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THE OFFICIAL NEWSLETTER OF THE LASER INSTITUTE OF AMERICA

LIA TODAY

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3D PRINTING
OF NET SHAPE GEOMETRIES BY LASER METAL DEPOSITION

LME & SUMMIT 2016
FEATURED GLOBAL OPPORTUNITIES & EMERGING APPLICATIONS FOR LASER MANUFACTURING PROCESSES

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LIA TODAY

THE OFFICIAL NEWSLETTER OF THE LASER INSTITUTE OF AMERICA

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

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

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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

Dec. 6-8, 2016	Orlando, FL

Laser Safety Officer with Hazard Analysis*

Sept. 19-23, 2016	Las Vegas, NV
Oct. 17-21, 2016	San Diego, CA
Nov. 7-11, 2016	New Orleans, LA
Jan. 30 - Feb. 3, 2017	Orlando, FL

*Certified Laser Safety Officer exam offered after the course.

Laser Safety Officer for R&D Training

Oct. 18-20, 2016	San Diego, CA

Industrial Laser Safety Officer Training

Nov. 16-17, 2016	Novi, MI

Medical Laser Safety Officer Training*

Sept. 17-18, 2016	Las Vegas, NV
Oct. 15-16, 2016	San Diego, CA
Nov. 5-6, 2016	New Orleans, LA
Jan. 28-29, 2017	Orlando, FL

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

Industrial Laser Conference

Sept. 13, 2016	Chicago, IL

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

Oct. 16-20, 2016	San Diego, CA

Laser Additive Manufacturing (LAM®) Workshop

Feb. 21-22, 2017	Houston, TX

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President's Message

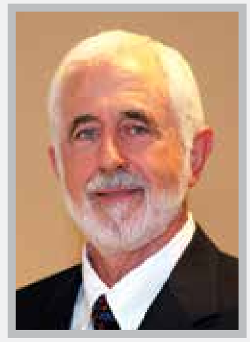
After 28 years of excellent service for the LIA, our Executive Director, Mr. Peter Baker, is to retire on April 1, 2017. With Peter's leadership and LIA staff's effort, the LIA has grown into a leading international association with a high reputation in laser materials processing and laser safety. The LIA conferences and workshops have grown from a single ICALEO® to now include LME®, LAM®, ILSC® and ICALEO. LIA now offers five classroom courses on laser safety and seven online courses. LIA has published nine ANSI laser safety standards and an established journal, the *JLA*. The current annual revenue of LIA has reached around $3 m. On behalf of LIA and the laser community, I would like to say a big "Thank You" to Peter for his leadership, dedication and lifetime contribution to the LIA and the world laser community. My task now is to ensure a smooth transition and recruit a good successor to lead the LIA for the next 10-30 years. A job description for the LIA Executive Director has been prepared and a call for applications will be issued shortly. Members of the laser community are welcome to apply for the post.

I chaired the LIA Executive Committee meeting on June 30 at Orlando in the LIA office, which gave me an opportunity to meet all the LIA staff. I was very pleasantly surprised to see the up-beat atmosphere within LIA offices, and enthusiasm and dedication of all the LIA staff for the services to our laser community. A focus of the discussion at the Executive Committee meeting was on the LIA internationalization plan with new initiatives for collaboration with Asian and European colleagues and partner associations. Education and outreach dominated the near future LIA business/expansion plan. Developing the LIA ANSI online courses into international IEC standard based courses and tailoring them to the local safety directives in Asia and Europe and offering them in local languages would be a way forward. Another opportunity is the development of STEM courses for the local community with substantial government grants.

This *LIA TODAY*'s issue is focused on additive manufacturing – a field that has around 35 percent annual growth rate. Laser based technologies are dominating the metal component printing. Many scientific and technological issues including controlling material properties, residual stresses, thermal distortions, surface finishes and component geometry as well as production rate and costs are still dominating the scientific and technological R&D. New design tools, high volume production machines, hybrid production machines and new applications are expected to boost the innovation and industrial usages of the technology.

Lin Li, President
Laser Institute of America

Executive Director's Message



Transitions II

Earlier this year I wrote about our society's annual transition of leadership, where we elect a new President, Officers and a third of Board Members.

Now we are coming to a more rare transition, one which hasn't taken place for 28 years. I am retiring early next year.

I started with LIA in November 1988, taking over from LIA's original General Manager Haynes Lee. Thanks to the combined efforts of our Presidents, Officers, Board Members, Members and LIA staff, we have added conferences, workshops, standards, publications and courses to our portfolio to carry out our mission to *foster lasers, laser applications and laser safety worldwide*.

Now it is time for me to retire and for LIA to bring in a fresh leader who will build on the base we have established. To adapt to changing times and to build LIA's strength and reach as we approach our 50th Anniversary in 2018.

For me, it will be tough to leave the best job I ever had. It has been a privilege and pleasure to work with each of the LIA Presidents, to admire their achievements, their work ethic and their amazing level of commitment to our society. Our officers and board members are a great resource who have worked with our LIA staff members to build our achievements.

For now let me just say please come to ICALEO® in San Diego so I can thank each of you as I say my farewell.

Peter Baker

Peter Baker, Executive Director
Laser Institute of America

3D PRINTING
Of Net Shape Geometries by Laser Metal Deposition

BY CARL HAUSER

Introduction
An additive manufacturing method developed by TWI within the framework of an EU-funded project could drastically reduce component manufacturing times.

TWI engineers have been using laser metal deposition (LMD) to produce net shape thin-walled engine casings, aiming to reduce the environmental impact of civil aerospace manufacturing.

In LMD, a weld track is formed using metal powder as a filler material which is fed, through a coaxial nozzle, to a melt pool created by a focused high-power laser beam. An inert gas carrier transports and focuses the powder into a small area in the vicinity of the laser beam focus (powder-gas beam focus). By traversing both the nozzle and laser, a new material layer develops with good precision and user-defined properties. The application of multi-layering techniques allows 3D structures to be created directly from a CAD model without the need of additional tooling. Historically, coatings and 3D objects deposited by LMD tend to be considered as near net shape.

The focus of the study was an axis-symmetric cylindrical casing with a maximum diameter of 300 mm, a wall thickness of 0.8 mm and a height of 88 mm (see Figure 1). The component is traditionally manufactured from a nickel alloy (Inconel 718), forming a complex geometrical topography requiring specialist tooling, all of which absorbs significant resource (six months lead time) and generates a large amount of waste material when manufactured.

From Design to Manufacture
Two years of development and six months of demonstration activity, led by the team at TWI's Technology Centre in South Yorkshire, concluded the validation of CAM-style software tools created as a plug in to TWI's ToolCLAD software: a software package being developed at TWI specifically for the LMD CAD-to-part-manufacturing process. The plug in maps a five-axis vector toolpath with deposition parameters to guide a three-axis coaxial LMD nozzle across a moving substrate manipulated by a two-axis CNC rotary table, creating a novel method of LMD manufacturing.

