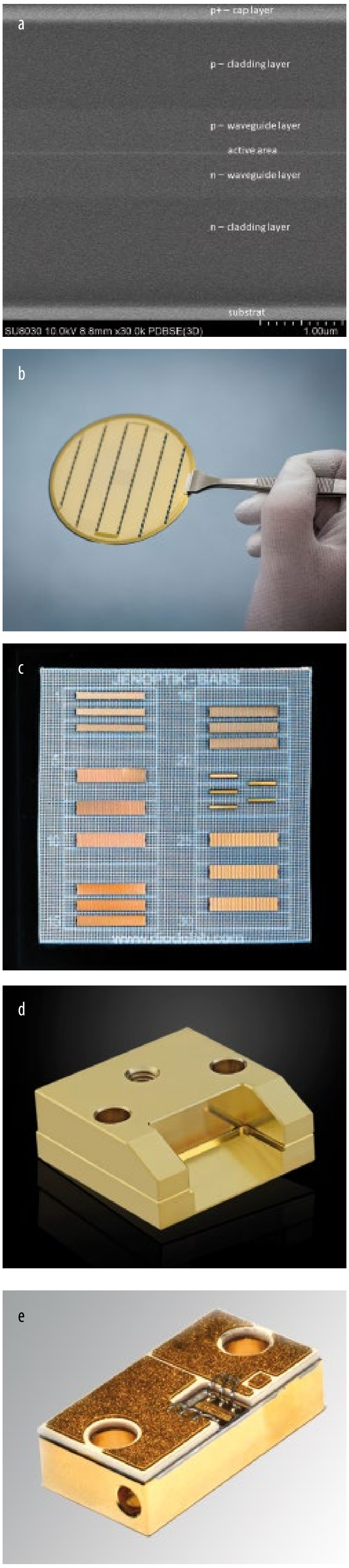

Fig. 1 Laser structure (a), processed wafer (b), unmounted laser bars (c), LK-heat sink for high-power laser bars (d), FH-heat sink for single emitters (e)

and a partially transmitting mirror on the other end. In that way, the generated light inside the laser is coupled out only from one end of the resonator. Since the energy density is very high at the out-coupling facet, additional surface passivation might be necessary to prevent catastrophic optical mirror damage (COMD).

Semiconductor laser diodes are very compact components that can either be fabricated as single emitters or laser bars. In the case of laser bars, several single emitters are monolithically arranged side-by-side to build the output power of the final device (Fig. 1c). In either configuration, the semiconductor chips must be soldered on a specially designed heat sink (Fig. 1d and 1e). The heat sink temperature has to be kept at a level that is determined by the chip design, since the properties of the laser diodes are very temperature sensitive. Removal of waste heat can be achieved either by active or by passive cooling. Active cooling (e.g. by microchannel coolers) is efficient but very elaborate and expensive (e.g. DI-Water cooling systems). Passive cooling is less complex and therefore less expensive since the thermal heat is transferred conductively from a copper heat sink to the system baseplate without any cooling liquid. Passive cooling is preferable to minimize the system costs.To extend the operating temperature regime of single emitter laser diodes or laser bars, the following two approaches for managing waste heat are pursued in combination: A) improved

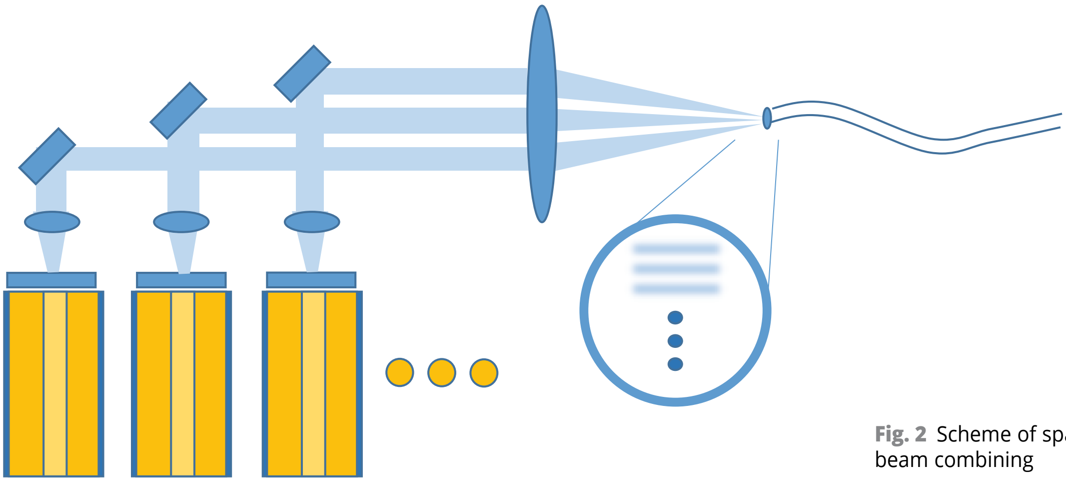

Fig. 2 Scheme of spatial beam combining

thermal stability of the laser diode itself and B) optimized packaging, i.e. heat sink design, heat sink material choice and soldering technique.

Very often, the emitted laser light has to be coupled into an optical fiber. The coupling efficiency is determined by the optical beam properties of the light emitted by the laser diode. One measure of beam quality is the brightness. The brightness of laser beam scales inversely with the beam parameter product (BPP). The BPP is proportional to the product of the beam waist which is typically the aperture size of the emitted beam at the out-coupling facet, and the far field beam divergence angle. Improved beam quality, corresponding to a low BPP at high power level, facilitates efficient coupling into fibers with small core diameters and low numerical aperture. For edge-emitting laser diodes, the beam quality perpendicular to the active area, so-called fast axis direction, is constant over the whole operation range of the laser since it is in its fundamental spatial mode and thus close to diffraction-limited. In contrast, the beam quality parallel to the active area, the so-called slow axis direction, depends on the nominal optical power emitted from the laser and is influenced strongly by the heat dissipation from the active area. These aspects are discussed in the following in detail for single emitters and laser bars where brightness is related to the slow axis direction.

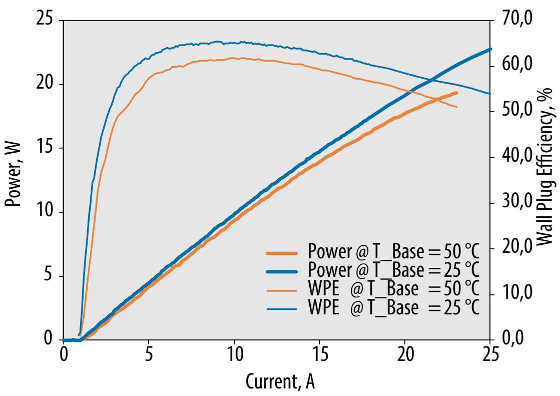

Fig. 3 Power and wall plug efficiency of 915 nm single emitters

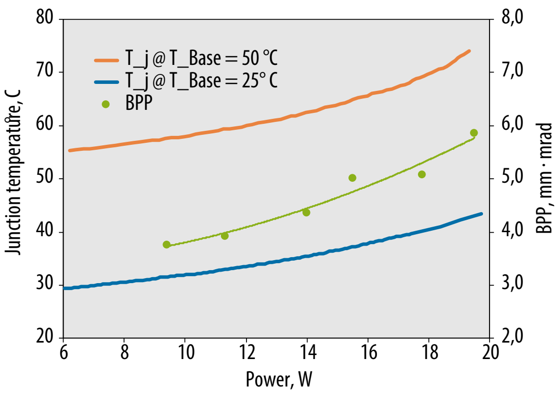

Fig. 4 Junction temperature and BPP of 915 nm single emitters

High-brightness single emitter laser diodes

Single emitters are the preferred light sources in low-cost pump modules, i.e. for fiber laser pumping. In single emitter based pump modules, spatial beam combining of several emitters is used for fiber coupling (Fig. 2). The beam of each emitter passes a set of lenses and mirrors and is focused into a fiber core parallel to other beams to completely fill the core area. For spatial beam coupling into a fiber with a given core diameter and numerical aperture, the maximum coupled optical power is limited by the brightness of the individual laser beams, which is a measure of the focal spot size, the individual beam power and the number of focal spots at the fiber core plane. In the project HotLas (part of BMBF-funded EffiLAS), several German companies and research institutes (Jenoptik Optical Systems, Coherent / Dilas Diodenlaser, Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik , and Weierstraß-Institut für Angewandte Analysis und Stochastik) worked together on the development of high-brightness single emitters for high-temperature operation at a wavelength of 915 nm. Besides 976 nm, 915 nm is a typical wavelength used for fiber laser pumping. The main topics of the project were the development of new semiconductor laser structure and emitter designs for highly efficiency, high-temperature operation at up to 20 W optical output power, enabling high-brightness operation with a BPP of 3.5 mm * mrad. Together with an optimized technique to provide an effective lateral current confinement, the best results were achieved using 6 mm long laser resonators. A maximum power of 19 W at 22 A operation current could be demonstrated at a baseplate temperature T_{base} of 50 °C (Fig. 3).

An optimal operation condition for this laser was found to be 15 W output power at nearly 60 % wall-plug efficiency. The far field divergence and the aperture width were 11° and 100 µm (95 % power content) respectively, leading to a BPP of 4.8 mm · mrad (Fig. 4, right axis) enabling efficient coupling into a 105 µm core diameter, NA < 0.10 fiber. The first test results on single emitters exhibiting mode suppression for higher order lateral modes further suggest that BPP can in principle be reduced from 4.8 mm · mrad down to 3.8 mm · mrad, which is close to the goal of the HotLas project.

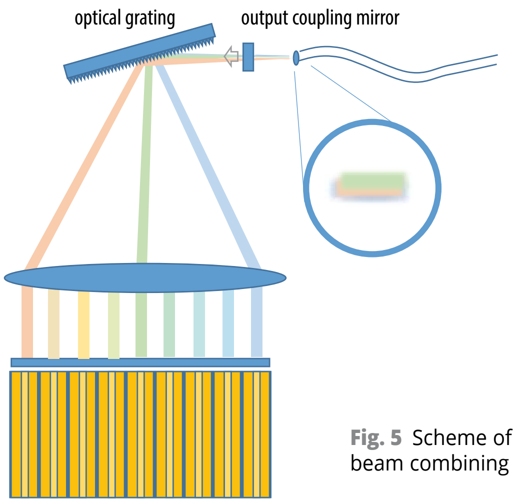

Fig. 5 Scheme of wavelength beam combining

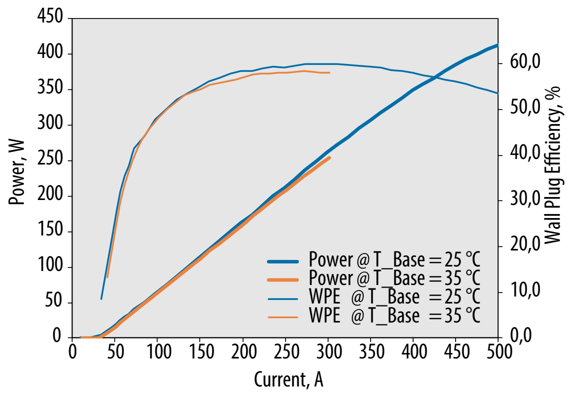

Fig. 6 Power and wall plug efficiency of 980 nm laser bar on LK-heat sink

At 50 °C base plate temperature of the heat sink, the junction temperature (i.e. the temperature of the region where the light is generated) is slightly less than 65 °C (Fig. 4, left axis) at 15 W. From our experience this value suggests reliable operation for medical and industrial applications. Detailed lifetime tests will start in the near future in order to determine median time to failure (MTTF) at this elevated heat sink temperature.

