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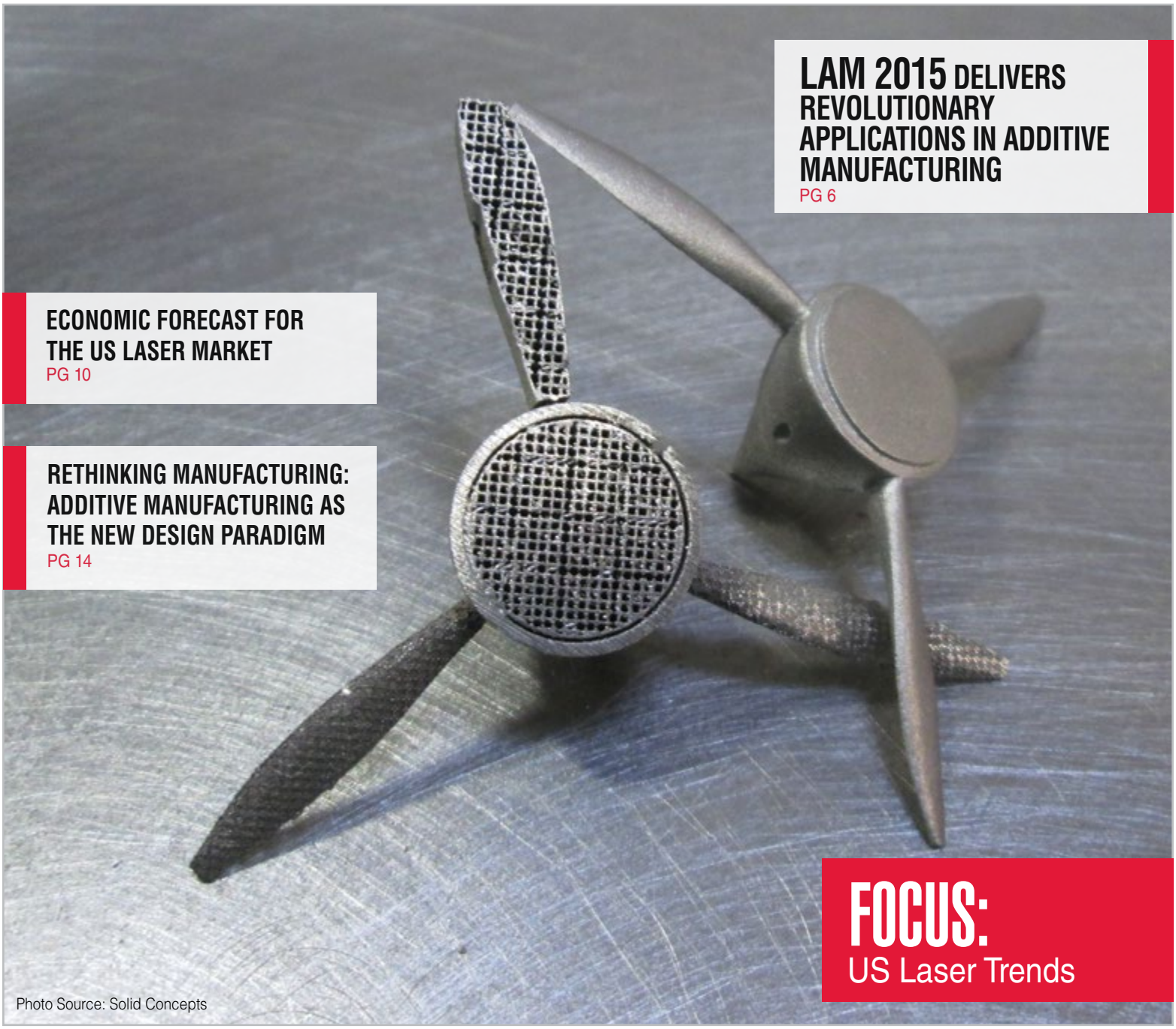

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FOCUS:
US Laser Trends

Photo Source: Solid Concepts

Laser Institute of America, the international society dedicated to fostering lasers, laser applications and laser safety worldwide.

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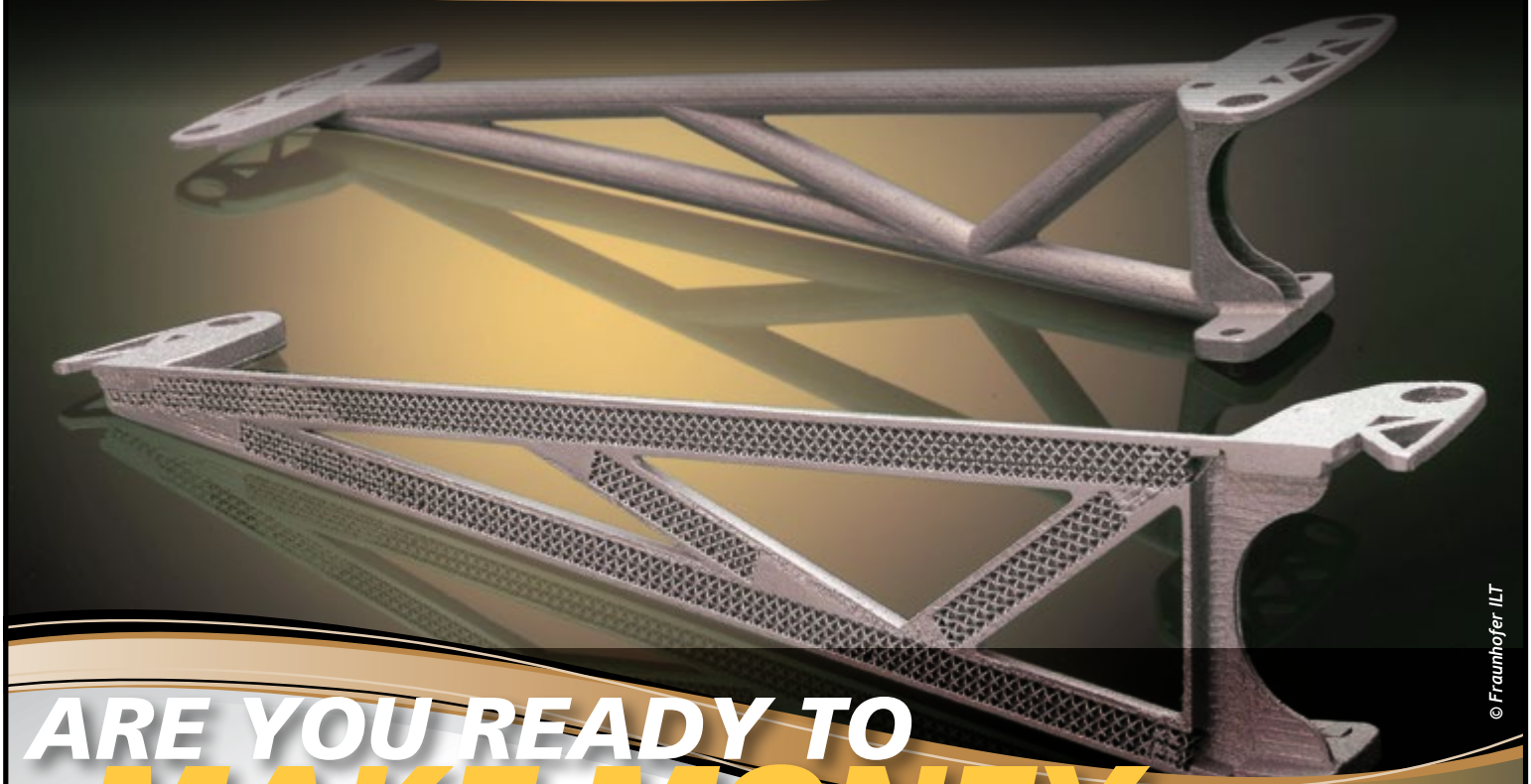

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LIA TODAY

THE OFFICIAL NEWSLETTER OF THE LASER INSTITUTE OF AMERICA

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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.