With precise synchronisation of the movements of rotation and tilt of the substrate with incremental movements of the coaxial nozzle (predominantly in the +Z direction), a continuous spiralling weld track can be deposited or 'grown,' layer on layer, from out of the substrate. The helical multi-layering technique allows a thin-walled 3D contour to form, which accurately follows the changing directions of the original CAD surface profile (STL file). The process is analogous to a clay pot forming on a potter's wheel. By allowing the substrate to control movement, rather than traversing the nozzle around a circular path, gives a consistent and regular weld track, and therefore, a good surface finish. Furthermore, the tipping of the substrate to axially align the orientation of the growing wall with the cladding nozzle allows overhanging features to be created without the need to build additional support structures.

A key innovation was the development and use of an adaptive slicing algorithm which automatically varies the numerical slice height (lead distance or pitch) between each helical revolution of the calculated tool path. The magnitude of the change is governed by the orientation of the facet (triangle) normal at the required slice height within the STL CAD model. However,

Figure 1.

during deposition, the actual build height is maintained at a fixed value to ensure a consistent surface quality. Hence, the adaptive slicing approach modulates the number of layers deposited per unit distance of build height which is governed by the tilt angle of the rotary table. Without this feature, printed parts would have a sizing error in the Z direction.

Modelling Heat Effects to Improve Precision

To assist with the experimental investigations the heat effects during LMD processing were replicated by Finite Element Analysis (FEA). With the utilisation of FEA models, the prediction of the shape change of the LMD built casing could be calculated and compared to the target CAD geometry. The results from modelling agreed closely with visual observations, where much of the temperature dependant distortion occurred in the first 15-20 mm of build height. This caused the cylindrical wall to pull inwards. This distortion is linked to the build-up of cylindrical stress distributions during cooling coupled with the thermal shock of depositing the wall onto a substrate held at room temperature. The calculation of the magnitude of the distortion, layer on layer, helped to compensate the wall movement and maintain nozzle alignment on top of the growing wall through appropriate adjustment of the tool path.

Bringing Real-World Benefits

The high integrity of the final part, coupled with the low thermal loading imparted by the process, allowed it to be removed from the substrate with little further distortion. This is evident from the results of geometric 3D scanning. Overall tolerance across the largest diameter was $\pm 250\ \mu$. The wall thickness averaged 0.854 mm with a tolerance of 0.8 mm ± 0.1 mm. The surface finish averaged 15-20 μ RA with the higher values centred on the fillet radii; probably because the powder-gas beam focus was not co-located directly on top of the growing wall during continuous reorientation of the table. This created a subtle stair step effect around a curved feature. It is important to note that a final heat treatment step would be necessary to alleviate residual stress that invariably builds up during LMD manufacture.

The LMD manufacture and subsequent dimensional measurement of a combustion casing prototype confirmed that the software and procedures developed in this study were capable of net shape manufacture. Furthermore, the LMD part was proven to have the same geometrical accuracy as a part produced by conventional manufacturing methods. The only difference was surface roughness, which increased from 0.8-1.6 µm to 15-20 µm in the LMD part; although this was still considered acceptable.

The key to the success of achieving the required geometric accuracy and surface finish was minimising nozzle movement and allowing the substrate to do most of the work. The 7.5 hr build time was a significant reduction over the current six month lead time. However, the LMD productivity rate of 0.1 Kg/hr of deposited powder was considered very low. This can be ascribed to the requirement of wall thickness and surface finish which dictated weld track size and quality. The density of the final part was at least 99.5 percent. The weight of powder material fused in the final part was 750 g and 1.1 Kg of powder was pushed through the nozzle during manufacture, giving a 70 percent material efficiency. Conventional manufacturing routes for the casing (including the manufacture of tooling) generated several 10's Kg of waste material.

The presented work is now being applied to other demonstrator applications across a range of different industrial sectors. This includes procedures to manufacture geometries with thicker walls, the addition of surface deposited features and parts with larger diameters (see Figure 2). ■

Dr. Carl Hauser is a consultant on Additive Manufacturing and 3D Printing for TWI and would like to thank Neil Preece (TWI, UK) and Loucas Papadakis and Andreas Loizou (Frederick University, Cyprus) for assisting in the experimental work and process modelling.

Figure 2.

LME & SUMMIT 2016

Featured Global Opportunities & Emerging Applications for Laser Manufacturing Processes

BY JESSICA DAWKINS

Advanced laser applications in automotive manufacturing, critical updates in additive manufacturing, 3D printing, prototyping and the foremost economic and safety concerns for today's laser professionals were just some of the topics center stage at LIA's fifth Lasers for Manufacturing Event® (LME®) and Summit, held from April 25-27, 2016 at the Renaissance® Atlanta Waverly Hotel and the adjacent Cobb Galleria Centre in Atlanta, GA.

This year's LME attendees were provided with more free educational opportunities than ever before, including key insight to benefit laser professionals of all skill levels and varied specializations. Continuing the annual tradition of equipping event attendees with the most essential "101" courses on every topic from laser manufacturing properties and applications to laser safety, LME also granted visitors the opportunity to sit in on their choice of intermediate, "102" courses, which discussed important and emerging topics such as laser welding, micro-machining, beam delivery and state-of-the-art laser marking. LIA also provided exclusive tutorials, including *Process Monitoring: Seeing the Unseeable* by Paul Webster of Laser Depth Dynamics, and an informative class on *Laser Additive Manufacturing* by Alabama Laser's Wayne Penn.

Once again, the Laser Technology Showcase proved to be the main highlight for 2016 LME attendees. Side by side with the educational courses at the event were four keynote presentations, including the kickoff *Industrial Laser Market Overview*, by Editor-in-Chief of *Industrial Laser Solutions* and LIA Past President David Belforte, and three additional speeches, *Laser Applications in Automotive Manufacturing* by Ralf Kimmel of TRUMPF Laser-und Systemtechnik GmbH, and *Laser Technology*, *Metal Additive Manufacturing* by EWI's Shawn Kelly and *Industrial Applications of Laser Materials Processing in GE* by Marshall Jones of GE Global Research.

The engaging set of 30-minute keynote addresses shared the advantages of utilizing laser technology with attendees.

"It was a great show to get a snapshot of the current laser technology market all in one place," said Charles Studiner, Process Development Engineer at 3M.

Participants who needed a quick answer about what types of lasers would be the best fit for a particular application, or what components were needed to build the most efficient production system, received answers at the perennial favorite "Ask the Experts" booth. Chaired by Neil Ball of Directed Light Inc., and joined by a rotating cast of industry experts, the booth included insight from the top laser markers and system integrators in the business.

