The Laser User

Issue 50 Spring 2008

Laser sources for cutting and welding

The AILU objectives

The principal objectives of AILU include:

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

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

Benefits of membership

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

the association of AILU laser users

Helping you make the most of laser technology

Courtesy Jenoptik

This issue includes an interesting selection of results, comments and opinions addressing the relative merits of high brightness solid state lasers and CO_2 lasers for cutting and welding. The cover photo is from the paper by Bergmann and Ploennigs (page 30) addressing robot delivered CO_2 laser cutting. Seefeld and O'Neil consider the merits of high brightness sources in their paper on page 32; see also Petring's observations on this paper on page 52 and those of Hartmut Pannen, the new Trumpf UK MD, on page 23, plus comments in the reports of the last two AILU workshops.

Erratum: In the article by David Toebaert 'An integrated approach to laser machine tool fabrication' on page 30 of the previous issue, the "autofocus" axis was incorrectly labelled as "Z-axis". For a proper understanding of the operation of the machine it is essential to appreciate that the Z-axis (movement of the cutting head as a whole) and the "autofocus" axis (movement of the cutting lens inside the cutting head) are completely independent axes. We apologise for any confusion caused.

Association

Tim Weedon wins 2008 AILU Award

Tim Weedon

The AILU Awards Committee are pleased to announce that the 2008 winner of the AILU Award is Tim Weedon, in recognition of his successful pioneering efforts to introduce Nd:YAG-based machining systems into the UK and for being a tireless champion of appropriately applying laser based manufacturing. The Award will be presented at the annual members' meeting on 8 April at Cranfield University

"Tim was the UK pioneer in the development of material processing systems using YAG lasers to meet the needs of production user applications," said Jim Wright MBE, co-founder of JK Lasers.

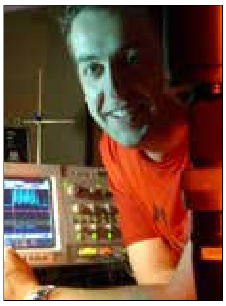
"Tim joined JK Lasers in 1975, where he applied his combination of engineering and computing (a rare combination at that time) to the potential industrial applications. His first application was the hermetic sealing of implantable heart pacemakers for Medtronic. The equipment was then deployed in both Europe and the USA. This was followed by numerous other welding applications in the electronics, automotive and aerospace industries.

"Tim was also responsible for the development of the first multi-axis hole-drilling machine for Rolls Royce and the further development of such machines for both Rolls Royce and other users throughout the world. His successful solution to the required precision of the inter-hole spacing on flexible combustion chamber components is just one testament to his combined computer and engineering skills. His reputation spread throughout the world and he was frequently invited to speak at international conferences in Europe, USA and Japan."

AILU President Clive Ireland, who worked with Tim for many years, added, "Tim is a champion of using the right tool for the job, and close customer/ supplier collaboration/co-operation to achieve it." He also noted that Tim was AILU President in 2004/5 and was passionate in his drive to see the Association successfully undertake our Design for Laser Manufacture initiative.

Dental work wins Fraser the Prize!

Fraser Dear is AILU's 2008 Young Laser Engineer in recognition of his successful development of fine laser machining techniques in zirconia for the manufacture of tooth crowns and bridges for dental restorations.



Fraser Dear at work

Fraser's work has been carried out at Heriot-Watt University with support from EPSRC and Renishaw dental division. He was nominated for the Prize by Professor Duncan Hand and Nick Weston, General Manager of Renishaw, Edinburgh. The application is a perfect example of 'mass customisation' where every part manufactured is different. As a result, moulding or extrusion techniques commonly used with ceramics cannot be used; instead it has to date been necessary to use a (very slow) diamond grinding process. Fraser has succeeded in developing novel laser-based processes to carry out both high speed 'rough' processing and high-precision (but slower) fine machining.

Renishaw dental products division are examining the economics of introducing these laser processes on a commercial scale, replacing at least some of their current mechanical diamond grinding processes.

AILU's new web site

The Association experienced severe problems with virus attacks towards the end of 2007 and the failure of AILU's web designer / internet service provider to correct the problem meant that our site at www.ailu.org.uk was sporadically out of service for long periods.

Radical action has resulted in AILU now having a new upgraded site hosted by another company, at the time of writing almost fully functional.

The new site is vastly improved in design and security and comments received to date have been very positive.

AILU's new SIGs
The new Medical Special Interest Group (SIG) launched at the AILU medical workshop in November now has over 50 members. It is holding its first dedicated workshop on 22 May in Ireland (see Events)

The Market Development SIG, which successfully launched the Design for Laser Manufacture web site in 2007, will be planning new activities in 2008 for growing the market for laser product and service providers. And at a recent meeting the AILU committee agreed for a new Product and Process Innovation SIG to be led by Lin Li. The PPI SIG will take initiatives for the benefit of those working in academic and industrial research centres.

People

New appointments at SPI

Jack Gabzdyl and Andrew Appleyard

SPI Lasers have appointed Jack Gabzdyl and Andrew Appleyard to the positions of Product Line Manager for Pulsed Lasers and High Power Laser Systems respectively, The Product Line Managers will drive the uptake of the new MOPA-based G3 pulsed lasers and the R4 system platform and spearhead the new product introduction for 2008.

In September 2007, SPI announced an extension to its pulsed laser product range for marking solutions. A brochure describing these developments is available from SPI.

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OBITUARY

Neil Lindsey

Neil with granddaughter Kari in 2007

The General Manager of Laser Process Ltd since its formation in 1990 passed away suddenly on the 15th March – his 55th birthday.

Neil was an integral member of the team that has seen the company become a leading job shop within the laser cutting industry. A recurring theme amongst the many tributes we have received is that Neil was 'a nice man' and we know that we would have to go a long way to find anyone who could disagree.

Neil was my brother, my colleague and my friend, he will be impossible to replace. He will be missed by all.

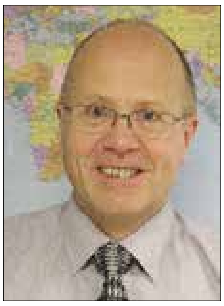
David Lindsey

Martin Adams

As we were going to press we received news that Martin Adams, a member of the team that developed the first fast axial flow laser and an AILU Award winners in 2000 died last week (W/B 17 March) after a sudden, short illness.

He is survived by his wife, Bridget, UK editor of Laser focus World

Purex's new Sales & Marketing head



Bob Pitchford

Bob Pitchford joins Purex International with 25 years experience in the electronics industry, most recently as Director of Business Development with Speedline Europe.

"Purex are hugely successful in laser fume extraction," said Bob. "The team have the knowledge, drive and enthusiasm to take the company to the next level of business and I relish the challenge of supporting them in their growth,"

Purex manufacture laser fume extractors in Rotherham UK.

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Peter Thompson appointed Technical Director for Laserdyne Systems

Peter Thompson

Prima North America has appointed Peter Thompson to the position of Technical Director for Laserdyne Systems.

Peter will be responsible for a combination of advanced process development and technical support for Laserdyne customers worldwide with emphasis on Europe and Asia. Part of Prima's strategic goal is to grow the Laserdyne business in these regions

Peter has over 35 years experience with international laser and aerospace industries. Prior to starting his own firm 'Laser Experience' in Rugby, UK, Peter was a senior process engineer for Lumonics for 10 years where he was responsible for projects including the introduction of laser drilling to Rolls Royce and laser welding to Gillette. He has also held senior engineering positions with Lucas Aerospace and MTE Ltd.

Contact: sales@prima-na.com

Research Positions at Purdue University USA

A number of research positions for PhD students and Postdoctoral Researchers are available in Prof. Xianfan Xu's laboratory at Purdue University in West Lafayette, IN, USA.

1. Ultrafast laser diagnostics of energy transfer in nanomaterials. Background and prior experience is desirable:

2. Laser-based nanomanufacturing. There are several positions available.

For more information, contact Prof. Xianfan Xu, Phone: +1 (765) 494-5639; Email: xxu@ecn.purdue.edu;

URL: widget.ecn.purdue.edu/~xxu; widget.ecn.purdue.edu/microlab

MEMBERS' NEWS

Business

Carlton Lasers wins CBM Award

Dennis Kent (right) Managing Director and Mo Jassi, Production Director of Carlton Laser Services receiving their Supplier of the Year Award from Edwina Curry, guest speaker at the event.

The highlight of the Confederation of British Metalforming [CBM] annual dinner at the Marriott Forest of Arden hotel on 19 March was the presentation of four 2008 company awards. For the first time since the awards have been presented, every one went to Midland companies, with Leicester based AILU members Carlton Laser Services winning Supplier of the Year 2008.

The supplier of the year award was won by Leicester-based Carlton Laser for having produced performance above the call of duty, demonstrating strategic alliances with both customers and suppliers to provide the best possible service to the industry. The judges were particularly impressed by the detail and openness of their 'warts and all' submission and commented that they have enhanced not only their own reputation but that of the metalforming sector as a whole.

In receiving the award Dennis said that he wanted to make it clear that he was receiving the award on behalf of all the Carlton employees. "I am very proud of our workforce, all of whom have played their part in our success" he said.

Mr Houseman, CBM Director General, commenting on Carlton Laser and the other three award winners, said that "Our sector is facing its toughest challenges since the early 1990s, with ever-increasing competition from low-cost countries, constantly rising energy and raw material costs and economic uncertainty. These firms are fighting back and showing us all just what can be achieved. I salute them all as heroes."

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Powerlase Manufacturer of the Year
Powerlase Ltd, manufacturers of the world's most powerful nanosecond Q-switched, diode-pumped solid state lasers, has been named 'Manufacturer of the Year for 2007' at the Elektra Awards.

Powerlase received the prestigious award in recognition of the company's success in the development of class-leading laser technology and its application within the Flat Panel Display manufacturing industry. The company has in particular contributed to innovation of the manufacture of Plasma Display Panels (PDPs), with a significant percentage of global PDP production reliant on Powerlase lasers.

The judges complimented Powerlase on the company's efforts to develop technology to meet customer requirements and for maintaining close working relationships with both customers and partner organisations.

The latest award affirms the achievements of Powerlase, which include victory at The Manufacturer Awards 2007 in the 'Design and Innovation' category and the company being listed as the 21st fastest growing technology company in the UK by The Sunday Times TechTrack Rankings.

Powerlase forges green innovation
Laser systems integrator HardRam has selected the Starlase AO8 laser to revolutionise PDP manufacture.

HardRam will use the Rapid Laser Patterning (RLP) technique to dramatically reduce the negative impact on the environment caused by traditional PDP manufacture methods and increase the speed and efficiency of manufacturing throughput.

Unlike previous wet-etch lithography approaches, RLP does not require harmful chemicals to treat thin film screens, instead relying on direct laser ablation. The chemicals used become contaminated with the removed film after each use. Removing these chemicals from the process significantly reduces the harmful impact on the environment as chemical waste disposal is no longer a part of the process.

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Rofin-Sinar buys Nufern
Rofin-Sinar, a world leading laser manufacturer, has purchased Nufern, the world's largest independent manufacturer of speciality fibres and fibre laser modules.

"This is a very important acquisition for Rofin-Sinar, not only because we are adding new products to our portfolio but also because we are further strengthening our technology base and enhancing the vertical integration needed to economically manufacture fibre lasers," said Gunther Braun, Rofin-Sinar's president and CEO. "We are confident that the talents and skills of Nufern will contribute to the future success of our Group."

According to the deal, Nufern will continue to operate as a stand-alone company and will provide its products to its existing customers, including other laser manufacturers. Based in Connecticut, US, Nufern has around 70 employees and markets its products to OEMs through its own sales network and distributors.

Founded in 2000, Nufern has built is business on selling standard fibres and custom fibre solutions, as well as fibre laser modules for use in material processing and the telecommunications, military and defense industries. Earlier this year, Nufern launched its first industrial CW fibre laser, which delivers an output power of 200 W.

Qioptiq Group buys Point Source
optics.org press release
Qioptic of St. Asaph, North Wales have purchased Point Source, Southampton, specialists in fibre optic laser delivery systems and lasers for biotechnology and semiconductor applications

Qioptiq already has optical interests ranging from high-precision visible and infrared assemblies to advanced optical coatings. Point Source will enhance Qioptiq's laser capability.

Point Source will become part of Qioptiq's Optical Systems Division headed by Volker Brockmeyer. The division focuses on optical systems for IT and communications, healthcare, life sciences and industrial manufacture, which are all targeted by Qioptiq as strong growth markets.

http://www.qioptiq.co.uk

Prima Industrie acquires Finn-Power
Industrial laser equipment specialist, Prima Industrie S.p.A. has completed the acquisition of Finn-Power Oy, an organisation with a 25-year track record of growth and innovation in the design and manufacture of sheet metal working machinery.

Through the 170 million euro deal, Prima Industrie group becomes a global leader in laser and sheet metal working systems, with annual sales exceeding 400 million euros, a presence in 50 countries, 10 manufacturing facilities located in Italy, Finland, USA and China, and more than 1,700 employees worldwide.

Finn-Power has its headquarters in Finland and operates manufacturing plants in Italy and Finland, as well as subsidiaries in Italy, Germany, France, Belgium, Spain, USA and Canada. The company's wide range of sheet metal working equipment includes punch presses, integrated punching and shearing cells, punching-laser cells, automatic bending cells and related handling systems. Finn-Power has also developed a strong reputation for its custom-engineered flexible manufacturing systems.

Commenting on the take-over, Tomas Hedenborg CEO of Finn-Power said: "Prima is the perfect partner for Finn-Power from the technological and product point of view. Synergies arising from this integration represent an outstanding opportunity."

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CRMA purchase Laserdyne 790 BeamDirector® System
Prima North America have announced the sale of a Laserdyne 790 XS - CL50k system to CRMA. (Société de Construction et de Réparation de Matériel Aéronautique), a subsidiary of Air France.

Established in 1957, CRMA has over 300 employees. The CRMA mission is to be the centre of excellence for repairing Air France's engines. The acquisition of the new Laserdyne 790 XS – CL50k is designed to enhance that position.

The system includes a full complement of Laserdyne hardware and software features such as Optical Focus Control (OFC) and BreakThrough Detection, allowing users to produce parts in far


The Laserdyne 790 XS system

shorter cycle times with superior air flow consistency.

"CRMA's commitment to Laserdyne technology is an example of another leading global aerospace company's positive evaluation of our technology," said Prima North America's President Terry VanderWert. "Laserdyne's latest software and hardware, which includes the Convergent Lasers CL50k, At Focus Drilling and Hole Diameter Compensation software will be important to future success for all manufacturers of turbine engine components."

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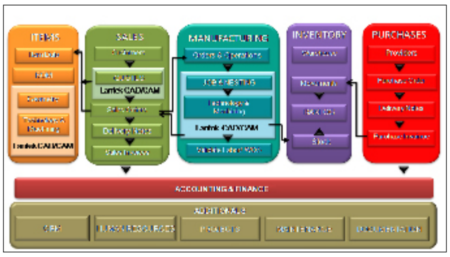
MEMBERS' NEWS

31% growth for Lantek.



The Expert III job management software

Lantek Systems Ltd has enjoyed a 31% surge in business at its Malvern office in 2007. The company, well known for its Expert II sheet metal CAD/CAM software, has seen particular interest in its Expert III job management software in the UK and Irish markets.

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Rojac Engineering relocates

Rojac Engineering Ltd has relocated to new and larger premises at Kitts Green, Birmingham, enabling them to expand their business and improve their level of service thanks to new automated plant.

Contact: +44 (0)121 789 4040
W: www.rojac.co.uk

New Products

Sources

New diode sources from Newport

ProLite® Xt Cygnus fibre coupled stacked arrays.

The Cygnus series, one model offering 200 W of output power from a 200 μm fibre and another outputting 400 W from a 400 μm fibre, is claimed to be the brightest fibre coupled diode solution available today.

