The Laser User

Issue 63

Summer 2011

Laser applications for manufacturing: An opportunity for a Photonics TIC

The AILU objectives

The principal objectives of AILU include:

- To foster co-operation and collaboration on non-competitive technical matters and provide a forum and mechanisms for sharing experience and expertise.
- To encourage the expansion of laser use into applications where they can add value and increase company competitiveness.
- To represent and promote the interests of industrial laser users.
- To disseminate professional and other information to members.
- To promote best practice in the commercial applications of lasers in materials processing and allied technologies.
- To support the maintenance and improvement of standards of laser safety and performance.

AILU membership is a valuable source of information concerning laser technology and applications. Benefits include:

Benefits of membership

- Subscription to The Laser User, the leading magazine on laser applications with news and views from the UK and world-wide.
- A 'hot-line' consultancy service provided by members for members.
- Free entries in the AILU Product and Services Directory on the web site.
- Regular meetings, including members-only meetings and open workshops e.g. where key areas of technology are open for discussion.
- Access to the members' area of the web site with lots of technical articles plus frequently asked questions, current laser safety and performance standards etc.
- Major discounts on registration fees for events organised by AILU and affiliated bodies.

the association of AILU laser users

Helping you make the most of laser technology

Courtesy ESP KTN

The front cover picture shows the director of Photonics for the Electronics, Sensors and Photonics KTN, Alastair Wilson, speaking at a recent consultation workshop on the possibility of a TSB funded Technology and Innovation Centre (TIC) in photonics. A nationally funded centre in support of industrial lasers and laser materials processing has long been discussed amongst our members and now there is a real opportunity to achieve this, if this is what our community seeks.

This issue contains a review of the consultation workshop, a message from the AILU President urging a response from our industrial members and information on online sources relating to TIC's. Time will be short: there is every indication that the decisions will have been taken before the next issue of this magazine is ready. Without a swift response from our industrial members the chance to have a national centre could quickly disappear.

Joining AILU

We are a non-commercial non-profit-making organisation driven by a fascination for lasers and their potential in manufacturing, and by a desire to help members make the most of laser technology.

If you have an interest in laser technology and/or applications and are not already a member of AILU, then do consider joining the most active association of users and suppliers of laser-related equipment and services bar none.

The cost of membership is modest and the potential benefits huge.

Apply for membership on line by following the 'AILU membership' link at

www.ailu.org.uk

or simply contact the AILU office at

+44 (0)1235 539595

AILU Pavilion at MACH

In 2012 AILU is supporting its supplier members by taking a pavilion stand at a major exhibition, and has chosen to do so at the Machine Technologies Association's biennial, week long showcase for the UK's manufacturing industry, MACH.

What we need now is for AILU members to support this initiative so that the AILU pavilion properly reflects the critical importance to UK manufacturing of growing the use of laser technology in the UK.

All AILU members, both visitors and exhibitors, can enjoy the benefits of the extensive lounge area within the pavilion and, in a special deal with the MTA, exhibitors within the pavilion can take advantage of a special 'easy exhibiting package' containing everything a company needs to be part of MACH 2012. *All you will need to do is turn up, display your products; everything else will be already done for you.* Pavilion stand holders also benefit from the support available from fellow members and the AILU office staff.

Product and service provider members of AILU (including laser and optics providers, machine integrators, sub-contract engineering provers, through to consultants and universities providing research services) will be able to join up to 500 other industry exhibitors from 16-20 April 2012 at the NEC, where almost everything associated with manufacturing technologies will be on show. Concentrating our efforts in a substantial pavilion located in the heart of the Engineering Laser Zone means that visitors to MACH 2012 will have available a highly visible one-stop service for advice and technical support in laser technology and applications through to hardware and software provision.

MACH 2012
CELEBRATING 100 YEARS
16 – 20 April
NEC • Birmingham UK
machexhibition.com

AILU President Martin Sharp is particularly keen that AILU take this initiative. With 80% of AILU's Corporate members advertising their products and services in the Association's on-line directory, the presence of a pavilion at MACH will demonstrate AILU's engagement with the commercial as well as the technical activities of members.

The 'easy exhibiting package' that the MTA has put together is designed especially to help AILU members who may not have any experience with exhibiting. To request a brochure and for further information:

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WELCOME TO NEW CORPORATE MEMBERS

MBA Engineering Systems Ltd

ArcelorMittal

Raising the profile

AILU is now listed (as 'Association of Industrial Laser Users') on LinkedIn, the professional networking site. A good number of AILU members are already members of the site too. In an effort to broadcast forthcoming events and other news to a wider band of industrialists AILU will now be assessing the benefit of more active participation than has been evident to date.

At the present time 14 people are signed up as 'followers' of AILU. By adding your name you will help raise the profile of AILU and thereby increase the impact and awareness of association activities within the LinkedIn community.

LinkedIn

Technology Transfer in the UK

The new Rolls Royce Manufacturing Technology Centre in Ansty Park Coventry is one of the network of seven research centres that make up the new Technology and Innovation Centre (TIC) in High Value Manufacturing. AILU's Product and Process Innovation Special Interest Group (PPI SIG) is privileged to be the first external organisation to hold a meeting there.

The meeting will take place on 18 August and will discuss the way forward for technology transfer in laser materials processing to UK manufacturing industry. Topics include Rolls Royce plans for the MTC (presented by Clive Grafton-Reed, Rolls Royce, who is generously hosting the meeting), the Photonics TIC proposal (presented by Malcolm Gower of Imperial College, London), the Photonics Fraunhofer Institute proposal (presented by Tim Hoult, Institute of Photonics), and the PPI Virtual Laser Laboratory proposal (presented by Lin Li, Manchester University).

Finally, Mike Green, AILU Secretary, will review AILU's recently completed survey of technology transfer activity in laser material processing in the UK. The full report of this survey is sure to make interesting reading. When complete it will be made freely available to AILU members.

Venue for ILAS 2013

In response to feedback from ILAS 2011 delegates, the next biennial 2-day Industrial Laser Application Symposium, will be a hotel large enough to accommodate the event under a single roof.

The Nottingham Belfry, described as a stylish oasis of magnificent proportions, can provide sufficient accommodation for all delegates, an exhibition area and seminar rooms for parallel sessions.

Group subscription to the e-Magazine

With the arrival of an electronic version of The Laser User, all AILU members now have free internet access to current and past copies of the magazine, and <u>for only £100 a year</u> Corporate members can take out a group subscription so that everyone in their organisation can access the magazine.
Contact *liz@ailu.org.uk* for further details

David English, who will be known to many, retired from Micrometric Ltd on 14th July.

David started life as an apprentice with Ruston and Hornsby in Lincoln where he progressed via a degree in production engineering at Aston University to Production Manager. He moved to Operations Manager at Micrometric in 1992. David also represented Micrometric in the Make It With Lasers Initiative continuously from it's start in 1990 to it's end in 2009.

Always calm and helpful, David is going to be missed not only by his fellow workers at Micrometric but also by many of us in the laser and broader engineering community.

Brooke Ward, 2009 AILU Award winner, recently decided to retire from his consultancy business, Europtics Partnership. Brooke helped found one of the first application's groups in the UK and one of the first industrial laser user's clubs, in 1968 at Culham Laboratory. Throughout, he has been an innovator and champion of laser processing.

Since 1976 Brooke has also been a leading figure in the development of standards and equipment for laser beam characterisation. The health of AILU and the industrial laser community owes a lot to Brooke. The 'Golden Oldies' on p14 provide a small sample of the many contributions he has made through this magazine.

JK Lasers enjoy success at Munich

The 20th Laser World of Photonics exhibition proved extremely successful for JK Lasers, part of the GSI Group, whose new System 5000 and 1 kW Fibre Laser generated considerable interest.

The event was hailed as an overriding success by the whole photonics industry, with many companies agreeing that the show marked a turning point for global manufacturing. According to the show organisers, the exhibition attracted a record 27,500 visitors (up 8% from 2009), as well as over 1,100 exhibiting companies from 80 countries. The global presence was certainly felt by JK Lasers, who received enquiries from USA, Japan, China and many European countries.

The System 5000, a flexible workstation that can be integrated with lasers from both the JK Fiber and Nd:YAG ranges, proved to be a talking point at the show. It was configured to demonstrate a cutting and welding application.

Overall, the company was pleased with the amount of interest that the show in Munich generated and it looks forward to exhibiting again in 2013.

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Laser cell for product development

Laser Mechanisms has recently installed a 3 kW fibre laser cell at its Novi, Michigan, facility for enhancing overall product development and testing capabilities. The Class 1 laser enclosure also contains multiple articulating robots.

As a result of this development, Laser Mechanisms' engineering group have an in-house resource to speed the design process and reduce costs associated with working in an outside lab.

"With all of the success of our recent product introductions for fibre lasers, the last thing we want to do is rest on our laurels," said Laser Mechanisms' CEO Bill Fredrick.

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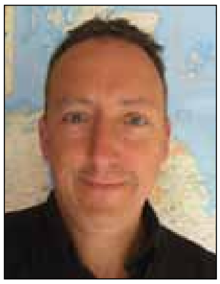
TLM Laser's new sales manager



TLM laser Ltd have appointed Tony Dain as their new sales manager for the UK and Ireland, bringing with him 17 years of sales experience in the industrial laser market.

In announcing this new appointment Andy Toms - Director of TLM stated "This is a new era, TLM is going from a predominantly service led to a product led business, showing a firm commitment to our suppliers that we are a serious player in the market. Tony has an excellent sales record and his broad experience of the laser business sector made him a perfect fit for TLM's requirements. His responsibilities will include the sales of laser marking and engraving equipment from FOBA (Alltec) of Germany, laser micro machining by Swisstec AG and laser cutting systems by Coherent."

"My engineering background played an important role in my progression through sales over the last 17 years," said Tony.

"I'm delighted in having the opportunity to join this progressive company. The market appears to be recovering and more buoyant than several previous years, so I'm excited about the possibility of increasing market share for our partners."

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Rofin receives Intel award

Rofin-Baasel will receive Intel Corporation's Preferred Quality Supplier (PQS) award for its 2010 performance. Along with 15 other companies, Rofin-Baasel is recognized for its significant contributions providing Intel with laser marking equipment.

"We are proud to receive this award for the fourth time in a row and are looking forward to continued success in our partnership with Intel," said Günther Braun, president & CEO of Rofin.

The PQS award is part of Intel's Supplier Continuous Quality Improvement program to encourage suppliers to strive for excellence and continuous improvement.

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Full details of all news items in the magazine, plus additional news items, can be found on the AILU web site

BUSINESS

Laserdyne Celebrates 30th anniversary
March 2011 marked the 30th anniversary of Laserdyne and the BeamDirector© family of multi-axis laser systems.

"Over the last three decades, Laserdyne multi-axis systems have played a part in major changes in component design and manufacturing," reports Terry VanderWert, president of Prima North America, manufacturer of Laserdyne systems. "Laser material processing has given engineers the flexibility to create product designs that are often lower cost with superior performance. Laserdyne technology has affected the design and manufacturing of products vital to a wide variety of industries including aircraft, automobiles, medical devices and turbine engines used in transportation and energy."

"Just as significantly, Laserdyne technology helped give birth to a number of entrepreneurial companies who have helped expand the use of laser technology", reported Mr. VanderWert. "Start-up contract manufacturing companies specializing in laser processing or using laser systems for processing formed sheet metal components began by employing Laserdyne systems. This trend continues today."

"Looking forward to the next 30 years, Laserdyne believes the trend for advanced innovation and increases in productivity will continue," reports Mr. VanderWert. "Designers, process planners and engineers, through continuous improvement programs, are upgrading their designs and manufacturing operations, which results in them presenting us with new challenges. Our research and engineering, backed by deep technical expertise and by the commitment to innovation and quality that are part of the Prima Group culture, ensure that Laserdyne will meet these industry demands and continue at the forefront of multi-axis industrial laser technology."

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Winbro record order intake
Following a significant expansion in the UK workforce and the launch of a new technology, development and production centre in Rock Hill, South Carolina in late 2010, Leicestershire based Winbro Group Technologies announced a record order intake in March 2011.

Delta Laser Drilling System (Left) and HSD6-III High Speed EDM Drilling System (Right) – part of the range of non-conventional machining systems produced by Winbro

Winbro Group Technologies is renowned as a leader in cooling hole technology for aero and land based turbine engines. The company's manufacturing, headquarters in Coalville, serves customers in 16 countries around the world – supplying laser, EDM and ECM turnkey machining systems as well as gas turbine engine components machined within the company's WAM (Winbro Advanced Machining) facility.

In March 2011 the Company booked orders for 14 new machines valued at over £5.5 million. This record achievement includes the first two machines won by Winbro's new facility in Rock Hill, South Carolina. Other orders, received from customers within the UK and Europe, include a Delta Laser system, with the new GSI JK604D drilling laser, and eleven multi-axis drilling machines – the company's EDM small systems workhorse.

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Major re-branding by Prima Industrie
In a major re-branding initiative the Prima Industrie group has been split into two divisions: Machinery (Prima Power) and Components (Prima Electro).

With the acquisition of Finn-Power Group three years ago and the subsequent integration of the two companies, Prima Industrie has become the third largest laser and sheet metal machinery manufacturer in the world.

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Trumpf business news
Sales jump by 51%
The Trumpf Group can look back on the biggest sales increase in the history of the company as it closes out the fiscal year that ended in June. The Germany-based machine tool manufacturer and laser technology specialist recorded sales of 2 billion Euros in 2010/11 fiscal year, an increase of 51%.

"This past fiscal year was the second most successful year in our company's history," said company President Nicola Leibinger-Kammüller in presenting the preliminary figures. "We succeeded in closing the gap to the record earnings posted before the financial crisis."

In view of the company's positive developments, the number of employees rose to 8,550. Trumpf has about 500 positions worldwide to be filled. It seeks engineers, technicians and software developers, among others.

Used Trumpf machines in UK
A new agreement between Trumpf and Severn Manufacturing Systems, the supplier of reconditioned second hand Trumpf sheet metalworking machines, enables UK manufacturers, for the first time ever, to buy a second hand Trumpf machine directly from Trumpf with its original specification guaranteed.

Severn Manufacturing Systems has been the UK's leading supplier of second hand Trumpf machines since the mid-1990s. All refurbishment of the used machines is undertaken by Trumpf qualified engineers at Severn Manufacturing Systems and all procedures are audited to assure quality. A standard 6-month parts warranty is provided by Trumpf from whom ongoing service, support and spares are also available.

At its 15,000 ft² facility in Worcester, Severn Manufacturing Systems currently has a good stock of used Trumpf punch, press brake and combination machines as well as a large range of second hand laser cutting machines. All of these laser machines feature laser resonators that have been stripped and rebuilt at the Trumpf laser technology centre in Ditzingen.

The entire stock can be viewed - and existing specifications downloaded - at the website below.

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SP's Mosaic 532-11 lasers

The Spectra-Physics Mosaic™ laser is designed for micromachining applications in a 24/7 manufacturing environment, where system uptime is critical.

High Reliability
Double the industry average diode life

Field-replaceable laser output window

EternAlign™ optics eliminate damage and optical misalignment resulting from vibration and shipping

Outstanding Performance
High peak powers resulting
Excellent pointing and p-to-p stability.

Simple, Elegant Design
Applications include: Scribing of thin film solar cell layers, ablating material on PCBs and PCB structuring, scribing, silicon wafer marking, edge isolation

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First 10 mm scan head

At LASER 2011 in Munich, Scanlab presented the whole range of scanning solutions for the photonics industry, the exhibits being clustered around "high end solutions", "software and systems solutions", and "standard solutions".

One of the show highlights was the new intelliSCANse® 10 – the world´s first scan head with only a 10 mm aperture.

Other highlights included:

- The dynAXISse® S with an all new, patented digital encoder design, ultra low inertia and uncompromised dynamic performance.
- Solutions for inline laser edge detection and through the head machine vision

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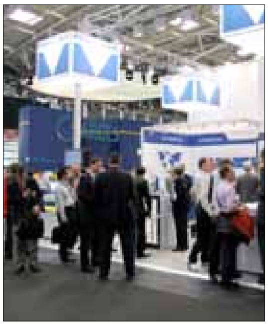
Precitec range on show



Some of the key items on the Precitec stand at LASER 2011 Munich were:

- The YW52 high power welding head with controlled welding position and weld width. The WobbleTracker measures the joint transversely and in the Z direction, only a few mm in front of the TCP.
- New - the small, compact coaxial cladding head YC30. This head is suitable for standard laser powers and can be used in both horizontal and vertical positions.
- The well-known coaxial cladding head YC52 with different nozzle concepts and a new motorised collimation adjustment system.

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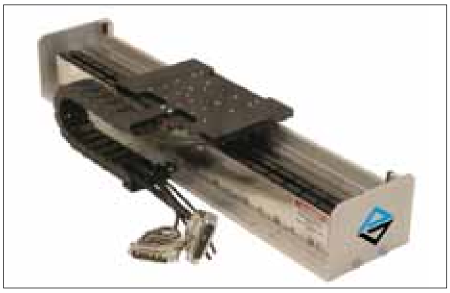
Enhancement for high-dynamic micro-positioning systems
Aerotech’s new ETM (Enhanced Throughput Module) combines sensor measured micro-displacement and a user friendly GUI that identifies and helps to reduce unwanted machine base and frame motion in high precision, high performance positioning systems. By optimising point to point move settling times and minimising dynamic position errors for high speed contouring, the ETM allows high and ultra-high resolution positioning systems to realise improved throughput and enhanced parts quality.

The ETM includes a very high resolution sensor that is simply mounted to the positioning system base or frame, in line with the axis of motion being corrected. When used with Aerotech’s Soloist™, Ensemble™ or A3200 controllers, the ETM software option works with the optional Dynamic Controls Toolbox to provide setup and monitoring screens that analyse unwanted frame motion during critical moves and plots position error vs. time to a GUI. Measured improvements in settling times by as much as 20% have been recorded.

The ETM is available in two versions - a standard solution for high performance motion systems and an ultra high resolution version for the most demanding applications. The convenient low profile package size of the ETM, with a footprint of just 85 mm x 70 mm is easily built into new applications, and existing Aerotech motion systems across all current Aerotech controller platforms can also benefit from retrofitting to get faster production throughput or improve parts quality.

New direct-drive ACT series linear actuators
Aerotech's new ACT series linear actuators are based on a cost-effective uncomplicated design featuring ultra smooth brushless linear servomotors, sub micron level encoder feedback and heavy duty linear guide bearings in demanding high throughput / high accuracy positioning applications for parts handling, assembly, dispensing, pick and place, non-contact inspection and scanning.

The modular ACT series provides the capability for higher production throughput and improved accuracy in comparison to ball-screw and belt driven alter-



natives with maximum speed to 5 m/s and acceleration to 5 g.

Robust and durable linear motion guide bearings with dual seals are used throughout the ACT series in graduated sizes to suit increasing load and dynamic performance. For the 165 mm wide stage, maximum horizontal load is 60 kg with a 30 kg side load rating. Across the range, the low maintenance/long life design is rated for 20,000 Hours MTBF.

The new ACT series can be delivered as a part of a complete motion control sub-system with Aerotech's advanced motion controls and servo amplifiers to ensure optimum performance.

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Hamamatsu new streak camera for UV to NIR Measurements

Hamamatsu Photonics has introduced a new streak camera series for UV to near-infrared measurements of extremely fast light phenomena. The C10910 series simultaneously delivers intensity vs. time vs. position (or wavelength) information with single-photon sensitivity and temporal resolution down to 1 ps. With such capabilities, the camera is suited to most photonic applications requiring high temporal resolution.

Also available are various peripheral devices for the streak camera, such as spectrographs for time-resolved spectroscopy applications and optical delay and triggering units to assist in synchronising with various light sources.

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Spectra-Physics pioneers new ultrafast laser for deep tissue imaging

InSight™ DeepSee™ delivers revolutionary performance in a turn-key system

InSight DeepSee takes multiphoton imaging to new depths. Based on a novel proprietary technology, it delivers nearly double the tuning range of existing ultrafast lasers and provides seamless access to long infrared wavelengths for deepest in vivo imaging. Robust and fully automated, InSight DeepSee provides easy-to-use, hands-off operation.

InSight DeepSee provides 680 to 1300 nm continuous tuning at 100 fs pulse width and high peak power. This infrared range is where tissue penetration depth is maximized. Fitted with a pre-compensator, the laser can deliver the short pulses through a microscope to the sample for maximum fluorescence. A dual wavelength option is available for advanced imaging techniques

This fully-automated laser can be seamlessly tuned, with the click of a mouse, to any wavelength within seconds.

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Air flow testing of laser drilled holes

FlowComp™ is a unique closed loop hardware and software feature that combines laser drilling with air flow measurement on Laserdyne 795 and Laserdyne 450 multi-axis laser systems.

Designed initially to meet aerospace turbine engine requirements, this new feature has application in both aero and land-based turbine engine components. FlowComp software adjusts the size of laser drilled holes without operator input to ensure that cooling holes are drilled within tolerance and that the result is verified by flow-testing. The end result is consistent processing at very high speed within specification and with data logging in real-time to verify compliance.

Laserdyne's FlowComp first records air flow test results and then adjusts subsequent hole size, as required, so that the laser hole drilling process remains within tolerance over the course of thousands of drilled holes. Higher quality holes means more consistent air flow with no scrapped or re-worked parts. Typically, the parts being processed are high value components, with real cost of thousands of dollars. Laser drilling is often the last operation performed so it is critical that the process is completed without problems.

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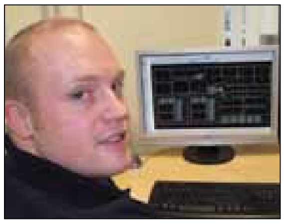
CASE STUDY Radan keeps the heat off as customers reduce lead times

Supplying finished products for customers across a wide range of different markets helped Spooner Industries remain buoyant during the recession. But with customers reducing their lead times, the period from the production department receiving an order, through to completing the manufacturing process, is getting increasingly shorter.

Nick Murgatroyd, who is responsible for lasering and folding the parts, says that Radan has played a major role in meeting deadlines, by programming and driving their Trumpf laser and Edwards Pearson press brake.

Spooner Industries set up a fully integrated operation incorporating Radan, Autodesk Inventor, the laser, the press brake and Microsoft AX business system. A bespoke Radan function speeds up the process of creating nests simultaneously from a number of works orders, contributing greatly to their ability to manufacture one-off products very competitively. “The lead time depends on the size of the job, but we can have a drawing issued in the morning and potentially start cutting in the afternoon. Previously, we couldn’t even dream of starting the manufacturing within a couple of days,” says Nick.

Operating with 125 employees from 60,000 square foot premises, Spooner manufactures products ranging from industrial ovens and sausage skin machines for the UK and overseas food markets, through driers for the tobacco industry and air turns for paper companies, to coil coating and other industrial processes for the metals sector.



Spooner's Nick Murgatroyd

Nick Murgatroyd says: “Radan reads the list and creates all the symbols and then the nests. All we have to do is input what sheets we’ve got and run the nester. Previously it was all done manually; now, the bespoke function provides a nest schedule for me.”

With the drawing office using Inventor as their main CAD system, a number of standard models has been set up as the starting point for most new designs. As a result, the drawing office can design parts which are test-proofed on the software before being approved for manufacture. The finished model is exported into AX, which creates the works orders; then the parts are cut on the Trumpf laser, before moving on to the Edwards Pearson press brake for bending.

“Now we have added Radbend to our suite of Radan modules we are able to fold a lot more, and Radbend gives us the ability to bend complex parts, freeing up valuable machine time and improving first-off reliability.

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Full details of all news items in the magazine, plus additional news items, can be found on the AILU web site

New Flatfoot screens from Lasermet

Lasermet's new Flatfoot are lightweight, semi-permanent laser blocking screens that are easily positioned to provide a safe working environment.

The screens are 2m tall x 1.55m and just 25mm thick. They have flat feet to eliminate the trip hazard and are of a smart, easily adaptable, modular design that provides a professional clean appearance for laboratory environments. Finished in a white powder-coating on both sides, the screens form walls using the easily assembled, right-angled or straight-line connectors.

Other products in the Lasermet laser-blocking range include curtains and roller blinds. All are designed for use as passive guards to enclose an area where Class 3B or Class 4 lasers, either to protect against accidental laser exposure or for long term blocking of laser radiation at lower power densities. All are CE marked and certified to EN 60825-4.

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Purex Launch the Sentinel Pack

According to the COSHH regulations 2002, equipment such as Purex extractors need to be Local Exhaust Ventilation tested at least once every 14 months.

As the manufacturer, Purex can now offer a competitive LEV and machine package available in the country; the "Sentinel LEV Testing & Support Pack" The Sentinel Packs are available in 1 year or 3 year options. Purex guarantee to beat any genuine 'like for like' quote for LEV testing.

The 3 year pack includes a number of features including: access to the largest LEV service team in the UK; reduced price filters and other replacement parts; 24/7 emergency technical phone support

A full list can be seen at: http://www.purex.co.uk/lev-testing/

To save customers time and money, any other LEV equipment across the building such as spray booths, welding extractors, downdraught benches etc can be LEV testing at the same time (In partnership with TES Ltd).

Scrappage Scheme
Purex have launched a new scrappage scheme for fume extraction equipment. Under the scheme, an old fume extractor can be traded in for a new Purex machine. The scheme covers both old Purex machines as well as machines made by other manufacturers.

For further information on this innovative deal contact John Young at Purex.

