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THE OFFICIAL NEWSLETTER OF THE LASER INSTITUTE OF AMERICA

LIA TODAY

DOE SPECIAL OPERATIONS REPORT ON LASER SAFETY IN RETROSPECT
PG 6

10 LESSONS IN SAFETY: NOTABLE MOMENTS FROM ALBUQUERQUE
PG 8

DRILLING OF COOLING HOLES USING HIGH POWER ULTRASHORT PULSED LASER RADIATION
PG 14

Photo Source: Laser beam image is courtesy of Coherent, Inc. Lasermet's Danger sign was photographed at LIA's 2015 International Laser Safety Conference (ILSC).

Focus:
LASER SAFETY

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

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IN THIS ISSUE:

FEATURES

DEPARTMENTS

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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.

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. 1-3, 2015	Orlando, FL

Laser Safety Officer with Hazard Analysis*

Sept. 21-25, 2015	Chicago, IL
Oct. 19-23, 2015	Atlanta, GA
Nov. 2-6, 2015	Scottsdale, AZ

*Certified Laser Safety Officer exam offered after the course.

Industrial Laser Safety Officer Training

Aug. 19-20, 2015	Novi, MI
Nov. 18-19, 2015	Novi, MI

Medical Laser Safety Officer Training*

Aug. 15-16, 2015	New York, NY
Sept. 19-20, 2015	Chicago, IL
Oct. 17-18, 2015	Atlanta, GA
Nov. 7-8, 2015	Scottsdale, AZ

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

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

Oct. 18-22, 2015	Atlanta, GA

Laser Additive Manufacturing (LAM®) Workshop

Mar. 2-3, 2016	Orlando, FL

Lasers for Manufacturing Event® (LME®)

Apr. 26-27, 2016	Atlanta, GA

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President's Message

High Energy Laser Safety, LIA's International Laser Safety Conference (ILSC®), Ultrafast Laser Applications — these are a few of my favorite things! This issue of *LIA TODAY* brings topics of great importance to many members of the LIA, and reflects the broad range of applied laser technology issues addressed by our society.

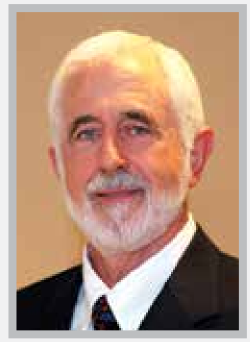
The topic of high-energy lasers is particularly appropriate as we approach the 50th anniversary of the first CO_2 gas dynamic laser. Only a few years after the first lasers were demonstrated, a big breakthrough occurred when Edward Gerry and Arthur Kantrowitz, working in the Boston suburbs, demonstrated a radical new laser design. This new form of laser was capable of producing tens of kilowatts of power and was scalable to hundreds of kilowatts of average power. This breakthrough ushered in the fields that are the stomping grounds of many LIA members, such as laser cutting and machining. These pioneers created an entirely new industry, now populated by a wide variety of laser technologies, operating at very high powers, and critical to the worldwide industrial base.

However, it is important to note that this first, truly high power laser preceded any well-defined criteria for laser safety by almost a decade! Our membership and committees that LIA sponsors, continue to lead the world in providing a safe working environment for these systems. As I write this, we have just returned from ILSC 2015. My compliments to Dr. John O'Hagan, this year's General Chair, along with conference chairs, John Tyrer (Laser Safety Scientific Sessions), Vangie Dennis and Leslie Pollard (Medical Practical Applications Seminar) and Tom Lieb (Technical Practical Applications Seminar), and LIA staff who put together an outstanding program. The conference for the past several years has included the "Practical Applications Seminars," which significantly broaden the audience for ILSC and provide significant application-oriented laser safety information for medical, industrial and research environments. Many of these papers and talks centered on usage of high power lasers in industry and research environments. Several authors of outstanding papers from the proceedings will be pursued for publication in the *Journal of Laser Applications® (JLA)*, so that a larger audience will be able to sample conference content. Our ANSI Z136 safety standards committee and subcommittees also met in conjunction with ILSC and made significant progress in updating the various documents within the series. Of particular note was the need to address persisting gaps in the risk associated with high power systems, as well as limited guidance for ultrafast lasers operating in the infrared spectrum… there is much work yet to be done.

It was great to see you all there, and offer personal congratulations to Mr. Jerry Dennis and Dr. Karl Schulmeister as they were presented well-deserved awards from the LIA! Watch for upcoming conferences, including the next ILSC, which will occur in the Spring of 2017.

Robert Thomas, President
Laser Institute of America

Executive Director's Message



TEAM LIA!

We made some encouraging progress in our last fiscal year ending in March. Attendance at our safety training courses was up 20 percent and OSHA was so pleased with our collaboration that they renewed our alliance for another five years.

At ICALEO® we introduced refereed papers which add value for our presenters. This allowed us to publish a special "ICALEO issue" of the *JLA* as well as an open access special issue on Laser Additive Manufacturing and the Future of 3D Printing. We also held our seventh Laser Additive Manufacturing (LAM®) Workshop which strengthens our presence in this exciting field.

In March we held our biennial International Laser Safety Conference (ILSC®) which features both basic technology as well as Practical Application Seminars. ILSC also functions as a "large tent" which provides space and time for committee and subcommittee meetings of the ANSI and IEC standards developers.

All of this happens because of the leadership of our officers and board and the fine efforts of our members, presenters, chairs, teachers, reviewers and trusty staff. All of us together are Team LIA. My thanks and compliments to everyone who made it another good year.

Peter Baker, Executive Director
Laser Institute of America

Department of Energy

Special Operations Report on Laser Safety in Retrospect

BY JAMIE KING

Due to a rash of serious laser accidents from 2001 to 2005, including six eye injuries, the Department of Energy (DOE) released a Special Operations Report (SOR) in February of 2005. A root cause analysis revealed that there were four primary causes for the accidents. They were: inadequate training, inadequate Laser Safety Officer (LSO) conduct, need for better internal oversight, and a failure to wear Personal Protective Equipment (PPE).

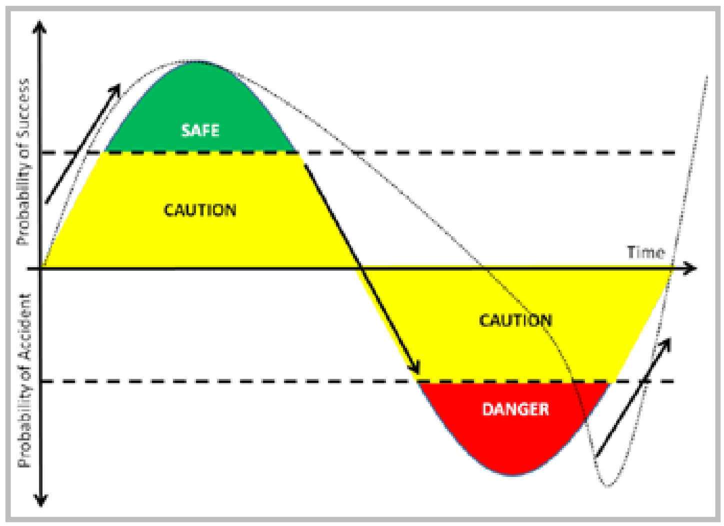
Insufficient training and an inadequate level of understanding of the hazards and controls were cited in each of the accidents analyzed. This was noted at the worker level, with those who oversee the operations, and supervisors of laser users. As many of the accidents involved students, the inadequacy or lack of training and a safety culture at the university level was mentioned.

The SOR reported that, while technology continues to advance, the LSO program had not kept pace. Most LSOs were part-time and did not hold the primary function or discipline as LSO. Training for LSOs was often generic and could be described as one-time and "one size fits all." There was no refresher training to help the LSO keep pace with laser technology and changes in regulations. Many were not performing their duties in line with all of the ANSI Z136.1 requirements. Another weakness uncovered was that though the DOE is a singular complex, each laboratory is independently operated with independent laser safety programs. There was no networking between LSOs and all best practices were being rediscovered by each facility's LSO. Each LSO was basically "reinventing the wheel" when it came to solving complex laser safety issues.

The report cited line management's oversight of laser operations was a contributing factor and that periodic assessments of lasers, when they did occur, were inadequately documented or lacked sufficient rigor, formality and follow-up. LSO inspections/audits either had not been conducted since the lasers were installed and granted operational status or had been inspected very infrequently.

A failure to wear PPE was cited in each of the seven accidents that occurred. Remembering that PPE is the last line of defense, how could this happen? In every single one of the accidents, the laser beam was either not where it was supposed to or intended to be. In situations where PPE is not worn, taking a shortcut is often the reason. The excuse given is that the individual thought that they could better "see" the beam without eyewear on. This is especially true with the lasers in the near infrared (750-800 nm).

How does a strong safety program fail? Everything in life works in cycles. Name what you will. Take a look at anything and there are peaks and valleys (like a sine wave). You are left scratching your head wondering how the valleys happened, even with lessons learned.



Speaking from experience, the cycle from the x/y axis origin point (calibration point) to the area where there is a probability of an accident (danger) is typically a four to seven year period. This may be shorter or longer with many variables contributing. The "calibration point" is that point in time where everything is zeroed. This is usually just after a serious accident when management takes action. The typical shape of the curve is not a true sine wave as the slope upward is usually very dramatic and the slope down is gradual until it hits a point, like the edge of a cliff (dotted curve), then rapidly ascends.

The slope upward is usually very steep. Here, management provides the backing and commitment (time and funding). This rise is even more dramatic immediately following an accident where a serious injury occurred. This is because all work has been halted as the investigation is completed. People are "shocked" into reality and the invincibility cloak is pulled away. The thoughts of, "that could have been me" are present in everyone's minds. At the peak, everyone has bought into the program and safety truly is "first and foremost."

The decline is something else. Usually you don't detect it until well into the "caution" area. Many things contribute to this decline: apathy, lack of focus, lack of resources, time, etc. The biggest issue here is that the accident is so distant in the rear-view mirror that people start to forget how easily it can happen and put the invincibility cloak back on. Safety becomes just a buzzword and very few are walking the walk.

The fall depends on two factors: management and the LSO. It is your responsibility, as an LSO, to keep management apprised when you find that the program is on the downward slope. You are the eyes and ears and as such are part of the management team. The goal is to keep your program above the x axis if not totally in the "safe" zone.

