LIA TODAY

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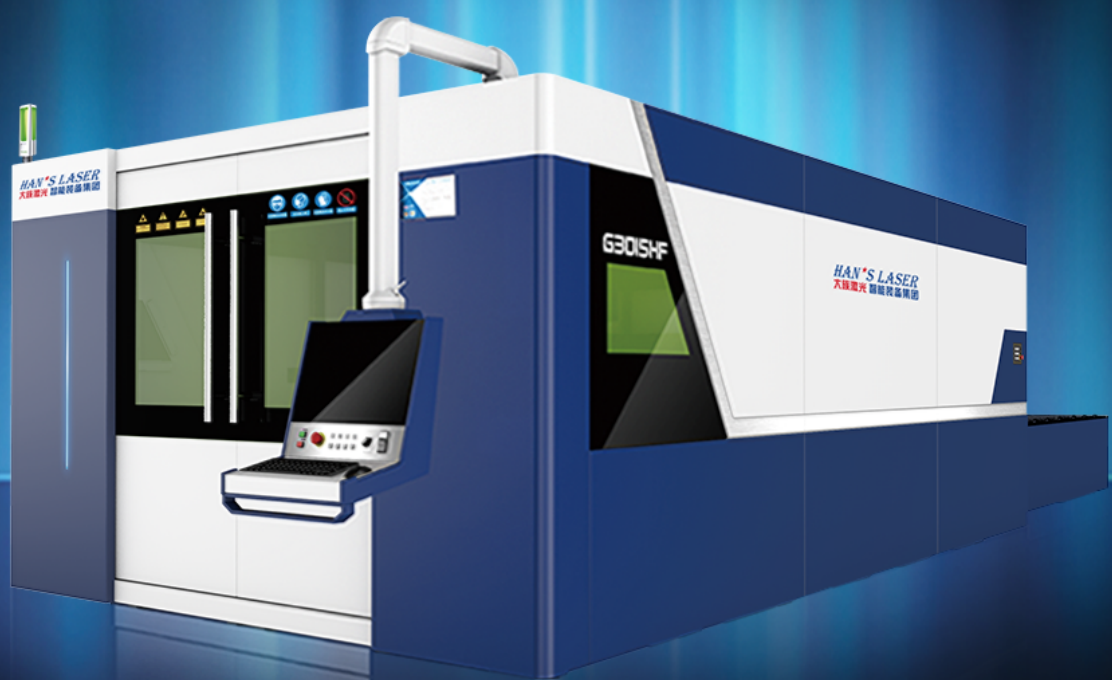

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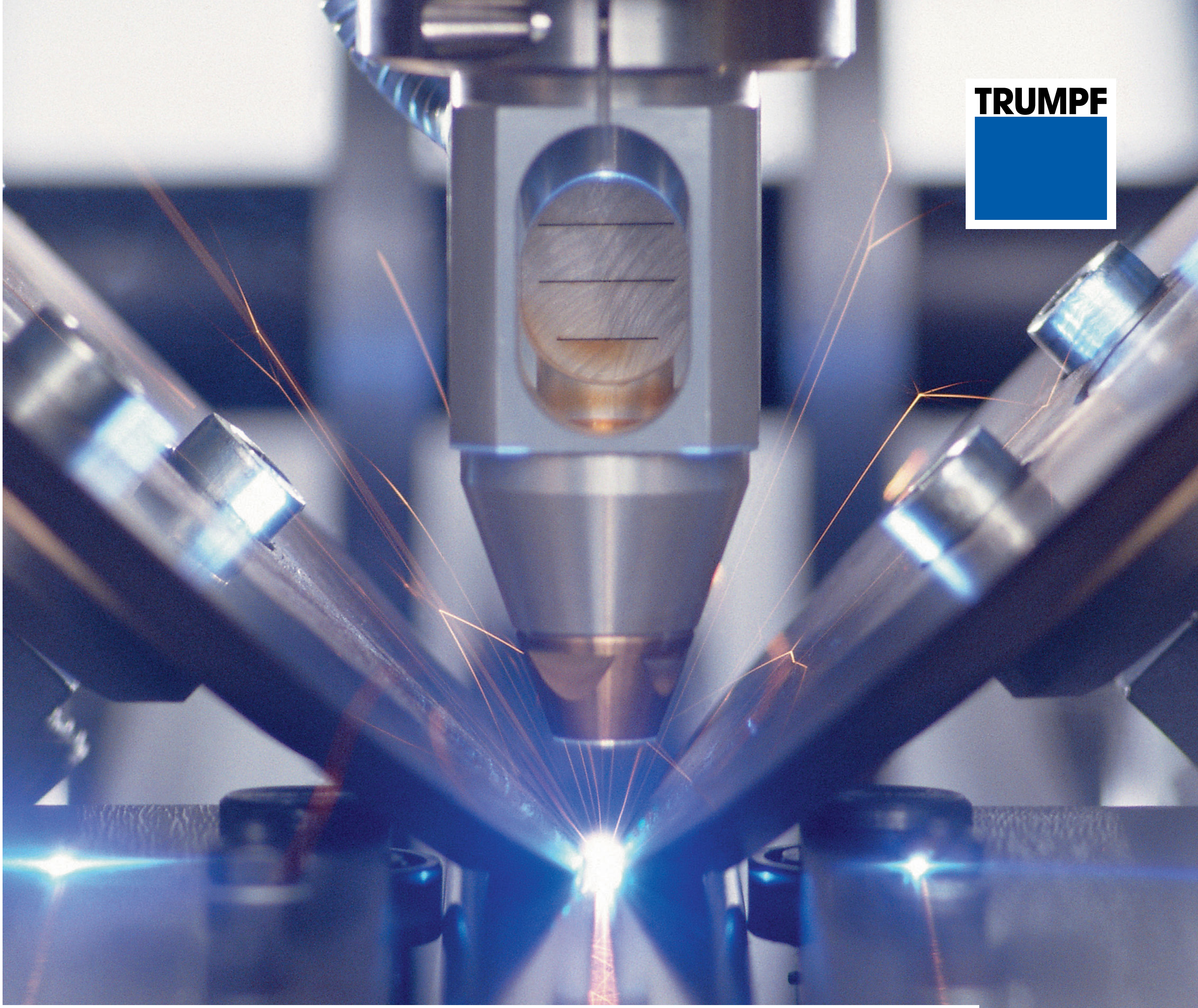
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Conference Highlight

ICALEO®
37th INTERNATIONAL CONGRESS ON APPLICATIONS OF LASERS & ELECTRO-OPTICS

ORLANDO, FL

Laser industry professionals from academic and industrial settings will gather to discuss the latest in laser additive manufacturing (LAM), laser materials macroprocessing, laser materials microprocessing and laser nanomanufacturing. Topics range from the interaction between a laser beam and a material to how a process can be integrated and optimized for an application.

ICALEO 2019 will feature presentations that focus on cutting-edge research in these technology areas for high impact applications in the following industry sectors:

OCT 7 2019	OCT 8, 2019	OCT 9, 2019	OCT 10, 2019
AEROSPACE	MEDICAL DEVICES & LIFE SCIENCES	MICROELECTRONICS	AUTOMOTIVE

LIA Laser Safety Trainings

LASER SAFETY OFFICER TRAINING

Orlando, FL ** BLS Certified Laser Safety Officer Exam offered after the course.* — Oct. 30 - Nov. 1, 2019

LASER SAFETY OFFICER WITH HAZARD ANALYSIS TRAINING

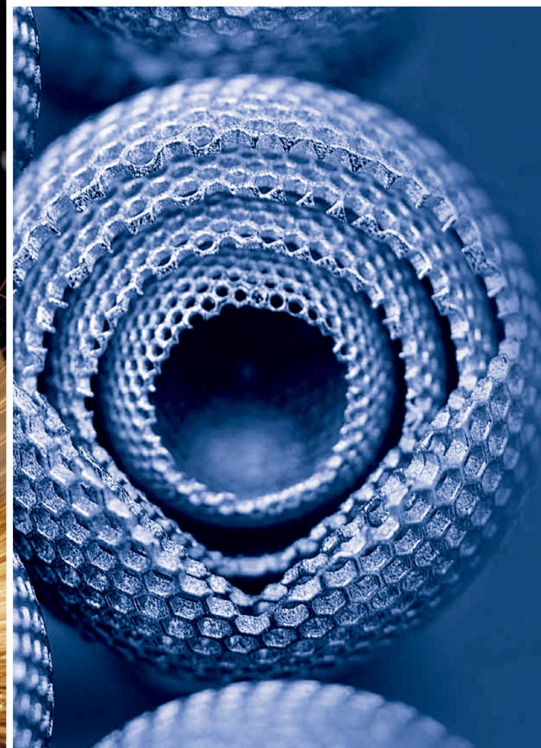
Orlando, FL — Nov. 4 - 8, 2019

INDUSTRIAL LASER SAFETY OFFICER TRAINING

Novi, MI — Nov. 4 - 8, 2019

MEDICAL LASER SAFETY OFFICER TRAINING

New York, NY — Sep. 28 - 29, 2019
Orlando, FL — Nov. 2 - 3, 2019



PRESIDENT'S MESSAGE

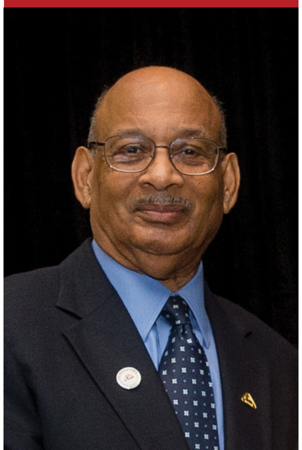
Minlin Zhong
LIA President

Every autumn since 1981, LIA has hosted the International Congress on Applications of Lasers & Electro-Optics (ICALEO), the largest premier conference of its kind in the western hemisphere. This year, the 38^{th} ICALEO runs October 7-10, 2019 in Orlando Florida. LIA modified its conference format to enhance the attendee experience and improve ROI for sponsors and exhibitors. ICALEO 2019 will feature four industry-specific conferences that will become the core focus of each day: Aerospace, Medical Devices & Life Sciences, Microelectronics, and Automotive. This improved conference structure will build on the traditions of the technical conference while driving commercial value. ICALEO's technical conference and workshops will be subdivided into five technical tracks: LAM, Battery Systems and Energy Conversion, Micro, Macro, and Nano. These tracks will highlight laser technology advancements within the four covered industries. Leaders and experts from the field of laser material interaction will be presenting cutting-edge results of their research in these technology spheres for high impact applications. In addition, ICALEO 2019 runs a unique parallel business conference and tradeshow, revolving around innovative photonics materials processing solutions. At this year's awards banquet, LIA will present the 2019 Arthur L. Schawlow Award, the William M. Steen Award and the Theodore H. Maiman Award.