Attendees were also able to find solutions to their current manufacturing needs in a wealth of industries, such as Optics, Automotive, Medical, Electronics and Energy – and chat with everyone from company owners to product managers to manufacturing engineers. This continued LIA's five-year tradition of spotlighting the latest developments in laser technology and providing the best place to work with the industry's elite.

As second time attendee Jefferson Odhner of Odhner Holographics said, "I'm here to explore how lasers are used in metal processing, and I am amazed of how much it has evolved. I have to keep abreast to what this industry is doing. This is the place."

The 2016 Lasers for Manufacturing Summit – Back & Better Than Ever

The event as a whole began on April 25 at the Lasers for Manufacturing Summit, back for its second year – by popular demand – to provide laser executives and the C-suite with a chance to touch on global opportunities for laser processes, provide vital statistics on both established and emerging markets, and to engage a spirited panel discussion and question and answer period to provide the kind of insider perspective attendees can't find anywhere else.

Top executives heard first-hand, expert intelligence on how to use these powerful tools most profitably in a variety of high-value manufacturing applications.

The Summit is particularly popular for executives, because it is the only event that focuses on the entire lasers in manufacturing marketplace in one afternoon. This year, it provided a comprehensive market perspective unobtainable elsewhere, with data segmented by applications and laser technology from the laser industry's leading resources. In addition, industry experts presented their views and analysis of laser-market trends, applications development and a business outlook.

David Belforte began the Summit program with a keynote presentation that offered important insights into the global laser and laser additive manufacturing market, as well as a look into the state of the additive manufacturing industry as a whole. Five additional presentations covered pivotal applications used in the industry, including evolutions and applications of engineered welded blanks, laser materials processing, and its new tools, laser welding, laser cleaning, laser removal and the Laser Seam Stepper, a new fiber laser welding tool.

Toward the Summit's conclusion, panelists engaged in a Laser Manufacturing Forum, also moderated by Mr. Belforte. The participants included Jim Evangelista from Shiloh Industries, Tim Morris of Blackbird Robotics, Inc., Dennis Nadeau of Wayne Trail, and Gene White of Laser Flex. To conclude the packed event, a VIP Reception was held from 5-6:30 PM to allow attendees to meet with high-level executives, speakers and LIA board members in an intimate setting.

Following the Summit from April 26-27, the two-day Lasers for Manufacturing Event at the Cobb Galleria Centre housed dozens of exhibitors, like American Photonics, HAAS Laser Technologies Inc., Pantron Automation Inc., Lumentum and Prima Power. Manufacturing professionals also benefited from the presence and guidance of media, cooperating societies and industry partners like Georgia Manufacturing Alliance, *Industrial Laser Solutions* and *Prototype Today*.

The guidance offered at the Summit, in the LME technology showcase, during the educational sessions, and on the exhibit floor allowed attendees to not only obtain crucial information on incorporating lasers into their production, but critical assistance in getting started with instant access to top suppliers.

"This year's event was an excellent summary of laser machining companies and technology," said Jefferson Odhner, President of Odhner Holographics.

"THIS YEAR'S EVENT WAS AN EXCELLENT SUMMARY OF LASER MACHINING COMPANIES AND TECHNOLOGY."

New in 2016 – The Laser Technology Tour

One of LME's newest 2016 offerings was the Laser Technology Tour – an intelligible way for first-year attendees to explore the massive event. Tour attendees were able to take advantage of the personal guidance of seasoned event experts, who walked them through the exhibit floor and introduced them to different companies, all while discussing the latest technology and products showcased.

LME's 2016 installation was exciting, inspiring and informative – and the next LME and Lasers for Manufacturing Summit will continue to be the foremost gathering place for the latest developments and insights for lasers in the manufacturing industry.

To sum up how 2016 attendees felt about this year's conference in Atlanta, first time attendee Ramiro Mendoza from Brake Parts Inc. LLC said this, "I came to see the latest technology to help my manufacturing production. I saw everything I needed to know!" ■

Follow updates for the upcoming LME and Lasers for Manufacturing Summit at **www.laserevent.org**.

(Images continued on page 10)

LIA EXECUTIVE DIRECTOR PETER BAKER WELCOMED ATTENDEES TO THE SECOND LASERS FOR MANUFACTURING SUMMIT

INDUSTRIAL LASER SOLUTIONS' EDITOR-IN-CHIEF DAVID BELFORTE LAUNCHED LME SHOWCASE THEATER WITH HIS MUCH ANTICIPATED KEYNOTE ADDRESS ON THE INDUSTRIAL LASER MARKET