Today, work is being performed with laser safety officers from several different DOE labs working on updating a laser safety training course originally developed by Lawrence Livermore National Laboratory in the early 2000s. This course will reflect the new ANSI Z136.1 (2014) revision and will put the labs more in tune with each other. There is also a strong mentoring program being fostered along with collaboration between the DOE laser safety officers and their academic counterparts. This will ensure that students will be instilled with a strong safety ethic.

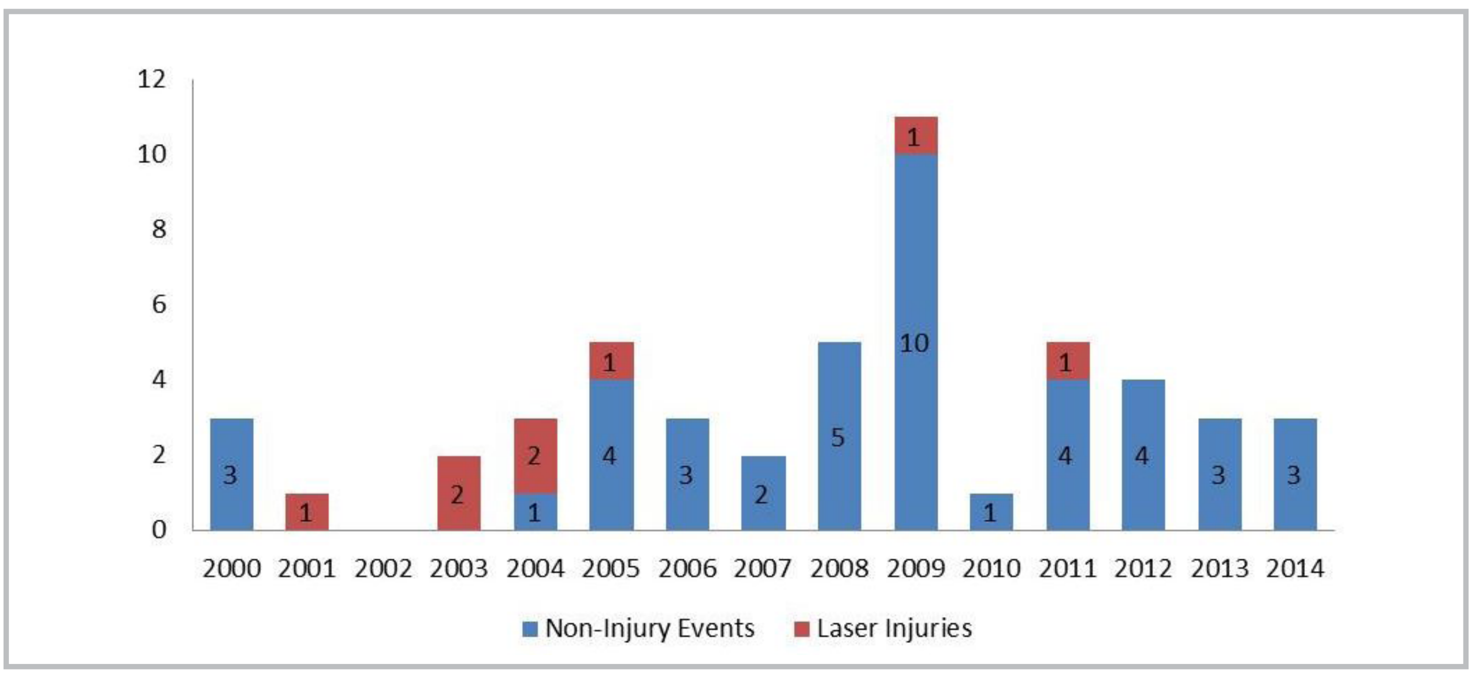
As far as networking goes, the DOE held an LSO workshop six months after release of the SOR and just celebrated its 10th anniversary this past summer at LLNL. This workshop has become the premier source of all things "practical laser safety" and is attended by DOE, other government agencies, academia and industry.

Upon completion of the fifth annual workshop in 2009, the Laser Safety Subgroup of the Energy Facility Contractors Group (EFCOG) reorganized and elected officers. This group meets quarterly via teleconference with a face-to-face meeting annually at the workshop. Here, a forum is provided for LSOs from the DOE labs to share in networking and a common approach to laser safety.

Finally, in relation to the benefits of networking, a subgroup was assembled to tackle a detailed comparison between the ANSI Z136.1 (2000), (2007) and (2014) standards along with the ANSI Z136.8 (2012). This was meant to provide the facts necessary for each lab to adopt the latest regulatory standard at their facility.

So where are we? When you take into consideration the several thousand lasers that are in use across the DOE Complex with approximately 4,000-5,000 of them being Class 3B and Class 4, it brings things into perspective. The use of high powered lasers within the DOE is being performed in quite a safe manner. What should be taken from this and the cycle of accidents, is that we must remain forever vigilant. As an LSO, it is your responsibility to keep safety first and foremost in the minds of your laser workers. As shown from the lessons learned in tracking DOE laser related occurrences over the years, accidents don't "just" happen. Safety is a team effort and all must participate for it to work! ■

Jamie J. King is a CLSO at Lawrence Livermore National Laboratory.



10 Lessons in Safety

Notable Moments from Albuquerque

ILSC® INTERNATIONAL LASER SAFETY CONFERENCE

BY GEOFF GIORDANO

Whether in the airway of a patient, the harsh environment of the Arctic or even in outer space, unique challenges continue to emerge in the battle against laser hazards.

Every two years, the International Laser Safety Conference (ILSC®) spotlights the latest efforts to combat routine and not-so-routine hazards. Amid long-standing discussions about standards, calculations, surgical plumes, tissue interactions and laser pointer strikes on aircraft, invariably there emerges a collection of uncommon issues and solutions.

ILSC 2015, held Mar. 23-26 in Albuquerque, didn't disappoint. As noted by LIA President Robert Thomas, ILSC illuminated issues with "lasers of immense peak powers, hand-held laser devices with power that cannot have been imagined a decade ago, and ever-expanding applications of the laser." Here we examine some of the more novel concepts:

Air, Land and Sea Safety

Many of the more than 1,400 lasers at Sandia National Laboratories are employed in national-security tasks like detecting airborne toxins or assessing explosions, said opening speaker Bill Seng, who manages a department handling lasers, optics and remote sensing. Sandia's technology ranges from enclosed indoor lasers to outdoor systems and run the gamut from UV to visible to IR to white-light lasers, Seng explained.

Sandia's corporate laser safety officer (LSO) and 26 deputies help assess "what evil can happen" before research begins. Sandia's stringent process for designing safe projects includes answering five questions: Who is the decision-maker? What are the unacceptable consequences? How can our system fail? What are the controls? How do we know the system works? Such "engineered" safety plans facilitate applications like remote laser sensing (5 km to 20 km away) to detect chemical, bio or nuclear contaminants. Sandia has LIDAR systems on aircraft, ships and even in the back of a van.

Baby It's Cold Outside

Analyzing laser hazards can be demanding under the best circumstances; try doing it for an Arctic-based LIDAR to be deployed on the Greenland ice cap with temperatures ranging from highs of -11°C in summer to lows of -50°C in winter. Michael O'Neill of the University of Colorado, Boulder, detailed efforts to model hazards in the area surrounding the building housing the autonomous system that will run 24 hours a day seven days a week.

The station, at an altitude of 3.2 km about 500 miles from the coast, will feature a dual-headed setup that allows data collection to continue even if one head is undergoing maintenance. Optics will split the signal into six measurable components. The laser will be run at 400 mJ and 355 nm. Given environmental conditions, "we need to pump a lot of energy into the atmosphere." Using the ANSI Z136.1 parent standard for laser safety, the team calculated multiple MPEs for the system "but chose to go with the repetitive pulse MPE value of 1.23." While the Z136.1 standard uses a Gaussian beam, the laser in this scenario is a modified top hat-shaped beam.

After simulating beam interaction with super-cold fogs and snow at various distances from the building to ensure the safety of laser operators and others, "we feel the diffuse and specular reflections are below the MPE limits below the 10 meters in which we're expecting people to operate," O'Neill concluded. "Direct ocular viewing is the main hazard in these conditions."

Look, Up in the Sky

Speaking of outdoor laser usage, Patrick Shriver of Metatech Corp. documented risks posed to space systems by accidental illuminations — not the least of which is the potential for international incidents from inadvertent satellite exposures. More and smaller satellites are being used, while the numbers and applications of lasers are increasing, so the potential for laser strikes has grown. In one exercise by an amateur astronomy club, a 1 W blue laser was pointed at the International Space Station and observed by an astronaut at about 350 km altitude. In the case of satellites, optical sensors are most at risk; evasive maneuvers are generally not possible, and onboard protection systems are potentially incapable of reacting quickly enough. Shriver suggested an international registry to document most lasers that can propagate beams into or through space, including space-based lasers. From there, safe-operation standards could be created.

Know When to Walk Away

A recurring theme of the Medical Practical Applications Seminar (MPAS) was the likelihood of confused and tense moments in operating rooms or other therapeutic settings in which less-than-optimal conditions — or personalities — might require a medical LSO to more forcefully take the reins to protect patients

and caregivers. And that might include shutting down the laser, asserted co-chair Leslie Pollard, president of laser consultancy Southwest Innovative Solutions. In a scenario-packed audience-participation session titled "What's the Verdict?" Pollard stressed that the person holding the laser keys is the last line of defense for the patient.

In a "walk-away scenario" years ago, Pollard encountered an ENT procedure in which a child was being treated using a tube that was not laser-resistant. Pollard escalated her concern by questioning the anesthesiologist, examining the tube's package and, ultimately, alerting the chief of surgery — who was on the facility's laser safety committee. "I was making this up as I went," she recalls. "I figured I was going to be fired." In cases using leased lasers, Pollard posed a rhetorical question: "Does your rental technician have the ability or the wherewithal… to say, 'Doctor I can't do that (procedure)… this is a walk-away for me.'?" The boss, she asserted, "is the laser safety officer at the facility, not the doctor."

The $30 Million Airway Fire

A 2012 case in Washington State illustrated what happens when a surgical procedure continues despite signs that a walk-away might be warranted. Attorney Matthew Wojcik related a case in which a 53-year-old woman with a history of vocal cord polyps suffered extensive burns and eventually died when the endotracheal tube being used ignited during surgery with a CO_2 laser.

