



# 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: LASERS FOR MANUFACTURING | VOLUME 20 NO. 2 | MARCH / APRIL 2012

## LME 2012

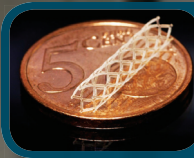
LASERS FOR MANUFACTURING EVENT

### Using Lasers to Improve Manufacturing Competitiveness

pg. 6



Courtesy Fraunhofer Institute for Laser Technology ILT, Aachen, Germany



Ultrafast Lasers in Medical Applications  
- pg. 8



The Future of Manufacturing Presented at LAM 2012  
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## Laser Institute of America

*Laser Applications and Safety*

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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*<sup>®</sup> 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](mailto:lia@lia.org).

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### CALENDAR OF EVENTS

#### Laser Safety Officer Training

June 26-28, 2012	Chicago, IL
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June 11-15, 2012	Boston, MA
Sept. 24-28, 2012	Anaheim, CA
Nov. 5-9, 2012	San Antonio, TX

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#### Medical Laser Safety Officer Training\*

June 9-10, 2012	Boston, MA
Sept. 22-23, 2012	Anaheim, CA

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

#### International Congress on Applications of Lasers & Electro-Optics (ICALEO<sup>®</sup>)

Sept. 23-27, 2012	Anaheim, CA
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#### Laser Welding & Joining Workshop

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

Oct. 23-24, 2012	Schaumburg, IL
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Visit [www.lia.org](http://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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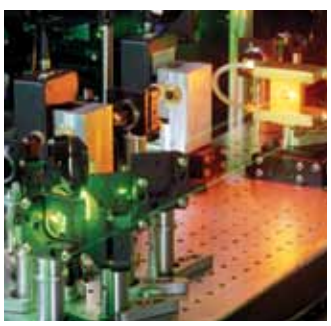
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## PRESIDENT'S MESSAGE



The high power optical technologies enter a new era: The age of DIGITAL PHOTONIC PRODUCTION. The vision of designing products in the computer and directly “printing” the data to real world parts becomes reality. The impacts on the main trends of our high wage society in mobility, health, energy, environment and security are expected significant. New designs and materials combined with high degrees of complexity demand individualized production in series at reduced costs. Very recently, new lasers in new time domains and wavelength

domains with high average powers have been developed for new processes like laser additive manufacturing, laser ablation by ultrafast lasers or laser polishing. Overall, the vision can be summarized “from bits to photons to atoms.” The direct manufacturing processes work without tools or molds and transform the computer-generated product directly to reality. Further advantages are the parallel production of products as well as the independence of cost on complexity of the structure.

One decisive component in this scheme is the perspective of additive manufacturing using lasers, or LAM. This includes selective laser melting (SLM), laser metal deposition (LMD) and controlled deposition of functional layers. LIA’s latest conference on the subject in Houston, LAM, was a great success for all participants and you can read about specific results in this issue and later in LIA’s *Journal of Laser Applications*®.

Typical laser powers employed in additive manufacturing are some hundred watts in the commercial world and KW level in the leading laboratory environment. The buildup rates have been boosted by a factor of 10 in the last five years to values of 20 mm<sup>3</sup>/s corresponding to about 1 cm<sup>3</sup>/s. The data depend slightly on the deposited metal and many alloys have been demonstrated for use in tooling for molds, bio resistive, bio compatible or bio resolvable implants, but also in series production, e.g. for automotive parts in large quantities.

As a next international event coming up, the Aachen Kolloquium Lasertechnology, AKL 2012, in Germany ([www.lasercongress.org](http://www.lasercongress.org)) combines latest laser application technology and industrial innovation. Be there!

LIA and its president wish you a productive and successful time.

Sincerely yours,



Reinhart Poprawe  
President, Laser Institute of America

## EXECUTIVE DIRECTOR'S MESSAGE

I am so pleased that Jim Sears and Bill Shiner encouraged us to launch LIA’s first Laser Additive Manufacturing (LAM) workshop in 2009. LAM has grown every year since then and this year was another big success.

Attendance was a record once again, the Technical Program was solid and the exhibit hall was active.

There is a growing realization that additive manufacturing will ultimately transform the way manufacturing is performed so I am very pleased that we are leading the way in adding to this body of knowledge and raising awareness of its potential.

We will carry this momentum through to our Lasers for Manufacturing Event, October 23-24, 2012 in Schaumburg, IL. This will feature tutorials and seminars on all aspects of lasers for manufacturing, including LAM, and will feature 90 exhibitors of lasers, systems, robotics and related equipment for manufacturing.



Peter Baker, Executive Director  
Laser Institute of America, [pbaker@lia.org](mailto:pbaker@lia.org)



# LME 2012 – USING LASERS TO IMPROVE MANUFACTURING COMPETITIVENESS

By Geoff Giordano

The Laser Institute of America has unveiled an expanded educational track for its second annual Lasers for Manufacturing Event, the highly successful exhibit launched to address a unique and pressing need for the North American industry.

LME 2012 will again provide attendees vital guidance on how to create effective and efficient laser-based production systems to increase profitability in a broad range of applications, predominantly aerospace, automotive and medical.



Four new courses addressing the fundamentals of laser additive manufacturing, cutting, drilling and marking have been added, as well as a pair of two-hour tutorials addressing welding and joining and ultrafast laser processes.

## YOUR SOURCE FOR ANSWERS

LME, being held once again in proximity to thousands of 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 photonics in production. The educational program will emphasize the rudiments of understanding the main types of lasers used for manufacturing, how to justify the investment and even maintaining laser safety.

In addition, the new two-day Laser Welding & Joining Workshop, chaired by Prof. Eckhard Beyer of Fraunhofer IWS, will run concurrently with LME on Oct. 23-24 in Schaumburg, IL. "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 noted. "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."

The Welding & Joining Workshop will feature 18 presentations, spread out to allow ample time for attendees to interact directly with OEMs in the exhibit hall.

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

Some of those applications will include powertrain welding, remote welding, hybrid welding and "micro" applications, he noted. Such applications are being refined constantly as lasers continue to evolve.

"We still see a big impact of the tremendous rise in beam quality and energy efficiency," Beyer says. "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."

## ADDITIONAL EDUCATION OPPORTUNITIES

Although slated as a tutorial this year, the program on ultrafast lasers could grow into another two-day workshop next year. For the inaugural session, LIA President Prof. Reinhart Poprawe of Fraunhofer ILT says the educational track will feature technical examples, a survey of Technology Readiness Levels (TRL) 1-9 materials and an overview of markets and materials. He says the session will be particularly geared to those involved with optical systems and scanning technologies, as well as users of precision machining applications with accuracy in the range of 10 microns and below.