Delivering reliable performance at 915, 940, or 980 nm, they are an excellent choice for advanced fibre laser pumping, direct materials processing, and applications in the aerospace, defence and homeland security market."

Active water cooling enables the low thermal resistance needed to drive the high power levels required to achieve extremely high brightness, over 4 MW/ cm^{2}sr. The field serviceable fibre design maximizes operational time for fibre pumping and other applications that require the highest performance.

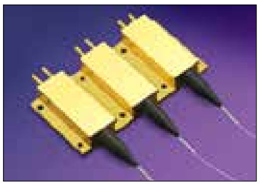
ProLite® Xt Corvus™ high brightness fibre coupled bar

The new ProLite® Xt Corvus series of high brightness fibre coupled bars provides the industry's highest brightness from a single bar solution, delivering more than 35 W of output power from a 100 μm fibre.

The Corvus series incorporates technical advancements in bar geometry design and beam shaping technology to efficiently fibre couple single diode laser bars. A low numerical aperture, small-diameter, single-core fibre provides a high intensity, high brightness 3 MW/ cm^2-sr output.

In addition, the field serviceable fibre design minimizes downtime for fibre pumping, plastics welding, and other material processing applications where serviceability is critical.

ProLite® Xt Orion™ Diode Laser



The Orion™ is the latest member of the ProLite® Xt family. This high brightness fibre coupled diode solution uses a powerful new "mini-bar" concept to deliver more than 20 W output from a 105 μm fibre at wavelengths of 915, 940 and 980 nm. The Orion diode laser's small footprint and low thermal load help ensure maximum design flexibility for commercial laser systems in the industrial manufacturing and life and health science markets.

"The Orion series exploits a long list of innovations in materials, device design and process refinement, and, as a result, it is one of the brightest diode sources commercially available," said Michael Atchley, Product Marketing Manager for Newport's Spectra-Physics Lasers Division.

Atchley added, "We believe that the Orion laser is an attractive solution for fibre lasers for two main reasons – to increase output power or to drive down system costs by requiring fewer diodes to pump the lasers."

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Best beam quality from a disk laser

For a comparatively low purchase price the TruDisk 1000 disk laser from Trumpf provides exceptional cutting and welding capability. With 1kW output, this laser precision cuts and welds thin sheets at speed and is also ideal for robotic 3D cutting.

This performance is thanks to the beam quality of the TruDisk which, at 2mm*mmrad, is the best of all the Trumpf continuous wave solid-state lasers. This quality allows the use of a 50 μm optical fibre cable that permits higher processing speeds and processing with longer stand-off distances, for example for remote welding.

A feature introduced with the TruDisk 1000 is the control system's TruControl, software that has proven its abilities on the Trumpf TruPulse series. As with the TruPulse lasers, TruDisk 1000 has a removable and easy to use touch-screen operator panel with turn-push buttons. This latest addition to the disk laser range requires minimum floor space and is therefore easily accommodated in any industrial environment.

Low cost is another important feature of the TruDisk 1000. It costs around 40% less than its predecessor the HLD1001.5. However with the cost reduction has given even better performance and greater flexibility. In common with all models in the TruDisk series, the TruDisk 1000 is based on standard components that provide both system modularity and economic efficiency.

The Trumpf TelePresence portal on the TruDisk 1000 facilitates convenient and secure maintenance, worldwide.

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New offerings from Photonic Solutions

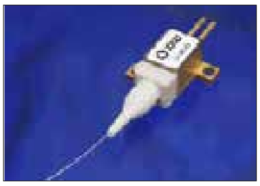
Quantronix's Thor Series

The Thor Series are Quantronix's high energy, low repetition rate Ti:Sapphire ultra-fast amplifier family, providing up to a Terawatt of peak power.

These compact lasers offer pulse energies to greater than 40 mJ from a sub 35 fs pulse, operating at repetition rates from single shot to 20 Hz. Standard building blocks from other well established Quantronix laser systems are used in the build of these lasers, enabling very reliable system operation and streamlined upgrades.

The Thor is available in three standard models: the Thor-C, Thor-HE and the high power version Thor-TW. The Thor-C and the Thor-HE are single stage amplifiers, as such they are supplied as a single box design. The Thor-TW is a multiple stage amplifier, with the first amplification stage typically the Thor-C or Thor-HE and the second stage amplification achieved through second stage add-ons. Customers have the choice to buy from the standard product list or equally the Thor can be customised to meet specific experimental needs.

JDSU's 10W CW fibre-coupled diode



JDSU's fibre-coupled diode lasers are now available with the next generation L4 platform, providing increased power and efficiency within a smaller footprint than previously.

The L4 multi-mode pump modules offer high-brightness and simplified thermal management by distributing the diodes, allowing the use of either air- or water-cooled architectures. Expanded fibre delivery options are available with the L4 platform with the choice of 100mm fibre delivery either at 0.22 NA or 0.15NA. This allows for higher brightness with the fibre, or the ability to focus laser light in a smaller diameter for specific applications.

The first of the single-emitter diode lasers to be launched is the 6398-L4 series diode lasers that offer 10W of output power from a 105 µm fibre into a 0.22 or 0.15 numerical aperture. Available at three wavelengths: 915nm, 940nm and 975nm, these diode lasers are designed for use in a broad range of industrial, medical and dental applications, including fibre laser pumping, materials processing and dental soft tissue surgery.

High Q Laser introduces the ultra compact femtoREGEN™

The all-in-one regenerative amplifier system femtoREGEN UC (Ultra Compact) is based on the high end Yb-doped laser materials for future power and repetition rate scaling. It utilizes High Q Laser's patent pending Intra-Cavity-Chirped-Pulse-Amplification (ICCPA) for ultra compact design.

The femtoREGEN UC integrates all pump laser diode modules, the seed oscillator and the amplifier in a single ultra compact housing. The seed laser is designed as a High Q Laser ultra compact (UC) module itself for high stability and compactness. The UC seed oscillator is operating with "de-rated" nominal pump current for longest MTBF and is based on High Q Laser's patented resonator folding technique withstanding a 50 g shock test for most robust performance. The semiconductor saturable absorber mirror (SESAM) assures passive and self-starting mode locking for high temporal stability.

The application sectors of the femtoREGEN include: semiconductor (mask repair, nano scale thin film ablation, waveguide writing, direct write lithography); medical/life sciences ("cold ablation" of biological tissue in ophthalmology and neurology, femtosecond laser dissection, cell nano manipulation); research (ultrafast spectroscopy together with our High Q Laser wavelength conversion system, non linear optics); nano processing (laser ablation for most precise material ablation or changes, e.g. photovoltaics, flat panel display repair)

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MEMBERS' NEWS

Component handling

New offerings from Aerotech

ANT-20G goniometer stages

Aerotech's ANT-20G goniometer stages provide a compact, high speed and high throughput solution for single or multi-axis angular positioning and alignment applications where free access is required at the central point of rotation. Aimed at the optical component industry and also suited to large scale laser and X-ray diffractometry systems, the range features a unique curvilinear direct-drive brushless servo motor that provides cog-free smoothness, solid in-position stability and zero backlash performance.

The patented motor design combines with high precision angular bearings, a high resolution linear encoder and a controller based multiplier system to provide a calibrated positioning accuracy to ± 10 arc-sec (± 5- µrad), with repeatability to ± 0.5 arc-sec (± 2.5 µrad).

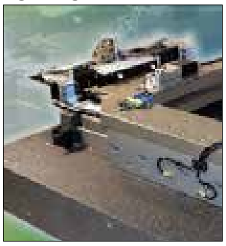
ANT-20G goniometer stages are available in four models, each with a progressively increased centre of rotation. Adjoining sized models are provided with common mounting hole patterns to permit orthogonal stacking, allowing two perpendicular axes to position around the same centre of rotation.

High speed rotary stage

Aerotech's new low profile, high speed rotary stage offers a compact alternative to traditional positioning spindles. Capable of a top speed of 2500 rpm and with a fundamental angular resolution of 3.6 arc-sec, the ADRH 100 features backlash and cog free, direct-drive servo motor technology with a directly coupled precision encoder for excellent servo bandwidth and maximum stiffness.

The new stage has been developed for high precision bidirectional speed and position control, high speed motion contouring, and rapid angular position indexing applications as required in disk drive testing, precision wafer inspection and high speed imaging. The stage will outperform the acceleration and positioning stability performance of traditional gear and belt driven rotary spindle mechanisms - offering an extremely long life and low maintenance solution for high throughput 24/7 production and test applications.

Open frame air bearing stage



With its open frame design, Aerotech's ABL3600 air bearing, linear motor driven X-Y positioning stage is aimed at semiconductor fabrication and test, scanning microscopy and other demanding scan and position applications requiring a large working aperture and perfect precision. Specifications for the 250 mm x 250 mm travel stage include a calibrated positional accuracy of ± 1 µm, a resolution range between 1 and 200 nanometres, and scanning speeds to 200 mm/sec. Delivered as a completely tested and customer ready motion sub system with an integral granite base and full cable management, the ABL3600 can be customised with wafer chucks or other customer-specific fixtures.

ARMS series rotary motion simulators

ARMS series rotary motion simulators provide highly accurate angular rates, acceleration and position profiles for inertial component test systems and instruments. The new simulators include a choice of slip ring assemblies and rotary unions for interfacing with the Unit Under Test and are supplied with matched servo drives, motion controls and GUI motion design software. Users are able to generate or download complex rotary motion profiles and execute them with a velocity stability to 0.0001% over 360 degrees for direct loads up to 170 kg. The range is aimed at dynamic in-process testing of gyroscopes, MEMS sensors, accelerometers and other rate table applications requiring ultra-precise rotational profiling for use on avionics equipment, automobiles, and other ground based vehicles and inertial platforms.

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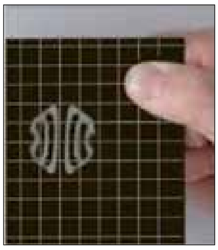
Diagnostics

Measure when you zap



Kentek's popular ZAP-IT® Laser Alignment Paper is now available with 2mm-scale grid on the front side and a documentation form on the reverse to record the zap date and operating parameters of your laser. It is sold in a box of 50, 4" x 8" sheets.

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Lasermet's new power meter

Lasermet ADM-1000 offers accurate peak power, energy per pulse and average power measurements in a convenient hand-held power meter with a response times down to 700 ns. For pulsed laser users, the ADM-1000 measures and displays waveforms up to 400 kHz.

A variety of high-performance photodiode and thermal heads are available to choose from depending on the laser characteristics and type of measurements to be undertaken.

The instrument is fully calibrated and traceable to international and UK National Physical Laboratory standards and comes with an illuminated display and keypad.

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CO_2 laser power meter

The Power Wizard™ power meter from Synrad offers a unique solution to the measurement of laser power and serves as a service tool to ensure maximum laser performance at any time.

Designed to measure power levels from 1-250 W, the PW-250 displays average laser power on an easy-to-read LCD screen.

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Software

CAMTEK support manufacture of tube components

Multi-axis, CNC tube cutting machinery using laser, plasma or waterjet technology is a fast-growing marketplace. 'Tube' components produced using these machine tools range from the very small – medical devices such as stents – to the very large – many building designs use tubular roof constructions, for example. In between the technology is applied to numerous and diverse applications for the manufacture of furniture, automotive, aerospace and agricultural components to mention but a few. Complex and versatile machine tools such as these are becoming standard equipment for many product manufacturers as well as for small-to-medium precision and contract shops.

PEPS SolidCut Laser Tube from Camtek is an established system that is easing the workload for CNC Production engineers who have to generate the programs for these machines. The recently-announced Version 6 includes an enhanced user interface, improved user help files, cycle-time calculations for estimating purposes, improved collision-detection.

With PEPS SolidCut Laser Tube engineers are able to create models of any tube required, using the range of standard tubes available or by drawing free-from cross sections. Apertures and tube ends can also be modelled and powerful tools such as pattern-repeated and wrapped apertures complete the design toolkit that is available. All definitions of a tubular component, tube ends and apertures are parametric; dimensions and positions can be modified at any later stage, the entire model is quickly re-calculated to incorporate the changes.

Maximising investment in design data

Companies who have invested heavily in proprietary CAD design solutions do not want or need to re-create designs in the CAM system. The SolidCut range of CAD translators deliver tightly-integrated CADCAM solutions. CAD native files are used in virtually all cases.

Cutting the part

Generating a complex multiaxis laser path in SolidCut Laser is made easy for the user. Feature-finding tools quickly identify areas to be machined and the user can control appropriate cutting technologies to be applied to any trim cut.

Cutting head orientation to the component surface can be set as a default and then changed as required. Options include 'surface normal', fixed angle and 'follow face'. On any trim, at any position the user can introduce 'change points' where changes in orientation, technology or details such as micro-joints can be applied.

A tube part routine can be used to prepare part programs for varying numbers of components that are to be manufactured from the same material section.

Verifying the toolpath

Once the toolpath has been generated full simulation including motion using the kinematics of the machine axis relationships can be used to accurately verify the program using rendered solid graphics. Construction and simulation needs of machine tools are many and varied, but all kinematic relationships can be handled by the simulation setup.

Errors such as collisions of the laser head and moves that cause over-travel conditions are identified and reported by the software. Collision conditions can be removed automatically. Alternatively the programmer can introduce safety moves interactively, by either setting appropriate axis values or by interactively manipulating the head.

Last but not least

There is a demand for very high percentage up-time for tube manufacturing machine tools. The single most important product of any CAM system for any CAM operation is CNC code to run the machine. This must be generated to a high standard and be technically accurate. Support for features such as hole and slot cycles on the machine controller should be supported. SolidCut Laser products have an impressively large – and increasing - range of proven post processor solutions for all machines in use today.

The combination of excellent graphical simulation and prove-out on the PC, coupled with the high-quality, proven code for the target machine virtually eliminate first-off prove-out at the machine, particularly important when only a one-off is required.

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Radan and EdgeCAM software helps Fife Fabrications Ltd

A leading supplier of precision sheet metalwork, electro-mechanical assemblies and engineered components for more than 20 years, Glenrothes-based Fife Fabrications Ltd (FiFab) is using Radan and Edgecam software systems to provide continuous improvement in its manufacturing capability.

FiFab's expertise extends throughout the product development cycle from concept design, prototype, trial and evaluation to manufacture. The company provides its customers with a 'concept to component' solution, both for low volume specialist and high volume fabrication.

The Edgecam system is a recent purchase, while Radan software was first installed in 1990 to replace an old DOS-based system.

Radraft solves the problems associated with less than ideal geometry from imported CAD files, converting them into fully defined machining programs. The software examines the line and arc geometry and corrects problems such as gaps in profiles invisible to the naked eye but sufficient to stop a profiling machine. This functionality is key to FiFab responding to customer requirements quickly and cost effectively.

The company's impressive machine set-up includes two Trumpf TC500's, CNC lathes, vertical machining centres and a Trumpf TLC L2530 laser. Supported by Radan's Radpunch system, FiFab has tremendous flexibility and capability to consistently improve quality and service across the whole operation.

"Radpunch speeds up the process from start up engineering through to punching and improves our efficiency and accuracy. We have increased output dramatically – typically, a job that used to take us four hours is now completed in just 30 minutes," said Dougie Smith, Engineering Manager.

RadbendCNC has allowed FiFab to import customer models of sheet metal parts and assemblies and unfold them accurately. Offline programming and simulation improves first-off reliability while the collision detection feature greatly reduces expensive errors.

"With many of our customers involved in high tech industries such as aero-

space, telecoms and medical equipment, Radan gives us the flexibility and reliability to provide innovative solutions for a broad range of requirements," says Smith. "Furthermore, working with expensive materials such as aerospace-grade titanium, our ability to maximise material utilisation and automate nesting allows us to streamline production and keep our costs down – savings we can then pass on to the customer."