An additional important aspect is the influence of optical feedback due to back-reflected laser light onto the laser facet. An amount of 10 % leads to a strong modulation of the near field intensity distribution with single high energy density peaks at the out-coupling facet leading to COMD. With an optimized laser structure, the sensitivity of the laser diode to back-reflected light could be significantly reduced. There is ongoing work in this field of robust laser structure development to ease the application of laser diodes in high-power laser systems.

High-brightness laser bars

To improve performance and reduce costs per watt, laser diodes are designed as monolithic laser bars. This reduces the packaging and beam combining effort in comparison with single-emitter based laser modules. Laser bars for high-brightness application typically consist of a small ratio of 10 to 20 % between the width of the light emitting area and the distance between neighboring emitters, which is also known as the filling factor. For fiber coupling, one approach is to focus the beam of each emitter separately to the fiber core using beam-shaping optics (equivalent to the scheme in Fig. 2). Wavelength coupling is another approach for coupling multiple beams into a single fiber. For high-power, high-brightness beam combining, an excellent beam shaping scheme is described in [1], where the individual beams of each emitter of the laser bar are combined using an optical grating and an out-coupling mirror in an external cavity configuration (Fig. 5). This leads to a superposition of all beams by self-adjustment of the wavelength of each emitter due to wavelength dependent beam steering by the grating. This wavelength beam combining allows for brightness scaling where the beam quality of each emitter is maintained. Due to close spatial separation of the individual beams, laser bars with high filling factors can be used for high-brightness fiber-coupled laser systems.

For both approaches, i.e. spatial and wavelength beam combining, passive cooling is preferable from a maintenance and cost reduction perspective. Therefore, Jenoptik has developed a new passively cooled heat sink – the LK-heat sink – which enables the construction of highly efficient diode lasers with optical output power up to 300 W, relevant for industrial applications. This is achieved by an optimization of the thermal contact between the semiconductor material and the heat sink in combination with an expanded *p* and *n*-side heat flow to the baseplate of the LK-heat sink, which has the industry-standard CS mount footprint. Due to specialized adhesive layers, operation of the bar remains stable at various temperatures even under hard-pulse operation. Jenoptik laser bars are designed for high-efficiency and high-temperature operation. Mounted on the LK-heat sink they show an optical output power higher than 400 W when the base plate temperature is set at 25 °C (Fig. 6). The laser bar designed for 980 nm wavelength has a 50 % fill factor with 100 µm emitter apertures and a resonator length of 4 mm. A wall plug efficiency above 60 % can be achieved at an operating point of 275 W. At this point of operation, the BPP over all emitters of the complete bar is 3.8 mm * mrad (Fig. 7, right). This enables highly efficient beam coupling for high-brightness beam sources. Even when the base plate temperature is set at 35 °C, the laser bars can be operated up to a power level of 200 W. At this power level, the junction temperature will not exceed 70 °C (Fig. 7, left), so highly reliable operation for industrial applications is assured. By combining more emitters of multiple bars, each operating in a slightly different wavelength regime, multi kW high-power high-brightness direct diode laser systems can be realized.

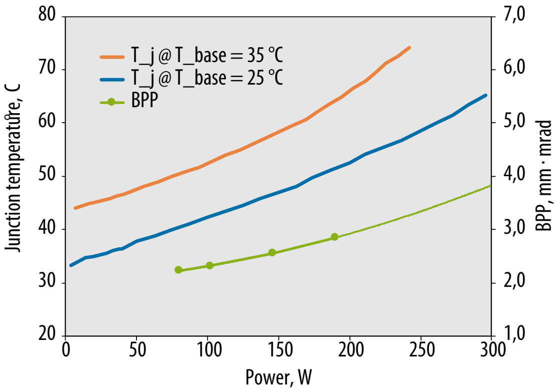

Fig. 7 Junction temperature and BPP of 980 nm laser bar on LK-heat sink

Summarizing, the potential of semiconductor laser diodes is enlarged by new achievements in the thermal management of diode lasers. Optimization of the laser diode itself in combination with new developments in heat sink design lead to single emitters and laser bars with excellent optical beam quality, high output power and acceptable efficiencies even at elevated temperatures.

*

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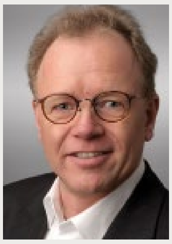

Ralf Hülsewede has significant experience in semiconductor technology with a focus on GaAs-based laser diodes. He studied applied physics at the University of Münster and received his PhD in electrical engineering at University of Duisburg. After working for several years on laser in the field of laser technology at the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH) he joined Jenoptik Optical Systems in 2002. As the head of technology development, he is responsible for the design and process technology of NIR high-power laser diode bars and single emitters.

Martin Zorn has more than 25 years experience in the development of metal-organic vapor phase epitaxy (MOVPE) and epitaxial structures for opto-electronic semiconductor devices. He joined Jenoptik Optical Systems in 2009 after many years with the Ferdinand-Braun-Institut, Leibniz-Institut für Höchstfrequenztechnik (FBH). He studied physics at the Technical University of Berlin where he also received his PhD. He presently is project supervisor for the development of epitaxy and epitaxial structures for semiconductor edge-emitting laser diodes and laser bars as well as for surface-emitting devices.

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A Green Wave for Electric Cars

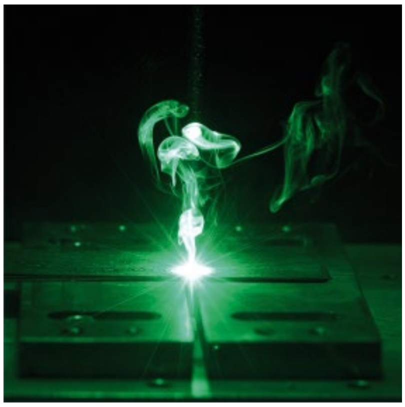
The most important trend in the global automotive industry is electric mobility

Stefanie Bisch and Sebastian Zaske

The automotive industry and suppliers are looking for production standards for the mass manufacture of electric cars. It turns out that green laser light is the ideal welding tool for copper electrical components.

Thanks to technical advances, legal requirements and changes in customer wishes, the electric car has long since freed itself from its niche and is now turning into a real mass product. Manufacturers, suppliers and machine builders are currently looking for processes with which they can produce specific components of electric mobility in high quantities and with reliable quality. Especially with the connecting and welding of copper electrical components to the battery, motor and powertrain, no production technology has yet established itself as the standard. With powerful green laser light, there is now a tool that meets all the requirements of the industry: productivity, safe processes, high welding quality and reproducible results.

The full article will be included in the June / July issue (3/2020) of PhotonicsViews and is already available online at www.photonicsviews.com or through the following DOI: 10.1002/phvs.202000019



Welding copper with a green laser (Source: Trumpf)

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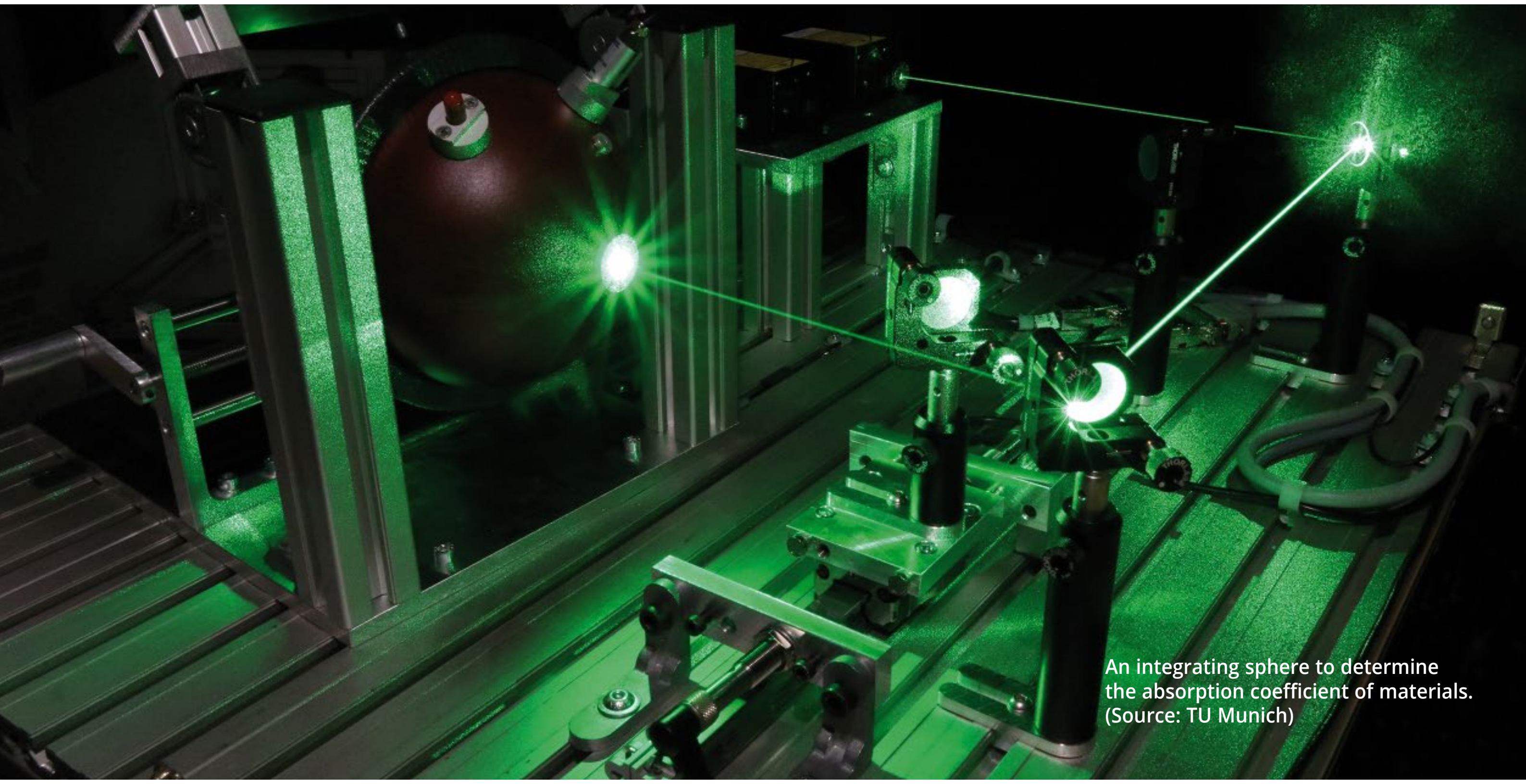
Green High-Power Disk Lasers and Industrial Applications

Innovative beam sources for increased process efficiency during laser beam welding of copper

Lazar Tomcic, Thomas Rettich, and Michael F. Zäh



An integrating sphere to determine the absorption coefficient of materials. (Source: TU Munich)

In the publicly-funded ProLasKu project, the laser manufacturer Trumpf has developed a high-power laser with a wavelength of 515 nm. Substantial progress in the industrial applications of green lasers has been achieved in a co-operation between the Technical University of Munich and the companies Siemens and Continental. In addition, a camera-based system for process monitoring and quality assurance in real-time based on image processing methods has been developed.