Numerous factors played into the accident, Wojcik said, including insufficient training of the surgeon, anesthesiologist and "laser nurse," the latter of whom had taken a laser safety course but not the certification exam. Furthermore, the surgeon was unfamiliar with the tube used, and the hospital's LSO had left two years prior and not been replaced by someone similarly credentialed. With the hospital settling for $12 million and a jury awarding $18 million on top of that, a further lawsuit is pending against the facility in which the patient — unable to speak or breathe without a ventilator — was treated until her death. "Empower the laser safety officer… to question and to call time out if anything doesn't seem right," Wojcik urged.

Whose Laser is it, Anyway?

With third-party lasers figuring more heavily into health care, Richard Gama of UHS Surgical Services stressed that the use of borrowed or rented equipment is drawing more attention from OSHA and The Joint Commission. Yet many facilities feel that if they don't own the laser, they don't need a safety program — which is "absolutely false," Gama asserted. In a recent informal survey of UHS clients, about 40 percent of 266 facilities that responded did not have an LSO or safety program. "Best practices" for using third-party lasers should include requiring the facility LSO to assess equipment for compliance, he advised. Service agreements should delineate vendor responsibilities and guidelines for issues like sterilization and storage.

No Slacking at SLAC

When it comes to safeguarding employees and visitors at SLAC National Accelerator Laboratory near Stanford University, a stringent in-house safety program means that "even if you're from (Lawrence) Livermore, you take our course," according to Michael Woods, the facility's certified LSO. "We require everyone to take SLAC's *Laser Accidents & Lessons Learned and Laser Alignment Practical* courses," Woods said. With dozens of lasers in house and more on the way, SLAC published a 27 page guidance document in August to augment SLAC's *Laser Supervisor Safety* training. The document covers everything from job roles and training of laser personnel to laser laboratory design, interlock requirements and even service subcontractor visits.

We Don't Need No Stinkin' Eyewear

Loughborough University's John Tyrer, chair of ILSC's Laser Safety Scientific Sessions, emphasized the concept that a lab can be designed to feature many enclosed lasers of multiple wavelengths side by side — without requiring operators or visitors to wear eye protection. ILSC General Chair John O'Hagan of Public Health England related changes in student attitudes about eyewear over a 10-year study of joint laser safety training by PHE and Loughborough. Their analysis of pre- and post-course questionnaires showed that after taking one of these joint training courses, students indicated that risk reduction through other means — for example, engineered controls — rose higher on their priority list than goggles.

No Such Thing as Safe Smoke

The idea that smoke is a primary hazard is not new — but it bears repeating. Vangie Dennis, MPAS co-chair, emphasized the point after Gama's presentation: "There's no such thing as safe

(Continued on page 12)

LIA PRESIDENT ROBERT THOMAS (LEFT) WITH ILSC GENERAL CHAIR JOHN O'HAGAN (RIGHT)

LASER SAFETY SCIENTIFIC SESSIONS CHAIR JOHN TYRER

TECHNICAL PAS CHAIR THOMAS LIEB

MEDICAL PAS CO-CHAIRS LESLIE POLLARD (LEFT) AND VANGIE DENNIS (RIGHT)

ILSC OPENING PLENARY SPEAKER WILLIAM SENG

2015 GEORGE M. WILKENING AWARD WINNER, JEROME DENNIS

2015 R. JAMES ROCKWELL JR. AWARD WINNER, KARL SCHULMEISTER

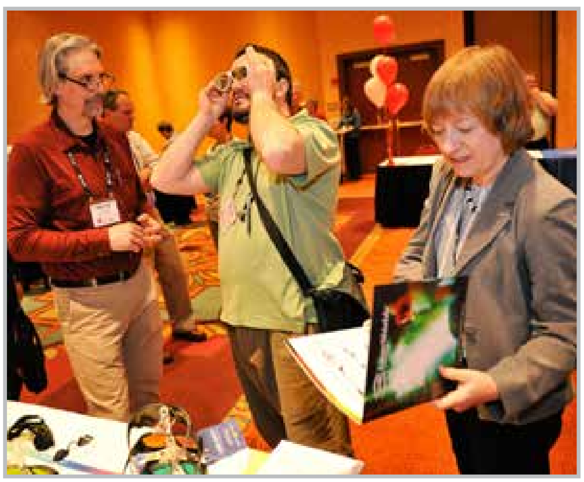
ANH HOANG PRESENTING LASER-TISSUE INTERACTION

GREG MAKHOV, LIGHTING SYSTEMS DESIGN, INC., DAZZLED ATTENDEES WITH HIS UNIQUE LASER LIGHT SHOW

ILSC POSTER PRESENTER, MARTIN BROSE, BG ETEM (RIGHT) AND BERNARD SCHMITZ, ECS GMBH (LEFT)

ILSC 2015

Showcased the latest efforts to combat routine & not-so-routine laser hazards



smoke… We have to use our first line of defense — and that's smoke evacuation systems."

Robert Scroggins of Buffalo Filter shared the latest information about the deleterious particles that can be present in and transferred by surgical smoke. Surgical smoke contains over 40 hazardous chemicals, he said, including carcinogens. Interactions of chemicals in the plume can be more hazardous than individual components like benzene. Biological components like HPV, HIV, viral DNA and Hepatitis B virus can sit in the lungs; there are even documented cases of cancer in surgeons who performed laser surgeries and were subjected to the plume. Surgical smoke also contains particulate material that is trapped in the alveoli of the lungs and can lead to COPD, asthma, bronchiolitis, atherosclerosis and thrombogenesis. Modern smoke evacuators, he noted, operate at 50 to 55 decibels — equivalent to normal conversation — and are easily portable. In fact, there should be one in every room where laser surgeries are performed — and should have automatic indicators to change filters.

Meanwhile, Tyrer presented a concept for a hand piece that extracts fumes and protects the beam during skin procedures while also being able to house a camera to ensure better outcomes. Two UK hospitals are testing the devices.

New Lasers, New Safety Concerns

More powerful and brighter lasers will necessitate the continued evolution of hazard prevention and industrial workstations. For example, David Havrilla of TRUMPF noted that diode-pumped disk lasers are being combined to achieve outputs of 20 kW to 30 kW. The femtosecond version of the disk laser could enter the terawatt regime within the next few years. He also noted that TRUMPF achieved more than 1.5 kW average power at 515 nm (green). Meanwhile, Tim Webber of IPG Photonics detailed advances in fiber laser powers on the order of 30 kW to 100 kW, for instance in welding applications for shipbuilding. These significant power densities will require "a little bit more science and a little bit more study" to properly address brightnesses and barrier requirements, Webber noted. ■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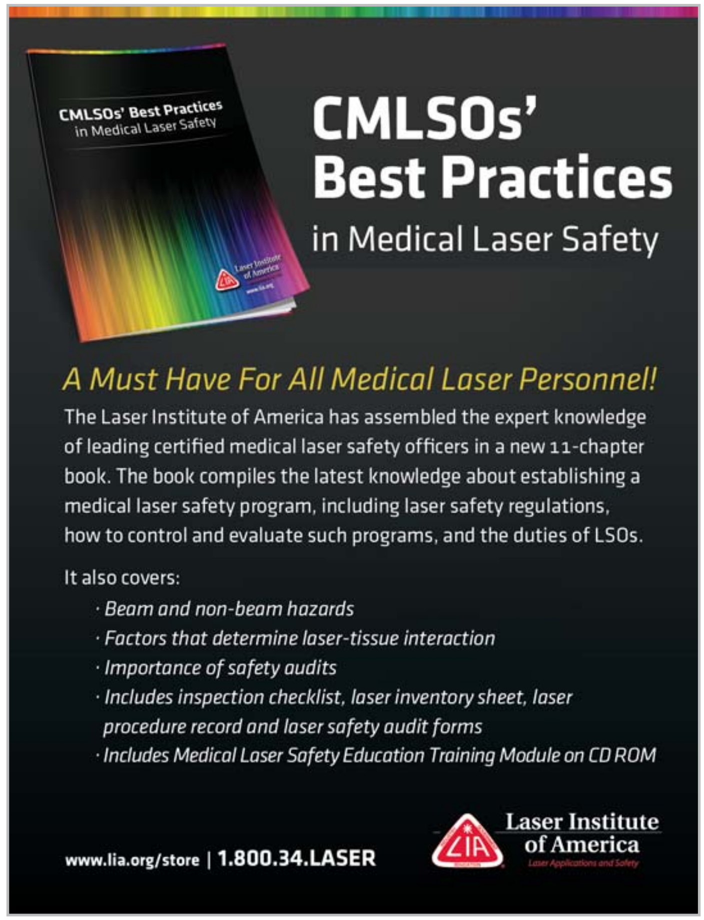
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Drilling of Cooling Holes

Using High Power Ultrashort Pulsed Laser Radiation

BY HERMANN UCHTMANN

One of the main applications for laser drilling is the manufacturing of cooling holes with diameters of e.g., 500 µm in turbine components such as turbine blades and vanes or combustion chambers. Nowadays, these cooling holes are drilled by using flash lamp pumped Nd:YAG laser radiation and partially by using QCW fiber laser radiation with pulse durations in the range of 200 µs up to a few ms. The main deficit of these conventional technologies is the appearance of recast layers with thicknesses up to a few 100 µm at the hole wall. These recast layers arise due to the melt-dominated drilling process. During operation of the drilled components, the recast layers can chip off or can be the initial point for cracks. Both effects lead to a shorter lifetime of the component.

The process related microstructure changes and defects shall be reduced by using ultrashort pulsed laser radiation. Pulse durations < 10 ps are shorter than the electron phonon interaction time, so that a "cold ablation" is possible as the material is directly vaporized. Thus, the appearance of recast layers and the initiation of cracks might be avoided. The comparison of the vaporization-dominated ablation and melt-dominated ablation is shown in Figure 1.

An Amphos ultrashort pulsed laser source is used with a wavelength of 1030 nm, an average power of up to 400 W, a repetition rate of up to 56.8 MHz and a pulse duration between 0.7 and 7.65 ps. Pulse picking is applied for repetition rates smaller than 1.43 MHz by using an electro-optic modulator (EOM). Depending on the number of picked pulses the average laser power is reduced e.g., approx. 50 percent of power if every second pulse is picked (715 MHz). A conventional galvo scanner system is used for beam deflection.