THE LASER MANUFACTURING FORUM PANALISTS INCLUDED DENNIS NADEAU, GENE WHITE, TIM MORRIS & JIM EVANGELISTA

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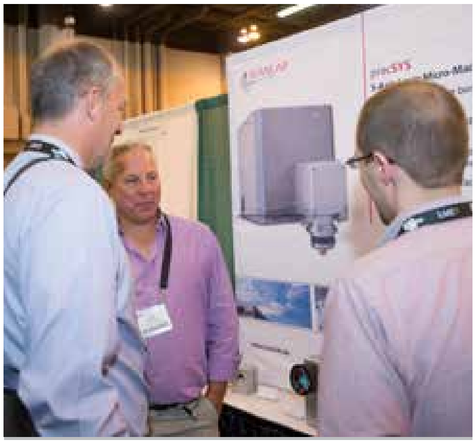
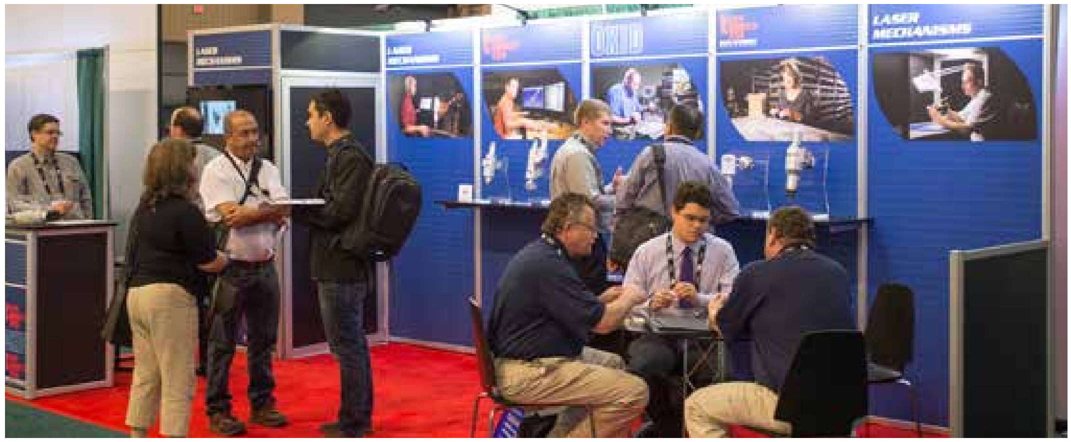
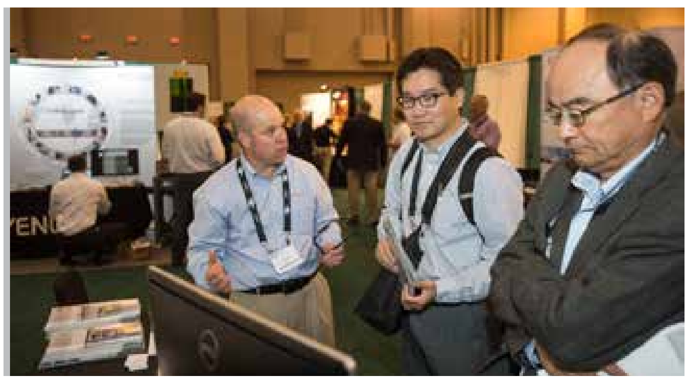
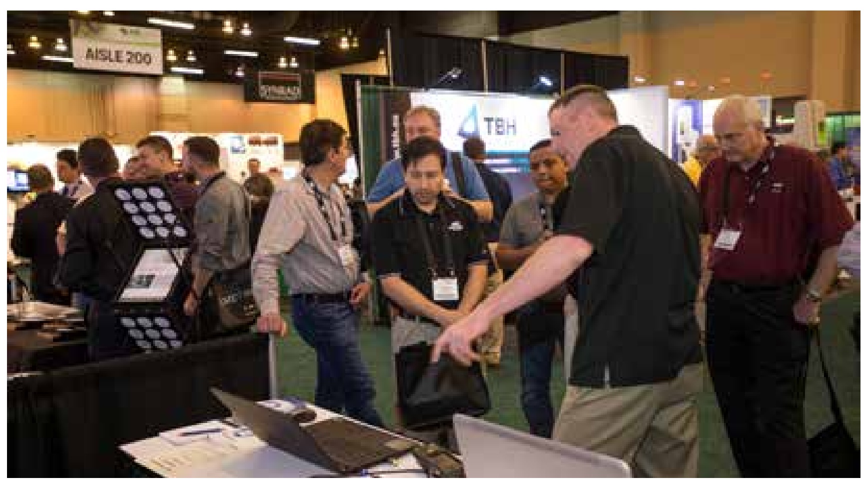


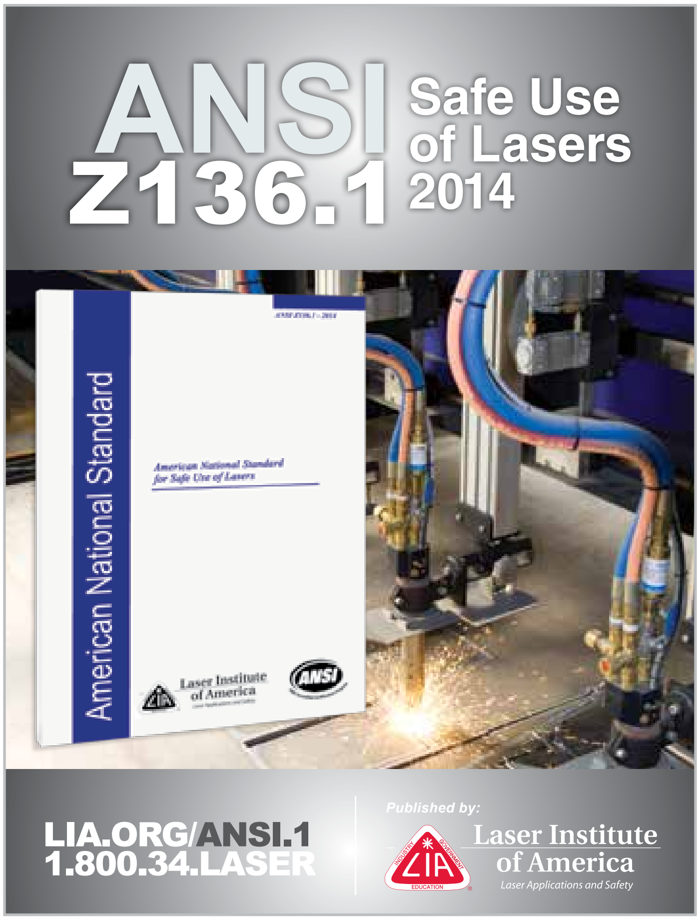


LME 2016 Exhibit Floor

Provided access to top suppliers assisting attendees on incorporating lasers into their production



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REGISTRATION OPEN

For LIA's Inaugural Industrial Laser Conference

INDUSTRIAL LASER CONFERENCE 2016

BY JESSICA DAWKINS

Registration is open for the Laser Institute of America's inaugural Industrial Laser Conference, to be held at IMTS 2016 on September 13, at the renowned McCormick Place in Chicago. Designed exclusively for the industrial manufacturing professional, the conference will showcase laser applications that are driving the evolution of manufacturing. From manufacturing directors to automation engineers to production specialists, every member of the industrial manufacturing workforce can benefit from attending this conference, learning over the course of a full day how to leverage lasers into their manufacturing processes in a high-tech, high-demand market.

From additive manufacturing to cutting, welding and marking, this content-packed event applies to every industrial manufacturer seeking a future-forward increase in skills, company profits and efficiency. As Industrial Laser Conference Program Chair Elizabeth Kautzmann of FANUC America Corporation explains, these innovative techniques are emerging and revolutionizing the industry to meet market demands, all rooted in the field's collective understanding of conventional machining.

"Just as significant as discussions about technology, are the means by which legacy manufacturers can incorporate and powerfully exploit the versatility of the technology," Kautzmann said. "We can now migrate conventional subtractive processes into realms where newer approaches, which combine innovative and fresh perspectives based on solid manufacturing building blocks, are already in place."

Inherent to laser technology is the means by which the process of applying laser types and techniques fosters innovation and creativity. Creation and innovation is a natural tendency in laser technology, Kautzmann points out, which is one of the most exciting parts about the future of industrial manufacturing – and one of the overarching themes of this year's conference.

As a Laser/Fabrication Program Manager, Kautzmann promotes and encourages developments in engineering features to advance discussions and applications in laser innovations. Over the course of nearly 30 years, Kautzmann's career has been one in championing the case for laser technology penetration in conventional and emerging markets. The Industrial Laser Conference is the best way, she believes, to continue her mission and inspire the future of the manufacturing workforce.

> "JUST AS SIGNIFICANT AS DISCUSSIONS ABOUT TECHNOLOGY, ARE THE MEANS BY WHICH LEGACY MANUFACTURERS CAN INCORPORATE AND POWERFULLY EXPLOIT THE VERSATILITY OF THE TECHNOLOGY."