Radview enables the drawings to be viewed by the quality and production departments, saving time and improving efficiency throughout the business by allowing feedback from users and increasing overall control.

Continuous investment in world-class equipment has resulted in FiFabs' steady business growth, allowing it to compete successfully against low cost manufacturers in the Far East. This has led to the more recent purchase of Edgecam's system, to extend FiFab's precision machining capability to meet the exacting demands of customers in the hydraulics, telecoms, oil, aerospace and defence markets.

"Edgecam allows us to make 3D models and tool up our lathes and milling machines," says Smith. "We chose this package following endorsements from other users, which were verified by demonstrations of its 3D modelling capability. The process is faster and more accurate – and quite simply the best tool to enable the engineering manager to do his job.

"We employ a rigorous training programme to ensure our workforce is experienced in every aspect of programming our CNC turning and machining centres. With the support of advanced software systems such as Edgecam and Radan, we can ensure that our commitments to customers are met every time."

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Lantek brings Expert III and the latest version of Expert II to MACH

Lantek will be launching Expert II V27, the latest release of its sheet metal CAM software and demonstrating Expert III, its popular sheet metal job management system, at MACH 2008.

Expert II V27 includes a host of important changes, including a new interface which eases manipulation and viewing of nests through the nesting explorer menu, as well as providing floating, dockable panels which give information and control over the nesting process.

The nesting capabilities have also been upgraded in Version 27. Colour coding eases part identification and improvements to the dragging of nested parts provide collision avoidance, ensuring that the resulting nest is valid. Expert II can now generate CNC code for several different machines simultaneously from one nest, allowing companies to maximise machine utilisation through last minute production cycle. Other improvements include manual multi torch nesting, handling of the Xp axis on Trumpf machines and new algorithms for remnant destruction on punching machines.

Lantek has introduced a completely new module for manufacturing mosaic patterns, which segregates materials into different types, so that these can be nested together. Expert II V27 also provides new functionality for lead-ins, and loops for profiling operations, and has speeded up and improved the cutting of parts with a large number of holes.

Expert III, Lantek's dedicated job management system, has been designed to suit the needs of sheet metal manufacturers. Starting with the quotation, Expert III can import CAD data or parts can be drawn directly in the system. Nesting groups the components as economically as possible on the sheet, and automatic cut length calculations and material cost data combine to produce an accurate cost per part. Shop floor documentation is automatically generated from the Expert III quotation, and feedback from the factory keeps managers up to date with the status of each job. The software also generates delivery notes and invoices, and interfaces with accounting packages, achieving substantial savings in administrative effort.

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Radan 08 offers more productivity and material utilisation improvements

Radan 08 is the latest version of Radan Computational's CAD/CAM software for sheet metal applications. It incorporates new functionality to maximise material utilisation and reduce cycle times.

Windows Vista compatible, Radan 08 upgrades and improvements include support for the latest 3D CAD file translators (adding functions such as material thickness auto detect and joggle support for RadbendCNC), improved handling of partly used sheets and offcuts and increased efficiency when producing NC programs for punching and profiling machines.

Radan has a policy of continued development of its software, as product manager Olaf Körner comments: "we want to ensure that our customers can benefit from maximised productivity."

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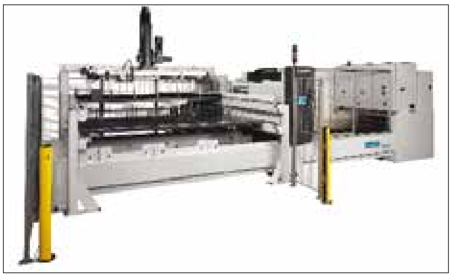
Flatbed cutting

LVD focuses on cost-effective automation at MACH 2008

LVD has cost-effective automation and integrated sheet metalworking solutions as its theme for MACH 2008.



Making its world debut the new LVD RoboCell automated robotic bending cell offers affordable automated bending with the combination of LVD's extensive press brake bending technology and Kuka robotic material handling together with integrated offline LVD CADMAN® software. Competitively priced against other robotic bending cells in the market RoboCell is easy to operate and program and is ideal for bending small to medium sized components. Flexible and intuitive RoboCell enables the operator to move from 'Art to Part' faster and with less interventions than other conventional robotic bending cells.

Complementing the new RoboCell the LVD Orion 3015 plus CNC laser cutting machine complete with automated autoload unit makes its UK debut. Ideally suited for subcontractors or OEM's that require a compact and value minded automated laser cutting solution, the Orion 3015 Plus Autoload is robust, reliable and compact.

LVD will also exhibit its leading CADMAN® offline software for bending, punching, and laser cutting, providing customers with the fastest route from 'Art to Part'.

"Affordable mid-level automation is increasingly important for sheet metalworking companies these days. The balance of 'should you automate or should you add labour' is an on going struggle for most sheet metalworking companies," said Chris Phillips, Managing Director of LVD. "We look forward to demonstrating how we can provide an affordable and cost-effective automated solution for the sheet metalworking shop."

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MEMBERS' NEWS

Bystronic - Latest technology on show
Bystronic UK Limited, one of the leading suppliers of sheet metal working equipment, will be exhibiting a wide range of equipment from its extensive portfolio of products at MACH 2008 including a world first and four other products previously unseen at an exhibition in the UK, two of which were launched as recently as late 2007.

Two laser systems will feature on the stand. The highlight is the ByVention laser cutting system, which will be presented to the trade visitors for the first time with a 4.4 kW laser source. Jobs can be processed faster and more cost effectively and the ByVention is almost as flexible as a high-end system yet considerably less expensive.

A major characteristic of the ByVention is its compact design which makes it the smallest laser cutting machine for standard-sized metal sheets. The machine requires just 6000 x 6000 mm (2.2 kW) or 6400 x 6000 mm (4.4 kW) of floor space. The control cabinet and the system's laser source are integrated in the machine frame and form a single unit. Additionally, the cooling unit and the used air filter have been combined in a compact, powerful unit.

Minimum training time is needed to use the ByVention as the machine is extremely simple to operate, by selecting predefined programs and cutting parameters using a touch screen.

With its innovative and clever material flow concept, ByVention guarantees immediate availability of the cut parts as well as exemplary flexibility when using various sizes of material and partly cut sheets. Cut parts are continuously and automatically transported from the cutting area and are immediately available to the user even during the cutting process. The removal area is fully accessible; making removal of cut parts simple and convenient.

The machine is offered at a fixed price with the cost including the Bysoft CAD/CAM software package, commissioning and basic training as well as the two year warranty and preventive maintenance. Thanks to the "everything included" concept, the customer knows exactly what the investment cost is.

A Byspeed 3015 laser cutting machine 5.2 kW laser source and a ByTrans automatic load/unload system will also be represented on the stand. The new ByTrans was launched last autumn and has been specifically designed for those companies that produce predominately medium to large size batches with a limited selection of raw materials. It is a portal solution providing vibration free handling of the cut sheets and the choice of model is dependent on individual requirements and space constraints. Production is said to increase by up to 50% when a laser is equipped with ByTrans with typically an extra machine investment of only 20%.

The ByJet Pro, launched at the end of last year, is Bystronic's latest waterjet cutting system. The machine is encapsulated for a cleaner and low-noise working environment and the new ergonomically designed shuttle table maximizes machine productivity. The system on show will have four independently driven slim cutting heads. It is claimed that, equipped with a shuttle table, positioning/cutting speeds and axes dynamics, it is able to produce up to five times as many parts per unit time.

Additionally, the efficient programming software, Bysoft CAD/CAM, and the control and monitoring of the cutting processes by ByVision, ensure that non-productive time and material usage are kept to a minimum.

Two new press brakes will be on show. The Bystronic Beyeler Xpert press brake, launched at the end of 2007, is said to deliver the highest repetition accuracy on the market. This machine features an extensive and expandable database which is available at the touch of a button. The control panel, with its intuitive user guidance, allows for ease of programming and operation.

Pressure reference (PR) bending technology, with hydraulic-dynamic crowning, continuous compensation of the side frame deflection, pressure control and protection of the tools against overload ensures maximum angle accuracy to satisfy the highest of bending demands.

In addition a Bystronic AFM EP 31-100 press brake with a bending length of 3150 mm and a press capacity of 100 tonnes will be on show. The machine provides an economical and flexible press braking solution requiring minimal set-up and programming times. With its 2D visualisation of the bending cycle and hydraulic crowning system the AFM EP range is the perfect introduction into CNC press braking.

There will also be a software forum where the range of Bystronic software will be demonstrated. At previous exhibitions this has attracted great interest from visitors.

In addition to its own range of products, Bystronic UK Limited is a supplier of the Pullmax range of punching machines and the latest Pullmax 520 punching machine, equipped with automatic load/unload facility for unmanned production will be on show.

Commenting on the company's presence at MACH 2008 Bystronic UK Limited's managing director Dave Larcombe said: "This exhibition is going to be exciting for Bystronic and visitors to the stand with so many new products on show. The message we are conveying is that Bystronic offers an optimal solution for every manufacturing application.

Bystronic is offering a number of fixed price and special price package deals to visitors to the stand. "This pricing system was introduced with the launch of ByVention and has proved popular amongst customers," said Dave. "The pricing includes delivery, assembly, start-up and training, software, maintenance contract and in the case of press brakes, standard tooling."

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Case Study

A cutting edge for Stevens & Carlotti

Life in the subcontract metalworking sector has never been easy. But as Kent-based Stevens & Carlotti has shown, investment in high capability CNC production technology can prove decisive in competing against low wage economies in Eastern Europe and Asia.

Established 40 years ago, Stevens & Carlotti has grown to become one of Kent's largest sheet metal fabricating companies. It has occupied its present site in Sandwich for more than 10 years and, with 75 employees, provides a comprehensive array of cutting, punching, folding, machining, assembly and paint shop facilities. Its products range from simple brackets and assemblies – in up to 25 mm thick mild steel and 8 mm thick stainless steel – to complete control panels, fuel tanks and canopies for customers in industries as diverse as power generation, pump manufacture and aircraft ground support equipment.

"Our wide range of services has enabled us to establish a 'complete job' mentality, both with our customers and workforce," says director Marco Carlotti. "We undertake virtually everything in-house to maintain greater control over quality and delivery lead times on our orders."

"We were early adopters of NC technology," Carlotti explains. "We installed our first computer controlled turret punches more than 25 years ago. Today, these are augmented by automated presses and folding machines."

Subcontracted

Until 10 years ago, all of Stevens & Carlotti's laser cutting requirements were subcontracted out. But in 1998, with the demand for profiling work growing, the company purchased a manually-fed 2 kW laser machine. A year later a second machine was added.

Equipped with a shuttle table loading and unloading system, the second machine represented the company's first steps in work handling automation. But as its profiling requirements continued to expand, Stevens & Carlotti looked again at ways of increasing productivity and throughput.

"As part of my search, I visited Prima's stand at MACH 2004 to check out the capabilities of its Platino machine," says Carlotti. "I was immediately impressed by its speed and accuracy, as well as its ability to be equipped with a series of work handling solutions.

"I anticipated purchasing another shuttle fed machine. But after evaluating the Platino's price/performance, low maintenance requirements and compact footprint against competitive equipment, we selected a 4 kW Prima machine, complete with 10-storey TowerServer automated work handling system capable of 'lights out' operation."

The ability to extend unmanned running beyond the normal working day offered significant cost benefits. Yet it took a while – and the installation of a webcam monitoring system so that Mr Carlotti could check the status of the machine from home – to build confidence that the Prima installation really would run for hour after hour without attention!

"It transformed our laser cutting capabilities – literally overnight. We can load the TowerServer with up to 30 tonnes of raw material, program the machine to produce a variety of jobs in different material specs and gauges, press the start button and walk away," says Carlotti. "The machine will simply continue to run until it has completed all of its jobs, or it runs out of material.

"I estimate that the shorter cycle times of the Prima machine, combined with its automated work handling system, have resulted in a 10-fold increase in productivity over the previous manually fed lasers we had on site."

Replaced

Within a year Stevens & Carlotti installed one of Prima's latest CompactServer units. A key benefit of this work handling solution is that it has been designed to both fit above and integrate with the laser machine's pallet changer without requiring any additional floor space. It is suitable for sheets up to 1500 mm x 3000 mm and features two shelves, each with a 3000 kg payload and a maximum raw or finished material stack height of 150 mm.

Like Stevens & Carlotti's previous Platino/TowerServer combination, the CompactServer equipped machine also runs under 'lights out' conditions if required.

"Although it doesn't have the capacity and sophistication of the Tower unit, the CompactServer does have the merit of being extremely robust and simple to use," Carlotti adds. "Crucially, it also has the benefit of fitting under our overhead crane, which eventually became an important factor in its selection."

Carlotti is quick to acknowledge the contribution made by the Prima laser equipment to his company's ongoing success. Its work handling systems mirror other investments made throughout the company – in automated paint plant, robotic welding and latest generation press brakes, for example – which are all regarded as essential for maintaining competitiveness, particularly against suppliers from Eastern Europe or further afield in Asia.

In addition to automating the company's manufacturing facilities, Stevens & Carlotti's is looking to update and streamline a number of its commercial systems. "New production control software is already in hand," says Carlotti. "We're also working smarter in other areas too – such as the use of common blanked parts on a number of jobs.

"Many of our contracts are for repeat work and although batch quantities are not very large – typically between 30 and 100 units – the ability to respond quickly and flexibly to customers' needs can often make the difference between winning or losing the business.

"Technology like Prima's high speed laser cutting and work handling systems will remain at the heart of our capabilities as we aim to expand our operations further during the next two years."

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MEMBERS' NEWS

Prima demonstrates automated laser cutting at MACH 2008

The speed, accuracy and productivity benefits of Prima Industrie's Platino laser cutting and CompactServer work handling technology will be demonstrated at MACH 2008.

Available with 2.5, 3.0, 4.0 and 5.0 kW heads and work areas of 3000 x 1500 mm or 4000 x 2000 mm, Platino laser cutters achieve cutting speeds of 140 m/min and head acceleration of 12 m/s^2, making them ideal for rapidly profiling a wide range of materials up to 25 mm thick mild steel.

The Platino's high dynamics are backed by exceptional precision – achieved through a fixed workpiece design and the use of advanced flying optics. As a result, the machine will consistently maintain a positional accuracy and repeatability of 0.03 mm across the entire work area. Its productivity and performance are also enhanced by off-line programming capabilities, optional nesting software and an in-built anti-collision safety device.

Suitable for flat sheet or the processing of round, square or rectangular tube – with zero changeover time – the Platino has proved to be equally cost-effective for short batch or extended production runs, with more than 1000 machines sold to date worldwide.

The equipment's versatility and productivity are further enhanced by a series of advanced work handling solutions. Prima's presentation at MACH will feature the company's CompactServer system, which enables Platino, Syncrono and Domino series machines to be operated as independent, unmanned manufacturing cells.

Equally suitable for OEM and sub-contract manufacturers, the CompactServer is designed to integrate with the laser cutter's pallet changer to provide highly efficient automatic operation, even under 'lights out' conditions.

With all components fitting above the machine's pallet changer, the new CompactServer requires no additional floor space. It is available as a factory-supplied equipment option or can be quickly and simply retrofitted to existing installations without the need for floor reinforcement or special foundations.

In operation, the new unit uses vacuum cup grippers to transfer unprocessed sheets to the pallet changer during the machine's cutting cycle – enabling downtime during the load/unload sequence to be minimised. The CompactServer is controlled directly by the machine's CNC system and incorporates a wealth of safety, referencing, sheet separation and measuring features to ensure trouble-free operation over an extended service life.

Suitable for standard sheet sizes up to 1500 mm x 3000 mm and up to 20 mm thick, the CompactServer offers a maximum single shelf payload of 3000 kg, with a maximum raw or finished material stack height of 150 mm. In addition, each of the unit's two shelves can be replaced by guide-mounted motorised pallets to allow stack handling by a bridge crane.

