LASERS IN MANUFACTURING: A FUTURE DRIVEN BY TECHNOLOGY

IN THIS ISSUE:

- Diode laser cutting
- Remote metal cutting
- UV micromachining
- Cutting glass & sapphire
- Laser micro welding
- Laser market review
THE LASER USER

Editor: Dave MacLellan
Sub-Editor: Catherine Rose

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The Laser User is the house magazine of the Association of Industrial Laser Users. Its primary aim is to disseminate technical information and to present the views of its members. The Editor reserves the right to edit any submissions for space and other considerations.

Authors retain the right to extract, in part or in whole, their material for future use. The Laser User is published quarterly in February, May, August and November by AILU for its members and is available in print or online.

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AILU has a new logo - after 20 years, the logo is getting a crisper and more contemporary look. During the next few weeks we will be replacing the logo everywhere it is used. If you have the AILU logo on your website just get in touch and we can email you the new versions.

WELCOME TO NEW CORPORATE MEMBERS

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Elected until 2018
Paul Goodwin  (TWI)
Roger Hardacre  (ALT)
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Louise Geeke  (Croft Additive Manufacturing)
Nick Longfield  (Rolls Royce)
Stuart McCulloch  (SPI Lasers)

Elected until 2016
Jon Blackburn  (TWI)
Gerry Jones (Trumpf)
Stan Wilford  (IPG Photonics)

Co-opted
Duncan Hand  (Heriot Watt University)
Louise Jones  (KTN)

Past presidents and founder members are also able to attend committee meetings.

Anyone wishing to join the AILU Steering Committee please contact the Executive Secretary.
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FIRST WORD

In October I attended my first AILU Job Shop Annual Meeting hosted by Yamazaki Mazak in Worcester, a factory I had visited in 1989 when it was almost brand new, but which has grown considerably in the intervening years. Of course, the factory is no longer brand new, but it is still impressive as an example of Japanese production planning, control and lean manufacturing.

There has been much talk about engaging with industrial end-users of lasers within AILU and the Job Shop SIG is the largest end-user community within our Association. Job shops also consume large amounts of steel and the outlook for the UK steel manufacturing sector has been much in the news recently. The “triple whammy” of a low oil price, a strong pound, and the effect of fierce competition from China (with half the global steel market) has led to significant problems for UK steel producers and the inevitable announcement of deep cuts. I was encouraged that UK Job Shops are still upbeat with several growing faster than ever, but inevitably the oil and gas industry decline will have a knock-on effect on business and jobs for many others in the supply chain.

We also saw the launch of our new SIG at TWI in Cambridge during our welding workshop which was attended by 65 people. This workshop received great feedback and over 20 people expressed interest in joining the SIG. You can see a review and some photos from the event in this issue too.

Next month sees our first ever workshop on Laser Surface Engineering, hosted by the University of Chester’s Laser Engineering and Manufacturing Research Centre (LEMRC) which promises to be a great opportunity to find out about new applications and new laser sources for innovative surface modification.

Also in this issue is a summary of the feedback from the AILU satisfaction survey I circulated over the summer. Thanks to the 60 people who responded, you can see a summary of the results later in this issue of The Laser User.

SHARP COMMENT

It’s been a struggle to find the time to sit and write an article for this magazine as I am bombarded with tight meeting deadlines and administration forms, as well as writing and updating umpteen lectures. This on top of all my other activities - and contrary to popular belief there was no let-up over summer!

I always feel slightly guilty writing such comments when I remember the pressure of industry, with the imperative to drive a strong business and maintain employment, especially in smaller companies, where such pressure can be intense.

Pressure forces people to focus on time management and prioritisation. Activities that were once routine now require justification to the point of extinction. While this can reduce inefficiencies, ultimately it undermines some activities that are beneficial to the enterprise, especially longer term.

This is perhaps most evident in areas such as networking and physically attending workshops, seminars, conferences, or visiting companies that may not satisfy an immediate relevant need for your company. Attending exhibitions and trade shows I have seen numbers fall, shows reduce in size, and visitors tail off drastically each afternoon.

We live in a “connected world” so this reduction in “physical” networking might not be a problem. Am I just old fashioned for hankering after it? I don’t think so.

There is something unique and spontaneous about face-to-face conversations. Strolling down the exhibition aisles, discovering a product or process you never realised existed - catching up with old friends, old colleagues, even your competitors! And of course, some gossip, the sort of “intel” that you won’t find on social media or the company website. Sometimes it is simply a case of reminding people that you and your company still exist!

Hence I believe attending events remains important and is largely irreplaceable. It is a vital function of the Association to provide suitable events and, more importantly, networking time within them. Like many others, I think AILU does this exceptionally well, with ILAS a highlight.

Martin Sharp
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PRESIDENT’S MESSAGE

Welcome one and all to the Autumn edition of The Laser User. There has been a lot going on over the summer and that trend continues as the leaves fall and the temperature (outside at least) begins to drop. Our new Special Interest Group in Power Beam Processing was launched in great style with a cake and brief but important speech by its new Chair Nick Longfield, during an excellent event that compared and contrasted different welding technologies, kindly hosted by TWI in September. There is significant interest from the community in joining this new SIG and we hope that it will reap benefits over the months and possibly years to come.

The new sub-group looking at end user engagement has also “met” via two conference calls and we are developing a strategy and content in support of growing our membership.

In fact we have had a number of new members in the last couple of months and we are aiming to accelerate that growth.

There has been good progress on the UK Strategy for Industrial Growth in Laser Enabled Manufacturing Processes which AILU is co-ordinating alongside the EPSRC CIM in Laser Based Production Processes. Working groups from across industry sectors have been populated with willing and very able experts from across the patch. The launch event for the strategy working group will be announced soon and then it will be all systems go for completion of the strategy in 2016.

Generating a sound and sensible strategy relies on getting the process right and I was reminded again of the importance of the process bit of “laser processing” during the recent workshop hosted by the Precision Manufacturing CIM at Photonex. A number of talks concentrated on the control, measurement and careful consideration of the process. The old debate of which pulse length is best nsec, psec, fsec is still raging on but as was pointed out if you get the process right then you can achieve equal quality results with pretty much any laser system you choose. There are of course caveats to this but the message - concentrate on the process and the results will come - is a good one to keep in mind.

Finally I was disappointed not to be able to attend the latest Job Shop meeting this month but I am informed that it went very well and you will find a report on the event on page 16.

Do check our calendar for the next events coming up and I hope you enjoy this edition of our magazine.

Ric Allott
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The 2015 AILU Satisfaction Survey online was circulated via email and social media and 60 people responded to it. Thanks very much to all who responded, the lucky winner of the prize draw was Mark Millar from Essex Laser who received an Amazon voucher for £25, see below.

The Survey respondents were drawn from members and non-members and some valuable feedback was gained about how AILU is doing and the various functions and services that it offers to members.

Gender and Age of AILU Members
AILU membership is 93% Male and 7% Female and the survey respondents roughly matched this. Around 82% of respondents to the survey were over 45, so this indicates a need to attract more female members and younger members to take AILU forward in a more representative manner.

Occupation or Status
Roughly half the respondents were taken from Job shops, end users or laser integrators and over 20% were from academia. There was a reasonable percentage of end-users (more than 10%). 88% of respondents had been using lasers for more than 10 years, indicating that perhaps AILU is not recruiting enough new users and/or younger members.

Gender and age distribution of respondents

Important AILU Benefits
In terms of what AILU benefits are most important, respondents clearly ranked news, networking, information and events as highly important (these were all picked by over 2/3 of respondents). These points also came out in the free text responses where people highlighted how AILU is most useful to their organisation.

Satisfaction with Publications
The Laser User Magazine scored very highly for both format and content, so in this issue you will see that the changes that have been made are not dramatic in terms of content.

The e-Newsletter was also very well received and with high scores for content (slightly lower for format) – the latest issue of the Newsletter (November 2015) was sent using Mailchimp to address some of the format issues.

The websites (AILU and Design For Manufacture) are showing some signs of age and need to be revamped (both for content and design) to make them easier to access, less cluttered and easier to navigate.

Finally the ILAS was also rated highly but with some comments about making it more appealing to end users and vetting the presenters and topics more carefully before finalising the programme.

Priorities for Change
When asked for the top priority for AILU to address the following were proposed:

- Growing the global nature of AILU
- More end-users and potential users at events
- Provide surveys and useful market insights
- Improve quality and relevance of speakers at ILAS
- Increase job shop membership and have regional meetings
- Have greater influence with UK Government to promote strategy
- More contact with non-users and linked end-user associations
- Smarter networking to secure funding from Innovate UK or EU
JOINT INDUSTRY PROJECT

A new joint industry project has been announced between TWI and Lloyd’s Register Energy to advance laser additive manufacturing. The project will bring together research and development efforts with real-world additive manufacturing practices to create new industry product certification guidelines. Project sponsors will be able to gain early adoption of ‘approved’ additive manufacturing practices for their products – a competitive advantage in today’s price sensitive market. TWI has considerable experience in additive manufacturing and combined with Lloyd’s Register Energy’s expertise in product certification to achieve compliance with global codes, standards and regulations, this major project will have a significant impact on the energy, offshore and marine industries.

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SPI PRODUCT NEWS

Starting December 2013, SPI Lasers Rugby (formerly JK Lasers) commenced the wind down of its CW Lamp Pumped Solid State Lasers (LPSSL). The total market size for LPSSLs continues to decline, with alternative, more price sensitive market. TWI has considerable experience in additive manufacturing and combined with Lloyd’s Register Energy’s expertise in product certification to achieve compliance with global codes, standards and regulations, this major project will have a significant impact on the energy, offshore and marine industries.

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NEW US DIRECTOR

German company SCANLAB has appointed Amanda Dobbins as Director of New Business Development for the American and global markets to focus on developing laser scanning solutions for applications worldwide. Amanda has 20 years professional experience in working with OEM companies developing systems which utilise lasers, precision optics, and beam steering devices. She graduated with a BSc in Physics from the University of Leicester, UK.

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TRUMPF INCREASES SALES

The TRUMPF Group has registered an increase in sales and orders over the previous year. Both values increased in the past fiscal year, ending 30th June 2015, by approximately 5%. The UK operation mirrors this upward trend and has declared an increase in turnover of 2% on the last financial year to £46.58 m. Of particular importance is the contribution that the company’s TruServices programme has made to this figure. TRUMPF continues to invest heavily in service provision and the popularity of this programme is evidenced by the company’s TruServices programme has made to this figure. TRUMPF continues to invest heavily in service provision and the popularity of this programme is evidenced by the increase of 9% in service related sales which equates to £12.5 m of turnover.

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AM INDUSTRY AWARD

Founder of Concept Laser, Frank Herzog, has been voted Best CEO in the Additive Manufacturing Industry 2015 by the London-based publication “European CEO”.

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INNOVATION AWARD

Open call for applications for the Innovation Award Laser Technology 2016 – closing date January 15, 2016

The Innovation Award Laser Technology is a European research and technology prize provided with 10.000 Euro prize money and awarded at 2-yearly intervals jointly by the associations Arbeitskreis Lasertechnik e.V. and the European Laser Institute ELI in recognition of outstandingly innovative work in the field of laser technology. The call for proposals is open. Closing date for applications is January 15, 2016. Application instructions and information for online-submission can be downloaded at www.innovation-award-laser.org. The official presentation of the award will take place in Aachen’s town hall on April 27, 2016 at the International Laser Technology Congress AKL’16 (www.lasercongress.org).

Application documents and further information: www.innovation-award-laser.org

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**NEW UV SOURCE FOR PLASTIC MARKING**

TRUMPF is expanding its TruMark Series 3000 with the new TruMark 3330 ultraviolet laser. In addition to inscribing glass, ceramics and organic materials, the primary use for the diode-pumped solid-state laser is marking plastics.