After last year's record-breaking attendance representing twenty-three countries, we have already received impressive paper submissions this year, so let's enjoy another marvelous ICALEO. Welcome to ICALEO 2019!

Watch the ICALEO Promo. Click Below to be Redirected to YouTube.

EXECUTIVE DIRECTOR'S MESSAGE



Nat Quick
Executive Director

ICALEO 2019 is rapidly approaching.

This year's conference has been redesigned to better bridge the gap between educational institutions and industry. We are introducing industry specific foci, and organizing technical presentations from five tracks (laser additive manufacturing, laser macroprocessing, laser microprocessing, laser nanomanufacturing and battery systems/energy conversion) that provide technical content directed to these industries. Four industrial sectors; aerospace, biotech, microelectronics, and automotive will be highlighted by a dedicated trade show. The intent is to be more user-focused. We are also introducing new business features such as market driver symposiums and panel discussions that encourage dialogue between industrial end-users and academia to solve and address core problems that require collaboration between industry and research. This type of forum exposes researchers and students to the needs of industry while exposing industry to the capabilities of academic research institutions.

LIA is a vanguard for disseminating information on cutting-edge laser-materials processing technologies and providing forums for exploring their applications. Our conferences, workshops and media allow a preliminary review and analysis of these innovations by industry experts. Our laser safety training courses allay concerns about the hazards of using lasers. These services make LIA relevant to the progression of laser materials processing and its applications.

This year we will be introducing the William M. Steen Award, which will be annually conferred by LIA to user organizations that demonstrate significant innovation in the use of lasers for advanced materials processing in several industrial sectors. The award finalists and recipients will present their innovations during the Market Driver Symposium or Live Users Solutions Forum. The Theodore H.Maiman Award will be annually conferred by LIA to the Steen Award Recipient that demonstrates the highest achievement in advancing laser materials processing technology.

We look forward to seeing you October 7-10 in Orlando. Enjoy renewing old friendships and developing new acquaintances to expand your network.

Surface Functionalization with LIPSS Continues to Expand into New Industries

Interview by Liliana Caldero

Camilo Florian - Baron will be presenting his team's research at ICALEO 2019

Laser researchers from Bundesanstalt für Materialforschung und -prüfung (BAM) have teamed up with medical researchers from Johannes Kepler Universität Linz (JKU) and Kepler Universitätsklinikum Linz (KUK) in a European research project to show the potential of laser materials processing for suppressing the adhesion of human cells to titanium alloy implants such as miniature pacemakers. This is only one of many research projects investigating the potential uses of surface functionalization. With the use of lasers, technical surfaces can be structured at nano- and micro-scales to mimic textures found in nature, copying the unique characteristics that make them hydrophobic, anti-bacterial, or anti-reflective; this is known as surface functionalization. In most cases, this type of processing reduces or even removes the need for certain chemical coatings.

The field of laser-based surface functionalization is expanding rapidly and new potential applications abound; this technology offers innovative solutions for biotechnology, automotive manufacturing, and machine building. As with most new solutions, the big question is how to make it fast and scalable to promote industry-wide adoption

According to Camilo Florian-Baron of BAM, the trick is using linearly polarized high-intensity ultrashort laser pulses to create laser-induced periodic surface structures, or LIPSS, which can produce these desirable biomimetic properties. With advancements in fast laser scanning heads and recent high-repetition rate ultra-short pulsed femtosecond lasers, surface functionalization with LIPSS is becoming more available for R&D and manufacturing. Florian-Baron and his research team are investigating the future of LIPSS applications. With more than 50 publications on LIPSS coming from BAM in the past decade, the group is among the leading institutions progressing the understanding of the interaction between ultrashort laser pulses and matter for micro- and nano-fabrication of materials[1]. Florian-Baron will be presenting at ICALEO 2019 on the latest applications of surface functionalization through LIPSS. He shared with LIA about some of the unexplored potential of this emerging field and some of the interesting projects his team has been honored to work on

CFB: Usually, materials processing at industrial scales with lasers requires the scanning of the sample of interest with tightly focused laser beams or sweeping the beam on a static sample surface. It means that the micro- and nanofabrication over large areas could take a long time due to the need of irradiating line-by-line or spot-by-spot until the desired machining process is completed. In contrast, laser-induced periodic surface structures (LIPSS) can be fabricated on virtually any material when irradiated with linearly polarized high-intensity ultrashort laser pulses, typically under loosely focusing conditions (large beam spots). The morphology of LIPSS corresponds to parallel arranged period lines featuring periods that can be controlled between only ~100 nm and a few micrometers. Their orientation is strongly influenced by the laser beam polarization used. It means that it is possible, for example, to produce nanometric spaced lines all perpendicular to the laser polarization with a laser beam size at the irradiated surface that is 1000 times bigger than their periodicity covering a larger area with nanostructures faster than conventional laser-direct writing. In an additive approach, these surface nanostructures can be easily superimposed to other surface microstructures, resulting in hybrid surface structures with multiscale surface roughnesses. Through all these surface topographies, along with accompanying laser-induced chemical alterations at the surface, different surface functionalizations can be realized, ranging from structural colorization or antireflective properties (as on certain butterflies), over a control of surface hydrophilicity/-phobicity (as on lotus leaves), and toward unidirectional liquid transport (as realized by moisture-harvesting lizards or bark bugs).

Techniques based on lasers could be defined as contactless digital manufacturing techniques, currently constituting a real industrial-

> **Techniques based on lasers could be defined as contactless digital manufacturing techniques, currently constituting a real industrial revolution that is transforming the production processes from the early stages of research and development to mass production and marketing**

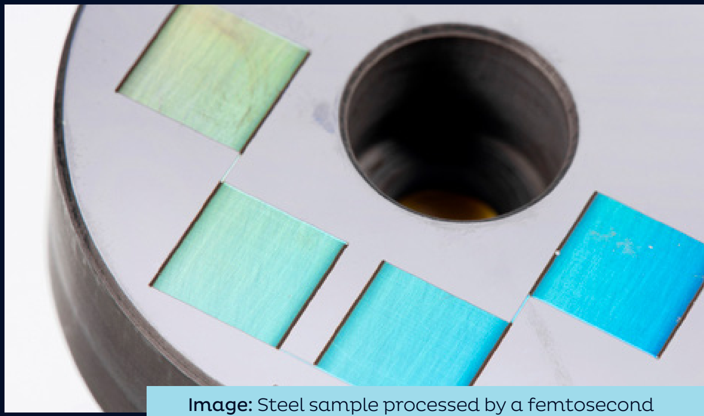


Image: Steel sample processed by a femtosecond laser. The colour effects of the four fields result from the diffraction of the ambient light by the laser-induced periodic nanostructures on the surface. *Source: BAM, Division Nanomaterial Technologies*

revolution that is transforming the production processes from the early stages of research and development to mass production and marketing [2]. The biggest difference in comparison with other fabrication methods is the possibility to perform design changes using only mouse clicks instead of modifying an already fabricated prototype, resulting in a faster, cheaper and more efficient way of materials processing. Besides that, the current advancements in fast laser scanning heads, combined with high-repetition rate femtosecond lasers allow producing LIPSS at industrially relevant scales and processing speeds, which in the end will be translated into cheaper fabrication costs at higher production rates. Importantly, the whole fabrication process is compatible and reproducible at room temperature and air atmosphere, which is very attractive to most industries that work under similar conditions.

LIA: Your research team has been investigating the mechanisms responsible for the formation of LIPSS to better understand how and when those structures can be formed; what are some of the exciting applications you are researching?

CFB: Our research group is specialized in developing strategies based on lasers to understand the mechanisms of interaction between ultrashort laser pulses and matter, to micro- and nanofabricate materials for specific applications.

Last year, we successfully finished a 3-year international research project funded by the European Commission called LiNaBioFluid [3] where one of the goals was to produce LIPSS on industrially relevant materials and scales to decrease the friction coefficient in tribological applications, as well as developing strategies based on LIPSS for passive fluid transport applications, including commercial lubricants, all based in biomimicking structures found in nature.

Image: Surface functionalization can mimic textures found in nature to reproduce specific properties. A popular texture to study is that of the lotus leaf, which is self-cleaning and hydrophobic.

As a continuation of this project, currently we are working in another European project called CellFreeImplant [4] (see the link below) that uses LIPSS to avoid unwanted cell growth on medical devices, such as smart medical implants. The promising results are at present in the hands of our medical project partners with close collaborations with a large pacemaker manufacturer to potentially take this laser-based approach for so-called 'leadless' pacemakers to real patients in the future.

One of the most exciting feelings when researching LIPSS is that the variety of the current applications are spread over different technological areas. On one hand, this allows us to learn more about the real producer and manufacturer problems, while at the same time solving them in an efficient way. On the other hand, and personally, with the research that we are currently doing at BAM, I feel that I am not only achieving milestones in a research project to fulfill it, I think that one day the research, time and resources we are investing could be applied in this particular case to real medical devices that any person can benefit from. In the end, the feeling is that with our tiny steps, we are making the world a better place.

LIA: With all that is being done already, what additional research would you like to see happen in this field?

CFB: Currently, the understanding of the formation dynamics achieved by the growing community of scientists researching LIPSS have allowed the development of different applications in different and diverse fields. However, due to the many different and specific conditions needed to fabricate them, a general model that includes all the possible experimental outcomes in the different materials is not available yet. More efforts should be focused on developing more complete models that will provide a deeper understanding of the formation mechanisms and laser-matter interaction dynamics that give rise to LIPSS structures. Consequently, with more understanding of the mechanisms involved, novel and innovative applications could emerge.

There are several areas where LIPSS could be useful but currently are barely explored, such as the case of catalytic and self-cleaning surfaces, antireflective treatments based on nanostructures instead of organic or inorganic coatings and perhaps bacterial or antibacterial surfaces for food manufacturing or applications in medicine [1,4,5].

From a practical point of view, the production speed of LIPSS is currently further boosted up by several research groups in Germany, France and Spain, featuring novel scanner technologies based on polygon scanners, along with high repetition rate ultrashort laser sources reaching MHz to GHz pulse repetition rates.

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6. **https://doi.org/10.1016/j.apsusc.2017.02.174**

8 OCTOBER

"*Surface Functionalization by Laser-Induced Periodic Surface Structures*"

Authors:

Camilo Florian-Baron, Sabrina V. Kirner, örg Krüger, Jörn Bonse

ABSTRACT

In recent years, the improved understanding of the formation of laser-induced periodic surface structures (LIPSS) has led to an emerging variety of applications that modify the optical, mechanical and chemical properties of many materials. Such structures strongly depend on the laser beam polarization and are formed usually after irradiation with ultrashort linearly polarized laser pulses. The most accepted explanation for the origin of the structures is based on the interference of the incident laser radiation with electromagnetic surface waves that propagate or scatter at the surface of the irradiated materials. This leads to an intensity modulation that is finally responsible for the selective ablation in the form of parallel structures with periods ranging from hundreds of nanometers up to some micrometers. The versatility when forming such structures is based on the high reproducibility with different wavelength, pulse duration and repetition rate laser sources, customized micro- and nanometric spatial resolutions, and the compatibility with industrially relevant processing speeds when combined with fast scanning devices. In this contribution, we review the latest applications in the rapidly emerging field of surface functionalization through LIPSS, including biomimetic functionalities on fluid transport, control of the wetting properties, specific optical responses in technical materials, improvement of tribological performance on metallic surfaces and bacterial and cell growth for medical devices, among many others.