"The ensemble of talent at this year's conference reveals a group of individuals pulled together for the sake of meeting manufacturing's greatest challenges, with technology's most diverse tool, the laser. Each of the presenters, as well as the prospective attendees, represent a collection of know-how, which is the very legacy that lasers intend to fortify during this age of innovative, manufacturing evolution."

From advancements in technology, expected challenges, and Kautzmann's favorite topic, Trends in the Trenches, Kautzmann expects the LIA Industrial Laser Conference to breathe new life into the present and future of industrial manufacturing.

"FANUC's founder, Dr. Inaba, once said, 'technology has a history, but engineers have no past. They only need to create.' I think that quote sums up the purpose of the new Industrial Laser Conference perfectly."

Registration to the 2016 Industrial Laser Conference includes access to the IMTS exhibit floor for all six days. For more information and to register, visit **www.lia.org/conferences/laser-conference.** ■

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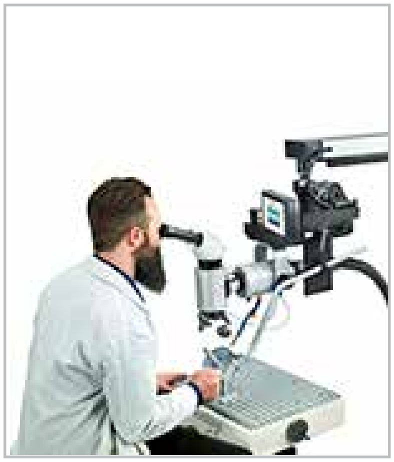

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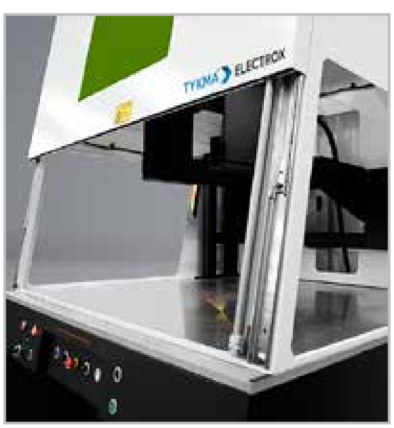
Our foldable laser safety panels were created with versatility in mind. Featuring 360° hinges that turn in any direction to protect the most unique laser environments, they remain flexible to move between laser applications. The M5P06 barrier material, has the maximum irradiance level of 1000 W/cm^2 for 100 seconds. Made to withstand direct and diffusely scattered laser light generated by Class 3B or Class 4 lasers as specified with ANSI Z136.1 – Section 4.4.2.5. Please visit us at **www.lasersafety.com** or call us at 1.888.496.7128 to talk to one of our Certified Laser Safety Officers.

plasmoeye Action Camera for Industrial Production Processes | *www.plasmo-us.com*

plasmo**eye** is used to monitor and support the analysis of weld process errors so that production processes can continually improve. Video images are used for process development by detecting the error root cause (less focus, splashes, weld pool too big, etc.). Up to six different camera types are available to observe different process sections and the process in detail. All cameras run simultaneously; traceability function by video; clear visualization of the process combined with performance results; can enhance defect analysis by combining with plasmo profileobserver and processobserver systems; stand-alone system is also possible



Large Laser Marking Field System | *www.permanentmarking.com*

TYKMA Electrox announces a new, transformative technology for marking large components, trays of parts and graphics without complex motion stages or axis movements. The large marking field system provides a continuous marking field up to 24" x 24" (600 mm x 600 mm) while maintaining a small beam diameter with high energy output. This technology excels over traditional XY stage systems that require more complex programming and higher cycle times, due to indexing movements of the XY stage. With our large marking field technology, expansive graphics can be processed in one cycle without any tiling or stitching, and large trays or fixtures of parts can be marked in minimal cycle time. This system is ideal for a variety of industries and applications, including deep engraving of firearms, annealing of medical components, color change marking on plastics and more. See it in action at IMTS 2016, Booth N-6276.

LOW-COST ROBOTIC AM
For Large-Scale Parts

BY RAYMOND WALKER & BRYANT WALKER

Expanding directed-energy additive manufacturing into very large parts based on a low-cost platform has been a thrust of Keystone Synergistic Enterprises, Inc. for the past decade. Keystone has successfully produced directed-energy additive manufacturing (AM) parts using a robotic pulsed arc platform enhanced by a suite of integrated process controls that provides a level of uniformity needed for a qualified additive manufacturing capability. To expand beyond laser powder, laser wire feed and electron beam (EB) wire feed AM processes, Keystone has established a very low-cost AM capability using the robotic arc-based process capable of making very large parts. Figure 1 shows the Keystone Robotic AM work cell for large-scale parts.

Figure 1. Keystone Robotic AM work cell

In the late 1990s and early 2000s, additive manufacturing was being seriously considered for a limited number of F35 airframe components, but that small market of parts was far from being a sustaining business case for a supplier base in additive manufacturing. While numerous airframe and gas turbine engine makers were investigating additive manufacturing, only part demonstrations, test parts and the production of test blocks of AM material were produced, representing a very limited volume of AM parts.

Keystone participated in numerous detailed cost-benefit analyses with the OEM companies, reviewing part after part for suitability for AM processes and looking for compelling cost reductions that would be the foundation for a strong business case. Given the high cost of powder metal and welding wire, the high capital cost of electron-beam or laser AM equipment, few good examples of cost reduction were identified that would inspire an OEM to substitute AM processes for castings or forgings.

In that timeframe, it was becoming obvious that the effort to qualify additive manufactured parts for use in flight-critical airframe and engine applications was becoming a significant roadblock. This constraint coupled with the difficulty to identify pervasive cost reductions by substituting additive manufacturing for existing manufactured components, proved that directed-energy AM processes would struggle to be a sustainable business.

Keystone's strategy was to expand the range and market of parts that could be made using directed-energy additive manufacturing, focusing more on non-critical parts, tooling and the reconstructive repair of non-critical components. This greater market segment would, however, require a significant reduction in the per-pound cost of AM deposited metal. A cost breakdown of an AM process reveals that the primary drivers are the cost of raw material, the cost of capital equipment, and the machine and labor-based cost of time in the equipment. These factors drove to a simple set of conclusions that defined the path forward for additive manufacturing to establish a foothold in the broader manufacturing industry beyond just aerospace.

Low-Cost Raw Material

Welding wire is always a lower cost than powder metal and the cost for handling and management of the raw material stream is lower. There are far more alloys available as welding wire compared to powder metal. This raw material stream is highly mature, broadly distributed and is lower in cost.