The drilling process is developed by initial experiments to drill holes with a diameter of 500 µm into 3 mm thick stainless steel 1.4301. The following aspects are investigated: The influence of type and pressure of process gas, the focal position in z-direction, the average power and the repetition rate of the laser radiation depending on the hole entry and exit diameter as well as the thickness of possibly existing recast layers. The laser radiation is deflected within a circular geometry consisting of 50 circles, see Figure 2. The diameter of the outer circle is 440 µm and the distance between any two circles 4.4 µm.

The variation of process gas is performed by using a repetition rate of 237 kHz and an average laser power of 75 W. The focal position is on the surface of the workpiece and the process gas pressure is 5 bar. The 50 circles are repeated 300 times

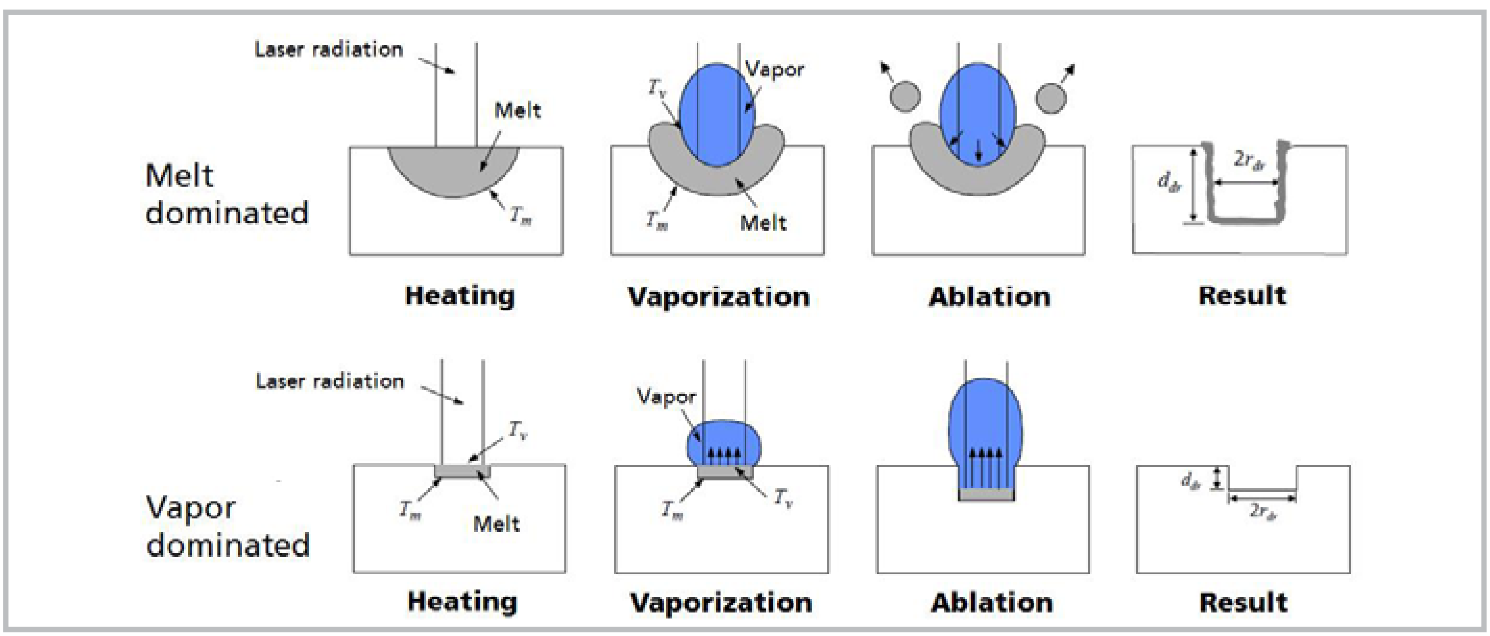

Figure 1. Comparison of material ablation be melt-dominated process with millisecond pulse (top) and by vaporization-dominated process with femtosecond pulses (bottom)

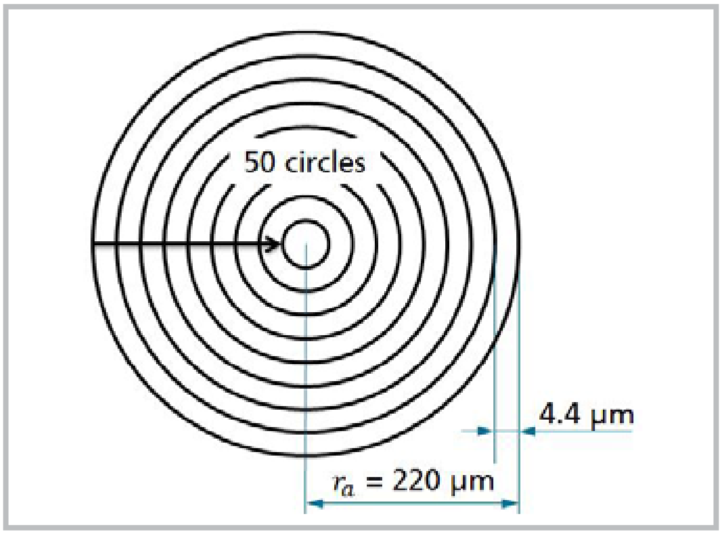

Figure 2. Laser beam movement for drilling holes with a diameter of 500 µm by using a galvo scanner

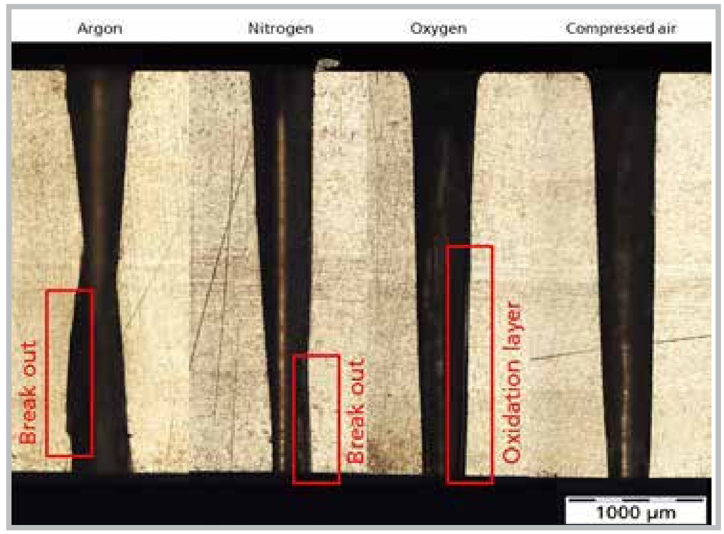

Figure 3. Longitudinal section of holes drilled into 3 mm thick stainless steel by using ultrashort pulsed laser radiation with different process gases

which leads to a drilling time of 146 s per hole. As shown in Figure 3, the holes drilled by using argon and nitrogen as process gas are not cylindrical. This is caused by the inert effect of both gases. Due to less available energy, the conicity of the holes is bigger. Furthermore, the hole walls are reflective. This leads to reflections of the laser radiation at the hole wall so that break outs in the lower part of the holes occur. The hole drilled by using oxygen has an oxidation layer of approx. 50 µm in the lower part. Only the hole which was drilled by using compressed air as process gas has no recast layer. Thus, compressed air is used for all further experiments.

Figure 4 shows the influence of the focal position in z-direction onto the hole entry and exit diameter as well as the recast layer thickness. The hole entry diameter is not affected by different focal positions. The largest hole exit diameters combined with

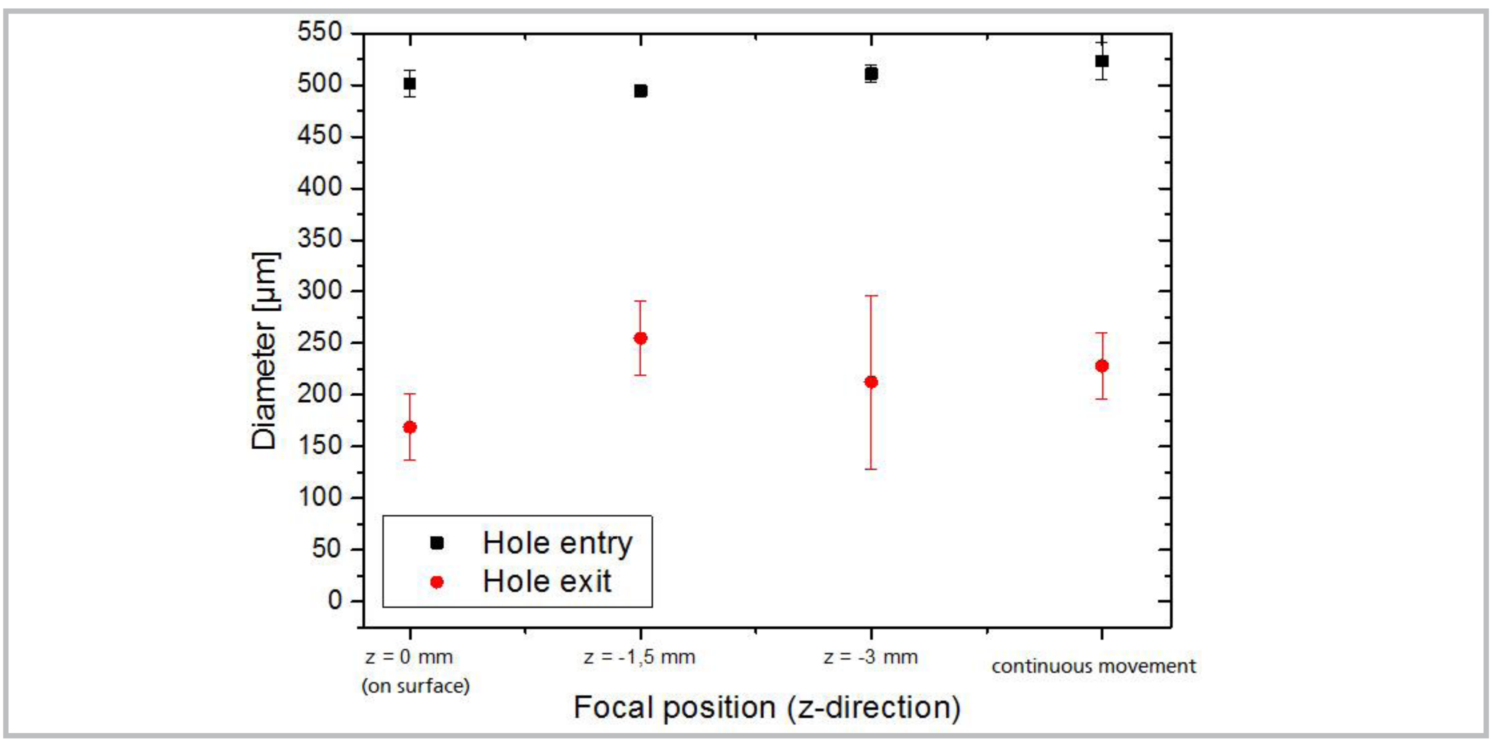

Figure 4. Measurement of hole entry and exit diameter depending on the focal position in z-direction

(Continued on page 16)

the smallest tolerance is achieved by setting the focal position to the middle of the workpiece (z = 1.5 mm). A continuous movement of the focal position in z-direction during the drilling process leads to smaller exit diameters.