LASER NANOMANUFACTURING

ICALEO 2019

CONFERENCE TRACK

NANO Co-Chairs

Ya Cheng, PhD

Koji Sugioka

Owing to distinct advantages such as environmental friendliness, decent fabrication efficiency, wide coverage of materials, versality of processing types, and flexibility in terms of geometry, laser nanomanufacturing has emerged to become an efficient tool for producing both nanostructures and nanomaterials as spurred by the inexhaustible new findings in the sophisticated interaction of light fields with matter. The Laser Nanomanufacturing Conference at ICALEO 2019 is intended to provide deep insight into the latest achievements in the fields of laser nanofabrication and nanoengineering for creation of novel nanostructures and nanomaterials. The topics of the conference include two-photon polymerization, laser synthesis and treatment of nanomaterials, 3D micro/nanoprinting, interference nanopatterning, manipulated laser beam processing, and laser-induced surface nanostructuring, etc. The conference program for the three-day event consists of one keynote paper, 14 invited papers and 18 regular papers for a total of 33 oral presentations.

Some of the remarkable achievements in recent years in this vibrant field are highlighted as follows. The conference will begin with a keynote presentation given by Prof. John Fourkas from University of Maryland, who will discuss nanotexturing of various surfaces using laser nanofabrication for investigating cell behaviors. Another example of laser surface structuring is to realize large-scale ultralow-loss photonic integrated circuits on crystalline lithium niobate nano-membranes using femtosecond laser direct writing, which will be reported by Prof. Ya Cheng from Shanghai Institute of Optics and Fine Mechanics. Moving to 3D nanomanufacturing, Dr. Eva Blasco from Karlsruhe Institute of Technology will speak about the design and preparation of functional polymeric materials for 3D laser lithography, which is of vital importance for additive micro-/nano-printing application. The discussion on the laser nanomanufacturing of novel functional materials will be extended to hydrogel by Prof. Mitsuhiro Terakawa from Keio University. In particular, the physical and chemical properties of the hydrogel can be 3D tailored by laser irradiation, enabling formation of composite micro/nanostructures. The laser provides not only a tool for nanostructuring but also a means for manipulating micro/nanoscale objects, which is highly desirable in the future nanomanufacturing. Prof. Min Qiu from Westlake University will demonstrate how to tackle the formidable challenges on light-driven motions of microsized objects in nonliquid environments using tailored laser pulses.

Highlighted NANO Papers:

7 OCT	8 OCT	9 OCT
NANOTEXTURED SURFACES FOR STUDYING AND CONTROLLING CELLULAR BEHAVIOR	***ADVANCED MATERIALS FOR 3D LASER LITHOGRAPHY***	***LASER-DRIVEN MOTORS IN NONLIQUID ENVIRONMENTS***
MEDICAL DEVICES & LIFE SCIENCES	MICROELECTRONICS	MEDICAL DEVICES & LIFE SCIENCES
John Fourkas, *University of Maryland*	**Eva Blasco,** *Karlsruhe Institute of Technology*	**Min Qiu,** *VP of Research, Westlake University School of Engineering*

LASER MICROPROCESSING

CONFERENCE TRACK

In a new format for ICALEO 2019, laser microprocessing is one of the five technical conference tracks featuring the exciting and innovative work of researchers and scientists from around the globe. The laser microprocessing field is on a high growth trajectory with major contributions to advance mobile device manufacturing, semiconductor and microelectronics, and the bio-medical industry.
Laser microprocessing enables miniaturization and provides accuracy and precision needed not only to process today's materials, but to open doors to process the new, innovative materials of tomorrow. The conference will highlight and capture progress achieved in the field by new sources, efficient beam delivery systems, and innovative processing solutions.

Micro Co-Chairs

Florian Kiefer

Rajesh S. Patel, PhD

One of the things that jumped out at me this year is roughly 40% of the papers in the laser microprocessing conference are discussing ultrafast lasers and its various industrial applications. Ultrafast lasers are no longer the exotic novelty toys reserved for research and the scientific community. The improvement in power levels, reliability, and cost competitiveness over the last decade or so have made ultrafast lasers a real contender for many industrial micromachining applications. This year at ICALEO you will have an opportunity to learn about use of these lasers in aerospace, automotive, medical, and microelectronics applications along with other traditional lasers. The traditional pulsed laser sources of various wavelengths are continuing to make inroads in various applications and proving their benefits to accurately and precisely machine tiny features in various 24/7 industrial applications.

Highlighted Micro Papers:

8 OCT	9 OCT	9 OCT
ULTRAFAST LASER PROCESSING OF COMPOSITE MATERIALS	*PARALLEL PROCESSING WITH DYNAMIC BEAM SHAPING*	*ANTI-COUNTERFEITING MICROSTRUCTURES INDUCED BY ULTRASHORT LASER PULSES*
MEDICAL DEVICES & LIFE SCIENCES		
Tara Murphy, *NKT Photonics*	**Eric Mottay,** *Amplitude*	**Jing Qian,** *Shanghai Institute of Optics and Fine Mechanics*

LASER MACROPROCESSING CONFERENCE TRACK

ICALEO 2019

MACRO Co-Chairs

Robert Mueller, PhD, CLSO

Brian Victor

The ICALEO Laser Macroprocessing Conference draws attendees and presenters from around the world and from a wide range of process and application areas. This year, in addition to the usual topics of cutting and welding, we have papers on cladding, cleaning, drilling, hardening and shock peening. We will hear presentations on processing of light materials – aluminum, titanium, CFRP – for aerospace applications, heavy welding and cutting, including deep welding of stainless steel superconducting magnet cases for the ITER Tokamak. Between these extremes, many applications from the automotive industry will be presented.

There are two topic areas that have an unusually large number of papers this year: beam shaping and process monitoring. The papers in the beam shaping sessions mostly report on the process properties and capabilities of concentric multi-core fibers. Most of the presentations are from the fiber manufacturers, but the study from EWI, "Adjustable Mode Laser Welding Evaluation", will give us an independent view of the capabilities of these new laser delivery fibers.

The other area with a significant number of papers is process monitoring, with several papers reporting on the capabilities of optical coherence tomography (OCT) to observe keyhole depth and shape. This series of papers culminates with a look at the ultimate goal of process monitoring – real time process control, with a paper from Trumpf, "Smart production - On the way to autonomous laser processing".

Our collection of global speakers, presenting topics from aerospace, medical, electronics, and automotive markets, will provide fresh perspectives on trends in laser applications from around the world. Each year, it is always exciting to see innovative approaches to established manufacturing processes in addition to new applications enabled by lasers. This year's diverse list of novel methods and technologies will surely make for an interesting macroprocessing conference.

Highlighted MACRO Papers:

7 OCT	8 OCT	9 OCT
HIGH-SPEED X-RAY IMAGING OF THE LASER CUTTING PROCESS	*INLINE WELD IMAGING AND MONITORING WITH SCANNING OPTICS*	*SIMPLIFIED CALIBRATION OF LASER POWER METERS FOR IMPROVED MEASUREMENT ACCURACY USING RADIATION PRESSURE AND CALIBRATED MASSES*
Jannik Lind, *IFSW*	**Christopher Galbraith,** *IPG*	**Paul Williams,** *NIST*

LASER ADDITIVE MANUFACTURING (LAM)

CONFERENCE TRACK

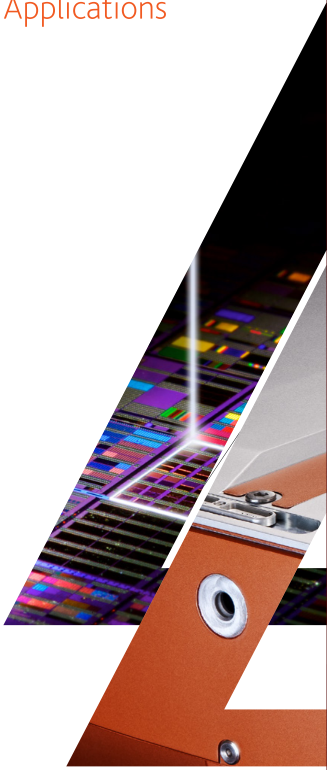
Under the new format for ICALEO, five tracks of technical specialization have been created, and based on the outpouring of interest within the community, one of these tracks is dedicated to the rich field of laser-based additive manufacturing technology under the Laser Additive Manufacturing (LAM) symposium. The symposium has attracted over 60 technical papers from around the world and will include 16 sessions conducted throughout the four days of ICALEO 2019.

The first day of the conference will highlight process technologies representing the two primary categories of additive manufacturing for metallic materials, powder bed fusion (PBF) and directed energy deposition (DED). Three sessions for each of these categories will extend throughout the day and discuss current trends and new research in PBF and DED technology. Several of the LAM presentations will address current challenges and the development of enabling technology for adoption of additive manufacturing within the aerospace industry, which is in keeping with the emphasis for the opening day of ICALEO.

Following the initial, comprehensive introduction of LAM processing technology, the second day of ICALEO will be devoted to aspects that are serving to further enhance and broaden the application of additive manufacturing of metallic systems. These sessions will include materials-related discussions specific to the needs of each process category, as well as a session devoted to the current research and application of advanced sensing technology for the PBF process. The second day will conclude with presentations having interest and relevance to a broad range of LAM processes, which will be captured in sessions on process modeling and post processing.

The LAM sessions planned for days three and four are dedicated to the development and use of specialized materials, processes, and diagnostics for unique applications of laser-based additive manufacturing. The rapidly growing field of hybrid processing, as it related to a wide range of process combinations, will be discussed, along with a session on development and characterization of emerging materials for laser-based additive manufacturing. The final session of LAM, Special Topics, was developed to display the synergy and complementary nature of laser-based additive manufacturing within the broader laser and materials processing community.

With the addition of the Laser Additive Manufacturing symposium, ICALEO 2019 promises to be a very special event. It will include one of the most comprehensive meeting of world leaders within the field of laser-based additive manufacturing with one of the world's premier laser materials processing conferences. ICALEO 2019 may indeed be this year's focal point for additive manufacturing within the United States based on the opportunity to assess the global landscape in laser additive manufacturing, coupled with the opportunity for dialogue with international leaders within the field.



