LIA TODAY

THE OFFICIAL NEWSLETTER OF THE LASER INSTITUTE OF AMERICA

The international society dedicated to fostering lasers, laser applications and laser safety worldwide.

FOCUS: MATERIALS PROCESSING | VOLUME 20 NO. 4 | JULY / AUGUST 2012

ICALEO®

31st INTERNATIONAL CONGRESS ON APPLICATIONS OF LASERS & ELECTRO-OPTICS

Featuring Cutting-Edge Explorations of Laser Manufacturing

pg. 6

LIA Presents Its First Annual Laser Welding & Joining Workshop - pg. 10

Femtosecond Laser Micro/ Nanomachining of Glass Materials for Optofluidic Applications & Beyond - pg. 14

Laser Institute of America

Laser Applications and Safety

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IN THIS ISSUE

FEATURES

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LIA TODAY

THE OFFICIAL NEWSLETTER OF THE LASER INSTITUTE OF AMERICA

LIA TODAY is published bimonthly to educate and inform laser professionals in laser safety and new trends related to laser technology. LIA members receive a free subscription to *LIA TODAY* and the *Journal of Laser Applications*® in addition to discounts on all LIA products and services.

The editors of *LIA TODAY* welcome input from readers. Please submit news-related releases, articles of general interest and letters to the editor. Mail us at *LIA TODAY*, 13501 Ingenuity Drive, Suite 128, Orlando, FL 32826, fax +1.407.380.5588, or send material by e-mail to lia@lia.org.

2012 LIA OFFICERS

EDITORIAL STAFF

BUSINESS STAFF

CALENDAR OF EVENTS

Laser Safety Officer Training
Dec. 4-6, 2012 | Orlando, FL

Laser Safety Officer with Hazard Analysis*
Sept. 24-28, 2012 | Anaheim, CA
Nov. 5-9, 2012 | San Antonio, TX
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Medical Laser Safety Officer Training*
Sept. 22-23, 2012 | Anaheim, CA
Oct. 20-21, 2012 | Chicago, IL
**Certified Medical Laser Safety Officer exam offered after the course.*

International Congress on Applications of Lasers & Electro-Optics (ICALEO®)
Sept. 23-27, 2012 | Anaheim, CA

Laser Welding & Joining Workshop
Oct. 23-24, 2012 | Schaumburg, IL

Lasers for Manufacturing Event (LME™)
Oct. 23-24, 2012 | Schaumburg, IL

Laser Additive Manufacturing Workshop (LAM)
Feb. 12-13, 2013 | Houston, TX

International Laser Safety Conference (ILSC®)
March 18-21, 2013 | Orlando, FL

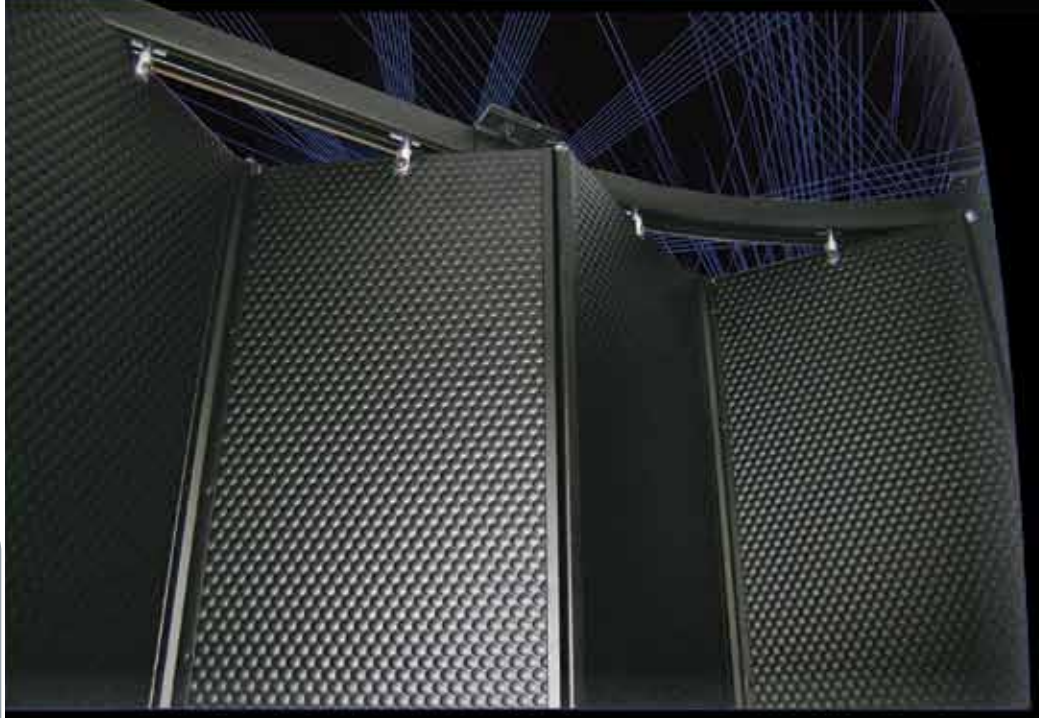
*Visit **www.lia.org** for all course and event listings.*

ABOUT LIA

Laser Institute of America (LIA) is the professional society for laser applications and safety. Our mission is to foster lasers, laser applications and laser safety worldwide.

We believe in the importance of sharing new ideas about lasers. In fact, laser pioneers such as Dr. Arthur Schawlow and Dr. Theodore H. Maiman were among LIA's original founders who set the stage for our enduring mission to promote laser applications and their safe use through education, training and symposia. LIA was formed in 1968 by people who represented the heart of the profession—a group of academic scientists, developers and engineers who were truly passionate about taking an emerging new laser technology and turning it into a viable industry.

Whether you are new to the world of lasers or an experienced laser professional, LIA is for you. We offer a wide array of products, services, education and events to enhance your laser knowledge and expertise. As an individual or corporate member, you will qualify for significant discounts on LIA materials, training courses and the industry's most popular LIA conferences and workshops. We invite you to become part of the LIA experience – cultivating innovation, ingenuity and inspiration.



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PRESIDENT'S MESSAGE

Dear LIA members, friends, colleagues and readers,

It's the time to face sunshine, beautiful weather and hopefully some vacation! But very soon from now, on September 24, we all shall meet in Anaheim, CA for ICALEO® 2012. We expect an outstanding event with great presentations and a powerful platform for bilateral and multilateral conversations. Beyond that you can look forward to a professional organization as well as wonderful surprises realized by the LIA staff, among others the Presidents Reception, which will be held in a really unique environment and atmosphere. I trust we will have an efficient, hopefully effective and definitely joyful meeting.

With respect to this issue you will find some preparing information for the conference program. In particular, there are articles titled "Femtosecond Laser Micro/ Nanomachining of Glass Materials for Optofluidic Applications & Beyond" (pg. 14), "Increased Process Efficiency and Quality by Lasers with Tailored Wavelength and Beam Profile" (pg. 16) and an overview of Laser Welding & Joining (pg. 10).

I truly look forward to seeing you then.

Sincerely Yours,

Reinhart Poprawe, President
Laser Institute of America

EXECUTIVE DIRECTOR'S MESSAGE

LIA – Your Source and Connection for Laser Materials Processing

For over 30 years ICALEO® has provided the forum for the world's experts on laser materials processing to present and discuss their research. Discoveries and advances in cutting, drilling, welding, texturing, laser additive manufacturing and other processes are then made available via ICALEO proceedings **www.icaleo.org**.

