The Laser User

Issue 65 Winter 2012

Onwards and upwards for laser-based manufacturing

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.

Benefits of membership

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

- 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

Group subscription to the e-Magazine

AILU members have free access to current and past copies of the magazine at www.magazine.ailu.org.uk and a search and free download facility in the magazine section of the main AILU web site.

For only £100 a year 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

What does AILU membership mean to me?

AILU's regular meetings are an opportunity for me to stay in touch with friends and colleagues in the UK laser business, which is most enjoyable, and the quarterly magazine is always an interesting read.

UK laser materials processing would be a far poorer business without Mike and his team's enthusiasm and would be voiceless at the UK government strategic level.

Andy May
Managing Director Rofin Baasel UK

Courtesy Materials Solutions

The cover picture of additive manufacturing in action at Materials Solutions highlights the AILU interview with its MD Carl Brancher (p14).

Growth prospects in laser materials processing is a recurring theme in this issue, including members' support of the AILU Pavilion at MACH (p1), positive job shop news (p11), an AILU report of technology transfer activity in the UK (p26) and figures for world sales of industrial laaers (p30)

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

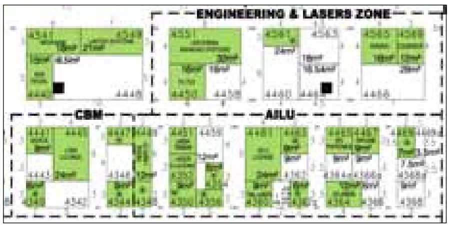
+44 (0)1235 539595

ASSOCIATION NEWS

Members show strong support for AILU Pavilion at MACH

Fourteen AILU members have reserved stands in the AILU Pavilion at MACH.

"My belief has always been that AILU should aim to take a pavilion stand at MACH for its members wishing to promote their products and services. This year, with the help of the MTA, we are doing just that,"said Martin Sharp, AILU President.



The AILU pavilion in Hall 4 borders the Engineering Lasers Zone and the CBM pavilion

The members who have taken a stand within the AILU Pavilion at MACH 2012 (15-20th April) will enjoy benefits over isolated exhibitors; not only because the pavilion will attract exhibition visitors looking to find companies that deliver laser solutions, but also because they will have use of the pavilion lounge and support from the AILU office team.

The MTA have reported that Stand bookings are running nearly 25% up on those for MACH 2010 and initial visitor pre-registration is already well ahead of 2010 and 2008 levels again pointing to a buoyant manufacturing sector and a positive exhibition.

New Product and Services Directory

For the AILU Pavilion at MACH a special edition of the hard copy laser-related Products and Services (P&S) directory will be produced. As with the online P&S directory on the AILU site, entries are free to members.

Space is provided for members who would like to take out a colour advert in the directory; details can be found on the AILU web site by taking 'Advertising' in the left hand column of links.

AILU AGM

The Annual General Meeting of the Association will take place on Thursday 19 April in Hall 4, commencing shortly after the show closes at 5:00 pm. Light refreshments will be served.

A detailed Agenda and the precise location of the AGM will to be issued nearer the time.

For information about stands at MACH:
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ILAS 2013

Industrial Laser Application Symposium

The Nottingham Belfry Hotel

12 & 13 March 2013

AILU's Industrial Laser Application Symposium (ILAS) provides a biennial opportunity for those involved in the use and development of Laser Materials Processing (LMP) to present their work and showcase their products; with the aim of stimulating further technological and applications developments and an increase in the use of LMP.

Building on the success of ILAS 2011, ILAS 2013 will provide a programme of technical presentations covering the state-of-the-art in the wide scope of LMP processes and applications, ranging from those already well established in industrial processes through to new developments to meet the themes of the UK's manufacturing agenda. ILAS 2013 will also provide an integrated exhibition area for suppliers of laser-related products and services and other outstanding networking opportunities for delegates. For persons new to the use of lasers ILAS 2013 will provide full support; including introductory presentations, reviews of the state of the art in laser processing and opportunities to network with the UK knowledge base and supply chain.

Block the dates in your diary NOW

The facilities at the Nottingham Belfry will accommodate the anticipated increase in delegate numbers and provide a large exhibition area and top class catering facilities.

The detailed planning of ILAS 2013 is already underway. At this early stage the committee would be keen to hear from any members with suggestions or proposals relating to the technical or commercial aspects of the event.

In the first instance, direct communications to AILU Secretary Mike Green (mike@ailu.org.uk)

Support for Manufacturing Centres

Thanks in part to AILU making a strong case to the EPSRC for laser materials processing to be included in their call for Centres for Innovative Manufacturing, this has proved to be the case. The scope of the call includes the application of laser-based manufacture, including novel non-contact processing, ultra-fast beam control and ultra-short pulses for precision manufacturing".

Full details can be found at: http://www.epsrc.ac.uk/funding/calls/open/Pages/centresforinnovativemanufacturing.aspx. The closing date for applications is 9 May 2012.

Obituary
Janet Folkes

The laser community will all be sad to hear that Janet Folkes passed away on the 17th of January, aged 52, after several years of fighting Cancer. She was someone who really filled up her life and grasped the day – both in her working life as an academic researcher at Nottingham University and in the achievement of the dozens of world records she held as a globe-trotting balloonist. I last saw her in the pub for lunch in mid December with several friends and she was the same as usual – fun, clever and brave. She will be missed by all who knew her.

John Powell

There are further comments in the Presidents Message (p 15) and Editors note (p 32), a Nottingham University contribution (with videos) at: http://periodicvideos.blogspot.com/2012/01/brilliant-janet-folkes.html

and condolences at: http://ourmemoryof.com/janetfolkes/condolences/

Dennis Kent retired as MD of Carlton Lasers in 2011 and it wasn't long before he was back at work: as Chief Executive of the Confederation of British Metalforming.

“I was invited to take part in the CBM’s strategic review, which began after the previous chief executive retired. It made sense to ask member companies what they thought of the CBM, and what more they wanted it to do for them. The board then invited him to implement the strategy that I had devised," said Dennis.

“It was a bit of a surprise, but I didn’t think twice about accepting my position at the CBM. I’m passionate about manufacturing, and given the economic climate it’s essential that we really fight our corner, so I was delighted to come on board.”

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InnoLas acquires AOT product line
Innolas Laser GmbH has acquired the complete ACE™ short-pulse product line of Advanced Optical Technology, the UK specialist company. The manufacturing of the lasers is being relocated to InnoLas Laser in Germany.

The AOT products are unique compact and efficient high repetition-rate short-pulse solid state lasers operating with high energy in the UV, visible and near infra-red. Proprietary high speed switching technology allows kHz pulses below 1ns duration to be synchronised to external events with sub-ns accuracy.

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National Composites Centre opens
On 25 November 2011 Vince Cable, Secretary of State for the Department of Business, Innovation and Skills formally opened the National Composites Centre, which is located on the Bristol and Bath Science Park and is hosted and owned by the University of Bristol. Peter Chivers is its CEO and Tom Hitchings heads up its business development team.

Rolls-Royce, GKN, Umeco and Vestas have committed almost £5½m of work over three years, and 2012 alone sees £5m of work from industry.

For more information please visit: http://www.nccuk.co.uk.

Good year for ES Technology
ES Technology Ltd, special purpose laser system builder and laser marking job-shop delivered turnover growth of 27% over financial year 2010, which itself was up 17% on 2009.

Turnover for the company has reached nearly £3M and profit was up 130% on the previous year. The two main drivers of growth have been sales of industrial laser machines into Medical Device and Automotive markets and the provision of subcontract laser marking services to a wide range of customers who need permanent etching or engraving onto components they machine from metal or mould from plastic.

Despite challenging economic conditions, ES is investing to grow further in the coming year and is recruiting a Sales Engineer for their laser marking job-shop. This important role will be focused on developing new business within the department and offers medium-term management potential.

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Prima Industrie announces formation of Prima Electro North America
Prima Industrie has announced the formation of Prima Electro North America. The new USA-based organization was formed by the merger of the former Convergent Laser Division of Prima North America and the OSAI brand of CNC and general motion control products and DOTS® (Dedicated Off The Shelf) electronic assemblies and is the result of the organization changes and re-branding announced by Prima Industrie in 2011.

“The new Prima Electro North America is responsible for sales and service of the OSAI brand of CNC and general motion control products and DOTS electronic assemblies within North America, and for the design, manufacture, sales and service of Convergent high-power laser sources for applications worldwide,” stated Terry L. VanderWert, President of Prima Electro North America.

With more than 70 employees and growing, Prima Electro North America operates in an 88,000 square foot facility in Chicopee, MA.

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New web site dedicated to the Lotus Laser Systems brand
After several years of brand and product development Laserite Ltd (UK) have launched a dedicated web site devoted to the Lotus range of laser marking and cutting systems on a global basis.

Dean Carpenter, Group Director, pointed out that the new Lotus systems have been very successful in the UK and that the company has created a factory within the Wuhan University and has invested in extensive new facilities and personnel at its UK HQ.

"The new Lotus Laser Systems are 100% designed, configured and tested in the UK. Plans are being made to grow local distribution and support partners in most of the economically developed parts of the globe," said Dean.

For more information:

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Newport to acquire ILX Lightwave
With a cash payment of $9.3 million, Newport Corporation has acquired ILX Lightwave Corporation, a market and technology leader in high-performance test and Measurement solutions for laser diodes and other photonics components.

Dr. Larry Johnson, ILX’s President, said, “Joining Newport will provide ILX with new opportunities to increase revenues and enhance our product offerings.”

Newport has enjoyed several quarters of strong growth recently, although that has been largely the result of a buoyant microelectronics industry, a sector that accounted for up to one-third of Newport’s revenues through 2010 and early 2011. However, the microelectronics industry is now in a slump and recent acquisitions are designed to make the company less susceptible to strong swings in demand by producing a more balanced portfolio. Together with the incorporation of Ophir Optronics and High Q, ILX Lightwave adds to the firm’s activity in industrial, medical and defence markets.

Newport’s goal is to increase its annual revenues to $750 million by 2013, and the ILX deal will provide additional momentum to that end.

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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

Sources from Laser Lines

Fibre-pigtailed option

Swedish laser manufacturer Cobalt AB has released a true fibre pigtailed option for the Cobolt 04-01 Series of single longitudinal mode lasers. In this compact and robust fibre delivery option, the fibre is fixed inside the hermetically sealed package where it remains permanently aligned.

The Cobolt 04-01 Series are CW diode-pumped solid-state single-longitudinal-mode lasers, operating in the visible wavelength range with a high level of stability, low noise, very narrow spectral bandwidth and near perfect beam quality. They are available at several discrete wavelengths from 457 to 594 nm.

High power UV ns lasers

Increased power is strongly linked to throughput in many industrial laser material processing applications. Responding to this challenge, Photonics Industries International has extended its range of Nd:YVO4 based DSH Series pulsed lasers, all of which provide pulse repetition rates up to 300 kHz with pulse widths ~40 ns while still maintaining TEM_{00} mode quality. Average powers include 50 W green (532 nm), and 30 W UV (355 nm). These efficient/high power lasers are offered for novel next generation crystalline Si or thin film based solar cell processing; glass cutting; thin or low K wafers and LED substrates scribing and dicing; via hole drilling; flex circuit cutting; ITO patterning/FPD processing; and other novel micro-machining applications.

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High-repetition-rate ultrafast amplifier

Spectra-Physics has introduced Spirit™, a compact industrial-grade ultrafast amplifier with software-adjustable repetition rates up to 1 MHz. Developed at High Q Laser (recently acquired by Newport), the Spirit laser extends Spectra-Physics' ultrafast amplifier portfolio to high-repetition rates needed for micro-machining and nano-structuring of medical devices and other materials.

The Spirit ultrafast laser provides high average power of >4 W and fully-automated adjustability over a wide range of repetition rates from 50 kHz to 1 MHz. Featuring a rugged one-box design, the laser delivers ultrashort 400 fs pulse widths with high energy of 20uJ per pulse. The highly reliable Spirit also has excellent beam characteristics with diffraction-limited TEM_{00} mode.

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New UV Excimer laser

The BraggStar S-Industrial series is a versatile UV light source delivering excellent performance for all types of FBG writing (phase mask and interferometric) as well as high spatial coherence applications in general. The BraggStar series provides repetition rates up to 1000 Hz, pulse energies around 10 mJ and operates at 193 and 248 nm. Corona pre-ionization and solid-state pulser technology produce a homogenous discharge, giving the BraggStar series better pointing- and energy stability.

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Replacement Trumpf cutting lenses

II-VI UK Ltd is now offering replacement Trumpf focusing lenses used for laser cutting. The design of the so-called 'cut lens' used in Trumpf's latest-generation single cutting head TruLaser machines includes a contoured flat on one edge for use with Trumpf's LensLine system for monitoring lens contamination. Also, the geometry of the Cut Lens allows it to be positioned only in one orientation, facilitating perfect alignment of the lens and its holder and eliminating the need for time-consuming beam centring each time the Cut Lens is removed and re-installed.

II-VI Infrared provides these replacement Cut Lenses using patented technology licensed from Trumpf.

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New FiberCut laser processing head

Laser Mechanisms has released a new FiberCut laser processing head. It is specifically designed for 3D robotic cutting with a fibre-coupled laser in harsh environments.

FiberCut is a compact, low moving mass head that minimizes inertia transfer to the robot support arm. All connections to the head enter at right angles, including the fibre, providing tight access to parts, easy cable routing and stress reduction on the input fibre. The FiberCut system comprises the cutting head, fibre collimator, linear drive with position measuring and an internal, low-noise height sense system that is insensitive to cutting plasma or piercing debris.

With rugged and effective simplicity, FiberCut is easy to maintain and operate in factory floor conditions. FiberCut laser processing heads have also demonstrated considerable success in replacing existing laser cutting heads that were costly and difficult to operate. The UK Distributor is Laser Lines Ltd.

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Laser Beam Products grows business in medical and dental laser market

Laser Beam Products (LBP), the UK's largest manufacturer of infra red mirrors, has seen steady growth in orders from customers in the dental and medical laser field.

"We've noticed a marked increase in sales in this sector," comments Mark Wilkinson, Managing Director. "We believe it is an important market for us as the demand for aesthetic laser treatments increases. Our range of gold-coated solid metal mirrors is ideal for dental and medical applications and we already have several well-established customers in this sector."

Mark believes that LBP's metal mirrors with electroplated gold coating offer the perfect solution to dental and medical customers because of their high laser damage resistance.

Another benefit of metal mirrors is that they offer good reflectivity over a wide range of wavelengths and can therefore be used with a variety of laser sources.

These mirrors are also extremely durable with long operating lifetimes. They don't break or crack; they are already used by many customers in high power metal cutting and welding applications where they perform for long periods in often dirty and dusty conditions.

Because the mirrors are made of solid metal, LBP are able integrate any number of additional design features in to the mirror, eliminating the need for customers to buy mirrors and mounts, adjusters etc separately. This speeds up and simplifies alignment during assembly and replacement, ensuring greater consistency. Mark explains "Over the years we have produced a whole range of custom-designed metal mirrors integrating features such as through-holes, grooves and alignment dowels. We've also made mirrors as small as 5 mm diameter, 1 mm thick."

For more information on mirrors for medical and dental lasers a pdf entitled 'High Quality Mirrors for Medical & Dental Lasers' is available for download from the LBP web site.

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New optical power meter

Newport has introduced the 1830-R Optical Power Meter, a completely redesign of the 1830-C model and replicating much of its functionalities and specifications. It is offered as a drop-in replacement for the 1830-C, which was the most popular Newport meter used in fibre optic component production and testing. DC power measurements can be displayed in units of W, dBm, dB, and relative measurement on the instrument's LED display, providing a wide dynamic range with power sensitivities down to 10 pW and full scale readings up to 2 W (detector dependent).

A built-in beeper, which changes its frequency as a function of incident optical power, can be utilized for optical beam alignment. The analog output can be used for fast control loop applications.

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W: www.newport.com/Optical-Power-Meter-1830-R/1001724/1033/info.aspx

New laser safety interlock

ICS-15XM is a failsafe laser safety interlock control system for advanced installation for long term service and remote monitoring. It is designed for use with multiple inputs to create an interlock system to prevent users being inadvertently exposed to laser beams by monitoring many switches and doors and disabling the laser if any are open. The Communications Module enables the controller to be networked so that it can be monitored remotely.

The ICS-15XM is not processor controlled and therefore does not have the obsolescence issues associated with operating systems, microprocessors and programming languages.

The system has been designed to comply with Machinery Directive standards for safety control systems and to EN 61508. It is suitable for use as a control system to SIL3 or as a component in a SIL4 system.

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Brinell Vision Limited to represent Protect Laserschutz in the UK

UK-based Brinell Vision, designers and suppliers of precision laser filter solutions for some of Europe's top companies, now represent Protect Laserschutz GmbH in the UK, manufacturers of a large range of laser safety products such as laser goggles, laser screens and curtains for industrial, medical and R&D.

Adam Brierley with Petra Fröbel of Protect Laserschutz GmbH (Nuremburg, Germany) at the signing of the partnership agreement during Medica in November

Adam Brierley, Director of Brinell Vision, stated that "the laser protection products from Protect Laserschutz will complement our growing range of laser and optical filters and we will help promote their brand in the UK during 2012."

Petra Fröbel, Managing Director of Protect Laserschutz, commented that Brinell Vision would be an ideal partner in the UK.

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New laser safety eyewear brochure

Photonic Solutions' new LaserShield laser safety eyewear brochure includes comprehensive information on the full range of laser safety goggles that the company holds in stock. Download a copy at: www.photonicsolutions.co.uk

Photonic Solutions supplies EN207:2010 certified laser safety eyewear. Frames carry a lifetime guarantee and are designed to be lightweight, comfortable and easy to wear. The range now includes the new FG1 mineral glass filter from NoIR, offering customers the choice of even higher protection levels combined with 75% VLT, in a robust and durable frame style. The FG1 glass filter offers high levels of protection along with excellent thermal stability over the wavelength range 850 to 10,600 nm.