High-power lasers for material processing have been widely introduced to the market only in the infrared spectrum at wavelengths above 1000 nm over recent decades. The reasons for the lack of alternative wavelengths in the visible wavelength range are challenges with beam formation. However, current technological developments such as electro-mobility have pushed the photonics industry to further develop their systems to meet the increasingly complex customer requirements. Especially for copper materials, laser processing is a challenging task. Its low absorption of infrared radiation and high thermal conductivity complicate process control and stability.

In contrast, copper materials have a higher absorption of green radiation at 515 nm. This allows more energy to be used for materials processing, thus increasing the overall efficiency. Within the ProLasKu project, a beam source based on second harmonic generation with a maximum output power of 2000 W was built and qualified for industrial use.

Fundamental investigations

The significantly increased absorption of green radiation by copper allows more of the emitted energy to be used for the welding process, thus resulting in higher process efficiency. The extended parameter window enables heat conduction welding. Investigations by the Institute for Machine Tools and Industrial Management (iwb) at the Technical University of Munich showed that weld depths of up to 270 µm with a laser power of 1 kW and a defocused beam are possible through heat conduction mode. The

Fig. 1 Surface comparison when using nitrogen, argon or compressed air (Source: Trumpf)

lack of a vapor capillary results in lower weld pool dynamics and a stable process regime, which consequently enables high surface quality of the seams. In contrast, similar to laser welding with infrared radiation, a vapor capillary forms during the deep penetration welding process. When using an additional high-pressure nozzle on the workpiece, it is possible to blow the vapor plume out of the beam path. Comparisons show that there is a significant influence on the maximum achievable weld depth. It can therefore be assumed that a significant fraction of the laser power is absorbed by the vapor plume [1].

The use of shielding gases for the welding process with the new beam source was investigated using Cu-ETP (electrolytic tough-pitch). For this material, hydrogen-induced cracking occurs during laser welding in a standard atmosphere. The use of inert gases to change the ambient atmosphere is advantageous here. In the Trumpf application laboratory, tests were carried out with two different shielding gases. The beads-on-plate weld seams were examined with regard to surface quality, melt ejections, and pores. It was observed that nitrogen has the best influence on the process. The seam has a smoother surface compared to welding with argon. Discoloration of the material is prevented as well (Fig. 1). Due to the changed atmosphere above the process zone and the removal of ambient air, a reduced pore formation was observed. The analysis of metallographic sections also showed a more constant weld depth when using nitrogen.

Application: electro-mobility

Especially for copper intensive applications in electro-mobility, beam sources with visible emission provide new possibilities and potential for production. The joining of so-called hairpins of a stator that is part of the elctric drive train was investigated. For the tests, actual components from the company Continental were used as a benchmark for the application. The production of these components is characterized by a high degree of complexity with a variety of processes, resulting in a highly integrated material composite. The connection of individual hairpins takes place towards the end of the production chain. In order to guarantee proper functionality, the contact area between the two joining partners must be sufficiently large and the surface quality has to be high. Defective joints in the stator lead to considerable costs. This places increased requirements on the welding process in terms of seam quality (Fig. 2).

Hairpins are usually contacted with high brilliance laser systems emitting at infrared wavelengths. Due to the poor absorption, process instabilities can occur that can result in defects. Common defect patterns can be spatters that lead to potential damage of the components or insulation material around the joint. In a direct comparison, the application of 1 kW green laser power shows a significantly more stable process with fewer melt ejections. The increased process efficiency means that less energy is required for welding and therefore the overall heat exposure on the pins is reduced. High welding speed and an increased power of up to 2 kW with a wider spot diameter enabled shorter process times.

For applications that require a higher weld depth, an infrared and green laser beam source can be combined for the welding process. In the ProLasKu project, a near-infrared laser beam source

Company / Institute

Trumpf Lasers

Trumpf's mission is to further develop and digitally connect production technology, to make it even more efficient, precise, and future-proof. From drilling the finest holes no wider than a hair, to welding panels in ship building, the disk lasers from Trumpf have been used in tens of thousands of installations around the world. Whether it be a continuous wave or ultrashort-pulse laser, disk laser technology demonstrates its advantages in the respective sector with both high pulse energies and high average powers.

www.trumpf.com

Institute for Machine Tools and Industrial Management (*iwb*)

The iwb at the Technical University of Munich is one of the largest production technology research institutions in Germany, and encompasses two chairs at the faculty of mechanical engineering in Garching near Munich. The thematic focuses lie in the areas of additive manufacturing, battery production, machine tools, assembly technologies and robotics, joining and separation technology, as well as in the field of production management and logistics.

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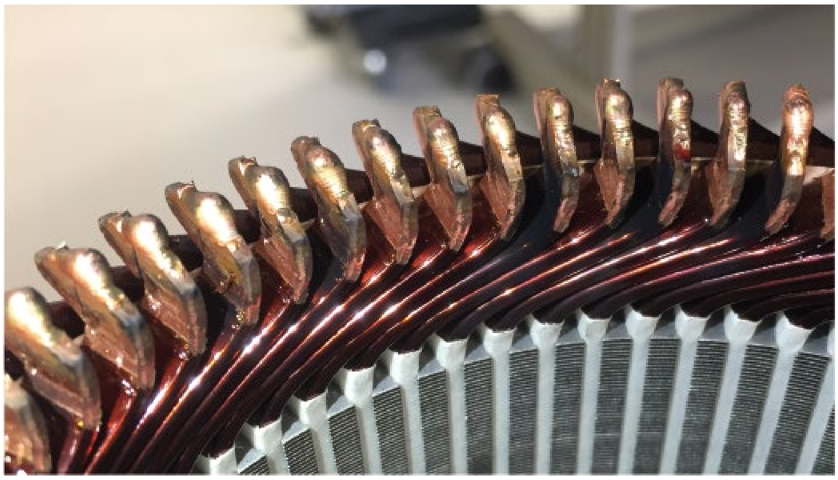

Fig. 2 Hairpins welded with green laser radiation. (Source: Continental)

Fig. 3 Deep weld seams achieved by combining green and near-infrared laser radiation. (Source: Siemens)

with 8 kW output power was used to investigate the potential application. The green radiation is used to melt the copper. In the liquid phase, copper has an increased absorption of near-infrared wavelengths. The added infrared laser power can then be absorbed better, which increases the overall process efficiency.

This enables higher welding depths. At the same time, fewer melt ejections can be observed, which indicates a more stable process compared to welding with a single-mode near-infrared beam source.

Real-time spatter detection

In addition to process knowledge, a suitable quality assurance method is required in order to qualify a process for series production. In-line process monitoring can be used to evaluate the process stability. A direct measuring method during the production process can save resources of expensive testing afterwards. Due to the criticality of melt ejections during the joining process of copper, a system for spatter detection was developed by researchers at the Technical University of Munich. Using coaxial high-speed camera images and image processing methods, it was possible to track and count spatters and provide the user with valuable spatter-related data in real time. In order to enable the efficient evaluation of the image data on the graphics card, computing operations that run in parallel were selected for the image processing algorithm [2].

Summary

A high-power laser system with emission at a wavelength of 515 nm has been developed by Trumpf and evaluated in the ProLasKu project. Originally planned as a 1.5 kW beam source, the targets were exceeded and a beam source with 2 kW continuous wave output power could be built. The increase in output power offers new potential for copper processing in order to exploit the advantages of the laser for a wide range of new applications.

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Blue High-Power Laser Diodes – Beam Sources for Novel Applications

Overview and outlook

Martin Behringer and Harald König

Applications for low and medium power GaN laser diode: near-to-eye projection, stagelighting, headlights and projection. Right: blue laser in TO package (Source all images: Osram)

High-power diode lasers are possibly the most efficient way of making electrical energy usable for material processing, like welding, cutting, soldering or other high-power applications. While IR laser were invented over fifty years ago and have been used in industry for more than two decades, GaN high-power lasers have only recently been used for material processing, especially for welding and soldering of copper. Although the blue wavelength offers unique and undisputable advantages over IR for the latter application, some difficulties still had to be overcome. Here is an overview of the development steps of GaN lasers from their commercial beginnings as a 1 mW light source in Blue-ray players to today's 1.5 kW system. Also, important investigations to reach power efficiencies of 40 % will be explained as well as considerations to reach lifetimes of 65 khr and longer. We also venture a prediction of future developments based on a comparison to IR laser diodes.

The first widespread application of diode lasers in the IR spectral range was in the seventies of the past century in CD players. Similarly, the first widespread applications for GaN laser diodes was as a light source in blue-ray players at 405 nm thirty years later. Those application require low output power in ground-mode operation with good beam quality. Also in the low output power range, near-to-eye applications for AR, VR, MR devices require single mode lasers for red, green and blue light. Those laser dies are typically rather small.

A laser chip for single-mode emission is depicted in Fig.2. It contains a GaN substrate, epi layers that contain a light-generating quantum well layer (<10 m thickness), waveguiding layers, current distribution layers and metal contacts. The chip design also has to support ground-mode operation and is structured in a way that gain minus loss for the ground-mode is higher than for higher order modes in order to enforce ground-mode operation.

Also in Fig. 2, a typical LIV curve is depicted. It can be seen that a threshold current as low as 6 mA can be achieved for a lower-power laser at 436 nm. 10 mW output power can be achieved at an operation current of 24 mA and a voltage of 4.1 V. This amounts to an efficiency of about 10 %. The very low threshold current is important, as those devices need to be operated at very high pulse frequencies and therefore they are normally always biased at around threshold current. The low value was reached by designing the mirrors to 99 % and 90 % reflectivity on the HR and AR side respectively. Single mode lasers with higher output power levels are often needed for range finding or leveling applications. An LIV curve for a high-power single-mode laser is shown in Fig. 2 on the right. It can be seen that the blue and the green laser diode have a threshold of about 11 mA and 30 mA and they reach 100 mW output power at 130 mA and 290 mA respectively. This higher operation level is directly connected with the higher threshold current as it was achieved by increasing mirror losses by lower reflectivities on the AR-side of the resonator.

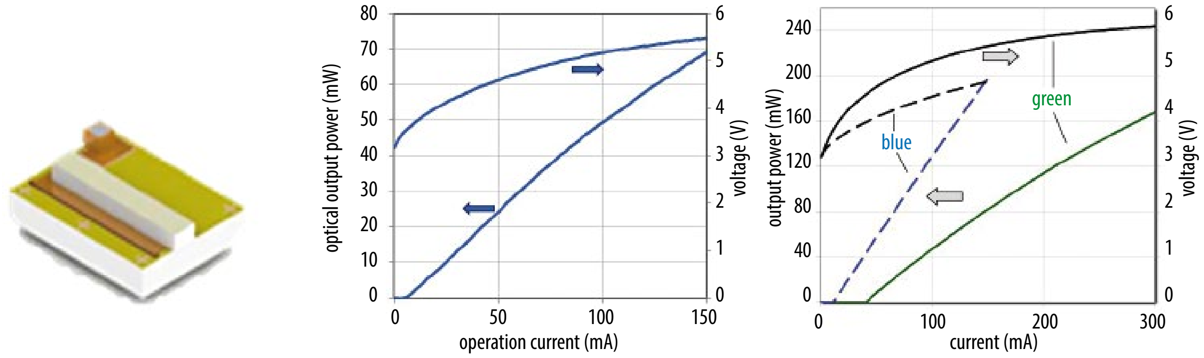

Fig. 2 Schematic of a laser diode (left), LI curve for a low threshold (middle) and LIV for high power single mode diodes [6]

Laser diodes in the 1 – 10 W range were often used for IR energy transfer or low-power soldering applications. Devices and packages for higher output power were developed over time. The output power per light source over time is shown in Fig. 3. For IR lasers, 1 W was achieved around 1980 and this increased steadily to about 100 W in 2008 and has now reached up to 1 kW per 1 cm laser bar or >300 W (cw or hard pulse) in commercially available systems, manufactured in high volume. Also for GaN laser diodes, there are many applications that require different output levels. This is shown in Fig. 3 on the right. Today, lasers in the single digit watts class are used for illumination (by pumping a converter to convert the 450 nm from the laser die into the desired color or into white light) or stage and show lighting. Automotive headlamps that require powers in the 10 W range are often used today in high-end vehicles. Future applications such as projection in a business environment or in a cinema start becoming interesting at power levels of about 100 W per package, and even material processing methods such as cutting, welding and soldering will be possible in the near future. For those applications, power levels of 1 kW and beyond will be necessary. For IR lasers and laser systems, it took several decades to develop the semiconductor chip, but the packaging technology as well as the materials and the optics also had to be improved to be able to configure multi-kW systems. For GaN, the development for power applications started after 2000. Progress was more rapid than for IR, as many building blocks developed for IR could also be used for 450 nm systems. While IR lasers started out with a short resonator length of 300 µm, narrow emitters and smaller die, they have now reached 4 to 6 mm in resonator length and a fill factor of 70 % or more in 10 mm wide laser bars. Today's GaN lasers are far from these design features.