Key papers can be submitted to our peer-reviewed *Journal of Laser Applications®* (JLA) to achieve wide circulation and availability online. Currently, the JLA has nine editors covering areas of the technology from laser additive manufacturing to laser systems and markets. In addition, the editors have prepared a special issue on "Generation of Sub-100 nm Structures by Nonlinear Laser-Material Interaction" that is now available as an open access issue. Check out the JLA at **jla.aip.org/resource/1/jlapen/v24/i4**.

As these various technologies mature and demonstrate significant improvement in manufacturing quality and value, LIA provides unique opportunities to learn about them and to connect with laser solution providers. Our Laser Additive Manufacturing (LAM) Workshop is entering its 5th year (**www.lia.org/lam**) and later this year we will introduce our first Laser Welding & Joining Workshop.

In October we will hold our second Lasers for Manufacturing Event (LME™) where we expect about 90 exhibitors and 2,000 attendees all focused on putting laser systems to work in manufacturing. LME features a unique range of educational offerings to bring new and potential users up to speed on everything from basic laser technology, through key processes, to return on investment (ROI) computation. Many of these offerings will be available on our website www.lia.org to those not fortunate enough to attend LME in person.

Of course, this newsletter always contains interesting articles and information on the practical (and valuable) applications of laser materials processing technology.

So, as you can see, LIA serves as both the trusted source of information on the technology and also the connection between researchers, laser and system suppliers and the rapidly growing end user community.

Peter Baker, Executive Director
Laser Institute of America
pbaker@lia.org

ICALEO 2012: FEATURING CUTTING-EDGE EXPLORATIONS OF LASER MANUFACTURING

By Geoff Giordano

When the Laser Institute of America brings its premier photonics research event back to Anaheim this year, attendees will hear about "green" photonics, advancing the role of lasers in a "non-laser" world and how various nations are sharing their technical expertise.

The 2012 International Congress on Applications of Lasers & Electro–Optics, or ICALEO®, will feature a full slate of cutting-edge explorations of, among other things, adding value and efficiency with laser-based manufacturing. As the technology gains a firmer foothold in the processes of many industries early in the 21st Century, ICALEO is staying ahead of the curve with a program of forward-looking plenaries and expert presentations to ensure that this pre-eminent laser event continues to strengthen the foundation of scholarship vital to laser progress.

"The most important trends in the use of lasers for manufacturing would be development of lasers and laser materials processing technologies toward flexible and energy-efficient production of high-precision, highly value-added components and systems with more affordable prices," asserted Congress General Chair Kunihiko Washio of Paradigm Laser Research. "The key laser drivers would be high-brightness, high-power lasers having flexible beam-delivery fibers in macro-processing, such as for welding and cutting, and high average power, picosecond or femtosecond, ultrashort-pulsed lasers in micro-processing, such as for high-precision patterning and surface structuring."

PLENARIES AND BUSINESS FORUM

Ultimately, the contribution of lasers to manufacturing efficiency and profitability is the primary concept ICALEO promotes with the research it spotlights. To that end, the Business Forum and Panel Discussion chaired by Ken Dzurko of SPI Lasers will focus on "Increasing the Role of Lasers in a Non-Laser World."

As president of Paradigm, Washio is of course familiar with the bottom-line issues facing the further adoption of laser-based manufacturing and other applications.

"Equipment cost, maintenance cost and productivity issues of lasers have been the primary concern in advancing laser applications in many fields to replace conventional processes," he noted. "Due to the evolution of highly reliable and higher-power advance laser sources, there seem to be significant advances

The Plenary Session at ICALEO 2012 will kick off four information-packed days.

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such as in ultrashort-pulse laser materials processing. There are a lot of opportunities for lasers in materials processing, such as for material removal, joining, modification, etc. However, in the real laser application market, metal sheet cutting is the largest market."

The vigorous exploration of such opportunities also informed the creation of the opening plenary session, "Green Photonics and Recent Progress in Laser-Based Light Sources and Their Applications in Materials Processing."

"For this year, the topics of the opening plenary are more industrial application-oriented and will visualize how lasers can bring benefits for a more eco-friendly, greener society," Washio explained. The slate of four presentations includes:

- Keynote speaker Thomas Baer of Stanford University discussing "Recent Status and Future Prospects of Global Research on Green Photonics."
- "High-Power Laser Materials Processing" by Eckhard Beyer, Fraunhofer IWS, who is also general chair of LIA's new Laser Welding & Joining Workshop in October.
- "Laser-Based Microprocessing Equipment for Electronics Industries" by Haibin Zhang of ESI in Portland, OR.
- "LPP-EUV Light Source Development for High Volume Manufacturing Lithography" by Hakaru Mizoguchi of Gigaphoton in Oyama, Japan.

MATERIALS PROCESSING CONFERENCE

Dovetailing with the LIA's added emphasis on laser additive manufacturing at its LAM 2012 conference in Houston, the Materials Processing Conference will also lean heavily on sharing advances in the ground-breaking field.

"Laser Metal Deposition," "Laser Processing of CFRP," "Process Monitoring and Control," "High Brightness Lasers & Systems" and "Processing of Dissimilar Materials" will be the featured areas of focus. "These are all cutting-edge technologies with a lot of new achievements," said returning Chair Stefan Kaierle of Laser Zentrum Hannover.

Echoing Washio's sentiments, he sees ultrashort-pulsed lasers on the rise. "Due to their high average powers achievable today, they can now go into processing of large-scale parts and applications."

While keeping an eye on developments in micro and nano processing, Kaierle said that, ultimately, it is vital that "laser machines must be usable like standard manufacturing equipment today in industry — with the same level of easy applicability and safety. The laser machine manufacturers have recognized this and design their machines more and more in that direction. The use of

ICALEO con't on page 8

ICALEO con't from page 6

laser technology and their great benefits must be transported into the non-laser world, mainly into the whole manufacturing market."

MICROPROCESSING CONFERENCE

Once again, the Microprocessing Conference is organized more by application or interest group rather than by the process, according to Chair Henrikki Pantsar of Cencorp. Pantsar — an ICALEO attendee since 2001, who has helped plan the conference for the past six years, and is in his second year chairing the Microprocessing Conference.

"Attendees will hopefully find interesting themes easier, instead of having to jump from one session to another," he said. "The program committee found very good invited speakers to support emphasized topics."

While of course catering to a broad array of interests, "my personal interests would be lasers in energy generation and storage, innovative laser optics, processing of brittle and transparent materials, monitoring and detection, and advances in laser sources," Pantsar noted. "This selection would give a very broad look on the efficient use of novel lasers and optics in areas that I see extremely important in the future." Over the past year, he's kept his eye on trends in the use of different optical configurations to enhance productivity and quality.

NANOMANUFACTURING CONFERENCE

The role of lasers in nanoelectronics, photonic crystals, optoelectronics, sensors and plasmonic devices will be high on the order of business in the schedule of presentations overseen by Yongfeng Lu of the University of Nebraska, Lincoln and Xianfan Xu of Purdue.

Attendees can expect to get caught up on two-photon lithography, 3-D micro/nanofabrication, laser synthesis and diagnostics of carbon nanomaterial, epitaxial growth of graphene for optoelectronics, nanolithography, nanoscale thermal imaging, plasmonics, surface nanostructuring, laser sintering and laser-assisted growth and epitaxy, Lu said.

"In applications such as laser writing and nanopatterning, some of the challenges include resolution, throughput and surface finish," he noted. "However, much progress has been achieved to overcome these challenges, including near-field lithography, two-photon polymerization, optical trapping, ultrafast laser writing and parallel processing." In terms of his own research, "We have achieved much progress in laser direct writing, laser nanomaterial interaction and nanofabrication using ultrafast lasers and laser-assisted growth of nanostructures."