Highlighted LAM Papers:

7 OCT	7 OCT	10 OCT
METAL DEPOSITION FOR INDUSTRY ADOPTION	***MONITORING OF POROSITY DURING ADDITIVE MANUFACTURING AND LASER WELDING***	***HYBRID ADDITIVE MANUFACTURING (AM) FOR LARGE FORMAT BLADE APPLICATIONS***
AUTOMOTIVE	MEDICAL DEVICES & LIFE SCIENCES	
Grace Tay, *A*STAR Advanced Remanufacturing and Technology Centre*	**Yung Shin,** *Purdue University*	**Peter Coutts,** *Pennsylvania State University Applied Research Laboratory Laser*

LAM Co-Chairs

Edward W. Reutzel, PhD

Richard P. Martukanitz, PhD

ICALEO 2019

BATTERY SYSTEMS CONFERENCE TRACK

ICALEO 2019

Battery Chair

Stan Ream

The revolution in battery and electrification applications is influencing every segment of our world. New, high-power, long-lasting, rechargeable batteries are powering everything from cell phones to locomotives, plus many stops along the way for items like drones, scooters, cars, boats, homes, satellites, renewable back-up power, and on, and on. This truly represents a revolution in electric power and "E-Mobility". Lasers are rapidly becoming the favored tool for addressing many materials processing applications in the new world of electrification. Battery tabs, buss bars, enclosures, interconnects, and even the batteries themselves are all candidates for laser processing. And, while much of the detailed design and development activity is shrouded in an IP cloud, the laser process developers in this track are able to present important new tools to address well-known challenges. Laser welding, cutting, and surface modification techniques are all contributing to the performance, reliability, and affordability of E-Mobility products.

The most recognized laser welding challenge in the battery and electrification arena is that presented by the inherent reflectivity and conductivity of inconsistent copper surfaces. The convenient 1 um, near-infrared, laser wavelength is particularly challenged by this behavior. Now, shorter wavelength lasers in the blue and green have become industrially viable for copper welding.

Another well-known issue among the battery welding challenges is the unfriendly metallurgy of typical aluminum to copper weld joints. This metal combination is frequently found in tab to buss welding. The specific metallurgical challenge is the formation of brittle intermetallics in the alloying of aluminum and copper that occurs during laser welding of the two metals. Brittle and frequently cracked welds can lead to poor conductivity, weak mechanical strength, poor fatigue performance, and enhanced corrosion. Laser welding solutions that can minimize this intermetallic formation are vital.

In addition to the multitude of laser applications for actual assembly welding of battery tabs, interconnects, bus bars, and enclosures, other enhancements to the fundamental battery performance are also being addressed by laser modification of the electrode surfaces. These emerging laser surface modifications are providing improvements to battery charging time and performance and are likely to have a profound impact on electrification in general.

Highlighted Battery Papers:

10 OCT

LASER APPLICATIONS IN AUTOMOTIVE BATTERY POWERTRAIN PRODUCTION

AUTOMOTIVE

Leonid Lev, *IPG*

10 OCT

KW-CLASS LASER WELDING WITH BEAM SOURCES IN THE VISIBLE WAVELENGTH AREA

AUTOMOTIVE

Tim Hesse, *TRUMPF*

10 OCT

PAVING THE WAY FOR INDUSTRIAL ULTRAFAST LASER STRUCTURING OF LITHIUM-ION BATTERY ELECTRODES BY INCREASING THE SCANNING ACCURACY

AUTOMOTIVE

Jan Bernd Habedank, *Technical University of Munich*

AUTOMOTIVE

Goodbye Adhesives, Hello Thermal Direct Joining

– Laser Pre-Treatment and the Future of Hybrid Materials

Interview by Liliana Caldero

Dominic Woitun will be presenting his team's research at ICALEO 2019!

Throughout the world, scientists are rising to the challenge of developing new techniques to improve the eco-friendliness of products and production lines. Germany has been among the strongest supporters of the movement to be more environmentally responsible. Innovations resulting from this momentum may lead to more efficient manufacturing, which could ultimately cut costs without compromising quality. Hybrid materials are growing in importance in the search for strong, lightweight materials that produce fewer CO_2 emissions. Dominic Woitun of the German-based Bosch is among the researchers investigating techniques for effective thermal direct joining of hybrid materials. Joining dissimilar materials such as metals and plastics can pose a challenge; this challenge is often solved with the use of adhesives or screws with sealants. Adhesives may work, but according to Woitun, they leave a larger carbon footprint. This is where thermal direct joining comes in. The process that Woitun is researching involves using laser ablation to shape macroscopic structures into a metal surface; the structures are then penetrated with a molten polymer which enables mechanical fastening, for instance. After solidification, a strong joint is obtained, which replaces the need for an adhesive. The shapes, or geometries, created by the laser play an important role in the strength and reliability of the joint, so better understanding the relationship between these geometries and the resulting joint will help make this a viable alternative to adhesives. Woitun shared with LIA TODAY why he started researching the impact of laser geometries on thermal direct joining of hybrid materials, and why companies could consider this an answer to adhesives.

LIA: For some in our community, the term 'thermal joining' brings to mind laser welding of metals; for those who are new to the concept of thermal direct joining of hybrid materials, could you describe what this process can look like, step-by-step?

DW: Thermal direct joining is a joining technique for metals and polymers. The adhesive forces of a thermoplastic melt to metals is used to join both partners. No additional adhesive is needed. However, to achieve strong joints, some form of surface pretreatment is needed. Laser structuring is a promising approach.

The process steps to a finished part could look like this:

1. Preparation: prior surface treatment (e.g. by laser ablation)

2. Joining: Many different techniques are possible! The only premise is a somehow molten polymer in the joining interface that can penetrate the structure. This can be achieved, for example, by heating the metal part with some kind of heat source and then pressing it onto the plastic part. Or, in my case, by using injection molding and overflowing the metal part with molten polymer in the molding tool.

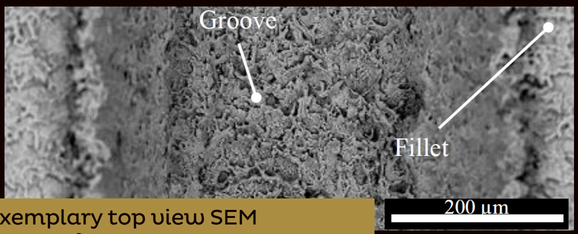
3. Finishing: the molten polymer solidifies instantly and directly after joining the joint has almost its final strength.

LIA: Tell us about what drove you to research thermal direct joining?

DW: In order to meet today's requirements for weight reduction and thus emission reduction, hybrid components are becoming increasingly important. Especially in the context of electrification. One main challenge for the production readiness of hybrid composites is the joining technology. Currently, hybrid parts are often joined by adhesives or screws in combination with sealants. Therefore, the interfaces need to be handled with special care and must be cleaned before joining. After joining, the parts need a certain curing time before they can be further processed. When it comes to recycling, there is almost no way to separate the often used and recyclable thermoplastic material from the duroplastic adhesives. This makes the current solutions time-consuming and costly.

LIA: What are you researching right now and how does it help to solve these challenges?

DW: Direct joining of metals and polymers based on a laser-pretreatment bypasses these problems and produces strong and media tight joints directly after the joining process. However, the enormous variety of laser sources, in combination with their adjustable parameters, open up endless possibilities for structures on the metal surface. This often ends in time-consuming empirical studies to find the best settings for one specific use case. That's why I'm investigating the influence of largely separated surface characteristics on the joint properties by generating well-defined structures on the metal surface by laser ablation. My aim is to find the best weighting and composition of surface characteristics to define the optimal structure for an application.



Exemplary top view SEM image of a groove

LIA: What benefits could companies gain from utilizing direct joining?

DW: If direct joining would replace adhesives, it would mean re-planning our production lines. Manufacturing chains could be shortened and combined because the components can be manufactured, joined and further processed in-line.

LIA: What further research is needed in this area?

DW: Fully describing the interdependencies in the boundary layer of the metal-polymer joint exclusively with experimental research will be difficult. For this reason, we are currently working on a multiscale simulation approach to gain better understanding of the interdependencies. One main challenge is to transfer the effects of different surface characteristics (microscale) to strength predictions at component level (macroscale).

LIA: What could this research mean for the future?

DW: Direct joining in general allows redesigning joints in comparison to adhesive bonds. If, in addition, the capability of the joint can be predicted, manufacturing processes can be optimized and the confidence in those joints will be increased.

8 OCTOBER

"*Precise Laser Structures as a Tool to Understand Metal-Polymer Joints*"

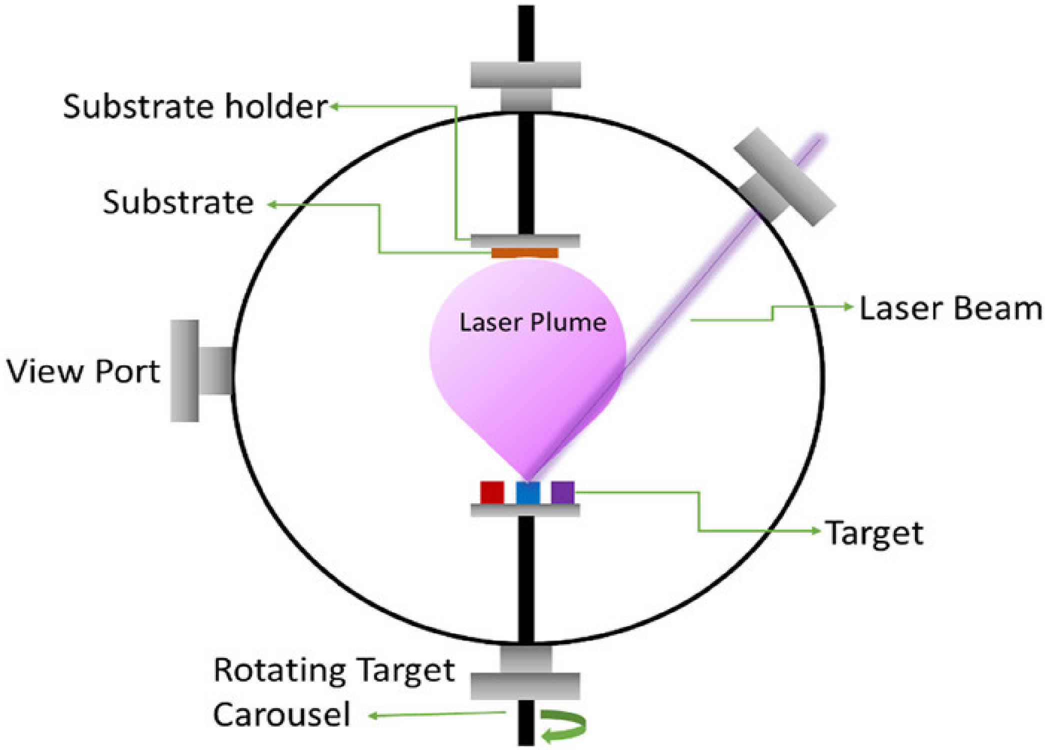
Authors:

Dominic Woitun, Michael Roderus, Thilo Bein, Elmar Kroner

ABSTRACT

Direct joining of metals and polymers is a promising approach for today's challenges in joining technology due to fast cycling time, its robustness and the absence of duroplastic adhesives. Laser pretreatment of the metallic surface has been proven to enhance joint strength and has become a popular method for joining hybrid components. However, the versatility of the laser process allows the generation of endless variations in structure geometry. Such structures possess various geometric characteristics like depth, width, density, and orientation, which all influence joint strength.