Operating at a wavelength of 355 nanometers, the TruMark 3330 opens up new possibilities for labelling plastics. That is because synthetics absorb the energy of the short-wave UV light far better than an infrared laser beam. This may eliminate the need for expensive additives. In this way UV lasers offer significantly better inscription, at greater contrast and optimal labelling quality – along with high processing speed.

**PULSED, GREEN LASER FOR WELDING COPPER**

TRUMPF has developed a pulsed, green laser for efficient welding of copper, the TruDisk 421 pulse. This new disk laser, in pulsed mode, operates at the mean power of 400 Watts, generating laser light at 515 nanometers. Light in the green spectrum solves the problems previously experienced when using infrared lasers to weld copper.

With the TruDisk 421 pulse, copper welding is more efficient, generates fewer spatters and achieves greater reproducibility of the welded seam, regardless of the nature of the surface.

**VISION**

**HAMIAMATSU IMPROVES IMAGE QUALITY**

Hamamatsu Photonics is proud to announce that the peak Quantum Efficiency (QE) of the ORCA-Flash4.0 V2 is now increased to over 80%.

Hamamatsu Photonics is confident that the higher sensitivity ORCA-Flash4.0 V2 allows imaging of previously hidden photons and faster image capture; of particular importance in applications where ultra-low light or short exposure times are crucial.

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**NEW WELDING NOZZLE**

Laserdyne’s new SmartShield™ welding nozzle provides protection against excessive oxidation in the weld area, enhancing laser welding capabilities of the 3 to 7 axes 795, 430 BD, and 430 Versa laser processing systems. Previously published welding data show that positive results are achieved with effective protection from oxygen in the atmosphere during laser welding of a range of materials, which are highly sensitive to oxidation. These include aluminum alloys, copper alloys, titanium alloys, nickel based super alloys and stainless steels including Types 304 and 316. SmartShield provides a high velocity gas barrier that prevents metal sparks from the weld zone contaminating the protective lens cover slide.

**VISION**

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**MODULAR FIBRE LASERS**

Coherent has expanded the company’s fibre laser offering with a new platform capable of delivering output powers to 4 kW and beyond. The new HighLight FL series employs Coherent’s unique modular architecture, which allows OEM customers and system integrators alike the choice of systems with turn-key operation, or modules to build their own custom fibre laser systems. The modular architecture combined with Coherent’s factory service training and qualification program enables OEM customers the ability to benefit from Coherent’s worldwide support infrastructure and the option to directly provide service to their end customers. HighLight FL lasers at all power levels are available with a range of output delivery fibre options optimised for cutting and welding of a broad spectrum of metals and alloys.

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**DIRECT COPPER BONDING**

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**DESKTOP PIEZO DRIVE**

The Ensemble QDe™ is a high-performance desktop nanopositioning piezo drive designed for seamless use with the Ensemble family of drives and controllers. The QDe connects to any Ensemble controller network enabling coordinated motion between piezo stages and servo axes at much higher rates than other controller or drive products. This power and versatility make the Ensemble QDe ideal for single or multi-axis applications ranging from fundamental scientific research to advanced OEM machine systems.

**AUTOTUNING TOOL**

EasyTune™ is the most advanced autotuning tool available in a commercial motion controller. Entirely data-driven, the algorithm largely mimics the process followed by an experienced controls engineer.

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**MARKING SOFTWARE**

SCANLAB AG is releasing the latest version of its laserDESK program to create and execute professional laser marking and material processing jobs. Available immediately, version 1.2 offers numerous new features, including a “Parameter Assistant” to easily optimise all laser and scanner parameters for any processing task.

Deeper integration with SCANLAB’s SCANalign calibration solution enables exactly-positioned marking on every workpiece. laserDESK 1.2 can be used in normal mode, or remotely – for automated execution of laser jobs – or even offline as a pure ‘Office Version’.

**COLLABSIBLE BARRIERS**

Laser Physics have introduced a new range of collapsible laser safety barriers from Kentek Corporation. This new range compliments the rigid EverGuard and lightweight ServiceRight barriers already on offer.

The 5M Flex-Guard™ Laser Barriers ship conveniently and set up quickly. With just 5 major parts including pre-assembled laser blocking panels, these barriers are ready for use in under 5 minutes.

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**SOFTWARE**

**SAFETY**

**MARKING SOFTWARE**

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POLYMER WELDING

ROFIN’s polymer welding system, MPS, is either sold as a turnkey machine or as a functional kit consisting of laser, clamping unit and software for process control. Within less than a year the new polymer welding solutions are already turning out to be a great success.

The MPS family houses a DILAS Compact Evolution laser, operating with 980 nm or 880 nm wavelength and a cw power of 150 – 500 W. A pyrometric process control allows for a constant welding temperature and hence optimised results. The MPS Family offers the ideal laser workstation for various material processing processes.

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ROBOTIC LASER MARKING

When a supplier of automotive engines needed to automate a new cylinder head line, Tec Systems was able to provided an assembly machine, a number of leak testing stations and a robotic laser marking system to identify the components going through the production line.

The laser system supplied consisted of a very compact laser marking head which weighs 10 kg including air cooling. The reduction in volume and weight of the marking systems employed by Tec Systems, combined with improvements in rugged design, allowed Tec to mount the systems at the end of a motion axis or an articulated arm robot, providing a ”mark anywhere” solution.

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NEW AM SYSTEMS

TRUMPF presented new 3D printing machines for metal parts at the Formnext trade fair, November 2015. Both laser metal fusion (LMF) and laser metal deposition (LMD) machines were on display. Both of these crucial metalworking technologies are included in the new TRUMPF product range.

Market demand is growing for 3D printers generating metal components suitable for use in the industrial environment. TRUMPF is the only manufacturer to have both of the pertinent technologies – LMF and LMD – in its product range.

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Inside the laser marking system

Industrial Laser Safety
Today’s state of the art for laser material processing uses standard articulated robots combined with a working head (e.g. Galvo scanners with flat field lenses) according to the individual process (e.g. welding, cutting, cladding). Due to the increasing complexity of work pieces or assemblies and the demand for further reduced cycle times, it is becoming less economic to use this technology.

Laser specialists at ERLAS, Erlanger Lasertechnik GmbH in Erlangen, Germany have developed a new type of tool machine with hybrid kinematics of both, the 3-D scanner by Cartesian Axes and the workpiece by rotating and tilting axes. The ERLASER® UNIVERSAL 522 contains a revolutionary concept of laser beam guidance and a turntable solution for simultaneous loading while processing. This gives reduced cycle times along with highly stable processes and high positioning accuracy for machining small and medium-sized assemblies.

All processes, motions and safety issues are controlled by one integrated solution. The ERLASER® UNIVERSAL 522 was constructed for welding assemblies with many component parts, many weld seams, assemblies with weld seams widely distributed, with butt and fillet welds and with small tolerances for functional measures.

Architecture
The ERLASER® UNIVERSAL 522 stands on a platform combined with a Cartesian X,Y,Z - gantry system. On the Z-axis there is a 3-D post objective scanner. It’s telescope is driven by linear motors to ensure a constant focus spot which has a z-range of 150mm, the mirrors of the scanner are handled by servomotors. All axes of this tool machine are controlled by the above mentioned one integrated solution.

Flexibility
Due to the modular construction and the gantry system, this machine is easily convertible from its turn-table-solution into an integrable system for production lines. The scalable open portals allow even huge workpieces to be processed. Through the exchange of the working head this machine can be transformed from a welding system to a cutting or a cladding system.

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THE NEXT GENERATION OF LASER MATERIAL PROCESSING

LEXUS CARDBOARD CAR IS LASER CUT IN THE UK

Lexus has unveiled a full scale working replica of their IS300h saloon which is inspired by Origami and has been shown at the Grand Designs Exhibition at the NEC.

The car is constructed from 1700 sheets of cardboard which were laser cut and assembled with glue by LaserCut Works from 350 kg of corrugated cardboard sheet.

Powered by an electric motor, the car has LED headlights, working doors and is built around a metal frame.

Using a CAD design of the body created by Scales & Models and supported by DS Smith and NVDK, LaserCut Works of London carried out the laser cutting on a Lotus Laser 100 W CO₂ laser system.

Dave MacLellan
dave@ailu.org.uk

Source and image credits: Toyota UK www.media.toyota.co.uk
**BYSTRONIC FIBRE LASER TRIPLES CUTTING SPEED**

Welsh firm Groundhog (UK) manufactures Health and Safety Executive-compliant welfare units in which staff working on construction projects, railways and other sites can wash, change their clothes and eat. Production of mobile welfare units has doubled over the past few years to 20 per week, while static units have risen from 2 to 5 per week. Highly productive machine tools are needed to support such rapid increases in throughput, together with the use of automation where appropriate.

The latest example of investment in new production plant was the installation in June 2015 of a 3 kW BySprint 3015 fibre laser cutting machine equipped with a ByTrans 3015 Extended 12-shelf system for automated handling and storage of sheet metal. It joined an automated turret punch press installed in 2010 and took over from a Bystronic CO2 laser cutting machine with manual sheet loading and unloading that had been in use since 2006.

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**TRUMPF LASER REMOVES AIRCRAFT PAINT**

Airlines regularly strip the paint off their aircraft and then apply a fresh coat, often using chemicals or abrasive methods such as sandblasting to do so. The problem is that these techniques are expensive, time-consuming, and produce large quantities of waste. In addition, some of the new materials used to build aircraft are very sensitive to chemical and mechanical cleaning methods, so aircraft manufacturers are increasingly seeking gentler and more precise techniques.

LCR Systems B.V., based in the Netherlands, has announced its intention to develop what it calls a “laser paint removal robot” by 2016, which would use a laser to strip all the paint off an aircraft in a completely automated process. The company says it will be compatible with all types of aircraft and markedly superior to competing products in terms of cost and performance. At the heart of the system is an extremely powerful CO2 laser, which is TRUMPF’s contribution to the project. This laser and a robot arm will be mounted on a mobile platform. The idea is that the platform will travel around the aircraft, permitting the laser to remove all the paint.

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**EOS AM SYSTEM USED FOR NEW BURNER**

Design, manufacture and testing of energy-converting micro gas turbines that optimise the combustion of fuels is the specialism of German firm Euro-K. The company has been steadily increasing the effectiveness of systems, concentrating on innovative burner geometry to raise combustion efficiency and lower exhaust gas emissions. In pursuit of these goals, it harnesses the versatility of metal additive manufacturing (AM) technology from EOS.

Whereas the formation of a combustible fuel/air mixture is relatively straightforward with gaseous fuels, liquid fuels present a challenge, as the surface area must be greatly increased. This is generally done by projecting it in a very fine spray using pneumatic, mechanical or pressure differential principles. Consequently, the availability of burners that support the use of liquid as well as gaseous fuels is limited.

Euro-K set out to produce a compact micro-burner that can handle both types of fuel efficiently. Its design freedom was greatly enhanced using AM, with which it has long been familiar, avoiding the constraints of conventional metalcutting and the uneven cooling of castings. The technology is able to produce small batch sizes economically and allows burner assembly costs to be reduced by 20 per cent.

One of the processes the company uses is an EOS M 290 metal AM system. For the design work, CAD software is used that allows data to be transferred quickly and easily to the EOS system following definition of the final shape and size of the burner.

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Matthew Stevenson (left), Design Manager at Groundhog (UK) and David Larcombe, Managing Director of Bystronic UK in front of the automated BySprint 3015 fibre laser cutting cell

TruFlow CO2 laser

New burner can use both gaseous and liquid fuels

To create the optimal burner for use in the micro gas turbines of one of its customers, a Berlin-based plant builder, the Euro-K project team chose EOS NickelAlloy IN718. It is a heat- and corrosion-resistant material that has excellent tensile strength, resilience, and resistance to creep and fracture at temperatures up to 700°C. The new burner is able to use gaseous and liquid fuels equally effectively.

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To keep the surfaces from being damaged, the laser will be carefully programmed to selectively remove one or more paint layers. An optical sensor will distinguish between variations in the colors of the layers and transmit this information to the laser control unit to regulate the laser power. A CO2 laser is a particularly good choice for stripping the paint off an aircraft because its long wavelength lets it remove a broad range of different paints with similar levels of ablation efficiency.