All eyewear is held in stock in Edinburgh for on-line ordering and next day delivery at www.photonicshop.co.uk

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Pro-Lite provides active viewing windows for high power lasers

The new patented active cabinet window from Laservision implements electronics into the safety circuit of the laser system so that, in the instance of a laser beam hitting the window and sufficient radiation impacting the sensor in the window frame, the laser will be rapidly shut down, before hazardous levels of laser radiation can escape through the window. These active windows are currently available for lasers in the wavelength range 820-1080 nm.

The windows are certified to EN60825-4 'Laser Guards' and are available as large area viewing windows (580 x 900 mm and 267 x 390 mm) for industrial high power laser installations.

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Aerotech's new and improved control

New APR series rotary stage

Aerotech continues to improve and innovate its direct-drive rotary stage capability with the new APR mechanical bearing series which offers positional accuracy to 1.5 arc-sec and axial load capacity up to 450 kg. Aimed at high precision rotary positioning for applications such as precision component testing, optical calibration systems, laser micro-machining and sub-micron metrology, the APR's brushless direct-drive technology easily outperforms traditional worm/wheel stages, delivering considerably smoother and higher speeds, much improved angular precision, with zero backlash and a far superior throughput potential.

The range covers seven models in three frame sizes with nominal square footprint mounting dimensions of 150, 200 and 260 mm, offering a clear through-aperture of 50, 75, or 100 mm respectively for electrical or other services such as slip ring assemblies, laser feed or air supplies.

(Note: A new brochure from Aerotech brings together a collection of rotary stages in one single 36-page resource to facilitate comparison of specifications and prominent characteristics for eleven different rotary stage types – from high performance low profile stages with air bearings and direct drive motors to large diameter/large aperture gear driven stages for rotary positioning.)

Trio ARMS new Motion Coordinator

Trio Motion has expanded its Motion Coordinator range with two new motion and machine controllers based on the latest 533MHz ARM11 processor - flexibly and economically providing new levels of multi-tasking servo or stepper control for high performance automation.

The MC403 will control two servo axes with a master encoder input, or three stepper axes; whilst the MC405 has a choice of four servos plus a master encoder or five step and direction axes.

The new MC403 and MC405 build on previous Motion Coordinators with an abundance of performance enhancements that the ARM11 core has enabled. With more than four times the clock frequency at 533MHz, an improved selectable servo update rate from 125 to 2000 microseconds and a maximum data table size of 512K, the processor delivers much improved servo loop accuracy with fast 64 bit real-number mathematics and 64 bit integer position registers.

The discernible differences between the two models, apart from the axis count and the encoder provision, relate to the multitasking capability and the number of virtual axes available, as well as physical variations such as I/O count, size and status display: The 2-servo/3-stepper MC403 can run six simultaneous tasks and has a total of eight axes in software, whilst the MC405 runs up to ten tasks with sixteen axes in software.

The MC403 and MC405 Motion Coordinators are aimed at relatively low axis count applications. Trio Motion's MC464 Motion Coordinator offers a diverse multi-axis capability for up to 64 independently configured servo or stepper axes together with a very wide range of fieldbus protocols, increased multitask support and numerous additional features where more complex motion and machine control is required.

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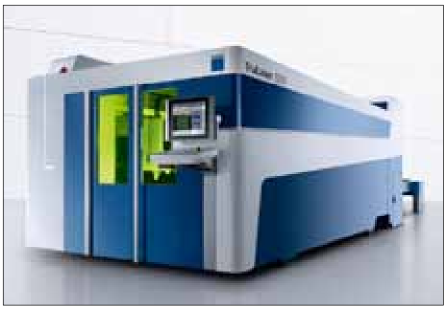
TruLaser fibre laser machines

In recent years, Trumpf's 2-D solid-state lasers have earned themselves a secure place at many sheet metal processing companies; especially the TruLaser 5030 fibre. Now this high-speed laser cutting machine, which is particularly suited to thin sheet metal and high batch sizes, has been joined by a longer and wider sibling, the TruLaser 5040 fibre. With a processing area of 4m x 2m, this new machine offers users even more flexibility in terms of sheet format



Both the TruLaser 5030 fibre and 5040 fibre models can now be shipped with a 5 kW laser – a real first for the market. This not only increases the maximum thickness of sheet that they can handle, it also speeds up their already impressive feed rates.

"Employing the TruDisk 5001 solid-state laser is an important innovation. Thanks to the higher laser output, they can now process material up to five times faster while using much less power than similarly performing CO_2 laser machines," said Mathias Kammüller, head of Trumpf's Machine Tool Division. Depending on the geometry, this brings down table time by up to 50%. Also, the machines are a cost-effective cutting option not only for stainless steel and aluminium but also for non-ferrous metals and even – with a new cutting set – titanium and titanium alloys.

The TruLaser 5030 fibre has won various design and construction awards around the world in recent months. One of the ways juries have explained their decision is by pointing out that this machine, fitted with Trumpf's own TruDisk laser, is very user-friendly, fast and precise. They saw that, combined with features such as a single cutting head strategy and automatic nozzle changer, the TruLaser 5030 fibre meets the manufacturing industry's current needs for increased productivity and cost reductions.

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Film coatings for fibre laser cutting

Thin sheet metal is often coated with protective film, and up to now solid-state laser cutting heads have had to make two passes over the sheet, once to cut through the film and again to cut the metal. With solid-state lasers in mind, Novacel (http://www.novacelinc.com) has developed and recently began selling protective film that removes the need of this additional processing step.

Trumpf has confirmed that with this film there will be almost no difference between cutting data for coated and uncoated thin sheet metal. As expected, the new film poses no processing problems for CO_2 machines.

Trumpf UK's largest single order

Valued at just over £2M, Trumpf UK has taken its largest ever single order, for a range of machines and associated automation from Stoke-based IAE, the country's leading manufacturer of livestock handling equipment, equestrian stabling, steel fencing and shelters. The IAE order included 5 machines, one of which was a TruLaser 3030 with LiftMaster Compact auto load/unload.

According to IAE Director Frank Klucznik, the move will not only allow the 500-employee, £44m turnover company to redeploy labour to other tasks, it will "speed response times, improve accuracy and raise the bar from a design and development perspective".

Products at IAE, which currently operates 24 hours a day, five days a week, are entirely manufactured from natural and pre-galvanised mild steel in sheet/plate ranging from 1 to 25 mm. Batch sizes can be anywhere between 200-off and tens of thousands, for customers across the UK and mainland Europe.

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Serving the aerospace and power generation industries

Prima Power Laserdyne has sold two Laserdyne 795XL seven-axis BeamDirector™ systems to Ace Precision Machining Corporation, USA. The company has now installed nine Laserdyne systems in the last decade, for laser processing components for the aerospace and power generation industries.

Terry L. VanderWert, President of Prima Power Laserdyne, made the announcement stating that Ace Precision has capitalized on the growth opportunities within industries that have a rapidly expanding need for the latest laser system technology, validating not only the slow and steady recovery in the manufacturing sector in the USA but also the robust expansion of turbine engine manufacturing worldwide.

With four $C0_2$ systems with up to 8 axes of motion, five multi-axis BeamDirector drilling systems with Nd:YAG lasers and a shuttle-equipped 2D cutting system, Ace Precision has the capacity, flexibility and precision required to produce highly complex combustion chambers, liners, turbine plenums, compressor housings, tailpipe and heat shield assemblies along with other precision engine components that it produces for companies around the world.

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High speed laser marking

Synrad $C0_2$ lasers are ideally suited to ablating many common inks used on card stock packaging for consumer items. Typically the laser bleaches out the ink, leaving a crisp white mark that is permanent and which eliminates the maintenance and consumables issues of inkjet printing.

This particular application uses a Synrad 10 W laser and an FH Flyer marking head to mark expiration dates at high speed on varnished, ink coated card stock, with a cycle time of 60 milliseconds. In a tracking application, these packages could be marked at a rate of approximately 16 cartons per second.

UK distributor, Laser Lines Ltd, offers the complete range of Synrad products

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Prototyping with a laser cutting system

The Stanford BioRobotics Lab is a university research group involved in the development of robots primarily for medical and industrial applications. But in 2006, the group started development of a “personal robot;” that is, a robot that could operate in a home environment and have sufficient dexterity to perform some basic household tasks, such as opening a refrigerator door and retrieving an item from inside. Another design imperative was to address the issue of human safety, that is, to work in the human environment and around humans without causing harm.

Personal Robot PR-1 Prototype

To achieve these ends, the robot was intended to move over the surfaces commonly encountered in the home, and to negotiate slightly uneven surfaces and transitions, such as door jambs and power cords, without difficulty. The final design concept consisted of a base mounted on pneumatic tires that move with two degrees of freedom. This omni-directional base supports the robot torso and enables it to rotate.

In order to handle and interact with various household items (e.g. tools, appliances, containers, etc.), the robot was also envisioned to have two arms, of somewhat similar size, strength and dexterity as human arms, and to be terminated with simple hands. This requirement posed a significant engineering challenge, since the payload ratio (payload weight/manipulator weight) for human-sized industrial robots is typically on the order of 1:10, while the human arm ratio is about 1:1.

As designed, each arm has seven degrees of freedom (pan, tilt and rotation of the shoulder joint, elbow flexion, forearm rotation and wrist flexion and rotation) and can lift loads of up to 5 kg. To achieve this combination of motion and payload capacity safely, a novel gravity compensation system was utilized comprising compression springs, highly geared small motors, and steel timing belts. Located within the arms, it allowed them and their payload to passively float, and it removes the need for large motors in the arms, enabling the use of back-drivable transmission. The latter is particularly important in enabling “push-back” against robotic motion, which ensures both human and robot safety in unstructured, real world environments.

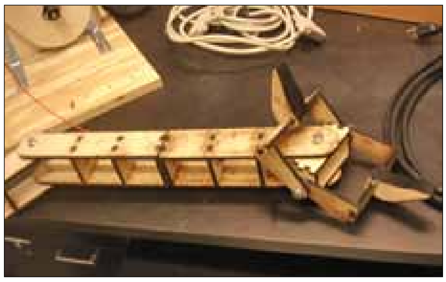
The basic design approach for these arms was to locate the upper segment and elbow drive motors as close to the shoulder joints as possible, and to use drive belts to deliver the motion over a distance. This was done in order to keep the weight distribution towards the shoulder, and thus minimize the net torque required for motion and reduce the chance that the arm will damage something it accidentally hits.

Laser Based Prototyping

The extreme mechanical complexity of this system necessitated numerous prototype cycles, which the group found to be excessively time consuming and cost prohibitive. A Coherent OmniBeam Laser Machining Center, a flatbed laser cutting with a 500W CO_2 cutting laser and a 1.2m x 1.2m working area, was therefore acquired to rapidly fabricate the prototypes. Depending on the material, the system can cut to a dimensional precision of up to 25 µm (50 µm repeatability), at speeds up to 50m/min.

The cutting characteristics of the CO_2 laser proved to be a good match to the prototyping needs of the Stanford BioRobotics Lab. Specifically, the far-infrared output of the laser is strongly absorbed by a wide range of materials including plastics, paper, films and carbon fiber, and the raw power of the laser was sufficient to cut thin metals as well. And as well as cutting, the system can score, perforate and engrave.

Coherent BEAM Laser Machining Centre



Early PR-1 robot arm concept prototyped with plywood

The photo above shows a segment of a prototype robot arm fabricated from 6 mm thick plywood. To achieve the necessary strength to weight ratio, the builders used mortise and tenon joints combined with dowel pins, epoxy cement and wood screws for attachment. The plywood was sufficiently strong for metal bearings to be press fitted into components, and the laser cutter produced holes with the necessary tolerances for press fits. In addition, the cutter delivered the precision required for gear and belt drive-pulley tooth profiles. As regards metal parts, the laser system was used to cut 1 mm thick aluminum for motor mounts, and occasionally thin steel (in the 1.6 mm to 3.2 mm range) for higher strength parts.

Typical structures produced with the Coherent Laser Machining Centre

Conclusion

The long-term goal of the project was to develop a platform that other research groups could build upon. By bringing rapid prototyping capabilities in house, the Stanford BioRobotics Lab was able to successfully develop the PR-1 personal robot. They have now partnered with Willow Garage, who have taken the original design ideas and refined them further. Their PR2 robot, constructed from metal, is currently available to other facilities and a growing community of researchers, who are now able to collaborate using a standard platform.

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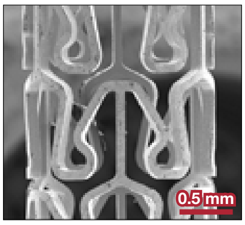
Micro-cutting stents using fibre lasers

Micro-cutting stents is one of the most demanding manufacturing applications in the medical device industry. With tube diameters between 1 and 10 mm and a wall thickness of around 100 μm, precision cutting is essential. The stents are inserted into arteries and are intended to be permanent fixtures, so it is therefore critical that the cut metal does not have any rough edges.

At this year's BIOMEDevice exhibition, held in San Jose, California, 6 - 7 December, visitors to JK Lasers' booth discovered how medium power range, single mode fibre lasers can micro-cut medical instruments to produce small (20 to 30 μm) kerf widths.

Featuring high beam quality and excellent power stability, they deliver dross-free cuts with very high contour accuracy (<5 μm). As a result, the amount of post-processing required to achieve a high quality finish is vastly reduced.

Delivering highly concentrated, controlled amounts of heat, the resulting Heat Affected Zone is small. Typical cutting speeds for medical stents with a single mode laser output are ~ 1 m/ min.



Mark Richmond, Product Manager for JK Lasers, said: "Medical device manufacturers are under pressure to improve productivity. Precise and highly controlled processing can be achieved using the JK Fibre Laser range, enabling manufacturers to weld and cut quickly without compromising quality. Our lasers also substantially reduce - if not eliminate - the need for further processing to finish parts. This leads to an overall increase in throughput."

Also on display at BIOMEDevice was JK Lasers' recently launched 1kW fibre laser (JK1000FL). This high powered addition to the JK Lasers' range is particularly well-suited for welding hermetic seals on medical devices and for cutting larger surgical tools, such as bone saws.

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Exploiting the SAP interface

Trumpf's TruMark marking laser now includes a driver interface that allows it to be directly connected to a Systems, Applications and Products (SAP) environment. Working within the SAP system, a TruMark can apply company logos, model designations, codes and serial numbers directly and indelibly on the product's surface without requiring any programming skills or additional software. The laser parameters required for a wide range of materials are included as part of the marking software package.

The innovative SAP driver connection is featured on the new TruMark Station 1000 (D). This compact, space-saving laser marking station is perfect for marking small components without the need for a mechanical z-axis.

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Add green to weld copper

Laser welding of copper has traditionally required high peak power pulsed lasers to overcome the inherent high reflectivity and thermal conductivity of the base material. At room temperature copper absorbs as little as 5% of laser light at 1 μm wavelength. A new patented process of mixing in a secondary wavelength at 532 nm (only 10-15% of the total energy) enables the absorption of laser energy to be much improved, offering consistent results even where there are differences in the surface condition of the material.

This technique is used in the new SLS 200 GX by LASAG AG (a Rofin subsidiary). The resulting welds from the SLS 200 GX are more consistent in diameter and penetration, plus very small spot welds (down to 25 microns diameter) are also possible. Following the initial pulse of green light, the energy is reduced however the main infra-red energy is maintained to allow the weld pool to grow. Molten copper absorbs the laser energy much better than solid material at room temperature.

LASAG launched the SLS 200 GX at the LASER 2011 exhibition in Munich and applications trials are available via Rofin-Baasel UK.

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Multi-Purpose laser workstation

Rofin's new Modular Processing System (MPS) is a medium-sized, multi-purpose workstation for a wide range of automated laser material processing applications. Designed as an all-in-one system, the MPS integrates laser sources, motion modules and control units within a single compact housing, where it can be configured for welding, cutting, drilling and structuring applications.

Four different motion systems are available ranging from the basic module, with a single Z axis, up to a high-precision granite setup featuring a cross table with linear servo driven axes and ±1 μm repeat accuracy.

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Laser cutting of composite

Hopes of more affordable flights soared recently when the new Boeing 787 Dreamliner took to the skies. Featuring a carbon composite design, the passenger jet is lighter than rivals, resulting in substantial fuel savings.

But the composition of carbon fibre reinforced plastics (CFRP) – in particular, the high heat conductivity of the carbon fibres themselves – makes processing difficult using traditional techniques. Mechanical milling and drilling has been known to cause costly heat damage, chipping, delamination and tool wear.

The good news is that much of this damage can be avoided through correct application of laser processing. An ongoing UK study by Rugby-based JK Lasers, in conjunction with Liverpool John Moores University, has revealed that lasers can effectively cut, mill and drill CFRP without compromising the material's integrity.

During trials, a 200 W fibre laser (JK200FL) and scanning head were used for trepanning and milling. The JK200FL was also used in cutting and drilling tests using more conventional process heads.

Compared to mechanical cutting and milling, the JK200FL's small spot size produced a much cleaner edge and caused minimal thermal damage. In composites of 1mm thickness or more it was used to spiral-drill holes, which produced a high quality cut with very slight burn-back that was limited to the top layer of fibres only. Also, the fact that the laser is a non-contact process is important in removing the risk of tool wear.

Mo Naeem of JK Lasers, who helped coordinate the research, said "CFRP can be used in a wide range of industries to create new products such as the lighter, more fuel efficient Boeing 787. But to fully realise these benefits, the costs and complexity of processing CFRP must be addressed."

"The preliminary results of JK Lasers' research in partnership with Liverpool John Moores University, suggest that lasers are more than capable of rising to the challenge. By revolutionising the quality of CFRP processing without compromising the material's strength and stability, lasers will help drive down the costs associated with carbon composite manufacture in the years to come."

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Laser demonstration facility

ES Technology now has a demonstration facility to show Additive Manufacturing using the new Concept Laser Mlab cusing machine, in particular how easy it is to build metal parts directly from 3D CAD designs. Parts can be built in just hours from stainless steel, cobalt chrome or precious metals such as yellow gold and silver and the system is designed to operate unattended overnight.