The Vendor Reception at ICALEO, featuring suppliers to the industry, is an excellent source of information and a great networking opportunity.

The Awards Luncheon during ICALEO sees the presentation of the Schawlow Award.

THE SHORT COURSES

As always, ICALEO also offers nuts-and-bolts introductions to various areas of laser materials processing. Silke Pflueger of ULO Optics has created another series of short courses for Sunday, Sept. 23. They are designed for those who would like to gain "a base in the given subjects, to better understand the new research being presented later in the week during the technical sessions, and also to give attendees who are relatively new to the laser field an overview of existing technologies."

"To spice things up, we also have a very exciting talk from Larry Marshall, who has founded several laser companies and now funds new start-ups," Pflueger noted. "We've decided to include this after last year's very well-received 'How to make money in the laser business' talk from Ron Schaeffer."

NETWORKING AND AWARDS

ICALEO's traditional networking events, starting with the Sunday welcome celebration, offers invaluable time for peers to share successes, questions, concerns and catch up with one another.

ICALEO "has always been the conference for networking," Pantsar affirmed. "The president's reception and the vendor reception are always must-see events." This year, LIA President Reinhart Poprawe will preside over a reception at the Marconi Automotive Museum, a short trip from the ICALEO venue, the Anaheim Marriott.

Another traditional moment of celebration, the presentation of the Arthur L. Schawlow Award, will take place at the Sept. 26 luncheon during which this year's winner, Isamu Miyamoto, will be honored. Miyamoto, founder and previous chairman of the Japan Laser Processing Society, will give a presentation on the "Origin and New Wave of Laser Welding." Washio, serving as a board member of the JLPS, knows him and his work well.

"Conventional laser welding was limited to metals and some polymers and could not be applied to transparent ceramics and glasses," Washio explained. "Professor Miyamoto has extensive experience in theoretical and experimental investigation of metal keyhole welding. He has recently pioneered the field of transparent glass welding by high-repetition ultrafast lasers." Prior to Miyamoto's work, the application of lasers in processing glass had been limited to cutting and scribing.

To register for ICALEO 2012, visit **www.icaleo.org**. ■

Geoff Giordano is a freelance writer.

LIA PRESENTS ITS FIRST ANNUAL LASER WELDING & JOINING WORKSHOP

By Geoff Giordano

While excitement continues to build around new, more efficient and more profitable uses of lasers, such as with additive manufacturing or ultrafast processing, traditional welding and joining applications are still at the forefront of the 21st-century photonics repertoire.

Emphasizing this major segment of laser-based manufacturing, the Laser Institute of America has added a comprehensive two-day workshop to its second annual Lasers for Manufacturing Event (LME™). It will run concurrently Oct. 23-24 at the Renaissance® Hotel and Convention Center Resort in Schaumburg, IL.

Chaired by Prof. Eckhard Beyer of the Fraunhofer Institute for Material and Beam Technology, IWS in Dresden, the Laser Welding & Joining Workshop will spotlight the latest uses of lasers in key industries: aerospace, automotive, defense, energy, health care and heavy manufacturing. Current research and practice will focus on general macro laser applications, remote welding and brazing, hybrid welding and joining of multiple materials, micro welding and welding of thin sheets.

"The workshop will start with short courses presented by industrial research experts to give a sound overview of laser basics and current developments," Beyer explained. "End users with longstanding experience will present their solutions to the typical challenges of laser applications."

Presentations are slated from large multiventure companies like GE, as well as automotive suppliers and OEMs, according to Dr. Gunther Göbel, a special joining technologies expert with Fraunhofer IWS. Also featured will be integrators and research experts.

For example, "ESAB will give us insights into the impact of lasers in heavy industry and how it is changing this industry from essentially low-tech, high-craft operations to more high-tech, low-cost production," Göbel noted.

In addition to the workshop, attendees at LME 2012 can participate in a two-hour laser welding and joining tutorial. The overall educational package is geared to everyone from process and applications engineers, to product designers, to business developers and plant supervisors.

"We hope that they will learn what the laser community is doing in macro and micro laser welding applications," Göbel explained. "They can use this knowledge to get new ideas on how to use lasers in their own applications effectively. We hope that all main trends of the welding industry will be visible. Of course, newcomers should learn why and how lasers work — and what they can and can't do."

Educational opportunities are abundant at LME.

LASER WELDING & JOINING WORKSHOP

What lasers are doing is creating significant bottom-line efficiencies by streamlining processing lines and reducing the use of materials and energy. The automotive industry is a major beneficiary of lasers' value proposition.

"Of course automotive is still important," Göbel said. "Here we see the impact of high-brightness lasers and lower investment costs. In my opinion this trend will continue for some time. I think this will be visible in several presentations."

"A very prominent example is still the powertrain industry. This also includes off-highway drivetrain components. We will have a presentation covering that. In this domain, the laser is a very important tool as it enables significant advances: higher productivity, higher efficiency, low heat input, low distortion, etc."

MUST-BE-AT-EVENT

At the inaugural LME in 2011, auto manufacturers were out in force.

"I had one guy asking about a battery welding application (and) another guy asking about glass processing; they do automotive glass mirrors and asked about laser scribing," said Robert Mueller of NuTech Engineering, who manned the expert booth both days and is chair of the "Ask a Laser Expert" feature again this year. "There are enough lasers in automotive now that they're starting to look around and go, 'OK, where else can I do it?' Management is comfortable to a certain extent with existing applications; now we can look around a bit farther."

LME, being held once again in proximity to many automakers and laser job shops, is geared to be one-stop shopping for those either seeking to refine current laser systems and applications or assessing potential new ways to employ lasers in production. The educational program, in addition to the focus on welding and joining, will emphasize the rudiments of understanding the main types of lasers used for manufacturing, how to choose low-cost methods, and maintain laser safety.

The Welding & Joining Workshop will feature 18 presentations,

W&J con't on page 12

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spread out to allow ample time for attendees to interact directly with OEMs in the exhibit hall.

"As many laser manufacturers and system builders are engaged in the workshop, this would be an ideal opportunity to get application-related questions answered and get new ideas on how to use lasers," Beyer said. "We are going to unite many people from the laser community who were and are shaping the way the world of lasers is today. This will make it possible to address lasers from basics to high-end applications."

"We still see a big impact of the tremendous rise in beam quality and energy efficiency," Beyer said. "Here the application fields are expanded in many ways: ultra-low distortions or the realization of new mixed-material joints like copper-aluminum using precisely shaped weld pools. Also, remote-beam applications are now standard; that was a field restricted to expensive high-brightness lasers just a few years ago. Furthermore, laser size reduction is a key development: Many lasers are now so small that machine integration is much simpler and can be done in a way not possible before."

TECHNOLOGY SHOWCASE

LME 2012 will again feature the highly popular Laser Technology Showcase, a stage at the front of the exhibit hall that will be used for keynote educational presentations and shorter informational addresses by many companies in attendance. The showcase format helped foster interaction between attendees seeking solutions and a wide array of industry leaders able to lend their expertise in person. New this year will be the opportunity to view working laser systems.

Attendees at the first-ever LME praised the unique session's efficiency in bringing together those with questions about laser-based manufacturing and the key industry players with the expertise to address their needs.

"It's a good opportunity for everybody to learn about all the technologies in the same place," said Octavio Islas, an automotive product engineer with Magna/Cosma in Mexico. "You can get a lot of information from all the suppliers. If you have any specific requirement, you have… people with a lot of knowledge and experience, and they can tell you about your application and all the details."