Precise laser structuring of aluminum by ns-pulsed laser radiation was utilized to gain a deep understanding of the correlation between structure geometry characteristics and joint strength. After laser pretreating the metallic surface the parts were subsequently joined with a thermoplastic polymer by injection molding. We were able to distinguish between the effect of surface enlargement and structure geometry effects, as well as directionality and arrangement of the structures on the specimen. Although we did not focus on producing joints with high shear strength, some specimen exceeded 12 MPa during lap shear testing. The results are a further step towards advanced joint design for thermal direct joining and their application.



APPLICATION OF LASERS

IN THE SYNTHESIS AND PROCESSING OF TWO-DIMENSIONAL QUANTUM MATERIALS

By: Zabihollah Ahmadi, Baha Yakupoglu, Nurul Azam, Salah Elafandi, and Masoud Mahjouri-Samani

Abstract: Recently, two-dimensional (2D) quantum materials and particularly transition metal dichalcogenides have emerged as an exciting class of atomically thin materials that possess extraordinary optoelectronic and photonic properties. The strong light interactions with these materials not only govern their fascinating behavior but can also be used as versatile synthesis and processing tools to precisely tailor their structures and properties. This review highlights the recent progress in laser-based approaches for synthesis and processing of 2D materials that are often challenging via conventional methods. In the synthesis section, the review covers the pulsed laser deposition as the main growth method due to its ability to form and deliver atoms, clusters, or nanoparticles for the growth of 2D materials and thin films with controlled stoichiometry, number of layers, crystallite size, and growth location. It is also shown that the tunable kinetic energy of the atoms in the laser plume is essential for healing defects and doping of 2D layers. In the processing section, the review highlights the application of lasers in crystallization, sintering, direct writing, thinning, doping, and conversion of 2D materials. The spatial and temporal tunability, controlled energy, and power densities of laser beams enable a broad spectrum of applications in the synthesis and processing of 2D quantum materials that are not accessible by other means.

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Laser World of Photonics – Munich

By: Dr. Ronald D. Schaeffer

"One of the largest, most exciting, and vibrant trade shows for the laser industry was held during the week of June 23rd in at the Munich Messe, and I once again had the pleasure of participating."

Aix-la-Chapelle

I visited Aachen the week before the Munich event to check in with the Fraunhofer ILT folks and also I had other business in the area (see my article in this issue regarding SLE processing). Aachen (also known as Aix-la-Chapelle or "Bad Aachen" because of the hot springs) is a beautiful, medieval college town located at the intersection of Holland, Belgium, and Germany. It is the ancient capital of Charlemagne (or Charles der Gross as he is known in Germany) and has been a thriving community since at least Roman times, and probably before, because of its natural hot springs. It boasts one of the oldest cathedrals in Europe and has been known for centuries as a center of knowledge and free thinking. This and its geographical location make it a perfect place for centers of higher education. During our stay we were witness to a Friday afternoon protest concerning global warming. Aachen has had consecutive years of increasingly record hot weather and it is a big concern in both the political arena and in the hearts and minds of Aachen's youth. This particular march drew over 20,000 people, mostly teenagers and young adults. 'Green' technology is not just a fad or something to be taken in passing as most of us in the US do, but it is real and urgent for most Europeans. The Munich laser event had numerous activities devoted to the subject of efficient energy use and climate control.

A Brilliant Career

Let's talk about ILT (Institute for Laser Technology). The Aachen campus has at least three Universities and I think three different Fraunhofer Institutes, all intertwined with local high tech businesses and spin-offs from the labs. Most of the laser activity was built up during the tenure of Prof. Dr. Reinhart Poprawe, who has been head of the Institute as well as University Professor for many years. Prof. Poprawe is a Schawlow award winner, past LIA president, journal editor and avid supporter of LIA and is well known to anyone who has attended any LIA events in the past. Thanks to his great commitment, Fraunhofer ILT, with its associated chairs, is regarded as Europe's largest institute for applied laser research and contract process development for industry.

The spectrum of Fraunhofer ILT innovations in the Poprawe era ranges from the development of the Innoslab lasers and the first diode-pumped multi-kW solid-state lasers for industrial applications, to the development and use of high-power ultrafast lasers, all the way to process and system development for laser powder bed fusion (LPBF) and extreme high-speed laser material deposition (EHLA). All of these award-winning innovations have been developed by highly motivated engineers and scientists, to whom Prof. Poprawe offered extreme creative freedom along with an outstanding infrastructure and a conducive institute culture. On average, a patent was filed at Fraunhofer ILT every three to four weeks during the decades of his work. Over the course of 20 years, around 30 companies were founded, which Prof. Poprawe actively supported with his networks during the critical initial phase. During his tenure, the number of employees at Fraunhofer ILT, the associated chairs and the photonics cluster grew from 250 to around 800. In the meantime, an area of around 30,000 square meters is available for R&D activities.

On Sunday night, at the start of the Munich laser show, there was a Symposium and retirement party for Prof. Dr. Poprawe. His many years of activity in the laser industry are well documented and his many awards are impressive to say the least. He is a true pioneer in the photonics industry and the attendees were almost a "Who's Who?" of the laser industry. The institute he built is a lasting testimony to him and his successor will have a strong base on which to continue to build. The big question now is.. Who will his successor be? Rumors abound and I think we will find out soon! I may have some inside information that I cannot share, but if my sources are correct I think the new ILT era will be very 'bright' indeed.

Back to the Show – Munich Messe

Now – the show. This year, almost 1,325 exhibitors (up from 1,293 in 2017) vendors participated in one of five halls at the Trade Center, with more than 34,000 total attendees – up from 32,700. There were 3,661 technical talks and poster presentations. Once again, over 60% of both the exhibitors and attendees were from outside Germany and the number of visitors from the US and Asia in particular increased this year. I do not have the final metrics yet, but in 2017 the US was sixth in the number of attendees, behind Switzerland and Japan, and I hope that the final numbers will show more US participation than they have in the past.

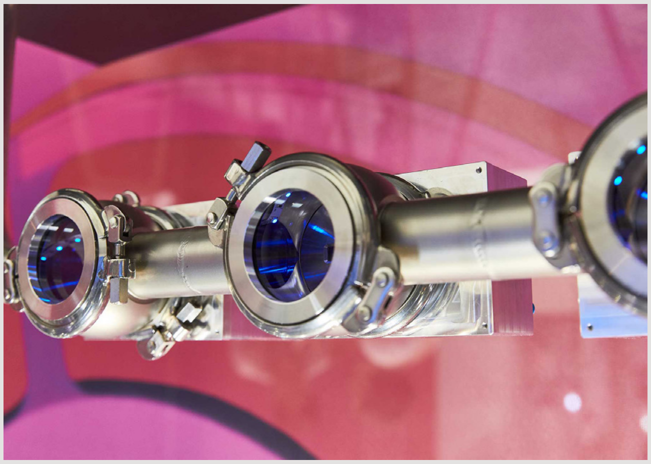
Except for the record heat, the event was great as usual with lots of things to see during the day and lots to do after hours – tons of booth parties, beer parties, wine parties and just ... well, parties! -The Messe organizers have an interesting way of doing things in that after 5 pm (and sometimes before!) dozens of booths break out the booze and – as long as you are already in the venue – you can stay pretty much until midnight drinking, eating and carousing (oops – I mean doing business). However, at 5 pm when the entry doors are closed, the air conditioning also gets turned off – what little there was in the first place, so free booze aside you are pretty much driven out of the Messe on a hot day – not that you will find air conditioning in too many other places in Munich. There are some excellent live bands on the show floor after 5 pm and elements of the Beer's Law Band did a gig at the Hotel Mariandl, a downtown Munich beer pub, on Wednesday night. - Come to the opening reception at ICALEO to see the Beer's Law Band in action!

The Messe is divided into the congress and the trade fair, meaning technical talks and vendor booths. Top-level topics such as electromobility and sustainability ('Green' topics) were as much the focus of the trade fair as new methods in medicine, which are made possible by modern biophotonics. The parallel congress was once again a meeting place for the international science elite with lectures by Nobel Prize winner Gérard Mourou, gravitational physicist Carsten Danzmann, quantum physicist Anton Zeilinger and other renowned scientists.

Fiber lasers were dominant on the show floor with dozens of companies offering their own brand. Blue diodes also were prominent, maybe more so than ever in the past, and USP lasers, both picosecond and femtosecond lasers, were everywhere. In fact, there is not enough time even with four days to see and investigate everything, so this year I pretty much concentrated on USP lasers, optics and systems vendors to the exclusion of most everything else, as I am in the process of collecting information for an upcoming webinar and a follow-up article in Industrial Laser Solutions.

Changes in the Photonics Industry

Two years ago, I was impressed with the stock rise of two companies in particular – Coherent and IPG (part of the Billion Dollar Club which also includes Trumpf and Hans Laser and – depending on your definition – Lumentum and II-VI), which together make up a substantial portion of the whole laser industry. Both companies had large booths this year, but there is definitely a change in the industry and the stocks of both companies show this. Coherent stock is about half of what it was shortly after the 2017 Munich laser show and IPG's stock has fallen about 40% from the high of about the same time. A significant part of Coherent's revenue still comes from Excimer laser processing and displays, both of which are difficult to navigate as evidenced by the lack of competition; mostly because of the scale of getting to the high power levels and excellent beam uniformity needed. There will be changes at Coherent, at least within the next couple years, as long time CEO, Dr. John Ambroseo will be retiring as soon as a replacement is found and trained. "In fact, I was standing in the Coherent booth with about a half-dozen old colleagues – all set to retire within the next two years – and we estimated we had about 200 years of laser experience between us, all of us being in the industry 30 or more years." OK – this is a challenge to the 'younger' folks, to step up into the industry and take your turn at making it grow.



I thought it was a task to review all of the USP laser companies, but it would be a real task to try to tabulate all of the companies now offering fiber lasers of every kind from very low to very high power. The fiber market is still growing, but the profusion of new, smaller companies (many Chinese) and the slowdown of the Chinese market have contributed to the IPG stock decline. In years past, IPG probably had 80% of the fiber laser market and SPI 10-15% with all of the rest being included in the few percentage points left. I would estimate IPG to be the largest supplier of fiber lasers still, but their market share has seriously eroded due to competition. The fiber laser, especially at low power, is now a commodity.

