LIA TODAY

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Battery tab welding using nanosecond laser welding . Image courtesy of Spi Lasers.

LIA™ 50 YEARS 1968–2018

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BUSINESS & TECHNICAL PLENARY SESSIONS	PLENARY SESSIONS	PLENARY SESSIONS	PLENARY SESSIONS	PLENARY SESSIONS
BUSINESS CONFERENCE	BUSINESS CONFERENCE	BUSINESS CONFERENCE	BUSINESS CONFERENCE	BUSINESS CONFERENCE

BUSINESS CONFERENCE

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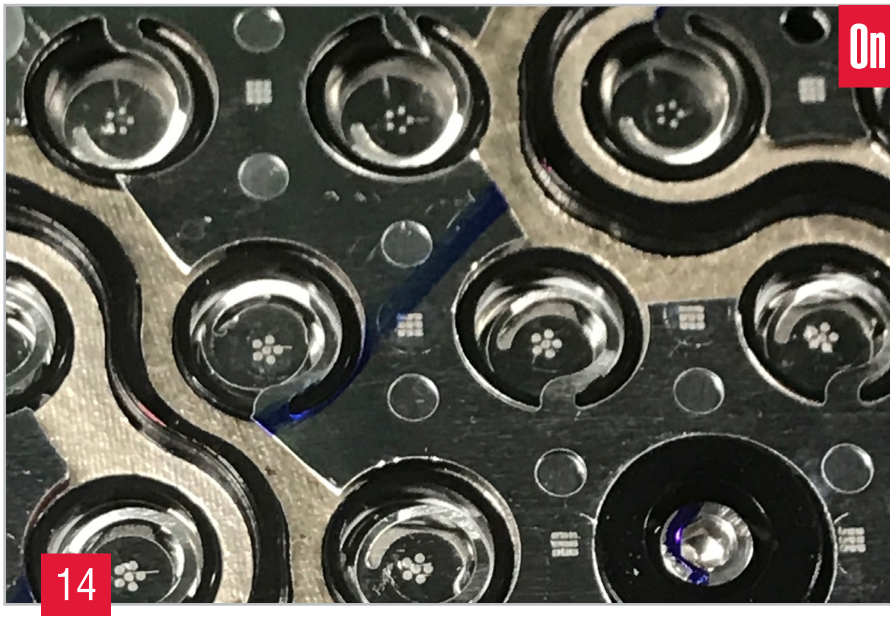
LIA TODAY
THE OFFICIAL NEWSLETTER OF LIA

LIA TODAY is published bimonthly to educate and inform students and professionals of challenges and innovations in the field of photonic materials processing.



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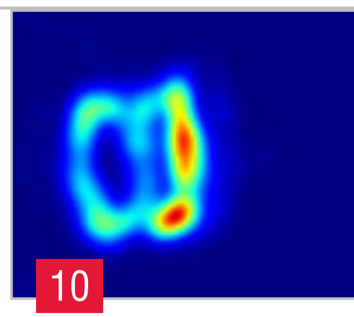

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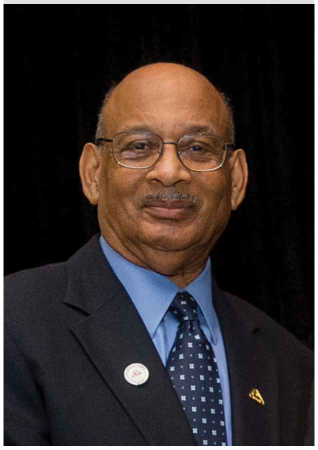
LIA PRESIDENT'S MESSAGE

We are living in a changing world. We have witnessed significant changes in 2018, covering political disputes, the trade war, Brexit, the refugee policy and the climate. All of these changes bring opportunities and challenges at the same time. So does the Laser Institute of America (LIA). When LIA celebrated its 50th anniversary in 2018, LIA also went through an impressive transformational journey, for better responding to the local and global changes, for providing more value to the members and for sustainable growth of the organization itself. ICALEO 2018, as one of these efforts and as a major and important activity of LIA, achieved remarkable success on the presentation quality, the numbers of attendees, sponsors and vendors and also the budget. According to the survey of ICALEO 2018 attendees on the quality of the conference, 20% found the overall quality of the conference to be excellent and 40% to be above average.

The year 2019 will be again a changing year; uncertainty could occur anywhere, anytime, about anything. However, one thing is certain, that we will make further efforts to enhance ICALEO. Many people know ICALEO before they know more about LIA. I myself attended my first ICALEO in 1996 when I was a PhD graduate student at Tsinghua University. I was so impressed by such a marvelous conference, which covered large research areas and cutting-edge advancements, hosted many recognized speakers, and provided such a lovely and friendly atmosphere. Since then, I attended many ICALEOs and ICALEO 2019 will be my 20th ICALEO. Meanwhile, I have been a part of LIA, contributed in my own way to LIA, and now am the person to deliver the LIA president messages this year. When LIA initiated ICALEO in 1982, it turned out to be the most recognized and important conference at that time in the world focusing on laser materials processing, laser application and laser safety. Even though there appear to be many conferences referring to laser materials processing in different countries nowadays, ICALEO is still a flagship conference with historic value, attractiveness and impact. We love ICALEO and we will continue to make ICALEO better.

Minlin Zhong
President

EXECUTIVE DIRECTOR'S MESSAGE



The International Laser Safety Conference (ILSC®) is one month away and we look forward to many presentations that describe the contributions of Industrial hygienists, EH&S professionals, health physicists, DoD & DOE researchers, laser safety officers (LSO) and medical laser safety officers (MLSO) to laser safety advancement. This year's ILSC brings back the FDA panel which was enthusiastically received at ILSC 2017. The Wilkening, Rockwell, and BLS Illumination awards will be presented and a new corporate LIA award, the Achievement of Laser Safety Education (ALSE) will be introduced. These awards are necessary to provide recognition and highlight the contributions of this community of experts which receives little publicity in the general technology community.

After reviewing the information on ILSC, I must ask myself, do I really understand the laser safety community and how it functions? After all, my background is in laser applications research. In preparation for ILSC, I asked Barbara Sams, Director of Standards Development , Publications, and the Board of Laser Safety, to prepare a crash course for me on the anatomy of the laser safety community.

I realize that I need to maintain a continuous learning process to keep abreast of developments in the world of laser safety. This is an objective of ILSC, to disseminate new information and to provide networking to advance the state of the community and to identify new opportunities for laser safety education. This is the base information required to develop plans for growth and increase participation in laser safety activities.

Some specific questions we are addressing include: how to grow the number of participants in the community, how to develop the next generation of laser safety instructors, how to attract young professionals to the profession, how to encourage employers toward supporting laser safety, and how do we usher more LSOs to active participation in the community?

Since its founding in 1968, members of LIA have been an integral part of the development of safety standards for the users of lasers. LIA continues to be dedicated to its laser safety roots and is looking to the future. Ideas to develop solutions for these questions include establishing a laser safety committee comprised, in part, of Board Members. Suggestions for growth and improvements are welcome; what can we do better?

Nat

Nat Quick
Executive Director

BLUE LASERS PUSH INTO NEW MATERIALS PROCESSING APPLICATIONS

By Jean-Michel Pelaprat,
CM & SO and Co-Founder NUBURU Inc.

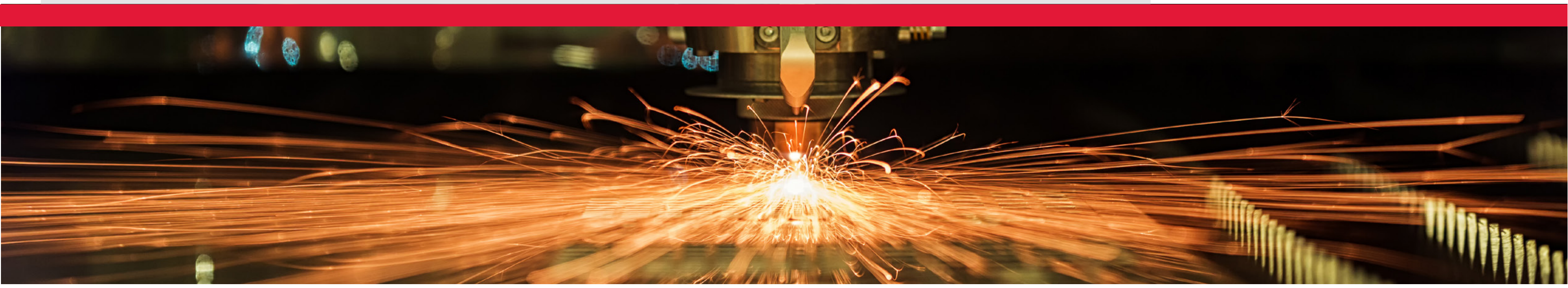
Materials processing continues to be a high-demand application for industrial lasers. The flexibility of laser welding provides unique advantages over alternative cutting, etching, and welding methods, but one challenge has proved difficult to overcome: welding “yellow metals.” Yellow metals — of which copper is the primary example — absorb infrared wavelengths poorly. This has led to the introduction of modified process protocols, such as “wobbling,” to try to get some functionality out of IR lasers in these applications, but even then efficiency is poor, joint quality is degraded, process time is increased — and capital equipment cost is quite substantial. In contrast, yellow metals absorb visible blue light much more efficiently. The physical advantage of higher absorption leads directly to significant performance improvements for such crucial applications as welding copper.

In 2017, NUBURU (Centennial, CO) introduced the 150 watt, 450 nm AO-150, first in a new class of disruptive high-power, high performance blue lasers ideal for these demanding applications. At the end of 2018, NUBURU added to the product line, releasing the AO-500, a high-brightness 500 watt blue laser that opens up an entirely new range of applications. The design of the AO-500 uses micro- and macro-optics to combine the beams from separate GaN diode laser modules into a single 400 µm core optical fiber. The 500 watts in that fiber provides high brightness in direct-delivery configurations, but high brightness is equally important with relay optics, where the initial beam parameter product limits the ultimate system performance.

The qualitative and quantitative advantages of blue laser copper welding are already bringing disruptive capabilities to bear on fabrication challenges for lithium batteries, consumer electronics, and automotive applications. The blue laser welds copper (and even some dissimilar metals) with unmatched speed and quality. The images in Figure 1a and 1b illustrate the entirely void- and spatter-free joints possible with blue laser welding. The blue laser is more flexible than ultrasonic and resistance welding and faster than infrared laser welding, and the weld quality is unsurpassed by any alternative technological approach. The higher power of the AO-500 expands the application space, opening up nontraditional possibilities, such as a 3X to 10X improvement in speed for selective laser sintering, a process where laser energy fuses metal powder into arbitrary shapes. The fundamental physical advantage of blue lasers introduces the opportunity to apply the flexibility of laser processing to an entirely new range of applications.

CORPORATE MEMBER

MOTION AND LASER CONTROL INTEGRATION IS VITAL TO PRECISION PROCESSING ADVANCEMENTS



By William S. Land, *Business Development Manager at Aerotech, Inc.*

Laser technology is one of the most versatile and valuable tools within modern industrial manufacturing. The fastest growing areas of industrial laser usage involve high-precision processing and sensitive materials. The newest laser technologies find use when manufacturing many consumer electronic components, drilling microscopic holes in car engine parts, machining medical implants, and in additive manufacturing at the micro- and even the nano-scale, to name a few. Industries finding value in high-precision laser processing differ widely, but share a common application attribute – success in laser processing requires a greater understanding and control of the laser-material interaction than in traditional macro-material processing like sheet-metal laser cutting. One must understand the interaction to control it, and then must control the interaction to affect processing outcomes at the micro-scale.

The need for more precise control of laser-material interactions forces a paradigm shift in how laser processing parameters are defined within the control systems of high-precision laser machines. Contemporary systems explicitly control simple parameters like pulse repetition rate, average laser power, and/or pulse energy through the laser source control system. To progress, these high-precision applications must begin defining parameters like average fluency, power density, and other richer more meaningful process parameters that can be directly tied to material interaction regimes. However, connecting simple laser parameters to rich process parameters requires knowledge of the laser motion across the part. The changes in a laser spot's speed and acceleration, required for processing accuracy and throughput optimization, drastically impact process parameters if the laser parameters aren't adjusted appropriately. As a result, the system's motion control engine takes a central role in coordinating delivery of laser energy to the part. We are beginning to see a dramatic increase in the level of integration between motion control systems and those of laser sources in industrial machines.

Users gain tremendous advantages by tightly integrating the motion control engine to the laser source. Throughput, processing accuracy, yield, and quality can improve when laser and motion control are tightly integrated. These advantages stem from the ability to simultaneously optimize the motion performance of a machine with the material-processing performance of the laser. Current systems serially optimize material processing and motion control. Processing quality is achieved through simple laser parameter setting, and then significant optimization barriers are placed on the motion control system in order to maintain the previously achieved processing quality. In the future, laser and motion parameters will be accounted for within joint control system logic, allowing for the explicit setpoint of actual process parameters and deeper levels of throughput optimization. This new paradigm is a necessary stepping stone on the path to full closed-loop process control incorporating throughput optimization.

CORPORATE MEMBER

QUALITY CONTROL PROCESS TO DETECT THE ANOMALIES DURING LASER SURFACE HEAT TREATMENT

M. Angeles Montealegre[1], David Atienza[2], Javier Díaz[1], Concha Bielza[3] and Pedro Larrañaga[3]

Talens together with its R&D team have developed a novel algorithm to detect the anomalies during a laser surface heat treatment process recorded using a high-speed thermal camera. This new approach detects the anomalies by tracking the movement of the laser spot performing an in-process classification system. Anomaly detection is a key step for ensuring the production of high-quality products in industry.