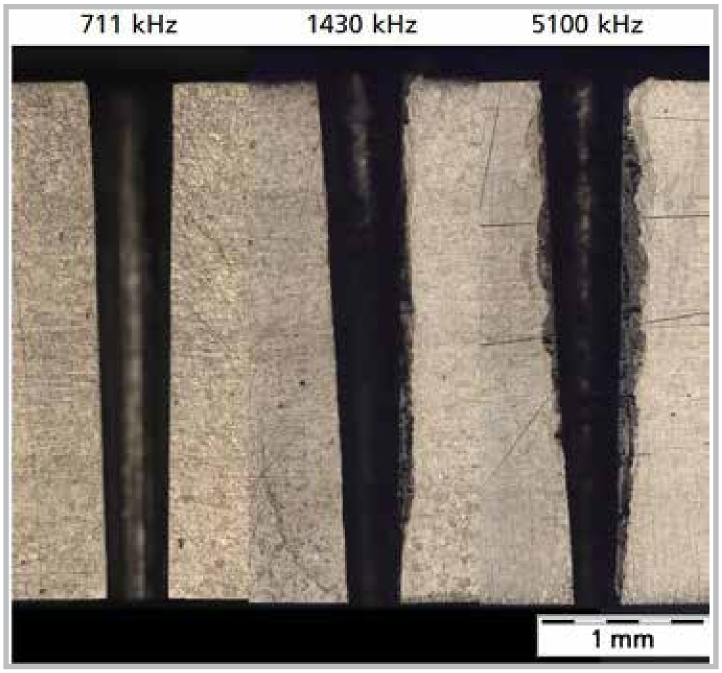

Figure 5. Longitudinal section of drilled holes with three different repetition rates at an average power of 170 W

Figure 5 shows the variation of the repetition rate at an average power of 170 W. A large heat-affected zone arises at a repetition rate of 5100 kHz. The high repetition rate and the small movement speed of the laser radiation leads to a high pulse overlap of 99.94 percent. Plasma arises due to the high pulse overlap. The material at the hole wall is heated by the plasma and by following laser pulses. The effect can be decreased by using a repetition rate of 1430 kHz. At a repetition rate of 711 kHz there is almost no visible recast layer or heat-affected zone. Both, hole entry and hole exit are sharp-edged.

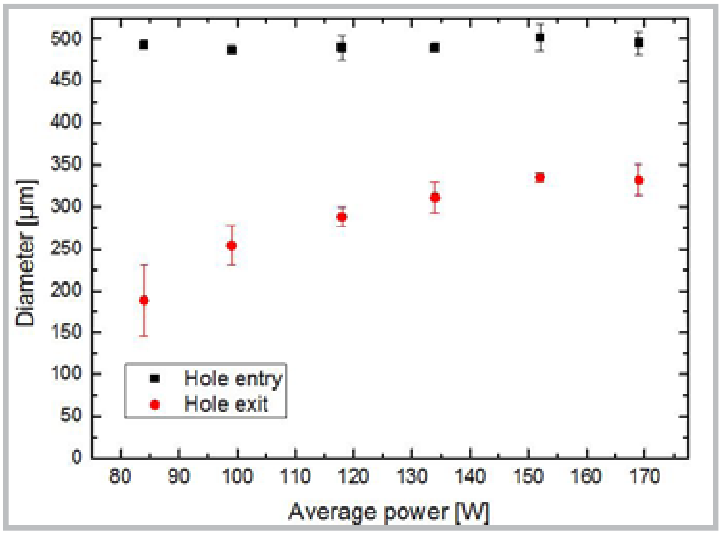

Figure 6. Hole entry and exit diameter in accordance to the average power at a repetition rate of 711 kHz

The average power is varied at a repetition rate of 711 kHz. As shown in Figure 6, the hole entry diameter is constant at approx. 500 µm. The hole exit diameter becomes larger at higher average power. The average power is limited in the pulse picking mode, which is necessary to realize repetition rates smaller 1400 kHz. Thus, the conicity of the holes cannot be avoided by varying the laser parameters.

Finally, holes are drilled by using a repetition rate of 237 kHz, compressed air as process gas and a laser average power

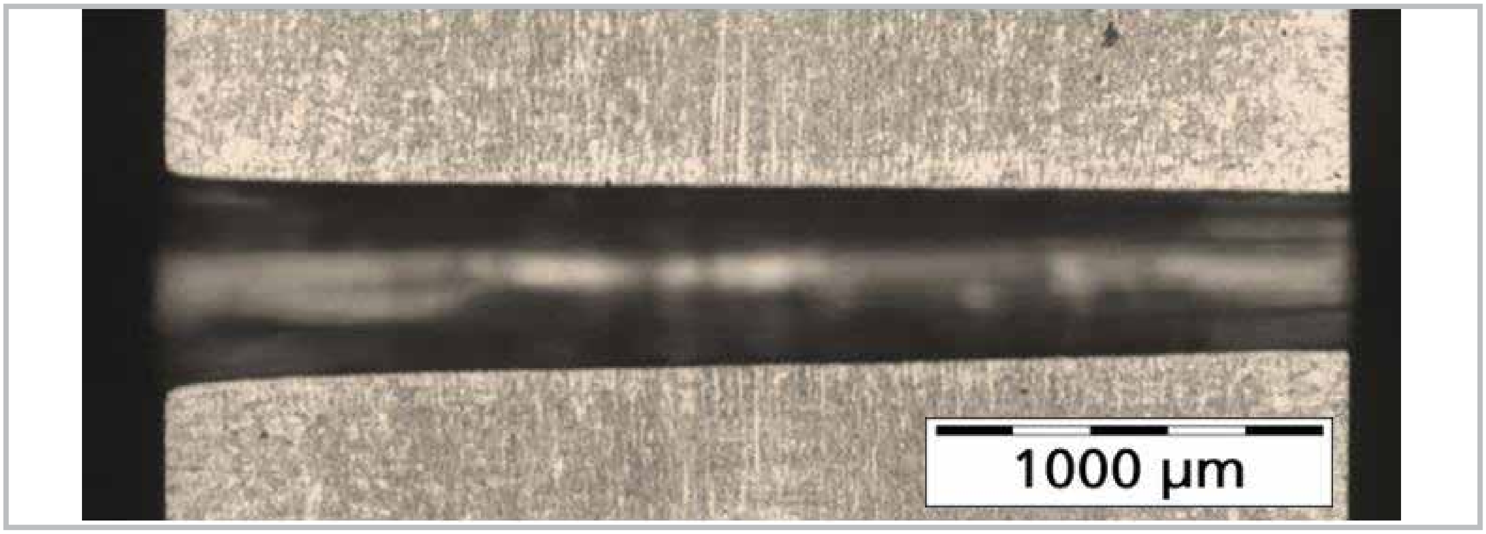

Figure 7. Longitudinal section of a drilled hole in 3 mm thick stainless steel without any recast layer

of 170 W. As shown in Figure 7 and the close-up view in Figure 8, there is no visible recast layer at the hole wall. The drilling time is 160 seconds per hole.

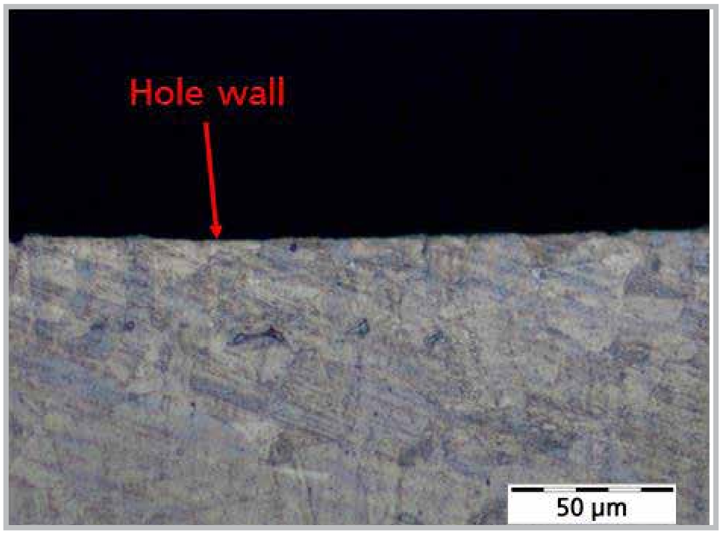

Figure 8. Close-up view of the hole wall of Figure 7 without any recast layer or micro cracks

These are the first macro holes in 3 mm thick material drilled by using ultrashort pulsed laser radiation. Further experiments could be performed by using a helical drilling optics. Thus, the existing taper of the hole can be reduced or avoided. To decrease the drilling time, high pulse energy e.g., > 1 mJ in accordance with low repetition rates < 1 MHz should be used. As soon as the two deficits, the conicity and the low productivity, are eliminated, the drilling process could be transferred in a first step to multilayer systems consisting of base material, bond coat and thermal barrier coating. Subsequently, the process could be transferred to industry for drilling turbo machinery components such as turbine blades or combustion chambers. ■

Mr. Hermann Uchtmann is a research engineer at RWTH Aachen University.

Laser Texturing

To Generate High Friction Surfaces

BY ANDREW DUNN

Lasers have been used for many years to transform surface properties, including both texture and hardness, for a wide range of applications. For example, the ability to create tailored texture and hardness properties means that the frictional properties of a surface can be modified. Together with colleagues at Heriot-Watt, SPI Lasers and MAN Diesel and Turbo, I have a particular interest in the creation of surfaces with a high coefficient of static friction. This is in contrast to the approach of many other researchers, which is to use lasers to reduce friction e.g., by creating indentations in the material surface which can then therefore act as micro-hydrodynamic bearings, lubricant reservoirs or as traps for wear debris, depending on the lubrication regime.