"The development of ultrafast lasers with pulse durations of some 100 femtoseconds to 10 picoseconds on an industrial scale with powers up to the kilowatt class, has led to a new level of laser processing with ultimate processing quality," Prof. Poprawe noted. "Starting with physical basics on ultrashort pulse interaction phenomena, the tutorial will give a survey on different applications from electronics, energy topics and tooling technology to large area processing for tribology optimization and surface functionalization."

The tutorial is particularly suited for engineers and scientists from machine suppliers and end users, Prof. Poprawe said. And "manufacturers of ultrafast lasers and optical systems (scanning technologies) will learn about the requirements on system technology with respect to laser parameters and processing parameters."

LIA is showing once again it is in the forefront of advocating cutting-edge laser technology, as "ultrashort pulsed lasers are heading to the edge of mass industrialization and will undergo similar growth rates like other lasers in the past," Prof. Poprawe asserted.

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.

For more information on LIA's Lasers for Manufacturing Event (LME), visit [www.laserevent.org](http://www.laserevent.org) or call 1.800.34.LASER. ■

*Geoff Giordano is a freelance writer.*



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# LME 2012

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*Ingomar Kelbessa, Fraunhofer ILT*

"It's exceeded my hope. (The) feedback has been, 'Wow, you guys pulled this thing together, and there's people here to buy stuff.'"

*Mark Taggart, President,  
Laser Mechanisms, Inc.  
Novi, MI*

"(At other shows) you get lost between the drill bits and the cutting oil. If you've ever looked at a laser application, this is the right place to come."

*Mike Klos, General Manager of Midwest Operations, IPG Photonics, Novi, MI*

"It's been a very good show for us. People come in for laser questions, unlike when you go to (some other shows)."

*Tracey Ryba, Product Manager, TRUMPF*

"(At other shows), there are 30,000 people walking by your booth; five are interested in lasers, and one actually finds your booth. (At LME) everybody is interested in lasers, they come to you with real processes and real questions."

*Silke Pflueger, Director of Sales and Marketing,  
Laserline, Santa Clara, CA*

"Unbelievable event! It's fantastic to finally see an event of this caliber in the U.S."

*Neil Ball, President,  
Directed Light, Inc.*

"Today I had the opportunity to learn all the basics."

*Octavio Islas,  
Product Engineer,  
Magna/Cosma, Mexico*

"For the first time, it's fantastic. I've already had a lot of opportunities to meet people, talk and set up some business opportunities. I like not only the exhibits but also the ongoing presentations."

*Larry Dossier, C.E.O.,  
Mound Laser & Photonics  
Center, Miamisburg, OH*

"If the show ended now (Tuesday morning), we would have been satisfied." There's never been (anything like that) in this industry. I saw people here that really wanted to exhibit here; a lot of people said, 'We should have been here.'"

*David Meissner,  
Account Manager, Kentek,  
Pittsfield, NH*

"I like the idea of the classes. I'm trying to learn the differences between different types of lasers. I definitely like the presentations."

*Anne Kitchel, Technical Specialist,  
Baxter Healthcare, Round Lake, IL*

"At LME you feel the pulse of the laser industry, see what everybody's doing, what everybody's needs are"

*Roger Burg, senior field sales engineer,  
Aerotech, Pinckney, MI*

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# ULTRAFAST LASERS IN MEDICAL APPLICATIONS

By Eric Mottay

Ultrafast lasers have come a long way since the time they were sophisticated research tools. Today, they are used in a variety of industrial medical environments, in fields as diverse as the semiconductor and display industries, as well as automotive, pharmaceutical and photovoltaics industries. Their unique advantage of being able to interact with matter in an extremely precise way, well known since the early days, have been complemented by tremendous improvements in lasers technology, most notably in terms of simplicity, reliability and size. In parallel, advances in manufacturing processes and quality control ensure consistent and reproducible deliveries in large quantities.

But ultrafast lasers are changing our lives in a growing number of medical applications. Although micromachining has been for a long time identified as an important market for ultrafast lasers, the first domain which has seen wide use of ultrafast lasers is eye surgery and more precisely, refractive surgery. The use of excimer lasers for vision correction (myopia, hypermetropia and astigmatism), was first established in the late '90s with the advent of LASIK (laser assisted in situ keratomyleusis), where a UV laser removes part of the corneal tissue to change the curvature of the cornea and restore perfect vision acuity to the patient. An important part of the procedure is the cutting of a corneal flap, in order to leave intact the living, sensitive external epithelium layer. Traditionally done with a mechanical blade, called a microkeratome, flap cutting is now performed with femtosecond lasers, where the accuracy, safety and absence of thermal interaction, have led to a wide customer acceptance.

## ENTERING THE EYE CARE MARKET

Femtosecond lasers are now poised to enter another large and significant eye surgery procedure, cataract surgery. Cataract is a gradual opacification of the crystalline lens inside the eye, leading to loss of vision and eventually blindness. The current

procedure consists in opening the capsule containing the lens with a scalpel, destroying the lens with ultrasound and placing an artificial lens inside the capsule. Ultrafast lasers are able to perform the capsule cutting (capsulorhexis) with a much higher precision and repeatability than with the manual procedure. The same laser can also cut the crystalline lens and strongly reduce, or in some cases eliminate, the ultrasonic power needed. Several manufacturers have received FDA approval for this procedure and systems are currently being widely deployed.

Active research is being conducted in other different procedures, such as presbyopia or glaucoma treatment, and we can expect further acceptance of ultrafast lasers in hospitals and ophthalmology centers worldwide.

## MAKING MEDICAL DEVICES

In addition to purely therapeutic procedures, ultrafast lasers are touching lives of patients in other indirect ways. Medical devices are high value components requiring sophisticated manufacturing techniques, where precision and quality are of essential importance. Because of the precision available from material processing with ultrashort pulses, ultrafast lasers are used in a growing number of industrial manufacturing processes in the medical industry.

The most important domain today is stent manufacturing. A stent is a small tubular prosthesis, which, when placed into a blocked artery, expands and restores the blood flow to the heart. Stents are small components, with intricate patterns and extremely high requirements in terms of precision and surface quality. Although ultrafast lasers require an initial investment greater than for the simpler lasers used today, they significantly reduce the post-processing costs (deburring, cleaning, electropolishing, etc.) by providing significant improvements in the initial micromachining quality. In addition, they are the only solution for manufacturing a new generation of polymer based, bioresorbables stents, which will dissolve gradually in the body over a period of 18 to 24 months when the artery has fully healed. Because of the sensitivity of polymers to thermal effects, long pulse lasers cannot achieve the required process quality.