To successfully apply the laser heating process, the laser beam should inject energy into the surface of the workpiece in a controlled manner. The laser beam moves by following a known pattern that is represented in Fig. 1 However, by using the Dynamic spot Software (DSS) [1] the expected pattern is modified whenever the laser beam has to avoid an obstacle, Fig.1. The system is able to detect anomalies during our proprietary laser surface heat treatment process using a high-speed thermal camera at 1000 frames per second (fps). For this reason, the algorithm models the normal behavior of a system, and then computes an anomaly score for each workpiece below 1s, enough time to manage the extraction of the faulty product from the production line to inspection.

The system detects the anomalies in the laser heating process by identifying unusual laser spot movements. For this reason and because the algorithm relies on a combination of Kernel Density Estimation (KDE) models, we call this approach: KDE-anomaly movement detector (KDE-AMD). If the laser spot movement deviates significantly from the expected pattern, the workpiece can be considered as anomalous. To define the expected pattern, a model of the process evolution is learned with the training data (containing the normal behavior of the process). In this case, the model considers the spatio-temporal characteristics of the laser heating process by learning the expected movements of the laser in different spatial regions and temporal moments, Fig.2. We trained our model using real data provided by a company related to the automotive sector

With the advent of this development, the laser heat treatment of complicated geometries and high added value components is considered to be on the way to becoming a conceptually improved industrial standard.

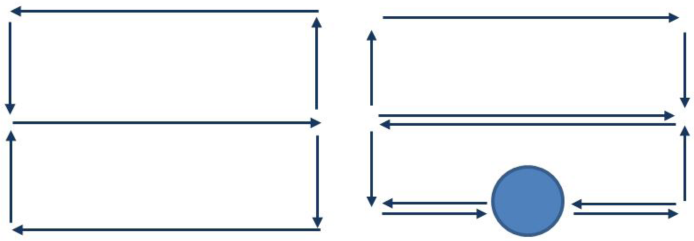


Figure 1. laser spot pattern (a) and modified patterns when the laser beam avoid an obstacle (b).

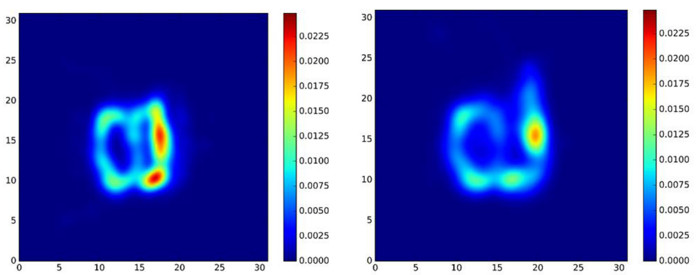


Figure 2. Original pattern (a) and pattern with anomalies detected (b). Red color shows the probability of position of the laser beam.

[1] "Dynamic Control of Laser Beam Shape for Heat Treatment". 36th International Congress on Applications of Lasers & Electro-Optics (ICALEO®

TALENS ETXETAR group

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1 Talens System – Etxe-Tar Group, Elgoibar. Spain

2 Departamento de Inteligencia Artificial.

Universidad Politécnica, Madrid. Spain

3 Aingura IIoT - Etxe-Tar Group. Elgoibar. Spain

HI VIS CURTAIN DOORS

By Tom MacMullin, *President, Kentek*

A laser laboratory poses multiple safety hazards that can be harmful to individuals and equipment. Engineering and other control measures must be incorporated into the operation of lasers to maintain a safe environment.

Laser safety barriers, either movable or free-standing, are often found surrounding the laser work environment and typically create low light conditions that make it difficult to locate egress points. Kentek's Hi Vis Curtain Door is an effective solution: installing the Hi Vis Curtain Door into a barrier system provides an easily identifiable entry and exit point, directs personnel toward emergency exits, and further enhances laser safety by deterring inadvertent entry into areas where laser hazards may be present.

The primary design element of Kenteks' Hi Vis Curtain Door is highly reflective silver tape sewn onto the curtain ends. Additionally, installing LED indicator lights integrated with Access Control systems can assist personnel in identifying whether the laser is in use by displaying a Steady Red when laser radiation is present, or, when it is safe to enter, by displaying a Steady Green.

Kentek recommends using a Hi Vis Curtain Door in curtain systems where a curtain bypass or material overlap is used as a primary access point to the laser environment. Using both the Hi Vis strip and the LED indicators greatly improves the laser safety program by providing identifiable access points and laser status.

WANT TO SHARE YOUR IDEAS WITH THE LASER COMMUNITY THROUGH *LIA TODAY*?

LIA TODAY

Check out the guest article guidelines below and get in touch with an editor today!

BEFORE YOU SUBMIT:

Content: We are always looking for great newsworthy content that covers challenges and innovations in the field of photonic materials processing, laser safety, and laser market trends. This is not a paid opportunity, but does carry the benefit of publishing your work on a platform that is read by thousands of your peers. All article topics should be confirmed with an LIA TODAY editor before writing your article. Please email your article ideas to liatoday@lia.org and an editor will be in touch with you.

Potential Categories: Safety, medical applications, research and development, laser applications fundamentals, history, business, and other categories.

Potential Industries: Energy storage, aerospace, DoD non-aerospace, automotive, medical devices and biotechnology, microelectronics and IC fabrication, Internet of Things, research and development, and other industries.

SUBMISSION GUIDELINES:

Style: The tone should be editorial and informative; it should not sound like a sales pitch. It should be comprehensible by a broad audience of readers with low to expert experience with the topic, so it is important to include examples and simple explanations alongside any technical language.

Length: 600 - 1500 words

Text: Please use standard fonts such as Arial, Calibri, or Times New Roman. Fonts, font sizes, and line spacing will be reformatted by LIA for the final piece. Grammar and mechanics will be edited to the LIA style guide by LIA, but please be mindful of spelling and grammar as you are writing so that your message is clear.

Headline: Please include two newsworthy headlines suggestions for your article using action verbs.

Images & Figures: Please include images to be used with the article. Submit as an email attachment (PNG, GIF, JPG, JPEG) (min. 1000px in width or height). Images should also be placed in the body of the text where the author would like them to appear in the final article. All figures or images should include captions.

Deadlines: All material is due no later than two weeks prior to the scheduled publishing date. Check with an editor for your deadline.

Note: LIA reserves the right to abstain from publishing a submitted article for any reason.

SUBMISSION CHECK LIST:

- Full text as a Word Document
    - Abstract: A 50 – 100 word summary in plain language
    - Two (2) headline suggestions using an action verb
    - Article 600 – 1500 Words
    - Images with captions placed in the body of the article
    - Article references when applicable
    - Short author *bio* (full title, company, 50 words)
    - (optional) Professional headshot of author
- Images attached in one of the accepted file types (.png, .tiff, .jpeg, .jpg) (min. 1000px width or height).

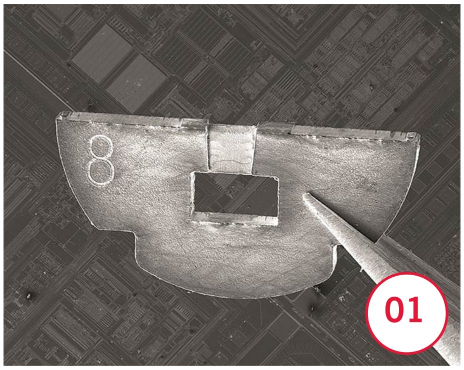
VIEW SUBMISSION FORM

LASER NEWS AND RESEARCH FROM PHOTONICS MEDIA

THE PULSE OF THE INDUSTRY

Top Picks for LIA TODAY Readers!

01 TRENDS IN INDUSTRIAL LASER SOLUTIONS



This feature article from the annual trends issue of *Photonics Spectra* magazine discusses how the demands on lasers grow as the need for precision in manufacturing and other applications increases. In general, lasers enable processes that cannot be performed economically in any other way — such as drilling holes, selectively removing material, or texturing a surface. Lasers also allow novel methods of imaging.

Such uses may require a variety of laser advancements, however, including shorter pulse width, higher repetition rate, varying wavelengths, greater power, better beam quality, and improved uptime. These needs must be met while simultaneously lowering initial and ongoing expenses. In response, vendors are improving current systems and researchers are developing new electro-optic lasers that offer much faster repetition rates.

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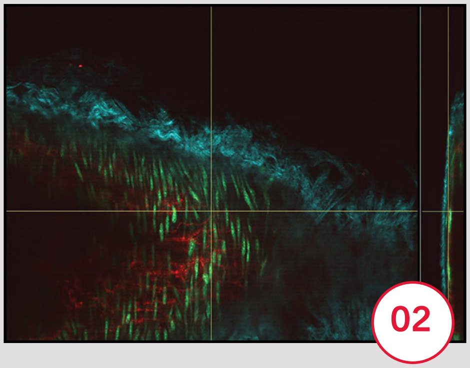
02 LASERS: A UNIQUE MICROSCOPY SOURCE



EuroPhotonics magazine looks at the latest developments in lasers for microscopy that are delivering a powerful combination of improved functionality and operational simplicity, and it's benefiting both end users and OEMs.

The optical microscope dates back to the time of Galileo. For most of the past century, microscopy was widely regarded as a ubiquitous and extremely mature field. Today, the picture is very different. Optical microscopy is an incredibly dynamic field with recent Nobel prizes given for new techniques that overcome the diffraction limit, as well as tools such as new fluorescent proteins that have enabled considerable advances in the life sciences.

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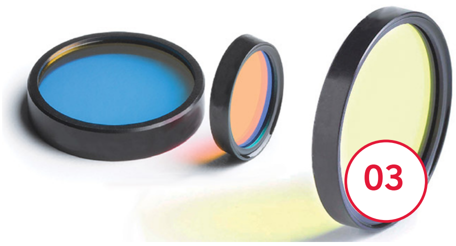
03 ADVANCEMENTS IN RAMAN SPECTROSCOPY FIND REAL-WORLD USES IN THE LIFE SCIENCES

From *Biophotonics* magazine, this article explores how with high-performance optical filters being incorporated into cutting-edge detection systems, Raman spectroscopy is finding new applications in the life sciences.



In general, Raman spectroscopy studies inelastically scattered radiation. If a sample absorbs energy after the scattering event and the emitted photon is lower in energy than the absorbed photon, this is referred to as Stokes Raman scattering. However, if the sample loses energy after the scattering event, then the emitted photon is higher in energy than the absorbed photon, which is called anti-Stokes Raman scattering.

Most commonly, a laser excites a sample and a laser-blocking optical filter is positioned between the sample and a spectrometer to block the scattered light and pass the Raman-shifted signal light, which is referred to as the "fingerprint" of the molecule of interest.

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E-MOBILITY OFFERS MULTIPLE OPPORTUNITIES FOR FIBER LASERS

Jack Gabzdyl and Ken Dzurko of SPI Lasers, LLC

E-mobility is continually in the headlines and represents one of the great predicted mega-trends for the next decade. The rationale is clear – the world needs to break its dependency on fossil fuels and electric vehicles offer the obvious solution. Predictions suggest that by the mid-2030s electric vehicles will be outselling petrol/diesel models. From a manufacturing perspective this is a paradigm shift from combustion engines to electric motors. Passenger vehicles can be either plug-in hybrid vehicles (PHEV) or battery electric vehicles (BEV) both of which need batteries and electric motors. The manufacturing of batteries and electric motors must undergo a transformation to match the forecasted growth in volume, accompanied by dramatic improvements in cost, yield and throughput. Fortunately, today's industrial lasers are the ideal tools for the manufacture of key components within both batteries and motors; this has stimulated a significant rise in demand particularly for fiber lasers.

Figure 1. Copper anode and aluminum cathode foils, coated with lithium ion compound demand high cutting speed and near perfect edge quality to replace punch press machines and render components that can be tightly packed without electrical leakage.

CUTTING OF LITHIUM-ION COATED FOIL ELECTRODES

Breaking down the key requirements, in terms of opportunities for lasers, we can start with the individual lithium-ion battery cells. These are made up of layers of coated anodes/cathodes made from thin aluminium/copper foils used in both cylindrical and prismatic cell designs. The first step where lasers can be involved is in the cutting of the electrodes. Traditionally, this has been done using mechanical cutting/stamping techniques, but there is a significant swing to the use of lasers for this process, due to their more efficient speed, lower cost and higher quality.

Quality is key, and there are stringent requirements on aspects such as burr formation, delamination, particle debris formation and heat affected zones. Single mode CW fiber lasers can be used very effectively for the cutting of bare foils, but may not be the best choice for the cutting of coated electrodes. Here the ns pulsed fiber lasers excel as the short, high peak power pulses can cut at high speeds with today's 200 W sources. SPI's EP-Z model can reach cutting speeds greater than 1 m/s with appropriate cut edge quality. There are parallel developments looking at alternative sources such as green and even ultrafast ps with the promise of higher quality, but the reality is that this comes at a cost, which is in direct conflict with the prime driver for manufacturers looking to increase speed and reduce total cost.

TAB WELDING AND BUS BAR WELDING OF BATTERY PACKS

Within the cell manufacturing process there are numerous opportunities where lasers are being considered, including welding, cleaning and drilling. Whether they are cylindrical or prismatic cells, these self-contained modules need to be assembled into battery packs where copper or aluminium bus bars are welded to the cells. The thickness and types of materials vary quite considerably, but these welds are in general quite challenging. They rely on welding highly reflective and conductive materials, such as copper or aluminum, either to similar or dissimilar material combinations; the latter being a process that is becoming increasingly common. Given that there are hundreds, if not thousands, of individual cells that need to be joined in a battery pack for an electric vehicle (EV), these joints need to be of high quality, reliability and repeatability. Requiring good static and fatigue strength, these joints must provide excellent electrical contact resistance, as the power loss at each joint affects the overall efficiency of the pack. Traditional mechanical fastenings with nuts and bolts add weight and cost – laser welding provides the answer going forwards.