LCR is hoping that its laser paint removal robot will reduce the time required for aircraft paint stripping by 30 percent. In the case of larger aircraft, this method would save two whole days of work. Other positive effects of the new technique include an 80 percent reduction in the costs for each aircraft, clean extraction of the gases, and a reduction of the CO2 footprint by 90 percent.

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LASER METAL DEPOSITION CUTS MANUFACTURING TIMES

A manufacturing method developed by TWI for an EU-funded project could drastically reduce component manufacture times.

TWI engineers have been using laser metal deposition (LMD) to produce net shape thin-walled engine casings for MERLIN, an EC project 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. By traversing both the nozzle and laser, a new material layer develops with precise accuracy and user-defined properties. The application of multi-layering techniques allows 3D structures to be created.

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 plugin to TWI’s ToolCLAD software: a software package being developed at TWI specifically for the LMD CAD-to-part-manufacturing process. The plugin 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.

Another innovation is the use of an adaptive slicing algorithm which varies the lead distance (distance the nozzle moves away from the substrate in one complete revolution) of the helical tool path according to the tilt angle of the substrate. Without this feature, printed parts would have a sizing error in the Z direction.

Precision and versatility

By manipulating the substrate, and minimising the movement of the LMD nozzle, features such as overhangs can be generated, with a vastly improved surface quality, without the need for any supporting structure. This leads to some impressive statistics:

- Component: helicopter combustor casing (Turbomeca)
- Material: Inconel 718
- Size: 300 mm diameter x 90 mm tall.
- Weld track: 0.9 mm wide x 0.2 mm deep x 0.5 km long.
- Dimensional variance from CAD: 0.16 mm (average)
- Surface finish: 15 microns RA (average)
- Build time: 7.5 hours

The final part has received no heat treatments or surface conditioning

Bringing real-world benefits

The high integrity of the final part allows it to be removed, without distortion, from the substrate. However, a final heat treatment step would be required to alleviate residual stresses that build up during manufacture.

The combustion casing is currently being assessed for suitability in prototype part manufacture for engine performance testing. If the process is accepted, manufacturing lead times would reduce from several months to several hours.

The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2011-2014) under grant agreement no 266271.

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NEW CUSING SYSTEM FROM CONCEPT LASER

Dutch company the Blok Group develops and produces high-quality components and solutions for demanding industries, including aviation. The Group has invested in two new laser melting systems from Concept Laser. They include an X line 2000R system and a new M2 cusing system.

The new X line 2000R at Blok will be the first system of this scale in the Netherlands. It currently offers the largest build envelope for laser melting metals. Its dual laser system is based on two 1,000-watt lasers and features a new sieving station that uses a quiet vibrating sieve instead of the tumbler sieve.

The X line 2000R

The concept is compact; the oversized particle container is now smaller, and has been integrated into the sieving station. The dose unit has also been redesigned; it is now filled completely and fully automatically within one cycle.

A new M2 cusing system by Concept Laser has been redesigned and the laser and filter are fully integrated into the system. The surface area of the filter has also been increased fivefold. Moreover the M2 cusing is fitted as standard with a water-submersible filter in order to guarantee safety when changing the filter.

M2 cusing system

This system will be used in future to build medium-sized 3D geometries, positioning Blok as a comprehensive service provider for laser melting metals in the Netherlands. Installation of the new capacity started in August 2015 with the M2 cusing, followed by the X line 2000R in Q1 of 2016.

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Five-axis manufacture of the helicopter engine combustion casing

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, out of the substrate. This 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.

THE CONCEPT IS COMPACT; THE OVERSIZED PARTICLE CONTAINER IS NOW SMALLER, AND HAS BEEN INTEGRATED INTO THE SIEVING STATION. THE DOSE UNIT HAS ALSO BEEN REDESIGNED; IT IS NOW FILLED COMPLETELY AND FULLY AUTOMATICALLY WITHIN ONE CYCLE.

A NEW M2 CUSING SYSTEM BY CONCEPT LASER HAS BEEN REDESIGNED AND THE LASER AND FILTER ARE FULLY INTEGRATED INTO THE SYSTEM. THE SURFACE AREA OF THE FILTER HAS ALSO BEEN INCREASED FIVEFOLD. MOREOVER THE M2 CUSING IS FITTED AS STANDARD WITH A WATER-SUBMERSIBLE FILTER IN ORDER TO GUARANTEE SAFETY WHEN CHANGING THE FILTER.
WORKSHOP REVIEW

Laser and Electron Beam Welding

22 September 2015
TWI, Cambridge

Firstly, thanks again to all the speakers, exhibitors and attendees for supporting a successful workshop, particularly those that travelled far. This is hopefully not too wild an assumption, as I’ve yet to see the feedback, but in contrast to the last AILU workshop I chaired at the very least there were no power outages to contend with.

All the presentations gave good stimulus for discussion around the increasing overlap between the processes, and on topics where there is good opportunity for knowledge transfer between the electron and laser beam processing communities – for instance, beam profiling and tailoring the energy distribution. Personal highlights were the presentations from the industry perspective (Nick Longfield, Jan Lundgren and Didier Horlaville), and from Markus Kogel-Hollacher on Precitec’s new IDM system for penetration depth control.

Despite being billed in some quarters as a ‘winner takes all’ battle between the photon and the electron, my perception of the consensus amongst the attendees was that the processes remain complimentary to each other and the growing areas of overlap between the processes should provide further opportunities for collaboration and knowledge sharing between the communities. As Jan Lundgren highlighted in his presentation, the choice between electron and laser beam technology is more often steered by a wider range of organisational factors – for example, existing machine availability or the historical preference of the manufacturing engineer – rather than just the absolute process advantages and disadvantages.

This consensus should provide a good platform the Power Beam Special Interest Group to move forward with – when’s the first meeting Nick?

Jon Blackburn
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EVENT REVIEWS

NITTO FIBERGUARD

Nitto Europe has launched a new generation of process tapes, the Fiberguard series.

Fiberguard is a surface protection tape that protects stainless steel surfaces during both CO₂ and fiber laser cutting processes. Fiberguard combines a white printed PE carrier with a release layer and pressure sensitive modified rubber-based adhesive. It has been especially designed to ensure that no pre-cutting is required, thereby saving users vital production time.

The white knight is the standard in stainless steel protection.

Nitto
For more information, contact our preferred distributor PTL

PTL
Protective Tapes Ltd

Staffordshire, United Kingdom
Tel +44-1782-833560
info@protective-tapes.co.uk
AILU was launched on 1 November 1995, at the National Motorcycle Museum, Solihull, as an independent body with a constitution to provide focus for industrial laser activities in the UK. The Formation Committee consisted of President Bill Steen; Vice Presidents Paul Hilton, Malcolm Gower, John Powell, David Price and Tim Weedon; and Executive Secretary and Treasurer Mike Green.

What better way to celebrate the 20th anniversary of AILU’s launch than a gathering of current and past committee members, including most of the original committee officers mentioned above. A celebratory dinner was held on 28th October at the Banbury House Hotel, Oxfordshire, the evening before a full AILU committee meeting on 29th.

The evening also presented the opportunity to say a fond farewell to Mike Green, who has been the Executive Secretary since the launch of AILU, and to Mike Barrett, who has been the invaluable technical support behind AILU’s IT requirements for almost as long. Dave MacLellan presented gifts including beautiful clocks with laser-engraved personalised panels on the back.

Mike Green and the celebration cake

The Centre for Innovative Manufacturing (CIM) in Ultra Precision organised this 1-day seminar and networking event to run at the Photonex 2015 Exhibition in Coventry at the Ricoh Arena. This was a joint event with the Centre for innovative Manufacturing in Laser Based Production Processes. The Centres’ events are usually held at locations where the attendees can visit either scientific facilities or see some industrial processes in action. This was the first time such an event had been run alongside a trade show, but its success suggests it may not be the last time.

Although the presentations had come in completely independently, there was a general theme on the day pointing at the process and control of the laser itself still requiring some research before its application is fully understood in all these manufacturing processes. While the laser is obviously not a new tool in the manufacturer’s arsenal of processing technologies, there is quite a lot of work still ongoing to fully characterise the parametric optimisation of lasers for specific processes and specific materials and it was encouraging to see so much of this manufacturing research ongoing in UK universities and research groups, and the application by the industrial laser suppliers.

The event was very well attended and delegates were provided with an extended lunch period to visit the Photonex exhibition in an adjacent hall. The feedback from delegates was extremely positive and there would appear to be a good appetite for advances in laser processing for ultra precision manufacturing in the UK, both in industry and academia. These networking events are intended to help bridge that gap, showcasing both academic research and industrial application of emergent technologies.

It would be quite easy to come away from this event, covering such a broad range of laser based applications; marking, cutting, surface texturing and finishing, drilling and metrology, believing that lasers were the solution to all ultra precision manufacturing in the UK, both in industry and academia. But there are still application areas and requirements that can’t be met by laser-based processes alone and the Centre will be visiting some of these subjects in 2016, keep an eye on the events calendar on the website: www.ultraprecision.org/events 

ADVANCED ENGINEERING

This event took place on 4-5 November 2015 and AILU had a stand at the exhibition in the Performance Metals Engineering area. On the Wednesday, Dave MacLellan gave a presentation titled “Past, Present, Future: An overview of laser material processing in metals" which was part of the Open Conference programme running alongside the exhibition at the NEC. The talk presented how lasers have improved in efficiency and what sort of applications are of interest in metals material processing. The audience was around 60-70 people and there were several questions and people wanting to chat at the end, with interest in aluminium marking, hardening, surface engineering, composites and cladding.

Thanks to Ric, Tony, Martin, Louise, Liz and Cath for helping with stand duty. We had several people interested in joining and were able to catch up with existing members and others interested in applying laser technology. It would be good to hear how other members found the show.

Dave MacLellan
dave@ailu.org.uk

ULTRA PRECISION MANUFACTURING

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Martin O’Hara
National Strategy Manager for Ultra Precision, EPSRC CIM
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Laser shock peening (LSP) is considered a hot topic for global research. Most of the work has been conducted in the area of LSP of metals and alloys, however, applied research and literature in LSP of ceramics is scarce. One of the reasons why this type of research with difficult-to-process materials draws interest is because a successful technique to surface engineer advanced ceramics would open new avenues for their use in demanding applications where metals fail.

The work undertaken using the EPSRC laser loan pool grant (NSL4) using a 10J ns Nd:YAG laser system was used for the first-time ever at the LEMRC and has already led to many key achievements in a relatively short-time scale. Our ongoing work on LSP of advanced ceramics has generated technical articles, national and international industrial partnerships and will hopefully save lives of end-users by implementing LSP to military applications. Further work on LSP in metals/alloys will also be carried out.

**HIGH RADIANCE LASERS**

The ‘brightness’ (radiance) of lasers is a term that is generally not given much attention in laser applications or in published literature, although it is theoretically and practically an important parameter in laser material processing. Researchers at LEMRC have so far established that radiance of laser beams plays an important role in laser processes such as laser surface treatment, whereby, a high radiance laser beam applied with identical processing conditions generates, sharper and more localised laser beam foot-prints, deeper penetration and in turn is cost effective in comparison to the conventional low radiance laser. Radiance density has also been established as a new parameter that should be adopted in laser material processing and is an effective means to characterise laser beams in general. Current and further research focuses on a complete comparison of high and low radiance lasers to a wide range of materials followed by a cost/watt analysis for various materials and laser systems. This work could lead to improvement of laser design and laser processes such as, sheet-metal cutting; precision mass production marking; large area engraving; laser welding; deep drilling; laser peening and surface treatment in general.