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New laser safety eyewear range offers safety with style

The functional and stylish UNIVET laser safety eyewear range, available within the UK from ES Technology Ltd, has been enhanced with a new selection of frame styles and materials.

The extensive range of frame styles, colours and lens shades available allows users to select a product which not only provides high protection levels, but also offers long lasting comfort and style. For further information:

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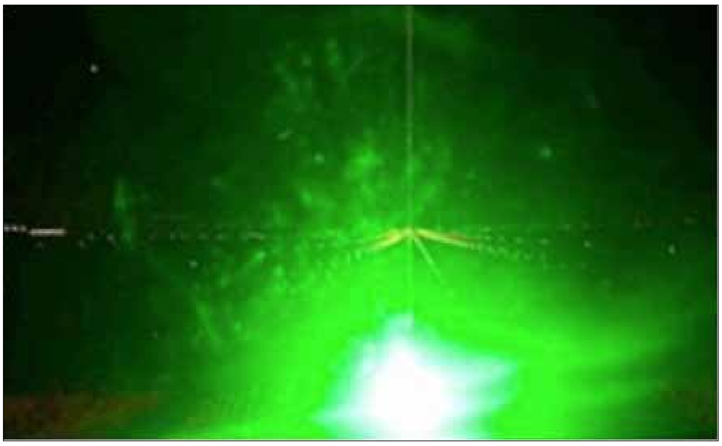
Dealing with the laser dazzle hazard in aviation safety



Pilots view on landing when a green 532 nm laser is shined into the cockpit.

Reports of green laser pointers (532 nm wavelength) being pointed at aircraft are becoming a common event. These sources often prove to be Class 3B and have the capability to permanently damage a persons sight over a range (the Nominal Ocular Hazard Distance) of a few tens of metres or more (see 'Reflections on laser injuries by overpowered laser pointers' in TLU (2011) 62, p14). Whilst aircraft exposure is generally at distances well beyond the NOHDs of such hand held devices, the dazzle hazard remains a major concern. Pilots report having to cover their eyes and others to taking evasive action.

Examples include a cargo plane from Aberdeen being forced to drop 400 ft as it approached the runway to avoid a green beam. An EasyJet Airbus carrying 59 passengers and six crew travelling on the same flightpath from Stansted was targeted 30 minutes later. Both pilots were dazzled by the beam, suffering a temporary loss of vision, and were forced to cover their eyes at a crucial point in the descent. Then in March this year two adults were arrested after a laser was aimed at a commercial plane near Midway Airport in Chicago. A police helicopter sent to investigate was also illuminated.

It is clear that sudden exposure to laser radiation during a critical phase of flight, such as on approach to landing or departure can distract or disorient a pilot and cause temporary visual impairment. Furthermore, flight simulator studies have shown that adverse visual effects from laser exposure are especially debilitating when the eyes are adapted to the low-light level of a cockpit at night. Recovery of visual performance after such a laser light exposure may take from a few seconds to several minutes. This effect could be even worse for example when the glass canopy of a Helicopter is illuminated by green laser. Apart from the obvious distraction of such a flash, the three most commonly reported physiological effects associated with green laser exposures are:

- Glare
  Visual blocking of an object in a person's field of vision due to a bright light source located near the same line of sight.
- Flashblindness
  Temporary loss of vision after the source of illumination has been removed.
- Afterimage
  A transient image left in the visual field after an exposure to a bright light.

Laser protection filters for infrared laser applications with good visible light transmission are relatively easy to design because the wavelengths to be blocked are outside of the visible spectrum. The 532 nm wavelength emitted by green lasers, however is in the centre and most sensitive part of the human Photopic region making filter design more of a challenge.

Brinell Vision has developed a laser safety filter technology which allows the user to see a completely balanced colour view while totally blocking laser light at 532 nm. As shown in the graph below, this filter technology effectively removes the transmission around 532 nm while at the same time offering outstanding visible light transmission when compared with other types of 532 nm blocking technologies: these other types use absorbing materials which generally remove all the blue and a significant amount of green from the visible spectrum. This can make the eyewear completely unsuitable for flying or in fact operating any piece of important equipment.

The Brinell CN-Green advanced filter technology is already being utilised by world leading optics and laser companies in demanding applications such as medical surgery and astronomy.

Equally well, green-beam applications in industry and research can benefit from this technology. These high durability advanced thin film interference filters with low absorbing design to work with high powered laser sources and are available at blocking levels from OD3 - OD6

Brinell filters are custom designed and UK manufactured. They are available in a large range of frame-styles from PROTECT Laserschutz GmbH

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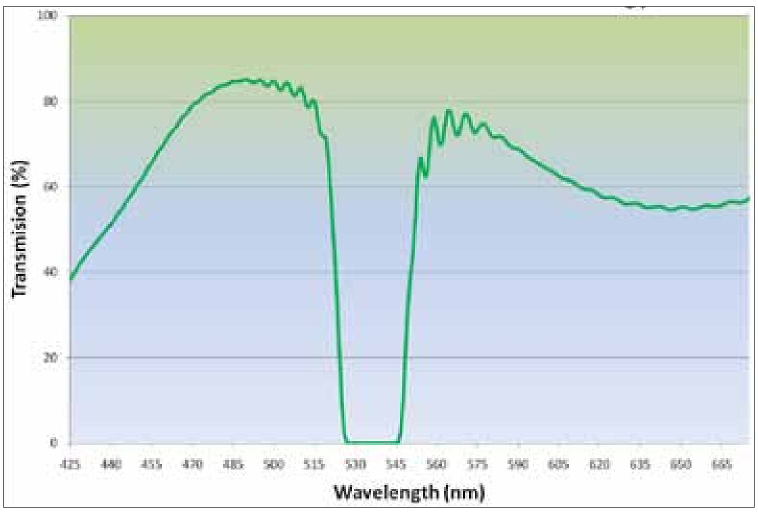

A Brinell CN-Green filter with high blocking levels for 532 nm

Orwin Integrate JK Laser Into Semi-Automated Welding Cell

Automation specialist, Orwin, has integrated a JK600HP Nd:YAG laser into their new Semi-Automated Laser Weld Cell. The machine has been developed at their headquarters in Tyne and Wear, UK, to weld pressure safety valves between 0.5” and 5” in diameter.

The laser welding machine has been fitted with two 6-axis Fanuc robots. The first loads and stacks the components in the welding nest, whilst the second is fitted with the laser processing head to weld in vertical and horizontal planes on the valves.

The JK600HP, developed by JK Lasers in Rugby, has been designed specifically for precision applications that require tightly controlled heat input at high process speeds. It is able to produce highly accurate, hermetic welds, ensuring that the valve remains stable even as pressure increases.

The component nest comprises of the JK process tool mounted to a servo-driven 360° rotary axis, enabling the laser to produce the orbital weld required. Two nests are included in the machine, both

can be used for manually loaded components and one of these can also be used for automatically loaded parts.

An additional advantage of the machine is the robot’s integrated vision system, which automatically positions the laser head above the join line of the components to be welded.

Both the vision system and the specification of the component nests, combined with the rapid processing speeds provided by the laser, result in increased efficiency, yield and through-put for the end user.

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Carrs embrace battery technology

"In a difficult economic climate, it always pays to look for emerging technologies and how you can use your skills to enter new markets and diversify your efforts," says Phil Carr, owner manager of Carrs Welding Technologies in Kettering.

"Using a laser to weld offers close control of the thermal profile. This has allowed us to join several battery cell projects for all electric vehicles and energy recovery systems. Keeping the cell under 85ºC is crucial if the battery is to maintain its working life and performance.

"I was so impressed with the technology that I bought an electric car, a Mitsubishi IMiev. It means greener Customer deliveries and the running cost is only about 1p a mile," he added.

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CASE STUDY: Laser tube cutting at the heart of an innovative business

In an area of 120,000 m^2 half of which is taken up by buildings located near Fiorano in the lowlands of Modena is the main facility of Gruppo System, which also has production facilities in Spain, China and USA. The Group is divided into three divisions: Ceramics, which deals with decorating and automation of ceramic products; Logistics, dedicated to automatic handling systems in various industrial environments and Electronics, which creates control and integration systems for industrial production. The three divisions are characterised by one common denominator: the spirit of innovation.

Mr. Stefani, President of Gruppo System, is a person with much enthusiasm who has followed his passions and turned them into a company of surprising dimensions. With his innovative ideas and just a small loan, he started to create a business that now has a total turnover of almost €280 M and a headcount of 800 employees, half of which are based in Italy. The current company was set up back in 1970 and the first system to be purchased was not a machine tool but an automatic storage system and this was already a sample of the ideas that would have later given life to the "business"; a business that started off by outsourcing in an industrious and dynamic environment in the plains of Modena where there was far from a shortage of craftsmen to outsource the initial ideas and what others could not do was done in-house.

A laser "training ground"

Mr. Stefani is an enthusiast and this spirit lead him to take on the challenge in the laser tube field, but only after being fully convinced of the advantages. "Relations with BLM have been ongoing for 15 years – explains Stefani – during which time I have listened carefully to the description of the machines that were being offered to me and mostly of the opportunities and the vast range of innovations that laser technology could bring to my company".

"At first, tubes were used for structural steel works and were generally of poor precision and quality, but today the increasing use of laser cutting has raised tube quality. Modern tube designs allow precise structures to be created without the need for expensive

and complicated mechanical processes to be carried out on machine tools".

Quality without laps

Mr. Stefani is the first to promote innovation in his company and is very careful not just to sit back when a target has been achieved; he is always on the go to reach new horizons. "Others can copy – he says referring to hypothetical competitors – but our ideas by that time are already well ahead". "When the first laser system (an LT JUMBO 20 for large tubes with diameters of up to 508 mm) was installed we started our training" he says, using the term that perfectly describes the efforts made at the beginning. "You go to a gym to train and, in effect, the initial samples helped in our training, giving us a deep understanding and helping us to seize the potential of the new tool that was available. Today we manage to produce complex structures using fitted tubes with unique reference keys that make fast and accurate assembly possible without errors and with a high final accuracy."

Initially, the choice of the ADIGE LT JUMBO 20 was made assuming that the weight of the structures produced using tube could be reduced by 40%. The savings from this effectively alone justified the purchase; but looking back, this was perhaps not the most interesting motivation for introducing the laser.

Installation of the second lasertube, an LT8 system with double bundle and single tube loader, added speed and performance with the same tube processing concepts and advantages for the production of smaller tubes. Logistics costs; replacement of boxes with tubes has reduced transport costs. Today, with precise tubes processed by accurate machines, quality can be achieved without the need for additional machining.

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Beakbane invest £0.5m in Trumatic

Kidderminster-based Beakbane Ltd, the UK's leading manufacturer of bellows and machinery protection systems, has invested £500,000 in a new TruMatic 6000 high performance CNC punch-laser combination machine from Trumpf.

Purchased as part of its ongoing investment programme, the new machine will ensure high accuracy, consistency and reliability of component production.

"The acquisition of this machine completes a major investment programme to improve the company's metal cutting, punching and folding capabilities," said Manufacturing Manager, Roy Legg. "The investment aims to maintain Beakbane's position as the European leader in the design and manufacture of machinery protection systems."

"If you take the strengths of the punch, in terms of accurately forming material, coupled with the speed of punching holes, and you take a part that has sweeping contours and irregular shapes where smooth edges without burrs is important; and you then put those two types of geometry into one part – that's the perfect combination machine component," says Mr Legg. Beakbane has many parts that fall into this category; the very nature of its business is high variety, low volume specialist work.

Mr Legg indicates that cycle times will almost certainly reduce due to fewer handling operations and the ability to complete parts in one hit. Beakbane will be able to tap, countersink, form and bend in a single set-up, thus reducing the non-value-added time associated with secondary operations.

Beakbane has been established since 1954 and is accredited to ISO9001:2008. Today, more than 120 employees help the company offer its clients a complete outsourced service from product design through manufacture to delivery.

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Full details of all news items in the magazine, plus additional news items, can be found on the AILU web site

MATERIALS PROCESSING

Rofin’s new PowerLine Prime series

Continuing the company’s philosophy of ongoing product development, Rofin’s Marking Division launched their new PowerLine Prime 15 laser marker at the LASER 2011 show in Munich.

The new PowerLine Prime 15 comes pre-configured and ready to use on a wide range of materials and applications offering high quality and high speed. Rofin’s new generation 15 W air-cooled laser marker is also extremely compact and this together with a 19” rack mount configuration for the control system, simplifies integration into production systems.

The PowerLine Prime 15 also incorporates a pilot laser and variable beam expansion as standard. Marking fields of 120mm x 120mm or 240mm x 240mm enable the system to process a diverse range of component types.

The “off the shelf” concept of Rofin’s new PowerLine Prime series lasers means that they are available for delivery and ready to use in the shortest possible timescales, providing customers with a quick and cost effective solution to a host of classic marking applications. This new pre-configured product line currently consists of the PowerLine Prime 15 and the PowerLine Prime 10, which with its 10 W laser, offers high precision laser marking and fine line widths.

These latest additions to Rofin’s comprehensive range of laser systems enables users to maximise the benefits of non-contact, abrasion-resistant, permanent marking onto many different products and materials.

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Customer orders two new Trumpf fibre-guided cutting machines

Hartmut Pannen (left), Managing Director of Trumpf UK and Tim Leam, Director at Lasershape

The Trumpf TruLaser 5030 Fibre has enjoyed phenomenal success since its launch at EuroBLECH 2010. To date around 100 units have been sold worldwide and in the UK alone seven have been ordered, the second highest order intake in the whole of Europe.

The machine’s proven ability to drive down the cost of thin sheet parts through high productivity and low energy consumption is the overwhelming reason for purchase. This clear business case resulted Lasershape ordering two TruLaser 5030 Fibre machines, their first Trumpf investment; for installation at its new factory in Nottingham.

Lasershape's core business has always been CO_2 laser cutting. That is until Director Tim Leam saw the TruLaser 5030 Fibre in Germany last year. “In all honesty I wasn’t considering Trumpf but this compact machine won me over. No gas, no mirrors, no maintenance, easy operation and considerably less power consumption, it’s a great combination.”

At present any copper and brass cutting is done by Lasershape’s waterjet machines. These materials are ideal for the TruLaser 5030 Fibre, which is immune to back reflection and therefore completely process safe. It is also considerably faster than waterjet which gives Lasershape a competitive advantage.

Initially Lasershape plans to retain its CO_2 lasers for heavy cutting and to divert thin materials to the new TruLaser 5030 Fibre machines. Although the economy of these machines is greatest for materials up to 4 mm, they can be used to cut mild steel up to 20 mm, giving Lasershape a good back-up in the event of an excess of orders in thick sheet processing.

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Turbomeca orders Laserdyne 795XS

Six axis beam-director system – increases its manufacturing capacity with the latest laser processing technology

Power Laserdyne, a world leader in precision multi-axis laser machining systems, announced the receipt of an order from the Turbomeca Tarnos site (France) for a six axis Laserdyne 795XS laser system.

This is the third Laserdyne system purchased by Turbomeca. It will not only expand their capacity for laser processing, but demonstrates a commitment to employing and benefiting from the latest laser system technology. The order is also significant in that it is further proof that the recovery in turbine engine manufacturing is a worldwide trend.

"This order follows significant orders in North America and Asia," said Terry VanderWert, President of Power Laserdyne. "As a user of Laserdyne products since 2002, Turbomeca and Laserdyne have worked together as partners to meet the requirements of the aerospace industry for manufacturing the next generation of turbine engines.”

Turbomeca is the world leader in the design, production, sale and support of the largest power range of gas turbine engines for helicopters. With over 73 years experience providing propulsion systems for the aerospace industry, "Turbomeca personnel understand the requirements for laser processing aerospace parts and are very effective at judging the value of system features," said Mr. VanderWert. "We believe that their positive evaluation of our latest system technology, with the third generation BeamDirector, is further evidence of the value of our recent developments.”

The Laserdyne 795XS is a six-axis system with a 1m x 1m x 1m (40 inch x 40 inch x 40 inch) work envelope including a 320 mm diameter high accuracy rotary table and Laserdyne’s latest controller, the S94P. By virtue of the system compact design, it provides unmatched access to parts for cutting, drilling, and welding.

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Full details of all news items in the magazine, plus additional news items, can be found on the AILU web site

Compact excimer lasers in FBG production

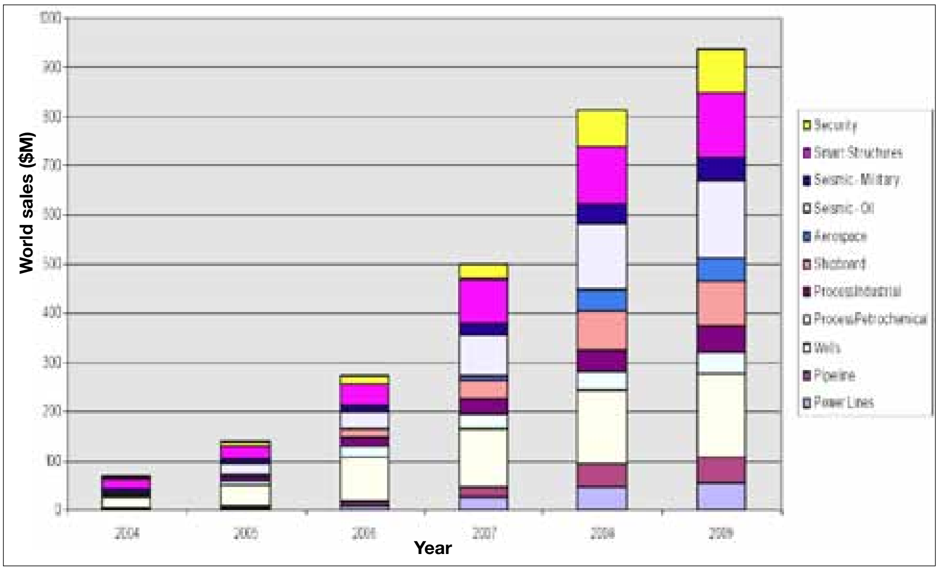

Figure 1: Total Fibre optic sensor market in million USD (Source: Lightwave Venture, LLC)

Fibre Bragg Gratings (FBGs) have found widespread use in optical telecommunications. They improve the performance of pump lasers in optical amplifiers, act as filters for gain flattening or for highly selective channel selection in wavelength division multiplexing.

Over the last decade, an increasing shift has occurred from optical communication toward optical sensing as shown in figure 1. Driven by global demand for strain, pressure and temperature monitoring in civil engineering as well as energy production and transmission, fibre optic sensor systems have emerged as an enabling technology, overcoming many of the limitations of electrical sensors.

The technical superiority of FBG based-sensor systems in these markets is in high sensor count, long strain range and low weight, plus they are chemically inert and not influenced by electromagnetic interference or harsh environments.

FBG sensor operation principle

A FBG is a form of periodic modulation of the index of refraction along the core of an optical Fibre as depicted in figure 2. When light from a broadband source interacts with the grating, a certain wavelength – the Bragg wavelength – is reflected whereas the remaining signal is transmitted. A mechanical force to the Fibre core spectrally shifts the reflected Bragg wavelength λ_r which is a function of the effective refractive index n_{eff} and the grating period Λ as indicated in figure 2. Hence, wavelength shifts as a result of grating periodicity and refractive index alterations induced by temperature, pressure or length changes can be used for optical sensing. To this end, an optical interrogation system such as a broadband light source or a narrowband fast tunable laser device is employed. The fibre containing the FBG has also to be embedded or otherwise contacted to the object, the strain or temperature changes of which is to be monitored.

Commercial FBG sensors achieve a strain measurement accuracy of about 1µm/m and measure temperature changes as small as 0.2K. When using tunable laser interrogation schemes, fibre lengths of up to 30 km are overcome at sufficient signal-to noise ratio.

Phase-mask FBG writing

The common method in FBG production is phase-mask writing using 248 nm excimer lasers. When illuminated with the laser beam, the phase-mask generates the ±1st order beams thus creating a regular interference pattern.

Typically, the fibre and mask separation amounts to a few hundred microns, avoiding mechanical damage to the fibre material. Enhanced spatial coherence length of the excimer laser improves interference contrast behind the mask. To this end, excimer laser models used for FBG inscribing, use high coherence resonator optics that achieve a more than 1,000 µm (FWHM) coherence length.

The fibre-phase mask assembly can be illuminated by a large beam covering the entire FBG structure of typically 10 mm length or by a small beam of typically 1 mm beam width which is then scanned relative to the phase mask in order to inscribe the FBG as indicated in figure 3.

The Fibre being in close proximity to the phase mask makes for a very stable mechanical system. With this method, the pattern recorded into the Fibre is a copy of the phase mask demagnified by a factor of ~2 which renders this technique well suited for automated production. Irregular grating profiles are obtained by using amplitude masks in front of a large illuminating beam or a controlled dither of the phase-mask with a scanning setup.

Today's compact excimer lasers offer billion shots tube lifetime, corresponding to 1 to 2 years tube and optics operation under FBG production conditions. Gas lifetime is of the order of 2 to 4 weeks, after which an automated new fill is performed in about 10 minutes.

Smart excimer lasers with output energies of some 10 mJ to 100 mJ per pulse have been established as affordable workhorses in phase-mask FBG manufacturing. These include (see figure 3) the Coherent COMPexPro 50 for static, large beam and the BraggStar Ind. for scanning, small beam fabrication.

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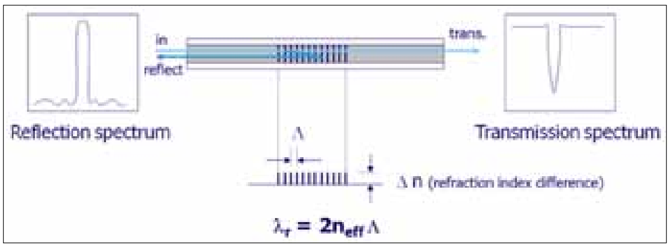


Figure 2: Principle of FBG-based fibre optic sensing

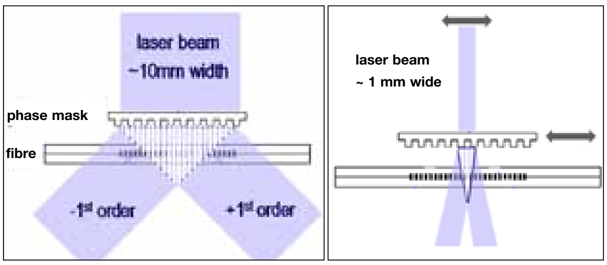
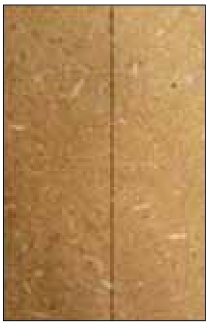


Figure 3: FBG writing with static, large beam (left) and scanning, small beam (right)

Applications of sealed CO2 lasers

Marking guidelines on wood

In mass-production wood processing operations, there is often a requirement for marking simple guide lines on wood products like plywood or particle board sheeting. Depending on the end application, these guide on panelling or exterior sheeting might show where a sheet needs to be trimmed further on in the production process, to specific custom length, or the line could be for a simple visual aid to indicate a nailing line on exterior siding or to show the on-centre position of framing behind the sheeting.

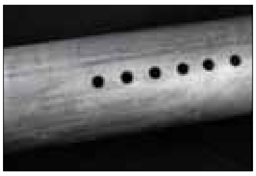


Fiducial marking

Laser marking eliminates the expense of using ink-jet printers and provides a consistent permanent mark in the wood. Synrad $C0_2$ lasers, available from UK distributor Laser Lines Ltd, are ideal for this application; A 10 W CO_2 laser and a Synrad FH Flyer marking head, equipped with a 370 mm focal length lens marked at line speeds of 15 metres per minute resulting in a clearly visible dark line.

Cutting mild steel pipe

Mild steel pipe is commonly used in many applications ranging from machinery and equipment fabrication to industrial plumbing to sign posts and fencing. The walls of these pipes are often cut, notched, or drilled to obtain precision part fit-up for welded pieces and to provide accurately-located fastener holes or holes for various types of welded or threaded fittings.



Holes trepanned through 1.6 mm thick mild steel tubing using 400W of laser power at a cut speed of 1.8 m per minute.

For this particular application, 50 mm dia. x 1.6 mm mild steel pipe was laser trepanned to create a series of 7.6 mm diameter holes. A Synrad 400 W laser from Laser Lines was used in conjunction with an XY table and cutting head outfitted with a 2.5" focal length lens that provides a 100 micron focused spot size. Oxygen gas assist at 6.9 bar was used. A series of 0.3" holes were successfully cut, as shown. The resulting cut edges had minimal dross and HAZ.

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Compact and flexible welding station

For manufacturers involved in small and medium batch laser welding, the new Trumpf TruLaser Station 3003 offers a flexible, economic and ergonomic solution.

The design of this machine allows the optimal beam source to be selected for the application. Typically for welding temperature sensitive components there is the Trumpf TruPulse laser.

Trumpf disk, diode and fibre lasers up to an output of 1kW can be specified for applications such as welding lap joints in heat exchangers. And for tasks such as layer removal and stripping of semiconductors the Trumpf TruMicro microprocessing laser would be the ideal choice.

The TruLaser 3003 is economical to run and is characterised by its minimal auxiliary processing times thanks to its programmable focusing optics. An integrated scanner optic makes this possible; neither the workpiece nor the optic need to be moved for processing. Linear axes that expand the working range are available as an option.