To register to attend LME 2012, the Laser Welding & Joining Workshop or the tutorials addressing the basics of laser welding or ultrafast machining, visit **www.lia.org/store/conf/lme2012**. ■

Laser welding technology displayed by Fraunhofer Center for Coating and Laser Applications.

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The joining procedure is the most central challenge in modern process chains and burden very often due to the significant costs. Because of quality dmands and the increased use of modern func-tional materials, the choice of the adequate joining process becomes more and more important.

The symposium 2012 gives the opportunity to discuss the latest joining technologies, their applications and striking innovative news.

The Exhibitor Forum will complete the symposium.

FEMTOSECOND LASER MICRO/NANOMACHINING OF GLASS MATERIALS FOR OPTOFLUIDIC APPLICATIONS AND BEYOND

By Ya Cheng

Nowadays, microfluidic systems for controlling and manipulating tiny volumes of liquids with high precision have attracted significant attention due to their capability of downsizing both chemistry and biology. In addition, it is often desirable to incorporate micro-optical structures into the microfluidic chips, which leads to not only compact chemical and biological sensors, but also tunable and reconfigurable laser devices. For both microfluidic and micro-optical applications, fused silica can be an ideal substrate material due to its excellent physical and chemical properties, such as chemical inertness, low thermal expansion coefficient, low autofluorescence, exceptional transmittance over a wide spectral range and so on. On the other hand, fabrication of three-dimensional (3D) microstructures with fused silica, including embedded microfluidic channels and microspherical optical lenses, has long been a challenge because traditional approaches based on photolithography inherently produce planar structures. Here, we show that these difficulties can be overcome by means of femtosecond laser micromachining.

FEMTOSECOND FLEXIBILITY

The 3D nature of the femtosecond laser direct writing offers flexibility for constructing complex microfluidic networks in glass. The main fabrication process includes two steps: 1) direct formation of hollow microchannels in a porous glass substrate immersed in water by femtosecond laser ablation (Fig. 1(a)) and 2) postannealing of the glass sample at ~ 1150 ^{0}C by which the porous glass can be consolidated due to collapse of the nanopores (Fig. 1(b)). The consolidated glass sample can then be used to confine liquids in the fabricated 3D microfluidic channel without any leakage, as evidenced by Fig. 1(c). Because of its capability to directly form large-scale microfluidic structures embedded in glass with arbitrary 3D configurations, this technique can be used for fabricating functional microfluidic devices such as the 3D microfluidic mixer illustrated in Fig. 1(d) which is usually difficult to achieve with other fabrication technologies. Fig. 1(e) shows the details of the middle part of the fabricated micromixer which is composed of a series of mixing units of a true 3D geometry. Indeed, such 3D micromixer exhibits a high mixing efficiency as shown in Fig. 1(f), owing to the chaotic flow in the twisted microfluidic channels. In contrast, we observe that efficient mixing of the same solutions does not occur in a straight 1D microfluidic channel with the similar diameter even after passing a distance of ~1.5 mm, because of the inherent laminar nature in the microfluidic channel.

Micro-optical components can be fabricated in a slightly different manner, namely, by femtosecond laser direct writing in fused silica followed by chemical wet etching in hydrofluoric (HF) acid. In this process, the internal areas modified by the femtosecond laser irradiation will gain a significantly higher etch rate than those unmodified areas, so that hollow structures embedded in fused silica can be produced by preferentially removing the materials in the laser-scanned areas. Using this technique, we fabricate micro-optical lenses with nearly diffraction-limited focusing performance on fused silica substrates. To create the curved surface as illustrated in Fig. 2(a), we first scan the sample with the tightly focused femtosecond laser beam and then carry out the wet etching as mentioned above. Afterwards, an additional oxyhydrogen (OH) flame polishing is used to smooth the curved surface. The fabricated microlens is shown in Fig. 2(b). In comparison to the simulation result (Fig. 2(d)) for a model lens with the same geometry, the measured focal spot produced by the fabricated microlens has a comparable size, as shown in Fig. 2(c). Recently, the microlens has been used in two-photon fluorescence imaging. The

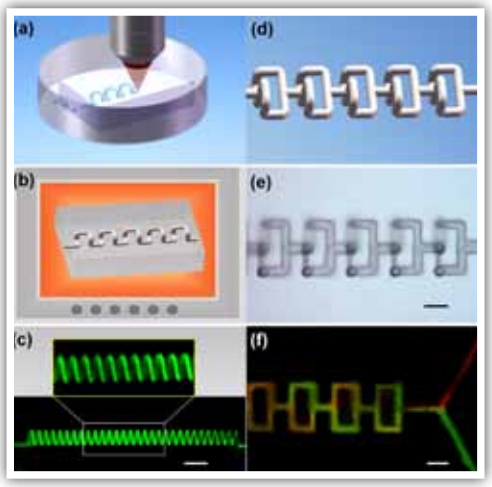

Fig. 1 (a-b) Flow chart of fabrication of microfluidic channels in porous glass by femtosecond laser. (c) A 3D microfluidic channel fabricated by femtosecond laser filled with fluorescein solution. (d) Schematic illustration of a 3D micromixer. (e) Close-up view of the mixing units of the fabricated micromixer. (f) Mixing of two fluorescence solutions in the micromixer (Green: Fluorescein; red: Rhodamine 6G). Scale bar in all panels: 150 mm.

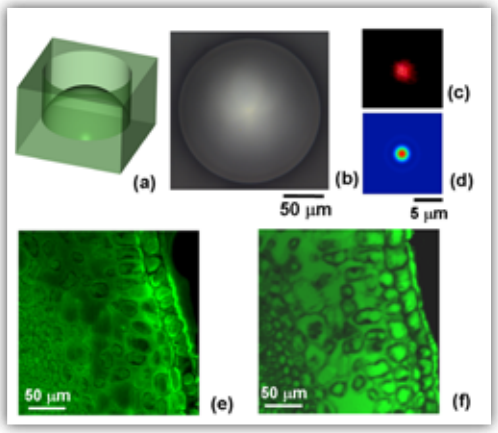

Fig. 2 (a) Schematic and (b) optical micrograph of the microlens fabricated by femtosecond laser micromachining. (c) The measured focal spot and (d) the calculated point-spread function of the microlens in (b). Two-photon fluorescence images of the leaf tissue acquired using (e) the microlens and (f) an objective lens (5x magnification).

two-photon images of a plant leaf tissue acquired with the micro-optical lens and with a 5x objective lens are compared in Figs. 2(e) and 2(f), showing little difference in their imaging performances.