"The Mlab cusing represents a breakthrough in metal direct manufacturing in terms of convenience and affordability" said Colin Cater, ES's Product Manager for Concept Lasers systems in the UK. "It is aimed at markets which require smaller metal parts, initially for dental and jewellery manufacture" Cater added.

To arrange a visit to the facility:

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Laser welder at Border Precision

Kelso-based Border Precision has installed a Trumpf TruLaser Robot 5020 3D automated laser welding system for handling complex seam geometries.

Wayne Ballantyne (l) with Trumpf UK Scott Simpson

"We bought it because we always strive to be at the forefront of new technologies," says the company's Managing Director, Wayne Ballantyne. "We identified laser welding as a process of the future, a method that represents a fast, cost-effective joining solution for our customers."

With around 150 employees and annual turnover in the region of £7-8 million, Border Precision offers a single source for all engineered products, the company offers capacity that includes laser and punch presses, as well as multi-axis press brakes. However, until the recent arrival of the TruLaser Robot 5020, the firm's welding capability was restricted to conventional two-dimensional MIG and TIG processes.

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Expansion following a record year

When Richard Andrews, Managing Director of Midtherm Laser Ltd set up the company in December 2000 with one Bystronic Laser machine in the corner of a factory that he rented off his father, little did he know that one day he would own one the largest subcontract laser cutting facilities in the country. Based on Peartree Lane, Dudley, the company has gone from strength to strength over the last 5 years, and a £1.9m investment project, which is due to be completed in the summer, includes an 8,000 sqft extension adjacent to its existing 12,000 sqft building.

The new building will house a 5th brand new, state of the art laser cutting machine, a press brake machine, extensive racking for storing sheet materials, and ample car parking for their future predicted needs.

"2012 is going be a very exciting year for the company," said David Wheatley, Sales Manager. "The whole team has worked hard to ensure that we exceed the expectations of our customers and our customer base is growing year on year. One customer-driven development was the introduction of a new estimation software package called IP Laser, which has already significantly reduced the amount of time it takes for us to submit a quotation."

"Over the last 2 years we have been investing in new equipment to ensure that we stay at the forefront of our industry," said Dean Cockayne, Operations Director. "In 2010 we invested over £600k in a 4th laser machine and a Nitrogen Generator "We are in the process of interviewing people for the new roles that the new build project has created. We are currently running 24 hours a day with a Saturday and a Sunday morning shift. In June when the project is completed we need to continue running 24 hours and I need to make sure that we have enough trained staff in place to have an efficient transition"

The company plans to spend the next few months working hard on a new marketing strategy to help raise its corporate profile in time for the arrival of the 5th machine. To maximise exposure Midtherm Laser are exhibiting for the first time at MACH 2012 and Subcon 2012 both at the NEC in Birmingham.

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£1M investment in year of growth

Laser cutting specialists SJC Hutchinson Engineering in Kilrea, who have just celebrated their 40th year of trading, have invested almost £1M in a new 5040 6 kW Trumpf laser with bespoke liftmaster as well as an expert training programme for their staff. They have created 8 new jobs and have expanded their facility by 4500 sq ft making it one of the largest plants of its kind in Ireland.

Mark Hutchinson, Managing Director of SJC Hutchinson Engineering said: "After 40 years in business and having faced some of the most challenging market conditions in living memory we recorded a significant year of growth, so far, at SJC Hutchinson Engineering.

The company has adopted a 'lean manufacturing' stance in conjunction with its clients who are based in the coach building, agricultural and quarry industries, throughout Ireland and the UK.

"We knew that to survive the recession and grow the business we had to be bold in our thinking and competitive with every aspect of production, " said Mark.

"Our new tube laser cutting machine has given us an important competitive edge allowing us to take on more jobs, speed up the manufacturing process and keep costs down for our customers."

"The decisions we made, such as investing in expensive new machinery and expert training from Trumpf, have set us on a path of growth that we intend to build upon," said Mark.

The company now has 3 flat-bed lasers and is the only company in Ireland to have a BLM LT8 tube laser.

Mark continued: "Our technology and know-how means we are a solutions-focused company who, because of our continuing investment in our infrastructure, can offer a competitive and holistic approach to laser cutting jobs."

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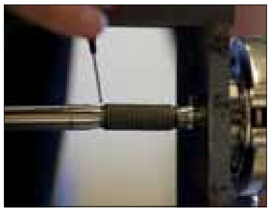
Weld leak testing



Carr's welding technologies are well known for their laser welding services, including leak testing of the welded joints. Carr's currently have 5 production jobs that they helium test, including an Inconel core that has dozens of welds and has to be tested at 3 stages during the assembly and welding process since some of the initial welds are covered by subsequent welds.

Helium gas is used because it exists primarily in atomic form and the atoms are small, relatively to atoms of other elements. Connecting the component under test to a vacuum pump equipped with a mass spectrometer to analyse the residual gas, any helium sucked in through even a tiny hole in a welded joint can be detected. If a leak is detected it is repaired and the component retested.

Helium leak testing is part of the welding process quality valuation and is not offered as a service on its own.

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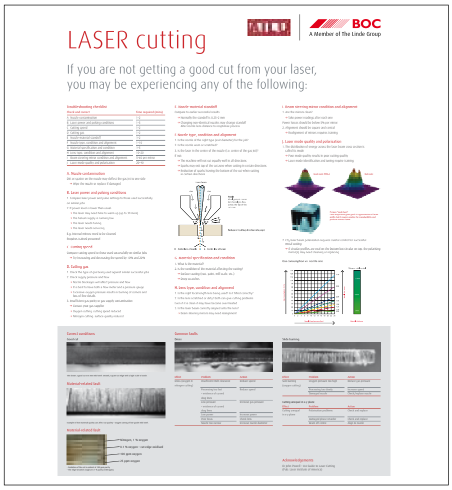
Laser cutting trouble shooting poster

BOC have recently launched a large laser cutting trouble-shooting poster, which they are offering free of charge to AILU members.



This excellent summary of problems and how to resolve then was produced in consultation with John Powell of Laser Expertise.

To obtain a free copy please contact:

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Operating Leases for Laser Machining Centres

Dave Connaway
Cirrus Laser, Burgess Hill, W Sussex

When I started in the laser job shop business in 1987 the company I worked for had a single state of the art Electrox M1200 CO_2 laser. At that time we were the only UK Company using CO_2 laser machines to laser weld diamond saw blades and diamond core drills. Over half a million blades and a quarter million drills were welded until a take-over transferred production to China and Luxembourg. In 1999 the company went through a management buy-out losing a dedicated welding machine to the previous owners and running three old CO_2 laser machines of 1.5 kW power or less: they were un-competitive, expensive to maintain and restricted to cutting thin material due to their low laser power. However, due to a policy of buying machines by the previous owners we had no outstanding loans and all 3 machines had been fully depreciated.

Leasing
In 2001 a new Trumpf 3030 with a 3 kW CO_2 laser was installed under an operating lease agreement. We shut-down one old machine, which took a further 2 years to sell and made 2 operators redundant. Since then we have had another 3030 with 3.2 kW laser, still have a 3530 with 3.2 kW laser which is being replaced in April 2012 with a 3030 L20 with a 3.2 kW CO_2 laser. The first UK Trumpf 5030 fibre laser machine was installed at Cirrus Laser in April 2011 under an operating lease agreement with Lombard. All 5 Trumpf machines have been leased on separate 60-month agreements with no capital investment, no depreciation on the balance sheet and leasing costs offset in the Profit & Loss Account.

By leasing machines we are always using the latest technology with faster machines keeping our prices competitive, our operators have new machines with typical up-times of 99.5% or better, our repair costs are minimal and our customers enjoy guaranteed lead-times due to our machines having excellent reliability. We are a laser cutting company who need machines to perform to our high standards: we are not in the business of refurbishing or selling old machines, we leave that function to machine dealers.

Rules and financial considerations
Generally an operating lease will cost the machine value over 60 months, so a new machine costing £300,000 will have a leasing cost of approximately £5000 + VAT per month. UK law on the subject of operating leases requires that in England the lessee (i.e. the laser cutting company) cannot have a capital investment in the machine, nor can the lessee depreciate the machine on their balance sheet. The whole point of the lease is not to buy the machine at the end of the lease, though this is possible if the lessee requests it, but must be done through a third party.

In the case of Cirrus Laser dealing with Trumpf, we place an order for a new machine, pay a deposit to confirm our order, usually 10% or less, and the machine is delivered, installed and commissioned. As this point the machine is sold to the lessor (i.e. the finance company) by Cirrus Laser ,the lessor then pays Trumpf 100% of the purchase price and Trumpf then reimburses Cirrus Laser with the deposit. At that point Cirrus Laser does not have any financial interest in the machine apart from making the 60 monthly payments to the lessor; in this way Cirrus Laser keeps a good cash flow at the bank.

The lessor depreciates the machine on their balance sheet and gets tax relief on the acquisition, but in the event of a total loss (for example fire at the premises of the lessee) the agreed depreciated residual value of the machine at the time of the loss is the value paid by the insurers and in most cases the lessee has to arrange insurance and repair and maintenance on the machine.

Insuring the machine
The lessee insures the machine in year one at the full purchase price but in subsequent years the capital value insured is the depreciated value e.g. the £300,000 machine in year two might be valued at £250,000, in year three £200,000 and in year five maybe £120,000. The lessor will insist on the machine being operated to the machine builder's specification and that includes using high purity laser gases in the case of a Trumpf CO_2 laser. Servicing has to be at the recommended Trumpf intervals using Trumpf or Trumpf recognised service technicians. In the case of our 5030 fibre laser the deal includes 5-year warranty and 5 year Trumpf service, the 3030 L20 arriving in April will have 2-year warranty and 5 year Trumpf service, which gives the leasing company confidence that the lessee will keep the machine in a serviceable condition.

Contracts
Contract and machine return conditions can be a sticking point with financial institutions. Most contracts are written for vehicles, which are easier to return than a 12 tonne 3030 with a CO_2 laser! Some institutions also demand that the machine is serviced before return which as we all know is a nonsense since a big proportion of a service and it's cost is changing demineralised water and filters, only to be emptied when the machine is moved. It is worth taking legal advice with solicitors who have contract experience to make sure that the contract does not favour the lessor.

Conclusions
For Cirrus Laser our policy of leasing lasers has worked with increased turnover and profit in what have been good times up to 2008 and in bad times with recession in the last 3 years. Our good cash flow has enabled us to purchase a new press brake and CMM in 2009, new automation for one of the lasers (Trumpf Compact Liftmaster) in 2010 and a new VMC (vertical machining centre) in 2011. All of these purchases are for machines that will not need technology upgrades and do not need expensive repairs and maintenance; the decision to purchase was taken with our experience of leasing high cost lasers. Good cash flow has enabled the company to ride the storm in the past 3 years; we have also been able to pay-off the mortgage on the property so our costs have been reduced, we do not have a landlord and rent on the property.

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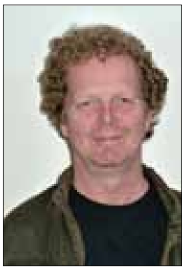
JOB SHOP CORNER

Chairman's report

Straw poll

Notes from Captain Jobshop



What Ho! Fellow Pirates.

There is an old nursery* saying – 'You can't polish a turd …' and there is the spin doctors response 'No – but you can roll it in glitter …' Well – this recession has been both polished and rolled in glitter – but it still looks pretty poor.

To find out what was really happening I carried out a survey of ten major jobshops just before Xmas and asked them all the same four questions:

1. How busy has your firm been this year? (i) Slowly going bankrupt, (ii) Treading water, (iii) Small profit, (iv) Good profits

Responses: 4 Treading water, 4 Small profit, 3 reasonable/ good profit

2. How busy do you expect to be in the first half of next year? (Using the same four judgement levels)

Responses: 9 Small profit, 2 treading water

3. How many cutting machines did you buy this year?

Responses: 5 none, 4 one, 2 two

4. How many cutting machines do you expect to buy next year?

Responses: 6 none, 3 one, 2 two

So – although it's not great out there, we still have a healthy number of firms buying new machines. And some firms even bought two machines in the past year – which, frankly, I think is just plain showing off.

I hope we can all afford to show off in a similar manner as this year progresses – but for the moment I'm looking for that box of glitter I packed away with the Christmas decorations …

Onward and Upward

John Powell
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*Only in general use in Mancunian nurseries

Job Shop Tips

Dave Connaway

A 'neat little trick' to keep scrap in place

Since February 2007 we have been making a component from very expensive hardenable stainless steel that has a little twist to the cutting sequence (see figure opposite)

When we did the original trials for the customer we were more concerned with getting the kerf correction and cutting parameters spot-on rather than assessing the implications of the scrap affecting the cycle time. We knew that we needed to remove bars from the cutting table, drop parts through and collect them from the tray at the end of the conveyor. Our pricing of the job included extra set-up to empty the tray and remove the bars. Having given the customer a price and agreeing the quality and tolerances we got an order for 2000 parts and off we went.

Within about 10 minutes we realised that we had got it horribly wrong: the operator was having to open and close the access door on our Trumpf 3030 after almost every component was cut due to the horrible little 'horseshoe' shaped bit of scrap flipping-up and getting in the way of the nozzle tip. The scrap was just too close to the profile, the head lifted on the scrap taking the focus too high and if it still kept the cut the dross underneath was going to take an age to clean off. (As an aside: since this experience, whenever we carry out tests we always run at least 20 in anger full speed to check for any problems in production!)

The Fix

Because of the 'horseshoe' we were losing money big time on 2000 of these parts. Each part has a material value of £3 and it's only 84 x 79 mm, so any scrapped parts were costing our customer a lot of money on his free issue material with everyone knowing the sheet yield: making it a double loss! The material (made in USA) is 10 swg thick and the horseshoe is only 3 mm wide, so putting 2 or 3 little transverse cuts on the horseshoe to drop smaller scrap through was not an option especially with the tolerances we needed to hold. If we could keep the horseshoe in the component long enough for the head to go round the profile without seeing the scrap and lifting then we were back on price.

Above: component to be cut with 'horseshoe' scrap

Right: The solution: the extra cut that springs the horseshoe to keep it in place.

The fix was to add another cut within the horseshoe, as shown in the inset picture. What we did was to pierce the centre of the horseshoe width and put a single line cut almost all the way around, then pierced again to cut the horseshoe. This had the effect of making the scrap into a spring and until the scrap cooled down (we cut with high pressure nitrogen) it stayed where it was cut and gave us just enough time to get around the profile without scrapping the component or having to open the machine door to push the scrap out of the slot.

This is a neat little trick, which we have used on other parts since this one. Our new Trumpf 5030 fibre laser has different support bars to our 3530, because of the automation, so instead of having to remove bars we can now cut across the whole table without the part obstructing subsequent parts and of course the horseshoe is still cut with our extra cut to hold the scrap in place.

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The Additive Laser Manufacturing business

*Interview with **Carl Brancher***
Managing Director of Materials Solutions Ltd

A leading subcontractor exploiting ALM technology provides an insight into turning this exciting technology into a money-making activity

As an engineering subcontractor offering ALM with lasers, do you regard Materials Solutions as part of the UK laser job shop community?
We are members of AILU and attend association workshops on additive metal processes, but to date we have not needed to call upon the laser job shop group within AILU or the wider community of laser experts. The people we feel commonality with are the welding and cladding processors, rather than laser users per-se. Since 2006 we have used IPG fibre lasers in our EOS machines and have had no laser problems: they have been both stable and reliable. We use the laser as a tool- and it works.

You wrote a paper in the Laser User (Issue 56, 2009) "Metal powder bed additive laser manufacturing: the good, the bad and the ugly" which amongst other things pointed out the limitations and pitfalls of designing for ALM. What advice would you give to a company that was considering manufacturing a component by ALM for the first time?
The advice I would give is that ALM is very good at some things but uneconomic at others. In particular it can make assemblies of parts as a single piece, but is a slow and expensive way of making massive parts- it is after all a direct-write process, so mass = time = money. To use ALM economically it's important to consider whole assemblies and completed parts, rather than individual components as conventionally made. ALM can save on the cost of laser drilling thousands of cooling holes in a part or forming interference fit surfaces and bolting together multiple components to make something that ALM can build as one.

What is your assessment the current health and capability of the UK subcontract engineering sector in Additive Layer Manufacturing?
We live in an international world and are reliant on principally overseas suppliers of equipment and software; nevertheless, we can demonstrate we are World-Class in the application of ALM to metals. We exported over half our sales last year and in the last few months have received orders from Canada, France, Germany, Spain, Switzerland, Japan and USA. I believe our UK competitors are in a similar position.

Financially, the ALM industry is still heavily reliant on grants- both direct and indirect (i.e. grants paid to customers who then pay for the parts produced). Whilst this is undesirable in the long term, every big change - from the settling of the American Plains to the take up of composites - has been supported by government grants; so I don't think we have to beat ourselves up too badly over it as long as we can show good progress towards the time when ALM no longer needs support and the UK has a self-sustaining leading position.

Where are the main markets for those in the UK providing ALM engineering subcontract services, for your company in particular?
We have tended to focus on certain materials- leading inevitably to certain applications and therefore certain customers. These have been the high temperature materials- in particular nickel superalloys. I believe some of our competitors have focused instead on particular market segments (e.g. dental) and/or have focused on particular ALM capabilities, such as mass customization (e.g. for medical implants).

There is a lot of research and development in ALM in the UK; there have also been government-sponsored collaborative project initiatives aimed at this process. Is all this having much impact, direct or indirect, on your business?
We have benefitted enormously both directly and indirectly from government grants - as has every other ALM operator in the UK (and perhaps also those in Europe- and beyond). Take for example Arcam (a Swedish provider of e-beam ALM systems): their sales to the USA are probably dependent on US government programs particularly those aimed at sustaining airframes beyond expected lifetimes.

Four of the five AM machines at Materials Solutions. A sixth machine is on its way

Any funding decision in the UK takes place in this international environment. We are competing with Fraunhofer-Institut für Lasertechnik (ILT) for projects for example. Also, I seriously doubt if the current state of UK expertise in ALM application could be sustained without the UK funding of programs - which is why EADS and GKN recently received about £2m for their ALM collaboration at Filton.