Despite its compact dimensions of 860 x 2000 x 1310mm, the TruLaser Station 3003 has a large working range of 300 x 300 x 500mm. Its automatic swing doors provide fast and ergonomic loading of workpieces.

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Automatic slag removal

It's quick, clean, time-saving and highly effective. Thanks to a new process, the new Trumpf TruTool TSC100 slat cleaner thoroughly removes accumulated slag resulting from stainless steel, mild steel or aluminium laser processing.

Not only are the slats cleaned on the sides but also in the hard-to-reach spaces in between. The result is an outstandingly clean flatbed laser machine.

The TruTool TSC100 automatically adapts to different slag thicknesses and the operator can move the tool up to the pallet frame. It is easy to handle and comfortably operated by one person. And on flatbed laser machines with a pallet changer, cleaning can be in parallel to production.

Clean slats are important to the process stability of the laser cutting machine. If slag is allowed to build up not only is the quality of the process compromised but so too is the quality of the finished part. As the TruTool TSC100 makes the job so easy, there's no need to let this happen. It can be used on practically all conventional flatbed laser machines with laser power up to 7kW, enabling slats to be cleaned several times before replacement becomes necessary. This can yield substantial cost savings when compared to manual slag removal.

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The following unlikely laser application appeared in the Daily Mail (Mail on line) on 13 October 2009

According to the advertising slogan, if you see Kellogg's on the box then you know it's Kellogg's in the box. But now the company has become so concerned about similarly packaged supermarket cereals, it has developed a laser to mark its logo on to individual Corn Flakes. The plan is to put a proportion of Kellogg's flakes, laser branded with the trademark, into each box to guarantee authenticity.

If the system is successful it could be used on Kellogg's other best-loved brands too.

Kellogg's embarked on the project to reinforce that they don't make cereals for any other companies and to fire a shot across the bows of makers of 'fake flakes'.

Apparently the marking process does not noticeably affect the taste.

Golden Oldies

Articles in The Laser User that made an impact over a decade ago and still have an important message today

Brooke Ward, winner of the AILU Award in 2009, may be especially well known to veteran TILU readers for the many pieces Brooke wrote on laser beam propagation, including the challenging and oft referenced 'An idiot's guide to laser beam propagation' (1996) Issue 4, p5-8. Its four pages make it too long to reproduce here. Instead, below are two related short pieces from Brooke's 'Odd Optics' series that appeared over a decade ago (Issue 17 (1999) and Issue 18 (2000)).

N.B. To download PDFs of any past article from the AILU web site simply log in and take 'The Laser User Magazine' link. Enter author names as 'free text' into the Search feature and a list of the author's publications will appear. Any you click will be downloaded as PDFs to your computer.

ODD OPTICS -No 1

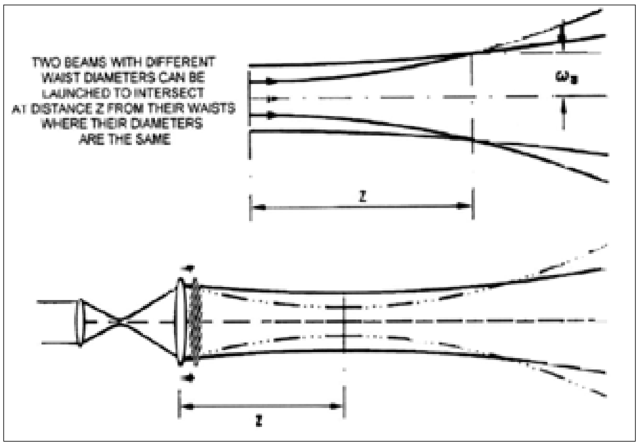
Mysteries of the beam expander

So, you've bought a beam expander* for your flying optic laser processing machine?

A properly designed beam expander for your machine will expand the output beam diameter of your laser to fill the aperture of the lenses and mirror in the gantry system. It should also position a beam waist in the middle of the range of the variable path length of the gantry. If this isn't the case, come and see me!

The next step is alignment. Of course, you are used to the problems of centering optics with the axis of the laser beam, so checking the positions of the beam expander optics in the beam will be nothing new. The only remaining problem is to adjust the separation of those elements so that they put the output beam waist where you want it: but take care! Which of the two waists do you want in the middle of your optical range?

Let's start the wrong way round. Think of a beam with a small waist diameter. Because it has a small waist, it will diverge rapidly. Now, how about a beam with exactly the same value of M2 but with a large waist diameter, starting from the same place as the slim waisted beam. At some point the two beams would cross over each other. In other words, there is a point where the two beams will have the same diameter.



Now turn this round the other way. Launch two beams with the same diameter. They can be made to form waists at the same place but with different diameters. This can happen with a beam expander. By changing the separation of the optical elements by a small amount the beam leaving the beam expander can have virtually the same diameter but it could form a large waist or a small one in the middle of your optical range.

So which one do you want? I would suggest that the beam with the larger waist would change its diameter more slowly with distance and that would be good. This is the beam that comes from moving the lenses a little closer to each other than the setting giving the smaller waist.

One further point. At one setting of the beam expander the two waists are the same size and overlap. At this position they are at their maximum distance away from the beam expander and their common waist diameter is 71% (= 1/√2) times the diameter of the beam leaving the expander.

** 'Beam expander' is the best name for this optical component, though it is often referred to as a' telescope' or 'collimator'.*

ODD OPTICS -No 2

Now I'm seeing double

Recent proposals for measuring the apparent source size of a diode laser beam produced this suggestion: "Put a lens between the laser and a viewing screen and move it until you get a minimum spot size. Then apply the simple lens formula u/v calculation to find the size of the object" Sounds simple doesn't it?

The experimental set-up is shown in figure 1. Unfortunately, for the relatively high quality of laser beams the simple ray optics formulae do not hold. In particular, the radius of curvature of a laser beams doesn't simply increase in proportion to the distance from its source, but follows the equation:

$$R_S = \frac{Z_r^2}{z} + z$$

z is the distance from the waist of the beam and Zr is the Rayleigh Distance (which is the distance from the waist at which the beam diameter has doubled itself).

Applying this equation to calculate the spot size on the detector is relatively simple, and the results are plotted in figure 2. They show that if you are not careful in your selection of the lens or the viewing distance, you can get some funny effects. In particular, as the lens is moved away from the laser the spot size on the detector will get smaller, reach a minimum then get larger again - then it starts to get smaller again and greater (the area doubling distance gets smaller) then the double focus effect gets even more noticeable

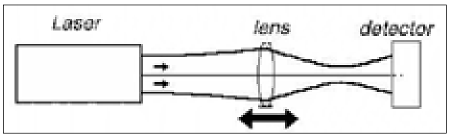


Figure 1. Moving the lens, there are generally two positions at which an image-size minima is produced on the detector. Which is the right one?

You are looking at a double focus - and it has nothing to do with that last glass of Malt! It also shows that this method for measuring the apparent source size can lead to some confusion. So look at this double cleavage and remember that life can get interesting with a laser!

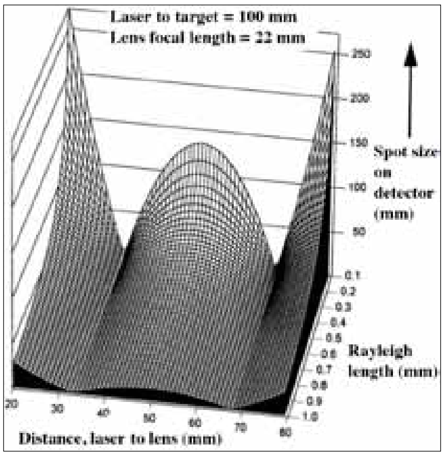


Figure 2. Calculation of spot size on the detector with distance from the laser to the focusing lens, for a range of Rayleigh lengths, Zr

Brooke Ward Europtics Partnership

PRESIDENT'S MESSAGE

Your Association needs you, or at least your input and feedback!

We have a opportunity in the coming few months to influence the creation of a Technology and Innovation Centre (TIC) in Photonics, funded by the Technology Strategy Board (TSB). Photonics is one out of a list of ten themes from which the TSB will select three to fund, and their choice will be strongly influenced by the level of support the respective communities can demonstrate. As part of the UK photonics community, I believe that we must play our part.

The point I want to stress is that a Photonics TIC is not an opportunity just for the academic members. In fact quite the opposite. The whole TIC initiative is about supporting industry and keeping the UK as one of the leading countries and players in the field of laser materials processing (LMP). In AILU's case our members who are job shops, system integrators and industrial laser users for in-house manufacturing should be the main beneficiaries.

Reports from the Electronics, Sensors and Photonics KTN have shown that "Photonics" has significant leverage In supporting the UK and EU economies and within this laser materials processing makes a significant contribution. But for too long there has been a "gap" between our academic research base and our industrial base. If the TSB were to fund a TIC in our area it would make an important contribution to reducing this gap and thereby bring benefit to our broader industrial base of suppliers and sub-contractors.

The facts are these:

- The government has told the TSB to invest in TIC's.
- A photonics TIC could be one of the next three out of a list of ten.
- If it is it would only cover one aspect of photonics.
- A key driver for deciding whether there will even be a Photonics TIC, let alone one supporting LMP, is whether there is a demand for this from industry.

Now we can sit and debate about whether this is the way forward or not, or whether money would be better used elsewhere (I have heard some interesting and arguably better alternative suggestions). You could also make the assumption that a TIC is of no relevance to your company, but if the AILU membership, as representatives of the LMP community, cannot demonstrate that there is an industrial demand, then the likelihood of a relevant photonics TIC disappears.

At this stage there are discussions about what form the TIC should take, where it should be and how it should operate. However, if demand is not seen from our industrial members then the TSB will use their money to support another sector, making such discussion irrelevant.

It would not be enough for the AILU committee alone to push for a Photonics TIC addressing LMP applications. To show that it's worth the Government spending money on such a TIC it needs the active support of the whole membership.

I will do my best in the coming months to make members aware of when and what sort of ammunition is needed and of opportunities to lobby for our community. Please get involved, make your views heard and your support clear.

A Photonics TIC would be a benefit to us all, but industrial demand has to be seen. Please do support the initiative.

Martin Sharp

PS Please see the meeting review on p 40 for more on the Photonics TIC initiative and suggestions for registering your support.

Greatest Cock-up

In the 1980's the laser manufacturer I then worked for had just dedicated a small section of the factory to do some rudimentary trials of laser material processing. It wasn't much more than a small motion controlled table accepting small sheets maybe 2 feet square, a 2kW CO_2 laser and a home-made cutting head. In it's day though it was almost a unique facility and a automotive manufacturer asked if we could cut and weld some of their parts. A demonstration was arranged, and several executives came along to see what was then 'space age" laser technology

When the laser had finished, the steel part fell into a small hopper below the table, where the eager young applications engineer promptly removed it with some "Mole Grips", before handing it to the visitors for examination. The first automotive executive took the cut part in the Mole Grips, made a show of examining the edge quality, and passed it by the Mole Grips to the second. The third executive however must have let his attention wander, and had not noticed the significance of the Mole Grips. When nudged to take the steel part to examine, he simply reached out and grasped the still extremely hot piece of steel in his hand.

He was lucky! A little later the mirror that turned the beam direction from horizontal to vertical was removed for cleaning and not replaced. Due to the absence of any interlocks on our home-made delivery system, the 2kW CO_2 beam travelled unshielded across several metres of busy factory to burn a hole in the wall opposite. It was only noticed when the application engineer could get no beam out of the cutting nozzle, despite the purple glow of the discharge and a power meter showing lasing action in the cavity.

The anonymity of the author has been preserved to prevent any embarrassment to those concerned!

Most Gorgeous Part

This picture of a ball made entirely out of square tube and held by slotting the sections together is a wonderful illustration of the ability of a modern laser tube cutting machine fitted with 3-D design software can free the designer to discover new possibilities for tube constructions.

Thanks for this contribution to:
Paul Lake BLM Group UK Ltd

An Englishman making a living in Germany

*Interview with **Steve Hastings***
Chief Technical Officer of abariscan GmbH

A laser scanning applications specialist offers his big picture of the photonics industry

Having lived in Germany for some years, how do you now view the UK industrial laser community and how does it compare with what you have found in Germany?

Well, it has been nearly two decades since I was last active in the UK community, and back then it was my private struggles in the late 1980's and early 1990's for anybody to take the digital laser processing of non-metallic materials seriously.

The scanned laser processing market has grown so much in the intervening years that it would be impossible to compare what the UK was like back then to how Germany is now. But I do believe that the various German regional governments have always taken investment and support in photonics engineering far more seriously than the various government bodies do in the UK. As a result Germany remains the powerhouse of laser systems integration within Europe, and I'm here, because one needs to be where the action is.

Before I left the UK I was getting a huge amount of private encouragement and mentoring from David Greening at V&S Scientific (now ULO Optics), I was buying Synrad lasers from a salesman who is now their President, Dave Clark, and it was Derek Down, then UK-based President of the Federation of European Screenprint Associations who recommended my innovations and ideas to Wilfried Kammann in Germany.

Just how broad is the range of laser materials processing applications that are dependent on scanning at the present time and in which applications are the limits being reached in terms of laser power applications and scan speed?

While I was developing systems and techniques in the 1990's to process papers, polymers and rubbers, etc., scanning was primarily developed for use by one major application; Nd:YAG semi-conductor chip marking. Even today we still have component specifications directly linked to this market, rather than specifically tailored to newer applications.

Everything changed in 2001-2 with the global semi-conductor dip. The growing scanning system integrators suddenly found themselves competing for a fast shrinking market. This led to the applications boom that continues today. There is continued market growth, plus this incredible applications-based bonus growth on top.

For nearly 30 years I've had customers arriving with a new material in their hands demanding a digital laser solution to replace their ageing analog process, and where their pre-process has long gone digital, and many of their other processes have followed suit.

The number of applications that have evolved is incredible, accelerating sharply over the past decade. These include: textile processing, automotive components, electronics, food and medical component manufacturing, via-hole drilling, solar scribing, I've even been involved in nanofilter perforating, Zirconium Carbide dental implants and the laser-machining of ceramic electronics micro-cooling channels of late. My favourite odd application by far though was macademia nutshell weakening, until one nut shot out of the prototype arrangement and hit me just above the laser safety googles. It hurt, and left a nasty bruise for a few weeks.

There will always be limits, and there will always be component mismatches to solve. Overcoming the limiting factor will lead to the next blockage that limits performance. And as each is overcome, scanned targeting gets faster and more repeatable and with higher resolution, and delivers increasingly more focused energy density to the target from less and less raw input power.

However, it is false to suggest that the limiting factor is always the scan speed, when it might actually be target material absorption, laser repetition rate or a host of other factors. There is a long train of innovations required that should be advancing the possibilities of bringing scanned laser beam processing into the 21st Century.

I understand that abariscan will specialise in industrial laser processing applications, especially those involving scanning, and that you will offer a complete solution. How much do you need to know about the application in order to provide the right laser and optics for the job?

abariscan will very soon become a global player with bases in the USA and Japan to compliment the German-European operation. But it will never be an integrator making entire processing systems. This is the territory of our customer base, and we recognise that never attempting to compete against our customers is how a supplier gains trust.

Our ethos is to fully understand the requirements of the application with our team of highly skilled individuals with more than a century of combined applied know-how, and then develop modular component approaches and co-design the equipment to our customers' requirements. Our expertise is in taking the raw energy from the exit aperture of the laser, conditioning it, delivering it and steering it to the target specific for the intended use.

The industry has evolved so much over the past decade, and where integrators previously produced 10, 50 or 100 systems per year for their particular niche market, they've grown to producing 100, 500, 1,000 systems per year and are actively demanding scanning products tailored to their specific application requirements; and in many cases, they wish to bring more value to their integrations by manufacturing their own scanning solutions and having their own unique identity, right the way to the front end software.

The days when you could produce a black box and expect the customer to fit it to their application are fast ending. The big OEM's are demanding the equipment co-designed for them, and the blueprints to fabricate and assemble. After all, they're all competing and pushing to increase their revenues too.

At the same time, for the big integrators there is a pattern of staff breaking away to start new spin-offs to chase even newer application trends. The whole thing is self-seeding and will grow faster as more new application demands can be enabled. The abariscan operation therefore also aims to understand new application trends, to develop components and techniques quickly, and to actively assist in the enablement of previously stymied applications.

How much is there to be gained from using a bespoke laser scanning system and/or laser controller for a specific laser materials processing application?

A great deal of optimisation is possible, depending on what is to be achieved. Imagine a not uncommon scenario, where you have a process that requires a £1m machine outputting 50,000 parts per shift. Deep within the machine will be scanning equipment costing a few thousand Euro. The drive system to move the part material through the machine and the checking system can go much faster, but the whole thing is limited by the scanning performance.

To produce 500,000 parts per shift you need 10 machines. But, if you were to fully analyse the precise requirements of the application, and could design and assemble a solution from a modular vertical component chain of products to perfectly fit the solution, the cost of the scanning equipment might not rise significantly, the actual laser source used by the integrator might end up being smaller and cheaper by better management and delivery of less energy, but the productivity of each machine could be significantly increased. You'd see the benefits straight away.

I concede that some very clever technology has entered the market in the past decade, many via the academic "solution looking for the problem" approach. I've spent my whole time marching along to the tune of a different drum, addressing the problem by looking right back through the system to the plug in the wall to seek the solution. It's a different approach, but it works for me.

The trick is in how to 'flow' the laser energy to the requirements of the application. Coaters, lens designers, motor position detector manufacturers etc. are all incredibly skilled at what they do, but they have so little contact with the users of the integrated system that more often than not the result is a Ferrari with tractor tyres running on Diesel. What's the point in having a car that can achieve 200mph if the speed limit is 70 and tyres will explode above 50 anyway?

Between 2000 and 2004 you wrote a number of papers in the AILU magazine concerning scanning CO_2 laser applications in the printing industry. At the time the key issue seemed be the control of laser power and its synchronisation with the scanning optics and a lot of the problem of laser control seemed to resided in the dynamics of the gas discharge. How has this situation progressed in regard to CO_2 lasers for this application and to what extent has the laser technology for this application moved on?

Simple: alternative lasers became available that overcame the problem. A 10W CO_2 laser will always be able to high-speed code, where raw speed to low price is required, rather than finesse or beam quality. 10 years ago nobody thought a 1064 nm laser could cut paper, let alone process polymers and difficult ceramics. The stability was achieved by switching to alternative sources. I've worked with nano and picosecond lasers that really open your eyes to the possibilities, and many of these provide a colder process where the frequency can be doubled, tripled and even quadrupled, fibre delivered to the scanning equipment to produce an even finer spot/higher energy density at the target.

What the picosecond lasers have not been able to achieve is price. The nanosecond lasers are getting right into the ballpark, and I fully expect the picos to have a very different price tag in another decade. With volume and age comes competition and price efficiency.

How do you see the future for remote laser materials processing, especially in regard to cutting and welding?

One of the big limiters of scanning will always be the beam entry angle change. This isn't a problem with CNC targeting, but really only affects partial or through-cutting,boring,drilling etc. CNC is slow and cumbersome, and major speed advances haven't materialised over the past decade.

As scan equipment moves up in resolution, and as certain (intentionally unspecified) targeting innovations come online, it is not unreasonable to anticipate 25m^3 fields where the entry angle doesn't really compromise the process. I've recently been working on one such application requirement in the Far East to target multi-kiloWatt Nd:YAG into the sky to create scanned plasma animation – controlled lightning points.

Laser surface texturing with short pulse (ps) lasers at high repetition rates and average powers seems to be pushing laser scanning technology to the limit. Where do you see this limit being reached and what technological developments are currently needed?

I don't agree that this is the current limit of scanning technology. Even before nano and picosecond lasers started to become commercial, laser-scan controllers existed that provided deterministic clean signalling at 5 MHz, and will soon go beyond. You just need to know who makes them.

The real limits will always be set by the next application, and I believe we're still a very long way from the development ceiling just yet. In my opinion, laser scanning is still in its infancy.

But I'll give you one defining example of a bit of a technical application headache: a client of mine wishes to put a probe through a patient's mouth and down the trachea into the stomach to non-invasively check for a cancerous tumour. Once/if the probe locates an affected area the surgeon wishes to 3D map the tumour and remove by laser the unwanted tissue with no pain to the patient and to an accuracy of a couple of microns; and all within a few milliseconds. How do you do it? You can't expect to get current scanning equipment into the body, so you need to innovate with the applied problem in mind… Watch this space! ■

Nitrogen Generators in the job shop

Dean Cockayne[1] and Martin Cook[2]

1. Midtherm Laser Ltd, Dudley, West Midlands
2. Cutting Technologies Limited, Barnsley

A recent convert to N_2 generators

After years of struggling with liquid nitrogen in bulk storage from one of the well know suppliers. Continually being told that prices are to rise, surcharges, environmental levy, broken down vehicles, too late to deliver today etc. We decided it was time to take the plunge.

In May of 2010 we took delivery of a nitrogen generator. It's quite a large piece of kit and easily takes up 43 square metres (see picture opposite). We have opted for a double system. That is there are two filters, two boosters and two of about everything. This decision was partly made as the need to back up if one unit should fail and partly as the amount of nitrogen required on a daily basis is quite large.

The system we have stores nitrogen gas at 300 bar. It's quite a simple process as air contains roughly 80% nitrogen and 20% oxygen. A large air compressor takes in air and compresses it to 10 bar, that's just the same as any workshop compressor. This compressed air is then fed through a series of filters where the nitrogen is extracted. The purity of this nitrogen can be adjusted as required. The higher the purity required the longer it takes to produce.

At this stage the nitrogen is still at 10 bar. This is fed into a booster pump where the pressure is raised to 300 bar and stored in cylinders. This 300 bar nitrogen is then fed straight to the laser machines through a regulator. We run three lasers from this, on an average day the generator keeps up with the machines nicely.

So far the whole system has proved itself excellent. The bulk storage tank for the old liquid nitrogen has been removed, thereby eliminating the rental charge. There are no heavy delivery or environmental charges and never a problem trying to arrange deliveries and move all the cars so the tanker can get into the yard to fill up.

The whole system cost £150,000 which we estimate will pay for its self within 5 years compared to the bulk storage system. The only extra cost involved is some servicing costs for the system and consumables such as oil, filters etc.

There has been a rise in the use of electricity to run the compressor and of course the filter system. This has been a little hard to evaluate as we are now running the whole factory and the nitrogen generator from the new compressor and it is coping well. Cut quality is good and as I have indicated the nitrogen purity can be adjusted depending on the cut quality required. The generator system is left on all the time and only charges when the pressure drops. In the future, if more is needed an extra 300 bar storage bank can be added.

So far the only down side that has shown itself is during a break down or service, but as stated the double system allows at least some nitrogen to be generated even when half the system is down for repair. We now cut all thin gauge mild steel with nitrogen as well, previously this proved too expensive against oxygen cut. This we find is saving us more in time and money and the customer has the benefit of a clean cut mild steel part that requires no treatment before painting or powder coat

Contact: Dean Cockayne
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A longer term user

We've had our Nitrogen generator since 2006. We decided to spec a system that would meet about 80% of our capacity. We can't cut 15 mm stainless across all our machines at the same time otherwise the generator runs out and we have to wait for it to re-fill. The reason we specified this volume was due to space – the more nitrogen you want, the bigger the generator, so we decided to go for a medium sized system and schedule our work more carefully.

In the five years we've run the system there have been very few problems. Initially the high pressure pump was an issue and this was replaced, but other than that there have been no major issues. Pros and cons of the system as we see it –

Courtesy Midtherm Laser Ltd

The domnick hunter nitrogen generator double system installed at Midtherm Laser

Pros

- Cost of nitrogen is dramatically lower
- We are not at the mercy of the "men in suits" constantly increasing nitrogen costs
- We can cut 15 mm stainless at the same relative gas cost as 1.5 mm
- Apart from the occasional service the generator is "fit and forget"
- It's a much greener system as there isn't the endless transport of gas
- You can choose the purity to suit the application

Cons

- Unless you specify a huge system there will be times when you run low on nitrogen
- The generator is noisy
- To increase capacity we reduce the purity and this leads to a blue edge on thick stainless
- Service costs can be high, and service is not that good
- Takes a lot of space

Contact: Martin Cook
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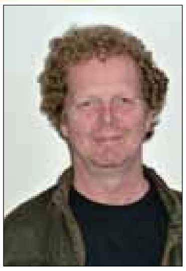
In conclusion this is one of the best purchases we've made – pay back was less than three years and provided nothing dramatic happens it should run for years longer.

JOB SHOP CORNER

Chairman's report

2011 Gas cost survey



First of all I would like to pass on Christmas greetings and the hope that we will all have a happy and prosperous 1978 from my uncle Fred.

But unfortunately we have to return to the real world – a real world where petrol costs about the same as beer and steel has become a semi precious metal…

So let me ask: How many of you thrusting young executives have signed up for the Job Shop gas cost survey?

Come on – it's a no-brainer - even my uncle Fred would sign up. The AILU office sent out requests to you last month to send in all your gas bills for the month of May. Mike Green will then remove the company names and give each of us a secret identity (it's all very 'Famous Five'), before producing a list saying that company 'H' is paying £73 a bottle for nitrogen but company 'C' is paying only £6 for the same stuff. As MD of company H, you can then go up to your gas salesman and say 'Oi, matey – what about this then?'

Several companies have saved thousands, and several gas salesmen have rued the day they ever heard of AILU. These salesmen – A curse upon their charming smiles and confident handshakes - should be made to suffer more – may their underwear be infested with the fleas of a thousand camels …. Come on – oppress your salesman today – send in your May gas bills.