Further, femtosecond laser micromachining can allow for electro-optic (EO) integration in active materials such as lithium niobate ($LiNbO_3$) crystal. For this purpose, we develop a technique for selective metallization of dielectric materials by femtosecond laser ablation followed by selective electroless plating, which permits to fabricate high-aspect-ratio microelectrodes deeply embedded in the substrates. As illustrated in Fig. 3(a), the fabrication of embedded electrodes mainly consists of four steps: 1) formation of microgrooves on the surface of substrates by femtosecond laser ablation; 2) formation of $AgNO_3$ films on the surfaces of the substrates by dip coating in $AgNO_3$ solution; 3) exposure of the coated substrate to ultraviolet (UV) light for reducing silver ions to silver nanoparticles, which become the seeds for the subsequent electroless copper plating; and 4) electroless copper plating at a temperature of ~45 ^{0}C. The embedded electrodes fabricated by femtosecond laser micromachining, as shown in Fig. 3(b) and (c), are integrated with a Mach-Zenhder (MZ) interferometer buried in $LiNbO_3$ crystal, which is composed of optical waveguides written by femtosecond laser, to construct an EO modulator, as illustrated in Fig. 3(d). The voltage required to completely switch on and off a He-Ne laser beam coupled into the MZ interferometer is measured to be ~19 V, indicating an excellent EO overlap integral of ~0.95. Since microfluidic, micro-optical and microelectronic structures can be simultaneously fabricated in dielectric materials using femtosecond laser direct writing, we envisage that femtosecond laser micromachining will open up a broad spectrum of opportunities for fluidic-photonic-electronic circuit applications. ■

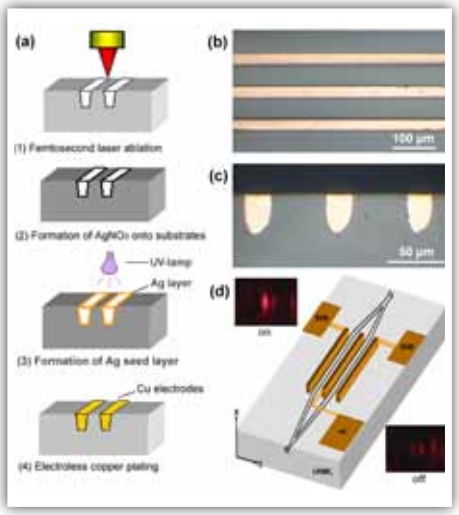

Fig. 3 (a) Schematic illustration of fabrication for embedded microelectrodes, and optical micrographs showing (b) top view and (c) cross-sectional view of the embedded electrodes. (d) Schematic layout of an electro-optical modulator. Insets: near-field intensity distributions at the exit of the Mach-Zehnder interferometer at different direct current (DC) voltages of 0 V (upper left) and 19 V (lower right).

Dr. Ya Cheng is a professor of the Shanghai Institute of Optics and Fine Mechanics (SIOM).

INCREASED PROCESS EFFICIENCY AND QUALITY BY LASERS WITH TAILORED WAVELENGTH AND BEAM PROFILE

By Keming Du

In the past years, a strongly increasing interest has developed in laser ablation processes for the removal of thin films, for instance the production of photovoltaic and display devices. The principal advantages of a laser in comparison with other processes are the high flexibility in combination with precision and quality of the processed area. In the production of thin film solar cells for example, two laser ablation processes are currently being used: scribing via selective ablation and edge isolation via deletion (Fig. 1).[1,2,3]

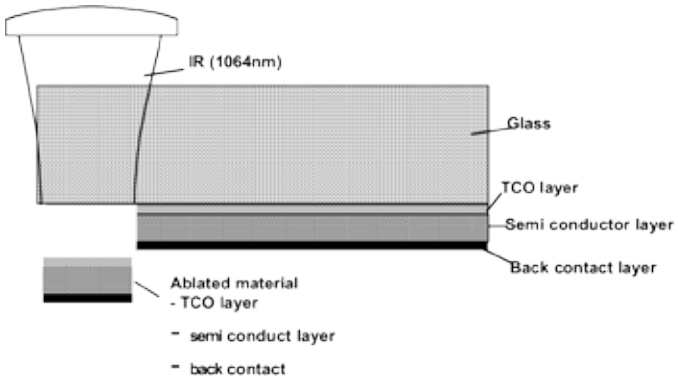

Fig. 1: Typical process for laser based thin film removal, illustrated at the example of a thin-film solar cell structure.

The laser based ablation processes used today are commonly performed by using classical commercial lasers such as solid-state lasers with a fundamental wavelength around 1 μm and with Gaussian beam profiles in combination with beam scanners and scanner optics. However, for ablation processes a rotational symmetric Gaussian intensity profile is not the best solution: the processing of large areas requires an appropriate side by side application of the individual pulses, preferably without overlap which is not possible with Gaussian beams. And the process itself has a threshold character, which causes energy losses for intensity profiles such as a Gaussian, as the parts of the Gaussian beam with intensities below threshold do not contribute to the process. An inhomogeneously processed zone such as illustrated in Fig. 2 is the result. A beam of rectangular shape and top-hat intensity profile however would perfectly match the process requirements of such an ablation process.

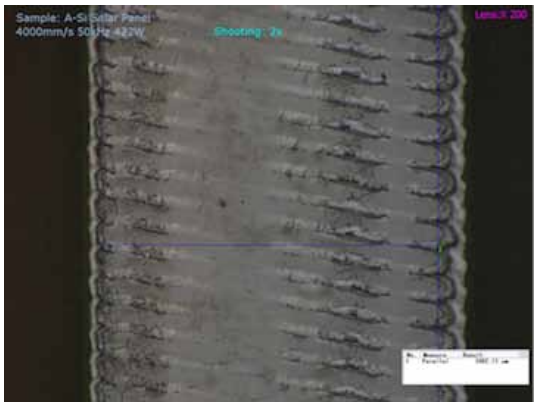

Fig. 2: Microscope image of the processed zone. Laser wavelength 1064 nm.

In addition to this problem with the beam shape, it is not preferable to process with one single laser wavelength as the absorption of the different materials layers in Fig. 1 cannot be matched optimally to one single wavelength. If two wavelengths are used and each wavelength is adapted to the absorption maximum of the individual layer (Fig. 3), the efficiency of the process and thus the processing speed can be considerably increased.

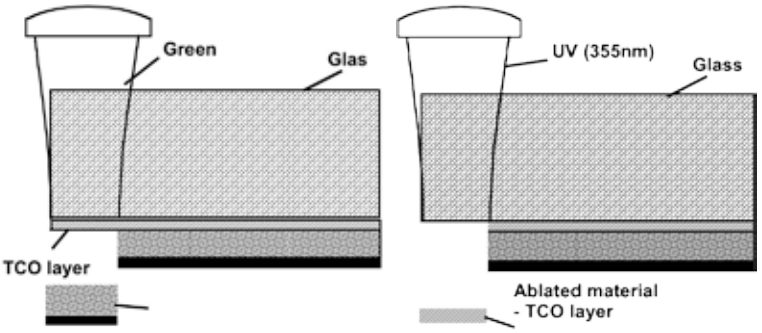

Fig. 3: Increased quality and processing speed by using a two stage process with different laser wavelengths (532 nm, green (left) and 355 nm, UV (right)).

In order to activate all these prospective advantages, it is necessary to use a laser, which inherently has properties, being advantageous for the creation of a rectangular beam with top-hat profile and with which a laser beam of different wavelengths can be produced efficiently. The laser concept shown in Fig. 4 has all of these advantages. The active laser medium is slab-shaped and therefore perfectly matched to produce a beam with rectangular cross section and by proper adaption of the laser resonator the cross-section of the beam can be made top-hat shaped as illustrated in Fig. 5. With such a beam shape, it is easy to create exactly and homogeneously the laser intensity required by the process and the beams of the individual laser pulses can perfectly be arranged side by side, assuring high process efficiency.

The second advantage of the laser concept becomes apparent when multi-wavelength operation is required. Commercial

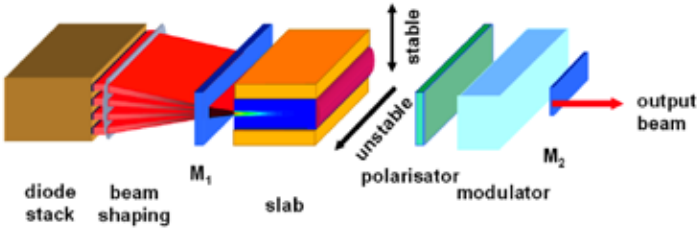

Fig. 4: Schematic set-up (top) and commercial example (bottom) for a high-power INNOSLAB-laser.

versions of the laser[4] are supplied with resonator-external nonlinear frequency conversion units (frequency doubling and sum-frequency mixing units), which allow the selection of different wavelengths without any mechanical modifications or adjustments. Here again, the big advantage of this type of laser is the rectangular beam profile in combination with high beam quality and short pulse length. With the high beam quality and short pulse length very high laser intensity can be produced at the position of the crystals for nonlinear frequency conversion. This ensures a high efficiency of the frequency conversion process. On the other hand the laser beam in the frequency conversion crystals has a rectangular shape with one dimension, which can be chosen very small, thus ensuring a good cooling of the crystals and thus a high damage threshold, needed for reliable laser operation.