In your experience, is the case for ALM still to be made to UK manufacturing industry? What do you perceive are the main obstacles to a greater uptake?
ALM is another manufacturing tool and the question still to be answered is: is it niche or mainstream? This is as much an economic as a technical question. I believe that if, despite its immaturity and high cost, it can gain some early application 'wins' where it is vitally needed; then this can drive the entire supply chain and create a virtuous circle of technology improvements, increased utilization and greater competition driving costs down. This maturation and cost reduction then opens up more applications.

How do you view recent developments in additive manufacturing machines and in the supporting materials, hardware and software?
I view developments positively, but in regard to equipment and software the changes have not seemed to me to be very rapid. We only became involved with the second wave of metals machines beginning around 2005,

with the arrival of lasers with high beam quality and high stability. To put this into context, in the decade following the initial introduction of commercial ALM machines in 1995 full melting of conventional alloys was not possible and the process and materials focus was on how to overcome the limitations of sintering and creating novel materials that would melt at the low temperatures that could be achieved.

Do you experience a shortage of trained personnel in your business and is staff training a major issue for you?

We've recruited metallurgists and materials scientists and trained them in-house on the operation of the machines and software. We're fortunate in being close to Birmingham University and in a centre of metal working. So, whilst staff training is important I do not regard it as an 'issue'

Where do you envisage Materials Solutions will be in 5 years time, in terms of its size and capabilities?

ALM's capabilities, our high temperature materials focus and current restrictions on the size of the build envelope, has directed us to aero engines. However, it is unrealistic to expect ALM use in aerospace to grow rapidly in the 5 year time horizon. Timescales in aerospace R&D are measured in decades, for the simple reason that it is a highly safety critical industry that demands very long components lifetimes. This point was well made by Ian Risk the Head of EADS Innovation Works UK at the recent opening of the Centre for Laser Additive Manufacturing (CALM) at Exeter University.

It takes several decades for any new manufacturing process to become fully developed and understood. Composites is a good example of this: first widely used in WWII it is only recently that they've become widely used for structural components in aerospace with the accumulation of decades of experience, the arrival of carbon fibre and better processing know how. Faced with this, we at Materials Solutions are therefore seeking to expand our materials competencies and grow our business overseas.

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PRESIDENT'S MESSAGE

This time last year there was a definite feeling that the worst of the financial crisis was behind us, and there was a buoyant mood supported by some strong sales. Unfortunately as we begin 2012 there are still financial clouds over us, particularly in European markets. This must be a cause of concern for many of our members, particularly those with significant European exports.

Similarly, cutbacks in government spending affect those of us in academia, who are finding it hard to get research funding. It must also be indirectly affecting many other members including those in the job shop sector, for which reduced public funding of building and regeneration projects is diminishing the demand for architectural and similar sheet metal work.

I do not believe that these problems are critical, but they do diminish business confidence, creating some uncertainty that in turn can lead to delaying decisions to invest in future developments.

Against this background I believe that AILU should be seeking to undertake activities that offer support to businesses and other enterprises. For this reason, I have been pushing hard for AILU to provide more support to members involved in the sale of laser-related products and services.

As a result, for the first time in our history we are going to have an AILU pavilion at MACH in April. We hope that this will help provide a focus for the companies that join us on the pavilion and will promote the use of lasers as a manufacturing tool of increasing importance in 21st Century manufacturing.

There will also be an AILU stand at LASYS in June. I am hoping that this might be a forerunner for a pavilion stand at this show as well, as a means of allowing members to better promote themselves in Europe.

For the research-active members we have participated in the consultation to launch new Technology Innovation Centres in the UK and have submitted a strong case for a Photonics TIC. We are also looking to engage with the so-called High Value Manufacturing Catapult, including organising workshops at its member sites.

As I write, AILU has become involved in a two-day invitation-only residential strategy workshop (Farnham Castle, 21 & 22 February) to develop a UK strategy for Laser Materials Processing, organised by the Electronics, Sensors and Photonics KTN and the so-called Photonics Leadership Group. Delegates include representatives from the laser materials processing community and representatives of the TSB and EPSRC. As such, it provides a real opportunity for AILU to make the case to these funding bodies that lasers are a key technology for future manufacturing and need to have continued support in research and development. It also provides the opportunity to address the issues that are inhibiting the uptake of laser applications in the UK.

All of these activities create an increased workload for the AILU secretarial team, and also incur costs. AILU is suffering in the current financial climate, and the situation continues to be tight. Membership fees have been held constant for the last seven years, but membership numbers have reduced and greater effort has been needed to maintain workshop attendance. I ask all our members to support AILU by continuing their membership and supporting AILU events; and to please use every opportunity to promote AILU membership.

I would like to take this opportunity to say a fond farewell to Pauline who retired just before Christmas. She has been invaluable in supporting Mike and Liz and was always a welcoming face at AILU events. I am sure that members will join with me in wishing her a long and happy retirement.

As I finish writing this, I am saddened to learn of the death of Janet Folkes, lecturer at Nottingham University and AILU committee member. I did my PhD with Janet under Bill Steen and, in the last ten years or so, enjoyed meeting her through AILU and Academic events. She was an exceptional lady, always positive, friendly and welcoming, and much respected by students, colleagues and collaborators. Her world record breaking exploits in ballooning pay testimony to her positive outlook on life. She will be missed by all who know her.

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Servitization in laser job shops: interviews with laser job shops and machine providers

Gokula Vasantha, Romana Hussain, Rajkumar Roy, Stewart Williams and Helen Lockett

Manufacturers often outsource laser cutting to laser job shops which will cut components to fairly tight deadlines and budgets. However, the concept of laser cutting as a way to improve manufacturing output is no longer novel; it has now been 'commoditised' and is driven largely by price and speed of delivery. Nevertheless, laser job shops add value through their expertise in processing design data, optimising material usage, machine operation and materials handling.

Laser cutting systems are expensive to procure and run, and generally come with two years of warranty. From the interviews we have held with UK job shop owners, the broad conclusion is that, depending on the machine's return condition, a good residual value could be realised over the first five to seven years and that , after ten to twelve years, the machine would have depreciated to scrap value. Also, despite the fact that laser systems have undergone rapid technological change, the laser job shops interviewed were not expecting many business-changing developments from laser technology within the foreseeable future.

The current situation for laser cutting machines

Most UK laser job shops currently prefer ownership (in contrast to those in Europe and Japan), with laser providers offering replacement and buy-back options.

Having a typical half life of 5 years, laser cutting machines gradually become less accurate and less efficient with time, increasingly suffer downtime and require more maintenance. Even when a machine supplier is willing to provide a five year warranty, no specific uptime is assured. It is the case that many laser job shops run some machines that they have owned for well over a decade; a common practice being a mix of old machines alongside new machines (that are regularly replaced). The option of upgrading older laser machines systems (rather than replacing them) is generally not regarded as a cost effective solution.

Leasing can help to address these issues. With this approach, machines are replaced regularly thereby ensuring reliability, updated technology and, thus, predictable costs. Regular replacement also avoids the situation of older machines occupying valuable floor space whilst operating less efficiently and being difficult to sell (although many old machines are now being refurbished and being sold abroad). Despite these advantages, only one UK laser job shop within this study was currently leasing its machines.

Another laser job shop within this study expressed an interest in pay-per-use machines. That is, the laser machine supplier places the machine on the customer's site for free and the customer pays per unit period of machine use. However, laser suppliers do not currently provide pay-per-use type business models, even though this practice has previously been used.

Services in the laser cutting industry

Although the uptime for laser machines is very high, when they do break down they can be very expensive to repair. Current service contracts can have charges for maintenance technicians and consumables either included or excluded for specific periods of time.

With few exceptions, services provided by the laser machine supplier have been reported to be excellent. Typically, the service engineer is dispatched the next working day, operatives are located through the UK , they are generally informed about what work is required and bring the requisite parts to the site. Repairs can often be made quickly. Nevertheless, more recently, a deterioration in service has been perceived: as the industry is coming out of recession, laser machine providers have appeared to find it difficult to meet the new peaks in demand for trained service technicians and spare parts.

Planned laser machine maintenance is typically carried out once every six months and this tends to take one to two days for each machine. Often, failures can be traced through error logs on the machine and failure causes can be identified this way, typically, 60% of the time.

The lack of transparency in conducting maintenance and services has lead some job shops to question if they have been receiving value for money; and there is a concern that whole modules are replaced rather than components although, undoubtedly, taking account of the cost of time, a repair could be more expensive than a complete replacement. When asked to respond to these concerns, laser machine providers who were interviewed have pointed out that high precision, technical products can be very costly to repair and that profits in spare parts are low.

Clearly, the trade-off between repair and replacement services should be explicitly agreed upon between the laser job shop and the laser machine provider ahead of time, and a good inter-personal relationship between the laser machine provider and the job shop could help to solve repairs more quickly and with less cost.

Remote monitoring of laser systems has not yet been well received by laser job shops due to the required increase in management effort. As a result, collected usage data tends not be employed effectively although it could provide valuable insight as to when, where and under what types of usage the machines tend to lose performance or fail. Such knowledge

What is 'servitisation'?

In general terms, 'Servitization' is the integration of services with products to finely meet customer needs. For capital-intensive products, this integration strives to make the best use of the product so that more value can be delivered throughout the product's lifecycle.

Servitization is widely considered to be one of the foremost ways to achieve and sustain competitive advantage. The competitive advantage comes from adding value so as to more closely meet the needs of the customer; such bundling of products with services can lock customers into longer-term relationships and can be difficult to imitate by competitors. Furthermore, providers gain knowledge of the customer's business and an increased insight into how their products and services are used by their customers to fulfil their business needs.

could be used to improve processes, the process environment or the machine to raise overall productivity.

Ancillary systems

Loading systems and forklifts

In general, there are two contrasting views with regards to automated loading systems in the laser cutting industry. The first is that automated loading systems take a considerable amount of time to set-up; and that even with such automation the total effective working time of the machine cannot be increased above 70%. The alternative view is that automated systems are effective for night shifts, reducing operators and facilitate the continuous running of machines.

Because automated systems reduce manpower, laser job shops expect payback on these systems after approximately eighteen months. However, should a problem arise such as a cut part flipping up when there is no one present to address the problem, the machine could grind to a halt. Automated support systems tend to be purchased rather than incorporated within leasing models as this technology is not expected to change significantly over the next ten to fifteen years.

As forklifts have been reported to break down frequently, this could be a piece of lower-tech ancillary technology which could be improved to increase overall productivity. However, there are newer business deals available to address this problem such as the supply of forklifts for a fixed monthly cost which are bundled with a four hour response-time maintenance service and which are replaced with another forklift if the problem can't be fixed within the stipulated time.

Accurate support systems are also required for segregating and counting cut parts as operators can make mistakes which can mean that the wrong number of parts are delivered to the customer.

Interest in servitization

The competence of the laser job shop usually lies in the processes surrounding laser cutting and the running of laser machines. In order to have a faster turnaround time, many laser job shops aim for an operating time of 24 hours per day, 6-7 days per week, whilst at the same time reducing operating costs; they also require options for mixed, normal and automated operations. Within this context, our research has shown that some laser job shops are willing to pay for a fixed price contract that would include machine hire, services and spares.

Generally, as the margins are tight for job shops, they try to avoid extra costs and require repairs to be at minimum cost. Given this context, laser job shops would be interested in a servitization model where the laser supplier's service costs are transparent and provide a smoothed cash flow.

Laser job shops' customers tend to prefer local, friendly job shops that deliver on time. To satisfy these needs, some laser job shops are also looking to develop new business models where, rather than increase their capacity, the laser job would locate some of their capability to or near to the premises of important clients. Such models aim to give more value to their customers by reducing transport costs and assure a faster service which should help to ensure a longer term relationship. They could provide very competitive rates for guaranteed business (volume deals) and also eliminate the need for the time consuming process of quotation. Other business models could also emerge where this process is supported by laser machine providers.

Servitization models should facilitate capability expansion of the job shops such as constrained local power supply. Servitization models are also expected to help to train operators who often require one to two years training depending on the experience of the operator and the type processes of the job shop.

Concerns with servitization

Laser job shop viewpoint

In general, customer loyalty appears not to exist within the laser cutting industry as the business is so price sensitive. Furthermore, the main concern with servitization has been expressed in terms of financial risk. Laser shops have argued that, for example, although a pay-per-use machine would probably mean a substantially reduced initial capital investment, it could end up more expensive in the long term. However, this can set against the higher level of uptime expected by regularly replacing machines. Job shops are also concerned that the laser machine provider may bypass them and deal directly with their clients.

On a separate issue, one job shop we interviewed had experienced difficulty in having the machine replaced at the end of the lease. At the moment, leasing contracts are not customized to the provision of laser cutting systems and to the job shop's resources in handing them over at the end of the lease. Indeed, laser machine lease agreements tend to be based on generic contracts for handling large assets. Some of the points in these contracts that have been criticized by laser job shops are:

- The job shop is required to take what is a large and unwieldy system to a designated place for return.
- Variable monthly payments tend to be stipulated rather than preferred fixed amounts.
- Return conditions tend to be problematic.
- Fixed insurance premiums are charged, without accounting for depreciation.
- The lessee is responsible for losses if the laser machine provider takes back the equipment for any reason.
- The laser system has to be serviced within 3 months of its return.
- The unnecessary use of premium, high purity gases is stipulated.
- Decolonising the machine, transportation, storage, insurance and repositioning tend to be excluded from the leasing agreement.

Laser machine provider's viewpoint

The critical concern of laser machine providers is that, under the leasing or pay-per-use models, they retain ownership of the laser system and so the cost of the machine is only recovered in instalments. Currently, they generally perceive this as too great a risk. Also, any operator misuse (along with delayed and improper fault-reporting) could greatly damage the machine, which would add to the laser machine provider's financial burden.

Two laser cutting machine manufacturers currently dominate the market and so, as such, there appears to be little competitive impetus for them to develop servitized business models and increase the support they offer. Machine providers are also concerned that some customer demands may not be wholly justified and that, if the laser machine provider met those demands (such as a faster service response time), the customer may be unwilling to pay for the extra cost. As this environment is driven by price rather than relationships, trust and mutual understanding between the laser machine provider and the job shop have not really developed. Furthermore, laser machine providers are reluctant to bring new business models to laser cutting job shops in the UK because this market only represents a small percentage of their total business.

The supplier scenario
The customers of laser job shops are usually manufacturers who procure laser cut parts and integrate them into larger products. They minimize job shop costs by procuring standardized parts and it has been observed by laser job shop owners that customer sales and service departments have no intention of building relationships with laser job shops.

Equally, although laser job shops can have around fifty of their own suppliers, these are not long-term relationships because the market is price driven. Gas suppliers offer supply solutions to laser job shops and they offer rental solutions for installed equipment (such as exchange regulators and bottles) as well as gas contracts. Laser job shops reported being unhappy about gas supply contracts that allow the supplier to adjust the gas prices after the contract has been signed: they therefore prefer a reasonably constant price for the contract period. Job shops are equally unhappy with the high costs incurred when leaving a gas contract; particularly during the removal of the supplier's equipment. Furthermore, the service charges of gas suppliers are reported as being especially high for small jobs. However, some job shops are happy with their gas contracts and have a good relationship with their supplier..

Developing novel servitization models
Building relationships between stakeholders is the primary requirement for developing any sustainable servitization offering. In this industry the key stakeholders are: (i) laser machine providers, (ii) laser job shops and (iii) end customers.

Stronger relationships could be developed by addressing and integrating the various stakeholders' needs. Developing win-win solutions which trade-off benefits and costs is the key to this. Creating servitization models for laser job shops lie in the overall cycle of operations of the job shop from the first contact with their client through to the delivery of processed goods. Even though the key performance indicators for laser systems are mostly measured in terms of piercing time, cut quality and cutting speeds, servitization offerings for laser shop jobs should primarily address three key parameters: consistent pricing for their customers, fast delivery of finished processed parts and high quality. As cutting speeds appear to have reached an acceptable level for the industry, for fast delivery, other processes that need to be examined.

To assist the job shops in predicting costs and speedy delivery, any servitized solutions would primarily require the transfer of capabilities between various stakeholders. Take the example of a servitization solution that requires a laser job shop to move closer to a large and valued customer: the infrastructure and space could be provided by the customer; the laser system could be supplied by the manufacturer on a pay-per-use basis; and the laser job shop could provide the operators to run the surrounding laser cutting processes. This way, each stakeholder would share its expertise and resources. Allocating the responsibilities for activities and key performance indicators between the stakeholders could generate other types of servitized solutions. This would cultivate long term relationships and ensure very competitive rates and immediacy of delivery for guaranteed, volume business.

Other potential solutions which would help to ensure predictable costs lie with minimising downtime and the customization of laser systems. The regular replacement of machines through leasing ensures reliability, updated and upgraded technology as well as a guaranteed uptime. Developing laser systems for innovative applications (such as hybrid cutting and welding) and with desirable features such as remote process control and monitoring, traceability, low power requirements, energy efficiency and increased "shutter up" hours of efficiency, could enable the development of innovative servitized offerings. Remote monitoring and control would facilitate a job shop running laser processes remotely if it had moved some of its capability to a client's premises. These features would facilitate to change the current price driven scenario to one driven by value.

Various support services could also be developed as part of servitized solutions to aid the estimation of operation times for various cutting profiles or speeds such as quick quotation preparation with consistent pricing, reduced inventory management, service call outs over the weekend and faster transportation with less cost. Furthermore, support systems facilitating loading, unloading and picking can play a vital role in increasing efficiency. The manufacturer could be driven towards servitization models provided that a minimum payment is guaranteed and that risks can be finely calculated and shared between stakeholders. The success of such models depends very much on framing suitable cost models according to the needs of the particular job shop involved; these in turn tend to be based around fast delivery, quality and consistent pricing.