The next Jobshop meeting is coming up on the 11th of October. We'll be having talks on all manner of things including Nitrogen generators, optics, laser steels and the real differences between CO_2 and fibre lasers. Most of the afternoon will be taken up by a general discussion because we have found these to be the best way for us all to compare notes on why we are now so bloody poor, before we all drive off in our Jags, Mercedes and TVRs…

John Powell
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A salutory lesson in laser safety

Pat Mulhern
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I must own up to having inadvertently shot a staff member of a client during a recent service visit: it was an unfocused short duration "range finder" alignment shot (low duty cycle pulse train (600Hz, 15% duty) with 1000 W peak power, 0.20 sec total duration) from a CO_2 laser at ~ 25 m. I hit the target on the elbow and he suffered a small superficial burn.

Before you jump too quickly to conclusions, I had taken a reasonable series of precautions:

- Cleared the "test area" from obstacles and other hazards;
- Ensured correct "test shot" program was loaded into the NC;
- Checked the settings within the program to ensure they were correct, not tampered with;
- Ran the program with shutter disabled and checked the real-time feedback values;
- Ensured that the red diode pointer was on the "target" large piece of 4.5 mm plywood being held at a safe distance by my assistant;
- Reposition the mobile HMI so that both my assistant and I have a clear direct line of sight of each other;
- Gone over our verbal protocol where he requests the shot when he is ready, then I respond verbally and he confirms, then I shoot (push start) but only if I am happy as well.

What went wrong was that due to strong direct afternoon sunlight streaming in the large roller door beside us, which meant that I could not clearly see the red alignment diode spot (indicates the approximate beam position) on the plywood from my position. Nevertheless, he called the shot, I pressed the button and there was no mark on the plywood?

We both scratched our heads, I confirmed that I had enabled the shutter key and we were setting about lining up again when a staff member from further down the shop came down to say that he had just been stung by something and that a strange mark had appeared on his elbow.

We had missed the target and the beam had passed through a small gap in a densely packed vertical storage steel rack and travelled though one of the 100mm gaps in a horizontally stacked pile of steel that were created by wooden supports every so often. He was leaning on the despatch bench further along when the beam hit him.

The subsequent incident investigation (this occurred at the premises of a large USA company with a good safety management system) found that the root cause of the accident was overlooking the need to carry out a site specific JSEA (Job Safety Environment Analysis), where the possibility that people beyond our area could be in the path of an errant beam; also the roller door should have been closed to allow sight of the alignment beam.

This shot was to have been one of several laser burns to plot the beam profile over several metres after it exited the "telescope" assembly beyond the working distance. These burn marks in plywood or MDF in conjunction with a full and half power mode burn into clear perspex help me reference the condition of the laser resonator and beamline optics. I also keep reference plots of output power versus current.

I have found these 3 tests to be the most reliable objective gauge of whether intervention inside the resonator is warranted, and are considering combining them into a single figure, to be known as the Ashes, with the index in Urns!

Accidents happen but one of the issues raised here is the importance (and legal requirement) of carrying out a risk assessment, especially for laser service activities. Readers, especially those unclear about this, should see the announcement below! Ed.

Laser vs micro-abrasive waterjet in the jobshop

Don Miller

Lasers and abrasive waterjets are complementary non-contact cutting beam technologies. Lasers typically cut materials much faster than abrasive waterjets, whereas abrasive waterjets cut a wider range and thicker materials than lasers. Both lasers and abrasive waterjets can micromachine but in the case of laser cutting there is a step increase in operating complexity in going from macro to micromachining whereas abrasive waterjet operation remains essentially the same.

Laser cutting was an established machining method before commercial abrasive waterjet systems were available, and laser job shops played an important role in developing the market for abrasive waterjet machining systems. Job shops with a number of lasers systems realised they could keep an abrasive waterjet system busy with the work they were turning away as unsuitable for laser cutting. They also realised that abrasive waterjets fitted into the laser job shop business model very well:

- Both lasers and abrasive waterjets predominantly profile parts from sheet materials;
- They both use basically the same software for programming cutting jobs;
- Set up times for both methods are minimal;
- Work holding arrangements are similar because the two methods involve no physical contact between a cutting head and a workpiece;
- Flexible operation is possible because many jobs can be scheduled for either a laser or waterjet.

Macro- vs micro-machining

The majority of laser job shops employ fusion cutting where a CW laser melts the metal and a high pressure gas jet blows the melt away. Not surprisingly, there can be a considerable Heat Affected Zone along the cut edge. The HAZ is acceptable for macro-machining but not for micro-machining, where miniature components tend to melt.

To prevent the melting of miniature features it is necessary to use pulsed lasers with a pulse duration of nano seconds or smaller. With a sufficiently high power density within a pulse, material is removed by a combination of melting, vaporisation, ablation and molecular bond breaking. It follows that whereas in practice there are only a number of laser types used in laser job shops (the CO_2 laser being far and away the most popular), there are many different types of short pulse laser in use for micro-machining; each being suited to a specific materials, material thickness, throughput requirement and tolerance.

Unfortunately, micro-machining laser systems are not compatible with most laser job shop business models. In particular:

- Operators need very high skill levels compared to macro-machining lasers as more cutting beam variables are involved and there is little or no operating experience built into commercial supporting software. It is not unusual for micro-machining lasers in a job shop to be operated by graduate or post graduate engineers or physicists.
- Extensive cutting trials can be necessary as part of the laser set up process. This means that micro-machining laser set up times can extend to hours, whereas macro-laser job shop business models require short set up times to achieve high machine utilisation.

Like laser macro-cutting, abrasive waterjet cutting is a thermal process. However, unlike laser macro-cutting, abrasive waterjet cutting is accompanied by extreme cooling from water droplets traveling at supersonic velocities. The presence of the water jet makes heating affects negligible. Where melting occurs, it is confined to the abrasive particles: this can arise when the workpiece is of material harder than that of the abrasive, such as a hard ceramic.

Software support considerations

Abrasive waterjet cutting has earned the reputation of being the machining method that comes closest to "having the skill built into the machine". To machine a part an operator may only need to input, through the human machine interface (HMI), a drawing file and then specify material type, thickness, cut edge quality and preferred locations for lead in and lead outs. The computer aided manufacturing (CAM) software behind the HMI calculates the cutting speed around the contours of a component, taking into account factors such as cut edge quality required, direction and curvature changes.

Figure 1. Finecut waterjet machining centre

A high level of CAM software support is available for abrasive waterjets because there are only a few operating parameters that affect cutting performance. For a given physical cutting head configuration there are no adjustable parameters that affect the cutting jet diameter, which remains the same between the cutting head and a workpiece. Consequently, the CAM software developed for abrasive waterjet macro-machining can equally well be applied to micro-machining. As a result, abrasive waterjet micro-machining centres, such as the one illustrated in figure 1, to be introduced into jobbing environments with minimal additional operator training.

Figure 2. Typical micro-jet machined components A 1 euro coin is shown for scale.

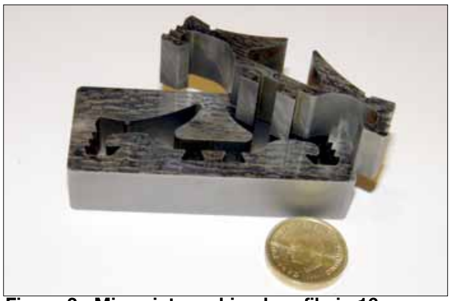

Figure 3. Micro-jet machined profile in 16 mm thick tool steel

In contrast, the laser emerging from a cutting head converges rapidly onto the workpiece and there are a number of parameters associated with beam focussing. There are even more beam parameters involved with a pulsed laser and I would claim that setting such a system up remains as much an art as a science!

Evolution of micro-abrasive waterjets

Difficulties in feeding cutting heads with fine abrasive powders have prevented the development of micro abrasive cutting jets, but these difficulties have now been overcome by the introduction of servo driven powder feeders.

A major difference between the parameters of macro and micro-machining centres is the accuracy of the cutting head motion system. Micro-machining requires a high precision motion system for which linear motors are increasingly used. Linear motors and position measurement by linear scales with nanometer interpolation provide for good repeatability and accuracy combined with high traverse speeds. In addition, the lifetime of linear motor motion system is much higher than that of a ball screw motion system.

The first commercially available abrasive waterjet micro-machining centre was introduced by Swedish company Finecut AB, Figure 1. It has a five to ten times better repeatability and accuracy than a macro-abrasive waterjets- cutting machine. The machining centre has linear motors on the X and the Y axis and a high precision ball screw servo drive on the Z axis. The linear motor drives, combined with linear scales and a state of the art Fanuc control system, provide repeatability of 3 µm and accuracies of 10 µm on some workpiece materials up to 10 mm thick. The cutting envelope is 500 x 500 x 80 mm. Total enclosure of the machining centre allows it to be used within machine shop environments.

Figure 2 shows components in a number of materials profiled by a micro-abrasive cutting jet. The limit in feature size is set by the diameter of the waterjet: the current minimum diameters available commercially are above 250 µm.

Figure 3 shows a profile cut in 16 mm thick tool steel with a waterjet of 300 µm diameter.

Surface finishes on components are comparable with most components profiled by wire EDM, while cutting speed is over five times higher. The accuracy and surface finishes achieved meet the requirements in applications that include profiling glass and ceramic substrates for electronics and medical applications, making human implants from difficult to machine materials, and making small mechanical mechanisms and components from high technology composite materials. Aside from profiling a wide range of engineering materials, there is a particular interest in the profiling of precious metals where narrow cut width and recovery of kerf material makes micro-abrasive waterjet machining financially attractive.

Outlook

Entrepreneurial laser job shops played an important role in developing the market for macro abrasive waterjets. Entrepreneurial laser and abrasive water-jet job shops are likely to play a similar roll with micro-machining, extending the use of abrasive waterjets into new high value markets.

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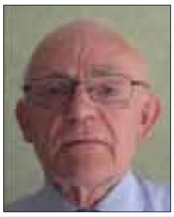

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Innovation and invention with high brightness lasers

Eckhard Beyer, Achim Mahrle, Matthias Lütke, Jens Standfuss and Frank Brückner

It is nowadays common practice to use the term "high brightness" to specify any type of solid state disc or fibre laser source regardless whether they are working as single or multi mode systems. This view may be owed to the fact that these laser beam sources are considered as a new class of material processing tools which possess some features that differ from typical characteristics of conventional CO_2 or Nd:YAG laser beam sources. It is also fair to say that the appearance of fibre and disc lasers in the multi-kW power range has stimulated a lot of experimental and theoretical work that generally gave new insights into the characteristics of laser materials processing.

The term 'brightness' is addressed in the adjacent text box, and in terms of measured brightness it is obvious from figure 1 that three distinct brightness ranges can be distinguished:

- Low brightness $B_L < 10^6$ W mm^{-2} sr^{-1}
- Medium brightness $10^6 \leq B_L \leq 10^8$ W mm^{-2} sr^{-1}
- High brightness $B_L > 10^8$ W mm^{-2} sr^{-1}

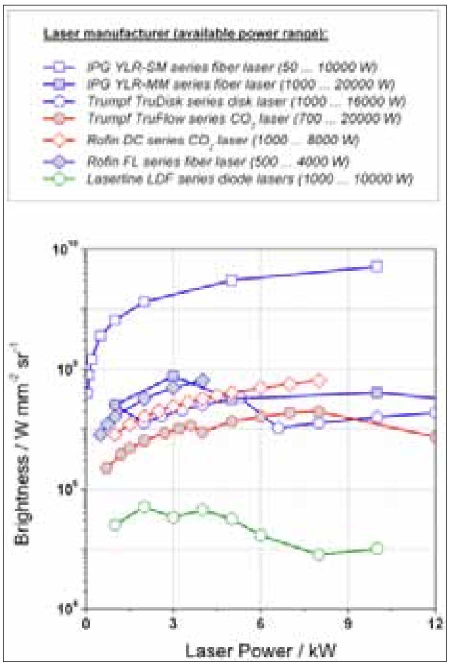

Figure 1 Calculated brightness of available laser systems of selected laser manufacturers

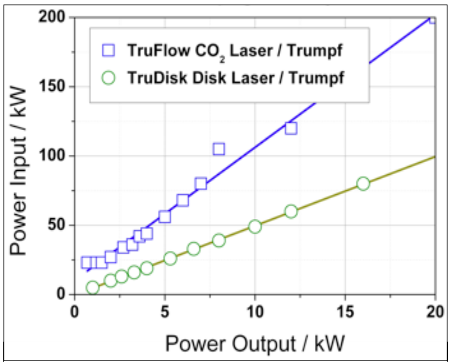

Figure 2: Wall-plug efficiency of Trumpf TruFlow CO_2 and TruDisk disc laser systems

As figure 1 shows, what we define as the 'high brightness' is currently reached by single mode fibre lasers only.

As industrial tools, disc and fibre lasers not only offer higher brightness but other benefits too, including a high electrical or wall-plug efficiency, respectively. For example, figure 2 shows the electrical input power versus the optical output power for the Trumpf TruFlow CO_2 and TruDisk disc laser series. Other benefits of these sources include a small footprint and size, a high mobility and a high reliability with significantly longer maintenance intervals. Moreover, the 1 µm emission wavelength allows optical fibre delivery to be exploited, with some important benefits in robot controlled applications and the laser treatment of complex three-dimensional structures.

Furthermore, the absorptivity of most metals to 1 µm laser radiation is noticeably higher than that of the CO_2 laser at 10 µm and plasma screening effects during processing are likely to be much smaller than with CO_2 laser material processing at the focused beam intensities typically used.

Cutting applications

The continuous development of disc and fibre lasers in the multi-kW power range has stimulated increased research efforts to compete with the well-established CO_2 laser cutting process. The work has produced promising results with considerably increased cutting speeds in thin and medium section applications only; however, the advantages decline as section thickness increases.

Brightness and the BPP

The brightness of a laser source B_L with an output power P_L is given by:

$$B_L = \frac{P_L}{\pi \cdot w_0^2 \cdot \pi \cdot \theta^2} \tag{1}$$

where w_0 is the focus radius and θ is the divergence half angle. The product of both quantities w_0 and θ is also referred to as the beam parameter product (BPP). It has the property of remaining constant value for a laser system with ideal beam delivery optics. It is also a measure of beam focusability, the smallest value of w_0 achieved by focusing the beam being given by:

$$w_0 = \frac{2f}{D} \cdot BPP \tag{2}$$

with f the focal length of the focusing optics and D as the initial diameter of the beam. The depth of focus is often characterised by the Rayleigh length z_R defined to be the ratio of beam waist radius and divergence half angle

$$z_R = \frac{w_0}{\theta} = \frac{w_0^2}{BPP} \tag{3}$$

The higher the BPP of a laser the lower is the beam quality. For a perfect Gaussian beam (subscript G), the BPP is proportional to the emitted laser wavelength λ:

$$BPP_G = w_{0,G} \cdot \theta_G = \frac{\lambda}{\pi} \tag{4}$$

The theoretical limits of the BPP of the common materials processing lasers are $BPP_{G,CO2}$ = 3.4 mm mrad for a CO2 laser (λ = 10.6 µm) and $BPP_{G,SS}$ = 0.34 mm mrad for solid state fibre, disc and Nd:YAG lasers It follows from Equation (1) and (4) that the brightness of a diffraction limited beam is:

$$B_{L,G} = \frac{P_L}{\pi^2 \cdot BPP_G^2} = \frac{P_L}{\lambda^2} \tag{5}$$

For real (non-Gaussian) beams (subscript NG) the beam parameter product BPP_{NG} is

$$BPP_{NG} = w_{0,NG} \cdot \theta_{NG} = \frac{M^2 \cdot \lambda}{\pi} \tag{6}$$

where M^2 (M-squared) is the dimensionless ratio of the BPP's of an actual and a Gaussian beam and is always >1. It follows that the brightness of an actual laser beam is less than that of a Gaussian beam by a factor of $(M^2)^2$:

$$B_{L,NG} = \frac{P_L}{\pi^2 \cdot BPP_{NG}^2} = \frac{P_L}{\left(M^2\right)^2 \cdot \lambda^2} \tag{7}$$

Calculated brightness values different laser systems are shown in figure 1.

Experimental and theoretical work pertaining to multi-mode disc and fibre laser and single mode fibre laser beams also shows a similar trend i.e. that the improvement gained by better beam quality particularly applies to thin and medium sheet cutting.

Another aspect of high practical relevance concerns the achievable edge quality of solid-state laser cuts in comparison to the almost smooth and low roughness cut edge surfaces known from CO_2 laser inert-gas fusion cutting. Indeed, the cut edge quality of solid-state laser cuts in thin sheet can be similar or even better in terms of nominal surface roughness, but the cut edge quality noticeably degrades with sheet thickness particularly in terms of surface roughness. The reasons for this are still a subject of controversial scientific discussion and it remains a pivotal question if there are technological means to overcome this limitation or if the degraded cut quality is unavoidably caused by an implicated physical limitation of the shorter emission wavelength of solid-state lasers. See, for example, [1].

Welding applications

Fields of welding applications that may particularly benefit from high brightness laser beam sources include remote welding with large working distances, welding of thick structures at very high laser power levels, and the welding of very fine structures. The last of these is a typical need in micro fabrication where low power single mode fibre lasers have already gained major market share. The excellent mode quality and high focusability of low power single mode fibre lasers allow spot sizes in the range of some microns, thus allowing high intensities and keyhole welding at very low power levels. As a result, welding of micro parts with very high processing speeds, lowest energy input, reduced heat-affected zones and minimized distortion can be achieved.

In the case of macro welding, a high brightness laser beam offers the potential to improve processing speed. For example, Figure 3.1 shows penetration depths as a function of welding speed achieved with a single-mode fibre laser system. The high aspect ratios of the resultant weld seam (see figure 3.2) were, until a few years ago, only achievable by electron beam welding.

In general, solid-state laser welding is considered to be much less sensitive to plasma effects than CO_2 laser welding, inverse Bremsstrahlung effects being found to be negligible. Consequently, deeply penetrated welds can be made at high power levels even in argon gas shielding atmosphere.

However, it was observed that the fibre laser welding process can be accompanied by particle generation, which is capable of forming a dense weld plume above the surface of the material to be welded that can attenuate the incident laser radiation. Without removal of such a plume the welding process might become unstable and the penetration depth can be significantly reduced. This phenomenon is especially important in the context of remote welding applications.

The strong focusability of high brightness laser beam sources is often accompanied by a considerable gain in weld penetration. However, reducing focused spot size by tighter focussing of the beam caused an increase in beam divergence and this can have a decisive impact on the welding depth, resulting in a decrease in penetration depth. There is therefore a limit to achievable welding depth, the lower the BPP of the laser beam the higher the welding depth.

Another issue, often discussed within the context of high brightness laser beam concerns the increased demands on beam delivery components. Thermal lensing and cooling of optics becomes an important issue due to the higher power loads of high brightness laser beams; this can cause a significant drift in focus position, distortion of the beam profile and reduced beam quality during operating with high power disc and fibre lasers with conventional optical components even if they are in a clean and new condition. Thermal lensing has to be considered as a temporal process affects the results of a particular welding process only after a certain critical processing time.

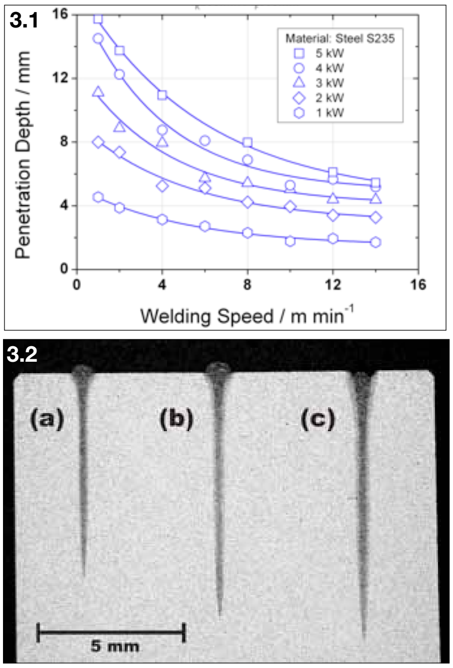

Figure 3: Bead-on-plate welding of mild steel S235 with a single-mode fibre laser system (IPG YLS 5000SM) at power in the range of between 1 and 5 kW: (3.1) Penetration depth versus welding speed as a function of laser power; (3.2) Weld seam cross sections at 5 kW laser power (a) 8 m min^{-1}, (b) 6 m min^{-1}, (c) 4 m min^{-1}.

Applications of single mode fibre lasers

For many applications, the use of high brightness lasers has led to significant enhancements of the process performance but besides such a pure quantitative improvement totally new and innovative processes have also developed. Some of these new technologies are presented in what follows.

<u>Remote cutting</u>

Conventional fusion laser cutting as applied to stainless steel and a diverse range of nonferrous metal alloys involves a high-pressure gas jet, typically nitrogen or argon at pressures up to 2 MPa, coaxial with the laser beam. The laser beam melts the material, which is then blown out of the resultant cut kerf by the gas jet. The distance between nozzle exit and surface of the material being cut has to keep small in order to guarantee an efficient blow out of the melt. The maximum average cutting speed for complex 2D-parts is limited by the inertia of the handling system to between 20 and 30 m min^{-1}, a speed much lower than it is possible to achieve in thin-section cutting with a high brightness solid-state laser. This has given rise to the development of the remote cutting process.

The particular feature of remote cutting is the replacement of the processing head (beam optics plus gas delivery and nozzle) and mechanical drives by a dynamic scanner mirrors system to deflect the massless laser beam. Such a methodology requires a large working distance, which implies long focal length optics and a high brightness laser beam that still provide, with these optics, a sufficiently small focal spot. Another essential precondition of remote cutting concerns the necessary abandonment of the cutting gas nozzle and thus the blow-out of the melt away from the cut kerf without the support of assist gas.

Our own experimental investigations on remote laser beam cutting revealed a strong correlation between the realised cut rate and the effectiveness of the melt

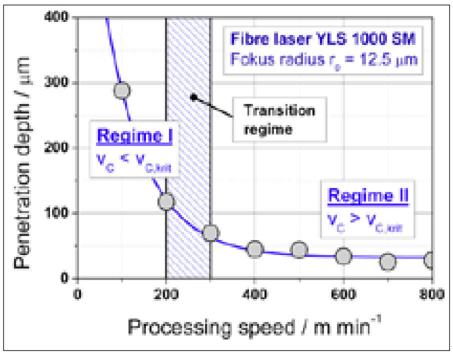

Figure 4: Penetration depth as a function of processing speed for single mode fibre laser remote cutting of stainless steel and identification of process regimes.

removal from the cut kerf. The penetration is indeed high below a critical value of the processing speed but the kerf is characterised by an obvious lack of melt removal, while there is an effective melt removal for cutting speeds above the critical value. As seen in figure 4, this characteristic behaviour separates the remote cutting process into two different regimes: without (regime I) and with (regime II) melt removal [2].

The need of a minimum processing speed limits in turn the maximum thickness that can be cut with a single pass. For higher thicknesses, a cut groove with partial penetration of typically between 30 and 50 µm is initially formed in stainless steels at multi-kW laser powers. Thicker materials have to be separated by a multi-pass technique, i.e. a rescanning of the cut contour. The cut kerf is then formed step by step or layer by layer until the material is completely severed and the effective cutting speed v_{eff} is equal to the processing speed divided by the number of scans. Such a methodology however works in a certain range of material thicknesses only. Remaining molten and resolidified material within the groove causes a re-closing of the generated cut kerf.

Experimental investigations with a IPG

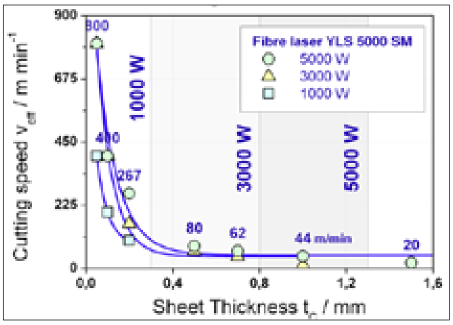

Figure 5: Effective cutting speed (v_{eff}) vs. material thickness for remote cutting of circles (radius = 5 mm) with different laser powers in stainless steel. Parameters: processing speed = 800 m min^{-1}, focus diameter = 25 µm.

YLS 5000SM single-mode fibre laser have demonstrated that the separable thickness increases with increased laser power or brightness, respectively. Increasing the laser power from 1000 W to 3000 W enlarges the separable sheet thickness of stainless steel from 0.3 mm up to 0.8 mm. A further power enhancement to 5000 W allows separating sheets of up to 1.3 mm thickness. The corresponding parameter windows of a high-brightness single-mode fibre laser as well as the achievable effective cutting speeds v_{eff} at different power levels are shown in Figure 5 [3].

The laser remote technique can cope with a wide range of materials and complex contours. One issue of practical importance is still the limited working area, this being limited by the focal length (= working distance) of the scanner unit. The working distance cannot be made too large, since effective laser remote cutting requires an intensity above a certain minimum. The working area effectively limits the maximum size of the part that can be processed in one manufacturing step. Developed solutions to overcome this limit include patching and on-the-fly techniques [3].

Patching is characterised by successive treatments of partial sections of a complete workpiece. After completion one section, the scanner unit and/or the workpiece are moved relative to each other to reach the particular working position of the following section. An alternative to patching exploits on-the-fly techniques to move the workpiece or the scanner unit continuously, relative to each other. In that particular case, the scanner thus works in a moving working field.