Fig. 6 shows the ablation result achieved with this laser: a very clean processed area can be seen and the two-wavelength process requires only about 10% of the laser energy of a process solely performed with the fundamental infrared wavelength. ■

Dr. Keming Du is the general manager of EdgeWave GmbH.

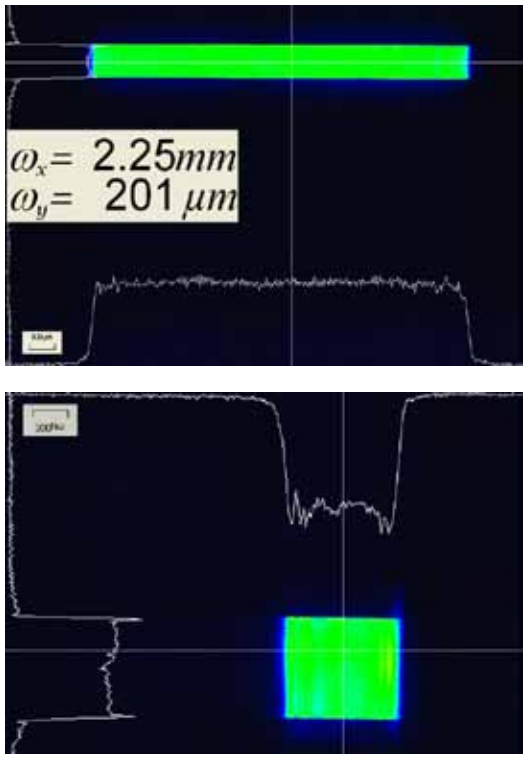

Fig. 5: Top-hat intensity profile of a specially adapted Innoslab-resonator, the beam has near-diffraction limited beam quality.

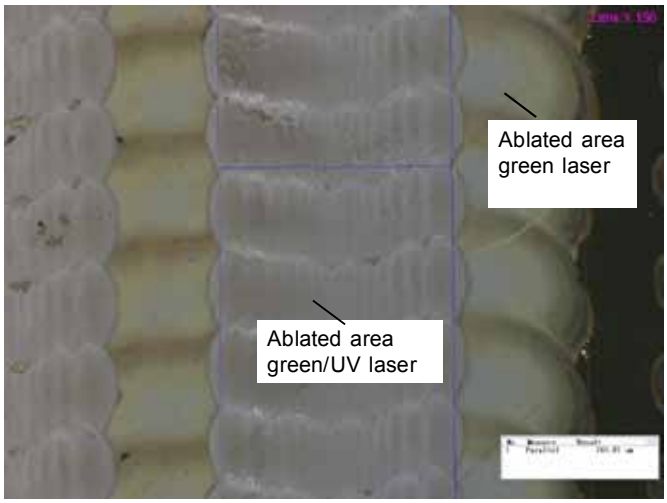

Fig. 6: Laser ablation of thin films according to Fig. 1, with a dual-wavelength (532 nm + 355 nm) slab laser.

References:

[1]S. Engelhart, S. Hermann, T. Neubert, R. Grischke, N.-P. Harder, R. Brendel, "Laser processing for high efficiency solar cells," Proceedings of 17th NREL Workshop, 1 903 (2007).

[2]S. Eidelloth, T. Neubert, T. Brendemiehl, S. Hermann, P. Giesel and R. Brendel, "High speed laser structuring of crystalline silicon solar cells," 34th IEEE Photovoltaic Specialists Conference, Philadelphia, June 7-12, 2009.

[3]S. Haas, S. Ku, G. Schöpe, K. M. Du, U. Rau, H. Stiebig, "Patterning of thin-film silicon modules using lasers with tailored beam shapes and different wavelengths," Proceedings of the 23rd European Photovoltaic Solar Energy Conference, Valencia, Spain, September 2008.

[4]www.edge-wave.com

CORPORATE MEMBER PROFILE | JOINING TECHNOLOGIES

LIA Corporate Member Joining Technologies is recognized as an innovator in laser welding and laser cladding applications, delivering absolute reliability through innovation and team. The company's top-notch expertise, exclusive technologies and high performance culture provide the foundation for long lasting partnerships with customers. Joining Technologies is most often called upon when the challenge is significant and the risk is high.

Founded in 1992 by Michael Francoeur, Joining Technologies, located in East Granby, CT, was founded on electron beam welding services and has grown to offer laser welding, TIG and plasma, complete supply chain management as well as additive manufacturing and additive research and development. Francoeur and David Hudson are today's owners and now have 60 employees at two facilities in East Granby, one of which is dedicated to laser additive manufacturing and additive R&D.

TODAY'S MARKET & RESEARCH

Joining Technologies provides the services of laser and electron beam welding, laser additive manufacturing, supply chain management and complete laser system design and integration. We deliver reliable, cost-effective solutions that enable our customers to lead in their industries.

Our advanced capabilities in micro laser welding deliver precision welds at incredible speeds, a process ideally suited for the manufacture of medical devices and other components with similar requirements of high process speeds and extreme accuracy. Our engineering staff is widely acclaimed as having the experience to develop the most advanced and economical solutions for joining components. Industries benefiting from our technology and engineering approach include medical device, aerospace and defense, firearms, alternative energy, and sensors and controls.

Joining Technologies operates from its headquarters in East Granby, Connecticut and a nearby secondary facility dedicated to research and development for laser additive manufacturing applications. In partnership with Fraunhofer ILT, Joining Technologies formed Joining Technologies Research Center (JTRC) to provide laser additive manufacturing research and development services as well as accessory sales. Combining the precision and reliability of Joining Technologies' laser cladding processes with Fraunhofer ILT's cutting-edge laser additive research and development capabilities bridges the gap between university level research and shop floor production laser cladding.

Laser cladding for spline repair.

Joining Technologies has been recognized both for its outstanding corporate culture and contributions to manufacturing. In 2011, the company received the Hartford Courant/Fox CT "Top Workplaces" Award for fostering a culture of innovation and teamwork, and in 2010, the company received CQIA's Platinum Innovation Award for the development of the Infinite Web®, an automated laser cutting and welding system for splicing extremely light gauge metal coils in the steel converting process.

Infinite Web® 340B

FUTURE OUTLOOK

Joining Technologies is on schedule to be certified this year to the ISO 13485 standard for the manufacture of medical devices. This certification sets Joining Technologies apart from other welding houses, and demonstrates its commitment to processing parts to the same rigorous standards as its major medical device customers. Achieving the new standard is expected to strengthen Joining Technologies' relationship with current customers, expand its growing medical customer base and further enhance its capabilities with tier 1 suppliers.

In the 20 years since its founding, Joining Technologies President David Hudson has seen significant industry changes. "We've seen the laser become much more user-friendly, and therefore many customers prefer to vertically integrate the joining or cladding process into their own facilities. To answer that need Joining Technologies launched a system design and integration division in 2006. The group has been very successful in delivering cost-effective laser processing systems to customers in a variety of industries. Additionally, the award winning Infinite Web®, a patented metal coil splicing system, is gaining wide acceptance in the steel converting and processing industry. The machine was introduced by Joining Technologies in 2010 and is enabling steel converters to process metal coils with gauge thickness down to 0.002 inches," he stated.