Conclusions
From the interviews we have held with representatives of laser job shops, laser cutting machine providers and end users, there appear to be opportunities for servitization within the laser cutting industry. The transition to a servitized business model would require the development of more substantial relationships and stronger partnerships between stakeholders. For some laser job shops, this appears to be already the case with some of their larger and longer term customers who place huge, repeat orders for laser cut parts. For such customers, laser jobs are already aware of a part of the customer's processes and this knowledge could be used by the job shop to create new product and service bundles.

With regards to the relationship between laser job shops and laser machine providers, a slower transition could be achieved by incremental changes through the provision of additional add-on services for laser cutting machines and new leasing options. This would allow all of the stakeholders to become more familiar with the concept of servitization as well as the risks and rewards that are involved.

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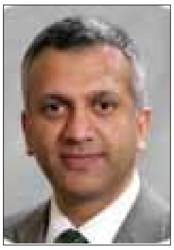

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See Observations p 29

Combining micro-milling and laser structuring for manufacturing complex micro-fluidic structures

Andreas Schubert, Stefan Groß, Bertram Schulz and Udo Eckert

Miniaturization has become one of the most important keywords for production technologies in the last years. Whether in microelectronics, medical engineering or production engineering, parts and assemblies are becoming smaller to provide a higher functionality in the same space or smaller. In the field of micro production technology, this means adapting established production technologies for the generation of small devices, structures and also the development of new technologies based upon ablation processes [1].

The department for precision technology and micro-manufacturing of the Fraunhofer Institute for Machine Tools and Forming Technology IWU in Chemnitz deals with the implementation of these processes particularly with regard to manufacturing-oriented process design in the fields of automotive, medical and production engineering.

A distinctive application example for the use of different micro manufacturing processes is micro fluidics, for example in the employment of medical sensors, where the goal is to produce micro fluidic structures with feature sizes ≤ 10 µm and a processing accuracy of around 1~2 µm (see table 1); and in large quantities. Hot embossing enables a fast and economic replication of these micro fluidic elements, but requires a master structure to be produced on a mould surface that can be pressed into a substrate at an elevated temperature, forming a negative relief replica of the master topography. Thereby quite different materials like plastics, metal and glass can be structured with a high reliability.

The manufacture of the hot embossing mould requires firstly, that the features are of the female mould and secondly, it is able to resist the process forces and high process temperatures (in excess of 750 °C). Only highly heat resisting high-alloy steels and ceramics are suitable. Normally, the structuring is done by milling or thermal ablation methods. These requirements place restrictions on the material and on the size of the structures generated. In particular, to meet the required dimensional requirements, laser ablation or electrochemical etching can be used.

State of the Art

Micro milling

In the field of micro manufacturing, the milling technology is typically used for the machining of tools, dies and prototypes. Milling tools can be used with diameters down to 50 µm under conventional manufacturing conditions. There are also structural shape and size restrictions; for example, the minimum tool diameter limits the sizes of channels and the forming of an inside radius. Moreover, using a very small micro milling tool greatly increases the processing time.

To address this issue a range of tools of different diameter can be used, with larger areas being milled with larger diameter tools to reduce the processing time and small diameter tools used only for fine structuring operations. However, multiple tool changing introduces the risk of reducing precision and increasing machining errors.

Laser machining

Laser technology has been qualified as a micro structuring technology. A pulsed laser beam focused to provide a high power density on a small spot area is capable, through ablative machining, of creating features in a wide range of different shapes and sizes, and in a wide range of materials (including difficult to machine materials like ceramics, carbide and hardened steel) with excellent productivity and surface quality [2, 3]. For example, see figure 1.

	micro fluidic structure	functional structure
maximal lateral dimensions	50 µm	750 µm
minimal lateral dimensions	25 µm	5 µm
maximal structure depth	500 µm	20 µm
maximal aspect ratio	5	15
dimensional accuracy of components	± 1 µm	± 1 µm
position accuracy	± 5 µm	± 5 µm
surface quality	Rz < 500 nm	Rz < 500 nm

Table 1. Geometrical demands on the micro fluidic structures to be generated

Figure. 1. (a) Laser machining of an embossing die; (b) Embossing die with micro fluidic structures (silicon carbide)

Laser ablation has clear advantages over traditional milling or electro-discharge machining, including an almost unlimited choice of materials, direct usage of CAD structure data, high geometric flexibility and no contact with the workpiece [4, 5]. However, whilst the very small diameter of the laser spot is a great advantage in the production of very small features, the processing time per unit area is large.

Comparison of technologies

A comparison of laser ablation and micro milling techniques reveals that both methods are generally dedicated to processing minimal structural geometries, such as are typical tool structures for micro fluidics. However there are specific restrictions on the structure sizes and shapes and processing times that can be achieved, see table 2.

process	for	against
micro-milling	high material removal rate	limited to feature sizes >> 10 µm
laser micro-machining	excellent for micron-scale structures	low material removal rate

Table 2. A comparison of advantages and disadvantages of the machining technologies

A meaningful approach is to combine the two processes: laser micro-machining for very small geometrical elements and structural sizes with dimensions of a few to several hundred microns, micro-milling for larger structures and areas, to reduce the processing time.

Combining the two processes

The practicality of combining laser micro-machining and micro-milling process was investigated using the micro fluidic structuring of embossing dies as an important practical example. For these first experiments a tempered high-grade steel (X3CrNiMo13-4) was selected; it is a typical material for injection moulding and hot embossing tools and it responds well to laser machining and milling.

<ins>Test geometry</ins>

Based on established microfluidic structures a test geometry was devised to simulate critical domains for the micro manufacturing. Referring to figure 2:

<ins>Element A:</ins> meander structure used as a micro fluidic channel. Key challenges are the radii and the constancy of width of the channel.

<ins>Structure B:</ins> All but the small bar can be milled. The problem for milling is the right angle between bar and basic structure.

<ins>Structure C</ins>: measuring chamber for a micro fluidic system. The individual cells have a diameter of 0.15 mm.

<ins>Structure D:</ins> a branched bar structure with a wedged channel. Such structures are often used as a hopper in the fluidic system. The minimum gaps between the bars are 0.15 mm.

<ins>Hardware</ins>

A sequential processing of laser and milling can be realized on a combined

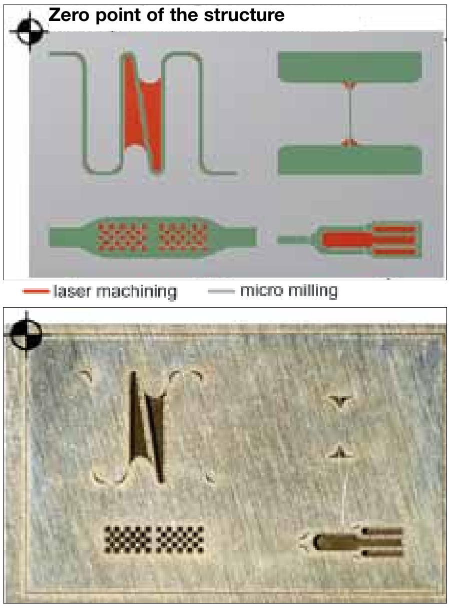

Figure. 3. Zero point detection for laser machining and micro milling:
(top) arrangement of test piece
(bottom) Workpiece after the first process step, laser ablation.

processing centre [6, 7]. Although this solution has the advantage of avoiding repositioning of the workpiece for each processing step it would not make good use of the main machine components (i.e. the spindle and laser) and would thereby impede major improvements in the economic efficiency of the manufacturing process from being made.

The challenge of using two different machines for the sequential laser and milling process is achieving a high precision orientation of the single references (angular position, orientation and scaling). Additional measuring equipment is required to calibrate the manufactured structures for the subsequent steps.

Micro-milling took place on a special test facility for high precision milling developed together with LPKF Motion & Control [8]. The facility combined an innovative motion concept with high sensitivity measuring Heidenhain scales to achieve micro-milling with an absolute accuracy of < 1 µm. For laser structuring a bespoke test stand was used with a frequency doubled Nd:YAG laser and a special scanner unit.

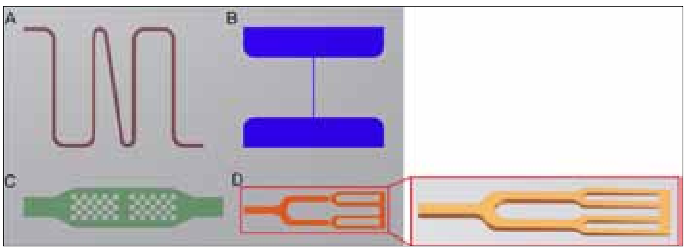

Figure 2. General view of the test geometry. The whole structure has a size of 10.5 mm x 6.5 mm.

The workpiece clamping was realized on both machining systems by a highest precision zero-point clamping system EROWA-FTS especially developed for micro manufacturing. The positional alignment of the milling and laser machining fields to each other was supported by external optical measuring equipment.

The first process step is the laser ablation (see Figure 3) whereby the first structures are processed. The subsequent adjustment of the milling structures occurs with the help of a zero point detection and the detection of the offset in regard to the laser structure.

<ins>Processing limits of a single process</ins>

A comparison was made of machining of the whole geometry by each process technology independently. To ensure a direct comparison between the laser and milling process, no tool change is carried out during milling i.e. only one size of tool was used, of 0.3 mm diameter. The test confirmed that not all parts of the test structure could be milled. *A simulation with an end mill cutter of 0.1 mm diameter gave a milling-only processing time of ~340 minutes for the structure.*

Figure 4 shows the whole structure manufactured by laser ablation, with all requested structures produced. *Due to the small spot size of the laser beam the processing time for laser ablation was approx. 330 minutes.*

<ins>Tests results</ins>

The chosen process sequence for the tests is a laser ablation with subsequent milling process. The milling program for the structure was generated for three cutter diameters (0.3 mm, 0.5 mm and 0.8 mm). In Figure 5 the segmentation of the three resulting programs are shown.

Figure 6 (a-c) shows typical errors encountered at the beginning of the experimental work. The milling and laser structuring have a different surface quality and there were unavoidable crossover sections between the various processing areas for milling and laser (see the marking in figure 6a and c). Also, short residual positioning errors in the working fields inside the separate working spaces of the two machines are apparent.

Figure 4. Machining of the whole geometry by laser ablation

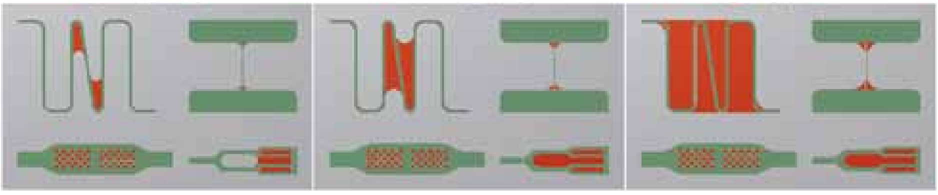

Figure 5. Milling programmes for drill size (l to r) 0.3mm, 0.5mm, 0.8mm

The green areas define the desired (fluid) structure and the grey areas show the parts which can be manufactured with the respective cutter diameter. The resulting red fields have to be structured by laser ablation. Between the laser and milling domains an overlap of approximately 50 µm is included.

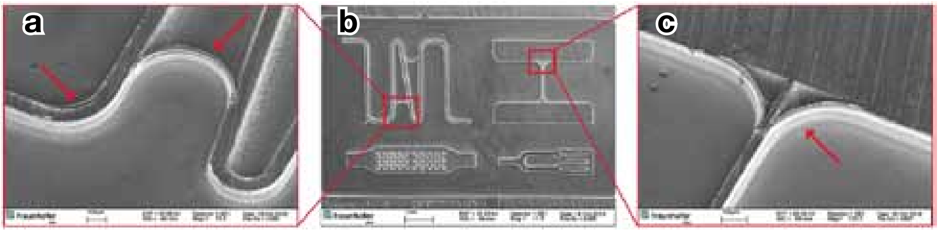

Figure 6. (a) Crossover section between laser (above) and milling area; (b) Test structure; (c) An unrequested step feature occurring between milled and laser ablated area

Through the further optimization of the described positioning algorithm on each machine system the reject rate could be reduced extensively (see figures 7 and 8). Reducing the use of laser ablation to the minimum dictated by the part geometry succeeds in achieving an essential reduction in the over-all processing time.

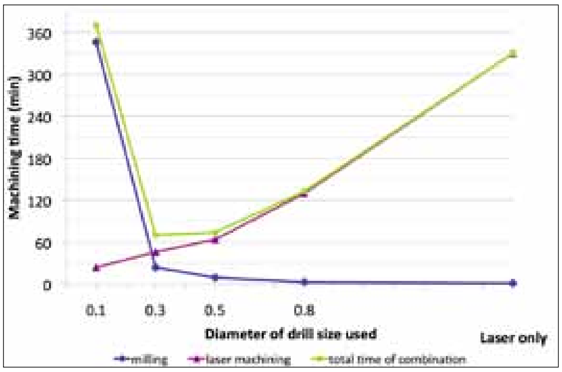

Figure 7. Processing time of the micro fluidic test geometry

Results and discussion

The investigations have shown how two processes in the field of micro-manufacturing can be combined to enable the generation of selective micro structures with high geometrical accuracy and excellent quality. In doing so, it has been demonstrated that processing times shorter than either process could achieve individually, can be realised (see figure 7). Finding an effective and reproducible method for precise positioning of the workpiece is essential, combined with high-precision adjustment between the micro tool (cutter or laser beam) in relation to the geometry and the workpiece.

The technologies have to be harmonized with highest accuracy to enable a controlled material removal from the discrete processing areas without creating ledges in the ground or at geometrical flanks. In the same way surface roughness has to be improved and be made more uniform over the different processed areas of the workpiece so that a good material removal and concurrently a high surface quality can be achieved over the whole geometrical structure.

Through experimental work, the application of a combination of laser micro-machining and milling has successfully been applied to create a mould for a micro fluidic tool, showing technique to be suitable and reasonable for the manufacture of ambitious micro structures. In particular, the work has shown that it is possible to conquer the resolution limits of micro milling (e.g. small structures size and flanging radius) whilst exploiting the advantages of the micro milling, including speed and surface quality.

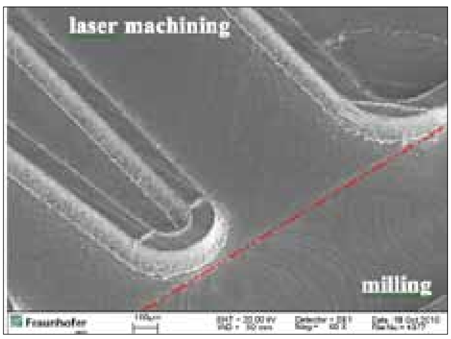

Figure 8. Sample of the successful laser structuring and milling combination work using a drill diameter of 0.8 mm, for comparison with figure 6.

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See Observations p 29

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Laser net shape welding

Lin Li, Ramadan Eghlio, Sundar Marimuthur

Over the last 40 years of laser welding practice, the top of the weld bead always ends up slightly above or below the parent material surface. In this paper, a new concept – net shape welding is introduced, whereby the weld joint fusion zone is flat to the parent material surface. In this paper we provide an experimental demonstration of net shape laser square butt welding and tensile test results that show that the net-shape welds significantly outperforms those of traditional weld bead geometry. We also provide computer modelling of the weld that assists in the understanding of net-shape weld formation and its superior mechanical properties.

Weld bead geometry is known to be a critical quality factor that can significantly influence the final mechanical properties (e.g. tensile and fatigue properties). A large volume of research work has been carried out on this to understand how laser welding parameters (e.g. laser power, welding speed, focused beam spot size) influence the geometry of the weld bead and the weld's mechanical properties. Yet despite this, little is understood of the characteristics of top and bottom weld bead surface formation.

Over the last 40 years of laser welding research and applications, the top and bottom of the weld bead geometry as produced generally sits either above or below the parent material surfaces, and it is commonly thought best to have the weld bead slightly above the parent material surface, see figure 1c. For some applications, a flat weld bead surface is desirable (e.g. for precision assemblies, removing the surface stress raisers, application of surface coatings, lowering the resistance to fluid flows (for pipes and vessels), better corrosion protections and cosmetic effects etc.), in which case it is common practice to machine the surface flat.

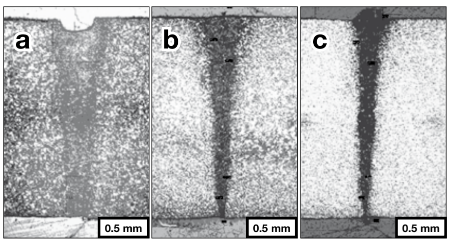

Figure 1. Variation of weld bead cross section geometry with increasing speed: a) laser power 575 W, welding speed 95 mm/s, focal plane -1.5 mm (below the surface); b) 500 W, 110 mm/s, -2 mm; c) 475 W, 120 mm/s, -1.5 mm.

Experimental results

The experimental work reported here was carried out using a IPG YLR-1000-SM 1 kW single mode fibre laser (1075 nm wavelength, M^2=1.1, delivered through an optical fibre with a 14 µm core diameter). The fibre output assembly was connected to a z-axis Precitec processing head with a lens assembly and a coaxial gas nozzle. The laser beam was focused via a lens of 190.5 mm focal length to give a beam spot diameter of approximately 50 µm at focus. The conical coaxial gas nozzle had an exit diameter of 2 mm and the workpiece was placed at a standoff distance of 5 mm from the nozzle. Argon shroud gas was used in the experiment at approximately 25 L/min flow rate to protect the weld surfaces from oxidation at high temperatures.

The welds were all square butt welds in mild steel sheet*, thickness 1.5 mm. The edges for welding were machined to have vertical walls.

Figure 1 shows typical weld bead cross sectional geometry at various welding conditions. At a low welding speed, a notched (concave) top surface was developed (Fig. 1a); at a medium speed a flat (net-shape) weld was demonstrated (Fig. 1b) and at a high speed a bulged (convex) weld head developed (Fig. 1c). Typical weld bead widths are 145 – 276 µm at the root and 275 – 400 µm at the top surface. The root length varied between ±75 µm.