**HIGH SPEED WELDING**

This research is focused on the high-speed laser welding of thin sheet metals. The quality of high-speed laser welding is generally restricted due to several welding discontinuities that occur with the change of traverse speeds. LEMRC research has already focused on a study of the production set-up by a food can manufacturer followed by an experimental investigation which showed that it is possible to obtain a laser welding speed of 98 mm/min to join 0.4 mm thick steels with minimal welding discontinuities using a plasma augmented laser welding arrangement (PALW). Current and future research involves modelling of high speed laser welding applicable for thin-sheet steels and aluminium to find an ultimate processing window to generate defect-free welds at high speeds. Work on a new design of high speed laser welding system could be used in both the food manufacturing industry and also the double glazing window spacer bar industry. This would provide a commercial advantage for manufacturers and enhance the knowledge of laser material interactions.

**ANTI-MICROBIAL SURFACES**

Bacteria have evolved to become proficient at adapting to both their extracellular surroundings and environmental conditions, making it possible for them to attach and form biofilms in almost all habitats. LEMRC is researching the laser surface engineering of common food industry materials to investigate the properties of contact surfaces as they are key in terms of establishing and maintaining microorganisms and biofilm growth. This is a surprisingly under-researched area and will allow us to understand early bacterial attachment and interaction properties. Modulation of surface topography by laser surface engineering is believed to, importantly; interfere with bacterial cell anchorage, reducing bacterial antibiotic resistance transfer and early results suggest that laser engineered polymeric materials could give rise to a reduction in bacterial attachment.
The annual Job Shop Business Meeting 2015 took place on 14 October at the Yamazaki Mazak European Technology Centre near Worcester. Over 50 people attended the meeting which this year had the theme of Second Operations and included a session on equipment to improve surface and edge finish on laser cut metal parts.

The day started with an overview of the host company Mazak and an introduction to the range of laser systems they offer by Ian White and Gabriele Peruzzo, followed by a presentation about sub contract laser hardening from the perspective of Tony Bransden of Ionbond in Germany. Jon Powell then gave a short overview of laser cutting with two emerging technologies, high power direct diode lasers and water jet guided laser cutting.

After a break for refreshments there was a short presentation on “how to sell your business”, and presentations from three suppliers of automated surface and edge finishing systems for metal parts, under the theme of “second operations”. Next were three commercial presentations relevant to Job Shops. Taneli Pokkinen from SSAB Swedish Steel described the laser cutting performance of some special grades of steel, Peter Olle of ipLaser presented the latest version of their online quoting and estimating software and then Stuart Wilders of BOC explained about their CRYOCLEAN cleaning system using solid CO₂ or dry ice to clean parts.

Matt Brown presented the results of the 2015 Breakdown Satisfaction Survey, and the Job Shop Committee presented a gift to Mike Green to thank him for the 20 years of AILU support for the UK job shop community. After lunch there was a lively Q & A session including discussion about selling your own business and some of the potential pitfalls if the process goes wrong. There were also some interesting discussions about raising customer expectations regarding deburring and whether this step is or is not included as part of the standard service. Generally it was felt that customers’ expectations are steadily increasing and that it might be necessary to offer this service. Many members were doing this manually at the moment so further exploration of the automated systems might be very beneficial. At the end of the day, there was the opportunity to tour the Mazak factory which was very impressive.

Mike Green (centre) receiving his laser engraved gift from the Job Shop Committee. Pictured with Mike are (left to right): Dave Connaway (Cirrus Laser); Dean Cockayne (Midtherm Laser); Neil Main (Micrometric); John Powell (Laser Expertise); Charles Dean (Fimark); Mark Millar (Essex Laser) and Matt Brown (Subcon Laser Cutting)

One rule for the big crooks...

Set in a laser job shop this crime novelette, written by Dave Brown (grandfather of Matt Brown of Subcon Laser Cutting), has just come to our attention. Titled “One Rule for the Big Crooks” you can find it on Amazon and some other online booksellers. Want to know more about the plot? You’ll need to read it!

Laser engraved ball bearing created by Charles Dean, Fimark

Dave MacLellan
dave@ailu.org.uk

‘One Rule for the Big Crooks’ by Dave Brown Paperback 206pp
Hamilton & Co Publishers October 1998
I'm very pleased to say that Jobshop 2015 seemed to be a resounding success. I think everybody that attended was impressed with the Mazak facility and although we had a slight hitch with the programme of events at the last minute everything seemed to come together. I hope that you all took some knowledge home with you.

I've managed to hand over the chairmanship of the jobshop committee to Mark Millar from Essex Laser and wish him all the best for the next two years. Over the last two years I've seen some changes to the committee and also to laser jobshop business. Although I think on the whole things have continued on the straight and narrow.

There seemed to be quite a bit of enthusiasm expressed during the event so I would encourage those that are keen, to join the committee and put their ideas forward.

Outgoing Chair: Dean Cockayne
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After managing Essex Laser Job Shop for over 10 years, I finally have a promotion, to AILU jobshop chairman! Unfortunately I soon learned that it wasn’t a paid position so I’ll have to keep the day job too.

I’d like to thank Dean Cockayne for all his hard work over the past two years and especially for his help at Jobshop 2015 which was a very enjoyable and interesting day. For those of you who didn’t make it, you missed the opportunity to hear some interesting talks and to see Mazak’s production facilities. What impressed me was that a large scale manufacturing facility in the UK is not only able to supply half of Europe but also be one of Mazak’s most efficient facilities in the world.

I take over the chairmanship at a turbulent time in the world of manufacturing. The UK’s steel industry is in crisis which invariably has repercussions further down the supply chain including the viability of both our customers and our own jobshop enterprises. I can’t help feeling the battle cries from those on the picket lines are too little too late for many of the UK steelmakers.

Only time will tell how these recent events will affect manufacturing in the UK but knowing the dynamic nature of our jobshops I’m certain most of you will be thinking the same as me, we’ve been through worse before & we’re still here! I look forward to both the challenge and the opportunity of speaking to you more over the next two years.

Chair: Mark Millar
General Manager
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AN INTERVIEW WITH TOM MONGAN
GENERAL MANAGER, SUBCON LASER CUTTING

Q. How and why did Subcon Laser Cutting start up in Nuneaton?

The company was formed in 1989 by husband and wife Bill and Christine Brown. Bill had worked for Laserlab, an Australian company founded in 1977, servicing and installing their flatbed laser cutting machines. Having worked overseas, Bill could see the potential for a subcontract laser cutting company to service the needs of UK industry. Although Bill came from Essex and Christine from Cumbria, they recognised that the Midlands was geographically a good location, with a significant market for industrial metal forming and a strong manufacturing base of automotive suppliers. By 1993 when I joined the company, it was located in a small unit nearer the centre of Nuneaton with a staff of around 6 people and had 2 Laserlab cutting machines running with Electrox CO₂ lasers fitted to them.
Q. After celebrating your 25 year anniversary last year, how does the company look now?

Currently we have a staff of around 30 and a turnover well in excess of £3 million. We moved into the current building 20 years ago, in 1995. We have 3 flatbed laser cutting machines, 2 have CO₂ sources and one is a fibre-delivered disk laser. We are adding a second disk laser system shortly. As well as flat sheet cutting, we have the advantage of being able to offer 3D cutting with our 5-axis machines which are all fitted with CO₂ lasers. All our current laser systems have been supplied by TRUMPF, and none of them is more than 7 years old. Many of our employees have been with us for more than 15 years, but we have taken on about 5 trainees during the past 18 months, most of them being in the age range of 18-21. We are typically turning out around 50-60 quotations every day and we have a success rate of close to 50% of these turning into orders. Order values range from £60 to £100,000 and there is an extensive range of materials and thicknesses we carry in stock to reduce the impact of delays in the supply chain. The demands of manufacturing are ever-increasing and same-day quoting of parts with delivery completion in 3-4 days is typical for our business. We are also running 24 hours per day to maximise the return on investment in our systems and reduce lead times for our clients.

Q. How have you found being a member of AILU has helped your business?

We have been AILU members for a long time and the job shop SIG within AILU has certainly helped us with advice and support when we have needed it. An example is when we decided, some years ago, to install a nitrogen generator on site to provide our own assist gas for clean cutting. Buying bulk nitrogen is expensive and wasn’t helping our overall carbon footprint. We were able to talk to other AILU members who had some experience in this area as not many people had taken this step before we did. Although we don’t discuss or share customer names, we do help each other out and you will sometimes find that we might send work out to other AILU members, or take in some of their excess work to ensure we can maintain a fast delivery to customers and keep them happy. This helps the industry to cope with step changes in demand and the occasionally uneven nature of the order book.

Q. What advantages does your solid state disk laser offer over the CO₂ sources?

When we first installed the disk laser we were able to compare a few jobs that had previously been processed on our CO₂ lasers. We cut a lot of aluminium and stainless steel, and much of our demand is for material under 6 mm thick. To give a couple of examples, in 3 mm thick stainless steel we were able to cut one component in half the time, and in 2 mm thick aluminium we were cutting 3x faster than on our CO₂ machine. Apart from doing existing jobs faster, the shorter wavelength and smaller spot size also allows us to cut materials like copper and brass which expands the range of materials we can offer to our customers. Previously we wouldn’t have been able to cut these materials owing to their reflectivity and thermal conductivity. Of course, we also see benefits for the CO₂ lasers when it comes to cut quality and speed in our thicker materials, especially over 10 mm thickness.

Q. How do you see the market in 2015 and what things make you successful?

As a job shop we have seen that over the years many of our best customers have either gone out of business, especially in the recent recession, or have reached a point where it made economic sense to bring laser cutting in house. We keep in touch with them though, as experience shows that they might well come back to us in the future. Our business is solid and profitable with around 400-500 customers varying from very small companies with one or 2 employees to large multi-nationals. We have found that there are basically three things that keep our customers loyal: knowledge, experience and investment. Business is built on relationships, people like to deal with people they know and trust and we have a team that is both experienced and knowledgeable. We are specialists in laser cutting and have kept our knowledge up to date, so we are in a position to be able to advise clients at the product development stage to make things run smoothly. As I mentioned before we have many people with over 15 years’ experience, and this means they know our business, our technology, our values and our customers well. And finally, investment means we can stay competitive. Since laser cutting technology is fast developing and the uptake of equipment is huge, we face many new competitors with new machinery. We must be able to offer fast turnaround and competitive prices – and having the latest equipment is essential to delivering these benefits to our customers. Hence, our level of investment is higher than many small companies could sustain.

Q. What investments do you see coming in the near future?

We are already committed to another disk laser system for our flatbed area, however there are always other things that we are looking at, to enhance our business and satisfy our customers. Within the next year we are likely to also invest in a solid state 5-axis system to complement our existing 3 CO₂ systems for 3D cutting of a wider range of materials. I also think that a dedicated tube cutting system and the addition of in-house capability to carry out high quality laser etching and engraving might be on our shopping list for future investments.

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METAL CUTTING USING A 2 kW DIRECT DIODE LASER SOURCE

EHSAN FALLAHI SICHANI ET AL.*

Advances in fibre and disc laser sources have dramatically altered the market place for laser material processing systems over the past decade, especially in welding and cutting. Less well documented is the dramatic improvement in wall plug efficiency and beam quality available from high power direct diode sources. Although direct diode lasers are becoming well established in thin sheet metal welding, laser cladding and hardening, where they have already become a viable alternative to CO2, fibre and disc lasers, this paper reports on the practicality of laser cutting of various metals using a 2 kW direct diode laser source.

Experimental method

The trials were carried out using a DIOCUt direct diode laser source manufactured by LIMO. The source can output a maximum power of 2 kW consisting of four different wavelengths (808, 915, 940 and 980 nm). For the purpose of the cutting trials, a requested power of 1.8 kW was used. The actual power delivered to the workpiece was measured to be 1.58 kW. The source emits a beam with Beam Parameter Product (BPP) of 20 mm.mrad. A beam delivery fibre with core diameter of 400 µm was used and a cutting head with a 54 mm focal length collimating lens and 100 mm focal length cutting lens fitted with standard copper laser cutting nozzle tips with different apertures. Beam delivery components were standard parts from HIGHYAG. An Anorad flatbed CNC positioning system was used.