In another example, femtosecond laser are replacing traditional methods for the manufacture of intraocular implants, used after cataract surgery to restore the accommodation power in patients. Here again, the implants are sophisticated parts, requiring a precise manufacturing process. The traditional mechanical process exhibits two major drawbacks. The first one comes from the softness of the material, forcing the manufacturer to cool the implant down to -10°C to maintain the necessary hardness for reaching high cutting precisions. The second one is the necessary post-process cleaning step caused by the creation of shavings all



Photo courtesy of Amplitude Systems.

**Stent manufacturing is one of the most important functions of ultrafast lasers.**



around the implant, which could irritate patient eyes. Femtosecond laser micromachining produces very sharp edges, without any heat affected zone, burr or shaving and decreases the total process time by a factor of two.

On a more prospective note, active research is now being conducted in other domains, such as nano-processing, texturing, tissue printing and engineering and even direct intracellular ablation. An active research and industry international community is just starting to explore the world of medical applications of ultrafast lasers. ■

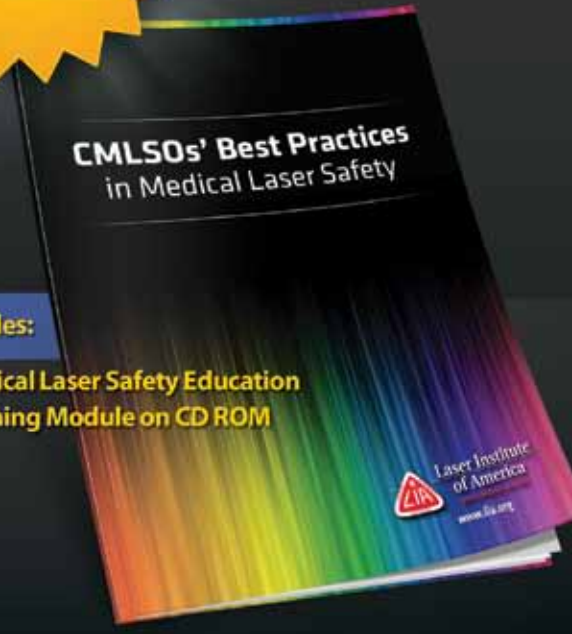
*Eric Mottay is president and CEO of Amplitude Systemes, [www.amplitude-systemes.com](http://www.amplitude-systemes.com).*

**Intraocular implants are sophisticated parts, requiring a precise manufacturing process.**



*Photo courtesy of Physiol.*

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# THE FUTURE OF MANUFACTURING PRESENTED AT LAM 2012

By Geoff Giordano

As additive manufacturing with lasers gains a foothold in a disparate range of industries, it could become known more for what it subtracts: production costs, fuel costs, retooling issues, part weight, lead time between design and finished product and even certification paperwork. All are being dramatically reduced as laser-additive manufacturing grows more prevalent in producing everything from highly customized consumer and



medical products to vital automotive and aviation parts.

The Laser Institute of America, globally renowned laser application and safety advocates since 1968, put LAM technology at the forefront of its fourth-annual Laser Additive Manufacturing (LAM) workshop on Feb. 29-March 1. Held once again in the cradle of the U.S. energy industry, LAM 2012 gave a record crowd of nearly 200 attendees an up-to-the-minute look not only at traditional laser cladding practices, but the cutting-edge future of photonic manufacture.

## SHOWCASING RAPID PRODUCTION

Expert keynote speakers Terry Wohlers and Dr. Ingomar Kelbassa of Fraunhofer ILT held a standing room-only audience rapt during the two-day event as they detailed advances in rapid production using powder bed and freeform methods.

LAM has been responsible for a slew of eyebrow-raising



On left, Keynote I, Terry Wohlers of Wohlers Associates and right, LAM Program Committee Member and Keynote II speaker, Dr. Ingomar Kelbassa of Fraunhofer ILT.

progress, they noted:

- Boeing, which uses the technology for 200 parts in 10 production platforms, can reduce a stack of certification paperwork to two sheets of paper.

- Airbus is gearing up to produce thousands of brackets that connect aircraft galleys and lavatories, saving 50% to 80% of part weight — and \$2.5 million in fuel annually on short-haul flights for every 220 pounds (100 kilograms) eliminated.

- Fraunhofer ILT can make an 80-blade high-pressure compressor BLISK (blade-integrated disk) with high-speed laser metal deposition in under two minutes per blade — 160 minutes total — near net shape. Compare that with conventional five-axis milling, which removes 80% to 90% of material — and takes more than 180 hours.

- So-called “personal” 3D printers — non-industrial units that cost from \$500 to few a thousand dollars — grew from about 66 units sold worldwide in 2007 to nearly 6,000 by 2010.

- Additive manufacturing was estimated to be a \$1.3 billion industry in 2010, with compound annual growth of 24 percent; it likely grew into a \$1.5 billion to \$1.6 billion industry in 2011.

## LAM ADVANCEMENT

Wohlers, who began his consulting firm Wohlers Associates 25 years ago in Fort Collins, CO, quoted progress on many fronts as detailed in his “Wohlers Report 2011,” noting an exceptional amount of LAM activity in Australia and South Africa. He enlightened attendees about small firms like Digital Forming, Shapeways and Materialise that offer a slew of customizable consumer products. He enthused about radical projects from a dramatically redesigned bearing for a clothes dryer to the wing of an ultralight craft created as one piece complete with hinged flap. He even raised the possibility of “printing” electronics or battery materials that conform to product shapes.

“We have a lot of fun in this area because it’s moving so fast,” Wohlers said. “So many new opportunities are developing



The LAM workshop captivates the audience.



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in systems and materials and services.”

Kelbassa summarized the promise of LAM's CAD-based flexibility succinctly: “Complexity for free. Individualization for free.”

“Small parts like fittings made of titanium can be made by the hundreds within an hour,” said Dr. Jim Sears, director of the Additive Manufacturing Laboratory at the South Dakota School of Mines and Technology in Rapid City, and executive director of the Quad City Manufacturing Laboratory. And “legacy parts are a great opportunity. If you look at aerospace manufacturing, 20 years ago we had 20 different aircraft being designed; today we have one — one major military aircraft being designed in this country and a number of commercial aircraft being designed. It's changed the metrics of how you do business.”