The reason for this difference becomes understandable when looking at some material parameters. Some characteristics are compared in Table 1. The

	GaN	GaAs
Band gap	3.2 eV	1.42 eV
Lattice constant	3.2 Å	5.6 Å
Thermal expansion coeff.	$5.6 \cdot 10^{-6}$	$5.73 \cdot 10^{-6}$
Activation energy p-type	200 meV (Mg)	0 meV (C 100 % ionized)
Thermal conductivity	131 W/mK	46 W/mK
Absorption	1 – 2 / cm	0.4 / cm
Melting point	2500°C	1240 °C
Surface Hardness	1200 – 1700 kg / mm²	750 kg / mm²
Mobility (hole)	<100 cm² / Vs	~200 cm² / Vs
Peak Efficiency LD	~50 %	~70 %
T_0	110 K	~200 K
T_1	>600 K	~400 K

Tab. 1 Comparison of material parameters for GaAs and GaN

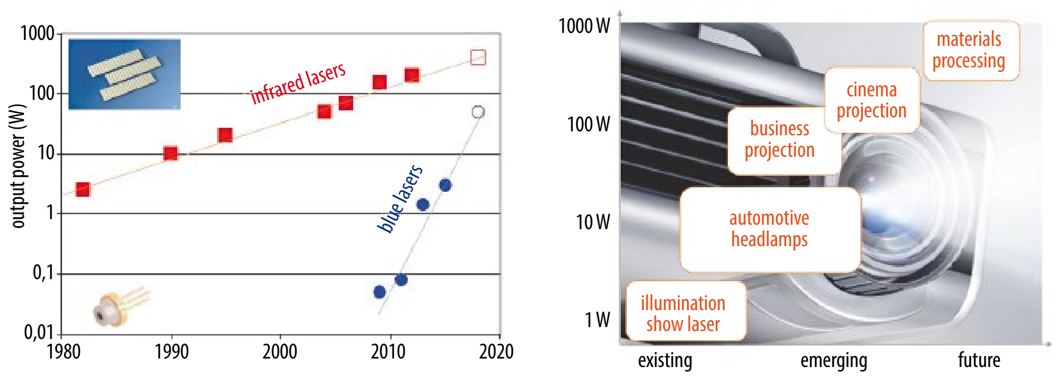

Fig. 3 Development of output powers for IR GaAs and visible light emitting GaN-based diode laser chips and packages. Applications for GaN Lasers with different power levels, data from [1...5]

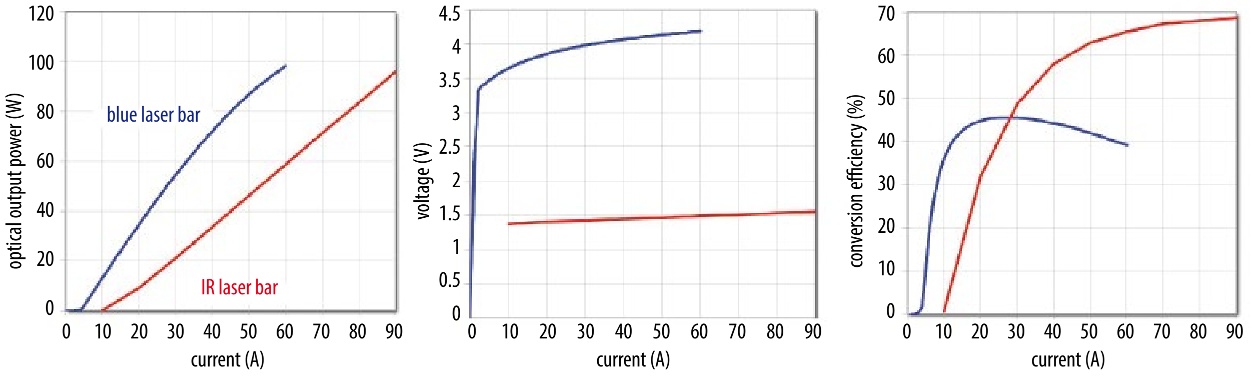

Fig. 4 LI, UI, and efficiency over current for blue and IR laser bars. [5]

first most obvious difference is the bandgap. While GaAs has a bandgap in the IR range with about 1.42 eV, GaN has a high bandgap of 3.42 eV. This difference is unavoidable when one needs a different wavelength. The different activation energies for p-type dopants, the hole mobilities, the absorption coefficients for light in the laser resonator and the characteristic temperature T_0 all have further technical consequences.

Due to the high activation energy, only a small fraction of the incorporated Mg actually acts as a dopant, resulting in many Mg atoms, which disturb the lattice and increase absorption, but do not improve carrier density and conductivity. In GaAs, carbon is often used as p-type dopant. This is 100 % ionized, which means that all carbon that is included contributes to high doping and low resisitivity. Similarly, the hole mobility in GaAs is about twice as high as in GaN, resulting in lower electrical resistivities and therefore lower electrical losses, even at lower impurity densities of C in GaAs compared to Mg in GaN.

The optimum resonator length of 1.2 per cm in GaN-based laser diodes is much shorter, compared to less than 0.5 per cm in high-power GaAs lasers, due to their higher absorption. This all contributes to a rather low value for T_0 which describes the change of threshold current with temperature. A small value of 110 indicates that a higher operation temperature results in a quicker and more drastic increase of threshold current compared to the higher value of 200 in the case of GaAs high-power lasers. The high values of T_1 for both GaAs and GaN devices indicate that the slope efficiency depends very little on temperature. Both together describe that GaN laser diodes react more sensitively to higher operating temperatures and output power degrades faster with temperature at a given operating current.

Some very basic problems had to be overcome to be able to make and operate GaN bars in the very beginning. For a long time, the substrate quality was not good enough. As laser bars are very big devices a low defect density of the substrate is mandatory. Also the crystal quality of the epi-layers had to be improved. For a long time it was considered impossible to make laser bars because GaN is a material with a higher dislocation density than GaAs. It was assumed that a single emitter failure would cause catastrophic failure as had been observed for GaAs laser bars in the past. As the operating voltage depends on temperature as well, inefficient operation of one emitter on a bar influences the neighboring emitters and thermal runaway had to be prevented by thermally decoupling the individual emitters as much as possible. All this made it possible to realize GaN laser bars.

In Fig. 4, the LI, UI and WPE over operation current curves for a blue and an IR laser bar with identical resonator length are shown. While in the left picture, the output power of the blue bar with 85 W at 50 A is much higher than for the IR laser (47 W), it becomes obvious that this is only due to the wider band gap and results in a much higher operating voltage of 4.1 V compared to 1.5 V for the IR laser bar. This results in a lower wall plug efficiency of only 40 % at 50 A compared to > 60 % (right picture of Fig. 4).

For IR diodes, the strategy over the past few years was to reduce absorption, increase contact size with an

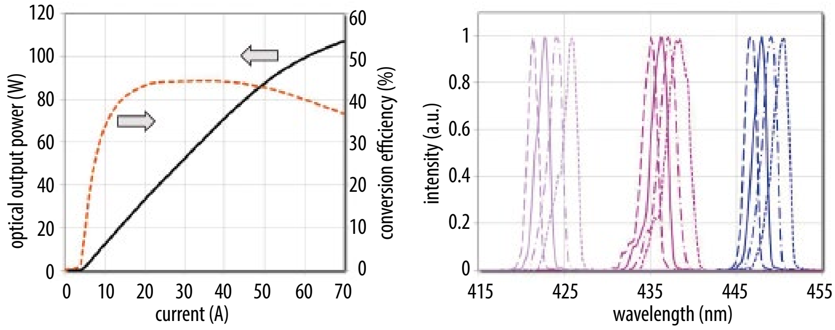

Fig. 5 LI and WPE curve for a 1 cm laser bar 450 nm [6] (left), spectra of laser bars for various wavelengths at different operation currents [5] (right).

increased fill factor and increased resonator length, and further reduce ohmic losses by reducing electrical resistivity. High output powers of > 300 W for cw operation in commercial applications are state-of-the-art today. GaN lasers in contrast cannot be made with long resonators while optical absorption in the devices is high. Similarly, the fill factor cannot be increased as this leads to high threshold currents. Therefore, different material parameters must be further improved before additional design opportunities can be realized.

Today's GaN laser bars for 450 nm emission exhibit fill factors below 10 % (to keep threshold current low and allow efficient cooling) and have resonator lengths up to 1200 µm to avoid absorption induced low slope efficiencies. Mounted on a water-cooled microchannel cooler, they can be operated up to output powers of above 107 W before thermal roll over, with peak efficiencies of ~44 % (Fig. 5, left). As can be seen in Fig. 5, right, the material combination of AlGaInN offers the possibility to adjust to different emission wavelengths, which is a requirement for wavelength multiplexing.

Today, laser diodes based on GaN for the emission of 450 nm light still exhibit low efficiency and lower total output power than comparable systems based on GaAs for IR laser light sources. In addition, production costs are still much higher as components are more expensive and production yield for this rather new material system is low. Nevertheless, they offer the unique advantage that some materials absorb IR light rather poorly while the absorption of blue or UV light is good, as can be seen in Fig. 6.

Several companies have successfully incorporated GaN laser diodes for 450 nm emission in systems with more the 1 kW output power [8-10]. Those lasers are designed for heavy material processing using the superior absorption of blue light. All blue and hybrid systems have already proven their better performance over pure IR systems in several applications. It must be expected that further applications will prove advantageous in quality, and with a steady reduction of costs and improvements in output power and efficiency, more and more systems will use GaN diodes as their light source.