The materials and thicknesses used in the cutting trials were as follows:

- Mild steel (S275 JR), 6 and 8 mm
- Stainless steel (AISI 304), 3 and 6 mm
- Aluminium alloy (1050), 2 and 6 mm
- Aluminium alloy (5754), 3 mm
- Copper (C101 HH), 3 mm
- Brass (CZ108), 3 mm
- Nickel alloy (718), 6 mm

Optics, nozzle stand-off and laser power were all kept fixed. The assist gas type was chosen according to the material to be cut.

Four parameters known to have major influence on laser cut quality were chosen, as follows: Cutting speed; focus position; assist gas pressure; nozzle diameter.

The following characteristics were assessed on the samples of each material/thickness combination: Dross size; mean height of the profile; kerf width; perpendicularity or angularity tolerance.

For each material and thickness combination, the cutting process was optimised stepwise using one factor at a time, then these results were categorised in terms of the quality of cut (using the measured characteristics above) to reach a semi-optimised parameter set. This experimental phase is referred to as “initial trials” hereafter. A further series of full factorial optimisation trials were then conducted to reach an optimum parameter set for each material and thickness combination. This experimental phase is referred to as “optimisation trials” hereafter.

Additional samples were cut using the optimum parameter set to confirm the repeatability of the results.

Results

Examples of the optimised cut quality are shown for 6 mm thick stainless steel in Figure 1, 3 mm aluminium alloy 5754 in Figure 2 and 3 mm copper in Figure 3.

Introduction

Low power laser diodes have already replaced traditional flash lamps in the pumping of solid state lasers, owing to the narrowband wavelength emitted by the laser diodes which is better absorbed by the laser crystal than the flash lamp radiation which increases the energy efficiency. Additionally, novel beam combining techniques have been developed to create multi-kilowatt “direct diode” lasers without the need for a secondary lasing media. Older generations of direct diode lasers have low brightness (high Beam Parameter Product) and have therefore been used mainly for processes like cladding, brazing and heat treatment. Recently, advances in the field of diode lasers have provided the high brightness beams which achieve the high energy densities required to cut sheet metal with good quality at reasonable speeds. The high energy efficiency of these sources increases the power to weight ratio resulting in more compact and efficient use of space – an asset for end users which reduces floor space required in factories, as well as reducing the levels of demand for mains electricity and cooling water. For industrial use, the low maintenance costs and high diode lifetimes make the direct diode laser competitive with other types of laser source for material processing applications. The experimental results of cutting a wide range of metal alloys are presented in this paper.

Figure 1: 6 mm thick stainless steel sample

Figure 2: 3 mm thick aluminium (5754) sample

Figure 3: 3mm thick copper sample

Initial cutting trials were also performed on 6 mm thickness plates of 1050 and 5251 aluminium alloys. Figure 4 illustrates the samples produced at the highest cutting speed for both grades.

Two sets of initial cutting trials were also conducted on 3 mm thickness brass (grade CZ108), using different assist gases; oxygen and nitrogen. For a given assist gas, the cut quality remained similar over the ranges of different cutting conditions investigated. Figure 5 presents the samples produced at the highest cutting speed with both gases. As can be seen, a marked improvement in quality was observed.
When nitrogen was used as the assist gas. Given this result, in the optimisation trials that followed, brass samples were only cut using nitrogen.

After initial stepwise semi-optimisation of process parameters, a full factorial experiment around the semi-optimum parameters took into account all influential factors as well as their synergistic effects. The optimum set of parameters identified at this stage maximised the potential productivity for that material and thickness combination. For each material and thickness, the samples produced in optimisation trials were assessed visually to identify the optimum parameters. Furthermore, two additional samples were cut using the optimum set of parameters identified, to confirm the repeatability of the results.

For each material and thickness, the roughness, dross size and kerf width of one optimum sample was measured. Optimum samples 6mm in thickness and above were then cut sectioned, metallurgically prepared and photographed under the microscope (Figure 6) to analyse cut edge perpendicularity.

Discussion

For all steel samples, the cut kerfs produced with the DIOCUT source were observed to be considerably wider than would be produced using either CO₂ or fibre lasers. This is due to the large spot diameter (740 µm) produced by the DIOCUT source with the set of beam focusing optics used. Cross-free samples were produced for 6 mm and 8 mm thickness mild steel as well as for 3 mm thickness stainless steel. However a dross free cut was not achieved for 6 mm thickness stainless steel. 6mm thickness nickel alloy samples were very similar, in terms of cut quality, to stainless steel ones of the same thickness. In either case cross free samples could not be produced. This is believed to be largely due to the short focal length of the focussing lens resulting in a short beam Rayleigh length.

Aluminium alloy samples had some dross, which is characteristic of aluminium alloy cut samples regardless of laser wavelength. This is largely due to the high surface tension of molten aluminium, which inhibits its ejection from the kerf. At thicknesses below 3 mm, the dross was soft and could easily be removed without tools. The cutting process window was also found to be much smaller for 1050 aluminium alloy compared to 5251. This was due to the higher aluminium content of 1050, which results in a higher thermal conductivity and reflectivity. For the same reason, the maximum cutting speed achieved for 6 mm 1050 aluminium alloy was half that of 5251 of the same thickness (i.e. 0.2 and 0.4 m/min respectively).

It was also observed that the cutting process window for laser cutting of copper was very narrow. This could be attributed to its high reflectivity and high thermal conductivity. However, a precisely selected set of cutting parameters can produce dross free cuts. Brass samples laser cut with oxygen as the assist gas were observed to have very poor surface quality, due to the formation of zinc oxide on the cut surface. Using nitrogen as the assist gas significantly improved the surface roughness but did not produce dross free cuts even at very low cutting speeds.

Conclusions

Through experimentation, the process windows and optimised results were documented for a range of material and thickness combinations. The 2 kW LIMO DIOCUT source proved to be suitable for certain industrial sheet metal cutting applications, in terms of the cutting productivity and cut quality that could be achieved, including up to 8 mm thickness of mild steel and up to 3 mm thickness in stainless steel, aluminium and nickel alloys and copper. Owing to the relatively large spot size (740 microns) available with the laser source and beam delivery used, the larger material thicknesses of 6 mm could not be cut in stainless steel, aluminium and nickel alloys. Brass in 3 mm thickness was also not cut suitably with the experimental setup.

Acknowledgements

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This article is an edited version of a paper published in the ILAS 2015 Proceedings of SPIE vol. 9657 96570C. ‘Laser Cutting Metallic Plates using a 2kW Direct Diode Laser Source’


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Ehsan Fallahi is currently working at TWI Ltd as a Senior Project Leader where he is responsible for developing, managing and delivering projects in various laser material processing techniques with focus on laser cutting.
Laser remote cutting offers a number of opportunities in the production of parts made from metal sheet. Applications in electric motors, battery foils and metal foam offer a viable alternative to punching or conventional laser cutting. This paper answers questions concerning cutting thickness, cut quality, cycle time and the impact on the material of the process. Future potential is also considered.

Introduction

Laser cutting is the second most widespread laser application behind laser marking or engraving. CO₂ lasers have dominated this market for a long time owing to their availability in the multi-kilowatt range on one hand and their proven reliability on the other hand. Meanwhile, high brightness solid state lasers like disk or fibre lasers have been capturing the market for laser cutting applications as an alternative laser source. Significantly higher cutting speeds of more than 100 m/min can be reached with these sources when cutting thin metal. In reality, due to geometric and dynamic motion system limitations, a typical cutting speed of less than 20 m/min can be achieved for a typical contour of electrical sheet steel as can be seen in Figure 1. This results from intrinsic acceleration and deceleration phases of the linear axes of the flatbed cutting machine. Therefore, a novel remote cutting process was established which does not need cutting gas. The relative motion between laser and work piece can be achieved by means of a galvanometer scanner beam manipulation which allows an almost inertia-free beam movement. It is crucial to have lasers with more 500 W focused to a diameter of less than 100 µm. Laser remote cutting is a fast and cost-effective alternative to fusion cutting for thin metal of less than 1 mm thickness.

Results and Discussion

Remote cutting of metal materials

A lot of developments have been achieved since the first implementation of laser remote cutting with continuous-wave high-brightness lasers and a wavelength of one micron. The economically viable sheet thickness for cutting has increased from 100 microns to 500 microns. The problem of geometric accuracy was solved by adaptive control software. A burr-prevention process strategy has been able to reduce or remove the burr. The limited working field was enlarged by on-the-fly cutting or high dynamic working field batching. Finally the list of materials which can be cut by this process has grown from stainless steel to all kinds of steel, aluminium, copper, brass or even exotic ones like tungsten or lead. But the process properties are as different as the material properties itself. The process is characterised by a repeated ablation of cut kerf material as shown in Figure 2a. The process involves a mix of molten and vapourised material in the process area. The vapourisation is needed to eject the molten material out of the cut kerf. The single pass ablation depth depends on material, laser power, laser intensity, feed rate and existing groove. Figure 2b shows the depth of groove for a single ablation with 1 kW laser power and intensity of 2 x 10⁸ W/cm², as a function of the feed rate for the first cycle for stainless steel.

At 300 m/min a break-even point is reached. Beyond this point, the increase of cutting speed does not significantly decrease the depth, but less cycle time means less cutting time. Unfortunately the geometric accuracy is reduced at the increased speed. Special software tools allow a classification regarding the accuracy requirements and an automatic adaptation of the cutting speed. The increase of laser power does not increase the cutting time linearly. Figure 3 shows the resulting cutting speed for different laser power and identical intensities for a single path speed of 1000 m/min as a function of the material thickness.

Figure 1: Typical cut contour for electrical sheet steel (left) and actual cutting speeds achieved by a typical flatbed cutting machine (right)

Figure 2: (a) ablation cycles of a remote cutting process (b) depth of groove as a function of process speed for stainless steel

Until now the maximisation of cutting speed was discussed. The increase of cutting speed often decreases the generation of burr. The choice of special process parameters near maximum speed could minimise that. Figure 4 shows typical shapes of burr before and after optimisation.

These complex correlations are influenced by the specific properties of the material. In particular, absorption, heat conduction, melting and vapourisation temperature influence the optimal cutting parameters enormously. For a lot of materials the behaviour or rather the strategy to find them out is well known.

Figure 3: Achievable cutting speed as a function of laser power and material thickness
Electrical steels

While manufacturing stator and rotor stacks for electric motors, the processing of electrical grade steels causes changes in the lattice and microstructure. In this context, punching and laser fusion cutting are typically-applied manufacturing techniques. As a consequence, mechanical and thermal stresses are induced within the material due to elastic and plastic deformation or temperature gradient in combination with a large heat-affected zone. Such deteriorations consequently affect the materials magnetic substructure in an unsatisfactory manner. In these days of efficient energy use and sustainable energy production, such wasting of energy is totally unacceptable. Nevertheless, current development efforts often deal with cost reduction and quality improvement for large scale production. Here, mechanical techniques are chiefly applied in order to create a high output volume.

A few years ago, the industry favoured steel grades with a gauge range between 0.5 mm and 1.0 mm. Today, the typical gauge range lies between 0.2 mm and 0.5 mm due to higher energy efficiency requirements for all energy consuming products in the residential, tertiary and industrial sectors. Emerging developments from other applications have today expanded into the field of manufacturing highly efficient electrical machines. In this context, a comprehensive process development was carried out in order to establish new laser remote cutting and surface treatment technologies.

Laser remote cutting beats laser fusion cutting in terms of cutting speed by a factor of up to three, without reducing the degree of flexibility. Depending on batch size and required magnetic performance the electrical machine manufacturer can focus either on maximum output or perfect magnetic performance. In any case, the magnetic performance of laser remote cut laminates is identical or even better to conventional punched or laser cut parts (Figure 6). Unfavourable heat build up can be prevented by selecting the right cutting strategy and process parameters considering geometrical aspects of the part to be cut. In that case, a certain idle time between some cutting cycles can be used for cutting other contour elements without decreasing productivity. Subsequently applied to any cutting process, the laser surface treatment process enables the recovery of manufacturing-related magnetic deterioration, which finally improves the performance of the electric motor.