A significant component of advancing LAM is not just being the provider of technology, but being a strong guiding partner to help clients capitalize on the potential cost savings.

“It's important to engage your customer,” Sears advised. “Designs made for castings or forgings aren't necessarily the best way to do build-up. If you can get with the design engineers... you can design for minimum weight. You can put holes in stuff; you don't need to put metal where you don't need it.”

Scott Killian, an expert in emerging technologies for EOS North America, noted that in addition to his firm's rapid-prototyping work, “We're really looking at moving our technology into manufacturing, and we're working with a lot of people... that are actually doing manufacturing with our platforms (plastics and metals).” EOS has four customers going to market with titanium

implant products, he said.

“These platforms do have cost advantages; it can be expensive compared to traditional methods, but in a lot of cases people find their designs are difficult to produce or there are long lead times, where as this technology can come in and produce parts in a matter of days,” Killian explained. One EOS aerospace customer had a “very simple box” made of composite that was replaced with a high-temperature PEEK part, slashing the original's 36-week lead time to about a week.

The good news continued as Dr. Richard Grylls, senior additive manufacturing specialist with Optomec, told the packed audience his firm has installed more than 150 LAM systems in more than 12 countries. Those systems do everything from make custom dental implants and pelvic bone-fixation plates, to repair cast-iron impellers, to mold tires. One Optomec customer reports \$1 million a year in savings; others have reduced repair costs up to 30 percent, repair times up to 50 percent and improved part weight ratios by 40 percent.

## COVERING THE BASICS

Of course, LAM 2012 also focused on the latest success stories in the more traditional uses of laser cladding to repair and prevent corrosion and wear. Representatives from “gold” sponsor Joining Technologies, VITO-Flemish Institute for Technological Research NV, Hayden Laser Services, and “bronze” sponsors POM Group and Titanova, detailed their latest work. (To view presentations and video excerpts of speakers from LAM 2012, visit [www.lia.org/conferences/lam/program2012](http://www.lia.org/conferences/lam/program2012).)

Workshops veterans and newcomers alike found plenty to pique their interest.

“I'm basically here to scout out laser-additive manufacturing and see what it's about, see if it's something we may be interested in,” said senior staff engineer Dave Siddle of Kennametal in Latrobe, PA. “We're keeping an eye on this to see if it's something we need to be a part of. All the speakers have been very good; we have the “Wohlers Report,” and it's good to hear what he had to say in person.”

Meanwhile, Dr. Ashish Dasgupta, research and development manager at Focus: Hope in Detroit, MI, has attended all four LAM workshops. “We have several different operations; we have



Platinum Sponsor Alabama Laser



LAM offers many networking opportunities.



Coherent's Keith Parker discussing equipment with an attendee during the Exhibitor Happy Hour.





The exhibitions at LAM were highly informative to the attendees.



new ways to use products, entirely new types of products — and that creates new businesses.”

Ever conscious of crafting a uniquely informative event that evolves with the industry, LIA officials and LAM Program Committee held a session immediately after the program concluded to begin devising improvements for 2013. Visit the LAM website, [www.lia.org/lam](http://www.lia.org/lam), for updates about next year’s workshop. ■

*Geoff Giordano is a freelance writer.*



LAM Program Committee Member and speaker, Jim Sears.



a full-fledged manufacturing floor where we do machining; we also do laser cladding, mainly for government applications,” he said. “We’re applying a modern technology to some old parts that are expensive, and then seeing whether we can squeeze some more life out of them so the government doesn’t have to keep spending a huge amount of money to buy new ones. These things were not there 10 years back. Now the tools are available; how we apply them and get the certifications — these are the current challenges.”

Even Wohlers raved about LAM, attending most of the 24 total sessions. “The presentations were excellent this morning. I had two full pages of notes, and I’m learning quite a lot.”

Stepping back into his role as prognosticator, he sees new and more lucrative opportunities on the horizon “because some of the biggest corporations in the world are making big commitments to this. Government agencies as well are wanting to use this to stimulate product development and new ways to manufacture,



LIA’s Executive Director Peter Baker with Salay Stannard from Joining Technologies, Inc.

## PLASMONIC DEVICES FABRICATED BY FEMTOSECOND LASER NANOWELDING

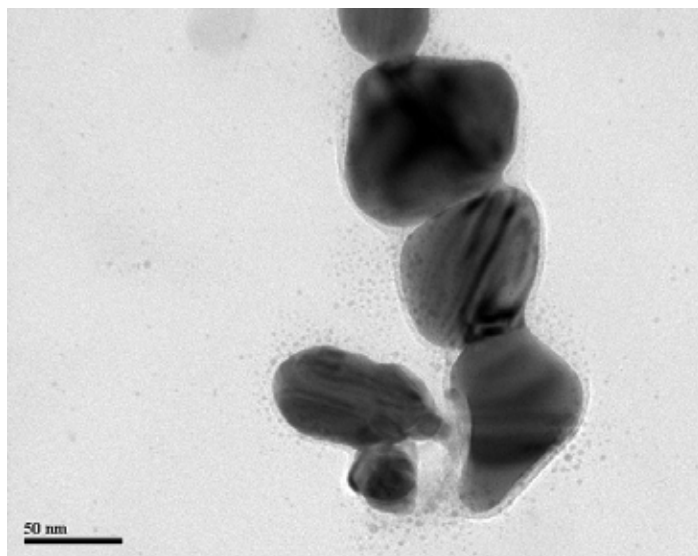
By Anming Hu and Y. Norman Zhou

The interaction of light with metallic nanomaterials has led to a new branch of photonics called plasmonics. It has been found that the external electromagnetic waves can excite the collective electron displacements, known as surface plasmons (SP), density waves of electrons propagate along the conductor surface like ripples that spread across the water surface after you throw a stone into a pond. Plasmonic devices offer the potential to transmit optical signals and electric currents through the same thin metallic circuitry, thereby creating the possibilities to combine electronic and photonic components on the same chip.<sup>1,2</sup> This will bring the revolution in high speed carrying of large scale digital data and optical computing.