Currently, the potential of remote cutting for an optimisation of the manufacturing of electrode materials for lithium-ion batteries is under investigation [4]. Cutting speeds of more than 600 m min^{-1} have be realised by use of a highly focused 5 kW single-mode fibre laser, simultaneously achieving good quality of the cut edges, see Figure 6. In comparison to conventional mechanical punching, the contact-free laser process offers a high degree of flexibility and low handling times without any tool wear.

Welding with Oscillating Beams

It has been demonstrated that laser welding with high brightness laser beam sources is capable of directly competing with electron beam welding in terms of weld seam narrowness, aspect ratio and parallelism of the seam edges.

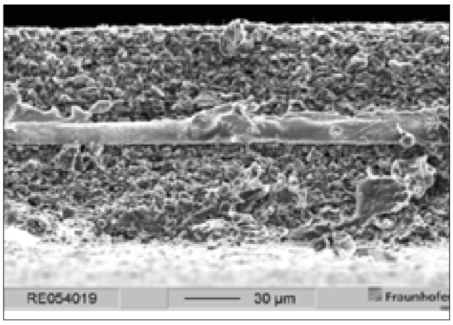

Figure 6: Cut edge of anode material (copper with graphite layers on both sides) of lithium-ion cells cut by high-speed laser remote cutting

Furthermore, the achievable travel rates, the corresponding amounts of linear energy and the life time of the generated melt pools are of comparable order for both processes.

Due to the smaller dimensions of high brightness laser beams and advances in scanner performance, a current design of laser beam tool allows 2D spatial oscillations of the laser beam at greater than 2 kHz, both with and without power modulation. Oscillating-beam working regimes can be applied to influence the properties of the welded joints. For example, Figure 7 shows successful weld seam geometries in stainless steel, with and without additional power modulation, creating possibilities for improvements in energy efficiency and reducing energy deposited into the workpiece.

A corresponding integrated laser welding system has already been successfully applied in combination with a 2 kW single mode fibre laser (Rofin Sinar FL020 S) for generating dissimilar metal joints such as aluminium-to-copper (electrically conductive joints, joints for heat sinks in electronics), stainless steel-to-copper (heat exchanger, vacuum engineering) and aluminium-to-magnesi-

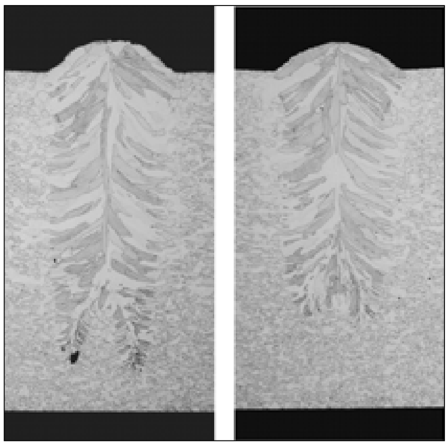

Figure 7: Seam of bead-on-plate welds in stainless steel made by single-mode fibre laser welding with transversal beam oscillation (0.5 mm amplitude 1500 Hz). Left: Without power modulation. Right: With power modulation.

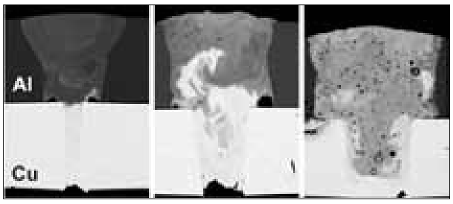

Figure 8: SEM analysis showing mixing ration of Al/Cu overlap welds as a function of scan width. Left: Without beam Oscillation. Middle: Scan width = 0.7 mm. Right: Scan width = 0.9 mm. Welding parameter: Laser power = 2000 W, welding speed = 4 m min-1, Scan frequency = 1500 Hz.

um (body-in-white and aerospace applications). It was demonstrated that the combination of a high brightness laser beam source and a high-speed scanning system with additional power modulation offers the potential for crack-free welding of those dissimilar metal joints [5].

Weld joints between copper and aluminium are interesting for a variety of applications in the field of electrical engineering and electronics, hereby providing improved electrical conductivity and heat transfer capability in comparison to mechanically joined connections. However, the material combination of aluminium/copper is hardly weldable due to the formation of very brittle intermetallic phases which possess only a poor ductility. The formation of such phases depends on the corresponding mixing ratio of the weld. It could be shown by experimental investigations that the mixing ratio can be favourably influenced by transversal high-frequency beam oscillations. Figure 8 illustrates the distribution of the involved elements copper and aluminium within the weld seam area

It is obvious from figure 8 that an adequate mixture of the weld zone is not achieved in the case of welding without beam oscillation. A noticeable increase of the mixing ratio was achieved for welding with beam oscillation and shows the mixing ratio of metals to be a strong function of the scan width. This effect is however accompanied by an increased porosity of the weld seam [6].

High-precision laser cladding

Conventional laser cladding with efficient diode laser sources is a well established technology, e. g. in automotive, aviation, energy, tool and medical applications. Weld beads possessing widths above one millimetre are predominantly used for the generation of contours, surfaces, bar structures or complex volume built-ups within such applications.

However, with conventional lasers it is not possible to perform efficient processing in the sub-millimetre range as required for new market needs in the field of turbine industry and medical engineering. Since the commercially availability of high-brightness single-mode laser sources, the precision of laser cladding has improved strongly and structure dimensions below 100 µm have became possible.

By way of illustration, figure 9 shows the cross-section of a structure with sub-millimetre dimensions generated by high-precision laser cladding.

One potential application of the filigree structures is the improved stability of thermal barrier coatings (TBC) used in stationary gas turbines and aircraft engines. TBCs are used to protect hot engine sections. They are strongly affected by the high working temperatures required to achieve a high efficiency in such systems. The huge thermal load can lead to intolerable failures and delamination of the TBC. Compared to plain surfaces, structured surfaces on turbine parts can improve the clamping of the TBC to the part and, hence, improve the durability of the coating as schematically shown in figure 9 [7].

Another application is the generation of micro implants e. g. for hearing aids. Laser cladding with fibre or disc lasers offers the high-accuracy build of small details that can then be individually fitted to the human patient combined with beneficial material properties.

Other applications of high-precision laser cladding can be found in the fields of micro tooling, rapid prototyping of micro components, metallic coding and embossed marking for Braille printing.

Summary and Conclusions

The availability of solid-state fibre and disc laser systems at multi-kW power levels has and still is having a major impact on the global laser community. Experimental and theoretical investigations continue to provide new insights into the characteristics of the different kinds of laser materials processing such as cutting and welding.

The advantages and benefits of these lasers as well as challenges to realising their potential benefits have been highlighted. Besides quantitative enhancements in the performance of several existing applications, the high brightness of single-mode fibre lasers in particular have given rise to completely new and innovative processes. We expect that the continuation of investigations on the potential of high-brightness laser beam sources will continue to stimulating further inventions in the field of laser material processing.

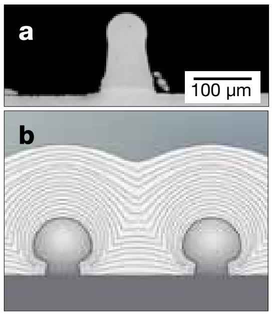

Figure 9: (a) Cross-section of a surface structure generated by high-precision laser micro cladding; (b) Improved stability of sprayed thermal barrier coatings by surface structures generated by micro cladding

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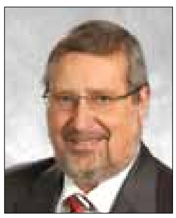

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Adaptive control in high brightness laser-arc welding

Chris Allen, Steve Shi and Paul Hilton

Precise workpiece fit-up and accurate alignment of the laser beam with the resulting joint line, pre-requisites for high quality welds, remain barriers to the wider take-up of laser welding. These requirements put restraints on welding fixtures and edge preparation methods, and impose tolerances that can prove difficult to meet in industrial practice. This can be particularly the case when welding large components or fabrications, where the assembly of a number of sub-components, or a build up of distortion, results in cumulative errors in joint fit-up, even with the best edge preparation. The ongoing emergence of high brightness, fibre-delivered, lasers, with their highly focusable beams, promising ever faster, lower heat input welds, but makes attention to such requirements even more critical.

Hybrid laser-arc welding is a potential solution to this problem, since due to the wire feed addition from the arc a greater difference in joint fit-up can be accommodated than in laser welding. Nevertheless, maintaining weld quality in an industrial setting can still present a challenge: the requirements of hybrid welding on part positioning, edge preparation and fit-up remain more than those of arc welding, thereby increasing the cost of material preparation and welding fixturing and raising the likelihood of weld defects.

Joint tracking sensors are already used in industry to increase the tolerance of welding processes (including laser hybrid welding) to incorrect joint placement. What is described here is the use of a laser vision sensor which has been used to track the joints robotically during welding and relay details of joint fit-up (not only position but also gap width and mismatch height) to the welding equipment, thereby enabling real time adaptive control of the robot speed or arc welding parameters to cope with any changes and maintain weld quality. Broad root-faced butt joints in 8 mm thick S355 steel and square edged butt joints in 6 mm thickness AISI 304 stainless steel, have been adaptively welded as test cases.

	6mm thickness	8mm thickness
Imperfection	Limits for weld quality Class B	
Cracks and crater cracks	Not permitted	
Porosity	Maximum diameter ≤1.8 mm Area fraction ≤0.7%	Maximum diameter ≤2.0 mm Area fraction ≤0.7%
Weld undercut	≤0.3mm	≤0.4mm
Excess weld metal	≤1.1mm	≤1.4mm
Excessive penetration	≤1.1mm	≤1.4mm
Linear mis-alignment	≤0.6mm†	≤0.8mm†

Table 1 ISO 13919-1 Class B (stringent) weld quality criteria
†In this work, linear misalignments up to 2 mm were addressed deliberately as a stretch target.

Experimental

Robotic hybrid welding trials were carried out using a Kawasaki FS-060L robot with a D+ controller, an IPG YLS-5000 Yb fibre laser and ESAB synergic MAG arc welding equipment. Suitable shielding gas/wire combinations of Ar/1.2 mm A18 (for steel) or Ar-2%O_2/1.2 mm 308LSi (for stainless) were used.

The weld qualities achieved were evaluated with respect to ISO 13919-1:1997. Table 1 summarises selected criteria for Class B (the most stringent class) from this standard.

A Servo-Robot Digi-I/S laser vision sensor used in the adaptively controlled trials is shown in Figure 1. The sensor is fitted with a V300 Robonet/ Master control unit and was calibrated with respect to the robot. Welds were made over joints with varying amounts of joint gap and/ or joint mismatch, with changes to conditions being introduced. In initial trials fixed changes were made to welding parameters to identify which were the most appropriate to change. After these trials, response programs (in the form of look-up tables) were developed and installed within the V300 or D+ controllers. Thereafter, joint fit-up information from the sensor was transformed by the response programs into real-time changes in welding conditions.

Figure 1: A laser vision sensor mounted ahead of a hybrid welding process.

The example in Figure 2 shows how such a table works by sending a suitable command voltage signal, to drive an increase in wire feed rate, when a joint gap over a given width is detected.

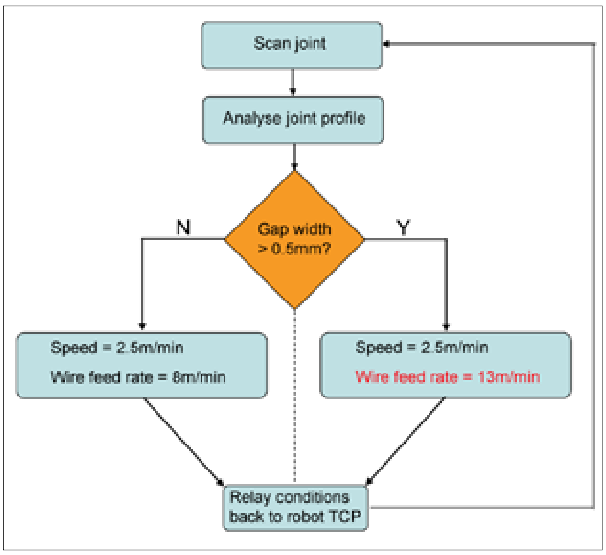


Figure 2: Example of an adaptive control algorithm

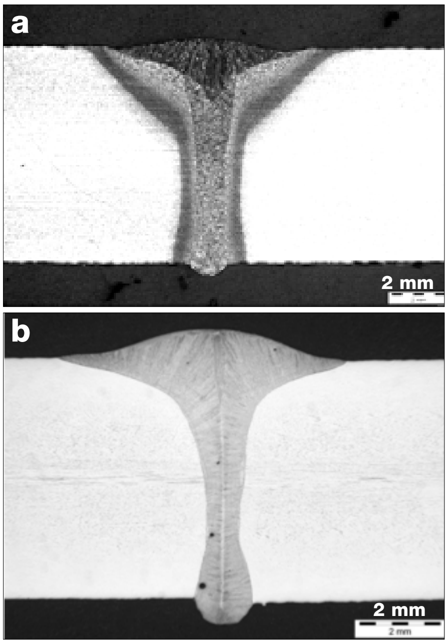
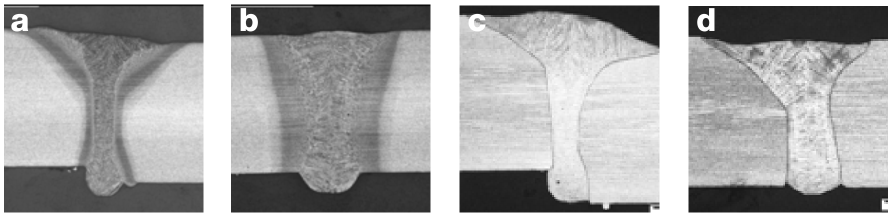


Figure 3: Class B hybrid welds made over close fitting, flush, butt joints.
(a) Butt weld between 8mm steel plates, made at 1.6m/min, with a wire feed rate 7m/min, and arc voltage trim of -3V;
(b) Butt weld between 6mm stainless steel plates, made at 2.5m/min, with a wire feed rate 8m/min, and without arc voltage trim.



1.2 mm mismatch tolerated, by reducing welding speed to 1.2 m/min.

0.6 mm gap tolerated, by reducing welding speed to 1.2 m/min, and increasing wire feed rate to 13m/min.

1.3 mm mismatch tolerated, by reducing speed to 2 m/min

1.3 mm gap, by increasing wire feed rate to 13 m/min.

Figure 5: The most successful results from adaptively controlled trials on 8 mm steel (a and b) and 6 mm stainless steel (c and d) and the tolerances that result. All weld cross-sections are to Class B.

Results

Applying the optimum conditions developed in the welding trials, figure 3 shows, for two material thicknesses, cross-sections of the Class B hybrid welds made over close fitting, flush, butt joints.

These conditions were also used to weld joints with a mismatch up to 2 mm high, or a gap up to 2 mm wide. Selected cross-sections are shown in Figure 4. Class B weld profiles were achieved up to a mismatch of 0.6 mm (figure 4a) or a gap of 0.3 mm (figure 4c) when welding the steel, or 0.5 mm (figure 4e) and 0.5 mm (figure 4g), respectively, when welding the stainless steel.

The root toe blend angles became re-entrant on the higher plate if the mismatch increased (figures 4b and f).

Conversely, the cap underfill became unacceptably deep if the gap became greater (figures 4d and h).

One or more fixed changes in the welding conditions were then tried, to improve the weld profile along joints with mismatch or gap, including:

- Reducing the welding speed.
- Increasing the wire feed rate and/or arc voltage trim.
- Changing the stand-off height of the welding head.
- Deliberately off-setting the laser beam off of the joint line (by off-setting the welding head).

The optimum results from these trials are summarised in Tables 2 and 3, for the 8 mm steel and 6 mm stainless steel welds, respectively.

As Tables 2 and 3 summarise, it appeared that changing the welding conditions would give rise to modest improvements in mismatch tolerance and would at least double the tolerance to joint gap. To confirm this, appropriate control algorithms were

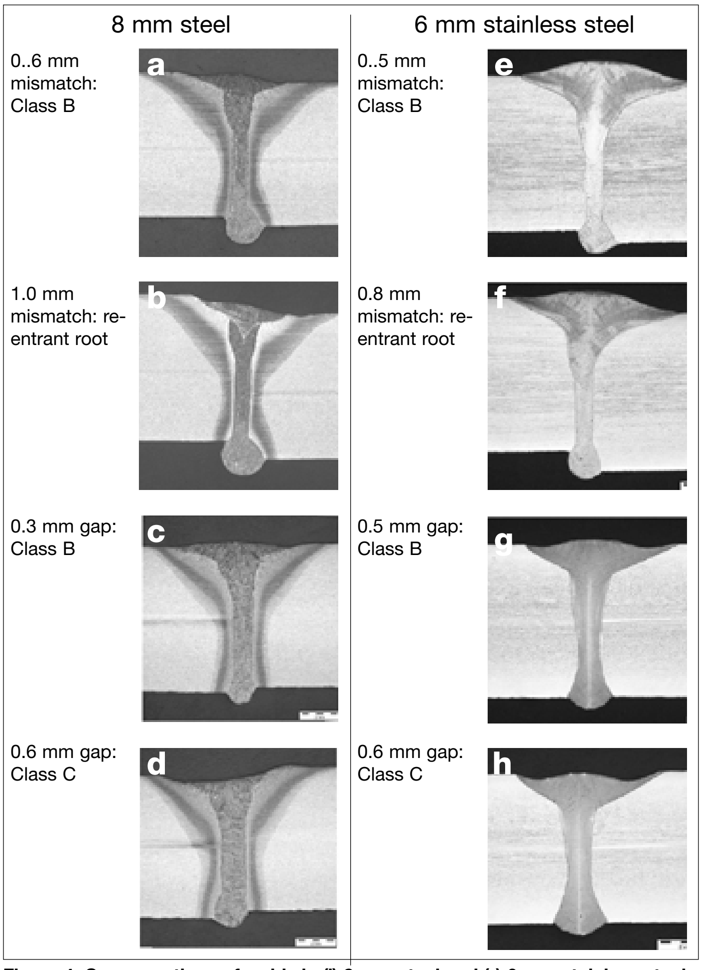


Figure 4: Cross-sections of welds in (l) 8 mm steel and (r) 6 mm stainless steel

Joint fit-up parameter	Optimum change(s)	Effect
Mismatch	Welding speed reduced to 1.2 m/min, and head stand-off by 4 mm	Tolerance limit increases from 0.6 to 0.8 mm
Gap	Welding speed reduced to 1.2m/min and wire feed rate increased (e.g. to 9 m/min)	Tolerance limit increases from 0.3 to 0.5 mm

Table 2 Optimum changes in welding parameters to increase fit-up tolerances suggested from fixed change trials on 8 mm steel

Joint fit-up parameter	Optimum change(s)	Effect
Mismatch	Welding speed reduced to 2 m/min	Tolerance limit increases from 0.5 to 0.7 mm
Gap	Wire feed rate increased (e.g. to 13 m/min)	Tolerance limit increases from 0.5 to 1 mm

Table 3 Optimum changes in welding parameters to increase fit-up tolerances suggested from fixed change trials on 6 mm stainless steel

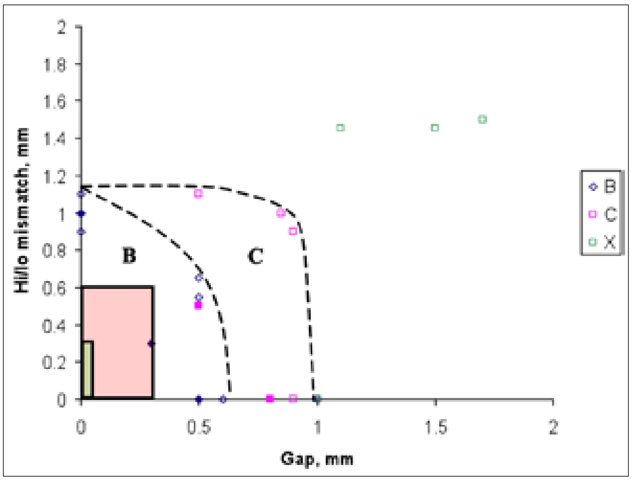


Figure 6: Tolerance of adaptive controlled hybrid welding in 8 mm thickness steel, for class B, C and unclassified (X) welds.

The green box indicates the estimated tolerances of autogenous welding without adaptive control; the red box for hybrid welding without adaptive control.

Filled symbols are from validation experiments carried out in this work. The dotted lines represent the limits for Class B and Class C welds.

programmed in to the process controllers, and adaptively controlled trials carried out on butt joints, where the joint preparation, in terms of gap and/or mismatch, increased linearly as the weld progressed. As the seam tracking device detected changes to the weld profile, an automatic change to a selection of the appropriate welding parameters was implemented. The most successful results are summarised in Figure 5. The benefits (in terms of increased tolerance) gained by using adaptive control can be seen by comparing Figures 4 and 5.

Figure 6 shows the extent to which tolerances have been increased for making either Class B or C welds in 8 mm thick steel, including those over a combination of mismatch and gap.

Conclusions

- The tolerance of high brightness hybrid laser-arc butt welding to joint gap and mismatch in 6-8mm plate, whilst still producing the most stringent class of welds to ISO 13919-1:1997, is ~0.3-0.5mm and ~0.5-0.6mm, respectively, if fixed conditions are used.
- Off-line trials can identify those parameters which, if changed, can increase these tolerances.
- A laser vision sensor can then successfully relay the fit-up details to process controllers, pre-programmed to respond with these changes, to maintain weld quality over a wider range of gaps and mismatches. Using this approach, in this work, these tolerances have been doubled for the production of Class B welds.

Acknowledgements

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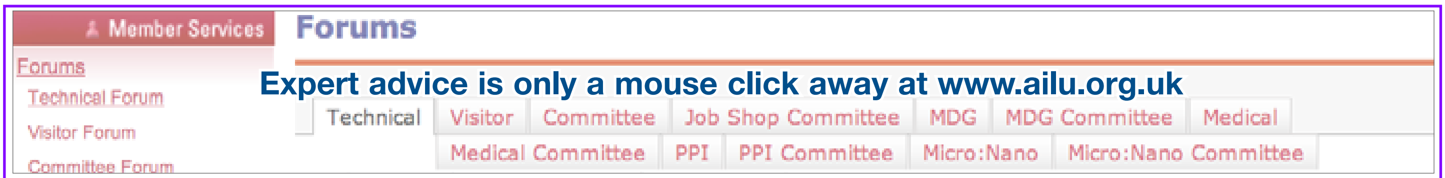

Message to the Technical Forum (open to all AILU members) posted 21/07/11:

Does anyone have experience of laser micro-machining of molybdenum? Are there any special tricks? Any toxicity issues?

Replies

1.

Just been on t'internet and found this;

Gupta, U.C., Gupta,_S.C., Trace element toxicity relationships to crop production and livestock and human health: Implications for management, Communications In Soil Science And Plant Analysis, 1998, 29, 1491-1522.

...it is clear from the data summarised here that acute molybdenum poisoning in human beings is very unlikely: a massive dose would be required [National Research Council 9, 1980]. Compared with some metals used industrially (antimony, arsenic, beryllium, cadmium, chromium, lead, mercury) molybdenum is of very low toxicity [Saunders, 1956; Browning, 1969; Ashmead, 1972; Nguyen-Phu-Lieh, 1971]

Lexpert

2.

There are no special tricks. Typically it takes a bit more power and a bit more peak power to cut/drill and it is harder to create a dross free cut compared to stainless for instance. Thin stuff is quite easy. We cut with a pulsed YAG but I know of others that use CO2 or many of the shorter pulse lasers. What scale of part do you want to do?

Molybdenum has very many oxidation states and forms many different oxides. These should be considered harmful. The dust exposure limit for just one of the oxides, molybdenum trioxide, is usually quoted as 10mg/m3 and is considered harmful to mucus membranes, eyes and lungs. Good fume extraction should allow the material to be cut in safety. Don't forget to be cautious of cleaning nozzles and jigs and also extract ducting, filters, etc.

Micrometric

3.

I did some work cutting with a pulsed YAG laser in the 1970s. It was successful and went into production. This involved cutting arrays of apertures in Moly sheet 0.1 to 0.5 mm thick. Oxygen and water vapour need to be excluded for best results; I believe this is because any oxide formed tends to be very 'fluffy' and interferes with the focus optics. We cut under argon with success. There is a problem making fine cuts to yield narrow bars as the surface tension of the melted zone would bend the bars in towards the cut. This was solved by interrupting the cut and going back later to cut the remaining 'lands'. Excellent geometry was achieved by pulses of about 40 microseconds at about 100 Hz. An air knife was used to keep the focus lens clean; it was not possible to use a coaxial assist jet because that made the sheet vibrate. The kerf width was in the region 8 to 20 microns.

It will be interesting to hear how people have got on at other wavelengths and pulse conditions.

Tim Weedon

The message for readers is:

You can easily get much more that an annual membership fee's worth of advice from a single trip to the AILU web site forums.

Designing surfaces by laser remelting

André Temmler, Edgar Willenborg and Konrad Wissenbach

The surface of a part or product strongly not only influences its properties (e.g. abrasion and corrosion resistance, insensitivity to scratches and how it feels to touch) but also its visual perception. It is particularly with regard to visual perception that many plastic parts have structured surfaces e.g. leather textures on car dashboards. Usually these structures are integrated in the injection mould and then transferred to the plastic part during the production process. An approach to enhancing the appearance of such design surfaces is to create a two-gloss effect by selective laser polishing based on remelting a thin surface layer. Remelting also allows a new approach to structuring metal surfaces in which a laser beam melts a surface layer and simultaneously reallocates the molten material.