Low-Cost Equipment for Large Parts

Electron–beam and laser AM processes require expensive equipment driven by the high cost of delivered and focused energy from an EB gun or laser. This represents a significant cost compared to an energy source such as an electrical arc delivery. A robotic platform capable of 6 or 7 degrees of freedom of motion in a very large work space is a very low cost alternative to a gantry-based CNC system supplying motion in an equivalent work space. A highly capable robotic welding platform can be acquired for $100 K to $200 K compared to millions of dollars for EB and laser systems. This led to the utilization of a robotic gas metal arc welding (GMAW) system as a robust, mature starting platform for a low-cost AM process using traditional weld wire as the principle material delivery system. Robotic welding systems are a very mature capability and represent a highly supported industry. The primary challenges with robotic AM processes are the lack of integrated process controls and the difficulty of programming for complex parts.

High-Rate Throughput & Deposition Rates

The up-time of robotic welding processes is very high, and the deposition rate for most alloys ranges from 7 lbs/hr to 25 lbs/hr. One operator can easily operate two to three robotic systems representing a low labor content.

However, one does not just take a robotic welder and become a qualified source for additive manufacturing processes. There are several other considerations required to make a capable AM system. Most significantly, closed-loop process controls need to be added to the robotic platform to build in a level of reproducibility and process consistency to provide confidence the material will be uniform. AM processes must be consistent, of predictable quality, be homogeneous throughout the AM build, consistently achieve minimum mechanical properties, and be equivalent from part-to-part, machine-to-machine and supplier-to-supplier. There are thousands of robotic welding systems throughout the country that could be placed into service performing AM processes, however without process controls, process specifications and procedures, qualification standards and certified mechanical property data bases, the output from these equipment platforms would be inconsistent, variable and lack reliability. The potential industry would falter and have strong negative perceptions.

The key elements needed for AM capability are process controls, written guidelines and specifications, and a solid path to qualification. Keystone is actively addressing these enhancements to make robotic pulsed-arc AM a qualified mainstream process.

The primary process controls that are needed to transform a typical industrial robotic welder to an AM capability are:

- Control of build height
- Control and management of part temperature during an AM build
- Monitoring the features of the melt pool during AM processing

Keystone has developed an integrated suite of sensors and control software that can be added to a welding robotic system and communicate with the robot's controller through analog and digital I/O ports. Figure 2 shows the Keystone lightweight integrated sensor head mounted on the robot end arm to provide closed-loop build height control, closed-loop thermal management and control, and melt pool size and feature measurement and monitoring.

Figure 2. Keystone lightweight integrated sensor head mounted onto a robotic end arm

Using these controls, Keystone has successfully produced a significant range of AM parts in many important alloys including titanium, aluminum, steel, iron-based alloys, nickel superalloys, cobalt alloys, and copper-nickel alloys. Parts and tools with over 550 lbs of deposited material have been produced at Keystone for production applications. Figure 3 shows several examples of AM parts produced by Keystone using robotic pulsed-arc methods. This capability, combined with a focus on very low cost and non-critical hardware, has enabled Keystone to expand the range of parts and tooling appropriate for AM processing, critical for the directed-energy AM market.

Keystone has generated AM source and process qualification guidelines for the robotic pulsed-arc process and facilities and is currently developing certified B-Basis allowable mechanical

(Continued on page 18)

Figure 3. AM parts produced by Keystone using robotic pulsed arc methods

property data for titanium and stainless steel alloys in support of US Navy projects. Along with process controls, these guidelines and certified properties databases provide the foundation for qualification against the criteria for both non-critical and critical hardware.

Keystone continues to mature and expand the capabilities of add-on process controls for robotic AM platforms, working to have a package that can transform an industrial welding robot to a viable AM machine and process. Expanding large-part AM manufacturing into many industry sectors will be a critical aspect of building a robust manufacturing supply base and enabling directed-energy AM processes to get a foothold as a viable approach for producing large-scale metal parts.

Keystone has installed a second robotic AM system at its Port St. Lucie, FL facility to keep up with the expanding demand for low-cost large-scale additive manufacturing for aerospace and industrial applications. We invite you to visit Keystone at **www.keystonehq.com** and consider potential applications for this emerging addition to the traditional directed-energy AM processes. ■

Bryant Walker and Raymond Walker are President and Vice President of Keystone Synergistic Enterprises, Inc.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EWI
A Tradition of Manufacturing Innovation

EWI®
We Manufacture Innovation

BY BETSY MARONE

As the premier engineering and technology organization in North America, EWI is dedicated to developing, testing and implementing advanced manufacturing technologies for a variety of industries. The 501(C)3, not-for-profit, organization provides applied research, manufacturing support and strategic services to industry leaders in the fields of aerospace, automotive, electronics, medical and more. With an extensive knowledge base in materials joining, forming, testing and modeling, the organization works with progressive manufacturers to create product design, fabrication and production solutions that prove practical, efficient and effective.

Incorporated as the Edison Welding Institute in 1984, when the industrial Midwest was at the lowest point in its economic downturn, EWI was one of the first centers funded through the state-initiated Ohio Edison Program. Additional support came from Ohio State University and Battelle. EWI's founding mission was to create new businesses and revitalize existing businesses by enhancing productivity and economic growth through applied R&D and the transfer of advanced welding and allied technologies.

At the time of its inception, EWI's contract research services centered on applied manufacturing R&D and educational services in materials welding and joining. Over the last 32 years EWI has grown; now providing contract research services that cover a wider range of technologies, including laser materials processing capabilities. The majority of EWI's contract research is completed as single-sponsor industry projects, with the results of that work remaining confidential to the individual sponsor. Though EWI's services and products are available to customers on a per-project basis, the organization also offers membership opportunities. With this option, companies receive direct access to EWI's technical staff, facilities and library research services – all of which helps them solve difficult problems quickly and, as a result, compete effectively in the global marketplace.

Today, EWI has more than 160 associates. The organization operates two laboratories – one in Columbus, OH and one in Buffalo, NY – with a third opening in Loveland, CO in Fall 2016. Additional extension offices are based in California, metro DC and Florida. Throughout these locations, the organization maintains numerous technology groups and testing services staffed with expert engineers and technicians. EWI's unique combination of engineering expertise and testing capabilities has led to its recognition as the leading organization for companies looking to validate their R&D, products, and manufacturing processes. The knowledgeable team members who make up EWI's technology groups – focusing on technology areas ranging from arc welding and additive manufacturing to microjoining, forming and beyond – help manufacturers innovate solutions to industry challenges.

As throughout its history, EWI has seen growth in all sectors of its work over the last five years. Most of this recent growth has taken place in the aerospace, automotive and electronic and medical device sectors. EWI's success stems from its ability to work as an independent, vendor-neutral technology innovator, which allows for its quick and effective response to industry needs. EWI has proven this repeatedly by offering novel options and solutions to manufacturers in all sectors, constantly remaining vigilant of, and responding to, a number of changes across industries. Despite industry differences, the common theme among changes has remained, providing premium, game-changing solutions that help manufacturers stay successful and competitive. EWI continues to answer this need, by developing a range of new applications from auto and aircraft engines to micro-electronics and oil pipelines.