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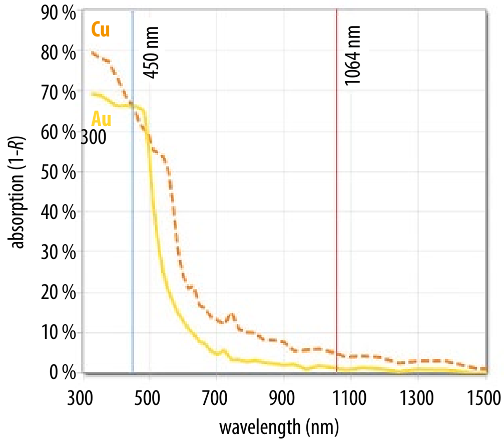

Fig. 6 Absorption spectrum for copper Cu and gold Au. [6] and data from [7]

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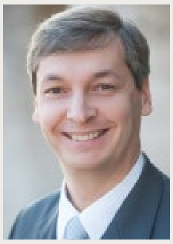

Dr. Martin Behringer was born in Würzburg, Germany, in 1967. He received his PhD from the University of Bremen in 1998 on "MBE growth of ZnSe-based laser diodes and their characterisation". He joined Siemens HL / Osram Opto Semiconductors in October 1998. After working on the development of high-power laser bars and packages, he led the LED chip development and research of the first phosphid, arsenid and later nitride LEDs. Since December 2018, he is responsible for chip development of diode lasers.

Dr. Harald König is principal key expert on chip design for laser diodes at Osram Opto Semiconductors. He received his PhD from Würzburg University (Germany) on 1.55-µm InP DFB laser diodes for telecommunication. In 1999 he joined Osram OS and held different project leader and managing positions in laser diode manufacturing and laser R&D groups. He gained more than twenty years of experience in semiconductor laser diodes ranging from InP telecom lasers, GaAs high-power laser diodes to visible lasers based on GaN. Recently he coordinated a German government-funded project "blaulas", which was dedicated to kW blue lasers for materials processing.

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Futonics laser welding installation with 50 W Tm-fiber laser and scanner system (Source: Futonics Laser)

2.0 µm Laser Transmission Welding

Welding of transparent and opaque polymers with single-mode Tm-doped fiber lasers

Peter Fuhrberg, Anja Ahrens, Andreas Schkutow, and Thomas Frick

2.0 µm fiber lasers provide a high beam quality and a high-power output, which makes them ideal for welding and cutting a wide variety of commercially used plastics, as well as marking plastics, metals or even food. At 2.0 µm wavelength the intrinsic absorption of most thermoplastics is high enough to weld or cut without applying any absorbent additives or coatings. Compared to commonly used near-infrared systems, welding with 2.0 µm lasers can improve heat distribution and gap bridging and enable transmission welding for challenging materials.

There are numerous applications for 2.0 µm lasers in many scientific, medical and technological fields. They operate in the eye-safe wavelength region and are ideally suited for lidar, free space optical communications, gas sensing or pumping laser sources in the mid-IR wavelength range [1]. 2.0 µm fiber lasers are well known for their application in welding of transparent plastics like polycarbonate (PC) or polymethylmethacrylate (PMMA) [2]. These materials are almost perfectly transparent not only in the visible but also in the short-wave infrared wavelength range as shown in Fig. 1. At longer wavelengths however, the materials inherently absorb parts of the laser radiation, enabling a welding process without any absorbing additives. The wavelength range around 2.0 µm is especially attractive for welding applications, since the absorption is strong enough to enable sufficient heat generation for the welding process –unlike more common laser sources with wavelengths around 1.0 µm –, but also sufficiently low to allow for volumetric heat

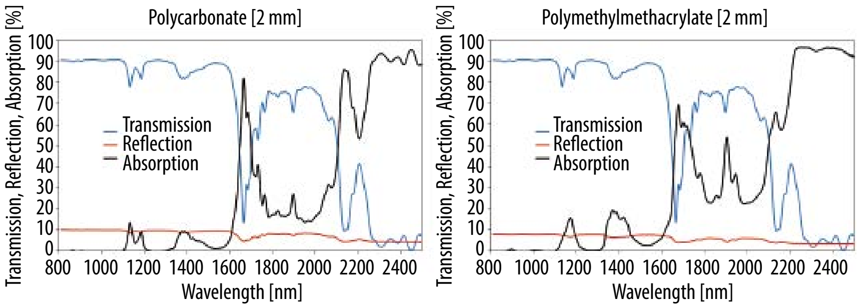

Fig. 1 Optical properties of PC and PMMA (Source: TH Nürnberg)

generation. This volumetric heat generation enables the two most important processing variants – heat conduction welding and transmission welding – and is suitable for butt-joints as well as for overlap and T-joints. Other laser sources, as for example CO_2 lasers operating at around 10.6 µm, would lead to direct surface absorption of the radiation, which would drastically increase the heat concentration. A high risk of thermal degradation or material ablation rather than a controlled and efficient welding process would be the result. In contrast, 2.0 µm laser welding of transparent polymers can be applied in various technical fields, like medical device manufacturing or polymer microfluidics, where the ability to precisely create hermetic weld seams without any additives is a key factor. Other applications can be found for example in the food industry for packaging fresh and ready to use groceries.

2.0 µm Tm-doped fiber lasers

Thulium-doped fiber lasers are well suited for the generation of high signal power in the 2.0 µm wavelength region. By using 790 nm laser diodes for pumping, the upper laser level is not directly excited, it is populated by a cross relaxation (CR) process. During the CR process, one ion from the ground state is excited to the upper laser level, when one ion from the upper pump level relaxes down to the upper laser level. Thereby two excited ions are produced by one absorbed pump photon. This enables high efficiencies for the system, which can be higher than the limit that is given by the quantum defect. The 2.0 µm Tm-laser transition ends in the ground state, which means that the lower laser level is thermally populated. To couple the power of fiber-coupled laser diodes into the active fiber, custom-build tapers or combiners are often used [3]. These components allow the realization of fiber laser systems with an all-fiber configuration.

Futonics offers high power, unpolarized 2.0 µm Tm-doped fiber lasers with single mode beam quality of $M^2 < 1.2$ (Fig. 2), that allow continuous and modulated operation up to 10 kHz. They are built in an all-fiber configuration with single-mode fibers and fiber Bragg gratings (FBG) to realize a robust and compact setup, as well as allowing the users to choose an operation wavelength between 1930 nm and 2050 nm, depending on the application.

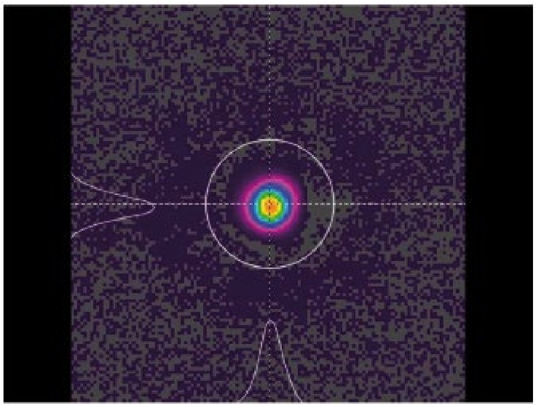

Fig. 2 Tm-fiber laser beam profile at 50 W output power $M^2 < 1.2$ (Source: Futonics Laser)

Optical systems for welding applications

For laser welding, cutting, and engraving applications, Futonics offers custom-built optical systems tailored to the users' requirements. These include scanner systems consisting of two mirrors to guide the laser beam with f-theta optics and processing heads, with or without integrated cooling systems, for welding and cutting applications. For custom applications, optics optimized for mid-IR wavelengths including collimators, focusing lenses and complete setups can be provided. Scanner systems can be upgraded with a pyrometer and a camera system that identifies the geometry of the workpiece to automatically detect the location of the weld seam and its temperature, as well as software to

Company

Futonics Laser

was founded in 2018 as a spin-off from LISA laser products OHG. It was founded by Dr. Peter Fuhrberg, who was also the founder of LISA laser products OHG. Futonics and its employees therefore have great experience in the development of infrared laser systems for medical and industrial applications, such as the processing of transparent plastics.

The focus of the company is the development and commercialization of 2.0 µm fiber laser systems, with output powers from 10 W to 250 W, that can deliver single mode beam quality over the whole power range. The systems utilize a highly robust design and can be built with selected wavelengths in the range from 1930 nm to 2050 nm. Futonics offers optics optimized for the mid-IR-range, such as collimators, processing heads and delivery fibers. Futonics and LISA can look back on over 20 years of experience, as well as many international research projects and collaborations.

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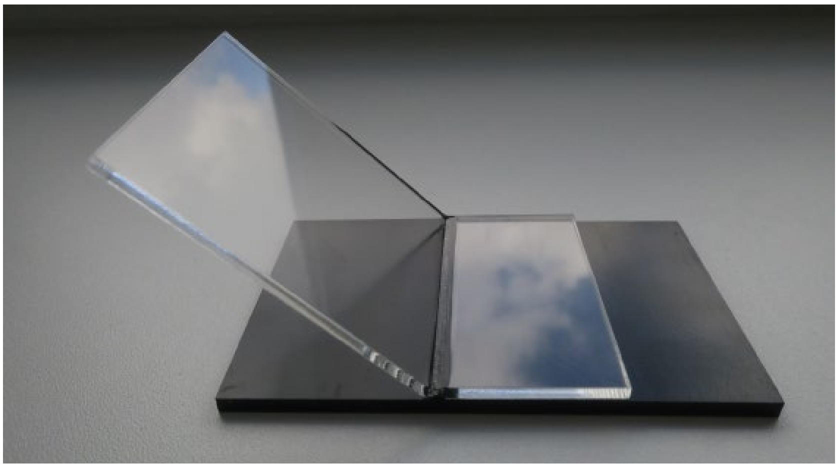

Fig. 3 Laser transmission welding sample (PMMA to ABS, source: Futonics Laser)

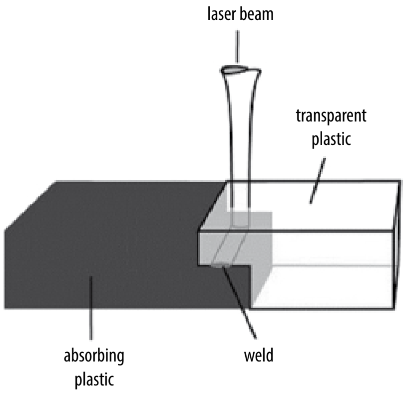

Fig. 4 Principle of laser transmission welding (Source: Futonics Laser)

adjust the laser power output depending on the velocity of the scanner. Laser connectors like FC/PC, SMA or QBH-compatible are available. By using custom focusing optics, a welding seam width as low as 30 – 50 µm can be achieved.

Laser transmission welding

Many welding applications for plastics use the laser transmission welding process, where a transparent part is placed in an overlap configuration with a second absorbing part, usually black colored by the addition of carbon black to the polymer (Fig.3). The joint is created directly in the contact zone by irradiating the surface of the absorbent part through the transparent component and causing heat conduction in order to melt the transparent part (Fig. 4). This method is widely used in automotive or consumer goods production, for example for fluid containers or the connection of transparent lids to the housing of lighting components. Despite the fact that this method does not require absorption in the transparent part, the application of a 2.0 µm thulium fiber laser was still found to be beneficial for those applications. Not only does the fiber laser enable longer working distances and scanner-based beam guidance with smaller spot sizes than commonly used diode lasers due to the higher beam quality, the wavelength dependent material properties lead to direct process improvements as well. The most obvious property difference is the absorption behavior.