Basic principles

Laser polishing

Selective micro laser polishing is based upon the remelting of a thin surface layer (< 5 µm) by using pulsed laser radiation, as shown in figure 1. The resulting surface solidifies without cracks, pores or hidden defects out of the molten material. While the surface is remelted, the micro roughness of the initial surface, in particular, is smoothed by the surface tension of the melt pool. The surface roughness can be varied by controlling process parameters, especially laser power and scan velocity.

In the experimental work described here a fibre-coupled Q-switch Nd:YAG solid state laser was used (wavelength 1064 nm; maximum power 400 W; CW and pulse mode with a pulse duration 100 – 700 ns). A galvo scanner plus variOScan provided x- and y- and z-direction scanning of the workpiece surface, which was kept in a process chamber that can be filled with inert gas.

In order to selectively laser polish surfaces made out of the tool steel 1.2343, the circular laser beam meanders along a folded path. Space-resolved changes in gloss levels are produced by modulating the process parameters along the path.

Structuring by remelting

The text box below describes the reallocation process. The height, size and form of the surface topography created depends directly on the average melt pool volume and its rate of change. The average size of the melt pool determines the resolution of the produced structures, and the absolute change and the time-dependant alteration rate of the melt pool volume determine the height and symmetry of the produced structures.

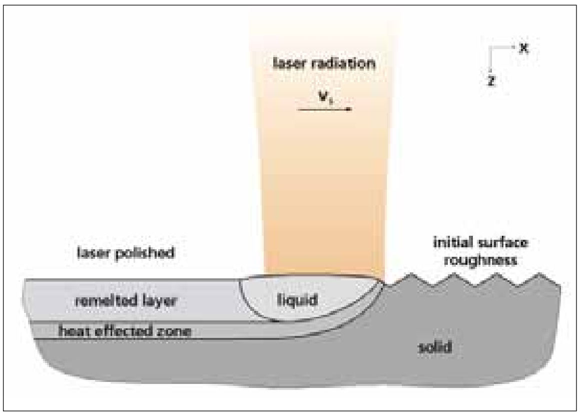

Fig. 1: Schematic of the laser polishing process by remelting a thin surface layer

In order to achieve periodic structures the laser power is modulated sinusoidally and the laser beam is scanned unidirectionally over the surface. The scan speed and frequency of the modulated laser power determine the wavelength of the remelted structures.

Moving material by surface remelting

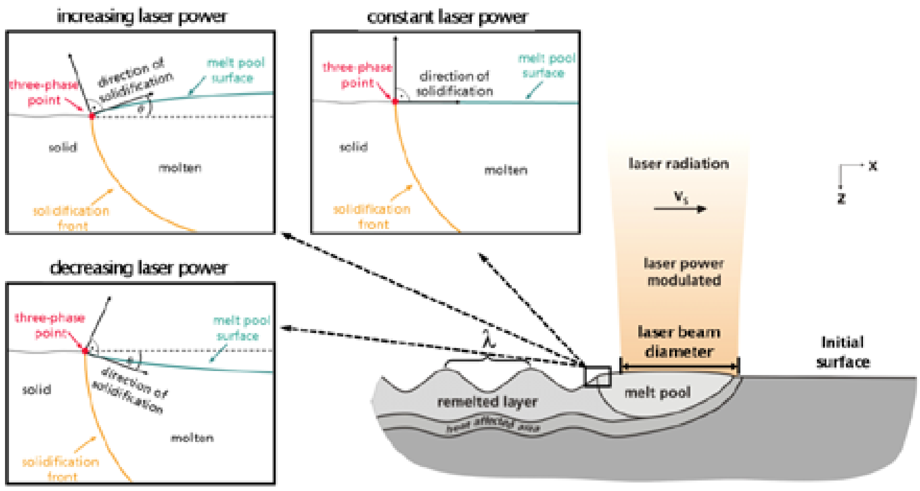

Figure 2: Schematic of the active principle for structuring by remelting in the case of constant, increasing an decreasing laser power while remelting the surface.

The process of structuring by laser remelting is based upon the interrelationship of the melt pool volume and the movement of the three phase line. This movement causes a change in the melt pool volume and hence the surface topography. In case of laser polishing these variations of the melt pool volume are unwanted, but in case of structuring by remelting the melt pool volume is precisely modulated by, for example, modulation of the laser power.

Figure 2 shows the principle of the structuring process. A thin surface layer (< 100 µm) is molten and solidifies afterwards. The direction of the solidification follows the melt pool surface. With constant laser power the melt pool surface is approximately flat and no structuring appears. With increasing laser power the volume of the melt pool increases, and the melt pool surface bulges outwards due to the density change from solid to liquid plus thermal diffusion and, therefore, the bigger volume of the molten material. The solidification follows the bulged surface; by decreasing laser power the process works in reverse. It follows that structuring can be achieved by appropriate modulation of the laser power while remelting a thin surface layer.

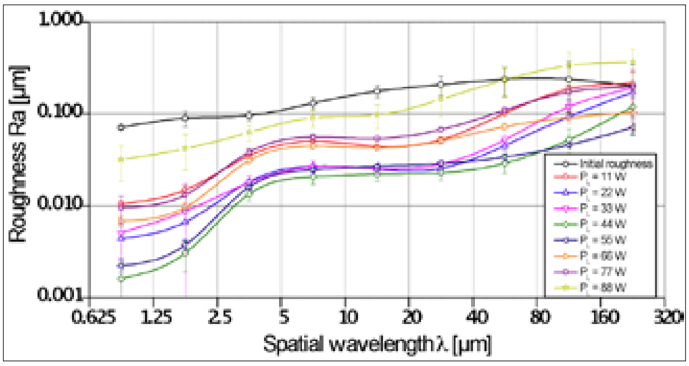

Figure 3: Ra-spectrum using whit light interferometry, showing the variation of roughness (Ra) with spatial wavelength of a laser polished surface. Under the particular parameters of this work the polishing effect is seen to improve for laser power up to 44 W.

Results for selective laser polishing

The contact-based mechanical methods often used to quantify the roughness of a surface area (e.g. the mean roughness index Ra) and as such they are not sensitive to the micro roughness of a surface that micro laser polishing addresses. Consequently, an alternative technique based on white light interferometry, followed by a spectral analysis of the surfaces roughness is used to assess micro laser polishing. The spectral analysis provides the mean roughness at regular spatial wavelength intervals. In this way a much more sophisticated characterisation of the surface condition is achieved. Typical results are shown in figure 3.

As previously described, the laser used for this work provided pulses of several 100 ns duration. As shown in figure 3, smoothing was achieved for spatial wavelengths up to about 80 µm. For smaller spatial wavelengths the roughness of the laser polished surface was reduced significantly; but whilst the initial roughness was reduced for all wavelength intervals and all laser powers investigated, the polishing effect maximised at a laser power of 44 W and was less at both lower and higher powers.

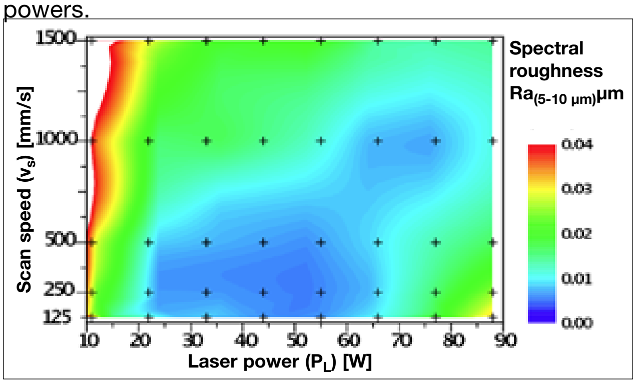

Figure 4: Plot of spectral roughness dependency on laser power and scanning velocity for the spatial wavelength interval from 5 to 10 µm. The black crosses within this plot represent the supporting points, in this case pairs of laser powers and scanning velocities investigated. Other parameters were kept constant.

In addition to laser power, scanning velocity is a crucial parameter. Figure 4 shows a plot of the variation of spectral roughness with laser power and scanning velocity for the spatial wavelength interval from 5 to 10 µm. As can be seen, the spectral roughness is minimum in the range:

$33 < P_L < 55$ W
$125 < v_S < 500$ mm/s.

i.e. the process window for selective laser micro-polishing is relatively broad.

For selective laser polishing in the scan direction the laser power had to be modulated. The rise time of laser power in the laser used for this work was 1.05±0.1 ms. Thus, in order to achieve a resolution of 125 µm, which corresponds to the smallest laser beam diameter used, the scan speed (v_s) had to be restricted to no more than ~100 mm/s.

Process chain

In order to selectively laser polish a leather-textured free-form surface several process steps are necessary:

1. Digitalization of the free-form surface (here, using a chromatic confocal sensor). It provides a lateral resolution of 12.5 µm for x- and y- direction and approximately 335 nm in the z-direction. An average measuring rate of approx. 30-40 s/cm² was achieved with a better than 2% error.

2. Preparation of data describing the selective laser polishing of the free-form surface. Specially adapted software was used to achieve this. The result takes the form of a black and white image of the intended leather texture, where the white areas represent the elevations and black ones the indentations.

From this output a machine adapted control code is generated, in a form suitable to drive a 3D laser scanning system and an appropriate laser beam source. A two gloss effect resulted from the contrast of selectively laser polished indentations and untreated elevations.

These process steps described above were carried out for a leather-textured free-form surface with lateral dimensions of 160 mm x 195 mm and a maximum depth of ~ 20 mm. The maximum value of the inclination angle relative to the surface normal was 25°. Figure 5 shows the resulting appearance of the selectively laser polished free-form surface in two different magnifications. The overall time for the selective laser polishing of this free-form surface was ten hours, of which 8 hours was taken up with the digitalization of the free-form surface.

Summary & Outlook

Laser polishing opens up the possibility of selective processing of small areas (< 0.1 mm²) on a tool's surface. Selective laser polishing enhances the appearance of design surfaces by creating two-gloss effects, which cannot be achieved with conventional machining methods without a high demand in human resources and time.

A broad process window exists for selective laser polishing and a proper working process chain has been developed, including the integration of a sensor system into the existing set up and the creation/adaption of the necessary software. The leather-textured free-form surface in tool steel demonstrates the successful operation of all process steps. The remaining work before selective laser polishing can be successfully introduced into an industrial environment includes the development of process steps to encompass free-form surfaces in general (especially those with greater inclination angles than 25°), and reducing the overall processing time.

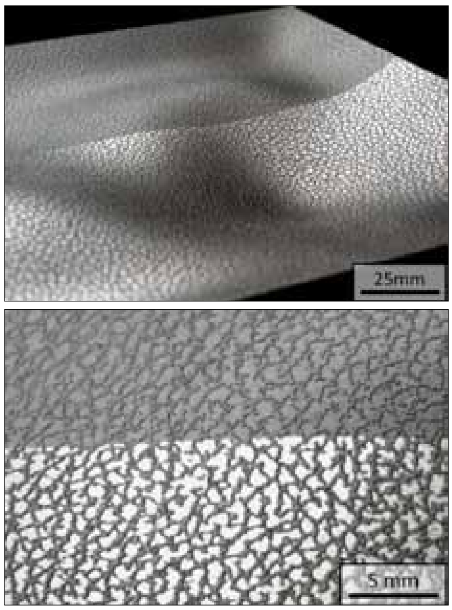

Figure 5: Photograph of a selective laser polished leather-textured free-form surface made of tool steel 1.2343

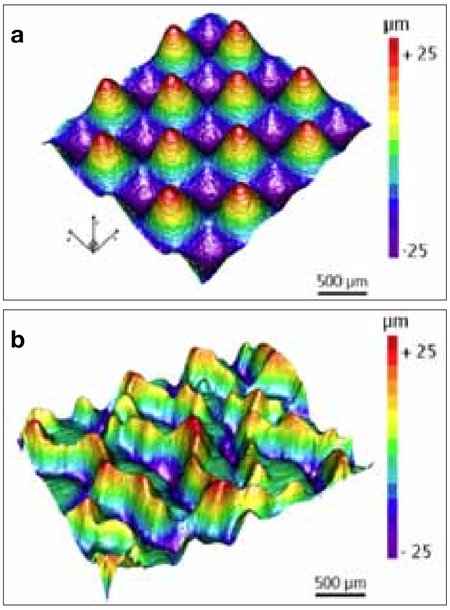

Figure 6: Miscoloured 3D representations of attained (a) periodic and (b) aperiodic structures, mapped by white light interferometry

Structuring by remelting

Finite element simulation

Until recently, theoretical investigations on remelting with small melt pool dimensions have been focused on surface rippling during laser polishing. The ripples originate in the fluctuation of the melt pool volume and a Finite Element Method program was found to accurately replicate this phenomenon.

The FEM program was then expanded to address the growing and shrinking melt pool during sinusoidal laser power modulation and the results were found to have a very high qualitative and quantitative congruence with the experimentally achieved surface topographies with regard to height, width and wavelength; thereby providing a good theoretical foundation for the structuring process.

Results

Figure 6 shows periodic and aperiodic structures produced by controlled modulation of the laser beam. The periodic structures produced to date have a spatial wavelength in the range 0.25 - 5 mm and a structure height in the range 5 µm - 1mm. The height of a remelted track depends on the spatial wavelength: from 2.5 µm for a wavelength of 0.25 mm up to 20 µm for a wavelength of 4 mm.

In order to achieve greater heights the process has to be repeated several times. Every time the surface is remelted using the same procedural parameters, the height of the structures grows. The time required therefore depends strongly on the combination of surface wavelength and height.

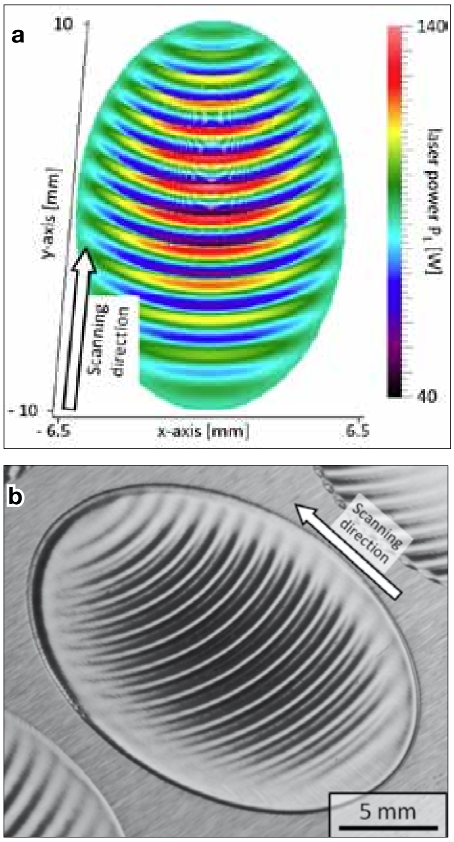

Figure 7: Representation of (a) laser power in dependence on position in x and y-direction and (b) structured surface based on the laser power modulation in (a). Feature height varies up to ± 30 µm of the surface.

The production of symmetric structures is a special case and needs a precise adjustment of wavelength and the amplitude of the laser power modulation. In normal cases, this means that without adjusting the laser power amplitude according to the required spatial wavelength used to the modulation, the structured surface topography will be skewed. The non periodic structure in Figure 6b was built up by using a non-periodic laser power modulation.

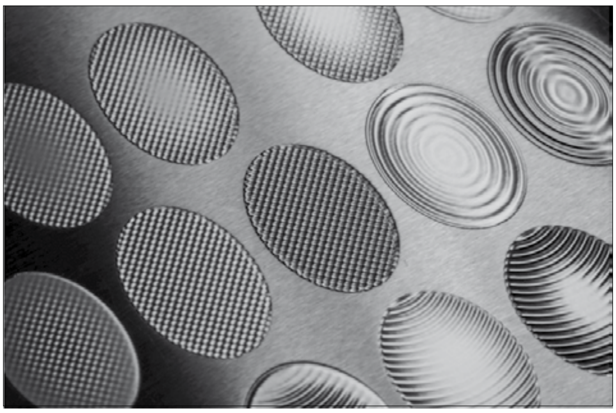

Figure 8: Photograph of several periodic and aperiodic structures created by laser remelting of tool steel 1.2343

In order to increase the complexity of surface structures in comparison to wave or burl structures, the space-resolved laser power modulation must be modified; for example, by an overlying exponential decrease of laser power or a space-resolved shift in phase; see figure 7a.

Such complex signals can be transferred to a metallic surface, leading to a structure very similar to the laser power signal used, as seen in figure 7b. Figure 8 shows a variety of structures achieved on tool steel 1.2343 by modulating the laser power in many different ways. The processing time for the structure shown in Figure 8 was ~ 30 – 35 s/cm^2.

Summary & Outlook

Structuring metallic surfaces with laser radiation based on the remelting of a thin surface layer can produce periodic and aperiodic structures. Using an adapted space-resolved modulation of laser power has produced multiple novel and complex structures on flat surfaces.

Despite these promising results, the reduction of machining time, transfer of the structuring process from flat 2D surfaces onto freeform surfaces and the exact transformation of user-defined structures on arbitrary surfaces remain challenging problems for future work.

Acknowledgement

For both the work on laser polishing and on structuring we would like to thank the Federal Ministry of Education and Research (BMBF) for strong financial support. For the work on laser structuring we would also like to thank the Volkswagen Foundation for their generous sponsorship of the research project: “Process and machine technology for structuring of design surfaces by laser remelting (FluidStruc)”.

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Micro-cutting with pulsed fibre lasers

Jack Gabzdyl

Nanosecond pulsed fibre lasers have made a significant impact in material marking, but as laser sources they are also proving to be extremely versatile, finding many applications in a variety of micro-machining processes. One such process is micro-cutting. Rather than the conventional CW laser melt and blow process, micro-cutting with a short pulsed laser source is primarily vaporisation driven: the traditional cutting gas nozzle with a concentric high pressure gas flow is no longer required.

Vaporisation driven micro-cutting generally requires short laser pulses of high peak power and high power densities at focus. There are two principle approaches to making the cut: the first is in a relatively slow single pass with a high level of pulse overlap to achieve high quality. This approach is generally implemented with a fixed beam delivery and the workpiece steered by a translation stage under the beam. It is more often the solution adopted with high pulsed energy Nd:YAG lasers and it allows relatively thick materials to be cut, but the capital cost of the laser can be high.

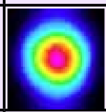
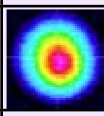
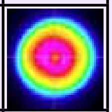
The alternative is to utilise a high speed scanner to repeatedly pass the beam over the cut line, removing a small amount of material per pass. With this approach burr free cuts can be achieved with a minimal heat affected zone. This technique, which requires just a simple laser marking system, offers a flexible, accurate and very affordable solution.

Nanosecond pulsed fibre lasers are low cost, compact, reliable and they require no maintenance. The short pulses and relatively high peak powers that can be achieved with directly modulated seed MOPA designs and are ideally suited to this vaporisation-driven cutting process.

Optical Considerations

The spot size is influenced by the F-number of the focusing optics and the beam quality factor (M^2). Values for M^2 are given in Table 1 for three models of SPI Laser nanosecond pulsed fibre lasers. Calculated values of spot diameter for a focused 8 mm diameter beam from each of the three SPI models is shown in Table 2.

SPI Laser range for micro-cutting

Laser model+	SM	HS	HM
Mode			
M^2	1.3	1.9	3.2
Pulse energy	*	**	***
Peak power	*	**	***
Spot size	***	**	*
Depth of field	***	**	*

* Low **Medium ***High

\+ SM Single mode
HS High Specification
HM Higher Moded

Table 1 Laser model, beam quality and pulse characteristics

Although a small spot size is a key attribute of the process it is not the only beam characteristic that needs to be considered, as can be seen in Table 1 where the higher the number of asterisks the better the parameter in the context of laser cutting.

All three models can be used for laser cutting, but exhibit slightly different cutting characteristics. For example the SM is best able to achieve narrow kerf widths while for thicker materials the HM generally produces better results [1].

An example of the difference in mode quality is shown in figure 1 which compares two holes cut through painted sheets. Identical optical arrangements were employed with a 20 W SM and a 40 W HM laser. Both lasers could cut the 1mm hole to the high tolerance required but whereas the high beam quality SM laser caused far less damage to the paint, the cut at a far lower speed than achieved by the HM laser which put more heat into the cut and produced the hole four times faster. It would be up to the user to compromise between quality and productivity.

Laser Model	SM	HS	HM
M^2	1.3	1.9	3.2
100mm FL	22	32	53
160mm FL	35	51	85
254mm FL	55	80	135

Table 2 Effect of focal length and beam quality on calculated spot size (μm) based on an incident beam of 8 mm diameter.

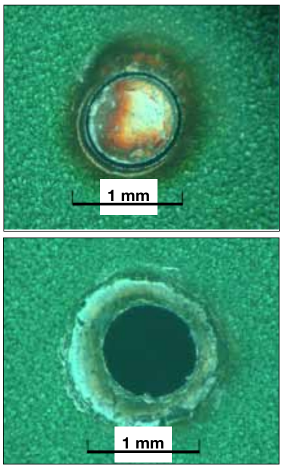


Figure 1. As processed 1 mm diameter holes cut in painted steel.

Left: 20 W SM - M2 <1.3
2s cycle time
low paint damage

Right: 40W HM - M2 3.2
<0.5s cycle time
some paint burn back

Cutting strategies

Pulsed laser cutting is a string of individual laser pulse events, each typically forming of a crater of depth 1-50 μm.

Translation speed and pulse frequency govern the amount of overlap between adjacent laser pulses. A high level of overlap is generally required but studies have shown that, depending on the optical characteristics of the material being processed, too high an overlap can reduce the material removal efficiency. For fine foil cutting a single pass of the laser beam may be all that is required, but for thicker materials multiple passes are required to achieve full penetration. However, as the aspect ratio of the kerf increases it restricts the ability of the beam to remove more material and it needs to be widened. A rule of thumb is to keep the kerf aspect ratio to no more than 10:1 Thus, while for materials <200 μm thick the cut can be made by overlapping repeating passes, for material of greater thickness a beam wobble technique is recommended, as shown in figure 2.

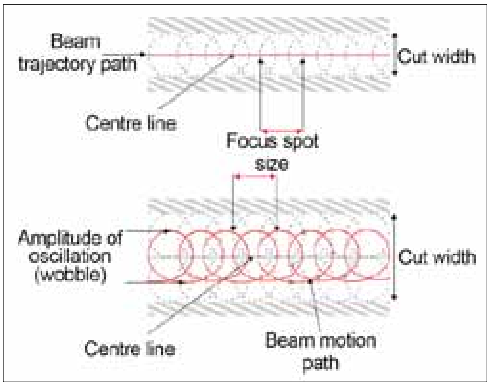


Figure 2. Schematic comparing a simple cutting technique with that of beam wobble

In this technique the beam path is a spiral of pre-defined amplitude along the cutting line; achieving such a trajectory is a basic feature of scanner-based marking software where it is extensively used to broaden the marking line width. Another technique is to off-set the cut line between passes but this is generally considered to be less effective. Using such techniques figure 3 shows cuts in a wide range of materials and thicknesses.

Materials

Vaporisation-driven micro-cutting can be applied to a wide variety of materials ranging from ferritic and non ferrous metals to ceramics, polymers and carbon composites. The cutting speeds that can be achieved vary considerably, depending on thickness, up to and exceeding 10 m/min for thin foils. These speeds are slow compared to conventional laser cutting but for many applications the low capital cost and the flexibility offered by ns pulsed fibre laser cutting/marking systems are highly attractive.

Stainless steel
is a widely used material particularly in the medical industry where there are significant fine cutting requirements. Cutting speeds in stainless steel exceeding 20 mm/min can be achieved with good quality in 0.5 mm thick 304 grade material [2]. Using a 40 W HM laser with a fixed cutting head and coaxial assist gas a speed of >1.5 m/min has been in achieved in 200 μm foil.

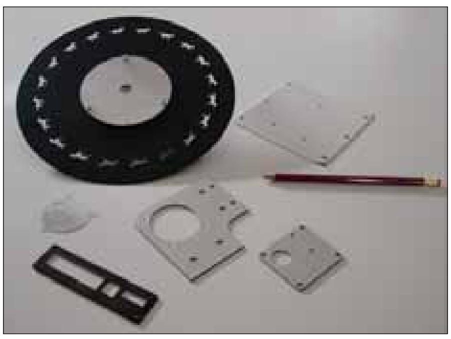


Figure 3 Cut samples include: 1.2 mm aluminium, 0.2 mm tinned steel, 0.5 mm & 2.0 mm anodised aluminium Courtesy of Newson Engineering NV.

High reflectivity metals
Pulse laser cutting is successful on metals with high reflectivity and conductivity, which are generally considered difficult materials to cut. High power densities are required to initiate the cutting process and this is readily achieved with ns fibre lasers.

Figure 4 illustrates high quality cutting of brass and silver. In both cases a 20 W HS laser can cut up to 1mm thick, the 40 W HM can cut up to 2 mm thick. The ability to create intricate patterns with low material wastage is highly attractive to the jewellery sector.