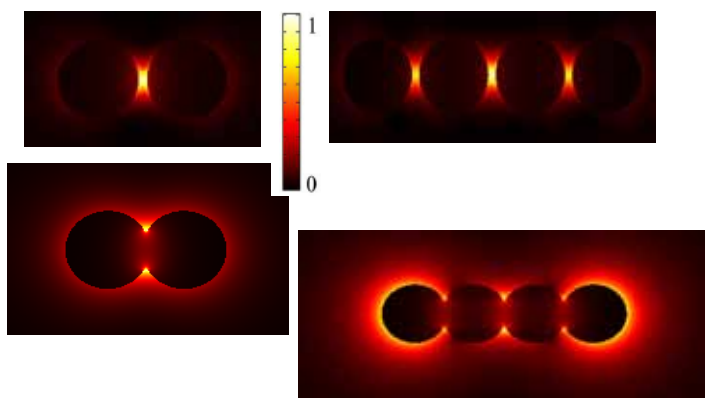
To date the fabrication of such a plasmonic device is technically challenged since the welding at a nanoscale is required for the permanent integration of individual functional components. Femtosecond laser induced non-thermal melting is a promising method to realize a nanowelding without dramatically changing the shape and crystallinity of nanoparticles. One femtosecond is only  $10^{-15}$  second. Nanowelding with ultrashort laser pulses ( $< 10^{-12}$  sec) is distinct from other fusion nanowelding processes because the interaction between ultrafast laser pulses and materials is a non-thermal phenomenon at the surface.<sup>3</sup> As the electron-lattice thermal coupling time (typically several picoseconds,  $1 \text{ ps} = 1000 \text{ fs}$ ) is much longer than the laser pulse width, the electrons do not have enough time to transfer the excitation energy to the lattice. Instead, electrons are excited leading to direct emission. This is accompanied by a reduction in the bond energy between lattice atoms, resulting in “melting” of surface atoms. This melting is non-thermal because it is not due to vigorously thermal vibrations of lattices at an elevated temperature. Furthermore, due to the surface emission the melting is a surface effect. Hence, in this process, melting occurs only on a nanoscale at the surface without damaging the bulk, making it ideal for welding of nanoparticles.

Fig. 1 presents welded Ag nanoparticles with 120 fs laser pulses at an intensity of  $10^{12} \text{ W/cm}^2$ . Four nanoparticles are welded together and form a chain structure. It is obvious that the nanoparticles kept their original shapes and the necks are formed by fusion. This is different from previous laser brazing with a nanosecond laser pulse where Au nanoparticles are totally melted and brazed individual Pt nanoparticles.<sup>4</sup> Certainly the surface melting is beneficial to keep the original function since the surface plasmonic properties can be dramatically changed by shapes. It is important to point out that the irradiation at a higher energy leads to split nanoparticles into tiny particles. This is consistent with widely reported results that laser bombardment results in the further refinement of nanoparticles. Thus, the key to femtosecond laser induced nanowelding is the proper choice of the energy range. It is expected that the proper energy is dependent on materials.

Plasmonic properties of welded Ag nanoparticles have been



**Fig. 1** Welded Ag nanoparticles with 120 femtosecond pulses at an intensity of  $10^{12} \text{ W/cm}^2$ .



**Fig. 2** The cross-sectional views of normalized electric field distributed at the surface of the nanostructures in air.

**Top panels:** adjacent two and four ag spheres with a diameter of 50 nm and a central gap of 5 nm.

**Low panels:** welded two and four ag spheres at the same diameter and an overlapped central distance of 5 nm (i.e., the central gap of -5 nm).

simulated numerically using a 3D finite element method and a Drude-Lorentz model.<sup>5</sup> The complex permittivity of silver was obtained from experimental data. Fig. 2 shows a comparison of the electrical potential distribution between two and four adjacent particles and between welded nanoparticles in air. The diameter of each nanoparticle is 50 nm and the gap is 5 nm for adjacent pairs and -5 nm for welded pairs (corresponding to an overlapping central distance of 5 nm). The results show that



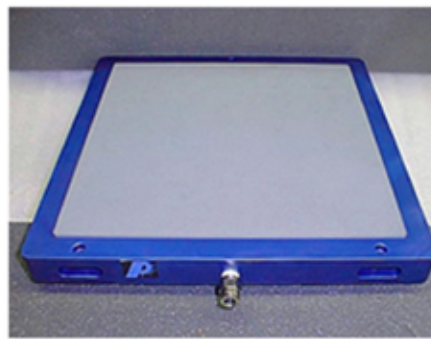
welded nanoparticles possess a ring-shaped hot spot in the neck area compared to a central hot-spot in pairs that are together, but not joined. This clearly indicates that the hot-spot area is enhanced in laser welded pairs. Unlike adjacent dimmers or trimers, which are bonded by a weak van der Waals interaction, welded nanoparticles form strong and permanent joints. These are suitable for use as stable, repeatable Raman probes. ■

*Anming Hu and Y. Norman Zhou are professors with the Centre for Advanced Material Joining, Department of Mechanical and Mechatronics Engineering, University of Waterloo*

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## CORPORATE MEMBER PROFILE

## RPMC LASERS, INC.

LIA Corporate Member RPMC Lasers, Inc., O'Fallon, MO, offers a wide range of lamp/diode pumped lasers, fiber lasers and direct diode lasers. These include femtosecond and picosecond lasers for cold machining and a wide range of nanosecond, microsecond, millisecond and CW lasers for machining, LIBs, seeding, marking, engraving, lidar, medical, military, etc. The company also offers a wide range of laser diode products.

### COMPANY BACKGROUND

Incorporated in 1996 by Dean Micke and Chuck Ratermann, RPMC Lasers, Inc. was started to assist LDX Optronics generate worldwide attention to its high quality laser diode products. This allowed LDX Optronics to concentrate on technical challenges without the diversions of sales calls and marketing endeavors. LDX Optronics has succeeded nicely. With that success, RPMC



realized it could do the same thing for other laser firms, and enjoy an economy of scale while doing it, thus adding value for its primaries as well as for the customers.

In June 2003, RPMC became the North American distributor for LUMERA Laser's picosecond laser products. And, over time, additional laser firms have been added to the list of primaries. Today, RPMC, which consists of eight employees, represents five North American firms, seven European laser firms and one Asian firm.

Owners Micke and Ratermann both have extensive experience in the laser industry and are very proud of the experienced staff they have assembled.

"We are OEM distributors of lasers and laser diodes, including some accessories like heatsinks and diode drivers. We do not offer finished systems. We try hard not to represent firms with competing products. We also differ from most distributor firms because we are not keen to represent many firms. Rather, our goal is to represent a few firms, and do it very effectively," Ratermann explained.