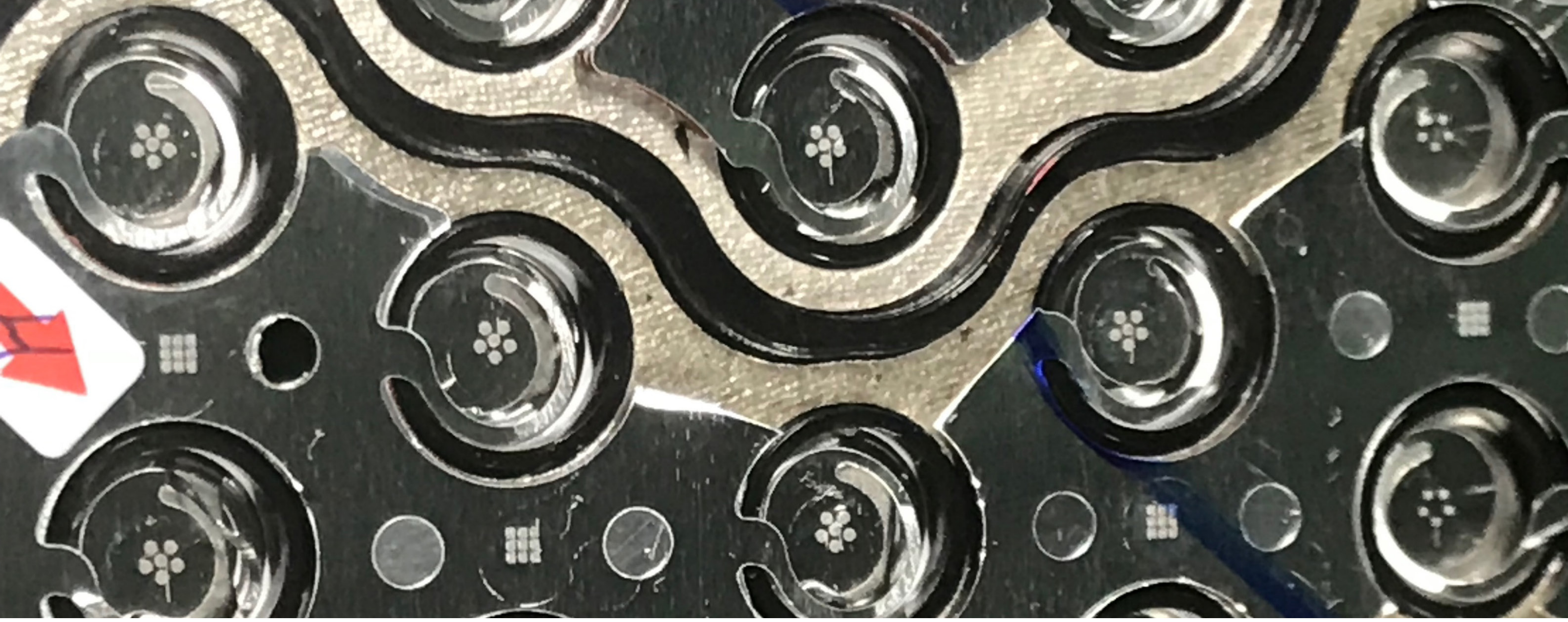


Figure 2. Battery tab welding using nanosecond laser welding achieves high strength and electrical conductivity without overpenetration. Thin metals and contained electrolytes under pressure make this a demanding application.

Initial installations focused on high energy, multi-kW, multimoded laser sources, with limited success. The requirements of this application require lap welds, which are ideally suited to laser welding. However, the resulting welds often suffered from high heat input, poor overall control of heat input, inconsistency in weld profile and penetration, and worst of all, high levels of spatter. Improved solutions have been developed based on the specific challenges of individual manufacturer's designs. In instances where material thicknesses are low and the need for control of heat input is high, then the unique proposition of SPI's ns welding process offers an ideal solution. Using 100 W lasers, excellent welds can be made in 300 micron Cu tabs. This technique enables multiple spots to be made to give appropriate bonding to the focus area using a spiralled spot. Control of heat input and penetration is extremely high, but welding time can be quite slow given the low average power when compared to multi-kW CW.

For applications that require high productivity and the ability to weld through thick metal, the recent introduction of high power single mode CW fiber lasers has enabled these welds to be done using an oscillation or wobble welding technique. This uses a very small focused spot that is rapidly oscillated to enlarge the weld area. This enables the width of the weld to be controlled independently of the spot size, enabling the weld to be tailored to the application. The rapidly oscillating spot also has the effect of controlling the heat input and the stability of the keyhole/melt pool. The resulting weld tends to have greater consistency in weld profile, top bead appearance and lower spatter. A 2 kW single-mode fiber laser can now create welds that are up to 2 mm in penetration with exceptional quality both in copper or aluminium.

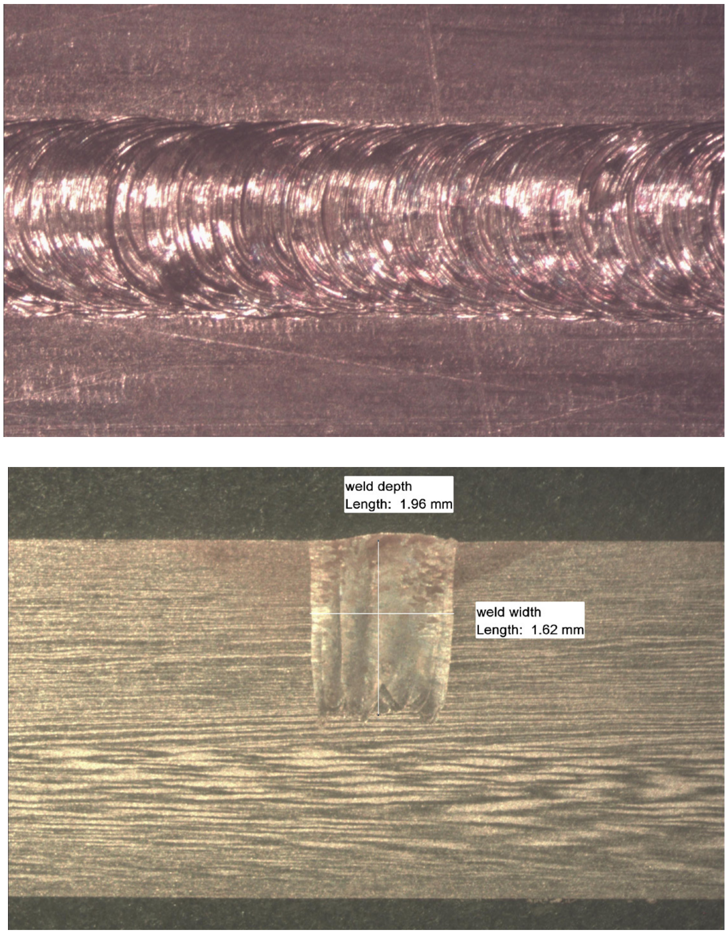


Figure 3. 2 kW single-mode wobble welding allows independent control of penetration and bead width. The high intensity of the single-mode beam results in efficient coupling and low spatter, even into highly reflective copper.

Continued on next page.

Figure 4. Hairpin ablation of dielectric coating prior to welding using ns pulsed fiber lasers offers a cleaner, faster and more repeatable result that wire brush mechanical removal.

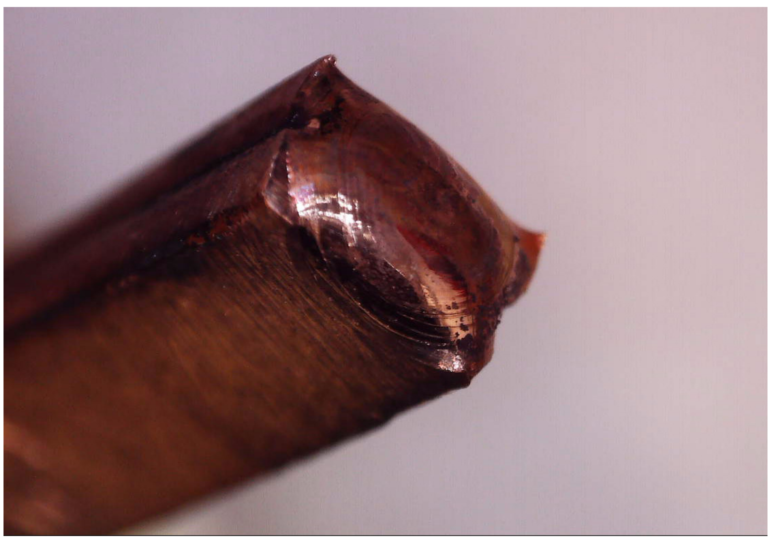


Figure 5. Welding of two rectangular tips of hairpins can be achieved using 2 kW singlemode wobble welding. The high peak intensity enables high coupling with minimal spatter, and the beam wobbling mitigates fit up gaps.

HAIRPIN ABLATION AND WELDING FOR ELECTRIC MOTORS

Another significant opportunity for lasers is in the manufacture of electric motors, particularly in the welding of the copper hairpins on the stator. These pins are typically coated with an insulating material that needs to be removed prior to welding. Conventionally this has been done using mechanical means such as through wire brushes, but this is difficult to control and prone to maintenance. These coatings can be effectively ablated by ns pulsed fiber lasers leaving no residual material whilst simultaneously getting the parts selectively down to bare metal ready for the subsequent welding step.

These pins come in various shapes and sizes but are often in a rectangular form with the long sides up to 6 mm in length. Welding with high power CW multimoded laser sources in the 4-6 kW range is currently being adopted, but this proves to be a challenging application for several reasons, including fit up, need for minimal spatter and the lowest heat input so as not to burn the insulating material only a few mm from the welding zone. Again, the use of a 2 kW single mode fiber laser using the beam oscillation technique offers an alternative that provides good control of heat input and limits spatter.

These examples are not exhaustive but reflect the level of dependency and reliance that the e-mobility industry is placing on laser materials processing. The success of the e-mobility sector and the inevitable need for increased manufacturing capacity will undoubtedly result in significant demand for industrial lasers in the coming decades.

ABOUT THE AUTHORS

Jack Gabzdyl is Vice President of Marketing and Business Development for SPI Lasers. He is a Fellow of the LIA and has been innovating and publishing industrial laser applications for over 25 years.

Ken Dzurko is General Manager of SPI Lasers LLC. He is a former board Director of the LIA and has continued the Gold Sponsorship of ICALEO for the past 11 years. He is responsible for SPI's business in North and South America.

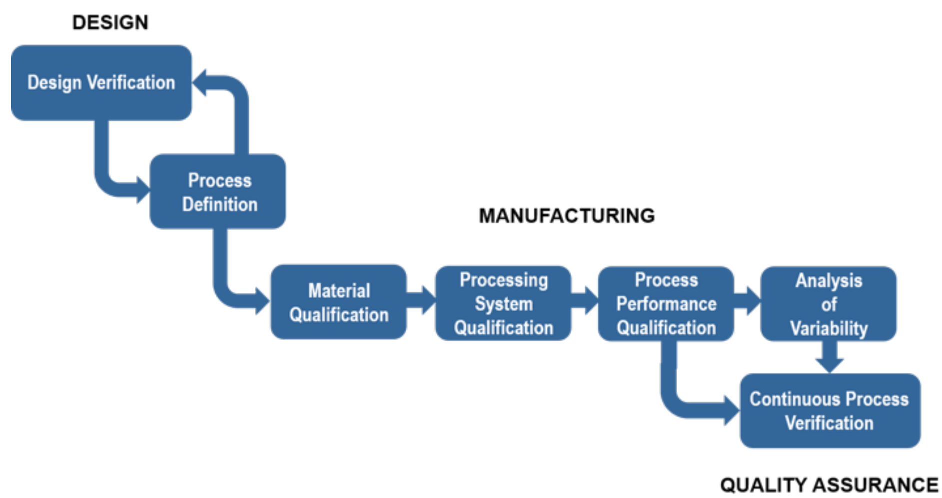
Ensuring Product Quality and Process Reliability of Laser-Based Additive Manufacturing

By R.P. Martukanitz, *University of Virginia and the Commonwealth Center for Advanced Manufacturing*

Laser-based additive manufacturing (AM) of metallic materials is receiving considerable attention for use in a wide range of industries based on its ability to dramatically increase design complexity with minimal increase in cost, capability to easily customize products, and capacity to act as a "point of manufacturing" for on-demand items. Because AM is currently considered a relatively low production-rate process that commands a premium, many of its potential applications are directed at high value components, and in most instances these components have high performance requirements. This requires that the process, which in the case of AM includes design, material, and processing conditions, are suitable for meeting the various performance requirements dictated by the application, as well as ensuring that the AM process is capable of repeatedly producing parts that meet these requirements.

The traditional method of maintaining a specified level of quality in a manufacturing process is to define and conduct the process based on a performance qualification protocol. This approach, which is used throughout many industries, relies on sufficiently defining and documenting the important parameters controlling the process that enables key performance requirements be met that are specific to the product and application. Test results are used to confirm that the process defined using these parameters are capable of meeting the requirements of the product. Once the process is established and provides the known outcome, these essential parameters are monitored and maintained. A concept for applying this approach to AM is shown in the below figure.

"The concept shown above has been formulated to address several unique features regarding AM."



Concept for Utilizing a Performance Qualification Protocol for Additive Manufacturing

CONCEPT FOR UTILIZING A PERFORMANCE QUALIFICATION PROTOCOL FOR ADDITIVE MANUFACTURING

The concept shown above has been formulated to address several unique features regarding AM. This includes the critical link between the design and manufacturing functions, important aspects of material feedstock quality and processing system stability, and potential use of process monitoring and/or sensing to ensure process reliability. The design and process definition or development stage is an iterative process. Once the design and process are defined, qualification of the material, AM system, and entire process is conducted by confirming that the resultant product will meet the intended performance requirements that had been established during the design and process definition stage. This is achieved by producing actual components or simulated components using the defined process and by testing the resultant product to confirm properties and/or characteristics that may define performance. The AM process is conducted while thoroughly documenting all material, systems, and processing conditions that may influence the process and resultant product. If the desired properties are attained from the performance tests, the process is formally specified as being qualified to produce the design using these prescribed parameters and conditions.