CALENDAR OF EVENTS

Laser Safety Officer Training

Feb. 24-26, 2015	San Diego, CA

Laser Safety Officer with Hazard Analysis*

Jan. 26-30, 2015	Orlando, FL
Mar. 9-13, 2015	San Jose, CA
Jun. 8-12, 2015	Niagara Falls, NY
Sept. 21-25, 2015	Chicago, IL
Oct. 19-23, 2015	Atlanta, GA
Nov. 2-6, 2015	Scottsdale, AZ

*Certified Laser Safety Officer exam offered after the course.

Medical Laser Safety Officer Training*

Jan. 24-25, 2015	Orlando, FL
Mar. 7-8, 2015	San Jose, CA
Mar. 21-22, 2015	Albuquerque, NM
Jun. 6-7, 2015	Niagara Falls, NY
Sept. 19-20, 2015	Chicago, IL
Oct. 17-18, 2015	Atlanta, GA
Nov. 7-8, 2015	Scottsdale, AZ

*Certified Medical Laser Safety Officer exam offered after the course.

Laser Additive Manufacturing (LAM®) Workshop

Mar. 4-5, 2015	Orlando, FL

International Laser Safety Conference (ILSC®)

Mar. 23-26, 2015	Albuquerque, NM

International Congress on Applications of Lasers & Electro-Optics (ICALEO®)

Oct. 18-22, 2015	Atlanta, GA

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

President's Message

Dear LIA members and *LIA TODAY* readers,

Although the ICALEO® conference is over, the excitement is still continuing. I have heard a lot of compliments from our colleagues who attended the event. The plenary session was wonderful, with presentations on research into the mysteries of the universe and killing mosquitos to reduce the risk of malaria. The technical sessions were exciting and included many talks on cutting-edge research. The business sessions were informative, teaching us how to bring technologies to the market as well as the different ways to succeed. Congratulations to Dr. Stefan Kaierle, the general chair of ICALEO, for a job well done. I would also like to congratulate Dr. Reinhart Poprawe, past LIA president, who received the prestigious Arthur L. Schawlow Award. This recognition for Reinhart is long overdue.

I feel very privileged to serve this community and work with these talented people. The individual who has played a key role in attracting these wonderful people is LIA Executive Director Peter Baker. Combining his British elegance and American cheerfulness, he has the art of turning tedious and difficult tasks into something fun and exciting. A few years ago, Peter and I traveled to Beijing and spent a bit of time in the famous Tian'anmen square. A little girl approached Peter and asked, "Are you the Santa Claus?" "Yes, I am," answered Peter, and gracefully agreed to the girl's request to take a photo with him. That moment is symbolic of how Peter treats people around him. I would like to thank Peter for his devotion and leadership in making LIA such a wonderful community.

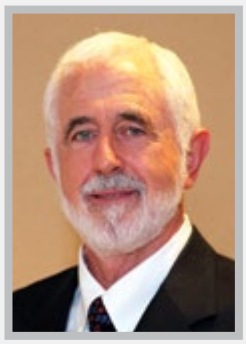
This issue has a focus on US laser trends. In the past decade, Germany and China have made remarkable progress in laser industries, both in making and using lasers. With the improving economic environment and strong research base in the US, I believe we will see faster progress in laser industries in the US as well. LIA will play an even more important role as we provide our members with information on integrated solutions in laser technology and business. Among different applications, laser additive manufacturing is picking up momentum. If you are interested in this area, please do not forget LIA's Laser Additive Manufacturing (LAM®) Workshop 2015 is coming soon.

The holiday season will soon be upon us, and I wish you all the best in your work and family life.

Yongfeng Lu, President
Laser Institute of America

When Peter Baker was known as the Santa Claus

Executive Director's Message



LIA Working Beautifully

It was very interesting and gratifying to see LIA working so beautifully at ICALEO®. There was open and positive communication during formal meetings of the board and many steering committees as well as informal discussions at breaks and receptions.

I was struck by the level of caring and commitment to the well-being of our society and I thank everyone for their valuable input. As a result of this, we are taking steps to further upgrade ICALEO with the addition of a session on bioinstrumentation and increased emphasis on imaging.

A major outcome of discussion was the decision to postpone the next Lasers for Manufacturing Event® (LME®) to the spring of 2016 and change the location to the southeastern US. This will allow us to grow and strengthen the Event in future years.

There were many other changes and improvements discussed, all of them aimed at advancing LIA's continued growth and success.

Thank you Team LIA!

Peter Baker, Executive Director
Laser Institute of America

LAM 2015

Delivers Revolutionary Applications in Additive Manufacturing

LAM® LASER ADDITIVE MANUFACTURING WORKSHOP

BY GEOFF GIORDANO

With more new workshops than ever purporting to give a true perspective on 3D printing and additive manufacturing, the Laser Institute of America's Laser Additive Manufacturing (LAM®) Workshop has been ahead of the curve when it comes to realistic assessments of revolutionary industrial applications.

In its seventh year, LAM 2015 will again provide an intensive two-day immersion in the full spectrum of laser-based industrial additive applications — from traditional corrosion and wear protection and repair to the more hype-worthy powder-bed and powder-fed methods.

For the first time, LAM will not be held in the power-generation hub of Houston but in LIA's hometown of Orlando, on Mar. 4-5 at the Embassy Suites Orlando – Lake Buena Vista South (Orlando, FL). LIA is a key part of the Florida High-Tech Corridor and the state's photonics community, which includes the nearby College of Optics and Photonics at the University of Central Florida.

For first-time General Chair Dr. Ingomar Kelbassa, achieving the full effectiveness of 3D printing applications is predicated to no small extent on sound vertical and horizontal process chains. Amid the swirl of events and presentations at ICALEO 2014 (see story, page 16) in San Diego in October, Kelbassa and his team were already putting in place the key elements of the education track for LAM 2015.

Taking LAM Forward

LAM "initially started as a workshop for just cladding for wear and corrosion protection," says Kelbassa, an adjunct professor at Australia's RMIT University, vice director at the Chair for Laser Technology LLT, RWTH Aachen University, department head at the Fraunhofer Institute for Laser Technology, and a member of the Fraunhofer ILT team that won an Aviation Week innovation award in 2012 for producing an additively manufactured BLISK (blade-integrated disk) in about 160 minutes — or, two minutes per blade. "That's why it has taken place in Houston — for offshore applications, mining, gas, oil, etc. Now we have developed and improved from, say, 2D cladding to 2.5D cladding through to 3D cladding and layer-by-layer buildup of structures as well as all the developments and improvements in the powder-bed processes, (also known as) selective laser melting (SLM)."

In keeping with prior LAM education tracks, LAM 2015 will feature an overarching theme each day: process chain and process integration on day one and real-world success stories on day two.

"Primarily, LAM was, is and will be, a workshop that is industry driven," Kelbassa asserts. "Therefore, the majority of the presentations will be on success stories from OEMs as well as from a service provider's perspective — highlighting industrially implemented AM chains in the aeronautics, power generation, offshore, mining, oil, automotive and tool, die and mold-making fields."

Day one is scheduled to feature four sessions with three presentations each addressing the paradigm shift in manufacturing – along the horizontal and vertical AM process chain; design and material; process and quality assurance; and systems and process integration.

> "WE CAN DEFINITELY SAY WE HAVE FOLLOWED UP ON THE ENTIRE HISTORY FROM DEPOSITION WELDING UP TO REAL RAPID MANUFACTURE. THAT'S WHY WE WILL BE ADDRESSING THE ENTIRE PROCESS CHAIN, HOLISTICALLY."

Because additive manufacture is not just one process step — it's one step out of many steps: from raw material and design through additive manufacture and proceeding through all the steps down to the adaptive finishing operations so you have your finished end products."