### TODAY'S LINEUP

The first products that began the company were LDX laser diodes from 620 nm to 2  $\mu$ m, and over the years, RPMC's product

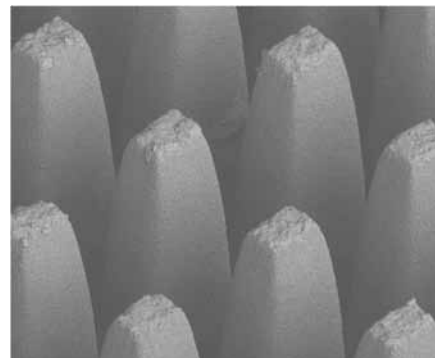
line has changed. "For a long period and continuing for many more years, laser diodes have been strong because they are used in so very many products. They keep improving the output power and the wavelengths available, of course. The picosecond lasers were very strong for some years and still are pretty strong. Fiber lasers have been significant as well," explained Ratermann. The newest technology soon to be available are 193 nm dpss 5 kHz 10 ns lasers.

"We offer a wide range of products at the manufacturers' standard prices. We help our customers find the best technical solution for their needs, and that means that we sometimes send them to another firm, if this is the right answer. We hope the next time they have a requirement, we have the best technical solution," said Ratermann.

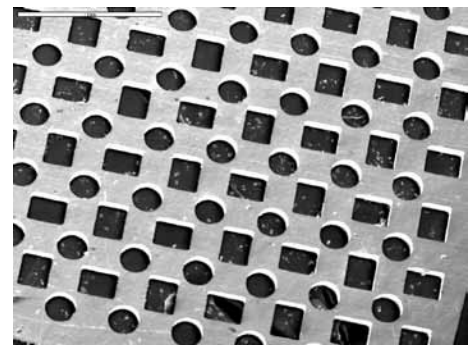
RPMC has been able to adapt with the times. "It is the age of specialists. Our firm offers products at the standard manufacturers' prices. We go to many shows on their behalf. We have economy of scale. We also largely sell in North America. To counter the recession, we have added some lines that give us a broader product offering," he said.

Ratermann sees membership with the LIA as being a great benefit to his company. "LIA provides vital safety training and offers tremendous venues for laser machining networking."

Visit [www.rpmclasers.com](http://www.rpmclasers.com) for more information. ■



**RPMC can help find the right application, such as sapphire pillows, top, and copper mask machined out of a 150  $\mu$ m-thick copper sheet 7W 1064 nm 100 kHz.**





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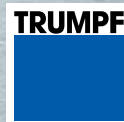
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# ASC Z136 UPDATE

The annual ASC Z136 meeting was held on February 17, at the Holiday Inn Resort Orlando – The Castle in sunny Orlando, FL. Given that this year’s meeting was not in conjunction with the International Laser Safety Conference (off year), attendance was high with 34 members and 12 observers, many of whom are CLSOs or CMLSOs as well as participants of these Z136 activities.

The meeting included the announcement of Ben Edwards as ASC Z136 Secretary (an appointment by the Secretariat LIA that does not require affirmation by the Committee membership), and the appointments of Robert Thomas and Sheldon Zimmerman, Chair and Vice Chair, respectively to the Committee. All previous subcommittee chairs and appeals pool members were reappointed. Standards subcommittee 4 (SSC-4) was brought out of furlough and Jeffrey Pfoutz was appointed chair.

Members approved to the Committee included Major Edward Kelly representing organizational member USAF Surgeon General’s Office, Joshua Hadler as representative for NIST, George Frangineas as representative for Solta Medical, Paul Daniel representing his new company Daniel Laser Safety, and a new individual member to the Committee, David Dewey.

Following the ADCOM’s administrative reporting, nominations for SSC-3 (safe use of lasers in health care) chair were discussed. Prior to the approval (Dec 2011) and publication

(Jan 2012) of the Z136.3 revision, Dr. Joel White had indicated he would be stepping down from the position. Several potential candidates were suggested; further review by the ADCOM is necessary before a recommendation to the Committee can be made.

Each subcommittee chair presented a brief overview of the year’s activities of his/her subcommittee. These presentations are available on the **Z136.org** website. After lunch the group was treated to two special presentations: Area Warning Signage by Bill Ertle for Bill Janssen and the newly developed Bioeffects Database for TSC-1 by Robert Thomas.

New Business included an idea to make a stand-alone document for MPEs (containing examples as well), thoughts on individual versus organizational membership on the Committee and possible collaboration with Photonics Spectra wherein the publication would run a series of articles on laser safety. ■



# ANSI Z136.3

## 2011 SAFE USE OF LASERS IN HEALTH CARE



### REVISED DOCUMENT ADDRESSES:

- New Wavelengths
- Audit Requirements & Procedures
- Management Model for Diverse Use
- Safety Concepts/Personnel Responsibilities
- Lasers for Home Use
- LSO’s Role in Rental Services
- Sample Forms

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# BLS UPDATE

All CLSOs and CMLSOs whose certification maintenance cycle ended December 31, 2011 and have not recertified – **Contact the BLS office today to avoid losing your active status!**

In accordance with the CLSO and CMLSO Policies & Procedures manuals, “it is the responsibility of the CLSO/CMLSO to submit CM forms and recertification fees on time.” Certification Maintenance (CM) worksheets with supporting documentation and recertification fees were due February 1<sup>st</sup>. The consequence of not recertifying by this date is “Inactive Status” – loss of the use of your designation.

To restore status, CM worksheets accompanied with appropriate recertification and late fees will be accepted up to and including May 31<sup>st</sup>. After that time, it will be necessary to retake the exam to become active again.

**Maintenance cycle ending December 2012 or later? Don't put off collecting your CM points until year three!** Maintaining your certification is a vital part of becoming a CLSO or CMLSO. Some categories to consider – membership in laser safety related organizations, and active participation in laser safety standards or regulations committees accrue one point per year. These easily obtainable points are irrelevant after the fact. Remember, attendance at laser safety or applications professional conferences or meetings are worth one point per full day; presentations earn 1/2 point each.