Applications of high static friction surfaces include the reduction of the tightening forces required for a joint or to secure a precision fitting easily, without the need for 'keying' structures. These applications are particularly relevant where the components being joined are very large, e.g., parts of large marine engines at MAN Diesel & Turbo, and so are expensive and/or difficult to machine to the required precision. MAN's particular requirement (for an application in such an engine) is for surfaces with a coefficient of static friction, $\mu s > 0.6$.

SPI pulsed fibre lasers are particularly suited to the creation of such surfaces, because of their independent control of temporal pulse length and pulse energy, which together with the spatial overlap of successive laser pulses on the surface, control the friction coefficient. The lasers used were the 20 W HS-L and the 50 W HS-S. In each case the laser beam was moved across the surface of the sample using a galvanometric scanner, focussed at the surface by an F-theta focussing lens; a very common laser machining arrangement. A two dimensional 'hexagonal' arrangement of pulses was used in order to generate a homogeneous surface structure with the aim of achieving an omnidirectional friction coefficient – see Figure 1. In addition Figure 1 demonstrates the difference between using a pulse energy of (a) 0.4 mJ and (b) 0.8 mJ. The finer scale, more complex texture obtained with the higher pulse energy was found to result in higher friction coefficients.

The friction coefficient was measured by clamping the processed part against an unprocessed counterpart, using a known force – the "Normal Force" – and then applying a force at 90 degrees until the parts slip against each other. This use of an unprocessed counter-surface reflects the application of interest, where a disposable processed 'shim' is used between two large parts.

The coefficient of friction was found to be strongly dependent on the Normal Force, presumably because it affects the degree of 'embedding' of the processed surface into the unprocessed counter-surface.

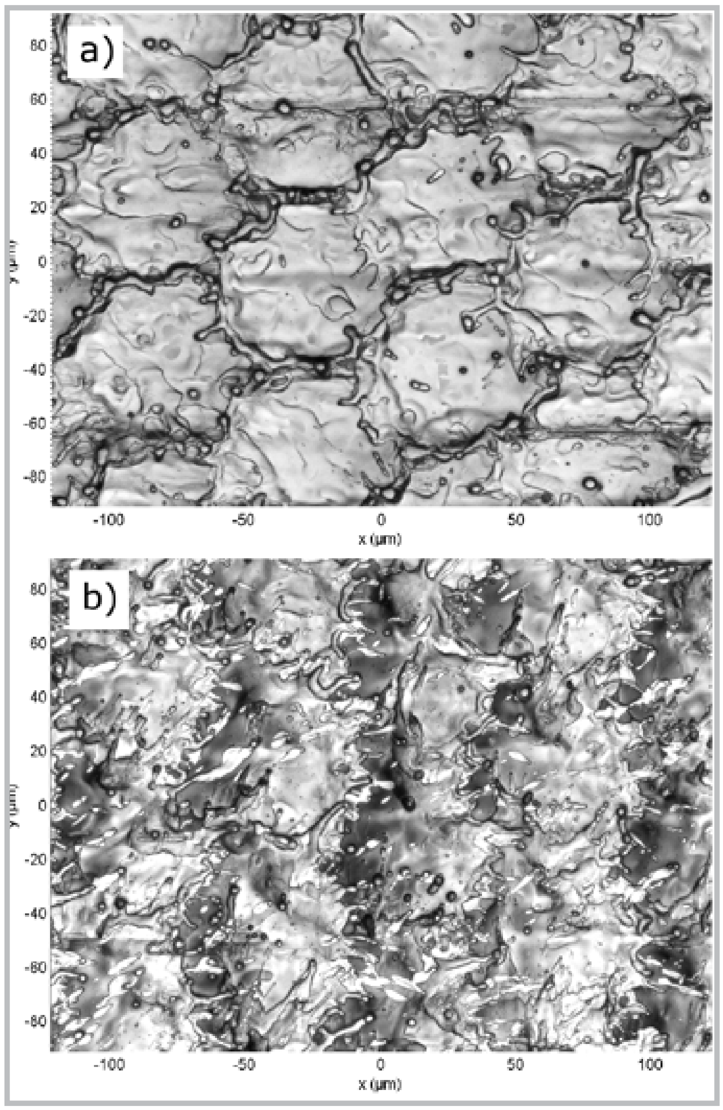

Figure 1. Micrograph of 0.4 mJ (a) and 0.8 mJ (b) pulse textures at -25% pulse overlap showing melt and ablation features respectively

Results are shown in Figure 2 for a range of steels and pulse overlaps, with the friction coefficient measured using a Normal Force of 40 kN. The overlap between the spots generated by adjacent laser pulses on the material was varied between -25 percent and 75 percent.

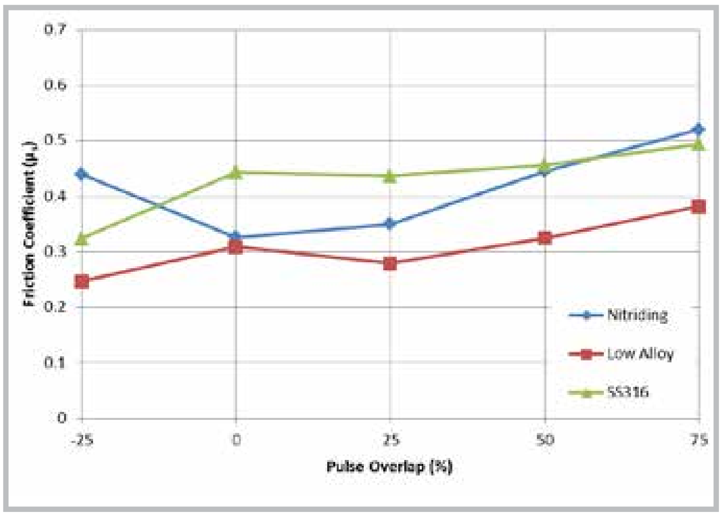

Figure 2. The coefficient of static friction plotted as a function of pulse overlap for three different materials with identical pulse parameters (25 kHz, 0.8 mJ pulse energy)

There is a general trend of increasing friction coefficient with pulse overlap. There is also a clear difference in the friction coefficients obtained with the low alloy steel compared to the others. This is particularly evident at higher laser spot overlaps, where the low alloy steel samples consistently provide a friction coefficient 0.1-0.15 lower than the other two sample materials. Untextured samples, for comparison, gave friction coefficients in the region of 0.2-0.25.

The hardness of the processed samples was measured using a macro-Vickers indenter, showing that the laser texturing process increases the surface hardness, with a larger increase for a higher pulse overlap. This increase presumably facilitates the embedding of the rough sample into the comparatively soft (low alloy) counter surface when the normal force is applied, thereby increasing the "ploughing forces" required to move the sample relative to the counter surfaces. This is backed-up by the plot of friction as a function of hardness shown in Figure 3, which shows an approximately linear relationship.

Given these results, the decision was made to further harden the samples using a nitriding process (giving a nominal hardness of 1000 Hv) in order to obtain the highest achievable

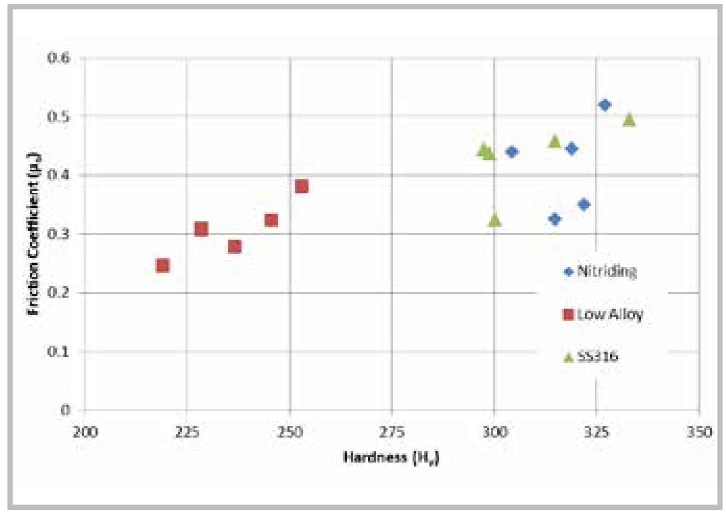

Figure 3. Relationship between friction coefficient and hardness for three different materials and a variety of processing parameters

friction coefficients. Laser processing was performed before nitriding on several samples and after nitriding on others. Figure 4 shows the friction coefficients achieved for these samples using the 50 W HS-S laser (25 µm spot, 0.71 mJ, 20 kHz) and tested with 40 kN normal force.

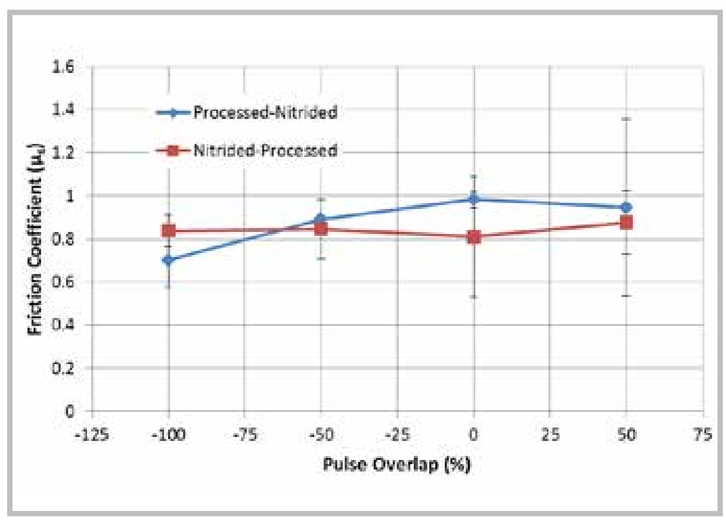

Figure 4. Friction coefficients as a function of pulse overlap for hardened nitriding steel. The blue data points were first laser processed and then nitrided, whilst the opposite is the case for the red points.

It is clear that nitriding provides a significant increase in friction compared to the non-nitrided results shown in Figure 2.

(Continued on page 20)

Also, in this case the friction coefficient is less dependent on the laser spot overlap, indicating that in the previous case the high overlap primarily increased the friction (compared with low spot overlap) via increased hardness rather than the additional topographical changes. Hence a dedicated hardening process in combination with laser texturing provides the largest increase of the static friction coefficient. This combination also means that a relatively small laser pulse overlap can be used, significantly reducing the laser processing time required.