On the other hand, USP laser companies are not only proliferating, but the larger and more active players are still growing in revenue. The companies I mentioned two years ago are all still very active (for example, Amplitude, Light Conversion, Ekspla, Lumentum, Coherent, Spectra Physics) and there are many new players. Light Conversion had a 25th Anniversary party on Monday night – this is a company with a great success story. They have chosen to remain independent, despite many attempts by 'bigger fish' to eat the little fish over the years. After 25 years of running the company, Dr. Algirdas Juozapavičius has assigned the helm to Dr. Martynas Barkauskas. Light Conversion has been awarded various business trophies over the years and in 2018 alone the company earned two innovation awards: a national one from the Lithuanian Innovation Centre, and an international prize from the Baltic Assembly and the Baltic Association of Science/Technology Parks and Innovation Centres. In fact, none other than Nobel Laureate, Prof. Mourou commented that Lithuanians deserve the Nobel Prize for their work!

I have been concentrating on the laser itself, but this show is not just about the 'light bulb', but about all the other supporting things needed to make the light do work. It seems to be in general agreement that the laser itself is not the end-all and it is very important to have the right optics, beam delivery, and systems integration (as well as the applications knowledge of how to use them). So, I concentrated on talking to the USP laser companies I know, meeting new companies getting into the market and also talking to a lot of optics and systems suppliers. All of this is for information to be used in my upcoming webinar and follow- up article!

There were a large number of papers in the technical session, which I did not attend due to the fact that I was on the show floor every moment. In particular, Prof. Mourou's talk was one of the highlights and was standing room only – not wanting to compare myself with such a distinguished person, but it feels like 'one of us' won the Nobel prize. Finally, the Germans in particular promote scientific inquiry by giving out innovation awards and also a special start-up award for new businesses.

Before the show, I sent out approximately 100 requests for information to companies that are making either USP lasers, optics for USP lasers, USP laser based processing systems and contract manufacturers (job shops!) for feedback to be used in my webinar and in a more detailed follow up article for ILS in January. I have received feedback from many people and I met more people and new companies in Munich, but I am sure that I have missed many players.

So, … if you are involved in USP laser processing and we have not talked, then please contact me at the address below to be included in this data base!

As I have said before, I feel blessed to be in such a growing, interesting, and dynamic industry. I am sure that once again I missed many cool things at the show, so please feel free to contact me with anything to share, and in particular anything involving USP lasers and laser processing.

I am already looking forward to the next Munich Laser show, but the next big venue is the LIA's own ICALEO conference which will be held this year in Orlando during the week of 6 October. This year, the conference will have a number of changes including industry specific days and a four-day trade show. Please use the following link to sign up for ICALEO and don't miss this next important gathering of laser professionals.

ABOUT THE AUTHOR

Dr. Ronald D. Schaeffer is an LIA Fellow and Member of the LIA Today Editorial Board as well as the ILS Editorial Board. He is CEO of HH Photonics and has worked at other laser companies in the past including Spectra Physics, Coherent/ Lambda Physik, Laser Photonics, Resonetics and PhotoMachining (co-founder). He can be reached at: rschaeffer072657@gmail.com

How to Design Safe Laser Consumer Products

By: Erwin K. Lau, PhD,
Edward T. Fei, PhD

As more competitors enter into specific markets, it is vital to maintain a competitive edge. Typically, this edge can be held by maximizing system performance. In almost all cases for laser products, performance is proportional to laser hazard risk. For example, primary performance specifications often involve brightness or sensing distance or signal-to-noise ratio (SNR) which require higher optical emission power, which often increases hazard risk. An example of this is the sensing range of a depth-perception laser illuminator system. Ultimately, the maximum sensing range is limited to the maximum safe laser emission. In many cases, maximum power would need to be reduced in order to meet laser safety requirements. Therefore, failure to consider laser safety as part of the initial product development stages may result in compromises made in performance specifications.

Conscientious and deliberate design of the laser system with a deep understanding of laser safety in mind often will allow for different design tweaks that can lead to a safer design without compromise of performance. For example, in the depth-perception illuminator system described above, it may be possible to modify pulse width, repetition rate, spatial pulse pattern or a number of other parameters that may achieve the same risk mitigation without significant compromise in performance than a simple reduction of laser power/energy. Furthermore, it is vital to ensure variability in laser system manufacture as well as reliability in the field are not too great so as to significantly change the optical hazard risk of the device.

This article describes one such approach to integrating safe design as part of the product development lifecycle. The steps outlined in the flowchart in Fig. 1 represent one proposed method for integrating laser safety into the product development lifecycle. Several of these steps were selected and described in further detail in the subsequent sections of this article. A more comprehensive review paper [1] describing all steps is available to the interested reader.

Laser Safety Design Classification

When a laser product is first conceived and the overall architecture for laser emission is being defined, product development teams typically focus on designing to meet the engineering requirement specifications (ERS). However, this stage is one of the most critical for designing with safety in mind as this is the stage where the most flexibility in changes to system architecture can be made.

Once a basic system architecture is defined, the nominal laser safety class can be determined.

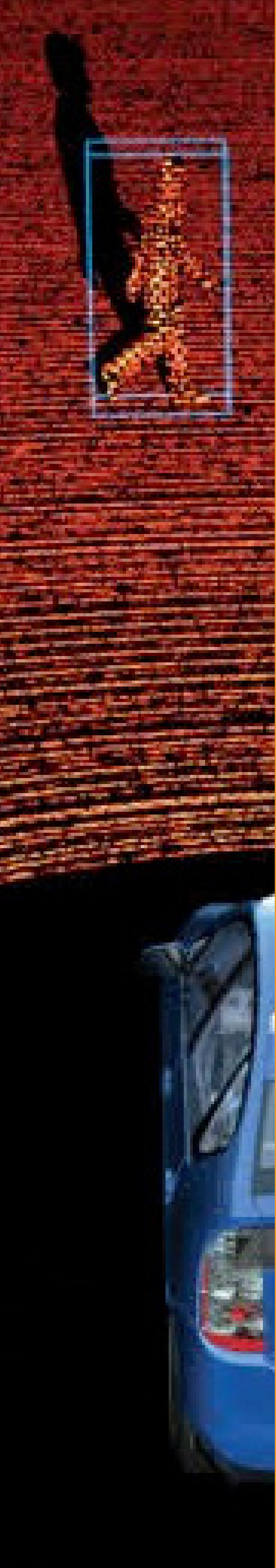
Depending on the complexity of the system, a raytracing model may be required to determine the worst-case points in the field-of-illumination (FOI). For a depth-perception laser illuminator, for example, it is often found that the most restrictive direction of illumination does not occur along the optical axis, but rather occurs at the corners or edge of the FOI, where the beam image is reduced by projection of the source at an oblique viewing angle, as well as more power is required to flood oblique angles in order to match performance at the optical axis.

Development of Laser Safety Risk Assessment

Once a nominal laser system is designed, the design of subsequent prototype builds is undertaken. At the build stage in which a prototype is desired to be operated in the presence of people where exposure is reasonable, whether for internal demonstration, application development purposes, user studies, or for mass production, a 1st-pass risk assessment should be performed.

Per IEC 60825-1:2014 (Edition 3) [2], Clause 4.3, "the evaluation [for classification] shall include consideration of any reasonably foreseeable single-fault condition during operation." To this purpose, a well-documented and thoughtful analysis of the various potential failure modes should be taken.

This risk assessment is also valuable to the design process, as this will typically inform what engineering safety systems need to be designed and implemented prior to release of the product. In addition, this risk assessment may be used to meet regulatory requirements, depending on the intended location of use and/or sale. For example, a risk assessment is a requirement for laser systems being classified per IEC 60825-1. A common and defensible method for performing a risk assessment is through a design failure mode and effects analysis (DFMEA).



Calculation of Required Response Times for Engineering Controls

For mass production laser devices, engineering controls should be implemented to mitigate risk in the case of a failure that increases optical hazard risk. Oftentimes, some of the specific failure modes would result in an increase in laser energy or power or a more focused beam. In these examples, the optical hazard risk may be increased. For a Class 1 laser product example, should the failure mode potentially result in the Class 1 PLR greater than 1 (i.e. the AE exceeds the Class 1 AEL and the laser is no longer Class 1), engineering control(s) should be implemented.

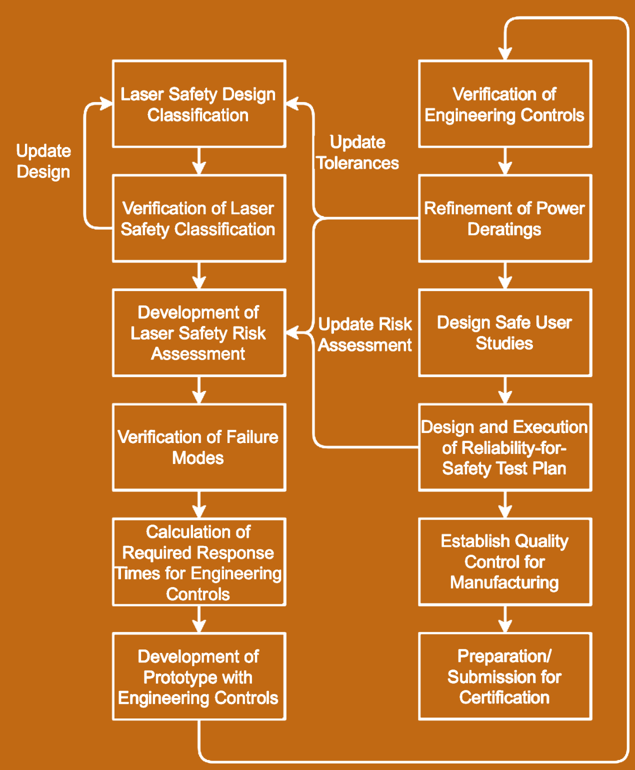
When engineering controls are being designed, the response time of the engineering control must be sufficiently fast enough so as to reduce the laser power enough so that the laser cannot exceed the designed nominal Classification (e.g. Class 1). A model of the failure mode must be constructed so that the increase to laser power can be determined and the time to exceed the Maximum Permissible Exposure (TEMPE) can be calculated. This defines the minimum response time required by the engineering control circuit in order to ensure the TEMPE is not exceeded before the safety response is enacted (e.g. the laser is shut off). Each failure mode that can potentially result in exceeding the nominal laser safety classification must be analysed in this way.

Refinement of Power Derating

It is rarely the case where it is desirable to set the nominal laser power such that the accessible emission equals the safety classification limit. This leaves no room for margin to account for manufacturing variations, variable environmental conditions during usage cases, and failures resulting in increased optical hazard risk. Therefore, a certain amount of power margin should be designed into the product. The design philosophy of how much margin is appropriate can be quantified by accounting for edge-case manufacturing variations and environmental conditions, as well as failure modes.

Oftentimes it is impossible to quantify all of these items a priori at the initial design stage. Experience, coupled with a utilization of available information, would be required to estimate the required margin at the initial design stage.