"Lights out operation allows customers to dramatically increase their competitiveness, particularly against suppliers from low labour rate economies," says Prima UK's managing director, Joe Attuoni. "The Platino's versatility not only allows them to produce high quality profiled products with minimal operator input, it also enables them to meet demanding delivery lead times that simply could not be achieved by sourcing overseas."

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LVD introduces the Orion 4020

LVD has introduced the Orion 4020 as an expansion to its Orion Series CO_2 Laser Cutting Systems for economical processing of large sheets up to 4 x 2 m.

Orion laser cutting systems feature a rigid, high-precision rack-and-pinion drive system for precise motion and position control, and permitting the machine to maintain high processing speeds without loss of cut quality.

Quick set-up

Orion 4020 employs a simple three mirrors beam delivery system for easy alignment and a stable beam path.

The standard laser cutting head accommodates a 5" or 7.5" quick-change water-cooled lens, which can be easily installed or exchanged using a self-centring system. Lens calibration is programmable and quick to achieve.

For ease in set-up and loading, the machine table is positioned at a comfortable working height and offers full access and visibility on three sides.

Automatic cutting gas selection and automatic cutting gas pressure control with servo valve are other standard features that further simplify machine set-up and operation.

Consistent cut quality

Orion 4020 is equipped with a high-pressure cutting head that produces exceptionally clean cuts. A crash-protection system protects the head from damage after collision with the workpiece.

A total power control feature automatically adjusts the laser power in relation to the cutting speed, ensuring an optimal cut at every contour width and minimizing the heat-affected zone. The machine's edge function feature processes sharp corners cleanly, particularly in thicker materials.

Integrated laser & CNC control

Orion 4020 employs the GE Fanuc RF excited fast axial flow CO_2 laser. The laser, CNC control, drives and motors are fully integrated, providing superior processing speed, high reliability, and low operating and maintenance costs.

The integrated GE Fanuc control provides excellent reproduction of programmed contours, producing acute angles at high speed. The laser power is matched to the vectorial speeds to achieve a constant cut width and a small heat-affected zone.

'PLUS' version

The Orion 4020plus provides automatic focal positioning and greater process control functionality in addition to all standard features found on the Orion standard series. Optional CADMAN-L 3D offline programming software provides a comprehensive laser-cutting CAM package.

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Evenwood Industries: re-investing in Trumpf

Evenwood Industries Ltd has continued its recent investment programme with the purchase of another brand new TruLaser 3530 2D laser cutting system from Trumpf.

This decision was made in response to the growing demand from its customer base and will allow the company to ensure that it is able to meet future demand, as well as providing capacity to take advantage of new business opportunities.

"We have four lasers currently, and this new machine mirrors one we bought last year," says Stewart Maudsley, Joint Managing Director. "The new generation of machines from Trumpf has provided us with the very latest technology available. With their better cutting speeds and sheet loading systems, the new machines give us extra flexibility to meet our customer demands going forward.

"We now have two identical machines sitting side-by-side," he continues. "Together they can perform lights-out operations and this means we can eliminate our requirement for a night-shift, with obvious benefits. De-nesting is done off-line the following morning and the parts can then flow efficiently through the plant during the day."

An additional fast, 300mm travel Xp-axis is mounted on the Y-axis gantry of the TruLaser 3530. This superimposes a high speed 300 by 1500 mm cutting zone on top of the normal X-axis travel. The effects are particularly marked when machining sheets up to 3mm thick with many positioning points/contours.

"We have an excellent working arrangement with Trumpf," concludes Mr Maudsley. "Regular investment is critical to a company such as Evenwood Industries. The new TruLaser 3530 will become an essential part of our manufacturing process, significantly improving our reliability, quality and efficiency."

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SuperModulation™ cutting with a CW Nd: YAG laser

Mohammed Naeem and John Chinn

GSI Group's proprietary SuperModulation™ (SM) technique involves storing some energy in a laser's power supply during the off time of the laser or when it is operating below its rated power, and then quickly sending this stored energy to the laser's lamps for extra bursts of peak power. In this way the output of GSI Group's high average power (400W-2000W) CW lasers can be provided as a square wave, sine wave (or some other repetitive shape) with peak powers up to 200% of the laser's mean power while also providing full mean power. [see Issue 31, p25 June 2003*].

The momentary increase in peak power provided by SM produces some exceptional results when cutting of a range of materials including of zinc-coated steel and aluminium alloys used in the automotive industry. The improvements can for the most part be categorized as:

- Higher cutting speed
- Cutting at acute surface angles
- Reduced dross, better edge quality

Cutting of zinc-coated steels

Square wave modulation increases the efficiency of the cutting process by creating more absorption and makes for a straighter burn-front that is closer to being perpendicular to the surface. The result in much higher cutting speeds than can be achieved with CW cutting, especially for thicknesses below 2 mm.

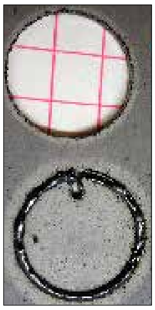

Fig 1. Cutting 1.5 mm zinc-coated steel at 3.8 m/min with 1000W: (top) Super Modulated; (bottom) CW

The benefit over CW cutting is even greater for zinc-coated material, as shown in figure 1, which compares the backside of a hole cut in the same material. Modulation reduces uncontrolled burning whilst retaining process speed and stability.

Cutting at Acute Angles to the Surface

When cutting tubes or any 3-D workpiece, many laser cuts must occur at angles acute to the surface. These are the areas where cut quality can really suffer due to what is often termed "oxygen over burn." A typical example of this is hydroformed tubes for automotive applications (figure 2).

Fig 2: Hydroformed tube cutting

Greater penetration is required when cutting off-normal, requiring more laser power or a reduction in speed. In addition the flow of oxygen into the kerf is less efficient and can be erratic. And while the robot may be moving quickly the surface speed of the laser focus at the cut may be relatively slow. In these situations the oxygen can ignite iron alloys to produce wide blowouts or a very rough surface finish. SM is very effective in such situations. Reducing the average power whilst maintaining a high peak power virtually eliminates over-burning and produces a more predictable cut edge quality.

Aluminium Alloys

When cutting materials such as Aluminium a large fraction of the incident laser energy is reflected from the surface of the part. For such materials SM produces dramatic improvements in cut speed and thickness capability and the dross level on aluminium alloy cuts are always reduced with square wave super modulation.

Piercing

Almost all cuts begin with piercing i.e. the creation of a hole through the workpiece to be cut. When cutting with standard high power CW lasers, piercing is carried out with high average power which creates excessive spatter, contaminating the lens and the nozzle tip. With SM producing a square wave output, blow-outs can be eliminated, the diameter in small holes (d<10 mm) can be better controlled and there is less slag around the hole entrance

In summary, SuperModulation™ is a significant new processing technique that can produce real benefits during welding and cutting. Cutting advantages include: improved cut quality in thick sections; reduced dross; eliminating uncontrolled burning whilst retaining process speed and stability; improved off-normal cutting; improved piercing speed and quality

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Case Study

Duright Engineering's CNC tube laser machines impart significant business benefits

A huge volume of tube is consumed by UK manufacturing every year. And although annual consumption has remained fairly constant over the last four years, the way tube is processed has changed dramatically, with a six-fold increase in the volume of tube processed by tube laser machines.

Judging by the experience of Duright Engineering, a West Midlands-based sub-contractor, the decision to move on from the traditional multi-machine approach can be a hard call to make. Although a well-established business with a 30-year track record, the installation of its first BLM Adige tube laser added 30% to turnover in the machine's first year of operation. And by the time a second, more powerful, BLM Adige tube laser was installed at the end of 2005 turnover had more than doubled over a three year period, although the number of people employed in the business had not increased. In 2007, with both its existing tube lasers working 24/7, a third BLM Adige tube laser was installed in response to the growing demand.

Ross Taylor, Managing Director, says Duright Engineering can produce laser profiled tube prototypes in minutes rather than weeks or months

"The production requirements of many UK companies do not justify the purchase of a tube laser," says Ross Taylor, Duright's Managing Director, "but continuing with the high labour costs of traditional multiple machine processes is making it difficult to compete against cheap labour economies. Subcontracting the work provides an attractive alternative and has significantly expanded our customer base. As well as competing for volume production we can also produce prototypes and re-designs in minutes rather than weeks or months, because it simply involves programming the tube lasers rather than the production of hard tooling."

Ross Taylor does, however, point out that investment in new technology is definitely a chicken and egg situation. "When we first considered installing a CNC tube laser, we found that without the machine in place customers would not talk about the type of work we might do for them on it. We were initially unwilling to take the risk but eventually we did and it has paid off for Duright and for our customers, who now enjoy the benefits of laser technology without having to worry about the up-front cost."

Looking back, Ross acknowledges that the greater risk to Duright lay in not investing in laser technology. He says the decision to install the first tube laser "changed the nature of our business virtually overnight".

The fact that the laser cutting side of the Duright's business has grown so rapidly is evidence that customers are obtaining significant benefits. Consolidating separate manual operations into a single, continuous, non-contact cutting process equates to reductions in cycle times and direct labour costs, while eliminating the cumulative error that inevitably results from the traditional multi-machine approach. Then there are the savings to be had on handling, rework and reject components. However, the major attraction is that virtually any shape can be laser machined on both ends of a tube or along its length, with components completed in a single hit and on a fully-automated basis. This frees up valuable floor space by reducing work-in-progress and material inventory, and the accuracy and consistency of laser-cut parts has a very positive impact on subsequent welding, assembly and inspection times.

"We have a standard pricing policy based on the complexity of the work, whether it is 20 components or 20,000 components," says Ross Taylor. "A customer can come into the office with a drawing and within 20 minutes a finished component can be on the desk in front of him. Changes can be made and samples produced before there is any need to commit to volume production."

Ideally, Duright likes to be involved at the design stage because this can save customers money. "It is not unusual to visit a company and find that it is carrying out second operation work that could be done on our laser machines at very little additional cost. In fact, once customers appreciate fully what these tube lasers can do, they start saying 'here's another part you could do'…"

Although servicing customers across a wide range of industry sectors, the automotive industry accounts for around 75% of Duright's output. According to Ross Taylor, the only way to compete in this highly competitive global marketplace is by investing in technology to counter the labour cost advantage enjoyed by competitors in India, China and other low wage economies. Nearer home he claims that the quality aspect of laser cutting and profiling puts it ahead of traditional alternatives such as punching and pressing.

On this basis, he extends an open invitation to visit Duright and see what is on offer, adding that "when have been invited to supply laser cut components on a trial basis, customers have never returned to tube machined by traditional methods. For example, we quoted on one job and delivered a trial order for 2000 parts, after which we heard nothing for a couple of months until the customer 'phoned to place substantial batch orders. His welders had pointed out how much faster – in some case up to 60% faster – laser cut parts went through the welding process. Why? Because laser cut components fit right-first-time and every time, and, in this particular case, produced a 15 per cent productivity improvement at the welding stage."

When Ross Taylor took charge of Duright on his father's retirement he was determined to make the company stand out from the crowd. "For more than half our customer base we now source material and provide full traceability of the machined component with a 100% inspection capability," he says. "Having fully embraced CNC laser cutting and profiling, our intention is to offer even more value by way of tube bending and robot welding, because the trend is for OEMs to out-source as many components as possible and to buy in completed sub-assemblies whenever possible."

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Welding

First ultra-fine cutting and welding system in the UK

Trumpf UK has just secured a highly significant order, to supply the UK's first TruFiber 300 solid state, ultra-fine cutting and welding laser. The laser will be used in conjunction with a Trumpf TruLaser Cell 3010 and the latest 3D version of the Programmable Focusing Optic (PFO). This approach gives high flexibility in terms of focus point manipulation, process capacity and speed.

The order was won against stiff competition. The deciding factors were Trumpf's ability to provide the elements necessary for beam guidance and focusing in combination with its machine tool know-how. The resultant cell is capable of filigree cutting and high aspect ratio welding.

The exceptionally high beam quality of the TruFiber 300 meets the customer's need for a process that ensures minimal thermal effect on exotic materials. The focal diameter of the beam can be as small as 10µm.

As well as being prestigious this order also puts Trumpf firmly in the ultra-fine market. The system is destined for initial use in R&D with a later transfer of its technology for production use. Further potential applications for the TruFiber 300 are in electronic and medical device manufacturing.

"The laser technology involved makes this a very exciting project," explained General Sales Manager, Gerry Jones. "But of greater significance perhaps is that it will open-up doors to new markets for Trumpf in the UK."

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Case Study

MedicAlert develops unique laser welding technique

Rofin-Baasel UK recently supplied a manual laser welding system, the StarWeld Performance, to the MedicAlert Foundation. MedicAlert is a registered charity (celebrating their 40th anniversary this year), the only non-profit making registered charity providing life-saving identification jewellery for individuals with hidden medical conditions and allergies. MedicAlert jewellery 'Emblems' are engraved with the owner's medical condition or allergy, a unique ID number and 24 hour emergency phone number.

Specifically, MedicAlert was looking to weld silver jump rings to attach their emblem bracelets and necklets and needed a timesaving alternative to traditional silver soldering. After experimenting with the laser welder from Rofin-Baasel they found they could achieve a better result, with higher throughput and requiring less finishing.

Over the past months the MedicAlert production team has been honing the technique of welding silver jump rings and has reduced the time per jump ring from five minutes to a matter of seconds. The ring is now welded with a single high energy pulse giving an excellent finish.

Rofin laser spot welders are highly versatile and pulse shaping has been one of the major contributing factors to the success of the One Shot Programme. Other key factors were the high pulse energy of the Performance and the patented Sweet Spot Resonator®.

"The development of the One Shot Programme using the Rofin Starweld Performance Laser has made the welding of jump rings on our Silver Bracelets effortless", said Alex Dayton, Head of Laser Welding Technologies at the MedicAlert Foundation.

MedicAlert are no strangers to laser processing as they had previously purchased two laser engraving machines from Rofin-Baasel to personalize the ID data on their emblems.

Laser Technology for Medical Device Manufacturing

The quality and performance expectations of the medical device manufacturing industry are exceptionally high and the range of applications is wide and varied. Examples of suitable welding, cutting and marking systems were included on the Rofin stand at the recent MEDTEC 2008 Exhibition.

Micro and Precision Welding

StarWeld Select is an ergonomically designed and fully integrated laser welding system. The system includes four high precision axes which can be controlled manually by use of a joystick or operated under full CNC control. This concept provides a high degree of flexibility for welding applications on medical device components. A flow controlled exhaust system with HEPA filters is also incorporated and a closed loop cooling system enables continuous operation.

Laser Marking on Medical Components

The CombiLine Flexible workstation is designed for manual loading and unloading of components and for production of small and medium batch sizes.

The system is used widely for marking operations on medical instruments and implants. A wide selection of Rofin laser sources (lamp and diode-pumped lasers, fibre and CO_2 lasers) are available.

Laser Cutting & Perforation of Polymers

Rofin offer solutions for cutting and perforation applications within the medical device and products markets.

A wide range of CO_2 laser systems combined with high speed scanner heads or X,Y axes provide solutions for cutting and perforation of filter materials, biofilms, plasters etc.

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MEMBERS' NEWS

Drilling

Rofin's StarScribe makes selective weakening and perforation easy

Packaging is a crucial factor within the consumer goods industry. Difficulties in opening packages are surprisingly common causing spills and sometimes even minor injuries. The opening process often requires too much initial force and can be hard to control due to a poor or inconsistent quality of mechanically created opening lines.

Easy opening

Rofin offers a consistent and reliable solution to a wide range of scribing and perforation applications. Additionally, by taking advantage of the different light absorption properties of polymers (e.g. PET, PP, PE) at the CO_2 laser wavelength the laser can scribe a particular film layer(s) whilst leaving intact other layers that are required to protect the product from light and humidity; and the scribe lines can be freeform, providing new inspiration and ideas for packaging designers.