*BS1449 (CR4, AISI 1018 / EN 10130) cold rolled mild steel (0.25% C, 16.85% Cr, 10.08% Ni, 1.91% Mn, 2.086 % Mo, 0.12% Cu, 0.62% Si, 0.03% Co, 0.029% P, 0.051% N, 0.001% S and balance Fe

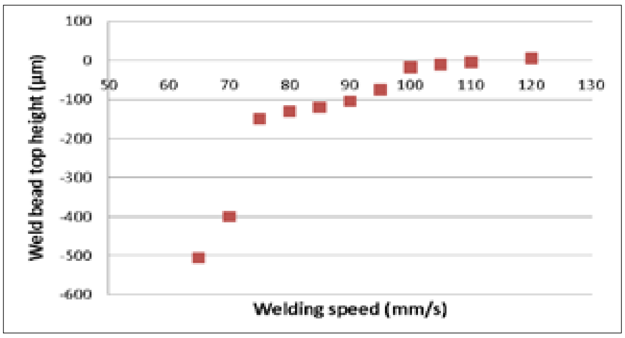

Figure 2. Variation of weld bead top height with welding speed at 600 W laser power and focal plane -2 mm.

This transition from concave to convex is shown in more detail in figure 2 where the weld bead top face height is plotted against welding speed; whilst in figure 3 the contours of the weld bead top face height are shown on a plane of laser power and welding speed. This figure shows clearly the power and speed combinations that give rise to net shape welds. If the laser power increases, the net-shape welding speed needs to increase as well.

Tensile test results are shown in figure 4. They clearly demonstrate that the net shaped welds have mechanical properties that are superior to those of other weld bead geometries. Indeed, the strength of the net shape weld is strong-

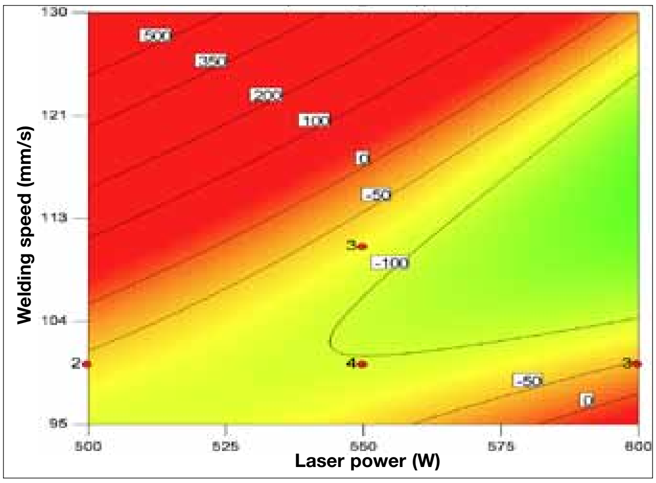

Figure 3. Contour map showing the effect of laser power and welding speed on the weld bead top surface height (µm).

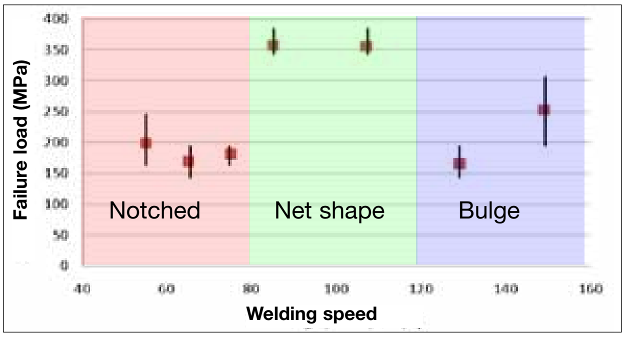

Figure 4. Failure load of test pieces for welds produced at 600 W laser power, focal plane position -2 mm, following ISO 4136:2001

er than the parent material. During tensile measurements the net shaped welds test piece broke in the parent material (values shown above are for the parent material) whereas for other weld geometries the break occurred in the weld zones.

Discussion

3D sequentially coupled computational fluid dynamic (CFD) modelling and Finite Element Analysis (FEA) modelling were performed to understand the weld bead surface geometry formation and to predict the melt flow, solidification and stress characteristics at various laser welding parameters.

Figure 5 shows the weld bead profiles under three different laser welding speed conditions at 600 W. Surface temperature varies with welding speed and on

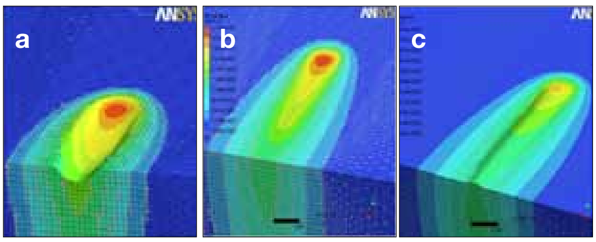

Figure 5. Different weld bead top surface temperature contours calculated using CFD analysis with 600 W laser power: a) 75 mm/s; b) 100 mm/s; and c) 125 mm/s.

the basis of the calculated temperature profiles the surface tension gradient is negative (decreasing towards the centre of the weld pool) at the lower welding speed (e.g. 75 mm/s) and positive at the high welding speed (e.g. 125 mm/s). A negative surface tension gradient causes molten weld pool material on the surface to flow outwards causing a depression in the weld pool centre after solidification; a positive surface tension gradient causes the weld pool molten material to flow inwards, causing a bulge weld bead above the surface after solidification. Between these two speeds, there is a point (Figure 5b) where the surface tension gradient is close to zero and there is a negligible flow of material, thus a net shape weld is formed. The surface tension gradient flips at this point from negative to positive as the welding speed increase. A similar phenomenon was observed by Zhao et al [1] during the study of Marangoni flow in laser spot welding of stainless steel sheets. They found that as temperature increases, the positive surface tension gradient reduces and 'flips' to negative (if the oxygen content is greater than 0.005%). As the oxygen content increases, the surface tension gradient also increases.

Figure 6 shows the calculated residual stress distribution on the surface after the laser welding at 600 W of laser power. The net shape welds and bulge welds at high welding speeds have much smaller residual stresses, presumably due to the smaller heat input to the material. Furthermore, the residual stress of the net shape welding shows smooth transitions and is free from stress concentrations, in contrast to the other two weld bead geometries.

Tensile strength

Experiments have shown that the hardness and microstructures in and around the weld zone were similar for the three types of weld geometry shown in figure 1, suggesting that the net shaped weld has superior mechanical properties largely because of its flat surface of the weld shifts and spreads the stress concentration to places away from the weld zones.

This was confirmed by non-linear finite element analysis incorporating multi-linear isotropic hardening. Modelling was performed to predict the generated stress and distortion of 3 typical weld surface geometries (concave, net-shaped and convex) assuming that the material properties are uniform within the weld zones and identical to those of the parent material. The simulation showed that the mode of stress concentration and the resulting displacements under load were quite different: for the net shaped weld the stress concentration and high distortion were away from the welding zone while both the notched weld and bulge weld a stress concentration (and high distortion) occurred in the weld zone.

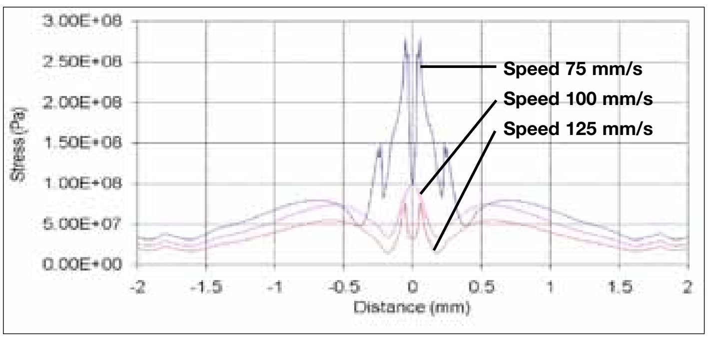

Figure 6. Comparison of residual stress distribution across the weld bead surfaces at three different welding conditions.

Conclusion

Net shape laser square butt welding of mild steel sheets has been demonstrated. CFD modelling has shown the main reason for the different weld bead surface geometries is the Marangoni effect with surface tension gradient flipping as the melt pool temperature (driven by both the laser power and the welding speed) changes. The weld bead geometry on the top and bottom surfaces varies with laser power and welding speed. The superior failure load of the net-shape welds compared with conventional weld bead geometry are largely due to the lack of stress concentrators at the weld zones.

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See Observations p 29

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Laser micro-adjustment using ultra-short pulses

Jonathan Griffiths, Stuart Edwardson, Geoff Dearden and Ken Watkins

MEMS manufacturing requires accurate positioning and high reproducibility. Lasers can be utilised in accurate post-fabrication adjustment, to compensate for manufacturing processes that have relatively large tolerances. Laser micro forming is a process that provides the precision adjustment, shaping and/or correction of distortion in micro-scale metallic components through the application of laser irradiation without the need for permanent dies or tools. The non-contact nature of the process is also useful in accessing specific micro-components within a device which may be highly sensitive to mechanical force. As such it has potential for widespread application in both the manufacturing and micro-electronics industry.

Experimental work

The experimental work focused on: (i) the manufacture of actuator arms; (ii) the exposure of actuator arms to short pulse laser radiation at levels close to the damage threshold; and (iii) the measurement of degree of bend of the actuator arm as a function of the number of overlapping laser pulses and the exposure level.

Laser micro-machining of actuator arms

MEMS-scale actuator arms were designed and micro-machined out of 50 and 75 µm thick AISI 302 stainless steel sheet, see figure 1. As shown, the actuator arms used in this study were of dimensions 1000 x 300 µm

The micro-actuators was laser cut using a High-Q IC-355-800 nm laser operating at 10 ps, 5 kHz repetition rate, 300 mW average power, 1064 nm wavelength. The laser output was focused to a spot of 35 µm diameter, and was traversed at 50 mm/around the cut path. For the 50 µm thick sheet a total of 600 overlapping pulses were required for full penetration.

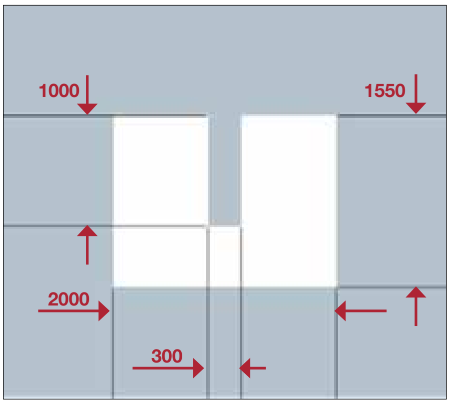

Figure 1: Schematic of stainless steel AISI 302 actuator style arms, dimensions in µm, laser machined out of sheet 50 or 75 µm thick

Laser forming of actuators

Laser micro forming (LµF) was performed using a 3 W average power Fianium Yb-doped fibre TEM_{00} laser with a pulse length of 20 ps, operating at 1059-1069 nm and 500 kHz pulse frequency. A Veeco NT1100 white light interferometer was used to measure the resulting bend angle. The irradiation path was a straight time across the width of the actuator arm and, somewhat arbitrarily, 100 µm from its base.

Results

Measurement of ablation threshold

Prior to thermal LµF being conducted the ablation threshold fluence (φ_{th}) of the stainless steel substrate was determined experimentally [3] using the 20 ps Fianium laser described above. Operating the laser at 200 kHz, the average power was varied in the range 650-100 mW and 12 holes were drilled at each power selected. Due to the dependence of φ_{th} on number of pulses per spot [4] the experiment was repeated for 400 and 600 pulses per drilled spot for validation purposes. The diameter (D) of the ablated craters was measured using the Veeco NT1100 white light interferometer.

The beam radius was determined from a plot of D^2 against E_p and found to be 14.7 µm. Using this value the fluence ($J\ cm^{-2}$) could be determined and the x-intercept of a logarithmic trend line from a plot of D^2 against peak fluence φ_0, was taken as the threshold fluence φ_{th}. This was found to be 0.09 J/cm^2 and 0.08 J/cm^2 for 400 and 600 pulses, respectively, with good correlation between the gradients of each trend line. Unfortunately, the laser forming effect proved negligible when working at or below the ablation threshold.

Introduction to laser forming and micro-forming

The Laser Forming (LF) process involves generating thermal stresses within a substrate using a defocused beam. Depending on the desired effect, the process parameters can be altered to either induce elastic-plastic buckling or plastic compressive strains. The most commonly employed mechanism is the Temperature Gradient Mechanism (TGM), which bends the sheet metal out of plane towards the beam. A steep thermal gradient is generated locally along the irradiation path, inducing more thermal expansion on the upper surface of the substrate. Upon cooling, providing the temperature was raised enough to cause sufficient thermal strain, plastic contraction occurs in this upper surface, creating a bend angle of 1-2 degrees per pass. In order to establish the required thermal gradient, the depth of heating must be relatively small compared to sheet thickness, this being achieved through an acceptable combination of traverse speed, spot size and laser power.

Initially the sheet bends away from the beam slightly as the flow stress on the upper surface is reduced. The magnitude of this counterbend is negligible compared to the resulting bend angle but is nevertheless detrimental to the process as it reduces the compressive stresses acting upon the region of plastic flow. With further heating the yield stress of the material is reached and any further expansion is converted into plastic compressive strain. Upon cooling this plastic compression is residual, and the associated conservation of volume or shortening on the upper surface causes the sheet to bend towards the beam [1].

Laser micro-Forming (LµF)

When scaling down the LF process, limits to conventional thermal forming techniques become evident, such as excessive, non-localised heating of the substrate and long thermal relaxation times. Research has been conducted on non-thermal LµF techniques, such as utilising shockwaves generated through the breakdown of air to induce compressive stresses in the material upper surface [2]. Providing the fluence (expressed in $J\ cm^{-2}$) is below or close to the ablation threshold of the material, ultra-short pulses can be used to form materials in a thermal process. When the pulse duration is shorter than the lattice interaction time, as is often the case with sub nanosecond pulses, there is little conductive heat transfer into the bulk material. This confines the heating effect to the surface layer of the material, thereby selectively inducing plastic compressive stresses and avoiding thermal damage of the substrate, as investigated in this paper.

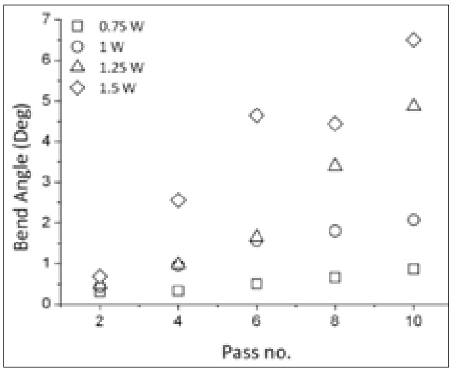

Figure 2: Cumulative bend angle variation with successive irradiations, 50 µm thick actuator arm. Laser parameters: 30 µm beam diameter, 500 kHz repetition rate, 10 mm/s traverse speed

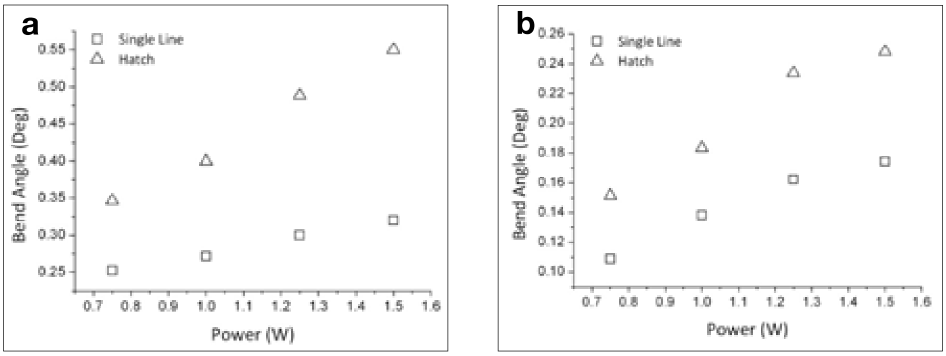

Figure 5: Bend angle variation with increasing power with actuator arm thickness: (a) 50 µm; (b) 75 µm. Laser parameters: 30 µm beam diameter, 500 kHz repetition rate, 35 mm/s traverse speed

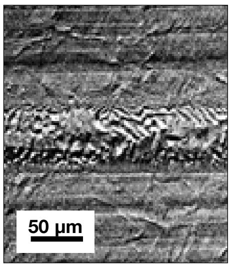

Figure 3: Scanning electron microscope image of the ablated groove after 1 scan. Laser parameters: 1500 mW, 30 µm beam diameter, 500 kHz repetition rate, 10 mm/s traverse speed

Bend angle

Figure 2 shows the effect of increasing multiple irradiations of an actuator arm, showing a cumulative increase in bend angle.

In addition to a cumulative increase in bend angle, an ablated groove was visible along the scan path, see figure 3. This ablated groove is attributed to the use of fluences above the experimentally determined values of φ_{th}.

An experiment was conducted in which the traverse speed was increased and the ablated groove depth and bend angle were monitored. From the results in figure 4 it is evident that the ablated groove has a detrimental effect on bend angle up, in this instance when it becomes deeper than ~2 µm. The optimum traverse speed at which a suitable combination of bend angle z-depth was achieved was found to be 35 mm/s.

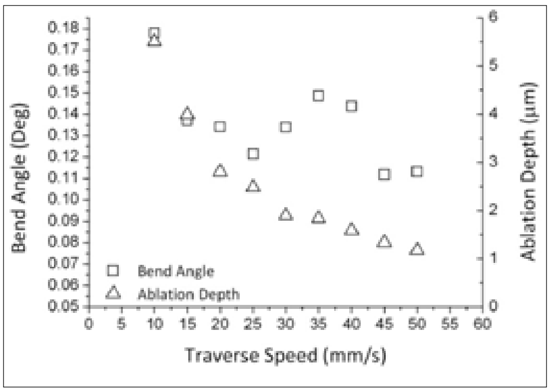

Figure 4: Bend angle and ablation depth variation with increasing speed. The top and bottom sets refer to 50 and 75 µm actuator arm thickness, respectively. Laser parameters: 30 µm beam diameter, 500 kHz repetition rate, 1.5 W average power.