Essential variables that define the process are monitored or verified to assure conformity. By continually tracking the variation of critical parameters and conditions, indications of trends may be used to intercede before exceeding established limits for controlling the process. Monitoring and controlling essential variables may also be augmented through real-time sensing of process characteristics. Various sensing methods have been developed that offer insight into the process, as well as improved resolution for assigning consistency to the AM process. These sensor techniques, as they relate to the laser-based powder bed fusion AM process, include high resolution imaging for identifying layer anomalies or defects, acoustic emission sensing for indication of crack generation, and diode sensors for measuring laser attenuation and process stability.

Dr. Richard Martukanitz is a Professor of Materials Science and Engineering at the University of Virginia and a Fellow in Additive Manufacturing at the Commonwealth Center for Advanced Engineering. He has over 25 years of experience in the development and deployment of laser-based manufacturing technology and the DoD.

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LASER PIONEERS

Interview with M.J. Soileau, PhD (Part 1)

September 14, 2018
By Chrys Panayiotou, Ed.D.
Executive Director and Principal Investigator of LASER-TEC

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.

M.J. Soileau received his PhD in Quantum Electronics from the University of Southern California, and is currently a University Distinguished Professor of Optics and Photonics, Electrical and Computer Engineering, and Physics at the University of Central Florida. He is known for his pioneering research in nonlinear interaction of laser pulses with optical materials and for leading the development of the internationally recognized Center for Research and Education in Optics and Lasers (CREOL) at UCF. Soileau holds 6 U.S. patents, the applications of which have contributed to the advancement of high energy laser optics used by the United States Department of Defense. His leadership has helped UCF become a catalyst for the region's high-tech development, stimulating the local economy in central Florida. He is a Fellow of IEEE, the SPIE--The International Optical Engineering Society, and the Optical Society of America. M.J. has been honored as a Foreign Member of the Russian Academy of Sciences, inducted to the Florida Inventors Hall of Fame, is a Fellow of the National Academy of Inventors, received the SPIE Gold Medal Award, and the OSA Esther Hoffman Beller Award.

I talked to Dr. Soileau 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: First of all, I would like to thank you for giving me the opportunity to come here and interview you and to tell us your story and journey through laser history. The purpose of this interview is to inspire, encourage and motivate the new generation of scientists, engineers and technicians, to get into this exciting field of lasers and photonics.

MJS: Well, if the purpose is to inspire the new generation, then perhaps I would be a good subject for this, because if I could become a laser scientist, then anybody could do it. And I think that's a good message to have young people understand, that they can build a career in laser science, independent of their background, family's status, or history. If they have a passion for science, then they can do it.

> "Well, if the purpose is to inspire the new generation, then perhaps I would be a good subject for this, because if I could become a laser scientist, then anybody could do it."

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

MJS: OK. I was born three quarters of a century ago on the north bank of Yellow Bayou, a remote area in rural, central Louisiana, on the Atchafalaya River. The Atchafalaya is the main distributary of the Mississippi, destined to be the next channel of the Mississippi when it moves again.

My family were farmers. Few of my family were educated. My father attended school to the second grade. He learned to read, write, and do simple math after the Second World War through the GI bill. People with a high school degree were able to get college degrees; people that were uneducated were able to get some level of education via the GI Bill. My mother's father died when she was 11 years old, she had to quit school then. She and my grandmother worked the farm, so she attended school to the seventh grade.

I was not only the first in my family to go to college, but first in my family to go to high school. Both my parents learned to speak English as their second language, even though they were like, eighth generation in North America. I was the first in my family not to learn to speak French, which is a tragedy.

My earliest recollection, we lived literally in the swamp. We had some not-so-good land that was available to try to farm, and it was on a dirt road in the middle of nowhere. My father was then, and throughout all of his life, a subsistence farmer. That is, we ate what we grew or what we were able to harvest through hunting or fishing and so forth.

Among the things that I remember in those days was the harvesting of Spanish moss. We dried the moss on the fences around the property. The little town nearby that had a gin that would remove the soft fiber from the outside of the moss, to reveal the very stringy inner fiber of the moss that people used for making seat cushions and horse collars. We slept in beds with mattresses stuffed with Spanish moss that came from the swamp. We had a smoke house, and my dad would smoke meat. We didn't have electricity or refrigeration, running water, or indoor plumbing.

We went from that to sharecropping. Sharecropping is an institution in the US, like peasantry was in Europe. Sharecropping was the institution that replaced slavery in the rural South. One worked the land of a big landowner, they would finance your seed, and then they would take one third of your crop. My dad farmed 20 acres of cotton and corn with a pair of mules, and we lived in a little shotgun house. A shotgun house is one that had three rooms. So called because one could open all the doors, no hallways or anything, and one could shoot a shotgun all the way through the house without damaging anything. The house had no screens or glass windows, only wooden shutters on the windows. We used a wood burning stove for cooking and heating.

It was a hard life, but it did a lot to shape me for the rest of my life. When one has to struggle just to have enough just to eat, one develops a different perspective of hard work.

We moved into town, a little town of Melville, Louisiana on the Atchafalaya River, about when I started school in 1950 and my dad started working in construction. He worked as a laborer in construction, but we always kept subsistence farming as part of who we were. In that little town, there were no laws to restrict livestock, so if you did not want cows in your yard it was your job to put a fence around your yard because cows could run free. We lived next to the river levee, so that we could turn the cows loose and they would go graze in the levee, and come home at night where we would feed them and milk them. We always had yard animal, chickens, pigs as well as cows and we raised rabbits. Anything to put food on the table. You can raise a rabbit actually quicker than you can raise a chicken, and my brother and I would pick the clover so you do not have to buy food for the rabbits.

Until recently we still had the little bit of the farm where I lived all through my high school days. My father would travel away to work in construction, and we would keep the farm going as best we could with, typically we had 16 acres, so we had 16 heads of cows. We would get all the orphans, when somebody had an orphan animal we would, we would take it, and we would feed it, because we had extra milk, and get it to be harvest size so we would eat it.

I grew up in that environment. I got interested in science in the fourth grade. That was my first exposure to astronomy in the fourth grade. From that day on I became interested in science. Before that, my first interest was in banking, because I went with my father to the bank to try to get a crop loan and I thought it was a marvelous place for two reasons. One, they had a fountain that would dispense cold water, which I thought was a miracle and it had air conditioning inside. I said, banking is what I want to do when I grow up. Later on, when I was about 5 years old we were sharecropping. In the spring when the chickens were laying a lot, we would bring some eggs to sell to the merchants in the town. From that we have a little bit of cash and we could go to the movies. I thought, well raising eggs would be a good profession to be. That was my second ambition. My third ambition was astronomy.

"When one has to struggle just to have enough just to eat, one develops a different perspective of hard work."

The school I attended was a little school out in the middle of nowhere. There were 27 people in my high school graduation class. I was not the brightest kid even in my graduation class. I finished number two out of 27. However, I had teachers that encouraged me every step of the way. My first grade teacher took up a collection at the school to buy me a suit at high school graduation. The first suit I ever owned. My sixth grade teacher, who became my Boy Scout master and second father to me, arranged for me to get a job at LSU, Louisiana State University, washing dishes in the cafeteria. He also introduced me to the Dean of Men, who eventually hired me to work in the dormitory. In addition, he introduced me to an astronomy professor who from vary early, I think even my sophomore year, employed me as a grader for his freshman astronomy class. The class that I teach this semester by the way.

Now, so that was my introduction to science. We had some great teachers in my little hometown school. All the men teachers were all World War 2 veterans that had gone to college on the GI Bill. These are all very practical people. They had been farm people that went off to the war. My high school math teacher, Mrs. Connolly, was the best teacher I had in all my years of education, and one of the turning points in my career was taking Euclidean geometry, plain geometry, under Mrs. Connolly. This was the first time that I truly understood mathematics and it formed the basis for a lot that was to come.

My mother and I hoed cotton for 50 cents an hour (minimum wage was a dollar and a quarter then, but agricultural jobs were exempt in those days), for my first semester tuition. Now, you hoe cotton in the middle of June, there is no shade in the middle of the cotton patch. The cotton plants are small; it is quite literally stoop labor. You are cutting the weeds away from the cotton plants, but you have to pay attention because you cannot cut the cotton plants and so forth. Therefore, it is intense, hard, boring work. Great motivation for studying in college.

CP: You mentioned astronomy. Can you recall a specific event, which was the clinching point, after which you decided, that's it now, I'm going to go for it.

MJS: I do not recall anything specific. It just was fascinating to me.

However, I do remember my first optical instrument. The joke was, my family thought the people on welfare were middle class. All right, we had no money, so to save a little bit of money to buy astronomy books was a hard thing to do. We children worked and I had to convince my parents that we needed to use some of that money to buy books. Every time I had enough money I would find a book on astronomy, and I would buy it. When I was about in the eighth grade I got my first optical instrument. It was an Edmund Scientific Space Conqueror, 3-inch, Newtonian reflector telescope, cost $30. I earned the money for that by taking an additional paper route. I subcontracted to a lady that was delivering the afternoon newspaper because I already had the paper route for delivering the morning newspaper. However, money from the morning paper route went into the family income, that wasn't available for spending money for me. I had to convince my parents to let me take this additional paper route which was one penny a paper. So 3,000 newspapers later, I had $30 and I bought this Edmund Scientific Space Conqueror telescope. That was my first optical instrument.

A couple years later, I bought a kit to try to grind my own mirror, a 6-inch plate, but I never finished it. However, I developed a deep appreciation for optical technicians that actually rub the glass to make the optics that we use to do lasers and everything else with these days. The interest in astronomy really drove an interest in optics. I'm just finishing a chapter now in my class called, "The Cosmic Messenger", and we learn almost all that they know about the universe from optics. So, if you're interested in astronomy, you'll automatically get interested in optics, get interested in light. The physics of light was always very fascinating to me even as a young boy, I tried to learn everything that I could about that subject.

CP: So, you started in astronomy at LSU.

MJS: I started in astronomy and physics at LSU. It was a joint degree program. There were two astronomy professors among the physics faculty at LSU. It was a physics degree with all the electives taken in astronomy. However, it was very important to me, primarily, because my interest in astronomy drove the other work. That is one of the messages I have to students that are interested in science: The key thing is to [have] interest in the topic. Learning science is very hard work. There are much easier ways to make a living than to study science. Why do you do it? You do it because you are compelled to do it. Because it is so darn interesting to do, and so much fun to understand things. My interest in astronomy drove me to learn mathematics and physics.

I had plans to go to graduate school in astronomy. I had plans, actually, to be an astronaut. I entered college in 1962, so that was early in the space race time. I was in Air Force ROTC, which was mandatory at that time for the first 2 years, and then I went into advanced ROTC. As it turns out, I'm colorblind. So I could not be a pilot, therefore, I could not be an astronaut. I eventually got a private pilot's license, but the Air Force would not allow colorblind pilots. That was a little kink in my career ambitions.

As an undergraduate, I started grading papers, monitoring tests for Professor Ryman Grinchik, a great man. In my senior year he hired me to give lectures at the planetarium at the University, and to host open house for the telescope. We had a little refracting telescope, about 12-inch diameter aperture, sitting on top of the physics building. And every Tuesday night we'd have an open house, and kids from school and the general population would come by, and also a similar thing with the planetarium. It was great work (sort of like teaching; they were paying me to learn astronomy!) Particularly the planetarium work, because I was paid for blocks of time just to sit by the phone to take reservations from school groups and work on the lectures. I could do homework during that time as well. That change my lifestyle as an undergraduate student.

I received a deferment from the Air Force (this was the time of Vietnam War) to get a graduate degree in astronomy from LSU. Fast forward to January 1967. On the day of commissioning, which was the day before graduation, the Professor of Air Science informed me that I had been selected by AFIT, the Air Force Institute of Technology, to go to graduate school. It turns out AFIT was the organization that approved my deferment from active duty. So I said to the colonel, "Colonel, you're mistaken, AFIT approve my delay from active duty to go to graduate school here in astronomy. He says, "oh, no, no, no. You were selected for the civilian institution program to go to graduate school".

That was kind of strange because I have orders. In the military you get single piece of paper with very serious wording, especially in time of war that informs you, if you don't do what it says here you'll be charged with desertion. Serious sounding stuff. I had learned by this time, I'd done my basic training, you have orders, you follow your orders, and my orders were to go to graduate school in 2 weeks. I had to be in class, otherwise I would be absent without leave.

"But no, no, you're selected for this program."

"How could I have been selected?"

"I don't know. Congratulations, it's a very competitive program."

I said, "But colonel, I did not apply."

To this day I don't know how that happened. I had plans to be at LSU, and had orders to study astronomy. I had this plan to get married in the summer. My soon to be wife and I had reserved marriage student housing. My wife to be had a job teaching school waiting for the coming September.

Our life was all set, and then all of a sudden, no, we are not going to do that.

My next questions for the colonel were when and where, and he did not know! He said words to the effect: "The guy didn't tell me, "I presumed you knew all of this."

"This is the first I've heard of it."

So it took about 2 weeks for him to find out where I was going, and in the meantime I had gone to the library, before the Internet, pulled all the catalogs from, from universities that had

contracts with the Air Force to send officers to graduate school and limited to about two dozen from coast to coast. There was question of starting in March, which was when I was supposed to start graduate school, so it had to be a quarter system. I narrowed it down to about a half a dozen schools. When he told me where I was going is Utah. I said, OK, University of, or Utah State? Both of them are on the quarter system, both of them had contracts with the Air Force. He said, “Oh, I don’t know. The man did not say. But he did say you have to apply immediately, because you have to be accepted to graduate school before you can enroll.” This is in February, now it started in March. So I applied to both not knowing where I would be going. A few weeks later, I learned it was University of Utah and that I should specialize in optics.