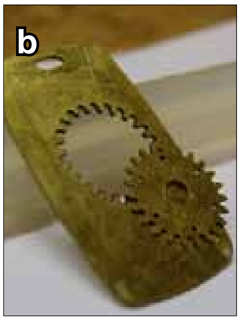


Figure 4: Pulsed laser cutting of highly reflective materials

(a) A high quality ornately patterned silver disc 0.55 mm thick cut with a 20 W HS laser in 13 min

(b) Brass sheet 0.8 mm thick cut with 20W HS in 7 min.

Courtesy of Orotig srl

The cutting of copper has many applications particularly in the electrical and electronics areas. One emerging application is the cutting of conductive copper tracks deposited on PCB boards.

Non metallic cutting
Pulsed laser cutting can be applied to a wide range of non metallic materials including plastics and rubbers. A key factor in determining suitability of a material is its absorption at the 1μm laser wavelength. Many plastics have high transmission and are therefore unsuitable, but not all. An example is shown in figure 5.

Figure 5: Laser marking and cutting outline of plastic labels. Courtesy of thinklaser

Figure 6: Small discs rapidly cut from a substrate of green aluminium nitride ceramic 3 mm thick with a 40 W HM laser using 6 passes at 50 mm/s

The same consideration of laser wavelength absorption applies to the cutting of ceramics, such as alumina and aluminium nitride where the success of 1μm laser cutting depends on the specific material and surface finish, see figure 6.

Silicon is widely used in the electronics and solar industries and there are numerous cutting applications. This material is conventionally diced or cut using mechanical diamond cutting wheels, but these have limitations on thinner materials and the cut edge is prone to chipping. The pulsed laser offers a flexible alternative that can to used to cut complex profiles and shapes with ease.

Summary

Nanosecond pulsed fibre lasers are ideally suited to vaporisation cutting applications. This paper highlights some specific techniques that can be adopted in improve cut quality and the material thickness range and the impact that beam quality can have. A diverse range of materials can be successfully cut showing the extreme versatility of these sources.

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See Observations p 36

Hazard potential and cleanup cost of fume created during the laser welding and soldering of steel

Jürgen Walter, Michael Hustedt, Volker Wesling and Stephan Barcikowski

In a typical automated laser welding or soldering process a filter system is integrated into the process chain to capture both the emitted gases and fumes from the process zone. Databases of process emissions can be used in principle to predict emissions for an industrial process. However, many of these were established more than 10 years ago and are often incomplete. In addition, there have been developments in laser technology and new trends in the field of semi-finished products, such as multi-metal material mixes.

In recent studies at Laser Zentrum Hannover, measurements were made of gaseous and particulate emissions during laser processes for sheet metal (mostly steel) of various grades, with or without surface coating, at four different industrial facilities. Details of the capture techniques, sampling and analysis can be found in the Proceedings on the Lasers in Manufacturing conference 2011 [1]. The hazardous potential of these emissions was then evaluated with respect to relevant threshold limit values (TLVs) classified according to the measures required by German environmental legislation ("TA Luft" [2]).

In total, measurements have been performed with 12 material combinations and 3 joining variants (soldering, deep penetration welding and heat conduction welding) including typical industrial surface treatments (pure, oiled, with residues of cold cleaning solvent, PTFE-coated and zinc-galvanized). This is summarised in Table 1.

Evaluation of results

Table 2 displays the relevant emission values of all investigated joining processes. The table shows that in all cases the aerosol emission was below the TLV values for total emission rate (200 g h^{-1}) and concentration (150 mg m^{-3} for rates below 200 g h^{-1}); for this reason individual vales for the volatile organic and inorganic aerosol components are not listed.

The last column in Table 2 shows the 'environmental effort category', leading to different measures for the cleaning of exhaust air*:

Cat. 1: No filtering measures for the exhaust air are necessary since all emissions comply with the TLVs.

Cat. 2: State-of-the-art particle filters are required if specific aerosol TLVs are exceeded.

Cat. 3: State-of-the-art filtration of gases is mandatory if TLVs for specific gaseous components are exceeded.

Cat. 4: Additional measures are required (e.g. acidic gases are emitted, which must be neutralized).

* Note that Germany has additional environmental protection requirements.

Every laser process examined in this work is seen to be Cat. 1 or 2.

It has to be noted that the hazardous potential of nano-particles has not been taken into account in the frame of the described classification; if such limits are set is future emission rules and environmental legislation then this will have to be taken into account in the analysis of process emissions.

Cost of environmental measures

As a starting point of this assessment the overall running costs of the laser joining processes was estimated by the four industrial partners whose facilities were involved in the emissions study. Based on these data, the costs for installation and operation of efficient capturing and filtration technologies for exhaust air cleaning (costs for environmental measures) were calculated allowing for depreciation, operating costs, electrical consumption and maintenance costs.

As shown in Table 3, the costs for air purification within all processes investigated (Cat. 1 - 2) are below 15 % of the overall costs of running the laser processing facility (including capital depreciations, operating costs, electrical consumption and maintenance costs). Clearly, the costs will rise with the environmental effort category and for joining processes; figures in excess of 15% for a process rated Cat. 3 or 4 can be expected to exceed 15 % of the overall costs.

ref no.	materials	thickness [mm]	coating / treatment	laser type / output power	focal length [mm]	feed rate [mm s-1]	spot size / weld seam [mm]	joining process variant*
1	a: electrical sheet, b: mild steel	a: 0.1, b: 1.5	a: polymer coating	CO_2, 0.5 kW (cw)	200	17	0.15	DP
2	a: baking tray, b: mild steel	a: 0.5, b: 1.5	a: PTFE coating	CO_2, 0.75 kW (cw)				
3	a+b: mild steel	a+b: 1.5	cold cleaner	CO_2, 1.0 kW (cw)				
4	a+b: mild steel		forming oil					
5	a+b: stainless steel 1.4404	a: 3.0, b: 5.0	none	Nd:YAG, 3.0 kW (cw)	200	58	0.2	DP
6	a+b: stainless steel 1.4301	a: 2.0, b: 3.0	none	CO_2, 3.4 kW (pulse max.)	200	5	1.2	DP
7	a+b: brass	a+b: 1.5	none	CO_2, 1.7 kW (pulse max.)			1.5	HC
8	a: DC 05/06, b: HLAD340	a: 0.7, b: 1.5	a+b: zinc-coated	Nd:YAG, 4.0 kW (cw)	200	60	1.5 – 2.0	HC
9	a: HLAD340 b: HLAD380 (Z 100 MB)	a: 1.5, b: 2.5	a+b: zinc-coated			30		
10	a: DC06, b+c: HLAD340	a: 0.7, b+c: 1.5	a+b+c: zinc-coated			32		
11	a: DC06, b: Usibor, c: HLAD340	a: 0.7, b: 2.0 c: 1.5	a+c: zinc-coated			27		
12	a+b: DC06 ZE 50/50	a+b: 0.75	a+b: zinc-coated	Nd:YAG, 2.7 kW (cw)	165	38	3.2 – 3.4	SD

Table 1: Sample description and joining parameters (*Joining process: DP: deep penetration welding, HC: heat conduction welding, SD: soldering)

ref no.	process (Table 1) and thickness [mm]	remarks	total aerosol rate [g h^{-1}]	total aerosol conc. [mg m^{-3}])	environmental effort category
1	DP thickness 0.5 + 1.5	lap joint	15.4	13	1
2	DP thickness 1.0 + 1.5		9.6	8	1
3	DP thickness 1.5 + 1.5		18.1	15	1
4			19.2	16	1
5	DP thickness 3,0 + 5,0	circular seam	2.3	17	1
6	DP thickness 2.0 + 3.0	circular seam	1.4	6	1
7	HC thickness 1.5 + 1.5	longitudinal seam	3.1	16	1
8	HC thickness 0.7 + 1.5	cabin capturing off	23.6	118	1
		cabin capturing on	20.0	100	
9	HC thickness 1.5 + 2.5	cabin capturing off	33.2	**166**	2
		cabin capturing on	18.6	93	
10	HC thickn. 0.7 + 1.5 +1.5	cabin capturing off	25.5	128	1
		cabin capturing on	18.9	95	
11	HC thickn. 0.7 + 2.0 + 1.5	cabin capturing off	38.3	**191**	2
		cabin capturing on	23.0	115	
12	SD thickness 0.75	cabin capturing off	11.8	59	1
		cabin capturing on	7.1	36	

Table 2: Aerosol emission rates and concentrations measured in the exhaust air. Values that exceeding TLVs are marked red. Total aerosol emission rate TLV = 200 g h^{-1}; Total aerosol conc. TLV = 150 mg m^{-3}

ref no.	laser type	process	overall process costs	costs for environmental measures	% of overall costs
1	CO_2 (cw)	DP	75 €/h	10.75 €/h	14.3 %
2	CO_2 (cw)				
3	CO_2 (cw)				
4					
5	Nd:YAG (cw)	DP	90 €/h	4.70 €/h	5.0 %
6	CO_2 (pulsed)	DP	85 €/h	4.70 €/h	5.5 %
7	CO_2 (pulsed)	HC	60 €/h	4.70 €/h	7.8 %
8	Nd:YAG (cw)	HC	100 €/h	8.30 €/h	8.3 %
9					
10					
11					
12	Nd:YAG (cw)	SD	115 €/h	8.30 €/h	7.2 %

Table 3: Environmental costs in relation to the overall process costs

Filter design and air-to-cloth ratio

The task of any filter system is to reliably purify a specified exhaust gas to comply with given limits for dust and other pollutants. Many parameter influence the filtering complexity: the carrier gas (usually ambient air), the particles and the filter medium properties, the operation mode, as well as the filter design.

The air-to-cloth ratio represents the flow through a filter surface in a given time. It depends on various factors and affects the performance of a filtering system: a large air-to-cloth ratio (~ 120 m^3 m^{-2} h^{-1} is the current state-of-the-art) [3] implies that the filter produces the minimum achievable pressure drop (< 2500 Pa for particles < 0.5 µm) and this should be the main objective of the filter design.

With this in mind the technical data of the exhaust systems in use on the four project partners' manufacturing lines are presented in Table 4. Comparing the two right hand columns it can be seen that in only one case (Company B) was the filter of the exhaust air system greatly (about x10) oversized (and therefore unnecessarily costly). The other filter systems were running economically, with close to optimum filter dimensions.

Company/ref no.	design flow rate of fan [m^3 h^{-1}]	target air-to-cloth ratio [m^3 m^{-2} h^{-1})]	required filter area [m^2]	actual filter area [m^2]
Company A / (1)-(4)	2,200	120	18	30
Company B / (5)	500		4.5	40-80
Company C / (6)-(7)	6,000		50	100
Company D / (8)-(12)	3,500		30	50

Table 4: Air-to-cloth ratios of filter systems in use

Conclusion

The results of this work demonstrate that the cost for compliance with environmental measures (air capturing, cleaning and disposal) has a strong dependence on the types of emission products and on the emission rates. The costs for environmental measures have been related to total process costs

Four categories have been defined in order to rank the expense of environmental protection, but the laser joining processes investigated here were all assigned to categories 1 and 2. Yet even with these assignments the cost of meeting environmental standards represented up to 14% of total running costs though figures of around 8 % were more typical, which is comparable to laser cutting of polymers with a typical cost fraction of about 10 % for handling and filtration of the exhaust air [4].

The interactive database "Laser Safety" [5] has been revised. It provides details of laser process emissions and has been available in the internet for several years as an aid to the planning and selection of suitable exhaust systems for laser welding and soldering.

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OBSERVATIONS

Short comments on papers in this issue

Laser vs micro-abrasive waterjet in the jobshop

Don Miller

I take interest in articles that offer a comparison of processing techniques as impartiality is often hard to achieve particularly if the author is a protagonist for one of them! A feel that the humble laser has been a touch shortchanged, but as a “laser jock” I would say that.

Multiple technologies can co-exist in manufacturing and commercial market forces are the final arbiters. In my estimation, laser cutting wins over waterjet because the majority of cutting applications do not require the specific benefits of the waterjet's cutting properties. For example, in the majority of cutting applications the Heat Affected Zone produced in laser cutting is not an overriding concern. Granted there are applications where the absence of HAZ is critical and then waterjet should be the preferred process; cutting thick aluminium and bright metals are also better suited to abrasive waterjet.

The article refers to micro-machining, but with feature sizes limited to the 250 µm minimum jet diameter I feel that the process is more accurately described as sub-millimeter.

I also take issue with the comment that pulsed nanosecond lasers, which can achieve features sizes a full order of magnitude smaller than abrasive waterjet systems, requiring operators with PhDs. This is somewhat at odds with my experience of today's nano-second lasers, which are highly reliable and reproducible and are installed on production lines worldwide making parts by the million for today’s voracious consumers of ever more sophisticated and elaborate mobile and handheld devices, under the supervision of operators, many of whom will little or no formal higher education.

Don's comments about precious metals and waste recovery are also at odds with my experience. In low thickness lasers can produce significantly finer kerfs, resulting in less material wastage, and my understanding is that the waste recovery from laser machines is relatively straightforward, especially when compared to extraction from gallons of water mixed with spent abrasive. Topics such as efficiency, energy consumption, cost of ownership and general green credentials, not addressed in the paper, also favour the use of lasers over waterjet.

Jack Gabzdyl SPI Lasers UK Ltd

Micro-cutting with pulsed fibre lasers

Jack Gabzdyl

Over the last few years and the development of the fibre laser, high speed micro cutting has gained greatly in importance. Fibre lasers with diffraction limited beam quality offer many advantages such as small spot size, high power density, enhanced processing speeds, reduced Heat Affected Zone for both cutting and joining applications. To date, the majority of micro-cutting applications have been addressed by low power CW fibre lasers. These laser sources can also be pulsed by gating at high frequency (up to 50 kHz) and pulse widths as short as 5 µs can be achieved. For micro-cutting applications the edge quality is more important than the cutting speed; hence for most applications cutting gas is normally employed. Jack has put together a very useful overview of micro-cutting using a pulsed fibre laser fitted with a scanning head. The article points out that it is possible to cut a range of materials, but there is no mention of the cut quality. It would have been nice to see some data on this.

Work carried out on cutting with a CW fibre laser at GSI with the same type of set-up has shown that polycrystalline silicon, alumina ceramic and plastic composites can be cut with very good quality without an assist gas, whereas materials such as steels, copper and aluminium based alloys all require assist gas.

Mo Naeem JK Lasers

Firstly, I have to declare that we at LML have been using a SPI 20W SM pulsed fibre laser since late last year and this has been the first (and only) fibre laser that we have used to date. My comments should be taken with these points in mind.

I can't disagree with the broad thrust of the article that a wide range of materials can be cut/drilled/machined with pulsed fibre lasers, and that good quality results can be achieved. We have also machined the same set of materials as is shown in the article and can support the quoted results/speeds that are reported in the article. Although the vast majority of LML's work uses other lasers, the fibre laser has, nonetheless, become a laser which we have found to be ultra-reliable and easy to use. On a practical level there has been no noticeable degradation in laser performance (meaning power drop-off or mode changes) of the laser in the past 10 months of use. Also, unlike some solid-state lasers that behave variably at times, we don't have to worry what the fibre laser performance will be like if we turn it on after a few days of it being unused.

Although we only have one unit of one model from one supplier to base these observations on, I hear broadly similar comments from other fibre laser users; so it does appear that the fibre laser is making life much simpler for many in the laser community. The fibre laser is certainly a very cost-effective way of buying machining photons and can be used with minimal intervention. However, like every other laser, what it can't do is give you a ready-made solution and so Jack's article is helpful in outlining some of the strategies that users may use to improve results. It has to be good for product developers and engineers to understand more of the capabilities offered by lasers (of all types) and this article makes its case very clearly.

Nadeem Rizvi
Laser Micromachining Limited

Design Surfaces by laser remelting

André Temmler et. al.

This article illustrates a high degree of refinement of the laser polishing and remelting processes with interesting applications both within the text and with a high number of corresponding potential applications in industry. I was particularly taken with the exemplary leather-textured surface as a tool for mould manufacture in the automotive industry – a good example of both process flexibility and application. Though the process speeds indicated are slower than those of etching processes, the elimination of chemical waste using this technology is an important consideration when comparing laser to competing processes.

Eamonn Fearon
Lairdside Laser Engineering Centre, University of Liverpool

Adaptive control in high brightness laser arc welding

Chris Allen, Steve Shi and Paul Hilton

I fully concur with the authors that attention to adaptive control is critical. The description of a response program with a look-up table described in the text sounds more advanced than the two-state, bang-bang control system, depicted in Figure 2. Of course, any control system is limited by the speed of response of the equipment and control variables. Welding speed, head stand off and wire-feeding rate cannot be switched instantly, but neither are they very 'lag-inducing'.

Although the title is fair, the system described here performs no actual feedback control of the welding process itself. It sets variable parameters at which to perform open-loop welding. It can be argued that this is a strength or it can be a weakness. Sensing the actual process and/or produced weld and then adapting parameters to achieve it, could reduce the need for pre-calibration and make the system more adaptable to unexpected transients. However, this could lead to a more complicated and expensive control system, one that could only adapt once the weld became non-ideal. In this case a slow speed of response would be very damaging.

Provided a library of response programs for different welding situations can be built-up, this system seems to offer a much-needed practical solution.

Andrew Pinkerton
University of Manchester

Innovation and invention with high brightness lasers

Eckhard Beyer et. al.

This paper begins with a discussion on 'brightness' when applied to today's industrial lasers and goes on to discuss several potential applications of high 'brightness' beams. It postulates that for appreciable laser powers, true high brightness is only available from a single mode laser.

I personally think that the term 'high brightness' has been over used in recent years to describe almost any new laser source, so to restrict the use of this term to single mode lasers is one way forward. However, it would seem just as clear to refer to the beams from such lasers, simply as 'single mode beams'.

The available power densities from high power single mode lasers offer great potential for those of us who wish to understand more about fundamental laser beam/materials interactions, as well as opening new processing possibilities, some of which are described in the paper. More understanding of the effects of the 'high brightness' beams available will lead to more applications. The single mode lasers, however, have one drawback when compared to their multi-mode brothers and sisters - the available length of the delivery fibre. It still remains to be seen if advances can be made in this area.

Paul Hilton TWI

The authors support the premise that where previously limitations in beam quality and power prohibited the rapid growth and acceptance of solid state lasers, 1 μm radiation laser sources are now fast overturning the dominance of high power CO_2 lasers at 10.6 μm in industrial processing.

The fibre and disk lasers technologies mentioned in this article share a few things in common as industrial laser tools, namely: both technologies provide an output wavelength of 1 μm, both outputs can be fibre delivered, beam quality is excellent and both have the capacity to deliver multi-kW of laser power to the process if required. However, there are important differences that the reader should to aware of.

With the fibre laser resonator the 1 μm radiation is produced in a fibre and remains totally within a fibre right up to the laser aperture. Even the diode laser pump energy for the resonator is totally fibre delivered. Truly this is a remarkable achievement in laser design and the benefits for industry include the elimination of bulky steering optics and many of the maintenance issues associated with beam delivery. Other advantages of this design include exceptional high beam quality, overall improved electrical to optical efficiency, size, mobility and reliability; all of which are very well presented in this article.

By contrast the disk laser has a resonator that is not in a fibre and although solid state laser diodes are used as a pumping source, the cavity is filled with bulk optical elements to direct the pumping energy to the doped mirrored disks that constitute the active medium. The disk laser is a fibre-delivered laser, not a fibre laser. As the authors rightly say, the single mode fibre laser is the only true laser source that can claim the title of a 'high brightness' laser source. This achievement is mainly due to the high integrity environment of the fibre laser resonator and the scalability of this design for very high power and high beam quality.

<u>Some benefits from 1μm sources</u>
The use of Galvo scanners has opened new opportunities for both cutting and welding with high speed, cost saving solutions never before possible. Other devices such as the AOM (Acoustic Optic Modulator) when used in conjunction with fibre laser has provided very fast beam switching mechanisms and beam deflection to modulate or deflect the 1 μm beam; application include high speed thin foil and polymer ablation. This application, used mainly in the printing and packaging industry, calls for very precise, repeatable spots that can be applied and modulated or deflected at a very high rate.

The coupling of the 1 μm radiation in most metals (including copper and brass) when cutting, drilling or welding, is well presented and documented. Positive comments from industry show the acceptance of 1 μm fibre and disk laser sources in many applications, in spite of the lead that CO_2 lasers have had over the years. One cannot help but observe the limitations and disadvantages of CO_2 laser technology that appear under the spotlight of the 1 μm fibre and disk lasers.

One of the more practical advances mentioned in this article is of course the use of lasers with robots; high power fibre delivery has brought significant changes and advances in the automotive industry amongst others.

The cut quality from 1 μm lasers remains a topic of a heated and somewhat subjective debate but it is well established that the advantages for 1 μm laser cutting far outweigh its disadvantages. Ian Luffman of Luffmann Engineering was quoted in June 2011 as saying that ''the laser cut quality on 6 mm mild steel is equal to if not better than that seen from my CO_2 lasers (Luffman purchased the first 3 kW flat bed fibre laser cutter in the UK)

The ability to produce small focussed spots with long focal length optics has a practical function in welding, where long standoff distances must be considered to avoid or eliminate 'molten splatter' contamination of process optics. High beam quality also allows optimum divergence to be maintained in deep penetration welding.

Recent advances in drilling aerospace components with 1 μm high brightness lasers have demonstrated that recast formation and side wall cracking were negligible and well within the acceptance protocols provided by a very strict industry. This development in beam quality has impacted on the improved geometry, consistency and parallelism of the holes drilled.

Continued on p39

Munich Laser Show 23 - 26 May

A selection of responses from AILU members who attended the exhibition

Also known as 'Laser Munich' this show continues to be the gold standard for industrial lasers. OEM's, Integrators, motion control, robotics, optical and diode suppliers are all well represented.

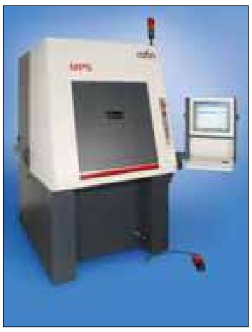
This year's attendance was up by 8% providing an additional 27,500 visitors. More than 80 countries visited Messe Munich and the overall attitude was positive for lasers and related component sales.

Femto and Pico second lasers continued to dominate the buzz and discussion regarding new and emerging technologies at the show.

Trumpf, IPG, and Rofin displayed an impressive array of equipment utilizing multiple wavelengths. This further demonstrates and confirms growth potential for the industry through new applications. These newer technologies have demonstrated the ability to couple with a wide variety of new and exotic materials.

Neil Ball Directed Light, USA

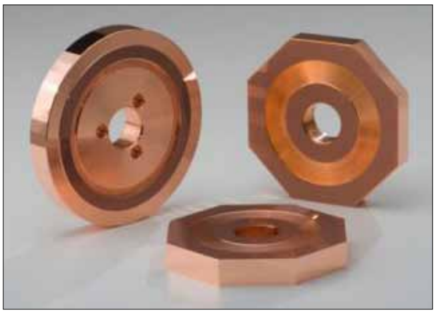
It seemed there were fewer exhibitors and less halls used this year than four years before, the last time I was there. In terms of products, it was good to see a number of companies offering ultra-short pico and femto pulsed fibre lasers for ablation and micro-cutting.



The only live demo of one of these lasers I saw at the show, however, was on the Rofin stand where we had a fs laser cutting stainless steel on a MPS 3-axis system, one of a new series of high accuracy and acceleration machines (see photo).

Dave Maclellan Rofin-baasel UK

This year's Laser World of Photonics once again proved to be an eminent event for the global laser and photonics industry. With growing exhibitor numbers and visitors attendance, in particular from overseas, the trade fair, combined with six conferences, was a great opportunity for us to hear about the latest products, technologies and scientific achievements in the photonics sector. Besides this year's focus on Biophotonics and "green" photonics, Laser material processing is still one of the main, if not 'the' main focus of the show. LIM 2011 (Lasers in Manufacturing), one of the six conferences of the congress, confirmed the ever-growing interest in ultrafast laser processing. One technology in particular caught our attention: the use of polygonal scanners as high speed beam deflectors for laser micromachining. A polygonal scanner is a rotating metal disk with facets cut into the edges (see photo)



Diamond machined polygonal mirrors by Lincoln Laser, USA

These scanners produce faster scan rates and dissipate heat more efficiently than conventional galvo scanners, a strong benefit for material processing applications based on high-energy lasers. On the "laser technology" front, the INNOSLAB amplifier seems to be a promising alternative to fibre or thin-disk solutions, in particular for short pulse amplification at very high power.

Arnaud Zoubir ALPhANOV, France

David Greening lives on. Four exhibitors at Munich who individually owe a lot to their mentoring by the late David Greening: (from left to right) Nick Ellis, Technical Director, ULO Optics), Steve Hastings (Chief Technical Officer, abariscan GmbH), Paul MacLennan (Sales Director, ULO Optics), and Mark Wilkinson (Managing Director, Laser Beam Products).

Steve Hastings abariscan, Germany

As always the Laser show in Munich is a great showcase for our industry and a good opportunity to meet customers, suppliers, integrators, distributors and old friends all in one place! Having a live demo of laser cutting and welding on the JK lasers stand attracted many people, but I was impressed at the proportion of visitors who were genuinely interested in using lasers near term in their applications.

Most wanted to find out about the newer technology and benefits of fibre lasers across the whole product lifecycle. I was interested to see the range of kW class materials processing fibre lasers units on display: from OEM modules to complete systems, some with robot integration. With improvements in the economy as well as in laser technology, it's an exciting time for growth in the industrial laser market.