"We will also address the vertical process chain, which is more or less the supply chain for the additive manufacturing process step itself. That means CAD/CAM algorithms for SLM/LMD (laser material deposition), the powders for that, AM-tailored powders, quality assurance by process monitoring and control and, of course, process integration."

Kelbassa is quick to note that "the entire process chain right now does not exist. Everything out there, including the supply chains, is mainly, at the moment, mostly for subtractive manufacture — material removal, (be it) five-axis milling, grinding, whatever. AM must be considered holistically" to succeed.

On day two, he continues, LAM 2015 "will feature a more industrially driven telling of success stories in different markets and fields of applications. So that means, for instance, wear and corrosion protection for the automotive industry, aerospace, power generation — flying and nonflying gas turbines — as well as rapid manufacture."

As with day one, day two's education track will feature four three-presentation sessions covering worldwide large-scale AM initiatives; wear and corrosion protection; maintenance, repair and overhaul; and rapid manufacture and visions.

"I call it 'visions' because hopefully (we will have a talk) on rapid manufacture of organic materials: not metals or ceramics, but depositing living cells. In the end, the vision is to print out 'spare parts' for human beings — organs."

Hype-Free Zone

While industrial additive manufacturing might be confusedly lumped in with the broad spectrum of emerging 3D printing options — particularly vis-à-vis the cheaper personal-style systems that turn out plastic trinkets — achieving a global perspective on real LAM growth is challenging. That's where LAM fills a significant need, Kelbassa says:

"At the moment, AM is a niche. But it will be growing. It will not entirely replace subtractive manufacture; it can't. But in the end there will be a larger divergence (in applications) and also larger technology transfer in different fields of applications. Where we come from now is (using AM for) high-value components (for) aerospace, power generation, automotive, highly complex parts for tool, die and mold making, and highly individual parts for mass customization — mainly in medicine such as for (dental) implants etc."

For those following trends in AM, Kelbassa notes, "it doesn't matter if we produce one part or 10 million parts, the cost per part remains the same. That means that everything that has to do with mass customization should be very easily addressable by laser AM technologies and processes."

Further, AM affords "the opportunity to design new lightweight structures and combine lightweight structures with lightweight materials. These kinds of lattice structures (result in parts with) a weight of 50 percent less, 60 percent less, but with the same structural integrity (and) the same mechanical properties. That opens new horizons; you can think about a part lasting, instead of 1,000 cycles, maybe 5,000 or 10,000 cycles. You do not have to repair it because there is no need."

That increase in product life cycle "can't be addressed by any production in conventional manners." "Growing" LAM, so to speak, will depend on several factors.

"The question is always availability of things," Kelbassa says. "That means availability of powder additives and new CAD/CAM algorithms. These will be available if the OEMs are seen sharing their own business cases." Sharing those cases, in turn, will improve the attractiveness and visibility of AM.

AM "also depends on the availability and existence of standards, and these are not out there at the moment."

While LAM 2015 will again provide as much global perspective as possible on AM initiatives and funding by various nations, it's no secret that Europe is ahead of the curve in making real parts, he notes; and, just because a country commits millions of dollars to pursuing additive manufacture by acquiring machines and systems "does not mean you have also acquired the know-how to work with these machines and systems."

Strong Speakers

Scheduled to open the proceedings is keynote presenter Christoph Leyens of Fraunhofer IWS. "He will be addressing what Fraunhofer always addresses: how we come from the

(Continued on page 8)

lab to industrial applications and what we call digital photonic production — coming directly from the CAD data via the laser light to the metal, to the component we build up," Kelbassa explains. "Hopefully, he will also be addressing the deficits of the technology today — because we are also far away in terms of system integration and (matching the output of) five-axis milling machines."

With the reproducibility of AM-produced parts a challenge, "deficits are always useful and necessary to talk about: How do you improve and develop a technology further if you do not know what to do? There's a hype out there about 3D printing: Everybody thinks you can do everything with it, and that's not true."

Also slated to present are:

- James Sears, GE Global Research: GE's initiatives in AM
- Daniel Schraknepper, Fraunhofer IPT: Process integration and adaptive machine finishing
- Claus Emmelmann, LZN: Functional and lightweight design
- Thomas Peters, Sulzer: AM-tailored powder initiatives
- Thomas Schopphoven, Fraunhofer ILT: Ultra-high speed laser material deposition
- Max Schniedenharn, Fraunhofer ILT: High-speed selective laser melting
- Milan Brandt, RMIT Centre for Additive Manufacturing
- Dongdong Gu, NUAA: AM approaches in China
- Scott Poeppel, Joining Technologies: MRO of heat exchangers used in waste combustion

Kelbassa is also aiming to include sessions on the additive manufacture of automotive and jet parts, as well as discourses on LMD in a controlled atmosphere, LMD systems and direct metal laser sintering systems.

Of course, with all these experts in the room, LIA will ensure a chance to network more closely by scheduling an Exhibitor Reception starting at 5 pm on Mar. 4. Attendees new and old will have a chance to ask their most pressing questions of some of the most experienced laser-industry professionals, including LAM Co-Chairs Sears and Paul Denney of Lincoln Electric — both of whom are past chairs of LAM. Alabama Laser will once again serve as platinum sponsor of the Workshop. Other sponsors this year include: Cambridge Technology, Inc.; DM3D Technology, LLC; Fraunhofer USA, CCL; IPG Photonics Corporation; Joining Technologies, Inc.; Laserline Inc.; LPW Technology; Optomec and TRUMPF Inc. A complete list of LAM 2015 Exhibitors can be found on the LAM website. ■

To stay updated on the educational track or to register, visit ***www.lia.org/lam****.*

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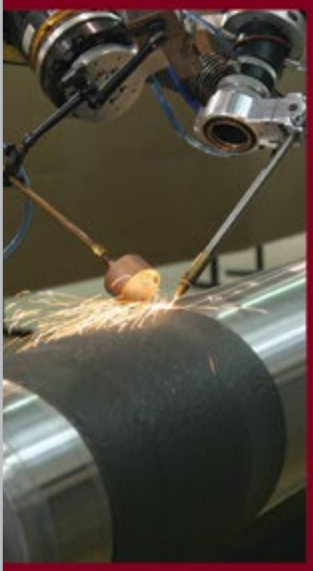

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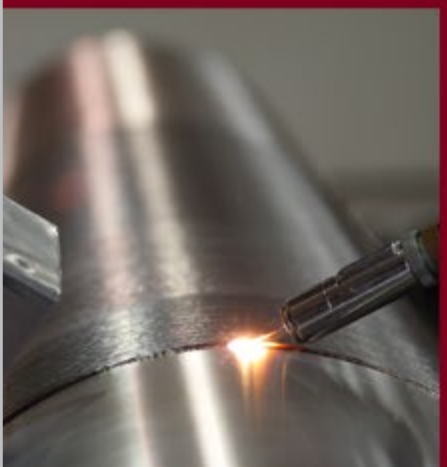

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Economic Forecast
for the US Laser Market

BY GEOFF GIORDANO

When Mark Douglass of Longbow Research kicked off the Laser Institute of America's inaugural Lasers for Manufacturing Summit on Sept. 22 in Schaumburg, IL, he painted a rather sobering portrait of global economies struggling to foster and sustain growth.

While the US remains "the best house in a lousy neighborhood," markets once thought to hold great promise for laser-based applications — Europe, Asia and especially South America — are proving challenging or an outright bust, he asserted.

"Not a whole lot has changed." said Douglass, a former laser researcher and engineer turned financial analyst. "A lot of (the latest data) seems to be reinforcing what I was saying in September."

In terms of specific industries, his September assessments for the US forecast some recovery in machine tool production; a possible double-digit fall in sales of farm equipment; successes in the heavy equipment, automotive, appliance and aircraft sectors; and booming business in new or retrofitted rail cars and related infrastructure.