Remote laser cutting technology offers a smart solution in order to overcome these challenges. Due to the high dynamic beam deflection, cutting speeds of more than 600 m/min are achievable. Most important is the cut quality of the edge. Compared to the state-of-the-art, laser remote cutting achieves perpendicular edge geometry, shown in Figure 5.

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Andreas Wetzig is Business unit manager at Fraunhofer IWS in Dresden, Germany. His current business focus includes laser cutting of metals and non-metals, laser processing of soft magnetic material and dynamic laser beam shaping.
Laser Marking technology has come a long way from simply identifying parts with logos and barcodes. Today the technology behind laser marking is making inroads into the area of micromachining and assists companies from prototyping through to volume production.

How laser marking works
Laser markers work by guiding a laser beam onto the surface of a material. This is carried out by a galvanometer, which consists of two independent mirrors moving in a single axis. As the mirrors are very light, weighing only a few grams, they can move at very high speeds.

To produce the mark, the laser is focused to a very tight spot by a lens. The size and nature of the lens controls the working area of the marker (see Figure 1). There are a number of different methods of laser marking, which depend on the type of laser used and material to be marked.

How long will it last?
A final key metric for choosing a laser marker, is the lifetime of the laser. As the laser light is created in different ways for each of the lasers the lifetimes vary, as shown in Table 2.

Choosing the best marking system
As has been discussed there are a number of factors that determine which type of laser marker to use. The wavelength of the laser must be matched to the material being processed and be able to produce the required mark.

The majority of laser markers today utilise a fibre laser operating in the 1 µm range of the infrared spectrum. These lasers offer a good range of processes at an affordable price.

The fibre laser has the ability to mark a wide range of materials including; wood, metals, ceramics, and certain polymers. It has the ability to mark sub 100 µm features, and although not as widely applicable as a UV laser, fibre lasers are by far the market leader in terms of sales.

Going beyond marking
In normal usage, the laser marker scans the beam once over the part to produce a mark. For some processes, the number of passes may be increased but in general marking remains a surface process. However a laser marker is capable of much more than simple marking.

By scanning the laser beam multiple times it is possible to remove bulk material and then...
the laser marker becomes a highly accurate micromachining tool, capable of machining to depths of 500 µm in materials ranging from copper to stainless steel and aluminium.

**UV lasers enabling**

Although CO₂ lasers can be used to engrave carbon based materials such as wood, and fibre lasers can give good results in both steel and even copper, it is necessary to move to UV lasers to get the most out of a marking system.

When laser light enters a material there are three processes that can occur; reflection, transmission and absorption.

As discussed above the reflectivity of UV lasers is a lot lower than either CO₂ or fibre lasers. This means that the laser light passes into the bulk of the material where it is either absorbed or transmitted.

For metals the laser light is absorbed very close to the surface, however for polymers the absorption and transmission is once again dependent on the wavelength of the laser used.

With the UV laser packaged in an affordable system, even small engineering firms can offer a range of processes, once the preserve of larger enterprises.

**Metal Processing**

UV laser systems can precisely machine a range of metal and alloy materials, such as:

- Stainless Steel
- Aluminum
- Copper
- Tungsten
- Nitinol

**Machining polymers without distortion**

Polymers have long been used in industries from electronics to medical devices. However traditional machining methods rely on mechanical operations that can put stress on the material and require post processing.

A UV laser is absorbed efficiently by a range of materials, leading to a clean and efficient cut without any burn or heat affected zone (see Figure 4). In particular, engineering polymers such as PEEK and Polyimide (kapton) can be processed with a high quality finish.

**Not just flat material**

One interesting fact about machining with a laser, is that it is efficient over a given depth of material. For a standard 100 mm focal length lens, a UV laser has about 0.75 mm ‘depth of focus’.

A UV laser can be used as a tool to speed up the prototyping of PCBs, with the ability to laser etch the copper with ultrafine lines, and drill through holes for subsequent metallisation.

**Selective layer removal**

As shown in Figure 6, there is a difference in the absorption of UV laser by different polymer materials. By taking advantage of the different transmission properties, it is possible to remove outer polymer layers such as nylon and polyimide, leaving inner layers such as PTFE untouched.

**Summary**

Laser markers can be used for much more than is typically specified, with even standard fibre based laser systems being capable of highly accurate 2.5D machining. However to get the most from a laser marker, it is necessary to move to a UV laser, which is compatible with a wide range of materials.

All the images shown in this article are processed by Blueacre Technology’s Quantum-Mark UV.

This article is an edited version of a White Paper of the same title produced by Blueacre Technology and available by contacting David Gillen (see contact details below).

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David Gillen is Managing Director of Blueacre Technology Ltd, founded in 2005 to provide laser micromachining services and equipment to the medical device and electronic sectors. David is also a Senior Lecturer in Lasers at Manchester University.

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**Summary:**

Laser markers can be used for much more than is typically specified, with even standard fibre based laser systems being capable of highly accurate 2.5D machining. However to get the most from a laser marker, it is necessary to move to a UV laser, which is compatible with a wide range of materials.
**NEW TECHNOLOGIES FOR LASER CUTTING GLASS AND SAPPHIRE**

**ANDREW MAY**

Although glass has been around for thousands of years, until recently it has mostly been used for decorative purposes, windows, bottles and drinking vessels. With the rapid development of personal computing in the past 25 years, and the explosion of tablet computers and smartphones this decade, glass is now the material of choice for screens and protective windows on a wide range of electronic devices.

**Introduction**

When compared to other materials, glass has many advantages which have contributed to an increasing number of new applications: it is readily available, can be recycled by melting, is economically manufactured and has many attractive physical properties. Although recent developments in polymer technology have made some inroads into traditional glass applications such as bottles, lenses and drinking glasses, there is a high demand for thin and flexible transparent and durable components which can be only be satisfied by glass, by transparent ceramic sheet, or by using sapphire and other transparent crystalline materials.

Glass manufacturers are producing thin sheets, in the region of 20 to 200 microns thickness for the portable electronics markets, and thicker sheets which are used in the architectural, automotive, aerospace, solar and optical markets. There is a constant desire to make products tougher and more resistant to scratching, cracking and shattering driving the development of new materials (Figure 1). At the same time these materials may not be easy to cut with the speed and quality required to exploit them in manufacturing, especially given their brittle nature.

Laser processing of these materials has always been challenging. Although most of them absorb the CO2 laser wavelength of 10.6 microns, they are largely transparent at the shorter wavelengths of the visible and near-infrared (NIR) lasers more commonly used for cutting with lowest heat input.

**Alternative laser cutting techniques**

Traditional methods for processing glass have required numerous process steps to achieve a high quality result – making volume processing less economical. In general the edge quality, as defined in terms of smoothness and minimal defects, of the cut edge of glass and other similar brittle materials is the single most important factor in determining the strength and resistance to thermal stress or mechanical bending. For this reason the smoother the cut edge, the more advantages in subsequent usage. To achieve efficient cutting with high quality edges there is a trend away from mechanical processing of these materials and towards laser cutting. Over the years a number of alternative laser cutting strategies have been used including:

- **Scribe and break**
- **Thermal glass separation by introduction of a specific stress profile**
- **Pure laser ablation**
- **Bottom up processing**
- **Internal glass scribing optical breakdown with high power density**
- **Classic laser fusion cutting**
- **Filamentation cutting**

Most of these techniques have their own particular strengths and weaknesses, for example scribe and break can achieve excellent results for straight line separation of thin (less than 0.5 mm thick) glass, but is not suited to any non-straight line separation.

Thermal glass separation by introduction of a stress profile, otherwise known as Multi Laser Beam Absorption (MLBA), uses a laser in the NIR wavelength which facilitates the propagation of a crack from the outside edge through the glass as defined by the path of the laser induced stress profile. The edge quality of the glass after this process is near-perfect and it is a zero-kerf application without the thermal effects of cracking shown by other methods. Again there are downsides in the application of this technique which has limitations in the case of closed contours, so applications like hole drilling cannot be undertaken.

Pure laser ablation using a short pulse laser can give good results but is usually a much slower process owing to the need to use multiple passes to ablate the full thickness of the substrate. Typically a speed of 1 to 10 mm sec is possible with this method for material thicknesses up to 0.5 mm. When cutting by laser ablation it is normal to have a taper of 10 to 12 degrees on the cut edge, together with a significant heat affected zone when ablating more than 200 microns deep.

In bottom-up processing the material is removed from the underside of the sheet, and the fragments of ablated debris fall from the ablation zone due to gravity. There are some limitations to this method including the fact that the processing speed is quite slow, typically only a few mm/sec, and strengthened glass is difficult to cut with this technique. Chipping of the edge is also common using this technique.

Using high power densities, created by ultrafast pulses with a focal diameter of less than 10 microns, an internal optical breakdown can be achieved in virtually all transparent materials. This technique enables high speeds, in the region of 1000 mm/sec, but an additional mechanical cleaving operation is necessary to separate diced parts. The scribed area has a higher roughness than other techniques and the fracture process can result in uneven cut walls.

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*Figure 1: Smartphones, tablets and personal electronics require tough transparent windows*
Finally there are two other processes which are very well suited to high speed and high quality cutting of glass and brittle alternatives in production which are considered in detail below.

**Fusion cutting of sapphire and ceramics**

Owing to the extreme scratch resistance and excellent transparency, sapphire has found a place in the watch market – as a protection for watch faces, and the mobile phone market as a window for protecting the miniature camera lens and CCD sensor array within the phone. Being a tough and fairly brittle material, it is difficult to cut with conventional machining. Laser cutting, using lamp pumped solid state lasers, has been available as a process for many years, but the speed achievable and the edge quality have meant that it has not been economically viable for most high volume production applications.

The availability of new pulsed fibre lasers has enabled this application to be achieved with higher cutting speeds per unit of capital cost – and the quality improvements are very noteworthy. In sapphire cutting with approximately 1 micron wavelength (the most common wavelength for solid state and fibre lasers) approximately 85% of the energy is transmitted, 14% reflected and only 1% absorbed by the sapphire. Hence it is necessary to focus the beam to a very small spot to achieve the intensity required, typically hundreds of megawatts per square centimetre, to melt the material.

Once sapphire is in the molten state, the absorption increases dramatically, making it possible to maintain the melt pool and perform a contoured cut. As the thermal conductivity of sapphire is also high, there is rapid heat dissipation into the bulk material, meaning that there is less risk of heat damage around the cut than with conventional glasses. In common with other fusion cutting applications, an assist gas – usually nitrogen or air – is used to blow the molten material through the kerf.

Advances in fibre laser source technology, have led to products such as the ROFIN LASAG LFS150 replacing the lamp pumped sources for reasons of improved beam quality, and the combined higher peak powers and average powers which make the process fast enough to be economically competitive, see Figure 2. The sapphire cutting process with these sources works best when focus is tightly controlled, and it is possible in this manner to avoid any cracks and to minimise edge chipping to less than 10-20 microns. 0.5 mm thick sapphire can be cut in a single pass, and taper is typically less than 2 degrees in this thickness. Surface roughness of less than 1.5 microns can be achieved, and minimum kerf width achievable is less than 20 microns.

**Cutting by laser filamentsation**

A new patented technique called SmartCleave FI is a type of laser filamentation which has proven that excellent quality and high speed can be achieved in cutting very thin or thick glass materials (Figure 3).

The process works by creating very fine filaments through the material, with diameter of a few microns. A laser with pulse duration in the region of a few picoseconds with a very high peak intensity creates a self-focusing beam with a length of several millimetres. This beam is created by a combination of two effects. Firstly the Kerr effect which is a non-linear optical effect where light propagates through the material by altering the refractive index. Secondly, when the intensity is high enough to create plasma within the material, there is a defocusing effect caused by the increase in the refractive index of the plasma on the beam.