My orders were to go to University of Utah, pursue a master’s degree in physics with a concentration in optics. There was one optics person at the University of Utah physics Department, Professor Grant Fowles, who was just an outstanding scientist. Among his students were Bill Silfvast, who ultimately was at Bell Labs and who did pioneering work in ion lasers of various kinds, argon and other ion lasers. I later hired Bill to be on the UCF faculty. Professor Fowles introduced me to holography. I was initially going to do a thesis involving calculation of diffraction losses and laser systems that one of the PHD students was working on. I was still a country boy, so if someone told me to do something, I did it. Later he came to me and said, “This idea is a little bit more interesting.” The idea was, to make a diffraction grating that would also focus light. The idea was you would not have to have a collimating lens, then a focusing lens. If it worked then you can make a diffractometer, basically, with a single element. Spectrometer, rather, with a single element, using holography.

This turned out to be among the more important things that I did in my education. The initial idea worked, but I had another idea of how it could work better, and the initial argument that it should work was kind of hand waving. All symbolic mathematics. I decided that I could do holograms with two point sources. When you illuminate the hologram with any kind of source, one of the images that it would produce would be a point source. Which means you have focused the light, with the hologram. I tried it, it worked in one case but not in another. I could not figure out why. I had to learn what would eventually become Fourier optics, it wasn’t yet a field of study. This is now 1967, so I, with some help of a PHD student I figured out how to quantatively model the process and explain what worked and did not work and why. This is a great thing for students to know, that when you go to graduate school, you learn a lot more from your fellow students than you learn from the professors. That was true then, and it is true now.

I learned just enough Fourier optics to derive an expression as to what the focal length of this hologram would be. Immediately before then, Prof. Fowles, said, “Don’t worry about it. You’ve got plenty enough data for a master’s thesis, just write it up and get out of here.” But, I went in the lab and changed the configuration, as the mathematics directed me to, and voila, it worked beautifully. I threw away all the stuff that I had been writing and, instead of a long experimental thesis that defined all the things that I had tried, all the things that worked, all the things that didn’t work, it was mostly theoretical with one experiment at the end to show that the theory worked. Very thin thesis. I wrote it over the weekend and my wife typed it up. I turned it in on Monday morning. This was very important to my career because it drove home this idea, that if you’re going to do something original you need to have good fundamental understanding of what’s going on. You have to let the theory guide you toward experiments. Of course, no theory is any good unless you can verify with experiment. That simple master’s thesis did that for me too.

“This was very important to my career because it drove home this idea, that if you’re going to do something original you need to have good fundamental understanding of what’s going on”

The reason it did not work initially was that I took great pains to make the path difference between the two beams used to make the hologram precisely the same. Now this is fairly early in lasers, 1967, so when you read things about lasers it was all about the coherence length and the coherence length was not necessary that good. To make holograms the path differences should be as close to equal as possible. As it turns out, the experiment that I was doing, the only time it would not work was when the path length of the two beams where exactly equal. I had taken great pains to make them exactly equal. I got a holographic grading, but because the path lengths were equal the focus of that grading turned out to be Infinity. Which means that it produced parallel [lights] on either side of the conjugate plane with the hologram, so it, parallel [light] here, and parallel [light] there, by accidental design. But putting the specifics in the mathematics, as to the focal length of what this thing should be, and doing that derivation, let me see how to do it in a way that would make the focal length finite instead of infinite, so that thing would image instead of just giving parallel lines on the grading. I would say in many ways that, that experience was more important than my PHD dissertation. Because it introduced me, in a very rigorous way, how to do original science. You start with an idea that comes from somebody else usually. My professors had read a paper on holographic gratings that had parallel grooves if you like, not parallel undulations, that would make a nice grading with the hologram, and had this idea of making one that would image. So, taking that but driving it to better understanding, I would say was very pivotal moment to my career in science. If you do not really understand something, even if you get the outcome that you want, tomorrow you might get a different outcome. If you do not understand it then you will not understand why you do not get the outcome tomorrow, that something that

you change that you were not aware of. It is always good to understand the basics of what you are doing.

That got me into optics. At the end of that period, I got a letter from the Air Force Weapons Lab at Kirtland Air Force Base in New Mexico, from the colonel that was the head of the weapons lab, saying that they started a new program in high-energy lasers. Would I like to be part of it? I thought, well, I was still a shy farm boy at heart, so I had orders already to go to Massachusetts to Hanscom Field near Boston, Bedford Massachusetts, on a project call LASL. I thought it must be some laser something or other. After all, the Air Force sent me to school to study optics and they gave me these orders, so I wrote a letter back to colonel, that's before Internet days, saying, thank you very much but I already have orders to go to Hanscom field and that was sort of the end of it.

CP: Let's continue from the Air Force, you got the letter and then?

MJS: Yeah, I was assigned to Hanscom Field, in Bedford Massachusetts, and it turned out that my assignment was to monitor contracts for varying seismometers in Montana. We had a meeting with the commander of all the junior officers, and everybody was complaining because they had studied to be an engineer, or a chemist, or a physicist and here they were just pushing paper around and nobody was very happy with that. The commander's response was the typical commander's response, well that's all fine and good, but the needs of the Air Force comes first. So, I was losing my shyness a little bit, so I raised my hand and said, but Colonel the Air Force must have a need for somebody in optics because they just sent me to graduate school to study optics. Surely they must have a need. His response was, "OH, that's interesting, let me check." So he did check and about 2 weeks I was reassigned to the MITRE Corporation.

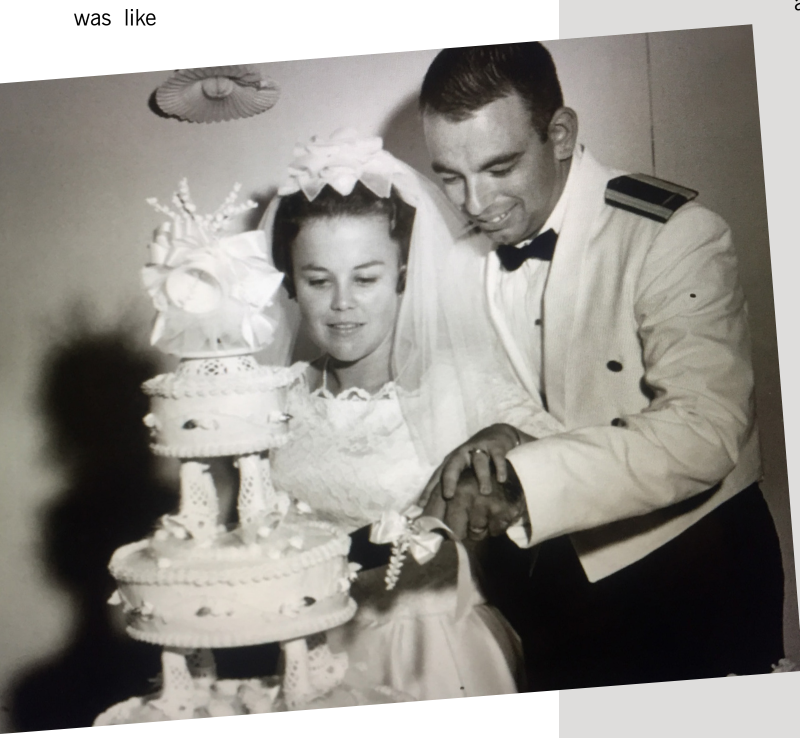
The MITRE Corporation is a think tank that does work for the government like RAND and several of these things. MITRE, MIT Research and Engineering, that's something that came out of MIT during the Second World War to do classified work for the government, as everybody was mobilized during the war. And it's maintained till today, still exists as a think tank, doing government work. So I was detailed to this civilian organization to work on a project that requires somebody that knew optics. And the project in a nutshell was to be able to locate and diagnose exo-atmospheric nuclear burst. At the time this was all top secret, highly classified, because we had found out by accident, really by accident, of a comment that a soviet scientist made at a meeting in Europe about a giant electromagnetic pulse that is produced when you pop off a nuke outside the earth's atmosphere. The interaction of those high energy particles with the earth's magnetic field produces a tremendous electromagnetic pulse which will zap all of your communications. So we had a system that we had designed, an anti-ballistic missile system, that will intercept missiles as they were coming down on the US and pop off a nuke before they got into the atmosphere, to destroy them, not realizing that we would then destroy our own command and control system by doing that. So there was a crash program, no pun intended, for the Air Force to try to come up with the concept formulation package as to how we should address this situation. So I worked intensely in a small vault down in the basement of the building where the guard had to recognize you, not only your badge, but you personally. And you go there and there were these battle plans for nuclear war on the table. It was kind of scary as a junior person. In fact, I didn't sleep for 2 weeks after being assigned there. After somehow, seeing those maps with targets on them, made the concept of potential nuclear war very, very real. Then the mind gets numb and you can go ahead and do the work that you're assigned to do. But I worked on that project very intensely.

That was another important thing for me because, most of the people at MITRE, they are permanent staff, were Ivy League people. They were MIT, Princeton, Yale graduates. All PHDs in physics, at the time I had a master's degree and a baccalaureate from two state universities most people didn't consider the tops in the world anyway. But what I found out, that most of those guys had never hit a lick of the snake in their life. That's a country saying that we had a growing up, they had never done at honest day's work in their life. And they'd sit back and puff their pipes and think deep thoughts. Meanwhile we junior guys were sitting there trying to figure out how to do this problem. And the only thing original that came out of that project, I must say, was a small team of four junior people, two junior officers and two junior civil service people just out of school, none of which had a PHD. And that was about as big a confidence builder for me, then anything that I experienced before or after. The way I characterize this, I found out that all these guys from Ivy League schools and all these super smart people that were much, much more than myself, they had body odor too. You know, they were just human beings. And they might be even smarter than I am, but they didn't work as hard as I did. I realize if I just took whatever grey matter I had and worked harder, I could perform, even in the company of such people and even excel. The Air Force actually gave me a medal, an Air Force commendation medal for my work on this project.

As the project was ending I could feel myself being sucked back into administrative work at Hanscom Field. And so I called Colonel Rowden, who was the Air Force Weapons Lab commander at the time and said, Colonel, you probably don't remember but you sent me a letter a year ago inviting me to join the high-energy laser program. I already had orders to go to Hanscom Field, I'm ready to go there now. And he said, wow, that's interesting, but you're in systems command. The commander doesn't like us to go cherry picking people from other parts of the command. If you weren't in another command I would get you tomorrow. But let me see what I can do, but I'm not too hopeful. Well fast forward to a year and a day after I arrived in Bedford Massachusetts, I left to go to Kirtland Air Force Base to work on the Air Force's high energy laser program.

That was another critical factor in my career, my education, and my life. That program was just the late Art Guenther, who was a hero of mine and one of my life mentors, and very important in the formation of the LIA, and the other was in gas lasers. So Art's group was looking at big solid-state lasers and another group was headed by a guy, a major at the time, Donald Lamberson, who very quickly became a general. And so those two branches, solid-state laser branch, and gas laser branch, filled with junior officers and, if you'll pardon the country expression, these were junior officers full of piss and vinegar. You know, they were just too dumb to know what they couldn't do. Any challenge was a good challenge, the bigger the challenge the more fun it was, and boy were there some big challenges. And one of the pieces of propaganda in the military then, I suppose they still use it, is to say, "If you join the military you be given great responsibility at an early age," and that was absolutely true. Here we were, a year or two out of college being given responsibility for huge projects. Basically a blank check to bill laboratories and too dumb to know what we couldn't do, and just full speed ahead to develop high power lasers for whatever the job there was to be done. That environment that in many ways more a kin to sort of a hybrid between universities and Bell Labs. In the sense that you had to work on something that the company was interested in, but it didn't have to be in detail with what they were interested in because they didn't know yet how they would use the technology. It was like

"There's a couple of great clichés about making devices. "We've got it all done now, it's only a materials problem." And the answer to that is, it's always a materials problem."



a University, in that it was just full of ideas, and churn of people, and enthusiasm to just discover. You were given a fairly long leash. If you had something you wanted to pursue, then just go at it, as long as you keep in mind that you had a mission to satisfy.

That's where I got introduced to high power lasers. This is before Star Wars initiative that everybody knows about during the Reagan administration. This was well before Reagan, this is 1969 when I arrived there, two days after the Apollo 11 landing by the way. I stopped by the hotel on the way there to watch the landing on TV, on the way to Kirtland from Massachusetts.

A lot of new technology had to be developed. The technologies being chased at Kirtland at the time, at the Air Force Weapons Lab, were gas dynamic lasers, eventually chemical lasers, and solid-state lasers. It was the weapons lab after all, so they had to be big lasers. And if you're going to try to make big lasers, which means you have all kind of big problems. If you're a young person, then big problems are the only problems you want to work on, because they're exciting.

You're going to make a gas dynamic laser. What the heck is that? It's a supersonic stream of carbon dioxide gas mixed with nitrogen and helium, sprayed through a nozzle at supersonic speeds to produce a population inversion, because you need a population inversion, more things in excited states than in the ground state, in order to get lasing to occur. We were basically, burning fuel to make the population inversion but it was more like an explosion than it was burning. An explosion is just very rapid burning after all, right? And you would send this stuff through a nozzle at supersonic speed, and that would depopulate the lower energy states of the CO^2 molecule so you'd have population inversion and you'd make a laser.

And at the time CO^2 lasers were the most efficient lasers ever made at that time, 10% efficiency. Eventually you had to put these things on airplanes or in spacecraft or something. So efficiency was a big deal. And they were meant to be simple, too, so that you could carry propellant with you, or fuel with you. You couldn't have extension cords following you around on the airplane. So if you could burn something, airplanes burn something after all, fuel, you could make a laser. But there were some problems. First you had to shine the laser through a window to get it out. These lasers worked at 10.6 microns, well in the infrared. You have very little optical materials at that wavelength. So that was my introduction to the problem of optical materials, and I spent much of my career working on problems associated with optical materials that you need to do in order to make the laser.