A member of Laser Institute of America (LIA) since 1996, EWI feels that LIA is integral to building connections between the individuals, companies and organizations that make up the laser industry. ■

For more information, visit **www.ewi.org**.

WELCOME NEW CORPORATE MEMBER

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

Member Innovations

Modular Prototype Production with Lasers Enables Faster Gas Turbine Development

The long lead time of turbine blades and vanes presents a big challenge to the validation of new part designs in engine tests. Conventional vane production through casting is unsuited for the fast iteration cycles required today in the development of hot path components. In a joint project, Siemens and the Fraunhofer Institute for Laser Technology ILT have now developed a faster production process based on selective laser melting (SLM). Components are manufactured in a modular way in the new process chain, resulting in additional benefits.

Last year, Siemens commissioned its Clean Energy Center, a new combustion test center in Ludwigsfelde near Berlin. The center plays a major role in developing and refining gas turbines as a facility for conducting realistic tests on various turbine components with liquid or gaseous fuels. Rigorously optimizing the combustion processes involved is the key to achieving greater energy efficiency in the turbines.

For more information, visit **www.ilt.fraunhofer.de/en**.

Sigma Laser Stent & Tube Cutter more Practical & Efficient

Amada Miyachi America Inc., a leading manufacturer of laser welding, marking, cutting and micro machining equipment and systems, announces a comprehensive system wide upgrade to its Sigma Laser Stent and Tube Cutter, which can be configured with either microsecond fiber or femtosecond lasers. Featuring 3 or 4 axes of motion, wet and dry cutting, an automated tube loader option, and easy access to sub-assemblies, the updated system can cut stents and tubes with diameters from 0.2 to 25 mm. The operator-friendly control software features a 22 inch graphic user interface (GUI) on a swing arm.

The Sigma system has been designed for efficient production and practical operation. New features include an open architecture with excellent work space access and a sliding door which provides quick access for part unloading and set up changes. In addition, all service components are now on drawers that can be easily accessed. The system also features high precision high acceleration linear drive stages that optimize cycle time, a 2 inch Z axis and optional lineal stage cross axis for off-axis cutting, and a smart water supply system that controls and monitors flow. A single-screen operator interface facilitates ease of use with password-protected access levels.

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

Members In Motion

IPG Photonics Appoints Catherine Lego to Board of Directors

IPG Photonics Corporation announced that Catherine P. Lego has been appointed to its Board of Directors effective July 6, 2016. Lego is principal and founder of Lego Ventures, LLC, a California-based firm that provides consulting services to early-stage technology companies. The election of Ms. Lego, who will serve on the Company's Audit Committee and Compensation Committee, expands the IPG board to 10 members.

Ms. Lego's firm, Lego Ventures, which was founded in 1992, supports early stage technology companies with business plan development, obtaining seed and expansion financing, and counsel in the area of strategic growth through mergers or acquisitions. The firm's clients have included Hybrid Networks, Opcode, Packeteer, Tripod, Dhaani Systems and Network Translations. From 1999 to 2009 Ms. Lego served as the general partner of The Photonics Fund, LLP, a venture capital investment firm focused on early stage investing in component, module and systems companies in the fiber optic telecommunications market. She served as the director of finance and investment analyst at Oak Investment Partners from 1981 to 1984, and as a general partner from 1985 to 1992.

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

Special Breakthrough Prize for the Detection of Gravitational Waves

In September last year, the LIGO Scientific Collaboration (LSC) researcher team had succeeded in experimentally recording the merger of two black holes for the first time. In February 2016, the evaluation was presented to the world press. Thus, the international LSC researcher team, including among many other institutions the Albert-Einstein-Institut (AEI) Hannover too, was able to prove one of the most important predictions of Albert Einstein's theory of general relativity after 100 years.

Under the leadership of the Albert-Einstein-Institut (AEI), the LZH has been working on the development of the laser system for the gravitational wave detectors LIGO (Laser Interferometer Gravitational Wave Observatory) for more than ten years. The lasers in the LIGO detectors were jointly constructed and integrated into the US observatories as a ready-to-run-system by the LZH, AEI and neoLASE, an LZH spin-off company.

For more information, visit **www.lzh.de/en**.

11th DOE LSO Workshop

The 11th Department of Energy Laser Safety Officer Workshop will be held Sept. 27-29 at Fermi National Accelerator Laboratory. The DOE LSO Workshop is the premier meeting venue to gain practical laser safety knowledge, discuss ideas with colleagues and gain maintenance points for BLS CLSO/CMLSO, CHP, CIH and CSP certifications.

A preliminary agenda is now available from the workshop website. Highlights include talks from Dr. Chris Stoughton of the Fermilab Holometer and Dr. Brian Nord of the Fermilab Center for Particle Astrophysics, a special optics tutorial, vendor exhibition and tours of various Fermilab facilities.

In addition to the workshop, ancillary meetings of ASC Z136 subcommittees TSC-1, TSC-4, SSC-8, and SSC-9, as well as a University AMLSO and the DOE EFCOG LSSG meetings will be held. Preceding the workshop on Monday, Sept. 26, the BLS is offering a CLSO exam. For more information on the workshop or to apply to sit for the CLSO exam, please contact the BLS at **bls@lasersafety.org** or call +1.407.985.3810.

ILSC 2017

It's not too soon to start planning for the 2017 International Laser Safety Conference. ILSC® 2017 will be held Mar. 20-23, 2017 in Atlanta, GA. Of special interest to our CLSOs and CMLSOs, the Practical Applications Seminars (PAS) complement the more complex Laser Safety Scientific Sessions (LSSS) by exploring the everyday scenarios that the LSO and MLSO may encounter. Leading the Medical PAS is the team of Kay Ball, Vangie Dennis, Patti Owens and Leslie Pollard, while the Technical PAS will be co-chaired by Eddie Ciprazo and Jamie King.

Attendance at ILSC will earn BLS certification maintenance (CM) points at the rate of 1 point per day. Present a paper and earn additional CM points! The abstract submission deadline is Oct. 6, 2016. For CM point specifics, please see "Maintenance" on the BLS website, **www.lasersafety.org**.

Job Opportunity

CLSOs – we have been made aware of a position available on the west coast. If interested, please contact Barbara Sams at **bsams@lasersafety.org**. Thank you.

OSHA | Update

An OSHA Cooperative Program

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.