Fig. 1



Establish Quality Control for Manufacturing

It is common practice to perform 100% safety screening on devices during production or as part of a final assembly testing procedure. For complex laser products that emit laser energy into a wide, often 2-dimensional field-of-illumination (e.g. LIDAR and depth-perception illuminators), it is common practice to test that no point in the field-of illumination will emit light that exceeds the as-designed classification and also does not exceed the power limit pass/fail threshold defined in the "Refinement of Power Derating" section. This requires some test methodology that tests the entire FOI. Additionally, depending on variability of divergence angle or other factors, the beam image size would need to be analyzed as well. Class 3B skin hazard measurements may also be desired to be performed. The philosophy for what specifications to test for quality control are those that, given no testing, would require overly conservative assumptions that would result in an analysis that would cause the device to exceed its as-designed classification.

As an example, if the beam image is not measured, in the example of a depth-perception illuminator module, one should assume the worst-case (i.e. lowest divergence) emission from the laser module. This may result in an overly conservative subtended angle, a, that could constrain the performance of the laser. If your performance requirements are sufficiently low enough to make this approach acceptable, then the product is much simpler to test and qualify. However, if your desire is to release a more competitive (i.e. powerful) product, it is necessary to ensure product variability is low and ensure each device is tested to ensure safety of the consumer.

Conclusion

Design of a safe laser product should be considered at all stages of the product development lifecycle. If the manufacturer considers laser safety as an afterthought, their product may suffer unnecessary performance cuts as laser power is ostensibly the easiest item to be lowered in order to meet the requirements of international laser safety regulations. Alternatively, if quality control is not carefully tested, non-compliant or unsafe products may be released with consumer injury or product recall as potential outcomes. Careful consideration of laser safety as early as the initial design stage can allow for the optimization of performance without sacrificing safety. Furthermore, it is necessary to remember that international laser safety standards require consideration of manufacturing tolerances, edge-case usage conditions, and reasonability foreseeable failure modes as scenarios from which the as-designed laser safety classification must be robust against change.

ABOUT THE AUTHORS

Erwin K. Lau, PhD

Dr. Lau's expertise covers a wide range of technologies, including optics, optical devices, consumer electronics, medical devices, and prototyping. Dr. Lau assists clients with resolving complex issues relating to due diligence, failure analysis, intellectual property, and product design, safety, and risk assessment. He specializes in assisting clients in managing risk, regulatory compliance, design-for-safety, and reliability of laser-based consumer electronics. He has over 20 years of experience in the design, characterization, modeling and simulation of electronic, optoelectronic devices, and optical systems. Dr. Lau is a Certified Laser Safety Officer.

Edward T. Fei, PhD

Dr. Fei is an electrical engineer whose expertise covers the areas of optoelectronic devices, optical telecommunication systems and devices, and laser safety for consumer products. At Exponent, his work has focused on radiation safety analysis of LEDs and lasers for consumer electronics, failure modes of consumer electronics laser systems, and design of safety systems to limit optical hazard exposure in the event of device or system failures.

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LASER PIONEERS

Interview with James Pearson, Ph.D.

September 13, 2018

By Chrys Panayiotou, Ed.D.
Executive Director and Principal Investigator of LASER-TEC

James Pearson received his PhD in Electrical Engineering from California Institute of Technology, Pasadena, and is currently the Executive Director of the Florida Photonics Cluster. He started his studies in 1963, when the fervor for laser invention and discovery was unprecedented. His career in industry includes positions in Los Alamos Scientific Laboratory, Hughes Research Labs, and United Technologies among others. Since 1993 James worked for SPIE and ISA as executive director, and he is now holding the same position at the Florida Photonics Cluster. Dr. Pearson is a Fellow of both SPIE and the Optical Society of America and senior member of the IEEE.

I talked to Dr. Pearson about his personal experiences in the early days of the invention of the laser and his journey through the last 60 years of laser history.

CP: Please tell us about yourself, when and where you were born, and what the state of technology was at the time you were in high school, before you started your college studies.

JP: Well, I was born in 1944 in the town of Evanston, Illinois. I lived just north of what was then a small town called Kenilworth. I only lived there 2 years, so I don't really remember it. My parents were divorced when I was two. A few years later, I moved with my mother and my brother who is 8 years older than I am, to the little town in northeast Arkansas where my mother grew up called Leachville.

I was 5 years old at the time of our move to Leachville and the first year I was there we had no electricity, so it was a very interesting time. Then, about a year later, just before I entered first grade, we got electricity and a television. I just remember being fascinated, wondering what's all this TV and radio stuff that is going on now. I was just starting to learn a little bit about it and I was very interested.

Eventually, we ended up moving to Phoenix, Arizona. Except for one year, I was there from third grade through high school. I remember when I was just entering 8th grade in 1957, just before I went into high school in 1958, that there were people who were Ham Radio operators, and I thought that was really cool. Because I was really interested in radio at the time and electronics, I strung a wire across the top of our house and made a little diode key thing that I could use. Then I think that's what really got me fascinated about all the interesting things you can do with electronics.

When I was in high school, technology then was basically all electronics. They were making TVs a little larger; you could [also] tune into certain radio broadcasts, and I remember somebody that was at KLMA in Oklahoma that would bounce its signals off the ionosphere, and I could receive it in Phoenix because it was a station I liked to listen to.

So, I got fascinated with what I learned later was "electromagnetic radiation". But as I entered high school, I had no idea about "optics". I mean, optics were just eye glasses and the stuff in windows. I didn't even think about optics or anything like that before I was in high school.

CP: How did you find your way into the field of lasers and photonics? Was there a specific instance or event that made you decide to enter this field?

JP: I think there were a number of things, but I think the one that stands out is the announcement of the discovery of the Ruby laser by Ted Maiman in 1960.

I was either just ending my sophomore year or starting my junior, I don't remember exactly when in 1960 it was. I just remember being fascinated by the thought that, here was a laser: What was it? And what could you do with it? Maybe you could do something with electronics and some optics, somehow. I didn't really know.

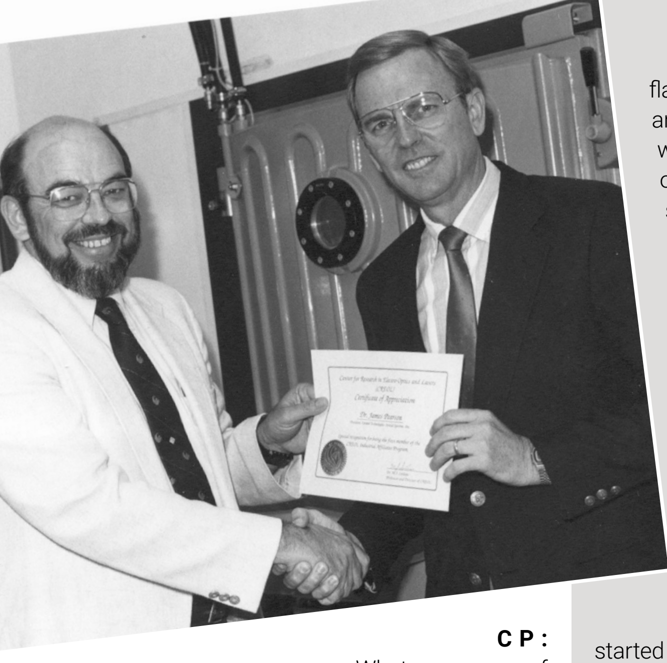
I think it was Ted Maiman who said, "the laser is a solution seeking a problem".

I think that comment was probably what convinced me that, if that opportunity presented itself, I'd like to learn more about lasers and optics and then study it when I went to college.

CP: What did you study in school to prepare you for a career in this field?

JP: Well, I've always enjoyed math, so I took any math course that I could take: science classes, physics, even courses in chemistry when I was in high school. And we had biology and other things like that, so I just wanted to learn as much about the different aspects of science as possible, in particular about physics.

Something else I found that I enjoyed, because I had some very good instructors and teachers, was taking what we call English. That was basically writing, reading, and trying to understand what the author was trying to present to you. That turned out to be very, very helpful and very useful in the future when I had to write technical papers.



CP: What areas of science were the most important to you in your career?

JP: Well, probably the first one that I can really remember, other than the general science kind of things you would take through eighth grade, was an electrical shop course in high school that taught the students how to make things. We had printed circuit boards where you took the components and plugged them in and then made different kinds of circuits, and then wired them all together. So, I would say electrical things, electronics, but also anything that started to tell me more about optics, and of course math. Not just algebra, but calculus and advanced calculus, and various aspects of that.

Anything related to photonics and lasers was very important. There wasn't a lot about that, even up through my college courses, other than reading on your own and looking at the new books that authors came out with, at least until I got into graduate school.

CP: Tell us about the state of the laser industry and education in the decades of 1970 – 90.

JP: I finished my graduate work in 1972, but even a little earlier than that, maybe the late 60s when I was an undergraduate, I remember working in a lab at Caltech where I was going to school. I was trying to align a laser, a $C0_2$ laser and make it work, and I thought I wasn't aligning it properly. A fellow named Milton Chang, who went on do a lot of wonderful things in our field, told me how he did it.

He showed me a laser that they had there. It was a helium neon laser that they had made. He said, "What you do is look down the barrel and you tweak the end mirror until the laser flashes in your eye." And I blinked at him and said, "You've gotta be kidding!". And well, this laser was about a microwatt of power or maybe a few microwatts, so it caused your eye to close quickly and obviously it wouldn't do any damage. But I learned how to do that and how to finally make a multi-gas $C0_2$ laser that would that would work properly. But of course, you can't see the infrared radiation from a CO_2 laser, so you didn't try to align that with your eye, other than with the helium neon or other beams you send down the CO_2 tube.

The 1970s were really moving into very high-power lasers, when the very high energy laser stuff started coming in. I actually got involved in that when they were doing work at Los Alamos on laser driven fusion, very early laser fusion stuff. Then later I was involved with what they called directed energy weapons, which initially were very high-power infrared $C0_2$ and chemical lasers, and eventually visible lasers, some of which were going to be spaceborne.

That's what I remember about that era, which continued on into the 1980s. What I remember, I'm going to forget the exact dates -- but, things were mostly gas lasers, solid-state lasers, crystalline lasers, neodymium YAG, ruby and things like that, and transverse-flow lasers. But then there started to be some more solid-state laser stuff and fiber optics started to become very important.

"I think it was Ted Maiman who said,

the laser is a solution seeking a problem."

I actually knew Carver Mead when I was at Caltech, along with my thesis advisor, Amnon Yariv, and their work on semiconductor lasers. Their research went from big gas lasers to making them smaller and operating them for more communications applications once the fiber optic stuff got built properly, and then to semiconductor lasers for communications. Now it just seems like everything is the 'optics-on-the-chip' kind of stuff that is still growing.

CP: As far as your profession, where did you start your career?