There's a couple of great clichés about making devices. "We've got it all done now, it's only a materials problem." And the answer to that is, it's always a materials problem. You don't have a materials problem if you don't make anything. If you're going to make something then you have materials problems. Especially if it's something new. So we had to shine the laser out of a window.

"I had learned to appreciate how you make a piece of optics. How you do that with salt turns out to be a whole different kettle of fish"

People were making infrared imaging systems using germanium optics. But if you put a lot of energy in germanium, it becomes, not a semiconductor, but a conductor, very quickly you have thermal runaway. The first thing that happens is the laser starts to shut down and then you blow out the window. Germanium was not going to work for a high power laser. So, what would work? What about table salt. Table salt? Sodium chloride. If sodium chloride, what about potassium chloride? Potassium chloride is what we old people take on our steak instead of sodium chloride, so we can reduce our sodium level. Potassium is a heavier ion than sodium, so the vibrational resonance is farther out in the infrared, so it has greater transmission at 10 microns. So, you're going to make a piece of optics, a big piece of optics out of salt. Good thing it was in New Mexico right, it's pretty dry there, but even so, you have to grow the salt, single crystals. You have to be able to polish it, you have to be able to handle it, have to be able to coat it, because you to have make antireflection coatings and that was even more problems. So I got involved in polishing and coating technologies. And that's going backwards to my hometown as a junior high kid walking around a barrel with a piece of glass rubbing on a piece of optics.

I had learned to appreciate how you make a piece of optics. How you do that with salt turns out to be a whole different kettle of fish. It is a very difficult task to do because salt is soft and hydroscopic. It is easier to polish things that are hard than to polish things that are soft, as it turns out. Salt is not only hydroscopic it is also a great desiccant, literaly pulling water vapor out of the air! And it wasn't available in sizes that were needed anyway. So, what to do about that? Well the windows for those gas dynamic lasers turned out to be supersonic wind tunnels. You make a supersonic shockwave across the tube containing the CO^2 gas. You had one engine burning to produce population inverted CO^2, another engine to make the window to get the light out of the cavity. The supersonic shockwave had to be uniform because you don't want to screw up the phase of the beam.

There were all kinds of problems making mirrors as well. We were making big lasers. How big? Of the order of number a megawatt, a million Watts of power. Well your mirror can't have too much absorption. Ah, it's ok, gold has very high reflectivity at 10 microns, so does copper and silver, 98%. Well 2% of a big number is a big number. We were not worried about losing 2%, we were worried about the conservation of energy. Where is that 2%? It's inside the mirror, so the mirror would distort. So, now the phase quality of the beam is no good, so you can't propagate it. So we had to develop new technology for making mirrors. The solution was very complicated honeycomb structures that you could flow water through, or a coolant through, and you would put a face plate of molybdenum top of the honeycomb cooling system, and then coat the molybdenum with something. We had to develop the technology for the mirrors, coatings for the mirrors and, polishing.

There was a big effort in DARPA to come up with new materials to use for laser windows for high power lasers at 10 microns. The outcome of that effort was the development of CVD grown ZnSe. The reality of the times was that there were just too many advances in the state of the art to produce a functional high power laser weapon. However many new technologies were developed, like ZnSe, that really helped spark the growth of lasers, especially work horse lasers like CO^2 lasers used in cutting, welding, and other industrial applications.

Another problem with high energy CO^2 lasers is the size of the optics required, and the efficiency. Diffraction limited optics for 10.6 microns means big optical components (diameter scales as the wavelength which means the area of an optic scales as the wavelength squared.) Which means the cost is really large for large optics for long wavelengths. If you make the wavelength shorter, everything becomes more compact, and cheaper, and more practical. The DOD turned to chemical lasers using hydrogen fluoride and deuterium fluoride as the lasing material. These devices had efficiency of about 30% and operated at 2.7 and 2.8 microns respectively. Put hydrogen and fluorine near each other and they combine instantly, make a big boom, and much of that energy goes into the vibrational mode of the hydrogen fluoride molecule. You have instant population inversion, huge gain, good efficiency, and the surface area of the optics is almost an order of magnitude smaller for the same diffraction limited spot. But these devices had their own problems. Hydrogen fluoride is nasty stuff. Fluorine itself is nasty stuff. It will react with everything. In fact, atomic fluorine has to be cryogenically stored, and pumped through cryogenically cooled lines. These are rocket engines with mirrors on either side. No shortage of challenges!

Big YAG and neodymium glass lasers were being developed at Kirtland and other places as well. Because if you're going to make a big solid-state laser, you can't make big YAG crystals so you make, you dope glass with neodymium, you make neodymium glass lasers. Most of the really big solid state lasers would turn out to be developed at Lawrence Livermore National Laboratory as part of the nation's efforts on laser fusion. But the first work on that sort of stuff was done at the Air Force Weapons Lab to try to make solid state laser weapons. The joke among the junior officers at the time was that being in the Air Force working on high energy lasers was the perfect job for a pacifist in the military. Because you knew darn well nobody would ever get hurt by one of those things, unless it fell off the airplane and fell on him. But a lot of technology was developed at Kirtland at the time in the areas of high power lasers and their optical components.

Some of these early problems persist. The community is always pushing new lasers, new wavelengths, and shorter and shorter pulses. As in the 1960-70's you are often limited by the capacity of the optics to support the laser itself. We see a lot of cartoons about lasers zapping things. The things that lasers more often zap are the optics that make up the laser themselves. The intensity of the laser is highest inside the cavity of the laser. So that drives the area of laser induced damage to optical material, which is the place where I made my career after leaving Kirtland to go to work for the Navy. I was introduced to that field by the late Art Guenther.

CP: How did you go from there to get your PHD and what did you do?

To Be Continued in the March/ April Issue of LIA TODAY.

Be sure to register for ILSC 2019 to hear Dr. Soileau speak during the Opening Plenary!

A REVIEW OF PHOTONICS WEST 2019

By Ronald D. Schaeffer, PhD

A REVIEW OF PHOTONICS WEST 2019

SPIE's flagship photonics conference was held from February 2-8 in San Francisco, CA. Actually, this conference consists of a number of sub-conferences (BIOS, LASE and OPTO). I have been attending this conference without a break for over 25 years and over those years I have been involved in teaching courses, giving papers, chairing sessions and helping in other organizational activities. This year LIA asked me to do a review of the show (from my perspective!) and it is presented below.

BIOS

BIOS is billed as the world's largest international biomedical optics conference, encompassing clinical, translational, and fundamental research and development in the field of biomedical optics and photonics. It provides a premier technical forum for reporting and learning about the latest research and development, as well as for launching new applications and technologies. Special events include hot topic presentations, the BIOS Expo, focus on Translational and BRAIN research, and industry-leading working groups and panels.

BIOS is held on the weekend before Photonics West actually starts, but though there are many of the same vendors, it is a totally different show and the tables/booths that are set up for BIOS are taken down and re-assembled the next day for the main event. I kind of always poo—pooed this show because it was bio related, it was on the weekend, and hey – why spend money to put booths at two shows in the same week and at the same place? Well, I got a lot of really good feedback about the BIOS show and was told that indeed this venue was better for lead generation in some areas than the big show itself.

So, I will definitely think about checking it out next year – but there goes another Super Bowl (the Super Bowl is on Sunday February 2nd, the same weekend as BIOS)! This year (2019) for the first time in four years I was actually at home to watch the Super Bowl, the last few years being in California attending Photonics West and the MSM show in Anaheim which is usually held on or about the same time as Photonics West. Two years ago I fell asleep at halftime when the Patriots were losing by something like 20+ points, only to wake up at the very end to see the final go-ahead – in my hotel room. Last year I watched in a San Jose pub and was definitely in the minority being a New England fan in California. This year though I got to fall asleep in my own house, and then get up very early the next morning to fly to California.

LASER MARKETPLACE SEMINAR

On the Monday event card, the premier attraction is the Laser Marketplace Seminar hosted by Pennwell Publications. Held each year on the Monday during Photonics West, the 2019 Lasers & Photonics Marketplace Seminar featured keynote presentations from the general manager of Trumpf Laser Technology and the CEO of Novanta – two of the most influential companies in the laser industry today. The Seminar is the only laser marketing event of its kind, where laser industry professionals meet to hear the latest industry forecasts and trends, while networking with their peers and mentors.

In the morning keynote, Trumpf Laser Technology general manager Ralf Kimmel spoke about "Solution-oriented integration as key for sustainable success in the laser business." Kimmel says that as laser sources for manufacturing applications have become standardized products, system integration remains the key to differentiating production solutions. This integration must be based on application and production requirements, and on the integration of optics, sensors, and beam delivery into turnkey installations. Connectivity and digitalization will drive further solutions to improve productivity, quality, and reliability. In his keynote talk, Kimmel provided specific examples of how application requirements result in new turnkey solutions consisting of more than an ideal laser source. For example, remote welding as an interpolated process with robotic kinematics, additional laser beam shaping, or cloud-connected sensors for lasers and optics are all solutions that illustrate how end users have new expectations of laser manufacturers. Even laser source development based on direct application requirements - such as green lasers for copper welding - must be based on the same solution-driven approach. These end-user expectations are changing the business model of laser manufacturers toward a solution-oriented turnkey provider, meaning that, more than ever, applications-specific know-how is the key to sustainable success.

The afternoon keynote discussion was entitled "A conversation with Matthijs Glastra, CEO Novanta." Glastra spoke with Laser Focus

World Editor at Large Conard Holton about Novanta's broad portfolio of photonics, motion, and vision technology that serve applications across major medical and advanced industrial markets. The conversation explored Glastra's views on the different applications that are now driving photonics markets, including industrial processing and life sciences, and also examined the competitive landscape for optics and laser manufacturers, and the opportunities for new technologies and products. They also discussed subjects such as Novanta's long-term growth strategy, including acquisitions and global markets.

Former Laser Focus World Editor Conard Holton is now focusing on this event almost exclusively in his semi-retirement. While there were no earth-shattering revelations presented, there was a record attendance of about 180 people. The most popular sessions were the ones on Flow Cytometry and Quantum Computing. The Quantum Computing session lasted 1.5 hours and remarkably everyone stayed to hear the whole talk, which also featured the public announcement of a new world's record. Both of the above talks will be made into webcasts and will be available on the Pennwell site in the March time frame. Stay tuned! Dr. Bo Gu gave his usual talk on the status of the laser industry in Asia and specifically China and as usual held the audience's attention. In fact, in the Wednesday show feedback on Optics.org they covered Dr. Gu's talk. Perhaps the most telling thing is that Conard told me he got a number of compliments – something he almost never gets after seminars! We also got to meet John Lewis from Pennwell who has taken over as Editor-in-Chief of the Pennwell Technology Group.

THE MAIN EVENT

The LASE and OPTO sub-conferences make up the majority of the main event. The LASE portion concentrates on industrial lasers, laser sources and laser applications. With 900 papers and presentations, LASE is probably the most comprehensive laser technologies conference. Topics include laser manufacturing, laser materials processing, micro-nano packaging, fiber, diode, solid state lasers, laser resonators, ultrafast, semiconductor lasers and LEDs, and 3D fabrication technologies. OPTO concentrates on Photonics Materials, Opto-Electronics and Devices. With 2,000 papers and presentations, OPTO is the largest optoelectronics conference in the US. Topics include on-silicon photonics, photonic crystals, optoelectronics, semiconductor lasers, quantum dots, and nanophotonics. This conference addresses the latest developments in a broad range of optoelectronic technologies and their integration for a variety of commercial applications.

The conference drew over 23,000 attendees with more than 5,000 presentations and 1,300 exhibiting companies. All of the vendor space was sold out. In fact, apparently a number of Chinese companies that had signed up for the show could not send people as Visas did not get processed in time, so the booths were canceled – but according to my knowledge, SPIE had a waiting list more than long enough to fill every space. Anyway, I did see any noticeably empty spaces.

Let me get one point across – this show is so big that my feedback is very limited in that I am only really interested in the state of the industry in general and the microprocessing portion in specific. Also, there simply is not enough space in a short review article to hit every part of the show, so personal bias certainly is at work. This year for the first time in over 25 years I did NOT teach my course (Fundamentals of Laser MicroMachining) and so I thought I would do something with the extra day that I have not done since the venue left San Jose – walk the show from one end to the other. Unfortunately for a number of reasons it did not happen. I did spend a lot of time in the German pavilion, mostly in the Light Fab booth, but I also had a lot of meetings at various places on the show floor and spent most of the time on the floor getting to and from places than actually browsing.

MKS is a large company that provides a variety of things from the lasers, to components and on to full production systems. I had a nice and somewhat long meeting with the folks at MKS and this meeting is a good example of some of the things to find at Photonics West (PW). MKS acquired Newport a while ago to add to its array of companies all designated to 'surround the workpiece'. MKS provides customers with key components (including its line of Spectra Physics lasers), systems and services that enable successful implementation of laser based manufacturing solutions. For the semi-conductor market, the work piece is the wafer. For other markets it may be a biological sample, glass sample, printed circuit board or metal sheet. MKS is fully integrated to provide the lasers, optics, motion control and any other element needed to

Continued on next page.

make these high-end manufacturing tools. They have an excellent resource available called the *MKS Instruments Handbook – Principles and Applications in Photonics Technology*, which was written by a collaboration of their smartest and most experienced technical gurus with many familiar industry names associated. Ask for a copy and check it out!

The most important thing anyone can do at these events is NETWORK! Years ago, I was intending to hire a very smart and experienced young lady for a technical sales position. Her company at the time was sending her to an ICALEO conference (more on this later) and we planned to chat there. The Sunday Opening Gala came and went – no sign. No sign on Monday at the talks or at the President's reception. She finally showed up for one of the Tuesday pm talks but was not planning to go to the Vendor Reception, which I found incredible. I asked why she had not been at any of the social venues. Her answer was that she did not know anybody, so what is the point? No, I did not hire her. The point is that there are LOTS of chances to network at these events and the planners go to great pains to create opportunities. Take advantage of them! Press as many hands as you can and CARRY LOTS OF BUSINESS CARDS!!