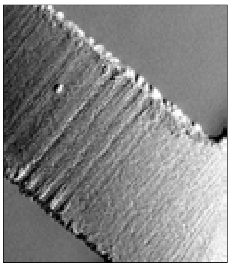

Figure 6: Scanning electron microscope image of ablated groove after hatch irradiation strategy. Laser parameters: 1500 mW, 30 µm beam diameter, 500 kHz repetition rate, 35 mm/s traverse speed

Whilst it was possible to limit the ablation depth for single scans, multiple irradiations caused the ablation depth to increase in an exponential fashion. This phenomenon could be attributed to a conditioning of the irradiated surface after an initial laser exposure [4], increasing the absorption for subsequent scans. As such an alternative to successive irradiations was required to control the bend angle. One option that was investigated involved a combination of varying laser power and adopting a hatched scan strategy for the laser beam path: in this case four single irradiation paths, scanned sequentially in alternate directions, each 30 µm apart, with little or no overlap.

Through variation of laser power with a single line scan strategy, controlled and repeatable micro-adjustment was achieved. The application of a hatched scan strategy increased the range over which micro-adjustment could be achieved whilst keeping the ablated groove to within~2µm depth Figure 5 shows the forming results and figure 6 the ablated grooves.

Conclusions

This novel laser technique for thin sheet LµF provides micro-adjustment of actuator style components offers a method of controlled and repeatable micro-adjustment. The LµF process has significant potential for the post-fabrication micro-adjustment of functional components in micro-electronic devices, as illustrated by the example in figure 7. Challenges include minimising ablation along the irradiated scan path and obtaining a larger range of deformation through optimised process parameters.

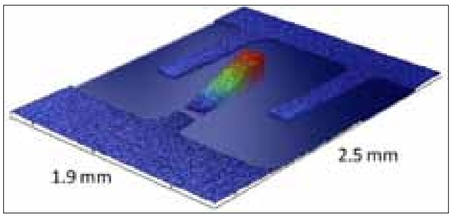

Figure 7: Veeco NT1100 white light interferometry image of deformed actuator arm in a comb drive arrangement

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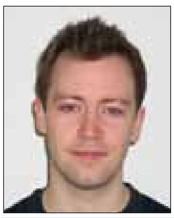

Jonathan Griffiths is a Research Fellow at the University of Lincoln. His research interests include numerical modelling of the laser forming process and laser ignition for gas turbines.

See Observations p 29

AILU survey of UK technology transfer activity in laser materials processing

Helping Small and Medium size Enterprises exploit laser materials processing in manufacturing

Mike Green and Martin Sharp

Laser Materials Processing (LMP) technology provides modern manufacturing with the most flexible and wide-ranging material-processing tool available; yet despite a relatively high level of research activity in UK universities, the exploitation of LMP by UK manufacturing industry is 5 to 10 times lower per unit of manufactured output than it is in Germany, the worlds leading country for laser use [1]. One reason for this identified by the Technology Strategy Board in the UK is a gap in R&D activity at Technology Readiness Levels 4 to 7* i.e. the development phases between laboratory demonstration of an application's feasibility and the demonstration of its technical and financial viability. It is to plug this perceived gap in technology transfer that the UK government, looking towards the success of the Fraunhofer model in Germany, is investing in the establishment of the TSB funded Catapult Centres (TICs).

In 2011 AILU was asked by the Electronics, Sensors and Photonics Knowledge Transfer Network (ESP KTN) to undertake a survey to identify the level of UK-based technology transfer in LMP and Small and Medium Size Enterprises (SMEs). Such organisations typically lack R&D resources and funding; and in this context the scope of technology transfer must also include activities that encourage the use of established laser processes, e.g. flatbed cutting, marking, engraving, and more recently, additive layer manufacturing. These processes employ systems that are off-the-shelf solutions offering production capability with flexibility to address a range of applications. Here the technology transfer challenge is to make manufacturers aware of the LMP opportunity and provide demonstrations and sample parts.

* Activity	TRL level
Basic research conducted	1
Technical concept formed	2
Proof of concept	3
Laboratory demonstration	4
Validation in relevant environment	5
Prototype demo in relevant environment	6
System prototype in industrial environment	7
Production run in industrial environment	8
Full production in industrial environment	9

Assessed total activity

The ESP KTN survey went out to both suppliers and potential recipients of LMP technology transfer. Suppliers were asked to estimate the level of their activity for a range of technology transfer activities (see listing in Table 2) and the results assessed for each specific technology transfer activity, grouping results by type of organisation (see Table 1). An average per organisation was first calculated and, using the data in Table 1, the results were scaled up by the estimated fraction of the total that the responding organisations represented. Clearly, this is likely to produce an overestimate of activity in that those more active in LMP were more likely to participate in the survey. Table 2 summarises total activity over all category of organisation.

Figure 1 shows results for two very different technology transfer activities. One observation that can be drawn from these, and which applies for each and every technology transfer activity that was assessed, was that a great majority of the total technology transfer activity promoting and supporting LMP for end users is provided by equipment suppliers and laser job shops, who therefore play a vital role. The survey did not attempt to distinguish between activities relating to utility LMP machines (where equipment suppliers and job shops will dominate) from those requiring significant process development (where most of the activities of universities and other research centres will be focused, though job shops especially undertake a significant amount of R&D activity too).

Technology Transfer suppliers	T	R	f
Higher Education Institutes	16	10	0.62 [a]
RTOs (excl. HEIs)	1	1	1.0
Manufacturers/suppliers of LMP-related technology:			
Research-active in LMP	18	2	0.11 [b]
Not research-active in LMP	152	12	0.08
Consultants in LMP	5	2	0.4
Sub-contract engineers in LMP	350	19	0.06
LMP- active associations and Institutes	8	2	0.25

Table 1. Estimates of total numbers of technology transfer suppliers in the UK. Column headings: T - total number in UK; R - number of respondents in this survey, f - fraction responding (= R/T)

Notes: (a) 16 university groups listed [2] as having significant activity in LMP; (b) 18 LMP research-active manufacturers listed [2]. Other estimates of total values shown are best estimates based on AILU database.

Laser materials processing technology transfer activity	Estimated total activity by UK organisations per year
Academic publications and conference presentations	550 papers and presentations
Articles in industry magazines and presentations at industry events	1400 papers and presentations
Informal discussions with experts	55500 informal discussions per year
1:1 in-depth discussions	24000 formal discussions
Consultancy services	5000 consultancy actions
Proof of principle	44000 proof of principle
Demonstration of process in action	15000 demonstrations
Batch production	440000 batch production runs
Short (≤ 6 month) contracts	500 short research contracts
Extended (> 6 month) contracts	230 extended research contracts

Table 2. Estimates of total laser materials processing technology transfer activities by UK providers scaled up from survey results

The survey report is available for free download from the AILU site [3], where full details can be found of the survey results.

The transfer of LMP technology

Much development of laser processes is carried out on a 1 to 1 basis between the end user and a potential supplier of laser equipment and by laser job shops hoping to receive a contract. Examples include work with ceramics, paper, thin films, precious metals, semi-conductor and other non-standard materials together with applications in laser welding, hole drilling and micro-machining and other such processes where a significant amount of preparation and testing is generally required. Indeed, the survey shows that laser subcon-

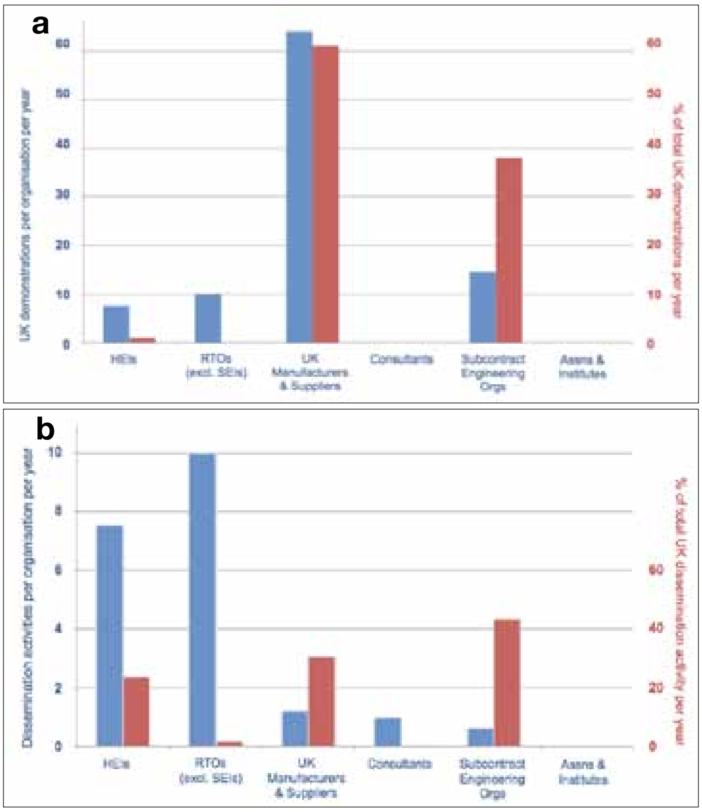

Figure 1. Activity per organisation (blue) and estimated total activity (red) for two of the 10 LMP dissemination activities addressed in the report: (a) through demonstration of process in action; and (b) academic publications and conferences papers.

tractors offer an invaluable service to manufacturing industry, providing a rapid turn-around on batch production, prototyping, as well as important proof of principle of the laser route.

A recommendation of the report is that such day-to-day work that equipment suppliers and job shops undertake should be presented to the customer for what it is: research and development. In this way the R&D process would be demystified and SMEs would become more open to considering R&D with a university or research centre.

<u>The changing world</u>

A significant positive change over the past few years has been the massive increase in the number of free or low cost events in the UK, including KTN events and free or low cost seminars and conferences run in parallel with exhibitions in an attempt to attract more visitors. Even so, it is becoming increasingly difficult to encourage people to take a day out of the office or factory with so much information available on the internet, as well as interactive business networking (e.g. LinkedIn), forums, video demonstrations and Webinars.

<u>Research options</u>

The survey found that Knowledge Transfer Partnerships (KTPs) play a significant role in the technology transfer process, with 22% of respondents indicating that they had been involved in Knowledge Transfer Partnerships (KTPs) in the last 5 years.

Setting aside financial and time constraints, the SMEs that participated in the survey expressed difficulties accessing the expertise that resides in universities. The cost of contract research was highlighted as a major consideration with manpower often costed in significant multiples of "researcher months" leading to high prices. However, the crux of the difficulty for universities in the present context is that academic research activity is aimed at achieving international research leadership in national research assessments. This often does not align with current UK industrial needs.

Many of the above issues are addressed by the concept of the TSB Catapult Centres, in particular the High Value Manufacturing Catapult and possibly a Photonics Catapult. One concern expressed in the survey responses is that the R&D activities of a Catapult may be prioritised by a small number of (large) companies that make up the ownership and membership of the underlying host. Meanwhile, university research groups that have invested in more production-relevant equipment to provide higher TRL activity may find the Catapults offering strong competition for research funding

Finally, any discussion of LMP technology transfer would not be complete without a mention of the importance of designing products/components with the flexibility and unique non-contact processing of lasers in mind. The course curriculum for design engineers should include this and internet sites such as www.designforlasermanufacture.com should be publicised at every opportunity to spread the message more widely.

Conclusions

There are government schemes available to assist SMEs to undertake R&D activity but for smaller companies the high capital investment costs and the timescale involved in taking the laser process from feasibility to production are the main disincentives. Nevertheless, there is a thriving laser subcontract sector in the UK which, together with suppliers of laser-related equipment, make a massive and much overlooked contribution to technology transfer in the UK, exceeding that provided by universities and other research organisations in every type of activity from technical papers to demonstrations, proof of principle and batch production

For other than utility machine-based applications, development through to industrial production is generally expensive and time consuming: which is not surprising given the heart of the process is a complex, dynamic interaction of intense laser light with matter. Optimisation of a potential LMP application will generally be far from straightforward and involve a significant investment in equipment and high level research, something that hopefully the new Catapults will make accessible to the SME community as well as the larger organisations.

Acknowledgement

The authors are pleased to acknowledge financial support from the ESP KTN and the many helpful conversations that they have had with AILU members and the support of the many AILU member organisations who completed the questionnaires.

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1. UK Laser Materials Processing statistics 2009' pub. AILU (See link at www.ailu.org.uk/association/market_development.html
2. 'Top level UK research in laser materials processing' pub. AILU 2008, updated 2010. (See link at www.ailu.org.uk/association/product_and_process_innovation.html)
3. To download the full report go to the AILU website and take the link on the right hand picture column of the home page

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Laser processing in schools and colleges

The laser was 50 years old in 2010, and was being used in industry to process materials within its first decade. Among the many industrial laser processes that have been developed over the intervening years, cutting, marking and engraving have become 'utility' applications that are widely exploited in production by manufacturing industry.

Today, laser cutting, marking and engraving systems can be found in many schools and colleges around the UK, where they introduce our future designers and engineers to the benefits of laser technology in manufacturing. Such an introduction is becoming increasingly important in view of the laser's growing role in manufacturing, high value and high volume manufacturing in particular, and there is strong anecdotal evidence to indicate that given the choice, students would prefer to undertake a design and technology project using a laser over other processing tools available in the workshop. I have heard, in several conversations, statements suggesting that a number of systems installed in schools and colleges are of low quality or have been poorly installed, maintained or supported. Rather than benefitting the student and the future uptake of lasers in manufacturing industry, such an early introduction to laser processing as unreliable and incapable of producing good quality results may then actually become a disincentive.

This can only be avoided by purchasing a quality unit, together with the necessary ancillary equipment (e.g. fume extraction, cooling unit), and keeping these units properly maintained and serviced. It needs pointing out that unlike a laser printer, a laser engraver is not a plug and play system; also that the embedded laser is Class 4 and therefore has the capability to cause eye damage and skin burns and could start a fire. Regretfully I have heard of several instances of fires being caused by laser engraving systems.

Advice to schools and colleges

So how to avoid problems? First and foremost work with a reputable UK based supplier, who can demonstrate a track record of successful installations, support and training. If you are talking with a relatively new supplier company, seek evidence that they have staff with laser experience: if they don't then how will they support you? Also, consider purchasing the whole system, including the fume extraction, from a single supplier: this removes any argument over who is responsible should there be an equipment failure or degradation in performance.

Secondly, before ordering arrange for samples to be provided. Samples should be representative of what you expect to use the machine for, and to test the claims made about the machine's specified performance. These trials should be replicated in an acceptance test of the machine at the end of its commissioning. Ensure the supply contract includes delivery, commissioning and training - part of which should be training during the commissioning period on how to find the optimum processing conditions for producing the acceptance samples.

Thirdly, check that the equipment is truly CE marked and conforms to BS EN 60825-1 'Safety of laser products. Part 1: equipment classification and requirements'. During the installation check that all access panels (e.g. the enclosure lid) are properly interlocked so that laser emission stops *immediately* the cover is opened, and that the interlock cannot easily be overridden. Check also that the fume extraction system, whether it is a recirculating system returning filtered air to the room, or is extracting to the outside, copes adequately with the fume produced by the process; in particular, that fume-laden air is not returned into areas where people may be present.

Fourthly: once installed, operate the system according to the manufacturer's instructions and conduct the routine maintenance indicated. Ensure that during training such maintenance instructions are demonstrated and that several staff members are trained in these maintenance operations. Of particular importance is dealing with fume contamination of beam line optics. Such optics must be kept clean to prevent them becoming damaged by the laser beam. (In this context, mirrors made from gold coated glass substrates are not suitable for use in areas where fume can be present: use metal mirrors).

Fifthly, during laser processing do not leave the machine unattended. Such

Examples of laser processing: (top) Mother of Pearl plaque used in the reconstruction of the "Lyre of Ur"; (below) Personalised denim – cut and marked using a laser engraving system

systems are not designed for unattended operation, depending on the action of a human operator to stop the machine if something goes wrong and there is risk of fire or beam escape.

The above is not an exhaustive list and there is much that can be added to help secure long, satisfactory and rewarding operation of such systems.

Next steps for schools

AILU promotes the use of laser technology in manufacturing and is keen to highlight laser applications. In particular the Design for Manufacture website at http://www.designforlasermanufacture.com offers a wide range of resources illustrating many applications and providing an excellent resource for teachers and tutors on laser processing. A number of AILU members are enthusiastic in promoting laser processes at schools and colleges and may help in giving the "bigger picture" about lasers to students.

AILU is always willing to assist any school or college to find a member in the locality who could deliver a message about lasers and manufacturing.

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OBSERVATIONS

Short comments on papers in this issue:

Servitization in laser job shops: interviews with laser job shops and machine providers

Gokula Vasantha et al

This is an interesting article based on several assumptions:

1. The relationship with machine suppliers can be improved and the job shop owner wants this

2. Customers prefer to buy locally from laser job shops and this is more efficient

3. Laser job shops would like long-term relationships with large customers

I'm sure for some job shops the above is true; however on a personal basis this is just not the case.

In the case of relationships with machine suppliers we see a widening gap. In the past we built personal relationships with the supplier that encouraged an open attitude to business and basic trust. This is no longer the case. In our recent experience we feel machine suppliers have lost empathy with their customers and are purely profit driven – not necessarily a bad thing, but not conducive for a closer working relationship. We no longer think of machine suppliers as a partner.

When we analyse our customer base the vast majority of our clients are outside an 80 mile radius of our location. We have local customers but they represent a low percentage of our turnover. What we've found is the way to a customer's heart (and pocket) is consistent service – if we say we'll deliver Wednesday morning we do it and the customer doesn't care how far we are from him. The idea of opening local manufacturing sites to service the customer base sounds tempting but in reality it's an expensive way of servicing your customer. Just instilling the right culture into a remote location can be next to impossible due to cultural differences and without the right culture customer service fails.

There are certainly laser cutting companies that specialise in large contracts and in these cases servitization is a no-brainer. To ensure piece of mind and return on investment it's quite possibly the only way to go – automating processes and becoming an intrinsic part of the customer's production makes perfect sense. However from experience this usually involves additional processes such as fabrication so is this really a laser job shop? By definition a laser job shop is a flexible company that adapts it processes to match a wide and varied customer base but focusses on laser processing. Personally we deliberately avoid large clients – we would never let a customer represent more than 8% of our turnover. We're increasingly looking for one-off contracts as the margins are much higher and there is less competition.