JP: My first job was when I graduated 1972 with my PhD. It was kind of a downturn in the economy and there weren't a lot of jobs available, so I ended up taking a job at Los Alamos to work on the high-power laser fusion stuff that was going on there. I really enjoyed that work. There was very, very interesting work going on and I got involved with that. I stayed there just long enough for my daughter to be born. Because my wife doesn't do well at high altitude and Los Alamos is at 7,200 feet, we ended up where I really wanted to work. It was the place where I had worked during some summers when I was in school -- Hughes Research Lab in Malibu, California. I got offered a job and moved back there and worked there for several years with some people I have stayed in touch with over the years. Bill Bridges was a guy that I got to know very well there. Bill is the discoverer of the argon ion laser. He has a great story to tell about how that worked, but I won't go into that. Then from there, again, a fellow contacted me who I had gotten to know at Hughes research labs and who had gone to United Technologies in Connecticut, but then had moved to West Palm Beach in Florida to start a laboratory there. We were competing with them at Hughes on some mirrors for very high-power laser operation. He called me up and wanted me to come and work for him down at the Florida location. I had been to south Florida once before, and I didn't think I'd like that at all. But my wife and I went down there and decided we liked it and moved down there and lived there for 15 years. I've had a very varied career in terms of the jobs I've had and the locations we've lived in.

We were working on very high-power laser stuff there in South Florida at United Technologies, at what later became United Technologies Optical Systems. When the Berlin Wall came down and stuff with Russia and the competition there subsided, the DoD funding for high-power laser technology was just cut off, and we had to shut the place down. So, I took a job as a Chief Scientist up at the United Technologies Research Center for a couple of years. The next opportunity I had was to join SPIE as their executive director. I had been actively involved with them for many years. I was first chair of what was initially called the Aerosense meeting early on in Orlando, it's moved around and is now named 'Defense+Commercial Sensing'; it's a rotating meeting today in terms of location.

CP: Tell us about the state of the laser industry and education in the decades of 1970 – 90.

JP: I don't know who really could foresee all the things that were going to happen, and all the applications that came about. I mean, the great research at the universities, including CREOL once it got set up in the mid-nineties, I think is much of what made that happen. But that's one of the things that has been fascinating about being a part of this community in technology. To see all the things that have been developed in terms of new laser devices, new ways to use those devices, whether it's very, very short pulse lasers and all the other laser stuff that is available now. I don't know who ever could have anticipated that. That is just some of what came out of the university work and turned into applications. I think great things about many of the universities that are involved with lasers, optics, and photonics., I'm most familiar with CREOL, and their ability and willingness to move this stuff on into applications, not just do the research, but take it into actual commercial development.

CP: Tell us about your time at SPIE and the role of the society in advancing the field of photonics.

JP: Well, I've been involved with SPIE for many years in a number of roles and I've been on their board of directors. The executive director, Joe Yaver, who took over from the founding executive director, set the stage and really made SPIE into what it has become over time.

I knew Joe Yaver quite well. When he decided to retire as the executive director of SPIE, he called me up and asked me if I'd be interested in the job. At first I thought, I don't know the first thing about all the stuff that society staff do such as organizing meetings, and doing publications, and everything like that. But he encouraged me, and I obviously ended up taking the job.

I think one of the great assets that SPIE had then, and has always had, is that Joe Yaver and I tried to continue some of the things that he had started. In particular, he would hire people because they were good at what they did and were interesting folks. And it was indeed a fantastic staff that I joined.

They were some of the best meeting organizers. One of the things that SPIE has always done, they conduct great meetings that bring together leading researchers and engineers on what are very timely subjects. Then they published the papers in what were originally paperback yellow books. In fact, there is a guy that didn't like it when we called them "yellow books" because they weren't peer reviewed papers. They were just presented at these meetings. But the chair of the conference, where those papers were presented, could reject a paper if they didn't think was written well or was inaccurate in some way. So, people wrote their papers well because they knew it was going to be out in the publication world, and literally distributed world-wide, very quickly, within a just a month or two after a meeting. That was one of the advantages for people who wanted to get their work out in front of others very quickly. And it went to an international audience. I found that this society was always very, what you might say, nimble and flexible in what they wanted to do. They would listen to their staff, as well as their many volunteers about what the hot topics were. Then they would create some sort of forum for that, whether it was a full conference or just a few papers in a meeting or whatever was needed.

New people coming into the field, and particularly those doing research, and young folks, could quickly get the results out to an international audience and start to get some recognition, start to get some visibility. And so, they put their highest value on information exchange and networking, connecting people and ideas all around the world and from all parts of the technical community. Not everybody was what you might call an *optics and photonics person*; they might be more on the mechanical side of things, or the application of the technology, or chemistry, or biology, whatever the application area might be.

So that was I think one of the great things that I loved about SPIE when I was there. We were able to grow the membership and revenues and we started a new peer review journal, *Journal of Biomedical Optics,* while I was there. They were having their big meeting out on the West Coast that was going on, it was called OE LASE and Biomedical Optics. I can't remember if it was the Republicans or Democrats, they took over the Convention Center because it was an election year and they were going to have their big event there, so, we then moved the meeting up to San Jose and started what today is Photonics West, now held in San Francisco.

> "To see all the things that have been developed in terms of new laser devices, new ways to use those devices, whether it's very, very short pulse lasers and all the other laser stuff that is available now, I don't know whoever could have anticipated that."

CP: In which area or sector of the economy were you the most surprised to see the use of lasers?

JP: Well that's a tough question, but I think the one that surprised me the most might be in the areas of medicine and surgery, and then the evolving imaging techniques that have come out of those applications. I remember one of the early things that we looked at and worked on, when I was with United Technologies in South Florida, was using lasers to weld blood vessels and nerves back together. One of our technicians that worked for us had an accident and had to go to a doctor and they mechanically stitched him up. The technician came back and said, I wonder if you could, instead of stitching it all up, do this welding with a laser?

And so, we got some funding and had some of the early demonstrations that it was possible, if it's done right, with the right kind of laser.

CP: Do you foresee the use of lasers in new fields of science or engineering?

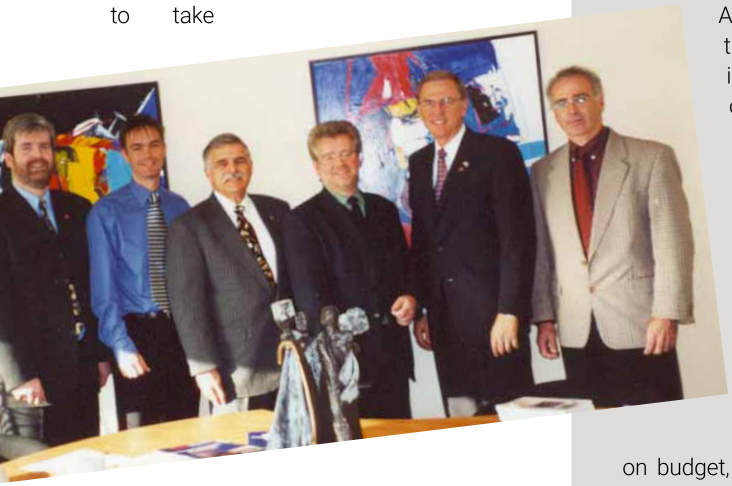
JP: Well, I think the answer to that is "yes". And I think we will continue to be surprised. What I have found is that almost every field of science and engineering, or every application area, utilizes some form of lasers. Whether that's in fabrication activities, or detection, creating different wavelengths, or causing something to fluoresce, or whatever it might be.

What those new fields will be and how they might use lasers and any other aspect of photonics technology, only time will tell us. But it will happen without question.

I always ask people, name me an application and I'll tell you how photonics is used in that, and probably lasers too. And so, I think that as time goes by, it's one of the reasons to be excited about this field, and it's one of the things I've enjoyed so much about being a part of this field. Lasers and optics, and all of photonics are constantly changing and you get to learn about them and hopefully even participate in the field in one way or another.

CP: What advice would you give to someone beginning college and unsure what to study?

JP: Well, once you get through the required courses that everybody has to take when you're in college, my advice is: even though those core courses may not be of the highest interest to you, make sure you're doing well at them, because they can be very valuable to you. People say, "Do I really have to take



that?" And the answer is: "Yes, you must for your degree". But try to find some courses that might be new and interesting to you. Maybe you might want to go into some area of chemistry, so, you obviously want to take some courses related to that topic. But look for things in biology, look for things in electrical engineering. Try to be as broad in your early years as possible and see what might get you excited or where you might see some opportunities or meet some interesting people. And try to attend meetings and talk to as many people in as many different areas as possible about what they do, and why they like it, and see where that information might lead you as you move forward in your education.

CP: What, in your opinion, are the keys to success for someone starting a career in lasers and photonics today?

JP: Well, one of the first things that comes to mind is to join and participate in at least one professional society. The Laser Institute is a great one for the laser field itself, and there are others as well, such as SPIE and the OSA. So find, join, and participate in at least one. And don't wait for somebody to ask you to volunteer for something. Maybe you can attend a meeting, or work on a committee. Try to meet as many people as possible. Get to know the field and who's doing what, and get to be known by people in the field. And when you have an opportunity, present a paper or an education course. Like I said, volunteer and try to participate as strongly as you can, I think that's a key.

And then I also advise people to try to learn as early as possible in your career, the subjects of economics and program management. One of the difficulties that I experienced when I was leading some photonics companies like United Technologies was hiring some very capable technical people who really knew the field, but they didn't know the first thing about making a schedule, keeping a schedule, keeping on budget, or how to budget for things. That's all part of program management. And a related part of that is make sure you are a team player. Make sure you can work well with other people. Even though you may not always agree with them, you have to be a team player to really be successful.

> "Once you stop learning you're probably going to be in trouble. Seek new technical knowledge and, as I mentioned, program management and economics. Don't limit your knowledge just to technical topics."

CP: Do you have anything you would like to add?

JP: I may have said this before: learn as much as you can and never stop learning. Once you stop learning you're probably going to be in trouble. Seek new technical knowledge and, as I mentioned, program management and economics. Don't limit your knowledge just to technical topics.

As other areas evolve, and new things come along, make sure you're involved with them as much as possible. And for those who are looking at a technician level job as the career path you want, I would advise you to seriously apply for the certification in photonics that ETA International offers. When you're trying

to seek new knowledge, continue to ask questions, try new things, get guidance from others that have been around for a while, or who may have done things that you wish you could do or want to do at some time in your career. That would be my advice.

CP: Dr. Pearson, thank you very much. We appreciate you giving us some of your valuable time for this interview.

About the Author

Dr. Chrysanthos Panayiotou is the Executive Director and Principal Investigator of LASER-TEC, a National Science Foundation Center of Excellence in Laser and Fiber Optics Education. He is also a professor and chair of the Electronics Engineering Technology Department at Indian River State College, Ft. Pierce, Florida.