In conclusion, laser texturing can be used as an effective means to increase the static friction coefficient of a surface. As a general trend, increasing the pulse overlap leads to an increase in surface roughness and the friction coefficient obtained. There is an associated increase in surface hardness, which appears to have a roughly linear relationship with the obtained friction coefficient. This is most likely due to the formation of a thicker, hard metal oxide layer at the surface which allows deeper embedding of the sample into the counter surfaces when the normal force is applied, increasing the ploughing forces required. The achieved friction coefficient can be increased further by introducing an additional step to the process to harden the steel. By nitriding the sample, either before or after laser texturing, friction coefficients as high as $\mu s \sim 1$ have been demonstrated. ■

Andy Dunn is a PhD student at Heriot-Watt University in Edinburgh, UK, and is funded by EPSRC and SPI Lasers.

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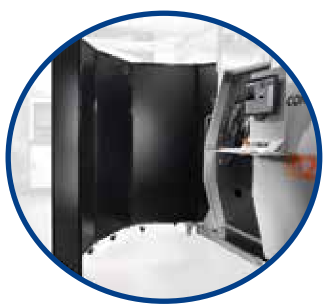


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Kentek Corporation

Global powerhouse & supplier of laser products & resources

Since 1983, Kentek Corporation has grown to become a staple in the laser community. Founded by Michael Toepel, inventor of Zap-It® Alignment Paper, Kentek has risen to prominence over the past decades by striving to provide the best and most comprehensive customer service in the industry. Throughout its history, Kentek's customers have come to rely on its wide range of products, accessible resources and expert staff for all of their laser component and safety needs. Kentek strives to provide excellent service to each and every one of its customers, both new and returning, and their clients have come to recognize and expect the distinct service qualifiers Kentek has adopted to establish them as a service oriented company. Personally answering each phone call, promptly and efficiently processing every order, and providing expert advice are all hallmarks of Kentek's commitment to quality that keep customers coming back. Today, the global powerhouse is owned and operated by Tom MacMullin who joined Kentek in 2000, and its legacy as a trustworthy and reliable supplier continues to be written; its rise to prominence was built on the promise of creativity and customizability for their clients by fellow laser experts. Those looking for help with laser applications can find it, those needing answers to laser safety related questions can get it, and those wanting the right replacement part for a solid-state laser can have it at Kentek.

Kentek is probably most well-known for its laser safety equipment. In the laser industry, one can never put too much emphasis on safety, and Kentek is constantly pushing itself to deliver the highest quality product on the market. They ensure that laser applications are safe by providing shoppers with a broad range of products including barriers, curtains, window glass and film, warning signs, access controls, interlocks and even full enclosures. Users needing eye protection can take advantage of their innovative eyewear search tool that allows customers to find unique goggles or glasses that perfectly match their specific application.

Furthermore, Kentek offers a wide variety of resources for both veteran and novice laser professionals. Their Laser Helpers™ knowledgebase is a treasure trove of information about lasers. From technical assistance such as diagrams on spot size vs. beam diameter, to practical advice on laser safety, Laser Helpers™ is an online toolbox not to be overlooked. For those needing more personalized advice, the Virtual LSO is one of Kentek's most innovative products, offering a custom-designed laser safety program for anyone who wants to take advantage of Kentek's more than thirty years of laser safety experience. The Virtual LSO is a life saver for new or overwhelmed LSO's who need a jump start on their laser safety operation. Kentek also manufactures, refurbishes and rebuilds many solid-state laser components including flashlamps, flowtubes, O-rings and laser crystals in every imaginable configuration.

On the horizon for Kentek is even more revolutionary laser safety equipment. New eyewear, including pilot protection that does not distort color recognition, has very high visible light transmission, and OD of 1+ for 440, 532, and 640 nm will allow for safer operations by increasing visibility. Also, new light gray polycarbonate lens eyewear for Nd:YAG protection will challenge the traditional green-gray mineral glass used in many applications.

Kentek now employs 28 laser professionals at the headquarters in New Hampshire or their sales offices in New Mexico, California and Florida. An active corporate member of LIA since 1996, Kentek is proud to support the work of LIA, including exhibiting numerous times at the various LIA conferences, as well as most recently being a gold level sponsor for the 2015 International Laser Safety Conference (ILSC®). ■

To learn more about Kentek, its products and its services, please visit **www.kenteklaserstore.com.**

WELCOME NEW CORPORATE MEMBER

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Grand Rapids, MI

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

International Year of Light

The power of light to improve the quality of life of people around the world — to heal them — is a key focus of the International Year of Light and Light-based Technologies.

“Light plays a vital role in our daily lives and is an imperative cross-cutting discipline of science in the 21st century,” according to the mission statement of IYL 2015. “It has revolutionized medicine, opened up international communication via the Internet, and continues to be central to linking cultural, economic and political aspects of the global society.”

The therapeutic use of photons was also a key focus of our latest International Laser Safety Conference (ILSC®). At ILSC 2015 in March, our experts touched not only on harnessing the power of light safely, but also some of the advances we can expect in laser therapies. (See ILSC 2015 roundup starting on page 10.)

What’s on the way goes far beyond current therapeutic procedures like ear, nose and throat surgeries — stapedectomy, mastoidectomy and the removal of acoustic neuroma or nasal and vocal cord polyps — or aesthetic/cosmetic applications like fat reduction, body contouring and hair and tattoo removal.

Updating her ILSC 2013 presentations on the coming advances in semiconductor (diode) lasers, Leslie Pollard, president of laser consultancy Southwest Innovative Solutions, noted that big progress is coming “and we need to be prepared. I don’t think the docs are prepared. (I’m) not even sure the manufacturers are prepared unless they have really astute engineers.” With these new devices in “little 10 lb boxes or 20 lb boxes… nanotechnology and medicine is about to be turned on its ear. I think a lot of people thought I was talking science fiction two years ago, but it’s really happening — and it’s happening faster than I even thought it would.”

One concept on the horizon that Pollard revisited is laser tweezers. “I just read an article on laser tweezers to pull out strands of DNA and reinsert different strands of DNA fixing problems before they become problems,” she noted.

Following Pollard’s presentations, Anh Hoang painted a picture of a future in which diode lasers become so small they can be put in a capsule and travel through the body. The versatility of these devices might provide the ability to “search and destroy tissue at the same time,” he said.

“The Egyptians were the first people that we know of to realize the therapeutic power of natural sunlight and to start using it for medicinal purposes,” noted June Curley in her summary of ENT laser surgery procedures. What’s next, Pollard suggested? Envision the possibility of putting semiconductor lasers on the fingertips of rubber surgical gloves. “Guys, this is far beyond Star Trek,” she concluded, “but it’s in our lifetime.”

Member Innovations

Buffalo Filter Launches LaparoVue™ Visibility System

Buffalo Filter is pleased to announce LaparoVue™ Visibility System our newest entry into the laparoscopic market. Understanding a surgeon's need to see clearly during laparoscopic surgery, LaparoVue is an all-in-one solution designed to take the complexity out of achieving optimal visualization. An easy to use, disposable multi-purpose device that warms, white balances, cleans and defogs, LaparoVue eliminates the necessity for multiple product purchases. "LaparoVue's design is unique in that it features two ports, one for warming and white balancing and one for cleaning and defogging. Both ports can be used simultaneously during surgery, providing greater efficiency and reducing surgery delays," states Kimberly Addison, Director of Marketing. "Additionally, LaparoVue features a scope cradle that safely and securely supports the scope reducing tension on the lens and potential for damage."

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

Thermal Precision: Advantages and Applications of Heat Flux Sensors

gSKIN® thermal sensors measure dynamic thermal influences in the form of heat fluxes or temperature differences. They offer ultra-high resolution of thermal parameters.

Temperature differences of 10 µK as well as heat fluxes below 0.05 W/m^2 can be resolved. Heat flux is the rate of heat energy passing through a surface. Depending on the exact definition of heat flux, its unit can be expressed as either W/m^2 or W. Temperature differences in a given system induce a heat flux. The induced heat flux always flows from the hot to the cold side. Heat fluxes occur everywhere.

In contrast to temperature sensors, gSKIN® sensors are able to measure this heat flux (dynamic) instead of the thermal status (which is temperature).

gSKIN® sensors are based on the Seebeck-Effect. The sensors contain a large amount of active piles made of an optimized semiconductor compound. Each pile generates a voltage in the nV to µV range. This voltage is proportional to the temperature difference and the heat flux flowing through it. By connecting the piles in series, the small voltages are added up and allow for a larger signal and a precise read-out.

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

Members In Motion

Domino Printing Sciences PLC Announces the Sale of its Fume Extraction Business, Purex International Limited, to Existing Management

Nigel Bond, CEO of Domino commented: "We are pleased to announce that we have today completed the sale of Purex International Limited ('Purex') to a company owned by Andy Easey and Trefor Jones, the existing management of the worldwide Purex business.

"Purex provides fume extraction solutions to meet applications in a number of industries, one of which is the coding and marking business of the Domino Group. Following a strategic review of options, the Domino Board decided that Purex would be better placed to drive expansion in its chosen markets as a business that was independent of the Group. We have no plans to expand the Group's business into broader extraction or purification applications and disposal of the company will allow us to focus on developing opportunities in coding, marking and digital printing.

For more information, visit **www.purex.co.uk**.

SLM Solutions launches new Applications Center in Lübeck

SLM Solutions Group AG, a leading provider of metal based additive manufacturing technology (also commonly referred to as "3D printing"), recently opened a new applications and demonstration center during their annual international distributors meeting. Lübeck Mayor Bernd Saxe and more than 200 invited guests attended the opening ceremony held at SLM Solutions headquarters in Germany.

Among the guests were international distributors from more than 30 countries, politicians, and representatives of the Economic Development-Lübeck. The SLM Solutions Executive Board thanked all of their contributors who assisted in the development of the applications center, and also stressed the importance of technical knowledge and training support that the new center will provide to those who are exploring additive processes for high production environments.

The new center will be used for technical presentation, training and hands-on demonstration of the entire line of Selective Laser Melting® systems (SLM®125HL, SLM®280HL and SLM®500HL). Furthermore, the site allows the production of component parts as a test center for new applications and technologies introduced to the market.

For more information, visit **www.slm-solutions.us**.