In conclusion servitization makes perfect sense for job shops that are prepared to adapt to become an integral part of a large client's production process. However for the rest of us it might actually compromise our processes.

Martin Cook Cutting Technologies

Combining micro-milling and laser structuring for manufacturing complex micro-fluidic structures

Andreas Schuber et al

This article shows an interesting comparison between laser and conventional milling and tries to answer the question 'which is best'? As we know with such technologies there is never a single, simple answer but the results illustrate nicely the pros and cons of the methods. The laser milling of metals (for moulds, printing drums etc.) is already advanced so this work adds to that expertise but the one thing I did find surprising was the lack of a visible 'join' between the laser machined and mechanically milled regions shown in figure 8. The usual state of affairs is that either a trench or a ridge is left behind when two processes overlap in a region so the result which was shown was exceptionally good.

Nadeem Rizvi Laser Micromachining

An interesting piece of work, laser finessing of mechanically machined components is an active topic, we have also had requests to laser post process laser sintered parts to improve accuracy and surface finish.

However as pointed out in the paper there are a number of problems to overcome. In particular a very high alignment accuracy is required between process steps and sophisticated machining algorithms are required to get acceptable results. This would initially limit the process to higher end applications that can justify the cost.

Paul Apte Rideo Systems

Laser Net Shape welding

Lin Li et al

This is an interesting paper that relates welding speed to observed weld bead geometry and hence to mechanical properties. As expected weld high undercut or high reinforcement have poor mechanical properties due to the stress raising features.

Of more interest is the reason for the observed weld bead profiles. The explanation given is of a reversal of surface tension gradient as the weld speed is changed. This reversal is extracted from FE modelling of the temperature field. It is unclear how this was done since a change in flow direction would have a marked effect on the temperature distribution. Therefore one assumes that this conclusion was reached by fitting the surface tension gradient to match the observed temperature distribution, and assumes that nothing else is changing to give the observed temperature distribution. If so, one would have to ask where has the material in the low welding speed case gone to? (There should be extra material at the edge of the weld bead or slumping on the root.) Similarly, at high welding speeds where has the extra material come from (some undercut at the edge of the weld or at the root would be expected)? No explanation is proffered. A simpler explanation could be that at low speeds the material is lost due to excessive vaporisation and at high speeds the reinforcement could be due to shrinkage or porosity.

As a final point I would say that in most welding applications the weld bead profile is specified to have an acceptable range of reinforcement, undercut and toe angles (due to the effect on mechanical properties). So producing weld bead profiles with a specific geometry is nothing new and does not need to be a given a fancy name – it does not add any further credibility.

Stewart Williams Cranfield University

Laser welding has many advantages such as narrow weld width, narrow HAZ, deep penetration and reduced distortion, however as the author has pointed out weld bead geometry plays a very important part in governing the mechanical properties of the welded joint. The weld bead shape has been found to be a function of the laser and processing parameter settings, such as power, focus position, shield gas, speed, weld joint, gap between the parts etc. This paper has highlighted that it was possible to

Continued over

produce perfect top weld bead shape with certain set of parameters.

The work reported here was carried out with low carbon steel, which does not require too much optimisation to produce good quality welds. I look forward to seeing some data for stainless steels and aluminium alloys which require detailed optimisation of laser parameters in order to produce good quality welds. With these materials, concentrating solely on achieving the best top bead geometry does not necessary produce welds with good mechanical properties. Some grade of stainless steels and most aluminium alloys are prone to cracking and porosity which can drastically reduce the quality of the welds.

Mo Naeem JK Lasers

Combining Laser micro-adjustment using ultra-short pulses

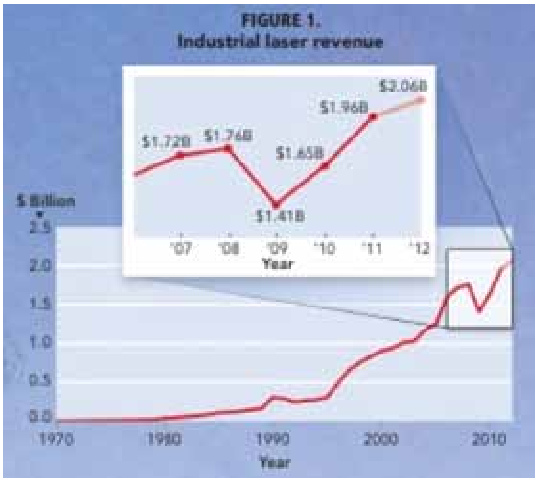
Jonathan Griffiths et al

It is very interesting to see this process being scaled down to work with ever smaller components and to see details published for a repeatable process. Some readers may not be aware that laser forming has been used in manufacturing for almost 40 years, having been carried out in the 70's using low repetition rate capacitor discharge Nd:YAG lasers and subsequently with switched-mode Nd: YAG lasers. Pulse durations were necessarily much longer than used here - hundreds of microseconds up to milliseconds - so the process was purely thermal. The process has been used on a range of components from sensors to relays and hard drive head flexures but there is little or no published information as the techniques have been largely treated as 'trade secrets' with equipment suppliers subjected to strict confidentiality agreements. Process calibration may have been determined somewhat empirically but since typically used within an iterative measure/adjust/measure sequence it didn't necessarily have to be spot-on.

Clearly for high-volume MEMS there are benefits in being able to use a predictable and repeatable adjustment process, such as that developed by the authors, so that a much faster single-step adjustment process might be used. However I do wonder whether for some MEMS structures the ablated grooves might act as stress concentrators with potential adverse effects on component life?

Keith Withnall
Keith Withnall Associates

At last, some good economic news



David Belforte's Annual Economic Review and Forecast in the January 2012 edition of Industrial Laser Solutions (PenWell Publications) confirmed all the anecdotal evidence we've been publishing in this magazine, that there has been a very strong recovery in the industrial laser sector.

As the figure from this report shows it seems that in terms of world revenue in industrial laser sources the recovery from the sharp decline in 2008 began on 2009 and continued strongly until, by the end of 2010, sales were approximately where an extrapolation of the growth curve pre-2008 would have expected them to be. Growth in 2011 was slower (19%) than in 2010 (35%) and is expected to be slower again during the current year (5%), but this is still very good considering the uncertainty in the world economy as a whole, especially in Europe, which is currently contributing about 1/3 of the total spend. (Note: the figures for the sale of industrial laser systems (machines that incorporate industrial laser sources) track the laser source curve but the revenues are approximately four times higher)

David provides some answers to the question of how laser sales did so well in 2011 in the face of the general economic malaise. He puts it down to the growth in six sizable markets: aerospace, energy (conventional and alternative), electronics, fabricated metal products and transportation. Within these sectors ILS "easily identified more than two dozen applications that showed strength in an otherwise dull manufacturing year", but for this the reader will have to refer to the original review, which can be found at www.industrial-lasers.com.

Job Shop's most beautiful part

We were recently asked by a customer to produce this intricate cup cake holder in card. The customer had no artwork so they sent us a scan of the actual part which we converted and then laser cut producing 80 of them with a total turnaround time from enquiry to delivery of 48 hours.

It is a very low tech product but we thought it looked good.

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A funny thing happened on the way back from an AILU meeting

In August 2011, Tim Holt (CEO of the Institute of Photonics) booked a FlyBe return flight from Glasgow to Birmingham to give a talk at AILU's PPI SIG event at the MTC in Coventry (see event review in Issue 64, p37).

"As this was just a day trip, I only had hand luggage, which contained my notes etc, as well as a green laser pointer. I always insert a small mechanical shutter in the pointer to prevent activation when travelling, mainly to preserve the battery. It is always in my suitcase as I often get asked to give presentations on lasers," said Tim.

"There were no problems in going through security at Glasgow airport, but on my return through Birmingham I was asked if my suitcase contained a laser pointer as one had been seen on the X-ray. I said yes. I was then asked if it was a green laser pointer. I said yes."

"I was then told that these were banned from being carried on board the aircraft. I argued that I had never heard of this, had carried this laser pointer on many trips abroad without any problems and that I was amazed that green laser pointers were banned when there was no requirement regarding power. And why only green? The best I was offered was that I could post the pointer to myself, which I did."

So, why the ban on green laser pointers at Birmingham Airport? In response to the query that Tim made with the Civil Aviation Authority, it was confirmed that the CAA does not consider laser pointers to be "dangerous goods" and places no restrictions on their presence in carry-on baggage, nor does the CAA prohibit the batteries in the laser from being carried on board. So far, so good.

Further investigations also revealed that lasers are not included on the Department of Transport's list of items that may be refused on the grounds of security.

The solution to this conundrum proved to be that Birmingham Airport operates a blanket ban on all laser pens (sic) within passenger hand luggage and that the airport security personnel are required to enforce this. In response to a letter from Tim, a Birmingham Airport Customer Relations representative stated that 'faced with a situation where some airlines ban them whilst others don't, the decision has been taken not to permit laser pens in any passenger's hand baggage'. This is indeed made clear in the security section of the Birmingham Airport web site. Tim then checked the equivalent security pages for BAA airports (Heathrow, Glasgow etc) and found no mention of laser pens or laser pointers being banned items. So it would appear to be only for travellers through Birmingham and possibly other non-BAA airports that the ban is in place. Laser enthusiasts beware!

AILU events

March 2012

29 **Lasers lead the way in Additive Manufacturing**
(Organised by the AILU Additive Manufacturing SIG)
Manufacturing Technology Centre, Coventry UK

April 2012

19 **Annual General Meeting**
To be held immediately following the MACH exhibition, exact location TBC
Hall 4, NEC Birmingham

AILU-supported exhibitions

April 2012

16 **MACH 2012 (16 - 20)**
NEC Birmingham

June 2012

12 **LASYS (12 - 14)**
Messe Stuttgart, Germany

November 2012

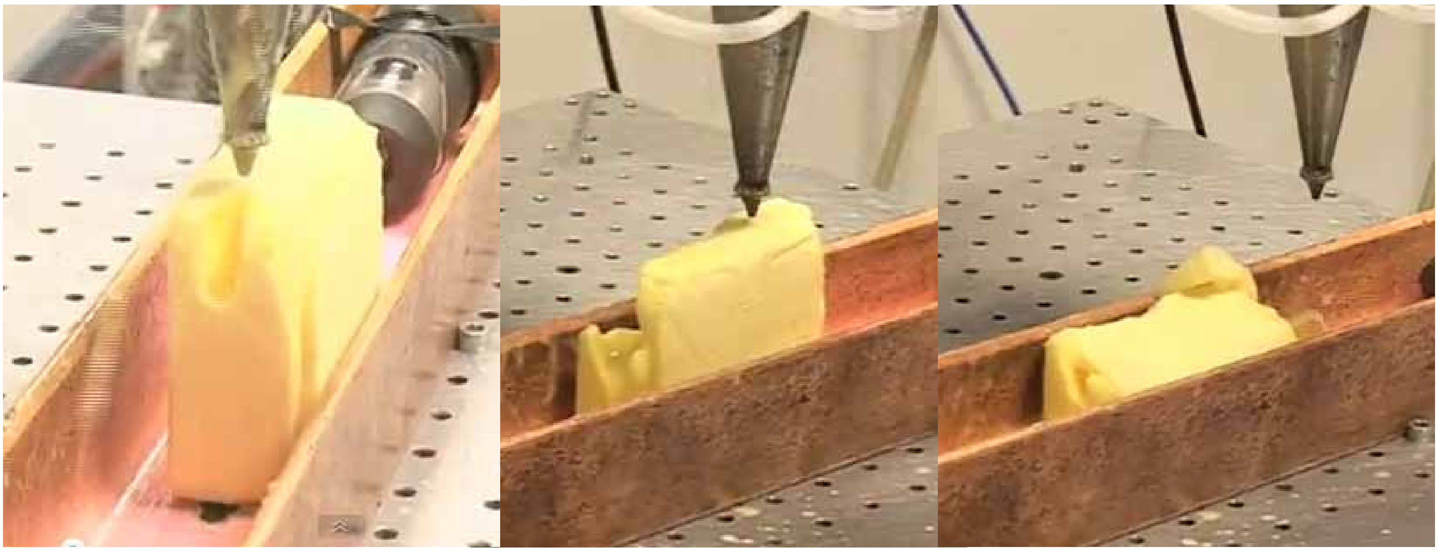
28 **espace LASER (28 - 29)**
Parc expo Mulhouse, France

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

Cutting butter with a laser

In memory of Janet Folkes, below are some frames from her YouTube video demonstration of cutting butter: with a hot knife, a 2 kW fibre laser and a waterjet cutter. Abiut six months ago Janet sent me a link to the video and suggested I might like to make a humorous piece out of it for the AILU magazine, and I regret that it didn't get done earlier.

Janet's memory lives on in the video: see it for yourself at: See http://www.youtube.com/watch?v=aRZ8TlvH2gc. The frames below show the evolution of the 2 kW fibre laser cutting butter: clearly not the best technique for this application!



Forward into 2012

"When it comes to getting the laser message out into UK industry, the lion's share of near market, real application support is provided by laser job shops and suppliers of laser-related products."

AILU plays a big part making the case for Laser Materials Processing in the UK. In this issue there is mention of the EPSRC announcement of funding for laser activity in Centres for Innovative Manufacturing and also news of a forthcoming strategy workshop to set a new strategy for LMP in the UK, and in both of these AILU has and will be playing a significant part.

However, as an article in this issue highlights, a recent AILU review of LMP technology transfer activity in the UK found that when it comes to getting the laser message out into UK industry, the lion's share of near market, real application support is provided by laser job shops and suppliers of laser-related products. AILU does its bit with the Design for Laser Manufacture website, at exhibitions (including a 14-stand pavilion at MACH 2012), and at other events, including in particular the forthcoming ILAS 2013.

The ILAS mission statement (see p1) includes reference to persons new to the use of lasers, stating that the event will provide "introductory presentations, reviews of the state of the art in laser processing and other opportunities to network with the UK knowledge base and supply chain." This will have to be a joint effort from AILU members: for applications that are already established for industrial exploitation, it will mainly involve laser job shops and laser product suppliers; where further R&D is needed, it will mainly involve universities and, we hope, the new Catapults (Technology and Innovation Centres).

I must save my final word for Janet Folkes, an exceptional member of laser research community in the UK, whose untimely death has stunned so many in the laser community. When I first met Janet in the late 1980s, she had only just returned to the UK after spending 2 years in Japan, working on laser welding at the Nissan Motor Company. At that time it was rare enough for a women to be working on industrial laser processes in the UK, let alone having work experience in Japanese industry. So it is not only in ballooning that Janet was unique! She was a great role model for women considering a career in engineering, and a most enthusiastic and helpful colleague over the years and latterly on the AILU committee.

Mike Green, Editor
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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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Easy exhibiting at MACH 2012

MACH is the biennial, week long showcase for the UK' manufacturing industry, successfully promoting the sector on a world-class stage.

MACH 2010 attracted over 20,000 visitors. The MTA have reported that Stand bookings are running nearly 25% up on those for MACH 2010 and initial visitor pre-registration is already well ahead of 2010 and 2008 levels again pointing to a buoyant manufacturing sector and a positive exhibition.

There will be a new pavilion for MACH 2012 featuring members of the **The Association of Laser Users**. The members who have taken a stand within the AILU Pavilion will enjoy benefits over other exhibitors; not only because the pavilion will attract exhibition visitors looking to find companies that deliver laser solutions, but also because they will have use of the pavilion lounge and support from the AILU office team.

And AILU members are offered Easy Exhibiting, a new initiative from MACH to help AILU members who may not have previous experience at exhibiting. Designed to make the process easy, the package gives members the opportunity to showcase their products, services, capability and capacities to a wide audience of buyers and specifiers all under one roof in a 5 day period.

Exhibit in the AILU Pavilion at MACH 2012 from as little as £399 a day!

For further details or to book your stand at MACH contact

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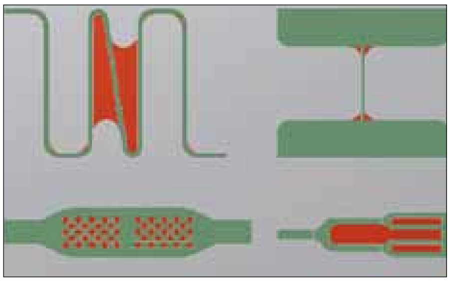
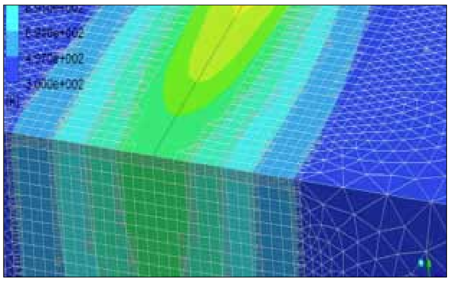
CONTENTS

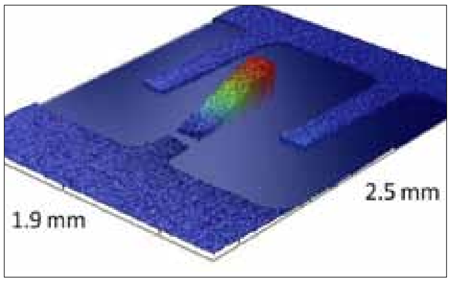
Laser job shop tip p 13



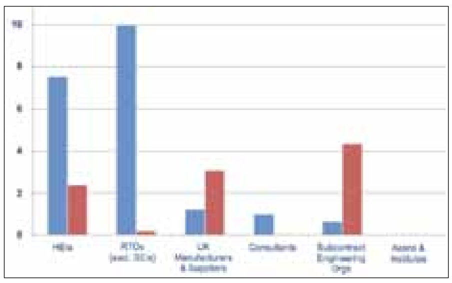
Micro milling and laser ablation p 19



Controlling weld bead cross section p 22



Micro forming p 24



Lions share of technology transfer p 26

Laser engraving in schools p 28