Reshoring of manufacturing to the US "might be hard to see, but it is real — although it's not a panacea for job growth." While US production levels have grown, employment shrinks. "We're at roughly 30 percent of (manufacturing) jobs we had before the big recession — but we're already at the same levels of output."

A little more than a month after the summit, his assessments remained in line with the then-current US GDP figure and company earnings reports.

Around the world, "Europe is weakening (and I) don't know if it steps back into recession or not," he said. "South America is a basket case… and it looks like the Brazilian elections didn't help its economic prospects, as the old administration is still in power." Other emerging markets remain weak, as well. "China is still OK; it's not growing as fast as people want, but there is still a lot of opportunity for many companies." Meanwhile, "Japan is in a funk, and Australia is getting crushed because of mining." In the Middle East, much oil and gas and other energy investment is on hold because of volatility in the region.

In light of all this, diversification is the key to success for those looking to invest in laser equipment or new end markets.

"In the near-term, there will not be investment by agricultural equipment companies," he said. "Construction equipment, at least in the US, seems to be picking up. Mining is probably at bottom, so maybe they'll be ready to invest in equipment over the next year-plus. Energy is still a market you want to be close to and involved with. Yes, oil prices dropping presents some near-term headwinds, but if you take a longer-term view there is still a lot of investment that's going to occur globally in energy markets." So-called "green" energy, however, "is as volatile as ever and risky because a lot of it needs to be propped up by government subsidies."

Meanwhile, the automotive industry is still "pretty healthy," while food and beverage packaging "is always a great market to be exposed to because there's always some amount of investment going on." Consumer-related manufacturing and even medical devices "are fine places to be in."

Regarding the electronics and semiconductor capital equipment sectors, "there's still not much going on in semi-cap equipment. There are pockets of orders here and there, but you're still not seeing a big investment due to the challenges they face in the new technologies, such as going to larger wafers and going to smaller nodes. There are still a lot of engineering challenges to overcome." But in consumer electronics, "IPG showed that (the sector) was pretty good for them. We'll see what Coherent and Rofin have to say."

However, the much-touted application of sapphire cutting for displays "is up in the air because the rumors had always been that the largest sapphire application, at least near-term, was going to be (done by) Apple." With sapphire supplier GT Advanced in bankruptcy, that's less certain; the company saw its shares plummet from nearly $20 in July to roughly 50 cents by the end of October. The turmoil in this sector might take about two years to play out, he said.

Laser marking, especially higher-end work, is a steadily growing activity. "IPG talked about deep engraving, and we've heard that from others — that lasers are becoming more attractive (for that use). Plus, there are a lot of regulations mandating product identification and traceability in all sorts of areas, pharmaceutical being one. That should be a good business for a long time to come."

For job shops, diversity of customers is key. "If their volumes decline, so do yours," he cautioned. "If they had

to switch suppliers or move production in-house, that really hurts you."

Being able to perform an array of applications is vital, too: "Send your guys out to learn more than 2D cutting setups; figure out how to do 3D cutting or multidimensional cutting. Figure out how to do some welding applications, or drilling or perforating. Try to be creative in how you can add value and take some of the new applications and developments in lasers and expand your horizons." [Learn more about cutting-edge applications at LIA's upcoming Laser Additive Manufacturing (LAM®) Workshop on Mar. 4-5 in Orlando, FL.]

Is it a good time to invest in new laser equipment, particularly as fiber and diode lasers gain ground in various applications? "It depends on what you want to do. I talked to one machine builder that is selling a lot more machines because their fiber laser technology is embedded and they are able to sell lasers to job shops that cut copper. Copper cutting is not nearly the size of a market as steel cutting, but it's an available market that if you buy a fiber laser you can process multiple materials you couldn't do before, or at least it was very challenging if you had a CO_2 laser.

"It's an easier decision to make if you're just replacing a system; it's a safer bet than trying to expand capacity and having to find new business to justify the capital outlay." ■

Dr. Mark Douglass is a Senior Equity Analyst at Longbow Research.

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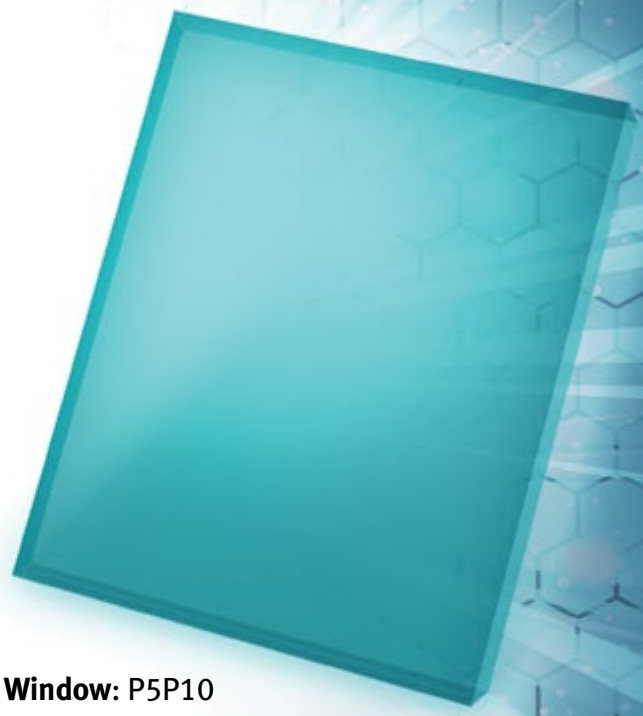

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Rethinking Manufacturing:

Additive Manufacturing as the New Design Paradigm

BY FREDERICK CLAUS

Additive manufacturing (or 3D printing) with metal has significantly advanced the fields of aerospace, medical and industrial manufacturing with complex geometries and expedited production by eliminating the cost and long lead times for traditional molds and tooling.

Inherent limitations of metal working processes – such as investment casting, machining or die casting – center on complexity. Each process is incapable of building one unit with many interlacing features and/or cannot produce without excessive labor and adjoining details, all of which are completely dependent on "line-of-sight" features. Shapes are left simple or, at best, weighted by additives, bulky overhanging walls and attachment fittings. By contrast, shapes produced using the additive manufacturing process termed Direct Metal Laser Sintering (DMLS) or Selective Laser Melting (SLM) incorporate the highest level of complex features without requiring line-of-sight features or attachment post-processing. Additive manufacturing offers freedom of design, and therefore a paradigm shift away from "designing for manufacturing" into manufacturing for design.

DMLS parts build within a chamber of inert gas to keep oxides from forming (similar to traditional processes, negating the formation of oxides keeps metals strong). The largest laser used in the DMLS process is a 400 W Yb-fiber laser. Two mirror galvanometer systems direct the laser energy using precision optics to shape the part layer by layer. The precision of this process is 40 microns on the Z-axis with an accuracy of ± 0.005" for the first inch and ± 0.002" per inch thereafter. DMLS is essentially a very fine welding process, where the welding initiated by the laser requires tremendous energy to melt the metal. In areas that are unsupported – such as overhanging features at angles greater than 45 degrees – the energy directed to the bed is so great, it causes some ablation resulting in the material being "blown out" of place rather than melting. Therefore, not only must parts be supported and welded to the bed of the build platform, but over-hanging or inner features must have build supports as well. All support material is made of the same metal as the actual part which makes the support removal process time consuming and difficult. After support removal, the part must be carefully sanded or machined for a smooth finish. However, the surface finish of a DMLS part before sanding is directly relatable to the surface finish of an investment cast part. Studies have shown that certain metals subjected to DMLS manufacturing resulted in better retention of strength and other properties than that same metal experienced from the often suggested alternative: Casting[1]. Parts are oriented on the build platform with the supports in mind, and areas that are more delicate are accounted for to provide easier support removal. Unlike other 3D printing processes, DMLS supports are added manually. To avoid ablation while keeping the integrity of a part, part positioning is studied to account for greater angles etc.; positions of parts on a build platform are complementary to angle and surface requirements.