The opening lines are clearly visible and opening the package therefore becomes much easier for the consumer. Even with strong packaging materials such as PE/PE combinations, Rofin lasers can create perforation lines which can have as few as 5 holes /cm up to as many as 50 holes/cm for easy tear-off applications. From the perspective of the product manufacturer laser scribing is a contact and wear-free process which guarantees consistent quality and high process reliability.

Perfect Perforations

Rofin lasers are also used to perforate product packaging. Perforations (below) are used to increase the shelf life of perishables and to control pressure changes in packages for cooking in microwave ovens. Laser perforation lines are also be used for easy-tear-off applications.

For package perforation applications Rofin lasers offer significant advantages

over conventional processes such as needles or flame. Pulsed CO_2 lasers are used to perforate all layers of the packaging material, micro-melting the hole edges to prevent the formation of micro-fissures which could undermine the packaging integrity.

StarScribe family of lasers

Rofin offers the StarScribe WD for scribing lines in the web direction of web-based material. Laser power is distributed to a number of individual focusing heads, each laser beam scribing one line into the web. Where cross web processing is needed (e.g. on bags and pouches) the Rofin StarScribe CW (cross web) uses fast scanner heads driven by galvanometer motors to deflect the beam across multiple axes. The control software enables the beam to create freeform scribing paths such as waves or squares etc., once again opening up new possibilities for packaging designers to make their products even more usable, more attractive and unique.

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Marking

Laser Lines Ltd announces the New Ulyxe Laser Marking System

Laser Lines Ltd is pleased to launch the new "Ulyxe" laser marking system from Laservall. Suitable for direct part marking on most materials, Ulyxe is probably the smallest diode pumped laser marker system on the market. Based on an all-in-one design concept, the laser source, scanning head, digital controls and monitoring functions are all integrated in a single compact housing. A robust polyurethane case with user-friendly touch screen interface completes the package. Ulyxe is extremely simple and easy to integrate with production lines or turnkey systems, only a power supply and PC with USB connection are required. Once installed the system can operate for thousands of hours without maintenance.

The Ulyxe software editor allows the user to create marking files that can include text, graphics, barcodes and 2D data matrix codes. Advanced functionality provides for automatic serial numbering, batch coding and date/time stamping operations. Materials that can be laser marked with Ulyxe systems include virtually all metals (aluminium, titanium, steels, Nitinol, etc) and plastics (ABS, nylon, PES, PVC, polycarbonate and many others) with excellent results.

The benefits of laser marking include: permanent indelible marks, low running costs, high speed, complete flexibility through total software control, no inks, solvents or consumables, simple installation and low running costs, non-contact process means no wearing parts, high resolution

Laser Lines fully equipped Applications Laboratory can perform feasibility trials and sample marking on your parts. Ulyxe provides high quality results at an economical price.

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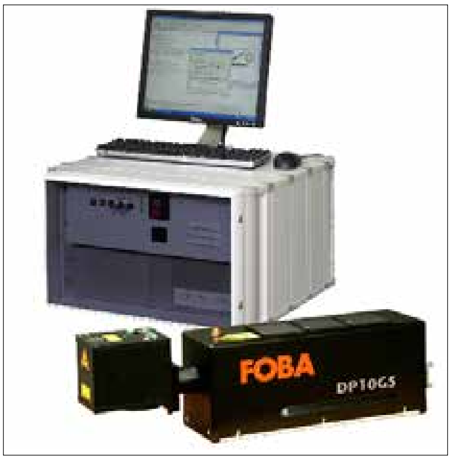
Kaye-Dee Marking Solutions exhibit FOBA systems at MACH 2008



FOBA's new IMP "Intelligent Mark Positioning" system together with the new high precision Vanadate DP10GS laser will be on show at the Kaye-Dee stand at MACH 2008.

The patented IMP offers a improving marking precision with its "through the lens vision" thereby avoiding scrap, reducing setup cost, improving quality and increasing product throughput. IMP's success is mainly attributed to its ability to improve marking and engraving processes. Its unique capabilities to provide quick, on line part verification and accurate mark placement, have made IMP the product choice for the automotive, the medical and coin industries.

The Vanadate DP10GS is ideal for use when optimal laser beam quality and performance are required. The system is especially suitable in the field of ID card and passport personalization, in particular for the marking of ID cards with grey scale images, as well as for lacquer removal to create day and night design. Advantages include excellent laser beam quality and pulse-to-pulse stability, single phase mains connection, no cooling water and little servicing with long working life diodes.

As UK and Ireland distributors for FOBA, Kaye-Dee Marking Solutions have over 30 years experience of supplying, supporting and servicing both pad printing equipment and laser marking systems. They have over 20 staff and on site manufacturing. They also distribute the high precision Swiss produced Teca-Print pad printers and quality printing inks from Ruco, Germany.

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Laser marking system from Rofin

The EasyMark II system from Rofin provides access to areas of laser marking which were once seen as the domain of laser specialists only.

One of the most compact laser marking systems on the market, EasyMark II operates from a conventional 240 volt power socket, does not require any external cooling, and has a Class 1 safety rating thanks to the fully enclosed marking area.

Versatile in operation

EasyMark II uses a diode-pumped Nd:YVO4 laser source and is capable of marking a wide range of materials including metal and plastic components. Optional linear and rotary axes allow marking on both flat and curved surfaces and can be easily achieved with a minimum of operator input. The system has a marking field of 120 mm x 120 mm and can accommodate components of 450 mm x 150 mm x 200 mm in size. Its self contained and compact desktop configuration means that the unit is easily portable, giving the user more freedom in the choice of location and operation.

Simple to use

The Visual Laser Marker (VLM) Software from Rofin allows the layout, generation and transfer of the required marking data to be sent straight from the PC to the laser marker. Focusing and positioning aids ensure that the system can be easily operated following a short introduction and training course.

The EasyMark II system is suitable for medical device manufacture, tool manufacture, jewellery manufacturing, gift personalisation etc.

Marking on medical saw

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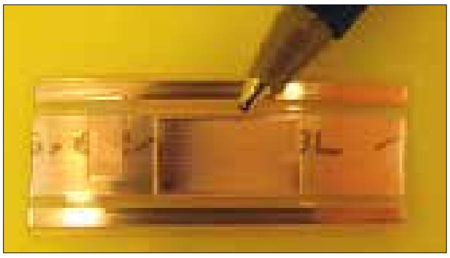
Ablating Polyethylene Cable Insulation

Extruded flat cable is becoming more popular throughout the automotive industry as manufacturers continue to add electronic devices and sensors to increase the safety and efficiency of modern automobiles. Flat cable is important to automotive designers because it allows them to position devices that require many conductors inside tight spaces such as doors, roofs, and even seats. Where traditional round cable diameters can range from 3.2 mm to 6.3 mm or greater, extruded flat cables with equal or greater wire cross-sections have typical thicknesses of only 0.38 mm.

In one such application, the requirement was to ablate the flat polyethylene (PE) insulation from specific locations on the cable without damaging the three copper conductors within.

Because copper is reflective to the 10.6 µm CO_2 wavelength, wire stripping in general is a perfect application for Synrad sealed CO_2 lasers. Careful selection of power and speed parameters ensures that the copper or surrounding insulation is not over-heated or damaged in any way.



A short length of PE flat cable insulation, ablated in the two areas shown

To complete the application, a Firestar t-Series laser was set-up and coupled to the new FH Flyer marking head. The Flyer head was fitted with a 125 mm high-power lens that provided a 180 µm spot over a mark field spanning 80 mm x 99 mm. Using the WinMark Pro Laser Marking software, two rectangular shapes (to be ablated) were precisely positioned. The laser power was set to 60 watts and a scanning velocity of 2.3 m/s. At these settings the 0.09 mm thick PE coating was removed—a total surface area of 99.32 mm^2 in 0.59 s. The results are shown in the picture above. The polyethylene insulation was completely vaporized, leaving a bare copper conductor with no debris, vapour, or thermal damage.

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Day and Night Design

How much of your attention does it take, and for how long, to find the right switch on your car radio? Thankfully, good ergonomic design makes for fast, safe operation of equipment within today's vehicles. "Day and Night" is the design concept used to make such controls easy to locate even in the dark,

<u>User-friendly car radio front panels</u>

Car radio front panels are injection moulded from transparent plastic. One side is sprayed, first with an undercoat of white paint and then with a top coat of black. Some of the black paint is then removed, so that letters and numbers appear white (see below).

This high-precision application to remove (ablate) micron thick layers of the black topcoat in the exact pattern of pre-programmed letters and symbols is achieved using a laser marking system. The result: white characters clearly and crisply defined against the black background. At night these characters are backlit for easy recognition.

The advantages of this production process are substantial. One European manufacturer has been using a Rofin marking system for many years: working three shifts per day, each laser system completes about 3,500 front panels. Changing the markings for a new product is a simple matter of entering new text or laser parameters at the computer keyboard or recalling a previous pattern from computer memory.

This laser marking process was the outcome of successful teamwork between Rofin applications engineers together with plastics and paint producers. New paint systems and computer software had to be developed. This technique requires paints which are highly opaque and fast-drying, so that the different paint layers do not mix. To stand up to the heavy wear on radio controls, the paint must also be highly durable. Customized, high-performance software, designed to handle extensive and special character sets, contributed significantly to the very high marking speeds and production rates.

<u>One laser, two marking heads</u>

Typical laser sources for this application are centred around 1064nm and include Nd:YAG, Nd YV04 and fibre lasers. The laser beam can be divided equally by a beam splitting mirror and directed simultaneously to two marking heads. And by using flat-field lenses with large (e.g. 230 mm diameter) marking fields, two radio panels to be marked simultaneously under each lens. Two galvanometer mirrors in each marking head precisely direct the laser beam at constant speed over the surface of the front panel, vaporizing the top layer of paint in the required patterns.

In addition to its flexibility, another significant advantage of this beam directing system is its compatibility with a high degree of automation in the manufacturing process. All operations can be computer controlled.

Laser markers can also be equipped and synchronized with automated handling systems to further enhance productivity. The laser systems installed at this customer's facility meet Class 1 laser safety requirements. This means that all laser energy is confined within the system enclosure. If the machine guarding for example, is opened, the laser system is shut down immediately. Vaporized paint particles are removed by a multi-stage air filtration system and during its routine operating cycle, the system produces no harmful particulates or hazardous emissions.

To further ensure safe operation, panels to be marked are fed to the marking stations on rotary indexers or linear indexing systems. The panels are held in position accurately by fixtures which are designed for easy loading and unloading. Whilst the laser is marking one set of articles, the operator removes finished panels and inserts new blanks, in a completely safe operating environment.

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MEMBERS' NEWS

The Trumpf stand at MACH 2008

Productivity with flexibility

Automation equals productivity, but all too often volume manufacture is only achieved at the expense of flexibility. And in today's highly competitive market both are critical factors.

The Trumpf stand will emphasise that there is no need to compromise. It will demonstrate the ability of its systems to accommodate changing production needs and still achieve quality parts at the lowest unit cost. Choices available for automation range from simple productivity gains from features such as automatic laser nozzle exchange through to all the elements necessary for full lights out production.

Degrees of automation

A range of Trumpf technologies will be represented at MACH 2008 – punching and forming, laser cutting, bending, laser welding and marking. Many of the machines featured will demonstrate different degrees of automation.

The single station punching or laser cutting head is a vital component of every Trumpf machine. This remains a unique feature and one that significantly reduces set-up and machining times. With the intelligent head system as a starting point Trumpf has the basis for lights out production.

In the field of 2D laser cutting for example the head works in tandem with another unique feature, automatic laser nozzle exchange. This makes it possible to process a variety of parts and materials using optimal cutting parameters, even during unmanned shifts.

Dependent on the machine model chosen, any sheet thickness from 1 – 25mm can be processed with the machine's single cutting head as the engineering beam guidance system automatically adapts to the material and adjusts the laser beam. Automatic nozzle changing will be demonstrated separately at MACH 2008 to highlight its significance.

2D precision laser cutting will be demonstrated at MACH 2008 by the TruLaser 2030. This larger format model is new to the UK and will be shown with the higher powered 3.2kW TruCoax laser that delivers exceptional beam quality. This compact machine has fully integrated load and unload and is designed for high productivity.

Fully automated bending

Turning the parts from the TruLaser or TruPunch machine into finished components will be the TruBend 5130 that is characterised by its short cycle times. Precise bending every time is assured by the Automatically Controlled Bending, a system that has potentially up to eight sensors. This press brake will be shown complete with BendMaster that will feed the machine blanks as well as sort and stack the finished parts.

BendMaster automatically selects a mechanical gripper for small parts or a vacuum gripper for larger ones. The TruBend and BendMaster are operated by a single control and jointly programmed by the dedicated TruTops Bend software.

Punching potential

Trumpf will also be emphasising another important point at MACH 2008 - don't dismiss punching! Thanks to continuous development punching is the quickest and cheapest method of producing many parts, especially those that require additional operations such as forming and tapping. The company's latest punching machine, the TruPunch 5000, will demonstrate this potential.

The high productivity of this machine has been achieved through faster processing and tool rotation, additional drives and faster acceleration thanks to lighter weight components. This has given the TruPunch 5000 a productivity boost of 15% on its predecessor. In common with all of the Trumpf high productivity machines this model can be specified with automation to suit the need.

Fine machining

The Trumpf stand at MACH 2008 will include equipment for marking and fine welding, including the TruMark Station 5000 which can perform a wide range of marking and microprocessing tasks on a range of metals, plastics and ceramics. Its compact design allows its easy integration into a production line and is also available with flow-through transfer allowing longer workpieces to be processed. Also on display will be the standalone TruLaser Station 5004, a compact and ergonomic workstation for deposition laser welding with wire. It represents a first in laser processing with the inclusion of an electronic stereomicroscope that allows quicker and easier set-up.

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Micromachining

Cutting It Fine With Lasers

Many fine cutting and micro machining applications can now be found across a diverse range of products and industries (especially within the medical and electronics sectors) that can only be satisfied using laser technology. The speed and productivity of laser cutting clearly exceeds the capabilities of traditional mechanical or chemical machining processes.

Rofin's StarCut Universal system has been designed to be a practical and ergonomic turnkey solution for fine cutting applications. It neatly integrates everything required for fine cutting applications into a standard machine. A large work envelope of 600mm x 300mm x 200mm combined with three high precision CNC axes provides flexibility and 50µ precision for fine laser cutting operations. Additional capability can be achieved by the use of an optional rotary axis enabling complex 3D geometries to be produced within the system.

StarCut Universal is available with a choice of laser sources, up to 300 W of power and frequencies up to 3,000Hz.

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Services

Job shop

Award Success RE Cooke

RE Cooke and Sons Ltd has won two major accolades in the annual Accelerate Supplier Awards in recognition for its excellence in the West Midlands' automotive industry supply chain. They secured the Small SME title and the accolade as the Best in Region for Staffordshire at these prestigious Awards in Birmingham.

RE Cook, which employs 48 people at its Stretton Business Park site in Burton-on-Trent, secured the Small SME title. A major contribution to this success was the company's progress since it moved into its purpose built £1.6million factory earlier this year. The judging panel, which featured representatives from the RAC and DTI, also singled out

RE Cooke Directors Harvey Cooke (left) and Bruce Cresswell with the SME award

RE Cooke’s plans for new products and investment in training requirements with the aim of meeting production needs and individual aspirations. The company operates a skills matrix that details changing processes, plans for new products and training requirements with the aim of meeting production needs and individual aspirations.

Accelerate Project Manager Rachel Eade said: “These awards have been a fantastic opportunity for the West Midlands to build on recent achievements and show the rest of the world that our industry is not only going to survive but lead the rest of the globe in product development and best in class manufacturing.”

RE Cooke Operations Director Bruce Cresswell added: “We are delighted with these two awards. They recognize the success of our work with BDS as part of the Accelerate programme and that our strategy of constantly examining the value and quality of our production processes to ensure a first class service to our customers is paying dividends.”