On the show floor networking can be done by just wandering the halls and talking to anyone that strikes the interest. I would imagine most attendees are more rigorous in that they are there to target specific vendors, talks, papers, etc., but everyone should leave a bit of time for browsing if possible. There are also talks on the floor and at some of the booths. There are refreshment times when everyone gathers in one of several available areas. So, besides being on the expo show floor or at the technical talks, where else can you network? The first place that comes to mind is the Poster Sessions. In addition to the large number of live talks, there are hundreds of posters and even free poster session drink tickets. The sessions occur several nights a week and last for a few hours, so it is a great place to network after the show and before later night activities. If you are 'in the know' there are dozens of off-site hospitality suites, open bars, dinners, etc. going on.

Note that for the plugged-in generation, there are a number of social media interactions available. First, you can download an app that will guide you around the show floor. There are other apps available that will plug you into specific user groups. SPIE has its own version of Beer's Law as well! A group of scientist/musician types started picking together years ago at the SPIE Defense conference in Orlando and later in Baltimore. This migrated to the Photonics West show and this year they put on a nice show at the Biscuits and Blues on Wednesday night. This is not show organized, but rather by Michael Thomas from Spica and a few other industry folks. Check it out next year!

One other thing of note happened during Photonics West week. The official announcement for ICALEO came out and the event will be held the week of October 6 in Orlando. It is not a secret that this announcement was very late in coming out, as it usually happens in the November time frame, so a number of foreign people I talked to may not be attending because they had to get their travel budgets in before the end of the calendar year. Executive Director Dr. Nat Quick and various LIA associates were working the PW show lining up prospective corporate members as well as vendors, sponsors and attendees for upcoming LIA events including ICALEO. I am told that due to vigorous LIA staff efforts, the expected attendance at ICALEO this year should be record setting. On the topic of ICALEO and Beer's Law – I had a chance to play a live gig with Henrikki Paantsar (Trumpf) and Amanda Dobbins (Scanlab) at a place in San Jose the Friday after PW and it was a great show for the first time we have ever played together. If all goes according to plan we will be doing a repeat performance at the Opening Ceremony this year at ICALEO!

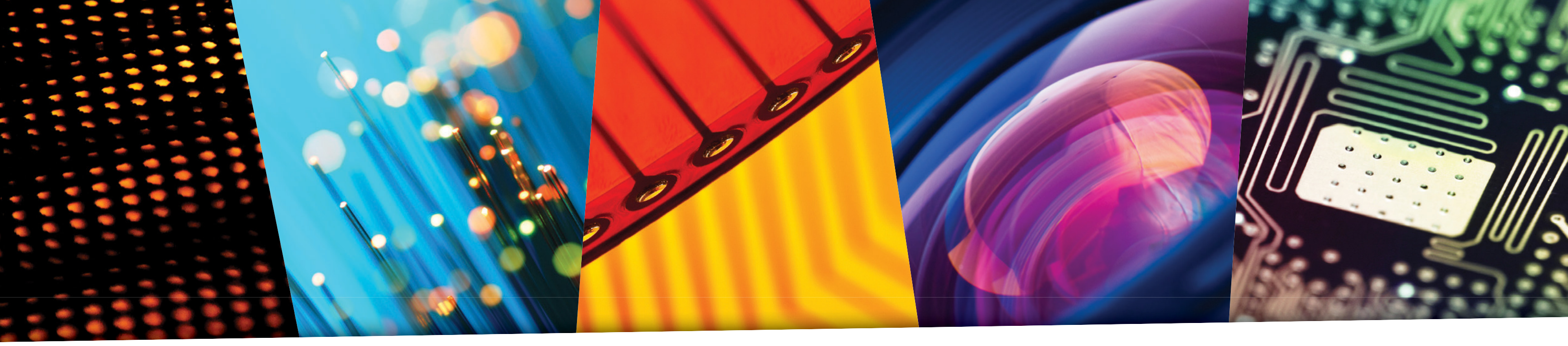
One final note about another conference – MDM West. This year was one of those years that Photonics West was held during the same week as the MDM show in Anaheim. Usually they are 'back to back' or maybe separated by a week at most, so it is possible for those interested to attend both venues, but some years they are held simultaneously. A lot of people have commented that there should be more coordination between the two sponsoring entities, namely SPIE (Photonics West) and UBM (MDM), but the fact is that they are two totally separate and independent entities and I seriously doubt either of them look at the other's advanced scheduling to determine their conference schedule – it is more a matter of available conference space.

While I am one of those who did not attend MDM so I could concentrate on Photonics West, I did chat with a number of my colleagues who did attend – some ONLY attended MDM and others attended both shows for a day or two. The general consensus is that while both shows were very busy and certainly provided ample leads and opportunities, it seemed that the MDM show attendance was affected more by the PW venue than the PW attendance was affected by MDM.

MD&M West is the most comprehensive medical manufacturing conference in the U.S., taking place in one of the world's largest hubs for medical device innovation — Southern California. This year's conference featured a program of sessions, panels, and workshops covering disruptive design, new materials, 3D printing, robotics & automation, regulatory guidance, and more. This year MD&M West presented the following venues which I think are quite interesting: the Smart Manufacturing Innovation Summit, 3D Printing Innovation Summit, and the Chief Robotics Officer (CRO) Summit. Smart Manufacturing, 3D Printing and Robotics ……. the same three growth areas that we see in the laser industry.

So, once again the Photonics Industry appears to be booming. Order books are mostly full, even if stock valuations are fluctuating. Everyone I talked to is expecting at least a good 2019 – anyway for the first 6 months of the year, with a wait and see attitude for the last half of the year. Another big venue is coming up in June – the Laser World of Photonics held in Munich June 24-27. I will be attending this venue and we will see where the economy is at then and how lasers are faring.

Ronald D. Schaeffer, Ph.D. *is Chief Executive Officer at HH Photonics, Editorial Advisor and Frequent Blogger for Industrial Laser Solutions and Technical Writer and Editorial Committee for LIA. He can be contacted at rschaeffer072657@gmail.com.*



MEET THE 2019 BOARD OF DIRECTORS

2019 OFFICERS

LIA's 2019 President, Minlin Zhong is a professor at the School of Materials Science & Engineering of Tsinghua University. He is the Director of the Laser Materials Processing Research Center. He received his bachelor degree on laser technology from Huazhong University of Science & Technology in 1983 and PhD in laser processing from Tsinghua University in 1997. From 1997-1998, he was a post-doc Fellow in the Laser Centre of French Welding Institute and guest scientist in Hannover Laser Centre in Germany. He started his research on laser materials processing since 1983, his research interests cover laser micro-nano fabrication, laser surface engineering and laser 3D printing. He has been the PI for 19 international cooperation projects, 20 domestic scientific projects and 20 domestic industrious projects. He has published 240 papers in peer review journals and 70 papers in international conferences, in addition to 18 patents and 4 book chapters.

Dr. Zhong has been active during the years in the domestic and international laser communities. He has co-organized nine China national conferences on laser materials processing. He has been the program committee member, session-chair, co-chair and international advisor member for numerous international conferences organized by LIA, OSA and SPIE. He was the General Conference Chair of PICALO 2008 and the co-chair of the "LPC" in Laser-World of Photonics China from 2006-2012. He has given over 60 plenary keynote, keynote and invited presentations in international and domestic conferences. Dr. Zhong was elected a Fellow of Laser Institute of America in 2010 and a LIA board member in 2005-2007, 2011-2013 and 2015-17.

Gilbert Haas, President-Elect, has worked with industrial lasers for the past 36 years. His education consists of a BS degree in Electrical Engineering from the University of Wisconsin and an AS degree in Laser Technology from North Central Technical College. He also has advanced his formal education by completing several additional classes in the fields of Mechanical Engineering and Metallurgy. Throughout his career, Mr. Haas has taught classes, given many lectures, published numerous papers and holds several national and international patents in the field of industrial laser applications.

Throughout his career with lasers, Mr. Haas always saw a need for new and innovative laser beam delivery technology. So in 1992, Mr. Haas founded Haas Laser Technologies, Inc. Today, Haas Laser Technologies, Inc. designs and manufactures custom laser beam delivery components, laser beam measurement equipment and laser systems for industrial applications at its facilities in Flanders, New Jersey.

Mr. Haas served on the LIA Board of Directors in 2015 and 2016 and as treasurer of the Executive Committee in 2017 and 2018.

Past-President Milan Brandt, has been involved with lasers and manufacturing technologies professionally for 34 years and is recognized nationally and internationally as the leading Australian researcher in the field. Prof. Brandt is a professor in Advanced Manufacturing in the School of Engineering, as well as the Technical Director of the Advanced Manufacturing Precinct, and the Director of RMIT Centre for Additive Manufacturing at RMIT University in Melbourne, Australia. He is the recipient of numerous awards and is the author of more than 200 publications, five book chapters, and a book on laser additive manufacturing.

Prof. Brandt has had a 30-year association with LIA, including his involvement on the organizing committees for ICALEO and LAM for many years, as well as serving on the LIA Board of Directors. Prof. Brandt was the organizer and General Chair for PICALO 2004 and PICALO 2006, which promoted industrial lasers and applications in the region. He is also the Senior Editor of JLA in additive manufacturing.

Treasurer Lucian Hand is President of Altos Photonics, where he has developed the EKSPLA-USA and Light Conversion USA brands, well recognized in the ultrafast laser community. Altos Photonics may be described as 'rarely within 9 orders of zero' – working with nano, pico, and femto-second pulse durations to achieve Giga, Tera, and Peta-Watt peak powers. Since joining Altos Photonics in 2002, Mr. Hand has been responsible for technical sales, installation, user-training, and technical support for lasers, laser systems, and opto-mechanical components. He has actively participated in design and development of high-energy lasers, with several reaching notable commercial success. Presently, Altos Photonics employs 14 persons, serving both industrial and research markets.

Mr. Hand has been active in LIA since attending ICALEO in 2002, maintaining corporate membership and exhibiting at ICALEO and LME. Additionally, he participates in the ANSI Z136 committee as a member of the dot-8 subcommittee for laser safety in research and development where he has worked to ensure that the standard is matched to real-world research techniques. Mr. Hand has a B.S. in Physics from Arizona State University, and is grateful for the many peers, customers and colleagues who continue to educate him.

Secretary Henrikki Pantsar is Director of Applications and Services at Trumpf, Inc., Laser Technology Center in Plymouth, MI. In this position, he is responsible for micro, macro, marking, and additive manufacturing applications, as well as after-sales operations, including technical services and spare parts. Previously, he held the positions of Chief Technology Officer and Vice President of Research and Development at Cencorp Corporation/Valoe Corporation. He has also worked in the field of laser applications at Fraunhofer USA, VTT Technical Research Centre of Finland, and Lappeenranta University of Technology. Dr. Pantsar received his Doctor of Science in Technology degree from Lappeenranta University of Technology, and he also received the Henry Granjon Prize of International Institute of Welding for his work in laser-hardening research.

2019 – 2021 BOARD OF DIRECTORS

Amber N. Black works as a Staff Scientist for the Welding & Joining team of Sigma division for Los Alamos National Laboratory, where she coordinates welding and additive manufacturing programs. Her primary research focus is high energy density processing techniques utilizing laser and electron beam. As well as leading the Sigma laser laboratory, she performs R&D on laser vacuum processing, directed energy deposition additive manufacturing, and process characterization for both laser and electron beam welding. Previously she worked for PTR – Precision Technologies, Inc. as a welding engineer and the Connecticut Center for Advanced Technology as a laser specialist. She has developed weld processes for Rolls-Royce, SpaceX, United Technologies Aerospace Systems, Detroit Diesel, Lockheed Martin, GE Power, and more.

Dr. Black is currently the chair of the AWS C7 committee on High Energy Beam Welding and Cutting and a past chair or active member of several other committees in both AWS and ASM. She is also a past Student Board Representative of ASM International.

Dr. Black holds a bachelor's degree in Mechanical and Material Science & Engineering from the University of Connecticut and a doctorate in Engineering Science from Penn State University.

Paul Denney has been involved in the development and implementation of laser materials processing for over 30 years. Presently he is a Senior Laser Applications Engineer at Lincoln Electric in Cleveland, OH. Previously I was the director of the Laser Applications Laboratory at the Connecticut Center for Advanced Technology (CCAT), the laser technology team leader at the Edison Welding Institute (EWI), the head of the High Energy Processing Department at ARL Penn State, a research engineer at the Westinghouse Electric Research & Development Center in Pittsburgh, a metallurgist at the Naval Research Laboratory (NRL), Washington, D.C. and a product metallurgist at C.F. & I Steel Corp. in Pueblo, CO. He is a fellow member of LIA and current member of the board of directors for LIA and has been general chair and the Laser Materials Processing chairperson a number of times for ICALEO. He was also chaired the LIA Laser Additive Manufacturing (LAM) conference the last four years. In addition to LIA, he is also a member of ASM and AWS where I participate in C7, C7C, and C7D committees on high power density processes. He has over twenty US patents.

Stefan Kaierle studied electrical engineering and went on to do his PhD in mechanical engineering at RWTH Aachen University, Germany. In 1998 he joined Fraunhofer ILT as a department head for system technology. In this role, his main research was focused on laser system technology, laser materials processing, laser process control and optics, as well as related fields like eco-efficiency, automation and laser engineering. He published more than 100 scientific papers in journals and conferences in that field. Also, he holds more than 10 patents. He had been appointed to two guest professorships at Changchun University (in 2005) and at Beijing University of Technology (in 2007), China.

In 2012, Stefan Kaierle moved to Laser Center Hannover (LZH) and assumed responsibility for the department of Materials and Processes. Currently, he is also President of the European Laser Institute ELI and Co-Executive Editor-in-Chief of the new NATURE journal "Light: Science & Applications".