An LIA Corporate Member since 2007, Joining Technologies recognizes the need to collaborate with the industrial laser community in order to share technical information for the sake of advancing the technology.

"LIA provides a forum where colleagues in various organizations, regardless of their competitive status, can come together and share ideas," said Hudson.

For more information, visit **www.joiningtech.com**. ■

ASC Z136 UPDATE

Save the Dates!

September – The annual DOE LSO Workshop is taking place September 11-13 at SLAC National Accelerator Laboratory, Menlo Park, CA. The workshop is for individuals with laser safety responsibility and interest in a research or academic setting who want to update and expand their knowledge. It also serves as the official annual meeting of the US Department of Energy Laser Safety Working Group (DOE – EFCOG).

Standards Subcommittee (SSC) 8, which developed the new Z136.8 *Safe Use of Lasers in Research, Development, or Testing* will hold a meeting on ***Friday, September 14*** at Lawrence Berkeley National Laboratory to discuss ways to promote the standard. Those interested in attending contact Ken Barat to arrange entrance access.

Rockwell Laser Institute is hosting two subcommittee meetings in Cincinnati, OH in ***mid-September***, Technical Subcommittee (TSC) 4, Control Measures & Training and Standards Subcommittee (SSC) 1, responsible for the development of the Z136.1 *Safe Use of Lasers* standard. Agendas and lodging information will be sent to subcommittee members; questions should be directed to the subcommittee chair.

March 18-21, 2013 – Mark your calendars now for the International Laser Safety Conference (ILSC®). As in previous years, the ASC Z136 Annual Meeting is scheduled to be held the ***Sunday, March 17*** before the conference begins. As we get closer to ILSC, ancillary Z136 and IEC meetings will be scheduled during the week. Subcommittee chairs, it is not too early to request meeting space, contact Barbara Sams at +1.407.380.1553 or bsams@lia.org. ■

ASC Z136
Safe Use of Lasers
Accredited Standards Committee

Board of Laser Safety Credits for Certification Maintenance Points

By Fred Seeber

OP-TEC (The National Center for Optics and Photonics Education) is funded by the National Science Foundation Advanced Technological Education (ATE Center) with the mission of promoting photonics education by assisting colleges around the country in developing and implementing educational programs that support the expansion of this critical technology. By providing information materials and networking opportunities, colleges and universities can take steps in implementing photonics programs that give their students the opportunity to work in this rapidly expanding, high-demand, high-paying field.

The Center has four goals:

1. Serve as the national clearinghouse for optics and photonics education and training.
2. Create, assemble, align and distribute coordinated curriculum materials designed to support optics, laser and photonics education in high schools, two-year colleges and retraining of adult workers.
3. Support established and new photonics education programs in high schools, community and technical colleges, universities and professional societies.
4. Provide education and training for administrators, counselors, high school teachers and community college faculty members to prepare them to: a) design new photonics technology programs that meet their local needs and b) infuse photonics into programs in photonics-enabled technologies and c) teach optics, photonics and lasers using curriculum materials distributed by OP-TEC.

Dr. Fred P. Seeber, co-principal investigator for OP-TEC, states that OP-TEC also offers two hybrid online courses entitled, **Fundamentals of Light and Lasers** (Course I) and **Elements of Photonics** (Course II). These are courses can be arranged to suit the student's schedule. The courses are offered for laser professionals including employed laser technicians. The subjects in module form cover areas of photonics from lasers and other light sources, laser safety, optics, fiber-optic communication and optical detectors and other areas. **These courses have been approved by the Board of Laser Safety for certification maintenance (CM) points under the category of continuing education.** The BLS and OP-TEC have teamed together to pursue similar goals in moving the photonics industry and photonics education forward. More information about these courses is available by e-mailing Dr. Seeber at (fredpseeber@comcast.net).

Dr. Seeber is a fellow of the Laser Institute of America and Chairman of the ANSI Z136 subcommittee that develops the Z136.5 *American National Standard for Safe Use of Lasers in Educational Institutions*. ■

LASER INSIGHTS

Laser Insights is a feature to give insight into the very latest developments in laser safety and the possible applications of laser materials processing. These overviews are designed to give you insight into the content and applications of the papers presented at our conferences and workshops.
*Visit **www.lia.org/laserinsights** to begin your search.*

REAL-TIME PROCESS CONTROL BY MACHINE VISION

by Christoph Franz

In recent years the use of modern solid-state lasers has brought about a distinct increase in operational speed in laser materials processing. Whether with scanners or fixed optics, high speeds – as far as possible in various axes at the same time – have almost become the norm. But although the movement of the optic is precisely calculated, the position of the processing point can deviate from the planned contour.

CO2 LASER CUTTING OF FLEXIBLE GLASS SUBSTRATES

by Xinghua Li

Ultra-slim flexible glass substrates have many potential applications, spanning from photovoltaics to e-paper to touch sensors. Previously, these applications generally incorporated glass substrates in the thickness range of 0.3-1.0 mm and benefited from inherent glass properties including high optical transmission, low surface roughness, high thermal and dimensional stability, and low CTE.

REMOTE CUTTING OF CARBON FIBER COMPOSITE MATERIALS

by Annett Klotzbach

Carbon fiber reinforced polymers (CFRP) are increasingly applied in the aircraft and automobile industries. The main reason is the highly mechanical load and the low density. Moreover, the corrosion resistance plus the damping behavior of the material can fully be utilized in highly stressed structures. However, the concept of manufacturing CFRP-parts near-net-shape does not substitute the need of cutting them. The different properties of fiber- and matrix-material constitute an ambitious challenge for the CFRP cutting process with a laser beam. ■

View complete articles at www.lia.org/laserinsights under the Featured Category.

JLA UPDATE

The *JLA* is published four times a year in February, May, August and November. It is available electronically to LIA members as a member benefit. To view the journal online, please make sure your membership is current.

JLA Special Open Access Issue to Highlight Revolutionary Nanoprocessing Research

For the first time, the *Journal of Laser Applications*® (*JLA*) is offering its special edition on recent cutting-edge research in laser-based nanoprocessing free for viewing and download.

The issue, "Generation of Sub-100 nm Structures by Nonlinear Laser-Material Integration," is a midterm progress report on a six-year study initiated in 2008 by the German Research Foundation (DFG). *JLA*, the official journal of the Laser Institute of America, is offering this open access edition to all viewers at **jla.aip.org/resource/1/jlapen/v24/i4**.

Research Highlight – Investigation of the Effects of Basic Laser Material Interaction Parameters in Laser Welding

W.J. Suder and S.W. Williams

The depth of penetration achieved in continuous wave (CW) laser welding results from a balance of many complicated phenomena, which are linked with the characteristics of the heat source. In this work, the laser welding process has been investigated in terms of basic laser material interaction parameters: power density and interaction time. It has been shown that these two parameters are insufficient to characterize the laser welding process. Thus, a third parameter, specific point energy, has been introduced, which along with the power density and the interaction time allowed the welding process to be uniquely defined. It has been shown that the depth of penetration is mainly controlled by the power density and the specific point energy, whilst the weld width is controlled by the interaction time.

View complete articles at jla.aip.org.