Figure 1. In the foreground, the DMLS part still sports the support structures necessary for a build. The background shows the DMLS part with supports removed and sanded.

Current DMLS processes offer metal compositions of stainless steel, cobalt chrome, Inconel, aluminum and titanium materials. A handful of suppliers sell variations of DMLS and SLM machinery. The main difference between these machine capabilities revolves around the process for compacting and smoothing metal powder, and the chambers the parts build within. Compacting and smoothing the powder between layers of melting is a critical factor in DMLS production. Metal powder is eager to bond, which can result in shifting or deforming parts if the metal is not neatly smoothed between layers. Depending on the part and its needed functionality and shape, the best recoater system for compacting the powder between layers may differ.

Figure 2. You can see the intense support structures that protected the sphere during building. Half of the sphere has since been polished while the remainder of the sphere shows signs of where the supports left off.

DMLS, while an incredible technology still fresh in the industrial sector, is not suitable for all metal applications. Large simple parts are better met by traditional practices of manufacturing. DMLS has the advantage in smaller, complex units and parts. The smallest features DMLS currently is capable of reproducing are ≥ 0.015". Larger parts can be seamlessly welded, though the current build platform volume is 9" x 9" x 10". The main significance in DMLS is cost effective manufacturing of complex geometries[2]. Given the extensive support clean-up DMLS requires, it is tempting to assume it might be easier to machine and weld a part in the attempt to achieve a somewhat similarly complex unit. However, when the entirety of both processes are broken down, DMLS proves to require less manual labor and less weld post-processing than a similar part that has been machined, and achieves far more complex features with no line-of-sight. DMLS can build units completely consolidated with integral features and have a fully functioning part ready in four to five days.

Figure 3. Shows the way parts are welded to the build platform.

To prove this, Solid Concepts built a Browning 1911M pistol. The pistol was built with 34 DMLS created parts, six non-critical pieces off the shelf (such as the springs, screws and the magazine), and a handle grip manufactured with a plastic 3D printing process. The metal components printed in 36 hours. Hand finishing took roughly 50 additional hours. Assembly time took less than seven minutes. If the gun had been built traditionally, it would have required machined patterns which can take weeks to refine. Then the gun would have required expensive casting. The barrel would have required machined rifling after being cast and post-processed. The whole process would take over a month. For Solid Concepts' 3D printed pistol, the rifling was manufactured in the DMLS chamber simultaneously with all other features, all built in 36 hours on one machine. The pistol additionally proved the incredible metallurgical properties of a DMLS manufactured part: The barrel sees pressures of 22,000 psi and has withstood over 4,000 rounds of firing. Special details on the inner features of the subsequent guns include further complex detailing incapable with machining or casting.

Projects similar in pressure and metallurgical property testing continue at Solid Concepts. The most important breakthrough of DMLS and other 3D printing capabilities is the shift in thinking away from designing for manufacturing and towards manufacturing for design. The old paradigm required design restraints conformal with traditional manufacturing process capabilities, which significantly limited the complexities of parts. With 3D printing on the industrial scale, manufacturing for design is the new paradigm. Complexities evolving towards more efficient, cost effective products on the industrial scale are beginning now with DMLS and have taken place for decades with other high performance 3D printing material. The changes in the way designers and engineers think about a new product will be indiscernible in the future, but for now it's the biggest leap in the revolution of manufacturing since electricity. ■

Frederick Claus is a business development manager at Solid Concepts.

References:

[1]*Jacob Keith, "Direct Metal Laser Sintering of Inconel 718", Columbia University & NASA Academy. 2012. http://jacobkeith.com/DMLS%20Poster%20Final.pdf*
[2]*Jacob Keith, "Direct Metal Laser Sintering of Inconel 718", Columbia University & NASA Academy. 2012. http://jacobkeith.com/DMLS%20Poster%20Final.pdf*

ICALEO 2014

Offered Attendees a Full Spectrum of Laser Possibilities

ICALEO®
33rd INTERNATIONAL CONGRESS ON APPLICATIONS OF LASERS & ELECTRO-OPTICS

BY GEOFF GIORDANO

Not resting on the laurels of its flagship conference, the Laser Institute of America instituted a peer-review process for its 33rd International Congress on Applications of Lasers & Electro-Optics (ICALEO®), held Oct. 19-23 in San Diego.

For the first time, ICALEO featured presentations given even more rigorous analysis than previous events; 56 of the 61 papers submitted for peer review were accepted. "It was quite a bit of a challenge" reviewing abstracts, said returning Congress General Chair Stefan Kaierle of Laser Zentrum Hannover. "We believe it was necessary… to change the way we present our work and especially to improve the quality." At least two people reviewed each paper in the double-blind process. About 35 to 40 papers will be published in a special edition of the *Journal of Laser Applications® (JLA)*, he said.

What is often called a laser family reunion, ICALEO featured another broad-ranging smorgasbord of laser research and experimentation spanning the traditional and the novel — from 3D patterning of cardiac cells and killing malaria-carrying mosquitoes to creating more powerful bacteria-fighting nanoparticles, powering a small flying craft and improving the dyeing and patterning of textiles. Lasers are even being used to listen to colliding galaxies, black holes and dying stars.

"We rarely see a conference lasting more than three decades and still experiencing expansion," said LIA President Yongfeng Lu in welcoming the more than 400 attendees from 30 countries. Such is ICALEO's reputation that many attendees have participated five, 10, even 20 times. Dozens of newcomers were evident from the light-blue nametag ribbons given to first-timers, a good number of whom were presenting papers.

Other highlights of the roughly 200 presentations included:

- Remote laser cutting to decommission nuclear facilities, especially Japan's Fukushima, for which researchers examined the use of CW and pulsed 6 kW fiber lasers to cut steel and crush ceramic debris.

- A four-lens, variable-zoom adaptive cladding system called ALAS that was developed by Spain's Aimen technology center and its partners, and allows on-the-fly adjustment of beam size from 2.7 to 5.5 mm for repair of parts with complex geometries.

- Numerous sessions on laser treatment of glass and sapphire, including crack-free marking and the creation of shiny aesthetic effects by changing process parameters and marking angles with a Coherent Helios 532 nm sub-nanosecond laser and using a common 2D galvanometer scan system.

- Power scaling of vertical and edge-emitting diode lasers to multi kW levels for applications like tailored NIR heating, selective laser melting, carbon fiber placement and pumping of solid-state lasers to facilitate laser cleaning or laser ignition of combustion engines. Power can be scaled, for instance, by producing arrays of 2,000 vertical emitters on one chip, then combining 56 chips. The resulting stack of 112,000 lasers emits 400 watts; combining 24 of those stacks can create a module with output around 10 kW.

- Renewable-energy applications, particularly the use of high-power lasers to increase solar absorption in photovoltaics. One possibility is to use lasers to microtexture silicon surfaces, which reflect away 33 percent of sunlight. Scanning a laser beam across silicon creates self-organized conic surface structures that trap more light for conversion to energy. Data showed light reflected away from a silicon surface so treated fell to about five percent. The method works better than antireflection coating, which works well for a given wavelength; the laser light-trapping technique can facilitate absorption of light over the broad solar spectrum, from 350 to 2,000 nm.

- A range of cladding applications, including diode laser deposition of synthetic diamonds on wire saws, which affords a metallurgical bond between the clad and the steel core and a chemical bond between the diamonds and metal matrix that is not possible with the electroplating process.

- Cutting applications, including micromachining of sapphire with UV nanosecond lasers; direct cutting with diode lasers; and cutting of carbon fiber reinforced polymers with a 30 kW fiber laser.