Yongfeng Lu is currently the Lott Distinguished Professor of Engineering at the University of Nebraska-Lincoln (UNL). He received his bachelor degree from Tsinghua University (China) in 1984 and M.Sc. and PhD degrees from Osaka University (Japan) in 1988 and 1991, all in electrical engineering. From 1991 to 2002, he was a faculty in the ECE Dept. at National University of Singapore. He joined the Department of Electrical Engineering at UNL in 2002. He has more than 20 years of experience in processing and characterization of micro/nanostructured materials. His group has research projects funded by NSF, AFOSR, ONR, DTRA, DOE, DOT, NCESR, NRI, private companies, and other foundations in Japan, with research expenditures of $20 million in the past a few years. His research has led to a number of commercialization and product developments.

Dr. Lu has authored or co-authored over 300 journal papers and 350 conference papers. He has been elected to SPIE Fellow, LIA Fellow, and OSA Fellow. He served as the President of the Laser Institute of America in 2014. He has also served as Chair and General Chair for major international conferences in the field including the General Congress Chair for the International Congress of Applications of Lasers and Electro-Optics (ICALEO) in 2007 and 2008, and general co-chair for LASE in Photonics West 2014 and 2015.

Eric Mottay was born in 1963, in France. He graduated in 1985 from the Ecole Superieure d'Optique near Paris, the leading institution in France for Optical Engineering. Within the Commissariat à l'Energie Atomique, he developed fiber delivery systems for Nd:YAG laser welding. In 1986, he joined B.M. Industries, a laser manufacturing company. Initially as a research engineer, then as Technical Director, he specialized in the development and manufacturing of solid-state lasers. He brought to market a number of innovative products, such as high energy Q-switched Nd:YAG lasers, advanced parametric oscillators, and Ti:Sapphire based ultrafast laser systems. In 1997, he moved to the US to start the U.S. operations of B.M. Industries, where the activity was growing and profitable within one year.

In 2001, he founded Amplitude Systemes in Bordeaux, France. Under a technology transfer from the University of Bordeaux, and starting from a scientific proof of concept, he developed the company into what is today a leading industrial ultrafast laser manufacturer. In doing so, he developed during the past ten years many scientific and industrial partnerships with research institutions, technology centers and industrial companies.

Robert Mueller, PhD, CLSO, is a Sr. Laser Solutions Specialist at NuTech Engineering Inc. in Milton, Ontario, Canada. NuTech Engineering designs and builds custom automated welding and cutting systems, and Robert's role is to lead the specification, design and process development for all laser systems and applications. Robert is also responsible for laser safety at NuTech, including system design, laser system certification, and laser safety training of NuTech and customer personnel.

Prior to joining NuTech, Robert worked with laser systems at Dofasco (now part of Arcelor-Mittal Steel), Powerlasers, and as a post-doctoral researcher at the University of Waterloo, and the University of Tennessee Space Institute.

Robert has over 25 years experience working with lasers of all types, and 20 years experience with industrial laser applications and systems. His areas of expertise include process development and system design for laser welding and laser cutting systems, and in-process quality monitoring and control. Robert has maintained his Certified Laser Safety Officer designation since 2003.

Rob has a PhD from York University, with a thesis on laser welding dynamics, as well as an M.Sc. in Laser Physics from The University of Toronto.

Andreas Ostendorf studied electrical engineering at the University of Hannover, Germany. In 1995 he joined the Laser Zentrum Hannover (LZH) as a scientist dealing with micro-machining using UV and ultrafast lasers. In 2000 he finished his PhD thesis on comparing the interaction models of those two laser principles. After holding different offices at LZH, in 2001 he became its CEO and a member of the board of directors. As a scientist, he has been involved in many national and international research programs and German Collaborative Research Centers. His scientific work is focused on laser micro- and nanostructuring. In 2008 he became full professor at Ruhr-University Bochum where he holds the chair of Laser Applications Technology (LAT).

Andreas Ostendorf was elected to the board of directors of LIA for the term of 2004-2006. Since 2005 he has also been a member of the executive committee of LIA, responsible for coordination of conferences. He was LIA president in 2008. Also, Andreas is a fellow of LIA and SPIE. Besides these positions he was co-chairing ICALEO® 2002, 2003, and 2004, responsible for the micro-fabrication conference. In 2005 and 2006 he was the general chair of ICALEO®. Andreas Ostendorf is also a member of the WLT German Scientific Laser Society, which cooperates internationally with LIA.

Rajesh (Raj) S. Patel has accumulated 20 years of experience in the laser material processing field. He is currently a manager at Spectra Physics, a division of Newport Corporation, and is responsible for managing laser processing applications lab and new laser product development project. Prior to working at Spectra Physics he had his own consulting company and has also worked at IBM, Aradigm, and IMRA America in the past. He received his PhD degree in mechanical engineering from the University of Illinois at Urbana-Champaign in 1989. His professional interests are in the areas of laser development, laser material processing and equipment design, mask technology, optics, and application of lasers in various fields. He has worked with various lasers for developing applications in microelectronics, semi-conductor, bio-medical, and the photonic industry. He is an author of 22 U.S. patents related to laser processing, optics, and the mask technology field and has published and presented more than 40 technical papers. He is a member of LIA and SPIE and has served on LIA's Executive Committee. He has also co-chaired LIA's ICALEO 1997, 1998, 1999, and 2002 conference, and was conference Chair of ICALEO 2004.

Karl Schulmeister received his PhD in biophysics on modeling of the risk for laser induced retinal injury in 2001 from the Vienna University of Technology.

Since 1994 he is head of the "Laser, LED and Lamp Safety" group at the Seibersdorf Laboratories, Austria. Karl is senior consultant on laser product safety, his department offers testing of laser and lamp products. From 1999 to 2009 he also served as lecturer for non-ionizing radiation protection at the University of Technology in Graz, Austria. His team has developed computer and ex-vivo models for predicting laser induced ocular and skin damage thresholds. The 2013/2014 update of the ANSI and IEC laser safety limits for retinal thermal injury is based to a significant degree on the work of his group.

Karl Schulmeister is co-author of the book "Laser Safety". He is author and co-author of over 100 peer reviewed and proceeding papers as well as book chapters. Karl was project leader for Edition 3 of the international laser product safety standard IEC 60825-1. He is member of ANSI Z136 TSC-1 "Bioeffects" and the ICNIRP Scientific Expert Group.

Brian Victor has been developing laser processing solutions throughout his career with roles in engineering, applications, manufacturing, service, sales, and management. He obtained BS & MS in Welding Engineering from the Ohio State University focusing on high-power fiber laser welding. As applications engineer at EWI, he developed processes for a diverse list of CO2, YAG, and fiber laser applications from paint removal and concrete drilling to cutting, welding, cladding, brazing, and hardening of metals. He served as applications, service, and sales engineer for Laserline's fiber-delivered diode lasers in the automotive and power oil & gas markets. As senior manufacturing engineer at a sheet metal and piping fabricator, he was responsible for the health and productivity of all laser cutting systems and robotic processes. Currently, Mr. Victor is Director of Industrial Applications at nLIGHT managing the global team of applications engineers. He supports nLIGHT's customers and partners by developing fiber laser processing solutions and troubleshooting their manufacturing challenges. He has been a member of LIA since 2006 and currently serves on the Industrial Laser Solutions editorial advisory board. As a member of the LIA Board of Directors, Mr. Victor hopes to further strengthen the connection between applied research and industrial innovations in the field of laser materials processing.

Conference Highlight

ILSC®
INTERNATIONAL LASER SAFETY CONFERENCE

MARCH 18-21, 2019
KISSIMMEE, FL

The International Laser Safety Conference (ILSC®) is a comprehensive four-day conference covering all aspects of laser safety practice and hazard control. Scientific sessions will address developments in regulatory, mandatory and voluntary safety standards for laser products and for laser use. The Practical Applications Seminars (PAS) complement the Scientific Sessions by exploring everyday scenarios that the LSO and MLSO may encounter. Professionals in all fields and applications will find ILSC a tremendous source for information and networking opportunities.

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LIA Laser Safety Trainings

LASER SAFETY OFFICER TRAINING	
Orlando, FL	May 29 - 31, 2019

LASER SAFETY OFFICER WITH HAZARD ANALYSIS*	
Orlando, FL	Jun. 3 - 7, 2019
Orlando, FL	Aug. 19 - 23, 2019

** BLS Certified Laser Safety Officer Exam offered after the course.*

INDUSTRIAL LASER SAFETY OFFICER TRAINING	
Novi, MI	May 15 - 16, 2019

MEDICAL LASER SAFETY OFFICER TRAINING*	
Orlando, FL	Jun. 1 - 2, 2019
Orlando, FL	Aug. 17 - 18, 2019

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Visit www.lia.org for all course and event listings

Course Highlight

LSO WITH HAZARD ANALYSIS TRAINING

This course takes a mathematical approach to laser safety, designed to teach LSOs administrative duties and hazard analysis calculations that will help them develop, implement and maintain laser safety programs while meeting the training requirements as outlined by the ANSI Z136.1 Safe Use of Lasers standard and OSHA.

All attendees will receive a course manual including a resource CD with useful LSO documentation forms, ANSI Z136.1 Safe Use of Lasers, LIA's Laser Safety Guide, and a certificate of completion. This course meets the training requirement to apply to sit for the official Certified Laser Safety Officer exam offered by the Board of Laser Safety.

JUNE 3 – 7, 2019

JLA Journal of Laser Applications

EFFECTS OF FEMTOSECOND LASER IRRADIATION ON THE MICROSHEAR BOND STRENGTH OF SOUND AND DEMINERALIZED DENTIN

P. F. CASSIMIRO-SILVA, FRANCISCO DE ASSIS M. G. REGO FILHO, LUCIANA SANTOS AFONSO DE MELO, TEREZA JANUÁRIA COSTA DIAS, CECÍLIA CRUZ FALCÃO, GABRIELA QUEIROZ DE MELO MONTEIRO, AND ANDERSON STEVENS L. GOMES)

The aim of this in vitro study was to assess the microshear bond strength (μSBS) of an adhesive system in sound (SD) and demineralized dentin (DD) after femtosecond (fs) laser treatment. Twenty specimens of human dentin were randomly divided into two main groups: sound and demineralized dentin ($n = 10$). In each of them, three different tissue conditions were produced: SD control group, SD etched with two different fluences of an fs laser (11 and 18 J/cm2, SD11 and SD18, respectively), DD control group, and DD irradiated with the same laser parameters (DD11 and DD18). An adhesive system was applied to the dentin surface, and a resin composite was light-cured to bond to the dentin surface. The μSBS was measured, and the fracture analysis was performed using an optical microscope. The data were analyzed using the Mann Whitney test ($p < 0.05$). Tissue morphology was assessed via 2D and 3D optical coherence tomography images, scanning electron microscopy, and atomic force microscopy. The optimum bond strength was recorded for the SD11 group (16.42 ± 4.63 MPa), and the minimum bond strength was recorded for the DD (8.89 ± 0.99 MPa) group. The Kruskal Wallis test revealed that sample groups were significantly different ($p < 0.01$). The Mann Whitney test demonstrated statistical differences between DD and all the other groups. The imaging techniques showed the opening of the dentinal tubules and that the bond strength could be related to laser-induced roughness. Femtosecond laser radiation was successfully able to remove smear layers, producing surface alterations that caused higher dentin-resin adhesion.

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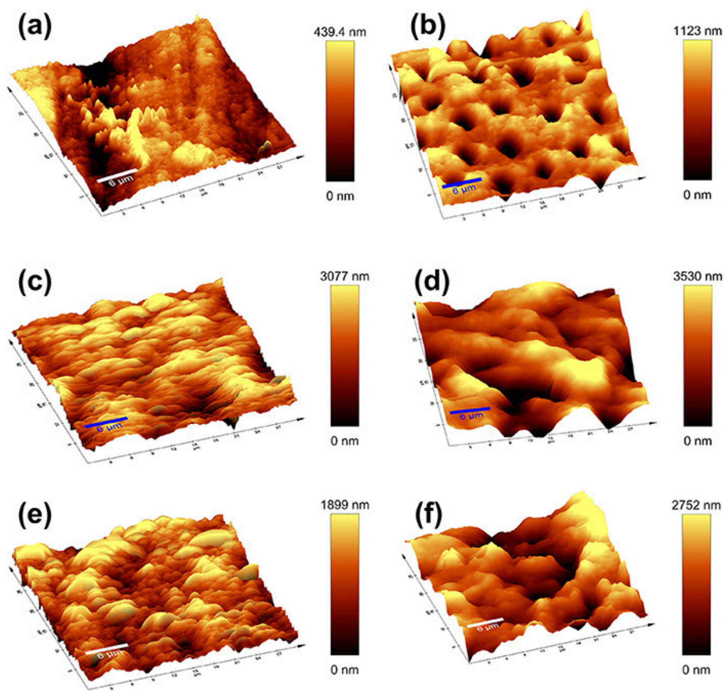

FIG. 5. AFM image of (a) sound dentin surface, (b) after erosive challenge, areas irradiated with Ti:Sapphire laser (c) SD_{11}, (d), DD_{11}, (e) SD_{18}, and (f) DD_{18}.

What's New?

In this conversation B C L S

Message
Today 10:11 AM

What's new with everyone over at LIA?

L
LIA TODAY

C
Conferences

The dates and location for ICALEO 2019 have been announced! See you in Orlando, FL from October 7-10. You can view the call for papers here: **www.icaleo.org**

B
Board of Laser Safety

We are proud to announce the winners of the BLS Illumination Award! Congratulations to Agiliti and Lawrence Livermore National Laboratory! The awards will be presented at ILSC 2019.

S
Standards Dev.

Accredited Standards Committee (ASC) Z136 will hold its annual meeting on March 17, 2019 just preceding ILSC! Observers are welcome to attend; please contact bsams@lia.org for more information.

Join the discussion! Send