These two effects can be used in combination to create a long filament in the range of 1 to 2 microns in diameter, creating a fine hole through the material. The cutting process is achieved by spacing these fine filaments close to each other by moving the beam or workpiece to generate the required geometry. This process can be used in glasses with thicknesses from 50 microns to 10 mm thick (Figure 4).

**Summary**

Single pass cutting of glass and sapphire at speed with excellent quality using the above processes has the potential to be widely adopted in manufacturing of windows for consumer electronic devices using the latest fibre laser technology.

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Companies always strive to increase production and lower associated costs. As technology advances and different techniques are developed, it becomes possible to lower costs, increase production speeds, and enhance product quality. Laser welding has made significant progress in the last 10 years and due to better techniques has been able to improve process applications.

Joining surfaces that are sensitive to heat has been a challenge that has been solved effectively years ago by a welding technique known as wobbling. Wobbling uses lower power and thus lower heat. The key component is the fact that wobbling does not point the laser beam directly at the two surfaces; instead it moves down the welding seam rotating the laser beam in a circular fashion. This allows for the lower power thus alleviating the heat distribution. It melts the surfaces, but not enough to degrade the two metals or change the surface characteristics. The drawback or disadvantage to this strategy is the increased time necessary for the wobbling or circular movement down the weld seam.

BS-Optics has developed a technique that uses the same low laser power as wobbling; however, the weld time has been reduced by over 50%. The weld time for the wobbling application shown in the illustration is 350 ms. The weld time for the BS-Optics Zig Zag technique is 160 ms. The time saving differential between wobbling and Zig Zag is the same across the board for all laser welding applications.

When the two types of welds are cut in half for analysis, it is clear that the BS-Optics Zig Zag technique provides a weld that is superior. A cross section photo of the two welds confirms the inferior quality (porosity) of the wobbling weld as compared to the Zig Zag weld. Superior welds in less than half the time is a game changer.

The Alice working heads were developed to provide the best in line picture quality. With the mosaic image reconstruction, it is possible to work with an image of up to 300 mega pixels. This has a twofold benefit, first, it gives precise graphical programming of the seam position, but also to enable machine vision repositioning of the seams. The repositioning feature of the Noone welding software makes it possible to accurately align the Zig Zag weld in production with a precision of 1-5 microns depending on focus length. The Zig Zag weld geometry is one of 8 available geometries as well as the ability to create custom weld designs.

What about vision inspection for welds in production applications? Normally, a production line has an additional line where vision inspections are completed after the welding has been completed. BS-Optics now has the capability to do in-situ vision weld inspection. VIDI Systems, sister company of BS-Optics, has developed a revolutionary new deep learning based vision inspection software. BS-Optics has integrated this new vision inspection software into their Noone welding software. This intuitive software is able to reproduce a human’s ability to differentiate between what is acceptable and what is defective. It has merged the human ability for cognitive inspection capability with better reliability and consistency. All parts and welds are not uniform and exhibit different patterns and aspects. The VIDI software learns what is acceptable or not by being fed images of good and bad results. It actually becomes more effective as it processes more and more images during the production phase. The image process time is in the millisecond ranges which enables the pass or fail result in production immediately after the weld.

One example of the possible benefit available when combining the repositioning function, Zig Zag technique, and VIDI in-situ inspection is taken from a customer in the electronics industry. They were doing multiple welds on a small part and then inspecting the part after the weld. The time necessary to weld the part was 5 seconds on their production line. This did not
include the time necessary to do the manual visual inspection.

Combining the strengths of the repositioning function, the Zig Zag weld technique, and the in-line ViDi vision inspection, the production time was reduced to 600 milli-seconds, **including** the vision inspection!

BS-Optics is the recognised market leader in ultra-high precision micro laser welding. The innovative and unrivaled Noone Software makes the most challenging applications simple and precise. This has enabled BS-Optics to solve the most difficult micro laser welding challenges.

The Swiss watch industry has embraced the capability of BS-Optics performance and the application solutions have spread to the medical, electronic, and automobile industries. Vast application possibilities are now available due to our power range of 10 up 3500 Watt lasers. BS-Optics was the first to introduce a laser welding system that could actually display the piece being welded during the application process. The on screen picture image of the working field is up to 300 megapixels which translates into ultra-precise positioning possibilities. This was a major breakthrough in the industry and cemented BS-Optics reputation as a market innovator and leader in laser micro welding.

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Figure 4: a defective weld image (a) before and (b) after ViDi in-situ inspection
The laser market has four main sectors which are, in order of importance: lasers for materials processing, lasers for communication, lasers for medical and cosmetic operations and laser for security and military applications. Laser companies either sell a laser source (the laser itself) or a laser system (a system with laser integrated technologies). Laser systems represented a market of $27.3 billion in 2014, which is about 3 times larger than the laser sources market, estimated at $9.8 billion in 2014.

Overview of different laser markets

Lasers in materials processing

Laser systems for materials processing is the dominant market sector accounting for more than 50% of the total market of laser systems when you include Additive Manufacturing: $14.2 billion in 2014 (see Figure 1). The technology is widely adopted for automotive manufacturing for instance. There is a strong design and manufacturing presence in Europe, TRUMPF is by far the major company with a $3.4 billion revenue representing about a quarter of the market. Most of the laser systems companies integrate components made by other suppliers, sometimes acquired as subsidiaries. The value chain is generally composed of 4 elements: laser-beam generation, beam delivery, process environment and workpiece handling. Only 3 companies cover all the components in the value chain: TRUMPF, ROFIN and Jenoptik.

Four “traditional” main processes involve laser technologies: welding, cutting, drilling and marking. Such operations require process gases, waste material evacuation, optimisation of laser power and pulse duration, and eventually efficient handling of the workpiece to achieve completion.

A fifth operation was introduced about 15 years ago: additive manufacturing, or 3D printing. This technology uses a computer-driven laser beam to solidify either a spray containing metals or plastics, or a bed of powder to build up a 3D structure layer by layer. Stratasys (Israel) and 3-D Systems (US) are currently the two main manufacturers.

There are three types of laser technology for traditional materials processing: Fibre lasers (the innovative technology, 36% of the global market), CO2 lasers (the traditional technology with high processing experience, 34%) and Diode-Pumped Solid State Laser (DPSSL) (easy to assemble and with high peak power pulses, 17%). More than 60% of laser systems are based on GaAs diode technologies.

Lasers in communications

Lasers in communications currently represent 20% of the global laser market. Profits in this sector come primarily from lasers based on InGaAsP/InP devices (low power, single-mode lasers with gigabit modulation). Customers are a small group of systems manufacturers: Alcatel-Lucent and Huawei, for example, who use these components to design highly-functional communications systems that meet network requirements. The sector is led by Finisar (16% of the sector revenues in 2014). Most of the companies are US-based but Oclaro (UK) still plays an important part (7%).

Lasers in medical and cosmetic

The medical and cosmetic sector currently represents 10% (about $3 billion) of the overall laser systems market. The European leader in the area of optics applied to medicine is Zeiss Meditec, with many years of experience and reported revenues of more than $1.2 billion in 2014. As much as $200 million may be attributable to laser systems for ophthalmic treatments.

Lasers in security and military

The security and military sector represents a vast and confidential market place. The market volume appears to be modest: only 3% of the overall laser system market (about $1 billion is spent annually according to our analysis). In Europe, France and the UK are among the major producers of military hardware. The major companies that work in this area are typically system designers that buy components through procurement such as BAE, Sagem, Thales, EADS with support of defence/security laboratories that help to design and evaluate systems for these companies such as the CEA or Onera in France. The worldwide leader in military defence spending is the United States, and by a large margin.

Key messages & strategies recommended

Provide value-added laser integrated systems

Currently it is not economical for laser manufacturers to produce these components alone, as laser components turn into a commodity, their prices drop. Strategic development of the laser industry should no longer be focused primarily on the value of laser components but on the development and
integration of lasers into value-added systems. Many companies, such as market leaders TRUMPF and ROFIN, already do this.

Know the specifics of each market

For materials processing:
The introduction of laser technologies in manufacturing is highly disruptive, creating competitive opportunities for manufacturing, because laser processing implements flexible, fast and reactive manufacturing sites that are highly beneficial to both large companies and SMEs.

The European industry is a worldwide leader in traditional laser processing with a strong presence across the entire value chain. Europe’s leading position in the major laser market sector is due to a number of factors:

- High level academic research with schools with a strong background in photonics: Institut d’Optique Graduate School (France), ICFO (Spain), university-trained laser scientist.
- A healthy job market, particularly in Germany, that is rich with opportunities for young graduates.
- Strong financial support from the European Commission for the development and deployment of lasers in industry and from the Federal Ministry for Education and Research (BMBF) for German companies.
- Two significant research projects that foster innovation: the Laser Mega-Joule in France and the HiPer project in UK which have secured long-term funding and will assure that the European fibre laser industry will be continuously stimulated to improve laser designs and optical materials.
- A strong network of industry associations like EPIC (a large number of its members are laser companies) that work to build communication between laser companies and new technologies and new customers.
- A common design structure based on the diode-pumped laser that is used for the simplest compact laser devices as well as the largest industrial and scientific systems.
- A significant network of user facilities that can be accessed by potential customers enabling evaluation of laser performance in specific applications (Fraunhofer, Laser Zentrum, AlphaNov).

Additive material deposition has become an interesting new market with a high growth rate of 20% per year during the last 10 years. It now accounts for 13% of all industrial laser sales. Stratasys and 3D Systems are already big companies by laser standards, approximately the size of Coherent or ROFIN.

Though the technology is very innovative, the process is still time-consuming. Finished parts made by 3D laser deposition are lighter but also less resistant than parts made with traditional laser operations. This explains why these systems are often currently used for prototyping, testing and evaluation.

In order to fulfill the optimistic growth projections for the sector, technology development will need to make progress in the deposition rate.

For communications:
Ten years ago, most of the competitive companies in this sector were European (e.g. Alcatel, Infineon, JDSU), now only Oclaro still has a strong position in the sector, most of the other companies have been consolidated or sold. The sector is now dominated by American and Asian companies.

Lasers in communications have the largest growth rate of the laser market sectors due to consumer demand for higher capacity networks. However, the sales in this sector are mostly for lasers components that are not high value-added systems. Moreover, to meet network requirements, an innovation cannot be introduced until the majority of customers agree to use it. The market evolves into a rise in manufacturing volume and a decline in unit price and margins.

There are many small European-based telecoms diode laser companies that produce innovative devices, mainly for customers developing prototypes that might be suitable for large-scale manufacture. In every case that we have studied, these companies are diversifying their products to meet demand in other sectors.

For medical and cosmetics:
Systems in this sector and particularly in the cosmetic sector have a tremendous potential to capture added value through the integration of up-stream features and capabilities. Indeed, cosmetic treatment uses small and relatively inexpensive diode pumped laser systems and the sector is not controlled by a few large medical equipment manufacturers.

For security and military:
This market is stagnating because of worldwide budget austerity programmes. Civilian deployment of security systems is an attractive supplementary customer base, but will likely make room for low-cost systems, such as burglary protection, that can be manufactured in large volumes. The major interest in maintaining activity in this sector is that military development pushes the design envelope regarding system performance and reliability and as mentioned before, Europe has a strong expertise in laser systems’ design. Spending on laser systems for military applications is dominated by the US and contracts are mainly limited to US companies. For this reason, European companies do not cover the whole value chain.

EPIC – European Photonics Industry Consortium
- is the industry association that promotes the sustainable development of organisations working in the field of photonics in Europe.