- A variety of experiments in the mid-infrared wavelength using a 120 W, 2 micron thulium fiber laser. The novel research conducted with this conventional, well-tried and tested laser — originally intended for surgical applications — included examination of material absorption, thin-film ablation, polymer welding and even marking of produce like apples and bananas. "It appears to be very robust fiber-laser technology (with) simply a different element as the active medium," noted IPG's Tony Hoult during his presentation. "The beauty of the thulium fiber lasers is that you can use conventional, off-the-shelf fused silica optics — all you need to do is have the right coatings… and the coatings have been available for some years because the holmium YAG lasers and the erbium lasers YAG lasers… have been around for years." He noted that a handful of patents have been applied for based on his work.

- Exploration by Amplitude Systemes of micromachining applications with a 600 µJ high-average power ultrafast fiber laser. "Scaling up of pulse energy [was] demonstrated by simultaneous use of chirped pulse amplification and divided pulse amplification," the firm's abstract noted. "The simultaneous generation of 60 W of compressed average power at 100 kHz, together with 320 fs and 600 µJ pulses, represent the highest performance achieved from an industrial-grade ultrafast fiber laser."

Beyond the Research

Meanwhile, LIA Past President Reinhart Poprawe, Managing Director of Fraunhofer ILT, received the Arthur L. Schawlow award at LIA's Annual Meeting & Awards Luncheon. "LIA always has been, for me, one of the true (forces) in the global development of the laser community and technology," he noted. Also at the meeting, outgoing President Lu handed the reins over to Robert Thomas of the US Air Force Research Laboratory for 2015 and announced Lin Li as President-Elect and Paul Denney as Secretary.

LIA Executive Director Peter Baker noted that the JLA's impact factor — a measure of the publication's popularity — had grown to 1.338 from 0.574. Additionally, he announced that a revamped Lasers for Manufacturing Event® (LME®) and Summit will be moved from the fall of 2015 to the spring of 2016. He also honored continued volunteer contributions to LIA efforts by Rita Lawson and Virginia Belforte.

Another development coming from this year's ICALEO is the creation of LIA's new Scientific Strategic Committee, Baker said, comprising roughly a half-dozen former presidents and ICALEO general chairs charged with identifying new laser technologies and applications and ensuring they are presented to LIA audiences.

At the end of the conference, Kaierle announced Silke Pflueger of DirectPhotonics as Congress General Chair of ICALEO 2015, which will be held Oct. 18-22 in Atlanta, GA.

Applications Off-the-Wall and Otherwise

Kaierle and his conference team again put a unique stamp in ICALEO by inviting compelling opening and closing plenary speakers who reside outside the manufacturing realm. Of course, the majority of sessions focused on material handling from the macro to the micro and nanoscales.

> **"THE NANOMANUFACTURING CONFERENCE HAS GROWN THIS YEAR. WE COULD NOT HAVE ACCOMMODATED ALL SUBMITTED ABSTRACTS IN ORAL PRESENTATIONS. SOME EXCITING PRESENTATIONS INCLUDED 3D PRINTING AT MICRO/NANOSCALES, PARALLEL FORMATION OF NANOPATTERNS, AND NOVAL APPROACHES TO SYNTHESIZING NEW NANOMATERIALS."**

(Continued on page 20)

LIA Past President Prof. Reinhart Poprawe *(center)* receives the 2014 Arthur L. Schawlow Award

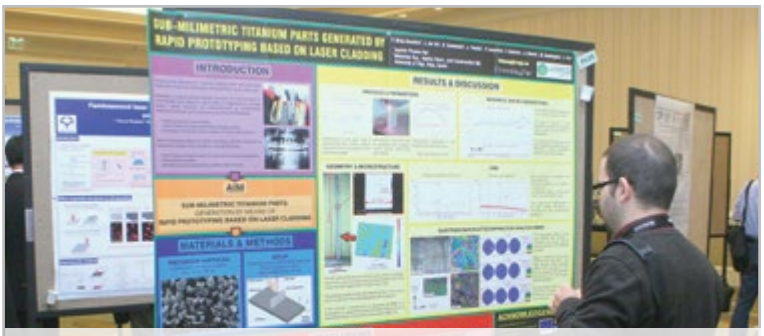
LIA President and Nanomanufacturing Conference Co-Chair Dr. Yongfeng Lu welcomes ICALEO 2014 attendees

Congress General Chair Stefan Kaierle *(left)* with Laser Microprocessing Conference Chair Henrikki Pantsar *(right)*

Laser Materials Processing Conference Chair Silke Pflueger

Beer's Law Band kicks off ICALEO 2014 at the Sunday Welcome Reception

ICALEO 2014 presentations included a new peer review process for the first time



ICALEO Poster Presentation Gallery 2014

(From left to right) **Steve Capp, Reinhart Poprawe, Milan Brandt & Ingo Kelbassa enjoying the ICALEO Welcome Reception**

ICALEO 2014

Networking opportunities included the welcome reception, president's reception, laser industry vendor reception & annual meeting & awards luncheon

In keeping with recent practice, the Nanomanufacturing Conference kicked off with a joint session with the Microprocessing Conference. Opening the session was a presentation on the use of a self-optimizing LCOS-SLM-based beam splitter for high-precision material processing. While average powers of ultrafast/ultrashort pulse (USP) lasers have increased, the paper noted that ablation rates haven't scaled up concurrently "because classic beam-steering concepts like galvo scanners are too slow to deliver the laser energy to the work piece effectively." Therefore, surface qualities have been compromised and thermal damage inflicted. A method detailed in this case used diffractive optics to increase productivity with a higher average power USP laser (50 W) by splitting the input beam into 196 beams for a drilling process in which every hole had a specific geometry. The distance between each beam was about 400 µm, and the size of each hole averaged 30 µm.

From the creation of microscale holes to the study of black holes, ICALEO 2014 deftly took attendees on a rollercoaster ride of laser applications across the spectrum of disciplines.

Opening the proceedings with the first plenary, Karsten Danzmann of the Max Planck Institute for Gravitational Physics opened eyes to the ongoing study of space with lasers. Noting that "all our knowledge about the universe really has come through light," Danzmann updated attendees on the latest in intergalactic photonic exploration. "There's a rule of thumb in laser interferometry: The sensitivity increases or improves by about a factor of 10 every decade," he noted. This has allowed contemporary researchers to "listen in" on colliding galaxies, white dwarfs (dead stars) and black holes. "We now have a large heritage of lasers that are flying," he explained. "Neodymium YAG lasers are flying on many, many missions and will be flying on even more missions," he noted. He also detailed the laser-driven LISA Pathfinder project, scheduled to launch around July.

Coming back to earth, Shaochen Chen of the Institute of Engineering in Medicine in San Diego discussed the nanoscale 3D printing of hydrogels for engineering human tissue. Growing functioning human cells requires supporting scaffolds. "We use ultrafast lasers to control light affecting areas down to 200 or 300 nm," he explained. "Then you can print nanoscale scaffolds," be they multilayer or "other structures like dot arrays with… drugs inside those dots."

In a later presentation, incoming President-Elect Li used a 400 W picosecond laser at 1064 nm wavelength to create silver titanium dioxide antibacterial nanoparticles that tested effective against E. coli. The laser-generated nanoparticles had a positive charge and outperformed "very expensive" commercial, chemically produced silver nanoparticles, which generally possess no charge. Most bacteria have a negative charge, he explained; a laser-generated nanoparticle is "like a missile" that targets bacteria faster and more effectively — and with lower toxicity to endothelial cells than distilled water. He also tested nanosecond lasers, which generated irregular-shaped and smaller nanoparticles that were "much less effective" in antibacterial function. Femtosecond lasers are being studied as well.

Other notable sessions included the opening plenary by Arty Makagon and Maclen Marvit of Intellectual Ventures Lab who are exploring the killing of mosquitoes to curb the spread of malaria in the Third World, and the closing plenary by Leonard Migliore of Laser Kinetics, who detailed novel attempts at laser-driven innovations including the drilling of holes in rice to improve cooking time.