Celebrating Nautical Design

In other news, RE Cooke has completed a pioneering modern art sculpture which has been erected at the Old Royal Naval College in Greenwich as part of The London Design Festival.

The company was commissioned by celebrated designers Edward Barber and Jay Osgerby to turn their ideas into reality and manufactured ‘The Fluke’ – a 1.3 tonne sculpture inspired by the lobe of a whale’s tail and the palm of an anchor.

Jay Osgerby explained: “The Fluke celebrates the language of marine anatomy and nautical design engineering which is a long standing interest of us both. We are delighted with RE Cooke’s expertise in manufacturing this impressive 3 metre high by 4 metre wide sculpture from

8mm Cor-Ten steel plate.” RE Cooke Managing Director Harvey Cooke added: “Our move to a new factory this year and our investment in the latest laser cutting and paint shop equipment has enabled us to tackle this challenging but very exciting project.

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Science, Art and Technology at LAU

Lasers Are Us, a laser marking, cutting and engraving job shop based in South Wales and directed by Simon Lau, has been working in a collaboration organised by SATnet which links scientists, engineers and artists in Wales for novel innovation and technology transfer.

Out of 6 interdisciplinary SATnet projects, 2 were undertaken in conjunction with Lasers Are Us. The catalyst in both of these was a nanosecond pulsed UV solid state laser which has been configured to produce "prints" allowing text and images to be reproduced on various materials and products.

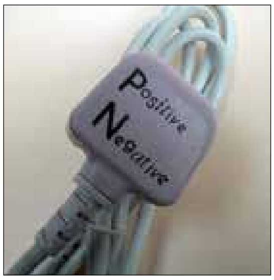
The Measure of All Things
by Craig Wood and Simon Lau
When the laser is configured for miniaturisation, the laser can "print" text or images in less than 1 square millimetre of area.

Wood saw the possibility of making the concepts connected to scale more explicit. In particular an opportunity to view and contemplate something truly enormous in terms of physical scale and concept, all within the confines of a single 1 mm speck. Hence, an image of the deepest Cosmos reduced to within 1 mm of space, viewed only via a microscope!

An exhibition of the artwork is on display at the Dynevor Centre attracting interest from an aesthetic and technical perspective but also raising fundamental questions regarding the connection of the micro and the macro and our uneasy relative position within.

Switched On, Plugged In
by Eilish O'Donohoe & Simon Lau
A project demonstrating the productive relationship that can ensue between industry and art. Using a UV pulsed solid state YAG

laser, everyday objects can be transformed from their mundane utility to an exciting product, from the mass produced item to the individual, sought-after iconic object. Here, the texts applied are based on a simple play of words, which contend with notions of excess in the use of electricity in our domestic lives. Extended both literally and metaphorically, these everyday citations are there to elicit a smile, a rueful glance and a nod of recognition.



SATnet is a Welsh Assembly Knowledge Exploitation Fund (KEF) network and research centre for science, arts and technology transfer and innovation based in the faculty of Art & Design at Swansea Metropolitan University under the guidance of Dr Karen Ingham.

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Research
NCLA to undertake research for Powerlase

National University of Ireland Galway (NUI Galway) has signed a contract with Powerlase to begin research into laser materials processing.

As part of this agreement, Powerlase will work with leading academics from the National Centre for Laser Applications (NCLA) to develop novel techniques for laser materials processing.

The NCLA was founded in Galway in the West of Ireland in 1989 and works with companies in a wide range of sectors including medical devices, electronics, precision engineering and aerospace. Powerlase is partnering with the NCLA to improve wider industry understanding of techniques in materials processing.

This agreement is the latest in a series of academic sign-ups for Powerlase, with its other research collaborations including work in EUV Lithography at the University of Central Florida (UCF) and University College Dublin (UCD), and a study of thin film patterning for flat panel display (FPD) manufacture at Osaka University.

Alan Conneely, centre manager at the NCLA, said: "The importance of a strong R&D base to Irish manufacturing industry has never been more critical. NCLA continues to help Irish industry to innovate new products and processes using laser technology. This partnership with Powerlase acknowledges the considerable reputation NCLA has established within the manufacturing community and underpins our ongoing efforts to bring the benefits of laser-based manufacturing to as wide an industrial base as possible."

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Bleak UK research outlook according to the Institute of Physics

Physics and astronomy in the UK is under threat and could face serious damage if the Science and Technology Facilities Council (STFC)'s Delivery Plan is not put on ice until the Wakeham Review has had time to report, according to the chief executive of the Institute of Physics (IOP).

The £80 million shortfall in STFC's budget has resulted in a delivery plan that will lead to job losses at universities and three leading research laboratories; a 25 per cent cut in university grants; and withdrawal from a number of high-profile programmes such as the International Linear Collider.

Dr. Robert Kirby-Harris, chief executive of IOP, said, "Funds must be provided to prevent damage being done before the Review has had time to report. A moratorium to put the cuts on hold must be established or we risk doing damage before the UK's scientific priorities are properly considered. We should not press ahead with a delivery plan that was produced in such a short timescale."

Because STFC has to meet a number of fixed financial commitments, such as international subscriptions, cuts have had to be concentrated in other budget areas. Consequently, the shortfall in funding has had a more serious effect on these areas, which include research grants to universities.

The AILU INTERVIEW

Trumpf

Interview with Hartmut Pannen

The new MD of Trumpf UK responds to questions sent in by AILU members

What are Trumpf's plans regarding laser sources for flat bed cutting machines?

Regardless of whether they use a disk, fibre or rod, solid-state lasers are a hot topic. However one thing that has remained clear to us is that the CO_2 laser continues to defend its position as the basis for an all-purpose cutting machine. This workhorse with up to 6 kW of output power can now cut steel from 0.5 to more than 30 mm thick.

This flexibility is vital for most manufacturers for whom ever-changing cutting patterns and short runs are typical of today's production. While CO_2 is able to cut thin and thick materials with equal cost efficiency the solid state alternative reaches its limits even at modest thicknesses of between three and five millimetres. As a result we see CO_2 as the preferred source for broad spectrum flat bed machining for some years to come.

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Have you any plans for introducing high power solid state laser sources?

Trumpf would not be doing its job as a technology leader if it did not offer a cutting system based on solid state technology. Introduced to the market in 1995, more than fifty systems have now been installed to date. This is a formidable share of the market if you assume a total European market of about 100 units. The buyers are those specialising in long production runs for thin sheet metal.

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What are your core strengths when compared to your competitors?

One area that is prime focus for us currently in the lead up to MACH 2008 is automation. All too often in today's manufacturing environment volume manufacture is only achieved at the expense of flexibility. And in today's highly competitive market both are critical factors. With Trumpf there is no need to compromise and that is a key differentiator for us.

Our new range of machines is designed so that the batch size, material and programme can be changed automatically with ease with no detrimental effect on manufacturing cost. The machines with their programmable focus single head and automatic laser nozzle exchanger coupled to flexible and expandable automation allows true lights-out production.

< >

Last year, to some people's surprise Trumpf unveiled its first fibre laser source. How do you see this developing?

Yes indeed, our TruFiber laser for ultrafine cutting and welding tasks was launched last year and we have just taken the order for the first installation in the UK. The exceptional beam quality of this laser provides minimal thermal effect on exotic materials and the focal diameter of the beam can be as small as 10 µm. This machine is destined for R&D but it opens up great potential for us in electronic and medical device manufacturing. These are certainly new markets with high potential for us.

< >

Why have Trumpf entered the micro market and how do you plan to be successful?

We are continually looking to expand into new market sectors, of course on the premise that it makes good business sense. Our TruMicro laser range opens up applications in several market sectors including the production of solar panels, wafer dicing and electronic packaging. We see these as being growth areas. Our key to success is based on offering innovation, an example being the TruMicro 5050 laser which is unique in the world market. This laser has a pulse duration of less than 10 picoseconds with an average power output of greater than 50 watts. This enables the user to process without any heat affect, so called 'cold working', at production rates previously not possible.

We understand that Trumpf is now also selling components, for example disk laser modules. Is this a permanent departure from your existing sales strategy or just an experiment?

In all honesty this is far from being a new concept. As far back as 1990 Trumpf started to sell RF generators as a result of its acquiring the Hüttinger Group. Hüttinger developed RF generation for laser excitation in the mid-80s and as this was – and still is – such a critical part of our laser technology it made sound business sense for Trumpf to take a controlling interest.

Now Hüttinger is a highly successful operation in its own right within the Trumpf Group. Indeed last year Hüttinger itself acquired a majority interest in Advanced Converters, a Polish company that sells process power supplies for vacuum plasma applications.

Investing in companies that have an important bearing on our core business is our policy. The most recent development is our acquisition of parts of the FISBA Optik operation. Initially it will allow us to offer our customers an even wider range of laser system choices, providing us with expertise in laser plastic welding and laser soldering. In the longer term it too may become an independent revenue stream.

continued over ...

Trumpf's main share of the laser welding market is in the automotive sector. How do you see this sector developing? And what other sectors are likely to provide significant business for Trumpf in the area of macro welding?

Trumpf has been a long term choice of the UK's tier one suppliers. Applications vary according to the origin of the car design. For example our lasers are used for body-in-white applications mainly on German cars whereas the predominant applications for others are in power train manufacture.

Obviously the way the sector develops in the UK rests on global economic factors. However aspects of the motor industry are currently alive and well in the UK and we hope to build on this success. We continue to work with bodies such as the International Automotive Research Centre at Warwick University and its Premium Automotive Research and Development Programme (PARD).

PARD is responsible for a portfolio of R&D projects aimed at enhancing the design and manufacturing capabilities of automotive suppliers based in the West Midlands. One of its most recent projects is focused on advanced body joining techniques for which the University has installed one of our high-powered laser systems.

Beyond automotive we are seeing a growth of macro-welding in line with a trend that involves going back to the drawing board in the way we manufacture structures. Rather than machine things out of solid, OEMs are minimising weight and waste whilst increasing strength by forming and folding from flat. This is creating a market for larger structures that require laser welding. Trumpf itself is an exponent of this concept - we have re-engineered the Y-beam on the TruLaser machines in this way.

First year membership

We are greatly indebted to Bystronic UK who recently took up AILU's laser supplier initiative and invited their customers to join AILU. Bystronic's membership drive has been highly successful as can be deduced from the list (opposite) of new corporate members.

If you are a laser equipment supplier, your participation in AILU's laser supplier initiative gives your customers the opportunity to be part of the largest and most active laser association in Europe, with access to the combined wealth of knowledge and know-how of the membership. What have you got to lose?

Contact mike@ailu.org.uk

Online trading identity

We are indebted to Emsea Ltd, a Tewkesbury-based laser subcontractor for provided the following warning:

Emsea have the web site address *www.emsea-laser.com*, but another company has registered the '.co.uk' permuation (*www.emsea-laser.co.uk*) for themselves.

Emsea recommend members check all permutations of their domain name to ensure that they have not been subject to this type of misuse of our online trading identity.

WELCOME TO NEW CORPORATE MEMBERS

Atomic Energy Commission

Ventilate UK Limited

DW O'Brien Ltd

Johnston Sweepers Ltd

Belle Group

Central Profiles Ltd

Electropak Ltd

Lasershape Ltd

Caterpillar Stockton Ltd

Ransomes Jacobsen

Laser Products UK Ltd

Technology Centre Hermia Ltd

Donaldson Filtration (GB) Limited

Onesite Solutions Ltd

Metal Ltd T/A Laser Industries

Yamazaki Mazak UK Ltd

Ripley Engineering Ltd

Laser Engineering UK Ltd

Most GORGEOUS PART

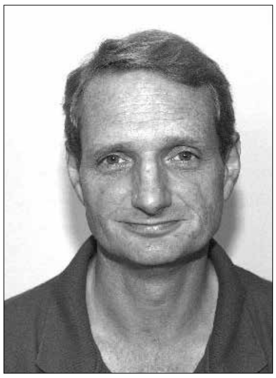
This titanium duct is part of the bleed air system on the new European military heavy airlifter the A400M. The part was originally manufactured from 8 separate cones, pressings and tubes; our engineers reduced the parts count to 2.

Middleton Sheet Metal took a new approach. Employing their Saab fluid forming system and using a complex trim, profiled on MSM's Trumpf 5 Axis laser, this final welded duct achieved a saving of 10 manhours over the previous method of manufacture.

Middleton Sheet Metal Co. Ltd. are aerospace fabricators specialising in the manufacture and repair of complex formed and welded assemblies. Based in a 20,000 sqft facility in North Manchester and employing 46 staff, MSM have a 70 year heritage in the aircraft industry. Further information can be found at www.msmgroup.org

Can we improve our laser processes through better specification?

Stewart Williams, Chair of Welding Science and Engineering at Cranfield University argues the case for a different approach to process parameters



Why has laser welding not been adopted more widely in industry, where arc welding still comprises the vast majority of metallic joining today? This despite the fact that laser welding is widely acknowledged as having several major benefits compared to other welding processes such as:

- **Low heat input - leading to low distortion.**
- **Fast welding speeds – leading to high productivity.**
- **Deep penetration.**

Granted there are some practical issues such as low tolerance to fit up and the difficulty of adding filler wire. However these problems can be overcome by hybrid laser welding where the laser is combined with an arc source.

This leads us to the main concerns which seem to be:

- High capital cost of laser welding systems (compared to arc only processes)
- The perceived reliability of the laser process

So what is being done by the laser industry to address these concerns? Well, to take the first point, laser suppliers are continually striving to bring down the cost of laser processing by improving laser efficiency and reducing capital costs (e.g. fibre, disc and direct diode lasers). But how about the second point - is laser process reliability really an issue? It certainly has been in the past.

Those of us who have been in the laser processing business for many years will remember problems with laser variability leading to poor process reliability. This often led to in-depth discussions as to the cause of the problem, which did not endear the laser industry to the end-user community. Thankfully things are much improved now and the quality and reliability of laser sources has significantly increased, although it is still not perfect!.

It would appear then that at least for laser welding the main concerns are and/or have been addressed, so why do I contend that laser users need to specify our processes differently? And how would this help?

I believe that as laser users we have not caught up with the laser industry. We are not exploiting the new high stability, high beam quality lasers that are available to us as well as we could.

Specifying lasers processes better will lead to the following benefits:

- Provision of a definitive method of checking whether your laser system is performing correctly.
- Much improved technology transfer from and between process developers, end users and laser equipment suppliers.
- Portability of the process specifications between laser sources and laser manufacturers.
- Much better comparison of research results between different groups.
- A higher level of understanding of process condition effects.
- Improved process reliability.

To illustrate how laser process specification can be improved consider laser welding as an example. Figures 1 and 2 illustrate the standard method of showing laser welding process data. In figure 1 the penetration depth obtained in X100 steel at various welding speeds is shown. Figure 2 shows the correlating graph relating penetration depth obtained as function of laser travel speed at various laser powers. Using this data it can be deduced that to produce full penetration welds in 6mm thick X100 steel a laser power of 4.5kW and a travel speed of 1m/min could be used (or some other combinations of these parameters).

What is wrong with this? *The problem is that these are laser system specifications and not laser material interaction specifications.* If we use a different laser system with the same parameters it is extremely unlikely that we will obtain the same result. Additional information is required to reproduce this welding condition on another laser system. In fact all the system parameters are needed. That is: a lens focal length of 250 mm, beam size on the focusing lens of 10 mm, perfect collimation on the focusing lens and finally that the beam quality was 16mm/mrad. So to specify the process with system parameters would be as shown in Table 1.