At the BLS, we want you to be successful in maintaining your CLSO/CMLSO active status! We pledge to make every effort to inform you of CM point availability, along with the number of points attributed to future events and opportunities. If you attend a training course or participate in an activity not currently approved for CM points, you may submit the information to the BLS for consideration of points toward certification maintenance. Visit the BLS website at [www.lasersafety.org](http://www.lasersafety.org) for additional information, or contact Barbara Sams at [bsams@lasersafety.org](mailto:bsams@lasersafety.org) or call +1.407.380.5833. ■

This is a large advertisement for BLS certification. It features a blue background with white and yellow text. On the left side, there are three vertical panels for BLS, CLSO, and CMLSO. The main text on the right reads "CERTIFICATION for Laser Safety Officers". Below this is a list of four bullet points: "Get connected with other laser safety professionals", "Gain a competitive edge", "Stay current on changes in the industry", and "Achieve recognition". At the bottom, it provides contact information: "For more information or to obtain a complete information packet. Visit: [www.lasersafety.org](http://www.lasersafety.org) Call: 1.800.34.LASER". There are also several circular inset images: one showing a person in a lab coat, one showing a laser beam, and one showing a close-up of a person's face with a laser beam. The BLS logo is also present in the top left corner of the advertisement.

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# 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](http://www.lia.org/laserinsights) to begin your search.*

## DEVELOPMENT OF AN ADAPTIVE CONTROL & OPTIMIZATION SYSTEM

by Ehsan Fallahi

A real-time, adaptive control and optimization system for laser flame cutting of thick plates of mild steel has been developed. The proposed system consists of two subsystems: a process monitoring system and a control and optimization system.

## LASER-BASED REPAIRING OF TURBINE AIRFOILS AND ITS ECONOMICAL & ENVIRONMENTAL IMPACT

by J. Michael Wilson

Replacement costs for high value engineering components are very high due to long lead times and a special tool required for processing high strength materials. Laser direct deposition provides an attractive and cost effective means for repairing or

remanufacturing high value engineering components. With the emergence of Laser Direct Deposition (LDD) technologies the limitations of traditional repair processes are overcome.

## LEADING TECHNOLOGY FOR THE CUSTOMER'S BENEFIT: LASER PROCESSING HEADS FOR WELDING AND CUTTING

by Markus Kogel-Hollacher

For decades Precitec has been the leading manufacturer of processing heads suitable for all laser sources including fiber lasers, disc lasers, CO<sub>2</sub> lasers, diode lasers, Nd:YAG lasers from powers ranging from the typically used power spectrum up to 30 kW. These are directly applicable to industrial laser materials processing in order to meet the highest criteria for quality in a given application. ■

View complete articles at [www.lia.org/laserinsights](http://www.lia.org/laserinsights) under the Featured Category.

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## JLA UPDATE

The JLA is published four times a year by the LIA 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.



The Laser Institute of America has made its official publication the *Journal of Laser Applications*® (JLA), an online-only journal, complete with new features for a broader audience. JLA is hosted on AIP Publishing's robust Scitation online platform, providing the journal with greater functionality and the ability to leverage a wide range of valuable discoverability features. JLA now features nine topic sections, a faster peer-review process and a more functional website (<http://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.

For non-members of LIA, call the American Institute of Physics at 1.800.344.6902 for subscription information. To receive your JLA table of content e-mail alerts, sign up at [http://lia.aip.org/alerting\\_services/toc\\_alerts](http://lia.aip.org/alerting_services/toc_alerts).

### Research Highlights – Silicon(IV) Phthalocyanine-Loaded-Nanoparticles for Application in Photodynamic Process

by Andreza Ribeiro Simioni, Fernando L. Primo and Antonio Claudio Tedesco

The aim of this study was to evaluate the potential application of biodegradable nanoparticles containing a photosensitizer in photodynamic therapy. The poly (D,L lactic-co-glycolic acid) nanoparticles were studied by steady-state techniques, time-resolved fluorescence and laser flash photolysis. The external morphology of the nanoparticles was established by scanning electron microscopy, and the biological activity was evaluated by in vitro cell culture by 3-(4,5 dimethyl-thiazol-2,5 biphenyl) tetrazolium bromide assay. The particles were spherical in shape exhibiting a 435 nm diameter with a low tendency to aggregate. The phthalocyanine-loaded-nanoparticles maintained their photophysical behavior after encapsulation. The cellular viability was determined, obtaining 70% of cellular death. All the performed physical-chemical, photophysical, and photobiological measurements indicated that the phthalocyanine-loaded-nanoparticles are a promising drug delivery system for photodynamic therapy and photoprocesses.

[View complete articles at jla.aip.org.](http://jla.aip.org)

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# MEMBER INNOVATIONS

## WAND-STYLE PHOTODETECTORS

Newport Corporation, Irvine, CA, has introduced a new family of 818-ST2 and 818-ST2-UV wand detectors. Designed with highly protective aluminum housing, the detectors operate from 200 to 1100 nm. The specifications are identical to Newport's legacy 818-ST and 818-ST-UV Series which will be phased out in four months. Sturdy metal cases for both new products are designed to safeguard the optics in the setup, especially in the UV wavelength range, and keep the housing and attenuator glue protected from potential high heat damage. For more information, visit [www.newport.com/818-ST2](http://www.newport.com/818-ST2).

## OPHIR RELEASES 2012 CATALOG

Ophir Photonics, Logan, UT, has released its 2012 Laser Measurement Catalog. The free catalog covers a wide range of laser power and energy sensors and meters and laser beam profiling systems for medical, industrial, defense, and research applications. The 2012 Catalog is a PDF-formatted reference book of tutorials and product data sheets and covers the entire range of state-of-the-art measurement products available from Ophir, Spiricon and Photon. Products are organized into four categories: laser sensors, power and energy meters, beam profilers and goniometric radiometers. You can download the entire catalog or specific parts. The catalog is available for download at [www.ophiropt.com/photonics](http://www.ophiropt.com/photonics).

## NEW EXCIMER LASER

The new BraggStar M from Coherent, Inc., Santa Clara, CA, delivers high pulse energy and superior spatial coherence for fiber Bragg grating (FBG) writing. High pulse energy is a critical advantage in some FBG writing applications, and high spatial coherence is always beneficial since it enables creation of FBGs with higher contrast and/or longer length. And because it can be operated at repetition rates of up to 100 Hz, the BraggStar M supports high throughput production of FBGs and is ideal for creating FBGs for a broad range of applications. These include reflectors in fiber lasers and reference wavelength stabilization in wavelength division multiplex (WDM) telecom apps, as well as fiber sensing applications.

Coherent has also expanded its OBIS family of plug-and-play smart laser modules with a new fiber-pigtailed (FP) option at several

wavelengths (e.g. 405 nm, 488 nm, 640 nm). Specifically, these OBIS FP lasers are offered with 1 meter of single-mode, polarization preserving fiber, terminating in a standard FC/APC connector, thus simplifying their integration into OEM instruments. For more information, visit [www.coherent.com](http://www.coherent.com).