Absorption behavior and melt pool geometries

In an overlap weld created with a wavelength of around 1.0 µm, the heat is generated almost exclusively in a thin layer at the surface of the absorbing part and spreads to the surrounding areas due to heat conduction, creating a thin, lens-shaped melt pool. When using a 2.0 µm laser, the increased absorption in the transparent part leads to more distributed heat generation and a lower peak temperature at the surface of the absorbing part, reducing the risk of thermal degradation. In quasi-simultaneous welding, where the weld seam is irradiated multiple times in short succession, the modified heat distribution together with the longer timeframe for heat conduction can lead to completely different melt pool geometries like the drop-shaped melt pool shown in Fig. 5. A thermal process simulation of the quasi-simultaneous welding process when applying a 1.0 µm (left) and a 2.0 µm laser (center) shows the modified melt pool cross-section: molten material (temperature above melting temperature) is shown in grey. Additionally, it has been shown that the absorption coefficient of carbon black filled polymers is also wavelength dependent, leading to a greater penetration depth of the radiation of the Tm-fiber laser [4]. This further increases the heat spreading and lowers the peak temperatures. As a result, the risk of thermal degradation of the absorbent material is greatly reduced

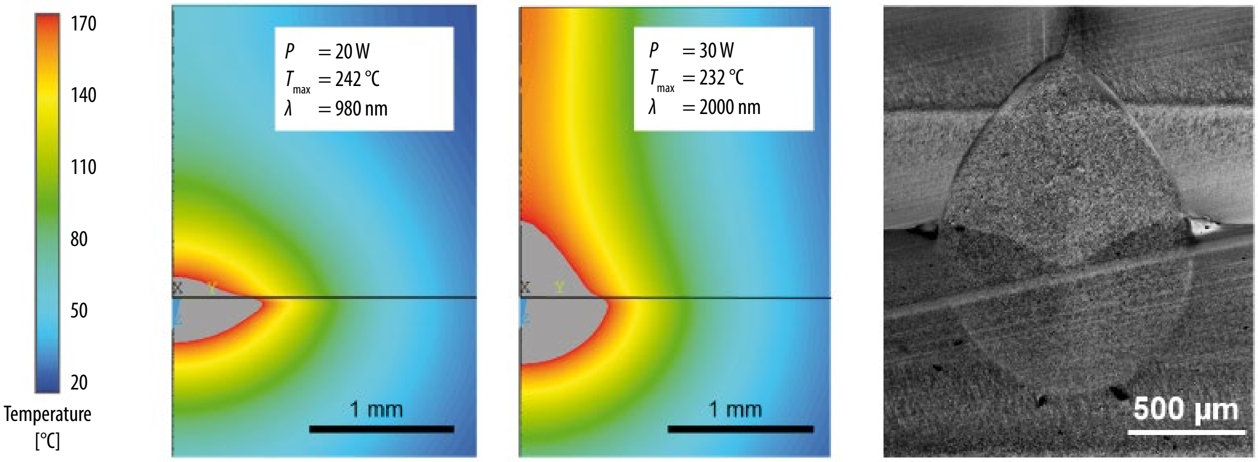

Fig. 5 Wavelength dependent melt pool geometries (Source: TH Nürnberg)

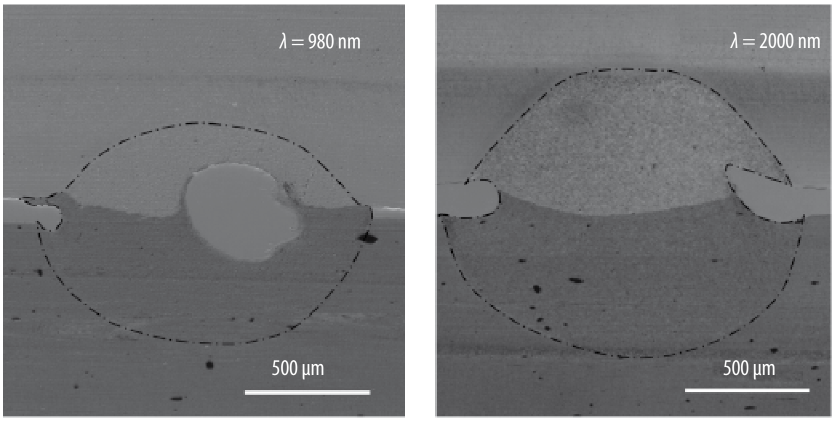

Fig. 6 Gap bridging during quasisimultaneous welding of PP (Source: TH Nürnberg)

and the heat-affected zone is enlarged. Both factors are beneficial in terms of a major limitation of the welding process, the limited gap bridging capability [5].

Gap bridging

In the conventional process, the transparent part is heated solely due to heat conduction. When manufacturing tolerances, warped parts or local defects cause an air gap between the two components, the heat conduction between the two parts is greatly reduced and thus the transparent part is not melted, making a welded joint impossible. Since the laser energy cannot be transferred to an adjacent part, the absorbing part gets hotter than intended and is likely to degrade or partially combust. When using a thulium fiber laser, both components are heated directly by the laser radiation. They will therefore expand thermally and thus increase the chance of successful gap bridging. This is especially important for flat-to-flat overlap welds as used for example in microfluidics. Fig. 6 shows the results of welding experiments using a quasisimultaneous welding process for overlap welds between two polypropylene parts, where an artificial air gap of 130 µm was created using metal spacers. Both gaps were closed during the welding process, however with the shorter wavelength, the absorbent part is partially combusted, resulting in a gas bubble in the middle of the weld. Most likely, the expanding gas displaced the molten polymer, leading to the gap bridging. In contrast, when applying a 2.0 µm laser, the increased thermal expansion of both polymer parts contributes to successful gap bridging and no thermal degradation is observed. The melt pool partially contracts during cooldown, leading to the observed necks in the joining plane [5].

When T-joint configurations are welded quasi-simultaneously, the joint area can be specifically designed to feature a melt-down rib, which drastically increases the gap bridging capability. Both parts are pressed together during the welding process so that the molten material of the rib is squeezed out of the joining zone in the areas where no gap is present, and the two parts approach each other until all gaps are closed over the whole weld seam length. Interrupted weld seams can be avoided by this method, but, depending on the processing conditions, there is still the risk of thermal degradation of the material before the gaps are closed and in some applications the (often inhomogeneous) melt ejection does not meet the aesthetic requirements of the finished product.

Benefits of longer wavelengths

The absorption properties are not the only important consideration for laser transmission welding. The transmission properties of the transparent part are at least equally important, so that sufficient laser energy reaches the joining zone between the two parts. The absorption in the transparent parts therefore limits the applicability of 2.0 µm laser radiation. For typical applications, however, the material thickness is in the range of a few millimeters, which still allows sufficient radiation to reach the interface between the two parts and enable the welding process. A major concern when welding with conventional lasers in the 1.0 µm wavelength range can be scattering in the transparent part [6]. Additives in the transparent part or even just the crystallite structures in semicrystalline polymers can lead to considerable scattering inside the transparent part. This can result in slightly increased weld seam widths and an increased demand in laser power for moderately scattering materials. For strongly scattering materials however, the beam profile of the laser beam can be considerably impaired and, in the worst case, the laser radiation is isotropically scattered out of the joining zone, which makes the welding process impossible or severely limits the weldable material thickness [7]. Since scattering processes are strongly wavelength dependent, the application of longer laser wavelengths can enable welding of materials that cannot be welded using conventional laser sources [6, 7].

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Authors

Peter Fuhrberg is the executive director of Futonics Laser. After studying physics at the Technische Universität Hannover, he started working in R&D at Spindler & Hoyer (today Qioptiq) and acquired his PhD in 1988 in laser physics, researching on new laser materials for the NIR region. In 1989 he founded Lisa Laser Products, which specialized in 2.0 µm medical and industrial lasers. He managed the company for nearly thirty years until it was sold to OmniGuide in 2018. In June 2018, he founded Futonics Laser, which is specialized in 2.0 µm fiber lasers for industrial applications.

Andreas Schkutow studied mechanical engineering and received a Dipl.-Ing. degree at the Friedrich-Alexander-Universität Erlangen-Nürnberg. He focused on additive manufacturing and laser-based processing of polymers and polymer derived ceramics. Since 2015 he has been working as a research assistant at the Technische Hochschule Nürnberg Georg Simon Ohm where his research concentrates on laser transmission welding of polymers.

Anja Ahrens finished her BEng in physical technologies in 2016 and MSc as an optical engineer in 2019 at the HAWK in Göttingen. She was employed as a scientific assistant at the Max-Planck Institute of Solar System Research in Göttingen from 2014 to 2019 and started working in R&D as field application specialist at Futonics Laser in 2019. She is responsible for evaluating and optimizing different applications of 2.0 µm fiber lasers.

Thomas Frick studied mechanical engineering and wrote his doctoral thesis on the laser welding of plastics. After working for several years in the field of material laser processing in industry, he was appointed professor of material science and joining technology at the Technische Hochschule Nürnberg Georg Simon Ohm in 2012. He is working on the topics of laser material processing, joining technologies and additive manufacturing.

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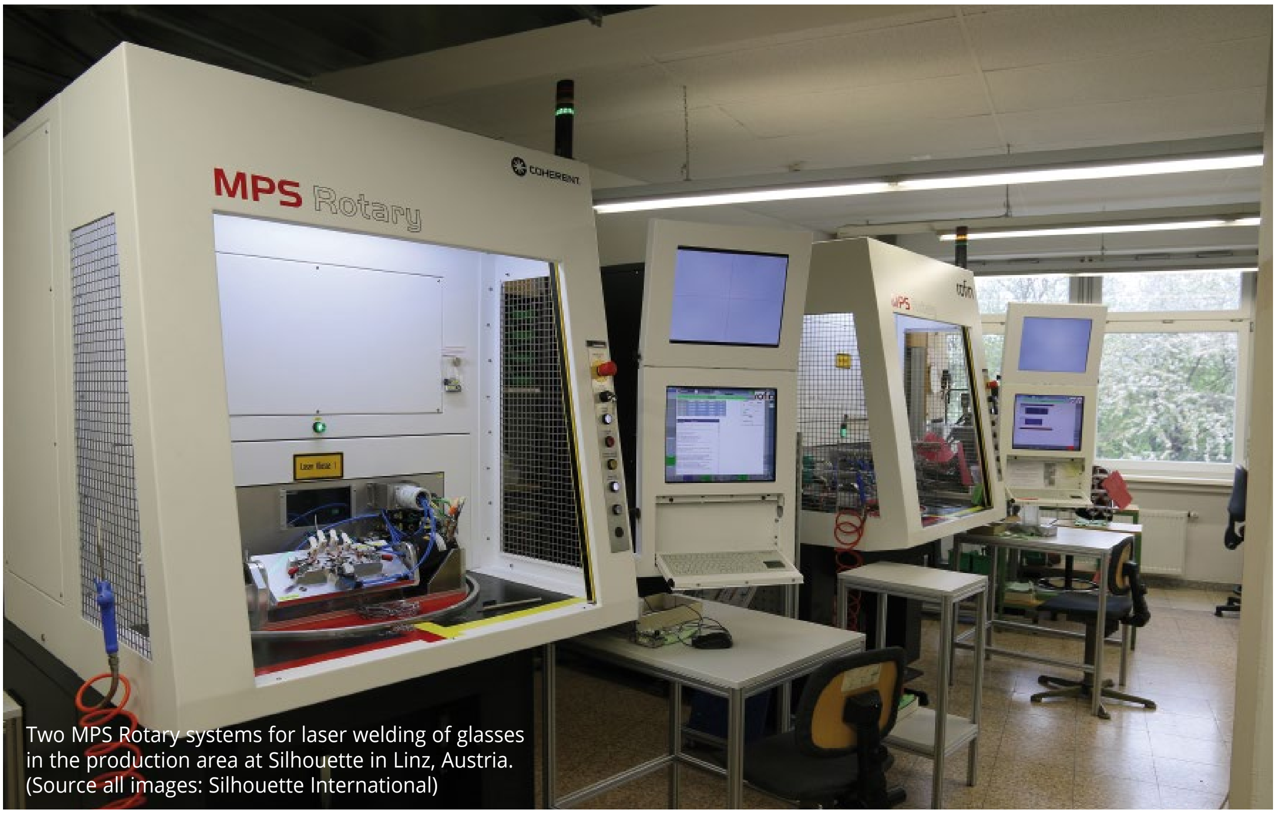
Unique and Durable Eyewear Thanks to Laser Technology

Lasers from Coherent bring a unique vision to reality

Wolfgang Illich and Thomas Schreiner



Two MPS Rotary systems for laser welding of glasses in the production area at Silhouette in Linz, Austria. (Source all images: Silhouette International)

The founding of Austrian premium eyewear manufacturer Silhouette International in 1964 was based on a simple idea: glasses should not only be a practical visual aid, but rather an accessory for better vision and appearance. That idea still drives the company. It motivates them to seek out new production processes to enable the realization of cutting-edge designs that are functional and reliable. Silhouette International has not been afraid to adopt new manufacturing technologies to achieve their goals, and laser welding systems from Coherent enable the company to produce some of their most advanced designs.