In practice these additional parameters are usually not provided or even known. The result is that when problems appear with the process it is very unclear as to

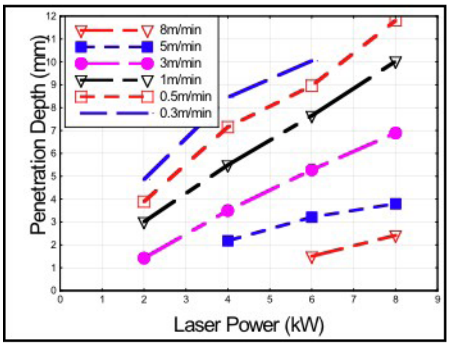


Figure 1 – Penetration depth as function laser power for X100 steel at various travel speeds

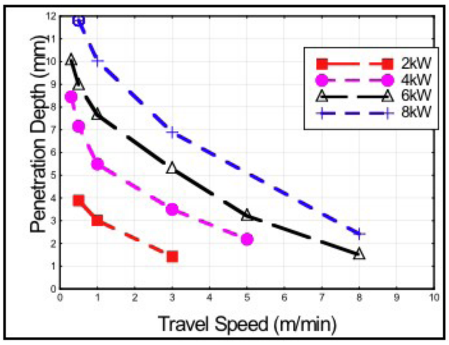


Figure 2 – Penetration depth as function travel speed for X100 steel at various laser powers.

Parameter	Value
Laser Power	4.5 kW
Travel Speed	1 m/min
Lens Focal Length	250 mm
Beam Diameter on Lens	10 mm
Beam Divergence on Lens	Collimated
Laser Beam Quality	16 mm.mrad

Table 1 – Full process specification using system parameters

what the cause is. This can lead to problems in the reliability of the process. Also it is very difficult to compare processes or change laser systems. The values of 4.5 kW and 1 m/min are very specific to this laser with this beam delivery system.

Alternative specification

The specification issue can be improved by moving to non system-dependent laser material interaction parameters. All laser material interaction physical processes are primarily controlled by only two parameters – the intensity and interaction time. This includes effects such as absorption, thermal conduction and melting, keyhole development, melt expulsion and plasma or plume effects. The result is that all laser applications such as surface treatment, welding, cutting and drilling are controlled by the same parameters. Hence, in many laser processing books the different processes are mapped against the intensity and interaction time; However, when the individual processes are discussed the authors often revert back to the meaningless system parameters shown in figures 1 and 2.

What is required is for the system parameters to be converted into the laser material interaction parameters. To do this it is necessary to obtain an accurate measurement of the beam profile in the plane where the material is being processed. For the data shown in figures 1 and 2 the beam profile was a circular spot with a diameter of 0.63 mm and a uniform intensity profile. The data given in figures 1 and 2 can now be replotted in terms of intensity and interaction time. The intensity is calculated by dividing the laser power by the area of the spot. The interaction time (on the weld centre line) is the spot diameter divided by travel speed. The result of this is shown in figure 3 and 4.

This data is now system independent. The specification for the welding process for 6 mm thick X100 steel is an intensity of 1.5 $MWcm^{-2}$ and an interaction time of 40 ms. This process specification can be transported from one laser system to another and the result, in terms of weld penetration depth, should be identical. This will be the case for all lasers (with a similar wavelength), independent of the laser beam quality. It will be appreciated that the interaction time can be obtained with different spot size and travel speed combinations but this should not have any significant effect over the normal range of spot diameters used for welding. However it is probably advisable to specify the spot diameter too as this may affect other properties of the weld such as bead width and weld quality (the spot diameter can be considered to be a second level parameter).

In addition to better portability it is likely that an improvement in process reliability can be obtained. This is because it is now clear what effect changes in the system parameters will have on the process parameters and therefore the process. For example if spot diameter changes of ±10% occur this gives a change in intensity of ~±20%. It can be seen from Figure 3 that there will be a corresponding ~±20% change in penetration depth, i.e. from about 5 mm to 7 mm. If the tolerance of ±10% was applied to the intensity and interaction time then the process variability would be reduced. This approach provides the opportunity of developing a full tolerance model for a particular laser system carrying out a specific process. The sum of variations in, say, laser power, laser divergence, laser pointing, optical aberration and optical misalignment can be added together to provide expected variations in process effects.

The benefit of specifying the intensity and interaction time tolerances for users is that it will allow them to determine what effect changes within the tolerance band will have on the process. If the process goes out of specification then the intensity and interaction time can be measured and if they are out of specification then the laser system supplier will need to determine what the cause is (e.g. incorrect setting of the system parameters in Table 1). The benefit of this approach for the laser system supplier though is that if the intensity and interaction time are found to be within specification then the problem is due to some factor outside of their responsibility (e.g. material surface condition).

I would like conclude by highlighting the benefits to the research community. If all data was provided with the basic material interaction parameters plus the spot diameter then comparisons of results would be easier. Also if investigations into secondary parameters (e.g. spot size, cone angle) were done at constant intensity and interaction time then the role of these secondary parameters could be more easily elucidated.

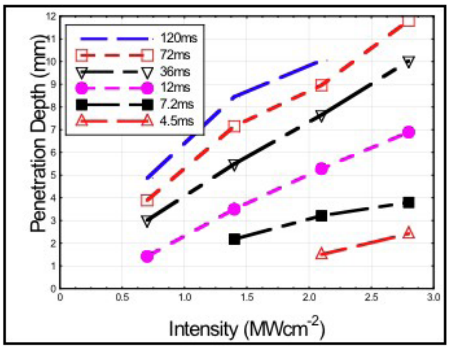


Figure 3 – Penetration depth as function of intensity for X100 steel at various interaction times

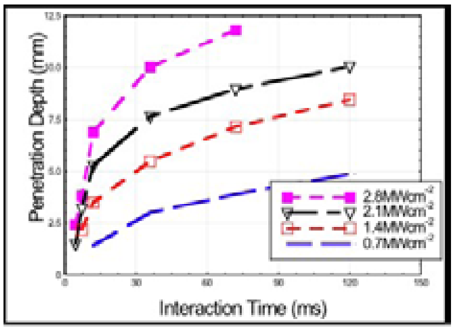


Figure 4 – Penetration depth as function interaction time for X100 steel at various intensities.

There are two potential issues with using the material interaction parameters for process specifications. The first is that the beam profile always has to be measured. However this should be standard practice (I believe all lasers should be sold with a beam profiler and a power meter as standard!). Whereas previously measuring the beam profile at focus could be difficult, there is now commercial equipment available to do this. The second problem is the difficulty in interpreting the data. The actual meaning of a change in intensity and interaction time is not intuitive for most people, especially interaction time, which is inversely dependent on travel speed. To address this I recommend presenting welding data as in Figure 3 but with the different curves labelled with both interaction time and travel speed.

Summary

I propose that all laser processes should be specified using the primary laser material interaction parameters, intensity and interaction time. The spot diameter may additionally be used a secondary parameter. This applies to all processes including surface treatments, welding, cutting, drilling and pulsed laser micromachining. Only in this way will end users be able to fully exploit the benefits of the high quality, high stability and high reliability of today's new laser sources.

EDITORIAL

PRESIDENT'S MESSAGE

The PKTN has figured large in recent issues of our magazine, and this issue is no different. Elsewhere within these pages you will read that PKTN authorisation (funding) has been achieved to start our new market study project that I referred to in my last President's Message, and the first phase of which aims to review R&D opportunities for AILU members. Again, all credit is due to Tim Holt and Anna O'Neil for their vigour and persistence in putting the case to the PKTN management for financial support to AILU.

AILU's on-going success in attracting PKTN funding, and for this new project in particular, led me to reflect on, and try and understand better, the government's current initiatives in support of industry. By happy coincidence, the latest (March) copy of, 'Overseas Trade Magazine', (published on behalf of UK Trade & Investment) includes a relevant article entitled, 'Strengthening our Research Base'. This article outlines the rationale underpinning the UK's current approach to R&D. To a greater or lesser extent, as members of AILU, we each have a stake in the future of UK manufacturing and R&D, and I thought it would be valuable to summarize here the key messages contained in the article.

The opening paragraph (abstract) of the 'Strengthening The Research Base' article notes that, in the global marketplace, manufacturing continues to shift to low-cost destinations, drawing the conclusion that, in order for the UK to maintain its strong position within the world, its focus has to be on the knowledge-driven aspects of the economy. Elsewhere, I have read that UK manufacturing continues to decline as a percentage of GDP; from near 50% after the last war, to approx 21% when the labour government came to office, to less than 14% today. ie the view expressed in the article seems well supported by evidence. It goes on to note that the UK is the top European location for R&D investment, and concludes that further growth in this area will help strengthen our high skill base and attract more new talent. As a result, it reports that a stated government target is to see combined public and commercial-world R&D spending (historically low/modest in the UK) rise from 1.9% to 2.5% of GDP by 2014, with the UK strengthening its position as a global R&D hub.

Part of the stated government strategy to achieve this increased R&D investment involves encouraging targeted international firms (the article notes 60 identified so far) to set-up or expand their UK activities and benefit from the UK's R&D capabilities. Financial incentives (stated as amounting to several £billion to-date), to encourage the growth include; the governments (Technology Board) collaborative R&D Programme, R&D tax credits to companies undertaking research in the UK and, in a number of key areas, the KTNs (of which our Photonics KTN is just one) to stimulate collaboration between the UK research base and companies. Interestingly, the article notes that the R&D Programme also aims to help UK companies increase their R&D activities abroad, and reports that 40 UK businesses have established operations overseas and 28 foreign companies have set-up in the UK, presumably with government financial help.

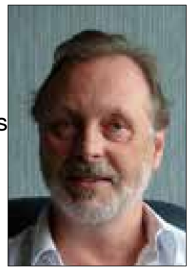
Coming back to where I started, it is clear from the above that there is a significant investment under-way, together with the necessary will, to stimulate UK R&D. Being the cofounder of a manufacturing company myself (and with an R&D background) I have a strong personal interest in this development, as well as a continuing wish to see on-going PKTN support for AILU. I'm sure that I speak for many members in expressing the hope that the government's R&D 'push' not only results in the strengthening of the technology and skills base for the best of UK manufacturing, but also works to improve competitiveness and stem its contraction.

My term as AILU president will soon be complete so I would like to thank the committee for their great support over the year. We made significant changes to the committee structure and the management of AILU in general and much of this is still to be bedded in. I'm sure you join me in wishing Stewart Williams the best of luck as he takes over the reins after the AGM in April.

Clive Ireland

Job shop corner

Neil Main
Chair



The UK laser job shops have seen mixed results in the last 12 months. It depends on who the customers are and how well they are doing. In the next twelve months and longer the world economic climate and local inflation will provide a lasting period of uncertainty for our customers and for us.

Most people are well aware of the issues: energy prices and industrial gas prices have sky rocketed and probably will never reduce; material prices are very volatile; a steady stream of customers relocate to eastern Europe or the far east; for the customers that stay price competition is fierce.

In the last issue I highlighted a number of benefits that go with membership of the AILU job shop group that make it worth the few hundred quid a year that it costs, highlights of which included the free surveys and the wealth of information you can tap into on the web-based forum.

AILU meetings and particularly the Job Shop business meeting each year are interesting, informative and a chance to network. Look over previous meetings on this web site (events archive) to see the range of topics. The job shop committee is pleased to hear of any ideas for meetings or web discussions or comparisons.

In addition we have discussed ideas of cutting standards (not taken further for now) a core operator training program (currently being actively examined) and a 'charter for laser job shops' will be drafted (addressing quality, service, arbitration etc), together with an AILU membership certificate, both designed to instill customer confidence.

This will be my last message as job shop chair. David Connaway of Cirrus Laser will be taking over from me in May. I wish him well in his efforts to make AILU of even greater value to the laser subcontract community.

Neil Main Job Shop Chair

Pulse length and beam shape: efficient material removal

Dave MacLellan

In the field of laser ablation the laser source technology is moving forward at a rapid pace, removing material more efficiently and faster and with finer features. This is being driven by a wide range of applications in consumer electronics, alternative energy sources and medical device manufacture, to name but a few; and by the significant interest in processes such as coating removal, direct writing of features and fine hole perforation. Here we consider the all-important influence of laser pulse duration on the removal of material, illustrated by the effect of a range of sources with pulse widths in the picosecond, nanosecond and microsecond regimes, on a wide range of materials.

Figure 1 illustrates the different solid state pulsed laser regimes with examples of lasers with a wavelength of approximately 1 µm. It is in this wavelength band that new developments in diode pumped rod lasers, disc lasers and fibre lasers are offering more cost-efficient manufacturing of advanced components and applications. Both shorter and longer wavelength laser sources are available, but to aid the comparison of performance with pulses of different duration it is these same-wavelength sources that will be considered. Innovations in beam delivery have also helped enhance material removal rates and for this reason a case study of square-cored fibre optic cables is included.

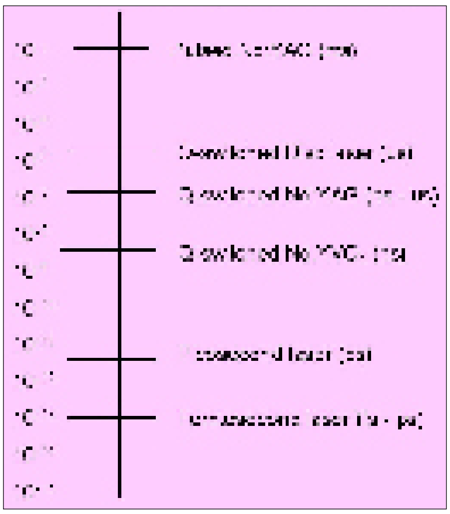


Fig. 1: Pulsed laser regimes and Neodymium based sources

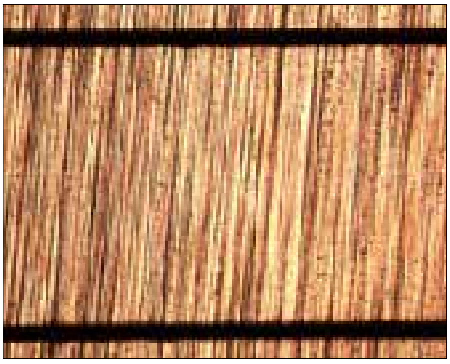


Fig. 2: 20 micron grooves in Aluminium coated polymer substrate (500mm/sec)

Picosecond pulses

The arrival of the femtosecond laser with pulse widths of 10's or 100's of femtoseconds ($1x10^{-15}$ s) as a solution to fine machining of a wide range of materials has created a lot of interest in academic research institutes and has produced some very impressive results. To date however, the cost-effectiveness of these sources has not been sufficiently attractive for most volume manufacturing applications because of the relatively low removal rates per pulse and the high investment costs. On the other hand, picosecond ($1x10^{-12}$ s) pulse lasers offer a sufficiently better combination of speed and average power to make volume manufacturing applications more commercially viable.

An example of this technology is the X-Lase range of lasers from Corelase (www.corelase.com), which offers up to 24 W of average power, pulse widths in the range of 20 ps and repetition rates up to 4 MHz. Lasers with such specifications can achieve optimum performance in very fine coating removal.

The heart of the Corelase system is a mode-locked fibre laser which can be delivered by fibre optic cable to a galvo (motor driven mirror) head, making it possible to achieve scribing speeds in excess of 500 mm/s. The ultra-short pulses ensure that the heat affected zone is minimised and virtually no debris is generated. Applications for this type of laser are in metallic coating removal from glass and polymer substrates, allowing the creation of conductive paths and isolated features by direct writing with the focused spot. An example of the removal of a fine coating of aluminium from a polymer substrate is shown in figure 2.

Nanosecond pulses

Q-switched lasers with pulses in the nanosecond regime ($1x10^{-9}$ s) have been available for many years. Nevertheless, the maximum average power of these sources continues to increase. Diode pumped rod lasers with nanosecond pulses and high average power are now available, offering very high removal rates due to the combination of high peak power and high frequency.

An example of this is the Rofin DQx80s which has 800 W average power and a maximum pulse energy of 120 mJ with a typically pulse duration of about 40 ns. With fibre optic beam delivery (either round or square) to homogenise the output beam, such souces can remove material using a larger spot size, which helps to increase material removal rate.