## IPG ENHANCES PORTFOLIO

IPG Photonics Corporation, Oxford, MA, has added enhancements to the company's optical amplification and transmission portfolio that enable cost effective, non-repeated ultra-long haul communication links in DWDM, electrical power utility, transportation, pipeline and other demanding applications. A new product that IPG is now shipping is the multi-rate transponder with G.709 FEC and a unique digital filtering scheme that extends the optical budget for telemetry links by up to 10 dB. A stand-alone pre-amp and booster chassis has also recently been introduced that supports up to 60 dB optical budget for legacy, third party optical transmission platforms. A 200 mW booster amplifier is paired with a pre-amp with -38 dBm receive sensitivity in a small 1 RU (1.75" or 43.7 mm vertical rack space) package that mounts in a 19" (478 mm) equipment rack. For more information, visit [www.ipgphotonics.com](http://www.ipgphotonics.com). ■

## MEMBERS IN MOTION

### AKL'12 IN MAY

The laser community will be coming together at the 9<sup>th</sup> International Laser Technology Congress AKL'12 from May 9-11, 2012. Catering to the interests of laser manufacturers, users and potential users, AKL'12 will be offering practical examples of innovative industry applications together with the very latest research findings. This year, new focus seminars on topics such as ultrashort pulse laser processing will be added. At the end of the conference, participants will also have the opportunity to witness 70 live demonstrations of laser technology at the Fraunhofer Institute for Laser Technology ILT. For more information or to register, visit [www.lasercongress.org](http://www.lasercongress.org).

### TECHNOLOGY AWARD GIVEN

Fraunhofer Institute for Laser Technology ILT has won the 2012 Innovation Challenge in the category "Power and Propulsion" for its additive manufacturing process of BLISKs from the magazine *Aviation Week*. BLISKs are important components for aircraft engine and turbine construction. Currently, BLISKs are produced with conventional manufacturing processes creating a great loss of material and use of energy and time, and causing very high production costs. Within the Fraunhofer Cluster for Innovation "TurPro" – in cooperation with Rolls-Royce Deutschland Ltd. & Co KG as well as in partnership with the Fraunhofer IPT – Fraunhofer ILT has developed a laser-based process that preserves resources during manufacture and maintenance of BLISKs. Fraunhofer representatives were presented the award in Washington, D.C. in March.

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## REVISED ANSI Z136.3 IS HERE!

The ANSI Z136.3 – *Safe Use of Lasers in Health Care* is recognized as the definitive document on laser safety in all health care environments. It provides guidance for the safe use of lasers for medicine, diagnostic, cosmetic, preventative and therapeutic applications in any location where bodily structure or function is altered or symptoms are relieved. This standard is intended for use by all personnel associated with the installation, operation, calibration and maintenance and service of a health care laser system. A must for hospitals, medical centers, spas, veterinary offices and clinics using lasers!

The Z136.3 revision was driven by the movement of the widespread use of medical lasers. This use of health care laser systems has made it essential to have a current document to guide us in the approach to the safe use of these systems. The ANSI Z136.3 represents many necessary compromises to make it fit the needs of this diverse population of users of these medical laser systems. Visit [www.lia.org/ANSI.3](http://www.lia.org/ANSI.3) to order your copy today.

## ICALEO 2012 – SAVE THE DATE!

The International Congress on Applications of Lasers & Electro-Optics (ICALEO®), which has a 30-year history as the conference where researchers and end-users meet to review the state-of-the-art in laser materials processing, laser microprocessing and nanomanufacturing, as well as predict where the future will lead, will be held Sept. 23-27, 2012 in Anaheim, CA. ICALEO



has been devoted to the field of laser materials processing and is viewed as the premier source of technical information in the field. Each year ICALEO features areas of topical interest. This year's featured sessions include diode lasers for processing and pumping, laser process monitoring and control, laser processing of biological materials, lasers in nanotechnology and environmental technology, laser hybrid processing, laser manufacturing for alternative energy sources and laser business development.

ICALEO offers various level sponsorship opportunities to help create a lasting impression with attendees. Sponsors are acknowledged in a number of ways ranging from onsite signage to visibility on our ICALEO website. Sponsors are also included in the Advance Program and Technical Digest, which is distributed to all attendees. From general refreshments to receptions, ICALEO can highlight your company both online and onsite! Find a sponsorship that best fits your company's strategy and needs. Visit [www.icaleo.org](http://www.icaleo.org) for more information, or contact Jim Naugle at [jnaugle@lia.org](mailto:jnaugle@lia.org), 1.800.34.LASER.

## LASER WELDING & JOINING WORKSHOP IN 2012

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).



**LASER WELDING  
& JOINING  
WORKSHOP**

There are sponsorship opportunities available for companies looking for that special niche market that this workshop represents. For more information, visit [www.lia.org/laserwelding/sponsors](http://www.lia.org/laserwelding/sponsors), or call 1.800.34.LASER. You can choose the level that best matches your company's promotional goals and boosts your brand visibility.

## LME 2012 IN OCTOBER

LME 2012 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 LIA's Lasers for Manufacturing Event (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.



There is still time to sign your company up as an exhibitor or sponsor of this one-of-a-kind event. A variety of levels are available. Visit [www.laserevent.org](http://www.laserevent.org) for more information or contact Jim Naugle at [jnaugle@lia.org](mailto:jnaugle@lia.org), 1.800.34.LASER.

## INTRODUCING CMLSOS' BEST PRACTICES PUBLICATION

The Laser Institute of America has assembled the expert knowledge of leading certified medical laser safety officers in a new book, *CMLSOS' Best Practices in Medical Laser Safety*. The book compiles the latest knowledge about establishing a medical laser safety program, including laser safety regulations, how to control and evaluate such programs and the duties of MLSOs (medical laser safety officers).

The 11-chapter book focuses on topics such as initial MLSO duties and responsibilities, beam and non-beam hazards and factors that determine laser-tissue interaction. The book's contributors also address the importance of safety audits once a laser safety program has been established. Packed with useful figures and tables, the book includes samples of a medical laser safety inspection checklist, a laser inventory sheet, a laser procedure record and laser safety audit forms. This book's publication coincides with the release of the just-revised ANSI Z136.3 standard. Both are available through LIA by visiting [www.lia.org/store](http://www.lia.org/store). ■



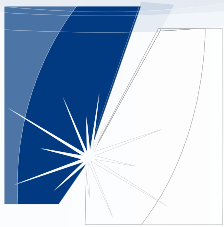
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