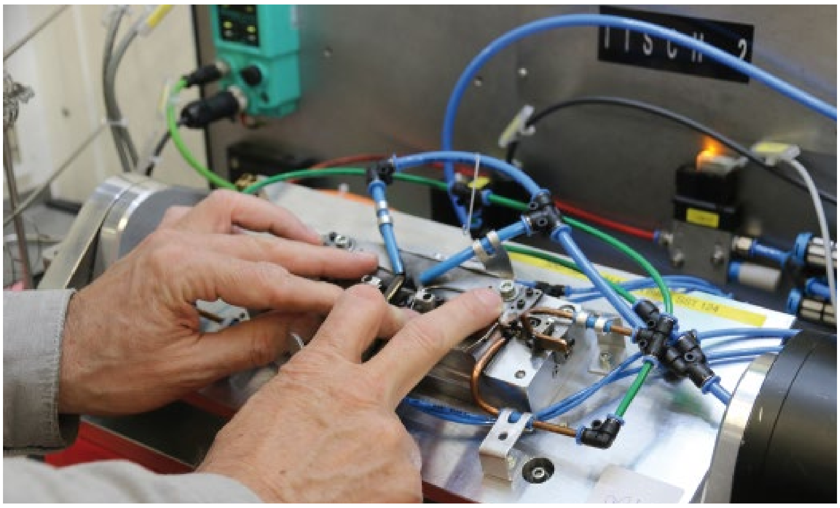
"Personal eyewear design is our top priority, because we want to create unique eyewear that fits the wearer's face harmoniously." This is how Silhouette CEO Thomas Windischbauer summarizes their design philosophy. This approach, in turn, necessitates several design imperatives. These include the requirement for easy adaptability to the individual needs of the wearer, as well as the use of materials that guarantee lightness and flexibility, but also stability.

Silhouette had a groundbreaking year in1999. The 1.8 gram Silhouette "Titan Minimal Art" (TMA), the first screwless and hingeless eyewear made of titanium, revolutionized the eyewear market and was an instant success story. To date, over twelve million units have been sold worldwide.

Used in space

The Titan Minimal Art was approved for space flights twenty years ago. The absence of screws and hinges guarantees safety by minimizing the risk of free-floating objects inside space helmets, breathing apparatus, and within the spacecraft. To date, the TMA has been the faithful companion of astronauts on more than thirty space flights.

Since 2017, Silhouette International has also been manufacturing its own glasses in the so-called Lens Lab, a specially constructed building on the fac-



Customized part holder for welding glasses

tory premises. Frames and lenses are manufactured at the company's location in Linz to the highest technical standards and tailor-made for the Silhouette eyewear collections.

Since the introduction of the TMA, Silhouette has applied this same hingeless approach to many other designs. In terms of manufacturing technology, this drives several requirements. First is the ability to join a variety of materials, including titanium and specialized alloys. Next is the capability to produce joints that are aesthetically pleasing; specifically, this means virtually invisible and cannot be felt. Finally, it also necessitates joints that deliver excellent flexibility and high strength, plus the ability to be cycled (folded and opened) numerous times without a change in shape or degradation in mechanical strength.

Partnering for a total solution

With these technical requirements in mind, plus the market requirements to support production of several new collections every year, Silhouette searched for a supplier who would support both the development of the manufacturing processes and provide the actual production equipment. Early on, it was determined that Silhouette would transition from traditional resistance welding to laser welding in order to meet their stringent quality and throughput requirements.

During this search, Coherent emerged as a favorite among potential vendors for several reasons. First, Coherent was one of the few companies who could readily supply the entire package, that is, the laser, all associated optomechanics, part handling, and software. Also, Coherent was both capable and willing from the outset to participate in developing the process, lending its substantial laser expertise to a company that didn't have much experience with the technology.

The first Coherent laser welding systems acquired by Silhouette were manual models used for prototype construction and repair work. The success of those led to the purchases of the Coherent MPS Rotary (Modular Processing System) for laser welding, adapted specifically to Silhouette's needs. Coherent's willingness to perform this customization was another key factor in their selection by Silhouette.

MPS rotary benefits

The MPS Rotary is an automated, turnkey system for metal welding, cutting and drilling, in this case, incorporating a Coherent 200 W fiber laser (Starfiber 200). A combination of scanner optics and travel enable a variable working field. The system is completely enclosed (Class I laser) for operator safety. Various options, including integrated machine vision, are available. The system also uses a rotary indexing table to allow part loading/unloading while processing is being performed.

User-friendly software enables use by operators with minimal skill and training. For example, the system automatically detects the type of part that has been loaded, and then calls up the correct processing program. Silhouette engineers typically change job parameters on a daily basis to support their specific production requirements, and the MPS Rotary software has proven responsive enough to support this schedule. Silhouette runs the system five days a week, two shifts a day, and has found that machine availability and uptime is excellent.

More flexible and cost-effective production

In terms of economics, the move from resistance to laser welding has been a tremendous success, delivering an overall cost savings in the range of 80 %. Specifically, laser welding has proven better suited to automation, and delivered a substantial increase in production throughput. Part of this is due to decreased setup times. Overall, the Coherent MPS Rotary has reduced tooling and manufacturing costs because multiple process steps are now

David Illitz, M.SC. (Head of Raw-Part-Manufacturing) and Raimund Öhlinger (Head of Department Connection Technology) – fully satisfied with the performance of the Coherent MPS welding systems

Glasses laser welded with the Coherent MPS Rotary system

performed in one machine, resulting in improved energy savings, sustainability, and productivity. Just as important is the superior weld quality; the welded parts themselves demonstrate high strength due to lower heat input into the part, and the elasticity of the welded joint is better. The MPS Rotary also supports Silhouette's need to quickly insert new designs into production to support the quarterly sales cycle, as well as to efficiently run limited lots sizes (typically 150 to 300 pieces).

"While we're always striving to produce more unique and fashionable designs, wearer comfort remains a top priority," notes David Illitz, Process Manager Raw Part Production. "This creates engineering challenges for us in terms of material limitations. Laser welding, which delivers highly precise and very repeatable results, has been a key factor in enabling us to bring these cutting-edge designs into production successfully. Plus, the flexibility of laser processing gives us confidence that we'll be able to keep utilizing this approach for many years to come. The enormous versatility of the MPS Rotary system, in particular, ensures that we'll be able to bring anything our designers create into production in a cost-effective way."

Smartweld

Another key advantage of the MPS Rotary is that it includes Coherent's Smartweld technology. Smartweld incorporates an advanced implementation of "beam wobble," that is, rapid motion of the beam during the welding process. Specifically, instead of simply moving along a weld seam, the beam may trace out circular, elliptical or even zigzag patterns, executing motion both along and perpendicular to the weld seam. These patterns are easily programmed into the MPS Rotary using the integrated software.

One key benefit of Smartweld is that it produces a higher quality and more reproducible weld. This is because the beam motion enables more flexible and precise distribution of the heat produced by the laser. For example, a relatively large Smartweld pattern can be used to preheat the material before it is completely liquefied, or to cool it down slowly after melting. The former can prevent bubbling and turbulence in the melt pool, which produce spatter and inconsistent results, while the latter can eliminate cracking as the material cools. Smartweld can also be used to alter the normal Gaussian distribution (highly peaked in the center) of the applied laser energy. Lowering the effective intensity at the center of the laser pattern can reduce melt pool turbulence by allowing vapor expansion to occur in a more controlled manner, again leading to improved process consistency. Here, Silhouette can draw on a wealth of experience at Coherent in optimizing Smartweld for different materials and weld geometries.

Another benefit of Smartweld is that it allows bridging of larger gap widths in the welded parts. This reduces fit-up tolerance, which speeds production and lowers costs.

"Silhouette currently produces about 2.2 million glasses per year," reports Illitz. "We need production equipment that supports this volume, and which delivers the quality we need in a way that still keeps us cost competitive. Plus, our production methods must be flexible enough to support our rapid and relentless design cycle that is a prerequisite to maintaining market success in any type of wearable fashion. The MPS Rotary has proven itself capable on all these fronts. And, just as important, Coherent has consistently partnered with us to provide the application and process know-how necessary to take full advantage of their machine's capabilities."

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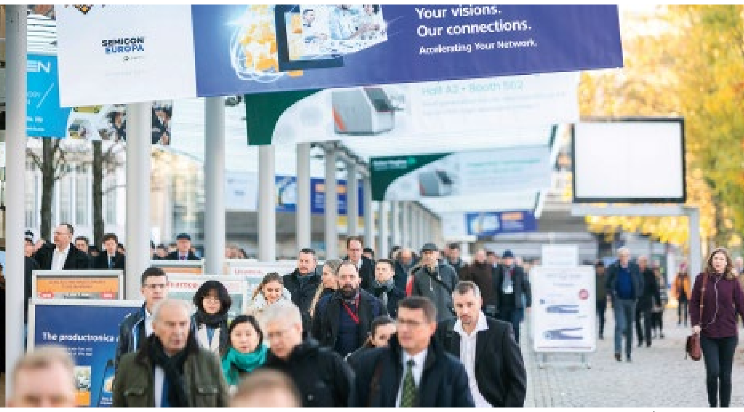
Source: Messe Düsseldorf



Source: Messe München

April 20 – 24, 2020
Hannover Messe
Hanover, Germany
www.hannovermesse.de

May 05 – 07, 2020
Rapid.Tech 3D
Erfurt, Germany
www.rapidtech-3d.com

May 05 – 07, 2020
T4M
Stuttgart, Germany
www.messe-stuttgart.de/t4m

May 05 – 08, 2020
Control
Stuttgart, Germany
www.control-messe.de

May 06 – 08, 2020
AKL 20
Aachen, Germany
www.lasercongress.org

May 12 – 14, 2020
CLEO
San Jose, CA, USA
www.cleoconference.org

May 12 – 14, 2020
Optatec
Frankfurt, Germany
www.optatec-messe.de

June, 16–18, 2020
SLT'20
Stuttgart, Germany

June, 16–18, 2020
LASYS
Stuttgart, Germany

New Date: July 3 – 5, 2020
LASER World of PHOTONICS CHINA
Shanghai, China
www.world-of-photonics-china.com

New Date: July 3 – 5, 2020
productronica China
Shanghai, China
productronica-china.com

At the editorial deadline, most or all events have been postponed or canceled due to the CoViD-19 situation.

Please check www.photonicsviews.com or the respective Web sites for updates.