Mark Richmond JK Lasers, UK

Applied Laser Engineering have been attending and exhibiting at the Laser Munich show for more than two decades and sometimes it seems that a show can never hold as much novelty as it did in the first few visits. For me that was not true of Munich 2011.

On a 'buying' level I was very interested to see the advancing industrialisation of various pico-second lasers alongside the continuously amazing advancement of various fibre laser technologies. It was also a great opportunity to discuss developments with all our laser and optical suppliers. On the 'selling' front we are always looking for new outlets for our seamless, cylindrical laser engraving platforms in areas such as printed electronics, engineering textures and novel printing applications where a reel-to-reel process is being employed with the high resolution and high accuracy that the drum scanning technique brings compared to any galvo scanning alternative. Here we had a dozen solid leads, which is excellent in the capital equipment marketplace for a company of our medium proportions (no jokes please from those who know me). Notably, we had four good enquiries from Turkish companies. Maybe the EU are funding capital investment in Turkey? To crown the week we loved being nestled in the UK pavilion amongst friends old and new and right next door to Bert's Bar (well done to someone).

Ed Birch Advanced Laser Engineering

Coherent introduced the VYPER, a novel excimer laser annealing system for volume production of low temperature poly-silicon (LTPS) for next generation flat panel displays (see photo). LTPS is also a key component for energy efficient and lightweight liquid crystal displays and organic light-emitting diode displays for smart phones and tablet-PCs.

As a result of developments LTPS, display manufacturers can make the transition from the current (Gen 4) to Gen 6, enhancing throughput significantly and permitting manufacturers to meet stringent cost targets.

Petra Wallenta Coherent GmbH, Germany

'Observations' continued from p37

Pulsed fibre lasers with near diffraction limited performance are edging their way into many industrial applications that have been dominated by Nd: YAG lasers. The authors has emphasized both multimode and single mode CW lasers with some reference to modulation and thermal management in welding and cutting; however, the pulsed fibre laser must be considered for its ability to produce very high peak power at very short pulse durations (i.e. 1ns currently, with ps performance in the near future) with near diffraction limited beam quality. Other longer pulsed options like QCW fibre lasers are offering industry the performance of multi kilowatt lasers from an average power that is approximately an order of magnitude less than the peak power. An example of this is the QCW 150 with near diffraction limited performance at 150 W average power and 1.5 kW peak power. In my opinion this pulsed technology is going to bring big advances and changes in Nd:YAG applications, both those that have either been dominated by laser technology and others that simply were not achievable or practical with existing sources. These new lasers have been christened the 10 X Laser because they have ten times the life of a diode-pumped solid state laser, ten times the efficiency of a conventional flash lamp pumped Nd:YAG laser and occupy one tenth its floor space.

In conclusion, the future looks bright for these innovative high brightness lasers. The possibilities are numerous with many unchallenged advantages in cutting, welding, cladding, micro-machining and additive manufacturing. It is clear from this type of application review that they are here to stay. Fibre lasers and disk lasers are in the forefront of this progress and as researchers and engineers find more and more ground breaking applications, a greater appreciation for the interplay of wavelength absorption coupled with increased efficiency performance will bring significant cost saving benefits for the end user.

Stan Wilford IPG Photonics UK

Hazard potential and cleanup cost of fume created during the laser welding and soldering of steel

Jürgen Walter et. al.

The article presents results of a study on emissions during laser welding of a range of coated and uncoated steels at four different industrial installations and the cost benefit analysis of installing suitable filtration equipment. The study is part of ongoing research at the Laser Zentrum Hanover on occupational health and safety aspects of industrial laser processing. Understanding gaseous and particulate emissions during laser processing and laser welding in particular is an important area of research with significant impact on the long term health and well being of operators.

The study has considered a range of steels with different thickness and coatings, CO_2 and Nd:YAG laser sources, process speeds and focused spot sizes in the range 0.15 mm to 3.4 mm. The study has confirmed that, for the materials investigated, laser welding produces low levels of aerosols at low concentrations; within the threshold limit values required by the German environmental legislation. In most cases the study has found that no filtering is required because of the compliance with the threshold limit values. In the two out of twelve material combinations tested where the aerosol concentration exceeded the relevant threshold limit the company had to have a suitable filtration system in place. The cost impact of such a system to the company based on its actual hourly process costs is marginal being on the order of 10% of the overall process cost.

Overall, this value adding article on the gaseous and particulate emission levels produced during laser welding of steels will be of interest to both users and occupational health and safety legislators.

Milan Brandt
RMIT University, Melbourne, Australia

The early part of the paper discusses health and safety of the employee and then moves on to environmental/pollution considerations. In Germany, with its tight pollution requirements, the two are more closely linked together than is the case in the UK. From my UK perspective I find it amazing that even when fume extraction brings the total emissions below the maximum allowed for employees there remains a need to filter the emission that goes up a chimney to the outside world.

The cost of the filtration also surprises me. Why is the cost of meeting environmental standards so high if we are almost always in category 1? Figures should surely be much smaller that the quoted values of about 8% of overall cost if all we need to do is occasionally replace the filters.

John Powell Laser Expertise

KTN consultation meeting on a Photonics TIC

The ESP KTN held a consultation meeting in London on July 14th to discuss the potential for a Technology Strategy Board (TSB) funded Photonics "Technology and Innovation Centre (TIC)"
***Martin Sharp** reports on the meeting and how this is of particular relevance to our industrial members*

The previous government commissioned the Hauser report to look at how well the UK performs innovative activities in support of the economy, The report Identified the so called "canyon of death", a gap between basic research conducted mainly at universities, and the final developments and exploitation of this by industry. The report recommended the establishment of Technology and Innovation Centres (TICs), business led centres that would allow the outcomes of basic research to be safely transferred across this canyon and delivered into successful exploitation for the UK economy. The current government has decided to support this recommendation and committed the Technology Strategy Board to establish between six and eight such centres with a budget of some £200M over 5 years.

An initial development coming quickly after the TIC announcement was the establishment of a TIC in High Value Manufacturing (HVM). A call was opened for parties to bid to run such a centre and eventually it was announced that the HVM TIC would be led by the Advanced Manufacturing Research Centre at Sheffield, together with six other manufacturing related centres, including the soon to be opened Manufacturing Technology Centre at Ansty, near Coventry. It should be noted that the TSB had not been committed to use the TIC budget to build a new physical centre, and that a TIC could be distributed over several geographical sites.

In the last few months, two further calls for TIC's in Stem Cell Therapy and Renewable Energies have been opened. For the Stem Cell TIC, expressions of interest to run the centre have now been received and the call is closed. From these, parties will be called to attend a workshop and a full application stage has begun with a closure date at the beginning of September. The Expression of Interest stage for the Renewable Energies TIC has opened and has a deadline of the 1st September.

Additionally the TSB has produced a list of ten possible TIC areas and has stated that three of these will be the subject of the next call. The ten areas are:

Photonics

Complex Systems

Digital media/creative industries

Future cities

Future internet systems

Resource efficiency

Sensor systems

Smart grids and distribution

Space

Transport systems and integration

Although there are no further indications at this stage there is a suggestion that the three TIC's will be announced at the TSB "Innovate 11" showcase event to be held in London during October.

It has also been rumoured that the choice of the three TIC's will be, to a significant degree, driven by the evidence of demand from the communities associated with each of the themes; and with this is mind, leading up to the July 14 consultation meeting, the ESP KTN began to coordinate actions to allow this "evidence" to be collected, mainly using online techniques.

It has set up a Photonics subgroup in the TSB _Connect networking site, and held an online survey. The July 14 meeting itself was part of this process, setting the target of bringing together members of the photonics community to consider issues such as: the demand for a Photonics TIC; whether in fact a TIC was the right vehicle for dealing with the "innovation canyon"; and if it was, what should the TIC do?

At the meeting Prof. Keith Lewis, Technical Director of the ESP KTN, outlined the background to the development of the TIC concept, reminding the audience the role of the TIC would be "Crucial to focus on innovation, rather than academic discovery alone". A "Hub and spoke" model may be relevant, exploiting the facilities that already exist in key locations i.e. a new build is not desired.

In particular, the following areas need to be addressed:

- What should be the goal of a TIC in photonics - what is it seeking to achieve?
- What are the potential global growth opportunities in photonics for the UK - what are the reasons for growth?
- Does the UK have the capability and capacity to exploit these opportunities - what are the challenges and barriers?
- What areas of photonics technology should be the focus for the TIC?
- What is the role of the TIC in developing the identified technology areas in order to unlock the identified opportunities - how would it connect to existing centres and industry needs?
- What is the expected impact and benefits of the TIC in areas such as job creation and value added?

The next speaker, **Mike Oldham**, the TSB lead for its TIC programme, gave an overview of the TIC concept. The key message for a TIC is to provide a critical mass entity that can help the UK improve on its commercialisation of research. To illustrate the scale of a TIC, it is expected that when a TIC is up and running it will have a turnover of between £20 - 30M per annum. The funding model for this would be a 1/3 of direct TSB funding, 1/3 from involvement in collaborative R&D grant funded research (e.g. TSB, FP7), and 1/3 from direct commercial R&D contracts. This level of activity would expect to be responsible for the employment of 100-200 staff.

Ultimately the TSB sees such an investment returning £1B+ to the UK economy. This means that a TIC would have to be globally recognised and that, for instance, it should "attract and anchor knowledge intensive activities of globally mobile companies".

Alastair Wilson, director of photonics for the ESPKTN then presented the results of an EU study on the leverage of the photonics sector. This suggests that Photonics is a key enabling technology that now has an impact on markets worth €3trillion in the EU and some 30 million jobs. This identification of phot-

Mike Osborne, OpTek Systems, providing a system builder perspective

onics as a Key Enabling Technology at European level has led to developments including a shift in funding level to higher TRL's and more support for SME's (both suppliers and users). A Photonics TIC would be well positioned to access such a change in funding.

Four talks followed that provided views on the potential Photonics TIC from different, commercial, perspectives. **Prof Robert Lamb** of Selex Galileo gave a "large company" perspective. Selex is a major supplier of electro-optic systems to the defence industry. It would want a Photonics TIC to support the development of photonics components. This would also need developments of new semiconductor formats for imaging arrays etc, and Prof Lamb saw overlap with any proposed TIC's in Sensors and Space.

Prof Lamb indicated that Selex is Interested in playing a role in a photonics TIC, but he also Identified some key Issues in the commercial operation of TIC's:

- The business model needs to be well defined.
- They already work closely with several Scottish universities
- Industry does not fund speculative research
- TICs must acknowledge the technology risk and the associated business risk taken by industry. Universities take no business risk.
- For industry to be involved it must help set the success criteria for a TIC
- The best way to transfer technology is to transfer people.

Next to speak was Steve Norman, CTO of SPI Lasers Ltd. Steve introduced SPI lasers to the audience as a successful spin out, manufacturing in the UK and with significant export activity, including into the far east market. It is also a company that collaborates, and indeed funds research in universities such as Southampton, Cambridge, Warwick and Cardiff. They have been involved in some very successful TSB funded collaborative R&D projects, but pointed out that such projects often "dissolve" on completion. He saw that a "Photonics TIC aligned with the Advanced Manufacturing TIC would provide continuity, industry focus and networking"

To be successful Steve identified these pre-requisites:

- Has to be internationally competitive
- Has to focus on technology solutions and deliverables, and hence led by engineers and entrepreneurs, not academics
- Must have strong linkages to other TIC's / Universities and Institutes.
- Has to be a business focussed organisation having:
    - Specific fields of focus with strong involvement of industry
    - Provision of state of the art technology that supports the need for:
        - Analytical services
        - Advanced optics and fibres
        - New applications development
        - Prototyping
        - Skills development
        - Industrial resources

Next, **Henry Hyde-Thomson** of Anglo-Scientific Ltd (AS) gave a Venture Capitalists perspective and a few important points. AS has been involved in spinning out 11 start-ups out of research labs and universities. Their experience suggests that it takes one to two years to move up a TRL, and that most VC money supports TRL 5-8 activity. There is very little VC money at TRL3-4.

However the next slide put the TIC concept in prospective, pointing out that Universities spend around £9000M on research (HEFCE and RC) per annum, Fraunhofers some £1350M p.a., while the TIC budget is some £50M per year. Henry therefore wonders whether TIC's should aspire to be National Centres of Excellence. A TIC budget of £10M is less than a third of the budget of Oxford Universities' Physics Department. A TIC would therefore have to work with Universities and would best concentrate on Innovation and Commercialisation.

He further pointed out that the current TIC budgets should not be split further, for a given TIC the funding is already below critical mass and that it would be best to site a TIC at an existing University or Research Centre.

Finally he listed ideas of Support Functions that the TIC would provide. These are very much along the lines of traditional business incubation centres, offering CAD and rapid prototyping, business support, accommodation, market research etc.

The final talk was given by **Mike Osborne** of OpTek Systems, one of our Association's members and a manufacturer of high precision and micromachining systems.

Mike was clear what SME's needed from the TIC, using the TSB graphic from the TSB report on TIC's, to say that a TIC needs to close the gap between concept and commercialisation.

He then gave a few views on how a TIC could help a SME. It should provide access to the market, and working with the TIC should offer global credibility. It needs to provide access for SME's to leading edge and complementary technology, recognising that the SME is likely to have leading edge technology of its own.

However the interaction with the TIC should be two way. The SME should identify new technical ideas and market opportunities to be supported by the TIC and allow the TIC to offer multifaceted approach to build its global identity.

There must be a symbiotic relationship between a TIC and the SME's in its particular technology community.

Following these presentations there was a break out session, where the audience were divided into small groups of around eight people and asked to identify several key considerations for a Photonic TIC.

The first was to identify sub-sectors of photonics with the potential global size that would provide the necessary market in which a TIC could operate and generate a suitable return.

On my table the first half of this item was dominated by energy efficient lighting specialists, with the contributors increasing the scope of this definition alarmingly as the time passed. I finally managed to get the chance to promote laser materials processing. I pointed out that the world market for laser materials processing itself is substantial (sales of sources / systems) and growing but equally importantly laser materials processing makes a substantial contribution to manufacturing across the whole of industry, thus contributing to the sort of impact that Alastair Wilson was describing earlier in the meeting. The LMP sector, both in source / system development and processing itself has both a strong research base and company base as evidenced by the AILU membership.

There was little time to discuss further markets, and after a short coffee break we tackled some further questions including what sort of services a TIC could provide and to some degree how it would be run. This turned into a rather wide ranging discussion. As reported before, some were keen on providing the sort of business services found in most incubators. But some good ideas arose, around funding, consortia building and in particular accessing European funding and markets. A common point was the need for the TIC to gain the sort of recognition in its field that the Fraunhofers receive. Technically I suggested that care must be taken not to overlap facilities with existing provision in the research community, something I feel is particularly relevant to our community that already has a strong physical research base. It must also strive to be inclusive and accessible to all.

Returning to the main hall, Keith Lewis was able to throw up some slides based on the feedback from the break out tables. On the market the three clear markets identified were Energy Efficient Lighting, LMP and Defence and Advanced Photonic systems. Other smaller suggestions included biosensors. The roles and services were largely those described above.

" ... if our industrial members feel they could benefit from the UK having a TIC supporting our laser community they really need to make their voice heard over the coming few weeks. And this includes offering direct support to the TIC written into a TIC proposal. Indeed the TIC proposal should have evidence of industrialists contributing directly to its writing."

Interpretation of a TSB view on TIC proposals

One particular issue that cropped up was the relationship of LMP with other potential TIC's and, of course, the now agreed High Value Manufacturing (HVM) TIC. In particular LMP will feature strongly in the activity of the Manufacturing Technology Centre (MTC) at Anstey. Does this take away the need for a TIC that is strongly aligned with LMP? Should LMP be seen as an enabling technology that contributes to many TIC's, a point I raised in the short questions section that followed Keith's presentation. Should a TIC relevant to our community be aimed at Laser Sources and Systems than directly at materials processing itself?

A short discussion also ensued on exactly where the industrial demands for a TIC were coming from, and in particular where is the SME demand? Someone in the audience asked for a show of hands from "real" SME's and there were no more than half a dozen raised. Greg May, TSB leader on photonics, pointed out that everybody was invited

Delegates at the break-out session

and suggested that maybe SME's were busy getting on with their business and couldn't attend. I pointed out that the AILU membership offered a substantial number of interested companies, many of whom were SMEs.

But the reality is that the majority of people in the audience were academics, many of which, I suspect, were looking to see if they could get some money from the TIC pot. So despite the TSB seeking to find evidence of real demand for TIC from industry, much of the discussion was driven by the academic community.

The ongoing process towards the decision on which TIC's to support is that it is expected that funding for three TIC's will be announced, possibly in October. These will be chosen based on evidence received over this summer. If a photonics TIC is one of these, then there will be a period in which expressions of interest are requested. The response to these will be developed by key players in the various sub sectors of the Photonics community, in support of their own particular technology.

These will most probably be whittled down by a panel of industrialists, and other experts into about four groups who will then submit a formal proposal to run a TIC.

In essence if a Photonics TIC is requested there will then be a competition between the photonics sectors to win the TIC. And the TSB are stressing that they will be seeking evidence of strong industrial and SME support in the winning proposal.

This means that if our industrial members feel they could benefit from the UK having a TIC supporting our laser community they really need to make their voice heard over the coming few weeks. And this includes offering direct support to the TIC written into a TIC proposal. Indeed the TIC proposal should have evidence of industrialists contributing directly to its writing.

If there is little evidence of such industrial demand then I feel that it is unlikely that our community will get the opportunity to shape and benefit from a TIC.

Martin Sharp
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FUTURE EVENTS

Further information and How to make known your views on the proposed Photonics TIC

• For a background to the Technology and Innovation Centres (TIC) go to the TSB home page (*www.innovateuk.org*) then take the 'delivering innovation' link and then the 'technology and innovation centres' link. This includes the list of the next ten candidate TIC's from which the next 3 TIC's will be chosen.

There are several ways you can contribute to the discussion or show your support for a Photonics TIC that covers an area relevant to your activities or sector:

• Make known your views by contributing to the ongoing TIC thread in the AILU technical forum and, if you would like to, make a simple statement in support of a TIC make it there.

• If you have not already done so, register with '_connect' and join the Electronics, Sensors and Photonics Knowledge Transfer Network (ESP KTN). This is free. To do this go to *https://ktn.innovateuk.org/web/guest*.

Once registered with '_connect' you should navigate to and join the following networks, groups and subgroups:

"Electronics, Sensors and Photonics" Network, https://ktn.innovateuk.org/web/espktn/overview

"Photonics" Subgroup https://ktn.innovateuk.org/web/photonics

"Power Photonics in Manufacturing" subgroup of the "Photonics and Plastic Electronics" group (this is the AILU supported subgroup for Laser Materials Processing)

https://ktn.innovateuk.org/web/power-photonics-in-manufacturing

The Photonics subgroup is specifically aimed at supporting the need for a TIC and has links to videos and PowerPoint presentations. You can also check the blogs in each of the groups as well as the official group for the overall delivery of TIC's. the latter can be found at:

https://ktn.innovateuk.org/web/technology-and-innovation-centres-forum

• If you do not want to leave comments on these public sites, please send any thoughts on the subject to Martin Sharp (m.sharp@ljmu.ac.uk), Neil Main (neilmain@micrometric.co.uk) or Mike Green (mike@ailu.org.uk)

AILU events

September

13 **Ultra precision laser manufacturing systems, technologies and applications**
(Organised by the Micro:Nano Special Interest Group)
Institute for Manufacturing, Cambridge, UK

October

5 **Industrial laser safety responsibilities and requirements**
(Half day tutorial)
Amada, Kidderminster, UK

11 **Job Shop 11: How to make the best of the economic recovery**
(Organised by the Job Shop Special Interest Group)
Trumpf UK, Luton, UK

November

9 **Lasers as a key technology in High Value Manufacture**
(Organised by the PPI Special Interest Group)
Advanced Manufacturing Research Centre, Sheffield

AILU-supported events

September

27 **MM Live UK (27 - 29)**
NEC Birmingham, UK

October

4 **Espace Laser (4 - 6)**
(Organised by IREPA Laser and CLP)
Paris, France

18 **High power diode laser systems (18 - 19)**
Ricoh Arena, Coventry, UK

18 **Photonex (18 - 19)**
Ricoh Arena, Coventry, UK

23 **ICALEO (23 - 27)**
Hilton in the Walt Disney World Resort, Orlando, Florida, USA

Full information can be found at www.ailu.org.uk/events

Subcon 2011

According to the show organisers, this year's show attracted an increase in visitor numbers, top-level buyers, real business done and an unprecedented level of rebooking by exhibitors.

The event, which was held at the NEC Birmingham from 7 to 9 June, attracted 7% more visitors on a like-for-like basis than when it was held alongside the MACH machine tool exhibition in 2010. It also benefited from crossover visitors from the Logistics Link Live and Tooling events, giving a total number of visitors that was 25% up on 2010.

In contrast to general engineering technology shows, the central focus of Subcon on subcontract manufacturing

Activity on the Laser Process stand

services meant that around 30% of visitors were from purchasing and supply chain departments.

The visitor profile was notable for the high level of supply chain professionals from blue chip manufacturers, such as Rolls-Royce, Siemens, Jaguar Land Rover, Mitsubishi, BAe Systems and Bombardier.

These were complemented by the design teams that have a major input into sourcing strategies for new contracts and the production professionals who are responsible for tactical subcontracting and special process sourcing.

Exhibitors were delighted with the levels of business done at the show.

Time to feel challenged

"... Despite this being the holiday season we have included a call to arms ... Please do take note of this and let your views be known."

More than any other single item, this issue of the magazine is about a window of opportunity for the laser materials processing community in the UK to benefit from some of the current government spend on Technology and Innovation Centres (TICs). What comes through is the great effort that Martin Sharp, as AILU President, has been making to ensure that the LMP community, especially its industrial members, have every opportunity to make their views known.

Fortunately for this issue of the quarterly magazine, much of the reported TIC activity has taken place in the last few weeks, so it is all still current. By the next issue the important decisions will probably already have been taken, so despite this being the holiday season we have included a call to arms (see the President's message on p15 and the meeting review starting on p40). Please do take note of this and let your views be known – a column explaining how to do this can be found on p43.

One might think that after 50 years of the laser and over forty of industrial laser materials processing there would be very little enthusiasm within this community to be thinking about new initiatives but, as is evident in this magazine and elsewhere, the laser materials processing direction remains steeply onwards and upwards! This is exemplified by the unanimously positive responses I received from members following a request for feedback on the Munich Laser Show in May (see review on p38). You might also want to read the optimistic views of Steve Hastings in the AILU interview (p16). To my recollection such positive views on laser technology and applications have always justifiably been expressed in this magazine (now well into its 16th year), as well as a liberal sprinkling of optimism. In this issue the optimism starts with the first item on page 1- plans for an AILU Pavilion at MACH next year- ; it ends with the last entry in the list of forthcoming events on page 43 - a workshop on lasers as a key technology in High Value Manufacturing.

What more of a sense of optimism could you ask for as you take a well earned break and put your feet up to read this Summer (holiday) issue?

Mike Green, Editor
mike@ailu.org.uk

Editorial Policy

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 maintain the right to extract, in part or in whole, their material for future use.

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Ultra precision laser manufacturing systems, technologies and applications

13 September 2011
Institute for Manufacturing, Cambridge University

Dramatic advances in photonics technology mean that today's industrial laser systems offer unparalleled capabilities in precision manufacturing and advanced materials processing at the micro and nano scale, thereby providing the flexibility and accuracy required to manufacture the products of tomorrow.

Ongoing miniaturisation continues to push manufacturing technology to its limits, and continued developments of lasers and materials processing applications is providing the means to produce ever smaller increasingly accurate and more cost effective micro and nano-features. Staying abreast of these developments is key to maintaining a competitive edge.

This annual workshop seeks to bring together industrial users of laser processing technology, suppliers of laser-based equipment, researchers in new laser technology and industrialists to review the latest innovations in micro and nano-scale laser processing and the opportunities that they create. This year's event is held for the first time at the Centre for Industrial Photonics at the Institute for Manufacturing, Cambridge University and includes a tour of the state-of-the-art work going on there.

Chair: Bill O'Neill, Director of the Centre of Industrial Photonics

The day will comprise presentations, exhibition and a tour of the Centre for Innovative Photonics

The programme and full travel and accommodation details can be found on the AILU website. Otherwise, details and bookings can be made by contacting the AILU office (T: 01235 539595).

The event is supported by:

The Institute of Physics

ESP KTN

Nanotechnology KTN

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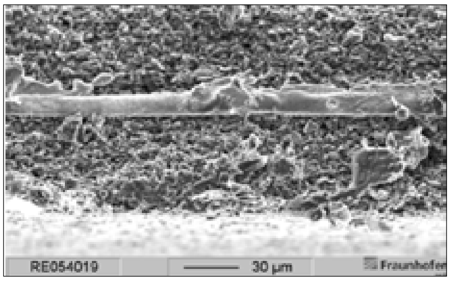

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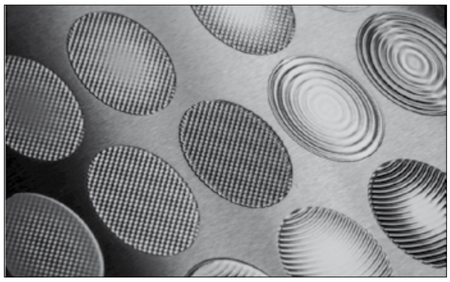

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