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ASC Z136 | Update

ASC Z136
Safe Use of Lasers
Accredited Standards Committee

Annual Meeting Overview

With 42 members and 8 observers in attendance, the annual meeting of Accredited Standards Committee (ASC) Z136 took place on Mar. 22, 2015 in conjunction with the International Laser Safety Conference (ILSC®) in Albuquerque, NM.

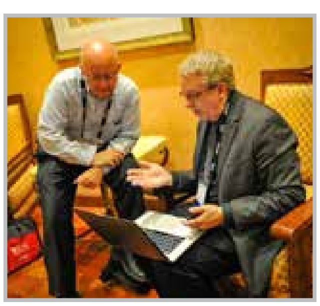
Opening the meeting, LIA Director of Standards Development, Barbara Sams, announced the appointment of Jeffrey Pfoutz as ASC Z136 secretary, and the reappointments of Robert Thomas and Sheldon Zimmerman as chair and vice-chair, respectively. Following approval of the agenda and previous year's minutes, Dr. Thomas presented the report of the Administrative Committee (ADCOM), which included the yearly activities of ASC Z136 consensus body balloting, announcement of subcommittee chairs and membership changes (see *LIA TODAY*, Vol 23, No 2, March/April 2015). It was noted that the ASC Z136 Procedures would need to be revised this calendar year to comply with ANSI's *Essential Requirements* by incorporating an antitrust policy statement. The ADCOM portion of the meeting closed with an overview of the previous day's subcommittee chairs and officers meeting.

Committee members then participated in a lengthy, but very necessary discussion pertaining to which information would remain within the ANSI Z136.1, parent document of the series. The consensus of the standards subcommittee members charged with revising the Z136.1 was that the document should remain the major resource for laser safety information it currently contains and the vertical standards should be for specific applications. The initial question called was, "should the vertical standards be standalone documents?" For clarification, one member asked whether all vertical standards would be published without Maximum Permissible Exposure (MPE) tables, i.e., should the MPE limits be contained in the Z136.1 standard and only referenced in the vertical standards? Conversely, specific control measures need to be contained in the applicable vertical standard. Consideration was given to applications not covered by vertical standards, redundancy, broken references due to [lack of] publication synchronization, and financial implications. A revised motion with more detail as to how to proceed was brought to vote and passed unanimously.

Status reports were presented for each standards and technical subcommittee, concluding with an update on the work of the Editorial Working Group (EWG). An action derived from the 2014 annual meeting, ASC Z136 Conventions now include a final review of the working examples appendix by technical subcommittee 7 (Analysis & Applications) concurrent with the final EWG review of a document prior to publication. Both groups are nearing review completion of the Z136.6 standard for *Safe Use of Lasers Outdoors*.

For additional information on the activities of ASC Z136, or if you are interested in membership on the committee or any of its subcommittees, please visit **www.z136.org** or contact Barbara Sams at **bsams@lia.org**.

ASC Z136
Members At Work & At Play



Awash in a sea of red CLSO and CMLSO ribbons, it was easy to pick out BLS® certified laser safety officers at the 2015 International Laser Safety Conference (ILSC®).
Participation statistics to be proud of include:

- Over 25 percent of conference attendees were CLSOs and CMLSOs
- MPAS co-chairs and TPAS chair are all certified laser safety officers
- 10 of 16 MPAS presentations were given by CMLSOs
- All Panelists for MPAS – *What's the Verdict?* were CMLSOs
- 7 of 15 TPAS presentations were given by CLSOs
- All Panelists for TPAS – *Integration or Separation: Standards & Regulation for Industrial Applications* were CLSOs
- 21 percent of LSSS presentations were given by certified laser safety officers

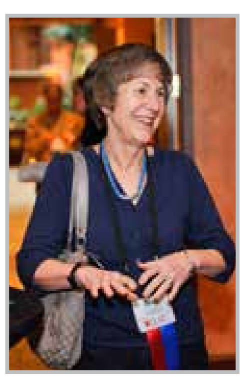
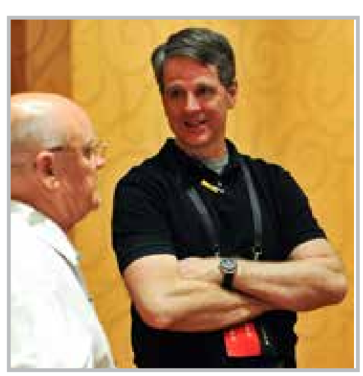
In conjunction with ILSC, the BLS Board of Commissioners held its annual meeting on Wednesday, Mar. 25. Sheldon Zimmerman and Candace Soles were re-elected as chair and secretary/treasurer, respectively, while Don Haes and Casey Stack were reappointed to commissioner seats for a second term. With an emphasis to further develop and enhance revenue streams, suggestions ranged from approaching other organizations to work with and/or promote laser safety officer certification to creating guides to better educate candidates prior to taking an exam. CLSO and CMLSO Review Boards will be established in the short-term to work on these projects.

For information on becoming certified, please visit us at **www.lasersafety.org** or call +1.407.985.3810.








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.

Capitol Hill Stands Down for Construction Fall Safety

Restoration work at the US Capitol Dome has been a prominent feature of the DC skyline for more than a year now. Inside an impressive 288-foot vault wrapped by a web of scaffolding, the dome's workers safely climb in and out every day making repairs to cracks in the iconic structure. In the shadow of this historic project, Turner Construction will stop work to remind those responsible for its completion and the nation why fall prevention is so vital.

On May 6, the US Department of Labor's Occupational Safety and Health and Administration joined Turner in Senate Park for a fall prevention safety stand-down. Deputy Labor Secretary Christopher Lu delivered remarks alongside the company's high-level representatives and safety experts.

As the leading cause of death in the construction industry, falls take the lives of hundreds of workers and leave thousands more with catastrophic, debilitating injuries each year. At Wednesday's event at the Capitol, Secretary Lu reiterated the department's call on the construction companies nationwide to take part in the National Fall Safety Stand-Down in recognition of these hazards. In 2014, thousands of companies and more than one million workers joined OSHA in a week-long series of events, the largest occupational safety event ever hosted.

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.

Simulated Investigation on the Deformation of Double Laser Beam Bilateral and Simultaneous Welding for Aircraft Panel

BY XIAOHONG ZHAN, GAOYANG MI AND YANHONG WEI

An experimental and numerical investigation of double laser beam bilateral and simultaneous welding is carried out in this paper. A dedicated heat source model is developed based on a combined heat source with coordinate transformation and mirroring. Several groups of heat source parameters are assigned, and the simulated results based on these heat source parameters are compared with the experimental results. The deformation after welding for a seven stringers welding panel is predicted by finite element analysis. To optimize the welding sequence, four welding schemes are applied to the simulation. Comparing the simulated results, the scheme 3 is thought to be the best weld sequence for the smallest welding distortion.

Subscription Information

BY PHONE — For non-members of LIA, call the American Institute of Physics at 1.800.344.6902 for subscription information.

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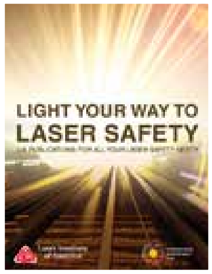

Whether you want to stay current in your career or insure against costly accidents, being armed with the information in these publications is the way to start. Make sure you are laser safe by using the latest and best available laser safety standards, guides and training materials.

We have recently revised both the the *Laser Safety Guide* (12th Edition) and the parent ANSI Z136.1 *Safe Use of Lasers* standard to keep up with advances in the laser industry. The *EVALUATOR Laser Safety Hazard Analysis System* has also been revamped to coincide with the updated Z136.1 standard.

For more information, or to dowload our new product catalog, visit **www.lia.org/store**.

Laser Revolution in Manufacturing on the Advance

Whether additive manufacturing, lightweight carbon production or machining of high-strength steel and hardened glass, lasers are paving the way towards new material and process worlds. The industry will meet in Munich for the leading trade fair LASER World of PHOTONICS from June 22-25, 2015. The laser revolution in manufacturing is advancing with unabated power, which will be shown by exhibitors and leading experts at their exhibition stands as well as in Application Panels and during the accompanying World of Photonics Congress.

More and more companies throughout the world are starting to use additive manufacturing: this technology is on the advance in the aerospace, car manufacturing and mechanical engineering industries, as well as at automation specialists and manufacturers of turbines, implants, jewelry and sports equipment. LASER World of PHOTONICS will present the potential and specific applications of this technology in Halls A2 and A3. The World of Photonics Congress, which will be held at the International Congress Center Munich (ICM) from June 21-25, 2015, will also focus on the young technology in a separate session.

For more information about the show please visit our website at **www.world-of-photonics.com** or contact our US office directly at **fnovak@munich-tradefairs.com**. Visitors can register online to order their Print@home Ticket.

Register Today for ICALEO 2015

Registration is now open for LIA's 34th annual International Congress on Applications of Lasers & Electro-Optics (ICALEO®). ICALEO 2015 will take place Oct. 18-22 and will be held in Atlanta, GA. ICALEO has a 33 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. 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.

There is still time to be an ICALEO sponsor or exhibitor. At ICALEO, your company will have the opportunity to increase conference-wide visibility, maximize awareness and generate sales leads. Unique to the industry, ICALEO attracts more decision makers to one place than any other laser processing event. Please contact Andrew Morrison, **amorrison@lia.org** for more information, or download the Sponsor/Exhibitor Brochure at **www.icaleo.org**.

Save the Date for LME 2016

Mark your calendar to attend LIA's Lasers for Manufacturing Event® (LME®) Apr. 26-27, 2016 in Atlanta, GA. LME is the place to see the latest in laser technology, network with the industry's elite and find solutions to current and future manufacturing needs. Our mission is to provide a one stop event for companies interested in integrating laser technology into their production. Attendees of LME can visit the show floor theater for keynote presentations on trending topics in the laser industry, attend expanded free educational sessions to understand why laser technology is the future of manufacturing and where and how it is applied, and connect with suppliers who can help you to benefit from using lasers in your manufacturing. For more information as it becomes available, visit **www.laserevent.org**.

Sign up today for LME 2016 to come and showcase your company to Buyers as an LME Sponsor or Exhibitor to reach your target audience. LME attracts Buyers that want to learn more about lasers, inquire about using lasers in their manufacturing process, and find out how lasers can help them. For more information, please contact Andrew Morrison at **amorrison@lia.org** or call 1.800.34.LASER.

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