Read event previews and reviews on www.photonicsviews.com/category/events/

To Herald the Benefits of the Optics and Photonics Industry, Research

Review: SPIE Photonics West, 1 – 6 February 2020, San Francisco, California, USA

Source: PhotonicsViews

More than 20,000 attendees packed San Francisco's Moscone Center at the world's largest photonics conference. Across one vibrant week, the SPIE Photonics West symposium, its BiOS, LASE, and OPTO symposia, and the inaugural AR/VR/MR conference boasted more than 1,300 exhibitors, 5,300 presentations, nearly sixty technical courses, and multiple industry-related special events.

From the glamorous Prism Awards honoring the top new optics and photonics products and the energizing Startup Challenge pitch competition, to the brand-new, industry-focused Venture Summit and the annual SPIE Job Fair, Photonics West showcased and recognized the best optics and photonics technologies, trends, and entrepreneurial opportunities. Latest research presentations – including a plenary by Nobel Laureate Eric Betzig – focused on both established and emerging areas, from sixty-year-old laser technology and advancements in biomedicine, to AI, lidar, and quantum.

As part of a larger professional development track, popular courses included "Optical Technologies and Architectures for VR/AR/MR and HMDs," and the brand-new "Modern Optical Measurements: An Introduction with Practical Applications." And, during a special event, SPIE and the University of Central Florida unveiled the 650,000-dollar SPIE-Glebov Family Optics and Photonics Graduate Scholarship Fund for the UCF's College of Optics and Photonics, the latest collaboration in the five-year, 2.5 million dollars SPIE Endowment Matching Program.

"We've had a super week both at BiOS and Photonics West this year," said M Squared CEO and Founder Graeme Malcolm. "I think the combination of those two shows is always a good barometer for the health of the industry, and we've had a really vibrant and inspiring week. We see a lot of areas underpinned by photonics really starting to come through - that's all the way from life sciences to chemical sensing to quantum. I think it's a really exciting time for our industry, and the show and the conference have really been a highlight of the start of this year, of 2020."

"The week has been incredible," noted Dan Ford, senior sales territory manager of MKS Instruments, Ophir Products.

Photonics West 2021 will take place 23-28 January at the Moscone Center in San Francisco. The call for papers for the 2021 event will open in early April.

www.spie.org

Successful Meeting of Future Industries

Review: W3+Fair, 26 – 27 February 2020, Wetzlar, Germany

With around 180 exhibitors and more than 2,800 trade visitors, W3+ 2020 attendance was slightly up on the previous year. 33 percent of the exhibitors came from Central Hesse, 46 percent from other regions of Germany and a further 21 percent from abroad.


Source: Fleet Events

The trade fair is particularly appreciated by exhibitors and trade visitors alike for its specialization in industry segments which, as overarching cross-sectional technologies, create the basis for competitive products and solutions. The main focus here is on the areas of medtech, life science, tools & machinery, automotive, aerospace and consumer electronics. Consequently, the core topics of optics, photonics, electronics and mechanics were combined for the first time this year under the guiding principle of "enabling technologies" that, either on their own or in combination with other technologies, generate significant leaps in user performance and capabilities.

This approach was also reflected in the newly designed N-Tec Talks program, in which renowned experts spoke on the key technological topics of medical technology, technology & management and production of the future. This first edition of the N-Tec Talks with 25 specialist presentations and a panel discussion was extremely well received.

Next year, the W3+ Fair Wetzlar will take place on Wednesday and Thursday, 24 – 25 February 2021.

Already this autumn, the second edition of the W3+ Fair Rhine Valley 2020 will open its doors in the four-nation region of Austria, Switzerland, Germany and Liechtenstein on 23 – 24 September 2020 in Dornbirn, Austria.

www.w3-messe.de

Preview: SLT 2020 – Stuttgart Laser Technology Forum

16 – 17 June 2020, Stuttgart, Germany

For the 11th time, highlights and innovations in industrial laser based manufacturing will bring together experts and users at the Stuttgart Laser Technology Forum (SLT).

The SLT 2020 conference is organized by the Institut für Strahlwerkzeuge (IFSW) of Stuttgart University, taking place in conjunction with the international trade fair for laser material processing (LASYS) at the trade fair center in Stuttgart, Germany.

Source: IFSW, U. Stuttgart

The latest developments in ultrafast laser beam sources will be highlighted along with the latest advances in their modulation and in fiber-based beam delivery, optical scanners, systems for massive parallel processing, and high-speed online process diagnostics. In the field of materials processing, you will see presentations on fascinating new applications that benefit from the high average powers of modern laser systems.

The mission of the SLT is to address laser technologies for materials processing in a fundamentally scientific and yet comprehensible manner, with a strong contribution by international and German research institutions, and to exemplify the scientific conclusions by presentations on corresponding industrial implementations.

The plenary speakers invited on 16 June are Dr. Christian Schmitz, Trumpf Lasertechnik GmbH, Prof. Constantin Häfner, Fraunhofer ILT Aachen and Winfried Kaiser, Carl Zeiss SMT GmbH. On 17 June Prof. Ludger Overmeyer, Leibniz Universität Hannover and Prof. Thomas Graf, IFSW, University of Stuttgart, will give their plenary talks.

The presentations will be held in English and German, with simultaneous translations for all talks.

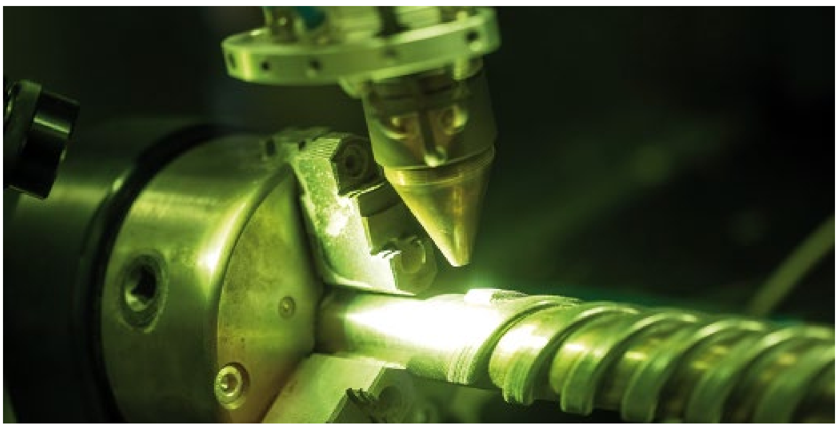
www.slt.uni-stuttgart.de

Preview: International Trade Fair for Laser Material Processing LASYS 2020

New Date: 21 – 23 June 2022, Stuttgart, Germany

Lasys, as the trade fair for laser material processing, is aimed at industrial users, and since 2008 has developed to become an absolute must-attend event for the sector. With its consistent focus on system solutions, Lasys clearly positions itself as a users' trade fair and presents laser material processing in all its facets.

Every two years, the combination of trade fair and top-quality accompanying events brings together the experts from industry and science in Stuttgart.



Source: Messe Stuttgart

Lasys will be taking place from 16 to 18 June 2020 at Messe Stuttgart and, as the only international trade fair to do so, will continue to focus on system solutions for laser material processing. Since the start of the trade fair in 2008, it has successfully established itself as a user platform for laser system solutions and applications. Lasys covers all industries and materials, and is primarily aimed at decision-makers from international industry.

Other industry fairs taking place at the same time will provide Lasys visitors with additional information. These include the Global Automotive Components and Suppliers Expo, the Engine Expo, the Automotive Interiors Expo, the Automotive Testing Expo, Surface Technology Germany and CastForge – the Trade Fair for Castings and Forgings with Processing.

www.lasys-messe.de

Preview: CHII 2020

27 – 28 May 2020, Graz, Austria

The Conference on Hyperspectral Imaging in Industry will take place in Graz, Austria. Internationally leading experts and users from all over the world will meet there for the fourth time to discuss the further developments and innovative application of hyperspectral image processing.

After the very successful CHII 2018 event, hyperspectral imaging pioneers Perception Park, Spectronet, the Styrian Business Promotion Agency and the Enterprise Europe Network are now organizing this technology conference for the fourth time: leading international experts and companies will be attending the conference to discuss the latest developments in this innovative technology.

The capabilities and the application opportunities of hyperspectral systems will be given more relevance than at previous events. CHII 2020 is organized to show hyperspectral imaging system developers the exciting opportunities of this technology and to convey ideas and experiences for their economic use. Important components of the conference are therefore numerous short presentations of successful applications as well as detailed presentations by leading technology providers. Those presentations will provide insight for interested visitors into the current state of the art as well as into future options for applications.

Accompanying the conference section, leading technology suppliers from around the world will exhibit their latest hyperspectral imaging developments and products. This second pillar of the event provides attendees with an ideal insight into existing components and solutions and offers plenty of room for discussion with experts from the respective manufacturers.

www.chii2020.com

Preview: EPHJ Trade Fair 2020

Postponed to 15 – 18 September 2020, Geneva, Switzerland

The next edition of the EPHJ trade fair, known as The World of High Precision, will again be held in the Palexpo halls in Geneva. With more than 800 exhibitors from five continents and 20,000 international trade visitors, the fair remains a unique event for high-precision technologies in watchmaking, jewellery, microtechnology and medtech. It is an eagerly awaited event where an entire industry presents its innovations and concrete improvements to existing technologies.

A common feature of all companies participating in the EPHJ fair is their excellence in high precision. This forms the basis for the synergies that are created each year between the diverse participants and the growing number of exhibitors (more than 350), indicating an increased interest in medical technology, a growing sector on a global scale.

Above all, EPHJ is known for its ability to facilitate new business relationships and the conclusion of new contracts for exhibitors. Every year, the vast majority of them say that they secured new B2B orders during the fair.

With its European business incubator, where start-ups can present themselves under extremely favourable conditions, the EPHJ fair also plays its role as an accelerator and innovator of new technologies to the full. The Grand Exhibitor Award and the Challenge Watch Medtech will again put companies in the spotlight that have convinced other companies and expert juries of the quality of their innovations. For this reason, nominees will be given ample space on the exhibition grounds.

www.ephj.ch

Preview: SENSOR+TEST 2020

23 – 25 June 2020, Nuremberg, Germany

Sensor+Test 2020 is well on its way with new conferences and new topics for an even more extensive innovation dialog.

At the annual press conference of the AMA Association for Sensors and Measurement in Nuremberg, fair organizer Holger Bödeker was able to give an overall cautiously positive outlook for this year's internationally leading trade fair for sensor, measuring, and testing technology. And that despite deteriorated circumstances.

The fair depicts the entire technical system competence for measuring, testing, and monitoring tasks in all industries – from simple sensors to sophisticated evaluations. According to Bödeker, the 2020 show holds its own surprisingly well. "Hall 1 is completely booked out and halls 2 and 3C are quickly filling up. Currently we expect more than 500 exhibitors from 30 countries, who will take up over 7,500 square meters of floor space. So, this event hasn't lost a bit of its attraction even in this difficult year." And again, the share of exhibitors from abroad will be up to almost 40 %, confirming the fair's status as the leading international trade fair in its field.

The comprehensive support program in 2020 again includes top-notch forums at two trade fair halls. Bödeker commented, "The quality of the submissions is very high thanks to the assessment by a board of experts." So, interested parties can already look forward to a very attractive program. The forums are complemented by a Career Center, the new high-carat conference with the SMSI 2020 – Sensor and Measurement Science International, and the ettc2020 European Test and Telemetry Conference in Hall 2, the most important international platform for telemetry, telecontrol, test instrumentation, and data processing.

www.sensor-test.de

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