MEMBER INNOVATIONS

SAFETY WARNING MODULE

Laser Safety Systems, Williamsburg, VA, has released the LSS2400 TFT Warning Module. The module is used at laser area entryways to warn approaching personnel of the area status with a bright, animated message. It is designed to interface with the standard Laser Safety Systems modular interlock system and will automatically change its displayed message based on the interlock condition. The screens can display ANSI standard DANGER, WARNING, CAUTION or other customized message chosen by the client when the room is armed for laser operation. The message then changes to a SAFE screen when the room is not armed. In healthcare facilities, the automated control of this display satisfies the ANSI Z136.3 requirement to cover or remove the warning when the laser is not in use. For additional information and example display screens, visit **www.lasersafetysystems.com**.

HIGHEST POWER GREEN LASER

Spectra-Physics®, Santa Clara, CA, a Newport Corporation brand, introduces Millennia Core, a new line of high power, continuous-wave (CW) green diode-pumped solid-state (DPSS) lasers. Millennia Core delivers 25 W of CW DPSS green power, the highest in the industry, along with superior beam quality and extremely low noise. Featuring a single, industrial-grade package that integrates the power supply, laser diodes and optical cavity, the new lasers are highly reliable and easy to use for demanding applications including ultrafast laser pumping, laser doping of solar cells and materials processing applications.

Spectra-Physics has also introduced the Excelsior One continuous-wave (CW) lasers series. The new line of ultraviolet (UV), visible and near-infrared (NIR) CW lasers integrate laser head and controller into a single, compact package. Available as free-space and fiber-coupled laser configurations, the plug-and-play Excelsior One series includes 11 different wavelengths and delivers up to 500 mW of average power. They are ideal for use in flow cytometry, confocal microscopy, DNA sequencing, and other bioinstrumentation applications. For more information on either, visit **www.newport.com**.

NEWPORT INTRODUCTIONS

Newport Corporation, Irvine, CA, has introduced the Series 819C/D high power silicon-based integrating sphere detectors that operate in the ultraviolet (UV- down to 200 nm) and can handle up to 10 watts of optical power. The new CAL2 models feature a built-in temperature sensor and OD1 attenuator sensor. When connected to Newport's power meter models 1830-R, 1918-R, 1936-R, or 2936-R, they automatically recognize the attenuator on/off position and the detector head temperature. Calibrated and traceable to NIST standards, the 819C/D Series spheres operate in wavelengths ranging from the UV region through the visible to the near-infrared (NIR) at 1650 nm.

Newport has also announced a specialized Integrated Vertical and Rotation Stage, the ZVR. Ideal for semiconductor wafer positioning, metrology, inspection and repair, it is also useful in LED production and applications such as 3D scanning, digitizing models and validation. The ZVR features a compact and rigid design with improved cantilevered load capacity. With significantly lower cross-talk than earlier designs, the new stage delivers higher dynamic system performance in a very low-profile footprint. The low mass, along with a high natural frequency, accommodates a variety of rapid step-and-settle positioning applications.

For more information on either, visit **www.newport.com/819** or **www.newport.com/ZVR**. ■

MEMBERS IN MOTION

BEYER RECEIVES AWARD

Eckhard Beyer, executive director of Fraunhofer IWS in Dresden, Germany and a past LIA president, has been awarded with the Fraunhofer-Medaille. The award honors persons who have performed a great service to the Fraunhofer-Gesellschaft. Beyer`s efforts to advance the Fraunhofer IWS and to integrate it into the scientific and economic community were noted. Beyer initiated and shaped the IWS project centers in Michigan and Wroclaw (Poland), centers that have decisively contributed to the international prominence and reputation of the IWS. The close and fruitful cooperation between the IWS and the University of Technology Dresden was also cited. Under his leadership, the two research institutes have successfully developed renowned research results in the field of laser and surface technology.

WELCOME NEW CORPORATE MEMBERS

Diode Laser Concepts, Inc.
Central Point, OR

Phillips Safety Products
Middlesex, NJ

For a complete list of corporate members, visit our corporate directory at **www.lia.org/membership**.

LIA RENEWS OSHA ALLIANCE

Reaffirming its role as an active partner in advancing laser and workplace safety, LIA has agreed to continue its advisory role with the U.S. Occupational Safety and Health Administration (OSHA). LIA, secretariat and publisher of the American National Standards Institute Z136 series of laser safety standards, renewed its commitment to continue working with OSHA to prevent beam and non-beam laser hazards, particularly in industrial and medical applications.

"The benefit for us with OSHA has been primarily to spread the word of laser safety," says LIA Education Director Gus Anibarro. "OSHA's concern is employee safety, and the LIA's mission is to foster lasers, laser safety and laser applications worldwide. With our alliance we can do this more effectively."

During the two-year agreement, LIA will furnish information that will inform users of OSHA's Safety and Health Topics web pages detailing laser hazards, laser/electrosurgery plumes and radiation. The OSHA and LIA alliance will also develop fact sheets for laser use and educate OSHA field staff on how to use lasers safely and share information on laser regulations and standards, laser control measures and laser safety program administration. The broadening use of lasers in more and more innovative applications makes this mission even more critical.

LIA and OSHA representatives have been collaborating extensively since first aligning their laser safety efforts in 2005. As new ANSI Z136 standards (available from LIA at **www.lia.org/store**) guide the safe use of lasers in health care settings outside the hospital and in research and development facilities, continued cooperation is vital in identifying new ways to improve laser safety and monitor the progress of those efforts. LIA has created a variety of multimedia tools to highlight information from the bulletin, which are available at **www.lia.org/subscriptions/rss.php**.

LME 2012 REGISTRATION NOW OPEN

Registration is now open for LIA's Lasers for Manufacturing Event (LME™) 2012, which will be held in Schaumburg, IL, Oct. 23-24 and will be the place to see the latest in laser technology, network with the industry's elite and find solutions to current and future manufacturing needs. The mission of LME is to provide a one-stop event for companies interested in integrating laser technology into their production. Attendees will learn about laser choices, beam delivery, automation equipment, safety considerations, applications development and meet exhibitors that supply these products and services.

LME 2012 will feature a Laser Technology Showcase, tutorials on ultrafast laser machining, the basics of laser welding and joining and keynotes on major laser application areas, markets and technology. Basic educational courses cover the main types of lasers, laser systems and fundamentals of laser additive manufacturing. Visit **www.laserevent.org** for more information and to register.

REGISTRATION OPEN FOR LASER WELDING & JOINING WORKSHOP

Join us in Schaumburg, IL, Oct. 23-24 at LIA's Laser Welding & Joining Workshop to learn from industry specialists from around the world about applying laser materials joining technologies to today's manufacturing challenges and opportunities. This workshop will offer quality technical sessions and networking opportunities to discuss equipment and applications with top laser industry leaders. Those that will be attending are manufacturing engineers and managers, product designers, process/R&D engineers, applications engineers, business developers and entrepreneurs, plant supervisors and anyone interested in laser materials joining technology (welding, joining or brazing). Visit **www.lia.org/laserwelding** to register now.

SAVE THE DATE – LAM 2013

LIA's 5th annual Laser Additive Manufacturing Workshop (LAM) will bring industry specialists, executives, users and researchers from around the world to show how cladding, sintering and rapid manufacturing can be applied effectively and affordably to today's manufacturing challenges. This workshop will have a significant impact on the widespread industrial implementations of laser additive manufacturing in what is a rapidly growing industry. Mark your calendars now to attend LAM, to be held Feb. 12-13, 2013 in Houston, TX.

ILSC COMING IN 2013

Make plans now to be in Orlando, FL March 18-21 in order to attend the 2013 International Laser Safety Conference (ILSC®). 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 laser safety officer and medical laser safety officer may encounter. Professionals in all fields and applications will find ILSC a tremendous source for information and networking opportunities.

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