Contact: Carlos Lee
Carlos.lee@epic-assoc.com

Carlos Lee is director general at EPIC, Europe’s photonics industry association. As part of the EPIC mission, Carlos works closely with industrial photonic companies maintaining a strong network and facilitating technological advancement.
METAL CUTTING USING A 2kW DIRECT DIODE LASER SOURCE

Ehsan Fallahi et al. (page 20-21)

It's very gratifying to see an article on materials processing with a diode laser source, as a supplier of high power diode lasers it's a topic I've been trying to push for some time. As the author points out, they've gained some acceptance for low beam quality requirements but not any real traction for more demanding applications such as cutting and also keyhole welding. With continued improvements in beam quality and efficiency, coupled with their low cost and compact size, this should be change.

It's a pity that the trials were conducted with such a large spot size. With a BPP of 20 mm.mrad a sub 300 µm spot size is readily achievable given the right optics. That would have enabled cutting with a smaller kerf width and then perhaps then the article could have compared the results with conventional cutting lasers (fibre, disk and CO2), which would be interesting to see. Nevertheless, cross-free diode laser cutting of mild and stainless steel of the thicknesses mentioned is impressive and the team should be commended.

Regarding aluminium, there's an interesting point worth mentioning. At 1.06 µm wavelengths it has an absorption of around 5%, which reduces to a measly 1.5% at 10.6 µm. However, it has an absorption peak of approximately 11% between 0.9–1.0 µm, in other words right at the diode laser wavelength. For aluminium processing this absorption advantage could make the diode laser a compelling choice.

Gary Broadhead, Laser Lines

LASER REMOTE CUTTING OF METALLIC MATERIALS

Andreas Wetzig et al. (page 22-23)

Care needs to be taken with the term cutting speed. In single pass cutting, cut speed and relative translation velocity are the same. That is not true here. The actual cutting speed is the translation velocity divided by the number of passes. Absolute clarity regarding this is needed in any comparison of speeds.

Direct comparison between cutting speed for single pass fusion and remote cutting is unfortunately missing. Remote cutting is described as being both “about one order of magnitude faster” and “beats laser fusion cutting in terms of cutting speed by a factor of up to three” in different places.

Variation of the extent of burr by “the choice of special process parameters near maximum speed” is interesting. It would be worth investigating the effect of changing power and or speed for different passes, similar to the pulse train shaping strategies that have been investigated in percussion drilling.

The article does a good job of highlighting specific areas and applications in which remote cutting has potential.

Katy Voisey, University of Nottingham

MICROMACHINING WITH UV LASER MARKERS

David Gillen (page 24-25)

David makes a good point about how the falling price of UV laser systems opens up both high quality “hard” material marking and small scale micromachining applications to a broader market. He describes an impressive range of applications and processes, all implemented with relatively low cost hardware.

It should be noted that the UV lasers referred to in the article are Q switched pulsed lasers with pulse durations in the nanosecond range and high instantaneous powers. This gives them the ability to mark, cut and scribe a wide variety of materials including metals and ceramics with very high quality.

These systems can be used for microfabrication, cutting, drilling and surface modification. However whereas laser marking processes are typically very fast, micromachining processes can be quite slow because multiple passes are needed to achieve the required depth and surface finish. We will probably see further cross over applications for low cost laser marking hardware in the future, eventually incorporating ultrafast sources. This very much to be welcomed as it broadens the uptake of lasers for new applications.

Paul Apte, Rideo Systems

NEW TECHNOLOGIES FOR LASER CUTTING GLASS AND SAPPHIRE

Andrew May (page 26-27)

This is a very readable and enjoyable article dealing with things that we all handle on a daily basis: phones and electronic devices with glass screens or sapphire windows. Since such parts are now made in their tens of millions, it is important to understand some of the drivers for manufacturing them and this piece clearly sets out the different problems of cutting glasses with lasers.

The pros and cons of different solutions problems of cutting glasses with lasers. The pros and cons of different solutions and this piece clearly sets out the different problems of cutting glasses with lasers.

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The pros and cons of different solutions and this piece clearly sets out the different problems of cutting glasses with lasers.
ease of implementation. No doubt the new filamentation method will be adopted in some cases and how much traction it can get across the entire display device market remains to be seen because a lot of production lines already exist using other approaches.

The results of the new filamentation technique are highly impressive - 300 mm/sec cut rate for 0.5 mm thick sapphire with 1 micron edge roughness and no chipping - but what is not clear from the article is the price level of the ps-pulse fibre laser used for the work. If, as suspected, the ps-fibre laser is going to sit in the same price bracket as many other short-pulse disk (or other solid-state) lasers then this raises another issue: how widespread can this new technology be simply due to its affordability? Although this point is not directly relevant to the contents of this article, it is nonetheless worth commenting on briefly.

It is well known that large multinational companies with worldwide production plants can adopt this kind of method and invest in such lasers (which cost six figure sums) but most development houses and job shops certainly can’t afford to do so. This means that often the latest techniques can only be made to work for ultra-high volume production and not when a SME or start-up only wants a modest number of parts.

The result of all this is that there is often an accessibility gap simply due to the availability of the latest lasers; a production line cannot be diverted just to make a ‘few’ prototypes for a new idea but neither can a small job shop buy the latest disk laser (or similar) because the cost is so prohibitive. So the small company with a new idea may miss out simply because the latest techniques are not yet available to all.

This is not the fault of the laser companies because they are doing an excellent job in selling large units for production but the latest (best) techniques will only really proliferate when more users can truly access their benefits. As in almost all applications of ultrashort pulse lasers, the results are astounding but at a price.

Nadeem Rizvi, Laser Micromachining Ltd.

**BREAKTHROUGH LASER WELDING TECHNIQUE**

Peter Whiting (page 28-29)

Manipulation of the laser beam (‘wobbling’ etc) when welding is becoming more commonplace in industrial applications. These approaches to tailoring the heat source are typically used to address a particular challenge in the joint configuration and/or the material being welded.

There are already a number of industrial examples of zig zag beam manipulation being used for macro-scale laser welding processes, most employing a 1D mirror in the process head (such as the ILV beam scanner). It would be interesting to understand a little more about the limitations of this approach for micro-scale applications, as quite often power modulation is needed to prevent a ‘saw tooth’ weld profile.

Jon Blackburn, TWI

**REVIEW OF THE LASER MARKET WITH A FOCUS ON EUROPE**

Carlos Lee (page 30-31)

This article by Carlos Lee is a very useful snapshot of the laser and laser systems markets in Europe. He concentrates on 4 key areas: Materials Processing, Communications, Medical and Cosmetic and Security and Military, offering some insight into the current size and growth opportunities within each sector.

Whilst mentioning cutting, drilling, welding and marking (and of course the now ubiquitous ALM) he has missed the important area of Laser micromachining which encompasses a whole variety of processes and techniques vital to industries such as electronics, displays and solar power.

By missing this he also misses out on the Excimer laser which though now “old” technology is still a very important work horse particularly for processing of amorphous silicon. However given the more European angle to the article this perhaps is understandable.

In discussing why Europe has a lead in this area he may have also considered the 3 key projects driving innovation under the Extreme Light Infrastructure programme in Czech Republic, Hungary and Romania.

Personally speaking I am not convinced that all laser companies have to become system integrators in order to survive. True there is added value in putting systems together but the supply of cutting edge, high quality, robust and compact lasers is a specialised skill and there are opportunities for companies to enter, expand and grow in the global market.

Finally it would have been good to see a few references for the data supplied – but I enjoyed reading the article and I think that AILU members will find it useful.

Ric Allott, STFC Rutherford Appleton Laboratory

**AILU SUPPORTED EVENT**

The Second Smart Laser Processing Conference 2016

17 - 19 May 2016
Yokohama, Japan

Deadline for one-page digest
25 January 2016
www.jlps.gr.jp/slpc2016
ASSAULT AND BATTERY IN THE APPS LAB

Some decades ago, I assisted with the hosting of a team of engineers from overseas who were looking to complete a set of sample welds on some lithium battery cells. Since we were only looking at the material interaction and the quality of the weld, they were empty cans – nobody in their right mind brings lithium into an application lab, if it can be avoided, due to the tendency to catch fire. All was going well and the welds were looking straightforward, good penetration, overlap and even the bubble leak test was being passed. Then came lunch and we adjourned to the conference room for the ubiquitous 90s buffet of sandwiches and savoury finger food.

After lunch it was back into the lab for some more laser welding. It was then that we found something odd was happening. Although the weld quality still looked good, there was the occasional blow hole appearing randomly during an otherwise perfect weld. A lot of tutting and scratching of heads followed, and the occasional French expletive was to be heard. Consulting the laser parameters revealed nothing different, and time was spent looking down the microscope and trying to understand what could have changed. It was at this point that some large items of debris around the weld were spotted.

Closer analysis suggested crystals of some unknown sort. Looking under the microscope, they looked like large white cubes of a very regular type. A short while later the connection was made with the salted peanuts which had been enjoyed by all during the lunch break, some unwashed hands, and the contaminated samples.

Out came the IPA to give the samples (and hands) a clean with some lens tissues, then another few parts were welded and before you could say “now wash your hands please” we were back in business. All welds now looking perfect and all leak tests passed.

What’s the moral of the tale? Well there are probably several. Washing hands is a good discipline. When you see something start to go wrong, look for what’s changed. Just because something was clean, doesn’t mean it still is (I have seen “cleaning” processes introduce impurities). And finally, weld quality depends on many aspects – all of them need attention.

Dave MacLellan
AILU Executive Secretary
E-mail: dave@ailu.org.uk

WOULD YOU LIKE TO WRITE FOR ‘THE LASER USER’?

We are looking for new content to make The Laser User more interesting, relevant and fun to read. If you would be interested in contributing to the magazine, we would love to have your input and we will do our best to use your words and high resolution images.

We need:
- Press releases
- Personnel & Business news
- Technical Articles
- Observations
- Anecdotes
- Case Studies
- Interviews
- Application guides
- Tips and tricks

To submit content, send by email to cath@ailu.org.uk
Laser Surface Engineering covers a wide range of applications where industrial lasers are used to change the mechanical, electrical or magnetic properties of a surface. Industries which are applying this technology include the automotive, aerospace, energy, military and medical device manufacturing. As well as hearing some of the research being carried out in this field, you will have the opportunity to hear and see some of the latest technology applied by laser manufacturers and a range of innovative applications identified by end users which are already used or soon to be exploited.

Programme

08:45 - 09:30  Registration and refreshments
09:30 - 11:10  Session 1

Welcome
Jonathan Lawrence  University of Chester (Workshop Chair)

Excimer laser surface modification
Zhu Liu  University of Manchester

Surface texturing by ultrashort laser: a roadmap from laboratory to industry
Girolamo Mincuzzi  ALPhANOV

Bio-inspired scale-like surfaces created by laser texturing and their tribology
Christian Greiner  Karlsruhe Institute of Technology (KIT)

New surfaces for new applications
Martin Sharp  Liverpool John Moores University

11:10 - 11:40       Refreshment break & EXHIBITION
11:40 - 13:00  Session 2

Laser peening of ballistic armour plates
Pratik Shukla  University of Chester

Laser surface engineering: a journey from implants to platforms
David Waugh  University of Chester

LIFT printing and laser sintering of wet inks for flexible electronics
Emeric Biver  Oxford Lasers

Scaled-up Pulsed Laser Deposition of Superconductors using Excimer lasers
Eamonn Maher  3-Cs

13:00 - 14:00       Lunch & EXHIBITION
14:00 - 15:30      Session 3

Surface engineering in the photovoltaic industry
Chris Moore  Dyesol

Surface engineering applications using short pulse lasers
Paul Fitzsimons  Fianium

Surface engineering applications for high power diode lasers
Mark Daichendt  Laserline

Surface engineering applications using fibre lasers
Mark Thompson  IPG Photonics

15:30 - 16:00       Refreshment break
16:00 - 16:40             TOUR
Laser Engineering and Manufacturing Research Centre

For more information including how to register see the Events page on the AILU website:
www.ailu.org.uk/laser_technology/events.html
### EVENTS: RECENT AND FUTURE

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**and further ahead:**
May 13-18 2016<br>The Second Smart Laser Processing Conference 2016<br>Yokohama, Japan