In keeping with making the most use of each venue, ICALEO 2014 afforded attendees plenty of chances to catch up with one another, from the casual Welcome Celebration and elegant President's Reception on the lanai at the Sheraton San Diego Hotel and Marina to the novel Laser Industry Vendor Reception & Tabletop Display at the hotel's spacious outdoor tent. The traditional president's morning run and Business Forum & Panel Discussion offered more opportunities to ask one-on-one questions of peers.

The Final Analysis

Whether one was a first-time attendee, first-time presenter or longtime participants, ICALEO once again opened eyes to the full spectrum of laser possibilities.

"I think the first time I attended ICALEO was 1986 in San Diego," Li recalled. "Lots of new science and technology has been reported at this conference."

Said Frederick Buldhaupt, a Boeing laser processing technician and returning attendee, "It's very informative, and it's a great way to network and meet new faces. It's a wealth of information (and) a very good use of time."

First-time exhibitor ALIO Industries was among the participants in Tuesday night's vendor reception in a large tent just outside the main venue. The company came to ICALEO because "We're doing a lot of laser work in China (and with) research centers, and we need to get more involved in the laser world," said founder and CEO C. William Hennessey. "Some of the sessions are very good (and featured) people we know or are working with at research labs. We're very involved in sapphire cutting, (so that was) my focus coming here."

First-time presenters Isaac Adebiyi of Tshwane University of Technology in Pretoria, South Africa, and Stephen Tate, a graduate research assistant at the Colorado School of Mines, found ICALEO to be a revelation.

"It's been a wonderful time," Adebiyi noted. "I really enjoyed this gathering. I've learned a lot about different fields and applications. At this conference, I've seen that lasers are involved in applications I never thought of." Added Tate, "It was interesting seeing a lot of the international (research) that I don't typically get exposure to." ■

*Online versions of the ICALEO 2014 proceedings are available for $180 ($150 for members) at **www.lia.org/store**. For more information on ICALEO 2015, visit **www.icaleo.org**.*

STUDENT PAPER AWARD WINNERS

1ST PLACE

Ultra-Short Pulse Laser Processing of CFRP with Kilowatt Average Power (Paper 702)
Christian Freitag; Institut für Strahlwerkzeuge IFSW, Stuttgart, Germany

2ND PLACE

Differences in Cutting Efficiency Between CO_2 and Fiber Lasers when Cutting Mild and Stainless Steels (Paper 905)
Jetro Kenneth Pocorni; Luleå Tekniska Universitet, Luleå, Sweden

3RD PLACE

Modeling of Laser Beam and Powder Flow Interaction in Laser Cladding Using Ray-Tracing (Paper 1803)
Wim Devesse; Vrije Universiteit Brussel, Brussels, Belgium

POSTER WINNERS

1ST PLACE

Experimental Analysis of the Influence of Beam Profile on Cladding Layer Formation Phenomena (Poster 118)
Daichi Tanigawa; Graduate School of Engineering, Osaka University, Ibaraki, Japan

2ND PLACE

Improvement of Gas Shielding Effect in Vertical-Position Laser Micro-Welding of Titanium Alloy (Poster 154)
Kento Shirasaya; Okayama University, Okayama, Japan

3RD PLACE

Surface Hardening of Titanium by Laser Surface Alloying Using Polyvinyl Alcohol Film (Poster 103)
Takuto Yamaguchi; Technology Research Institute of Oksaka Prefecture, Oksaka, Japan

Corporate Member Profile

Synrad, Inc.

Synrad, Inc. is a global leader in the manufacturing of CO_2 lasers. With over 200,000 lasers active worldwide, Synrad pursues both quantity and quality in the laser market. Providing benefits for businesses in a wide range of applications, the company's multifaceted approach to laser construction allows for a variety of products and solutions.

Founded in 1984 by CO_2 innovator Peter Laakmann, Synrad has been producing high-quality lasers since the company's inception. Making a mark on the industry with the creation and proliferation of the RF-excited CO_2 laser, Synrad now manufactures products with the company's patented "All Metal" tube technology. Synrad is located in Mukilteo, WA, where there the lasers are designed, assembled, tested and shipped to customers. Additionally, Synrad is a subsidiary of GSI Group, Inc., a large-scale supplier of photonic solutions to original equipment manufacturers with a focus on customer collaboration. Its headquarters are located in Bedford, MA.

Known for CO_2 lasers and applications, Synrad has expanded on the original "All Metal" tube design to accommodate industry needs and emerging markets. The 48-series remains an industry standard, with operating lifetimes above 45,000 hours due to product stability and resilience. The Firestar series includes the Firestar t-series, which makes use of a hybrid-unstable resonator design, as well as the Firestar v-series, which provides high power in a small frame. Each of these are produced with ease-of-integration in mind, allowing for precision cutting, marking, welding and drilling no matter the material or production environment. Other laser options include the Pulstar series, with the new p250 introducing high power laser processing to the latest markets and clients.

In addition to the wide range of lasers and OEM-integrated solutions, Synrad offers numerous marking heads, power meters and laser controllers to facilitate the fullest use of the company's products. Laser accessories such as beam delivery components and Closed Loop Stabilizer kits further enhance the power and operations of lasers in industrial use. With a widespread global presence and a complete catalog of lasers and accessories, Synrad has the capability to both serve industry needs and adapt quickly to the growing demand for laser products.

For more information, visit ***www.synrad.com****.*

Member Innovations

Buffalo Filter Launches PlumePen® Elite Surgical Plume Evacuation Pencil
Pushing the boundaries through design innovation, Buffalo Filter is pleased to announce our next generation surgical plume evacuation pencil, PlumePen® Elite. Featuring a compact, ultra slim, ergonomic design that is significantly smaller (up to 46 percent) than competitive electrosurgical smoke evacuation pencils, PlumePen Elite offers surgeons the comfort and advance feature set they demand.

"PlumePen Elite changes the standard for surgical smoke evacuation pencils," states Joe Lynch, Vice President of Sales and Marketing. "Elite was designed with surgeon input and feedback. The advanced product design features the slimness and comfort surgeons are demanding and delivers a unique set of features unmatched by competitive electrosurgical pencils." For more information, visit **www.buffalofilter.com.**

Underwater Laser Cutting
Underwater construction on offshore wind farms, bridges or locks must presently be done by scuba divers. For maintenance and repair of metal constructions, a number of processes are available, but these are time consuming and difficult on the divers. For this reason, engineers at the Laser Zentrum Hannover e.V. (LZH) and the Leibniz Universität Hannover (LUH) are developing a process for automated, underwater laser cutting.

At the moment, mainly light arc oxygen cutting is being used for underwater cutting. The electrodes are hand-guided. Depending on the material thickness, divers need a workday to cut 20 m in material. For a diving period of five hours this means a cutting speed of only 7 cm per minute. For more information, visit **www.lzh.de.**

WELCOME NEW CORPORATE MEMBERS

Boss Laser, LLC
Sanford, FL

RT Technologies
Dunwoody, GA

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

Members In Motion

Rogowski Named VP, Technical Service
Effective Oct. 1, 2014 James Rogowski was promoted to vice president, technical service of TRUMPF Inc. In this role, Rogowski is responsible for technical services and training for TRUMPF's machine tools installed across the United States. Jim Rogowski reports directly to Peter Hoecklin, president and CEO of TRUMPF Inc.

Rogowski began his TRUMPF career in 1998 as a sheet metal applications engineer. He held various roles in product management before assuming the role of managing director of TRUMPF Canada in 2008. In 2011 he returned to TRUMPF Inc. in Farmington, CT to become director of machine and power tool products. During this time he gained extensive experience in machine development, new product introduction, and market research. For more information, visit **www.trumpf.com.**

US Secretary of Commerce Penny Pritzker Announces GE's Christine Furstoss to Serve on the National Advisory Council on Innovation and Entrepreneurship
US Secretary of Commerce Penny Pritzker has announced that Christine Furstoss, Technical Director for Manufacturing and Materials Technologies at GE Global Research, is one of the 27 individuals who have been selected to serve on the National Advisory Council on Innovation and Entrepreneurship (NACIE). The Council will operate as an independent entity within the Office of Innovation and Entrepreneurship (OIE), which is housed within the US Commerce Department's Economic Development Administration (EDA). NACIE members will advise the Secretary of Commerce on issues related to accelerating innovation, expanding entrepreneurship, and developing a globally competitive workforce.