Ohio Auto Parts Manufacturer Faces $3.42 Million in Fines after OSHA Finds Company Willfully Exposed Temporary Workers to Machine Hazards

The US Department of Labor's Occupational Safety and Health Administration issued 57 citations for safety violations to Sunfield Inc., an Ohio auto parts' manufacturer. The agency has also proposed the company pay more than $3.42 million in total fines for its failure to disconnect machinery from a power supply and prevent sudden movement before maintenance and service; and to train workers in how to operate machine presses safely and to service and maintain them.

The fines assessed are one of the largest OSHA penalties ever filed against a company in the automotive parts industry.

Federal investigators inspected Sunfield's Hebron plant after two workers suffered severe injuries in separate incidents in January and February 2016. The facility has an extensive history of federal safety violations dating back 20 years. The company, which investigators found to have a high rate of employee turnover, supplies parts for several major Japanese and domestic automakers.

OSHA today issued citations for 46 egregious willful, two willful, one repeated and eight serious safety violations with penalties totaling $3,426,900 to Sunfield. The agency also placed the company in OSHA's Severe Violator Enforcement Program for failure to address these safety hazards. Most of the violations involve lack of machine safety procedures which expose workers to amputation, lacerations and other injuries.

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

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.

Vertical-Cavity Surface Emitting Laser-Diodes Arrays Expanding the Range of High-Power Laser Systems & Applications

BY ARMAND PRUIJMBOOM, ROLF APETZ, RALF CONRADS, CARSTEN DEPPE, GUENTHER DERRA, STEPHAN GRONENBORN, JOHANNA SOPHIE KOLB, HOLGER MOENCH, FELIX OGIEWA, PAVEL PEKARSKI, JENS POLLMANN-RETSCH, ULRICH WEICHMANN, XI GU AND MICHAEL MILLER

Thermal treatment may be by far the most frequent process used in manufacturing, but only at a few places lasers could make an inroad. For thermal treatment, homogeneous illumination of large areas at a lower brightness, and accurate temporal as well as spatial control of the power is required. This is complicated for conventional high-power lasers, while vertical-cavity surface emitting laser-diode (VCSEL) arrays inherently have these capabilities. Because of their fast switching capability and low power dissipation, VCSELs have been widely used for datacom and sensing applications. By forming large-area arrays with hundreds of VCSELs per mm^2, their use can be further expanded to high-power applications. In this way, power densities of several W/mm^2 are achieved, making the VCEL arrays an ideal solution for many heating applications, ranging from melting and welding of plastics and laminates to curing, drying, and sintering of coatings. A turn-key system concept has been developed allowing fast and easy configuring systems to the specifications of the applications.

To continue reading more about this paper, visit **jla.aip.org**.

Subscription Information

BY PHONE	For non-members of LIA, call the American Institute of Physics at 1.800.344.6902 for subscription information.
ONLINE	Sign up at **jla.aip.org/alerting_services/table_of_contents_alerts** to receive your *JLA* table of contents email alerts.

Back by Popular Demand: LIA Relaunches Sales of Laser Safety Signs

Laser Institute of America (LIA), recently announced the relaunch of laser safety signs sales to accommodate the needs of Laser Safety Officers (LSOs) and their professional laser safety teams. Back by popular demand, the customizable laser safety signs are available in both plastic and laminate, and feature newly updated, clearer safety warnings and instructions.

Four distinct signs are available for Class 3B and Class 4 lasers or laser systems per the *ANSI Z136.1 – Safe Use of Lasers* standard, including warning and danger signs for Class 4 lasers or laser systems, and warning signs for Class 3B laser-controlled areas. In addition, LIA has made a notice sign available for purchase for instances when a Class 3B or Class 4 laser or laser system is being repaired.

Additional resources for LSOs and laser safety professionals are available in LIA's online store. From online courses for the busy laser professional, to safety publications, videos and guides, LIA's online store is your complete shopping hub for everything laser safety, including laser safety signage.

To purchase laser safety signs or any other resources, visit **www.lia.org/store**.

LAM® LASER ADDITIVE MANUFACTURING WORKSHOP

Showcase Your Company at LAM 2017!

Make your plans now to attend next year's Laser Additive Manufacturing (LAM®) Workshop, which will take place Feb. 21-22, 2017 at the Hilton Houston North in Houston, TX. At LIA's LAM, attendees will learn more about 3D printing, cladding, rapid manufacturing, sintering and other revolutionary AM methods, including those being used by doctors and dentists. This annual workshop is the place to discuss the latest advances in the additive manufacturing industry.

If you or your company is interested in being represented at LAM 2017, now is the time to sign up as a Vendor or Sponsor. Sponsorship is a valuable way to reach a highly-qualified target audience. Communicate directly with influential decision makers, provide solutions to technology challenges, promote brand recognition through high visibility, and source new products to your target market with our exclusive packages. Don't miss this strategic opportunity for direct access to your customers! Please contact **lam@lia.org** for more information.

For more information on LAM 2017, visit **www.lia.org/lam**.

ICALEO® 35th INTERNATIONAL CONGRESS ON APPLICATIONS OF LASERS & ELECTRO-OPTICS

ICALEO's Advance Program is Available

The International Congress on Applications of Lasers & Electro-Optics (ICALEO®) is coming up October 16-20 in San Diego, CA. ICALEO has a 34 year history as the conference where researchers and end-users meet to review the state-of-the art in laser materials processing and predict where the future will lead. See the Advance Program for details on this year's information-packed presentations on the latest breakthrough laser solutions.

The opening plenary session will spotlight laser applications beyond the everyday. Join us during this session as we visit Mars, self-driving cars, and revisit LIGO. The closing plenary session will bring you new ideas and processes to expand your horizons. It will feature presentations which cover surprising new developments in applications — from iPhones® to planes. Register today and participate in the premier conference for technical information of its kind.

To view the ICALEO 2016 Advance Program or to register, visit **www.icaleo.org**.

ILSC® INTERNATIONAL LASER SAFETY CONFERENCE

Submit Your Abstract for ILSC 2017 & Save the Date

The biennial International Laser Safety Conference (ILSC®) will take place Mar. 20-23, 2017 at the Sheraton® Atlanta Airport hotel, gathering laser safety experts from around the globe. ILSC is a comprehensive four-day conference covering all aspects of laser safety practice and hazard control. Scientific sessions will address developments in regulatory, mandatory and voluntary safety standards for laser products and for laser use. The Practical Applications Seminars (PAS) complement the Scientific Sessions by exploring everyday scenarios that the LSO and MLSO may encounter. Professionals in all fields and applications will find ILSC a tremendous source for information and networking opportunities.

The ILSC 2017 Call for Papers is currently open for submissions. Authors are invited to submit their abstracts for oral and poster presentations by Oct. 6, 2016. Papers should contain original, recent and unpublished results of application research, development or implementation. To submit your abstract, visit **www.lia.org/conferences/ilsc/abstract_submission**.

For more information on ILSC as it becomes available, visit **www.lia.org/ilsc**.

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