Christine Furstoss has spent 25 years at GE working in various roles, and she currently leads a team of 450 manufacturing and materials researchers. Based at GE's Global Research Center in Niskayuna, NY, Christine is responsible for working with both R&D leaders at GE's industrial businesses and with strategic partners to set strategy for growth, and to implement critical process and material developments for industry-leading products and manufacturing. Currently, Christine also is leading GE's participation in the new manufacturing innovation institutes announced by President Obama last fall to boost advanced manufacturing in the US. For more information, visit **www.geglobalresearch.com.**

ASC Z136
Safe Use of Lasers
Accredited Standards Committee

Have you ever wondered what a particular clause in an ANSI Z136 standard means?

Occasionally questions arise regarding the intent of a portion of a standard as it relates to a specific application. When the need for an interpretation occurs, the request is channeled through LIA, secretariat to ASC Z136.

Once LIA receives the question, the request is reviewed to determine whether it is for explanation or interpretation. An explanation relates to a simple clarification of a portion of a standard as it is written, e.g., a clarification of a definition. An explanation does not address the implication or intent of a portion of the standard.

On the other hand, a bona-fide interpretation relates directly to the implication or intent of a portion of the standard as it applies to a specific application. It is a unique form of commentary on a standard; it can only discuss, address and clarify what the standard currently says. It is not an explanation of what the standard should have said and it cannot change the meaning of a standard as it currently exists. Even if the request points out an error in the standard, the interpretation cannot fix that error.[1]

A request judged to be an actual interpretation is forwarded to the chair of the appropriate standards or technical subcommittee for processing. Since ANSI Z136 standards represent a consensus of concerned interests, it is important to ensure that any interpretation has also received the concurrence of a balance of interests. For this reason, LIA is not able to provide an instant response to interpretation requests, except in those cases where the matter has previously received formal consideration.

After consensus has been obtained from the associated subcommittee and the question resolved, LIA will provide the formal response to the requestor. In addition, the question with resolution will be made publicly available.

To view responses to previously received clarifications and interpretations visit **www.z136.org** and choose Z136 Interpretations from the main menu. To make a request for interpretation, please contact Barbara Sams at **bsams@lia.org**.

[1]*Revisions to a standard resulting from requests for interpretation shall be processed in accordance with the procedures of ASC Z136 and ANSI.*

Annual Reminder

With the end of 2014 right around the corner, now is the time to remind those who have achieved certification and are nearing the end of the certification maintenance (CM) cycle to submit their CM worksheets for renewal.

After passing an exam, it is to the responsibility of the CLSO® or CMLSO® to maintain his/her certification by demonstrating completion of sufficient professional development activities to ensure continued competency. The CM cycle begins on Jan. 1 of the year following the year in which the exam is passed and ends on Dec. 31 of the third year. During this three-year period, the individual must obtain at least 10 CM points to renew certification.

There are a number of different categories in which to receive CM points:

1. Laser safety experience (i.e. your job)
2. Attendance and successful completion of laser safety specific education/training
3. Publication of laser safety or application related articles
4. Teaching laser safety (outside of your company/organization)
5. Membership in a laser safety-related professional/technical organization or society
   LIA offers a special three-year membership to those who have achieved certification for only $235! This membership rate is only available to CLSOs and CMLSOs.
6. Active participation in a laser safety standards or regulations committee (outside of your company/organization)
   Join ASC Z136 or one of its subcommittees to ensure your voice is heard! Curious how the committees function? Observe a meeting while at ILSC®.
7. Attendance at laser safety or applications professional conferences or meetings
   Attend ILSC 2015 – THE conference for laser safety professionals!
8. Presentations or poster papers at laser safety professional conferences or meetings
9. Writing exam questions (accepted by BLS® Review Board)
10. Related professional certifications; review of approved laser-related journal articles

Lastly, a CLSO or CMLSO may retake the applicable exam if they are unable to achieve the 10 CM points and wishes to maintain active certification status; however, the exam must be taken prior to Dec. 31 (end of cycle).

For a thorough review of certification maintenance including CM categories in detail, please go to www.lasersafety.org/certification-maintenance. To download a CM manual or worksheet, please go to **www.lasersafety.org/forms/certification**. If you have any questions regarding activities for certification maintenance, please contact the BLS at +1.407.985.3810 or email bls@lasersafety.org.

LIA is committed to keeping the workplace safe from hazards associated with lasers. LIA formed an Alliance with the Occupational Safety and Health Administration (OSHA) to help achieve these goals.

OSHA and LIA recognize the value of establishing a collaborative relationship to foster safer and more healthful American workplaces. This Alliance provides LIA's members and others, including small businesses with information, guidance, and access to training resources that will help them protect employees' health and safety, particularly in reducing and preventing exposure to laser beam and non-beam hazards in industrial and medical workplaces. In addition, the organizations will focus on sharing information on laser regulations and standards, bioeffects lasers have on the eyes and skin, laser control measures and laser safety program administration.

Beginning Jan. 1, 2015, there will be a change to what covered employers are required to report to the Occupational Safety and Health Administration. Employers will now be required to report all work-related fatalities within eight hours and all in-patient hospitalizations, amputations, and losses of an eye within 24 hours of finding about the incident.

Previously, employers were required to report all workplace fatalities and when three or more workers were hospitalized in the same incident.

The updated reporting requirements are not simply paperwork but have a life-saving purpose: they will enable employers and workers to prevent future injuries by identifying and eliminating the most serious workplace hazards.

Employers have three options for reporting these severe incidents to OSHA. They can call their nearest area office during normal business hours, call the 24-hour OSHA hotline at 1.800.321.OSHA (1.800.321.6742), or they can report online at **www.osha.gov/report_online**. For more information and resources, including a new YouTube video, visit OSHA's webpage on the updated reporting requirements.

*For more information, visit **www.osha.gov**.*

JLA | Editor's Pick

The Laser Institute of America's official refereed publication, the *Journal of Laser Applications*® *(JLA)*, an online-only journal, is complete with new features for a broader audience. *JLA* is hosted on AIP Publishing's robust Scitation online platform, providing the journal with great functionality and the ability to leverage a wide range of valuable discoverability features. JLA features nine topic sections, a faster peer-review process and a more functional website (**jla.aip.org**) that makes content easier to access and more interactive. Readers will find full-text HTML rendering featuring inline reference links and the ability to enlarge tables and figures by clicking on them. Among the new features are enhanced search functions with more options and better controls to explore returned content in more useful ways.

High Average Power Passively Q-Switched Laser Diode Side-Pumped Green Laser By Using Nd:YAG/Cr4+:YAG/YAG Composite Crystal

By Siqi Zhu, Qing He, Sue Wang, Zhenqiang Chen, Anming Li, Hao Yin and Zhen Li

BY JOONAS PEKKARINEN, ANTTI SALMINEN AND VELI KUJANPÄÄ

A high average power passively Q-switched, laser diode side-pumped green laser at 532 nm was reported by using Nd:YAG/Cr4+:YAG/YAG composite crystal for the first time. The performances of the average power, pulse width, and pulse repetition rate on pump power were measured. Under the pump power of 187.5 W, the Q-switched green laser was obtained with the average power of 27.2 W, pulse width of 210 ns, and the repetition rate of 21.2 kHz. The single-pulse energy was 1.28 mJ and peak power was higher than 6.1 kW.

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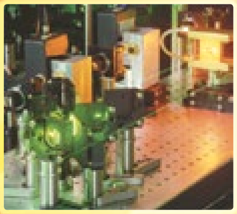

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