Applications for this type of laser include photovoltaic (solar cell) manufacturing, for edge isolation (removal of coatings from the outside edge of the solar cell), which can be carried out at removal rates of order 25 to 50 cm^2/ sec. Another application is the local removal of zinc coatings from car body steel to allow overlap welding of two sheets of steel without the risk of weld porosity, as illustrated in Fig. 3.

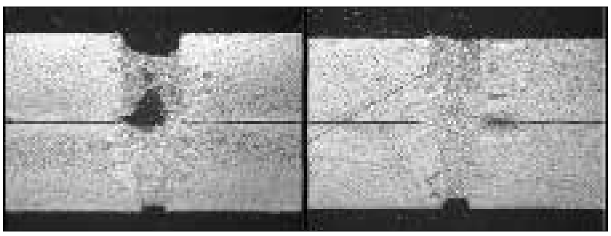


Fig. 3: Overlap welded zinc-coated steel. (Left) Welding without laser removal of the coating showing clear evidence of porosity. (right) A high quality weld produced after after laser removal of the zinc coating.

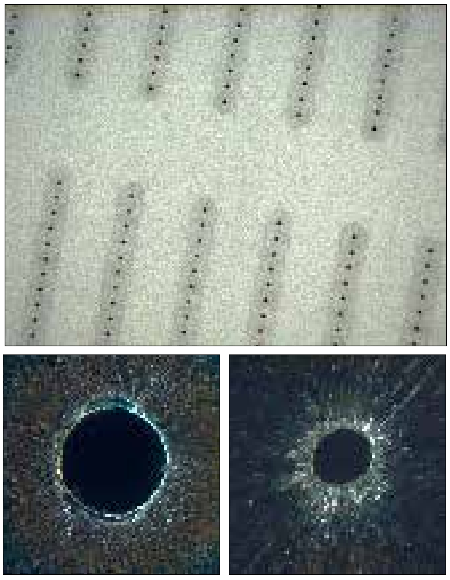


Fig. 4: High speed (3,000 holes/sec) percussion hole drilling in a silicon wafer. Bottom photos show the 60 µm diameter entry hole ad the 30 um diameter exit hole

Microsecond pulses

New developments in disk lasers have enabled the high quality CW laser output to be Q-switched, producing pulses of approximately one microsecond (1×10^{-6} s) which can remove a much higher volume of material per pulse. For example, the Rofin StarDisc is capable of 60 to 80 W average power with a fundamental mode TEM_{00} beam. In combination with a galvo head, this laser can used for removing coatings, scribing or drilling fine holes over a wide field.

An example of the capability of such a laser is in the drilling of fine holes in silicon wafers or stainless steel substrates. Unprecedented drilling rates (eg. 3,000 holes/sec in silicon and 1,400 holes/sec in steel - both 200 microns thick) can be achieved with this unique product type, which finds applications in the photovoltaic and other high technology markets where maximum throughput is vitally important. An example of high speed hole drilling in silicon is shown in figure 4.

Square fibres

A new development in beam delivery is the use of fibre optic beam delivery with square output to deliver a homogenised beam with the capability to remove material more efficiently from a surface. Figure 5 shows the beam plot of the output of such a fibre delivery, an Optoskand square fibre (www.optoskand.se), revealing a reasonably homogeneous profile.

A square fibre is not ideal for all situations; for example, it will produce a varying line width when ablating along a curved path, but in the case of large area removal the benefits are significant.

A square of side 'd' has a 27% ($4/\pi$) larger area than a circle of diameter 'd' and as well as the increased surface area the overlapping of square spots can remove a wider band of material – typically resulting in a 50% increase in the ablation width.

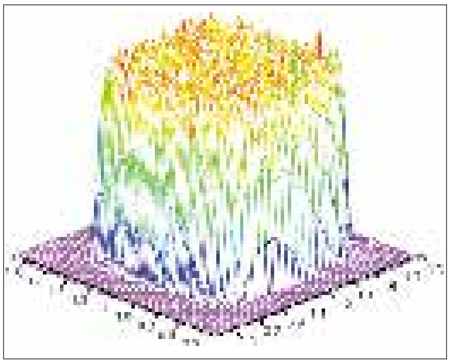


Fig. 5: Beam profile from 600 micron square Optoskand fibre

Future Trends

As a result of the trend towards higher processing speeds, pulse energies, and average and peak powers, laser processing is becoming an increasing attractive option for number of applications. Significant drivers in this area are the developments in "green energy" and the desire for larger and higher resolution displays for televisions, PCs and other personal electronic equipment. One thing is certain, the development of enhanced laser sources and beam delivery will continue its rapid evolution.

Dave MacLellan is Sales Manager (Laser Mircro) at Rofin-Baasel UK, Sopwith Way, Daventry NN11 8PB

Contact:

E: sales@rofin-baasel.co.uk

See Observations p51

The Laser Institute of America (LIA), in cooperation with the Laser Processing Committee of China Optical Society and Tsinghua University (Beijing, People's Republic of China), will host its first International Enterprise Summit on April 17th during PICALO 2008.

"The PICALO 2008 International Enterprise Summit is a unique event offering an opportunity for chief executives from China, North America, and Europe to meet face to face and discuss the aims, opportunities, and problems in achieving growth in the global laser marketplace," said Peter Baker, executive director of the LIA.

Laser cutting of complex parts

Jean Pierre Bergmann and Birk Ploennigs

Over recent years a major trend in the automotive industry has been the increasing complexity of design, functionality and mechanical strength of components. This is particularly true in the context of structural or chassis components, where complex end-parts are formed using metallic sheets with thicknesses below 2-3mm.

In order to reduce the complexity and costs of the forming tool, manufactures often decide to shift several tasks to later production steps. For example, tasks such as trimming or adding holes to components are held over in the production process, to be subsequently executed with high accuracy and without causing mechanical deformation.

The case for lasers

Traditional production processes such as cold forming and punching that are based on mechanical contact carry the risk of causing deforming and damage. In addition, the robot systems needed to automate such processes have to be highly robust and stable in order to absorb the applied forces.

Water jet offers several advantages and presents a reliable technical solution but cutting speed is limited and there are the additional steps of drying and cleaning the parts after cutting, particularly their edges.

A promising alternative solution, as summarised in Table 1, is laser beam cutting with a simple robot-based system. This technology offers high flexibility and high cutting speeds without contact and without mechanical stress or pressure to the parts. Furthermore it offers:

- high physical accessibility of the laser beam
- narrow heat affected zone
- small spot size (typically lower than 0,3 mm), which allows cutting with very small kerf width

	Punching	Water-jet	Laser cutting
Mechanical contact	yes	no	no
Accessibility	limited	medium to high	high
Assisting medium	none	water/ abrasives	gas
Heat input	none	none	small heat affected zone
Part complexity	low	medium to high	high
Automation ability	low	medium	high
After treatment	deburring	drying after rinsing	none

Table 1 Overview of principle properties of the major processing methods for cutting formed metal sheet parts.

Fig.1: Votan™ C-BIM (Beam-in-Motion) System for CO_2 laser cutting and trimming of metal sheets after forming, casting or deep drawing

The integration of laser procedures into highly reliable and traceable industrial processes is a key factor in the acceptance of the laser as a tool. The market demands low investment costs and reasonable operating and maintenance costs, but of equal importance is the simplicity and effectiveness of the technology and its ability to adapt quickly to the changes in product design. Only by considering all these prerequisites will the laser be judged an attractive tool for cutting formed metal sheet parts.

The robot option with free space delivery

A robot-guided solution for moving the laser beam enhances the flexibility of the entire system and the physical ability of the beam focal point to reach areas of the parts which would normally difficult to access with gantry-based 5-axis systems. In addition this approach to beam delivery offers a higher flexibility and simple programming.

A key component to successful integration of the laser beam in a robot-based system rests in the laser beam delivery itself. A conventional solution is to couple a solid state laser with the fibre and then to guide this with the robot to the required working position. The disadvantage of this solution lies in the limited flexibility (minimum bend radius) of fibres and the potential for fibre damage.

By contrast, a CO_2 laser generally has a high quality beam that can provide a focal spot (and kerf width) of only 0.1-0.3 mm. Furthermore, the investment and operation costs for a CO_2 laser are lower than for solid state lasers. The wavelength of the CO_2 laser (10.6 μm) makes it unsuitable for glass fibre delivery but guiding mirrors is well established in 3-axis system for 2-D (flat sheet) applications.

<u>Options for beam delivery</u>

In the first robot-based CO_2 laser systems an external arm held the beam delivery mirrors and the laser head. The arm itself was guided by a robot hand (6th axis), an approach that reduced the free movement of the whole system.

Another option, suitable for lasers with CW outputs less than 2 kW (due to the weight) is to position the laser on one of the robot axes and deliver the beam through mirrors to the laser head. In this concept the complete laser source (perhaps weighting 250-300 kg) is carried, which significantly restricts the mobility, accuracy and dynamics of the system and has an adverse impact on the lifetime and maintenance requirements for the laser and robot system.

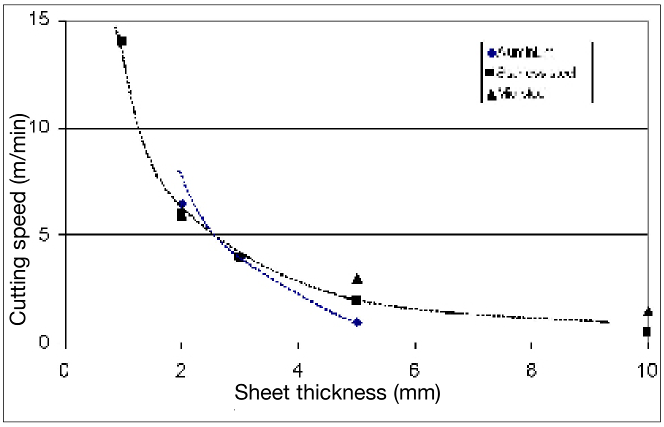


Fig.2: Cutting diagram for a 2.5 kW CO_2 laser (Courtesy Rofin Sinar, [1])

The Jenoptik Automation approach, which is suitable for laser powers of up to 5 kW and provides improved accuracy and dynamics, is to mechanically decouple the laser from the robot and to optically couple the laser beam to the foot of the robot (a development undertaken in collaboration with Stäubli GmbH), providing a complete integration of the optical path from the source to the tip of the laser head. Such a system is illustrated in figure 1.

This new concept is made possible by means of adjustable water-cooled mirrors, which are integrated into the joints of the robot. In order to prevent damage to the mirror by particles, the complete beam guidance is protected by a purging pipe system (figure 1). The CO_2 laser beam is integrated within the robot arm and suffers reflection losses of less then 5% over the complete beam path.

Figure 2 shows the typical cutting speed with a 2.5 kW CO_2 laser and confirms that for sheet thicknesses below 3-4 mm (as is used in automotive structures) can be trimmed and cut with speeds exceeding 4 m/min up to 14 m/min (1 mm stainless steel). Due to its design, the robot maintains its dynamic properties and accuracy (± 0.1 mm) over the full range of operating parameters.

This solution represents a promising and reliable alternative to solid-state laser system at lower cost and for many application equivalent performance.

Table 2 provides an overview over the basic options available for different CO_2-based laser system with different robotic beam delivery strategies.

	External mirror arm	Integrated laser source	Jenoptik Votan™ C BIM
Moved weight during processing	external mirror	laser source	none
External moving limiting elements	external mirror arm	laser source	none
Buckling load of the robot	medium	high	low
Dynamics of the robot	limited	limited	full
Accuracy	limited	limited	full

Table 2 Overview of principle properties of the robotic free space delivery methods for cutting formed metal sheet parts.

Industrial implementation

Figure 3 shows one solution for a compact processing cell (total footprint 12 m^2) containing an integrated robot and laser with chiller and other secondary services, mounted on a platform, with loading and placement of the component through a turn table. The laser system, filter and other services are positioned on the rear of the cell. The cell can easily be moved as one single unit. Typical size of handled parts are up to 1400 mm x 700 mm x 500 mm.

The combination of two robots in one processing unit, with either two lasers or one laser and a beam splitter, is also well established. Such arrangements are especially useful for processing large parts, parts with high complexity and difficult accessibility or applications with low cycle time requirements. More generally, such processing units provide a high degree of flexibility and represent an optimum solution for companies that need a flexible cutting system to carry out recurrent high grade jobs that are not identical.

Such systems offer:
- high flexibility and it is easy to program also for parts with complex contour
- high dynamic behavior and high degree of physical accessibility
- fast cutting speed with an available laser power till 5.000 W
- compact design which can be easily moved from one location to the other and it is easy to start up again into operation within a short period
- high degree of integration (loading, cooling, exhaust, etc.)

Conclusions

The recent increasing trend towards automation of cutting processes, particularly for 3-dimensional processing, represent a challenge for automation companies. High accuracy and flexibility, high cutting speeds, fit-for purpose beam guidance concepts with reasonable investment cost and compact design are the focus of interest.

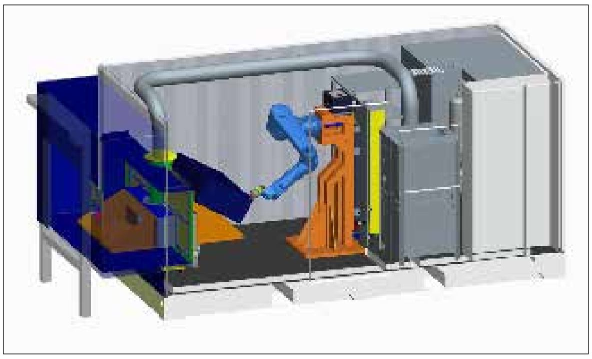


Fig.3: System concept for a Votan™ C-BIM (Beam in Motion robot integrated laser cutting cell with a CO_2 laser system (on demand power up to 5 kW)

Literature

[1] Introduction to industrial laser material processing, Rofin, (2004)

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Cutting and welding with the new high brightness lasers

Thomas Seefeld and Bill O'Neill

For many laser applications, including cutting, marking and remote welding, the processing capability of a laser is strongly dependent the power and quality of the beam to create a high power density on the workpiece surface. The quotient of these two beam properties, power and quality, is often used to define the term 'brightness'*. The term 'high brightness laser' is currently reserved for the new generation of high power diode-pumped fibre and disk lasers that offer high beam quality at a wavelength of ~ 1 µm.

All other things being equal, the focal spot size of a laser beam decreases (and hence the brightness of the source increases) as the laser wavelength decreases. Because of this, many solid state lasers, operating at wavelengths of approximately 1 µm, are brighter than even the highest quality CO_2 lasers with a wavelength of 10 µm. For example, a 1 kW Ytterbium (Yb) fibre laser producing a high order mode output with M^2 = 5 has a Beam Parameter Product (BPP) that is 50% that of a 1 kW CO_2 laser providing a low order mode (i.e. high beam quality) output with M^2 = 1.1. In this case the brightness of the Yb fibre is twice that of the CO_2 laser: with the same focusing optics the focal spot diameter would be half and the power density four times that of the CO_2 laser! Moreover, the operating wavelength of around 1 µm gives a room temperature absorption on steels some seven times that at 10 µm wavelength. It also has the effect of changing the Brewster angle for metals from around 88° (w.r.t surface normal) for a 10 µm wavelength, to around 75° for 1 µm wavelength. This last point may have a considerable impact on the relative cutting performance of the two lasers.

Taking the above example, there are three main effects that a lower BPP has on beam propagation:

1) Low BPP values allow much smaller focus diameters to be generated.
2) The lower the BPP the lower the laser power required to produce a given power density.
3) Beams with a lower BPP provide a greater Rayleigh range or depth of focus.

* A working definition of the brightness of a laser is its output power divided by Beam Parameter Product (BPP). Ed.

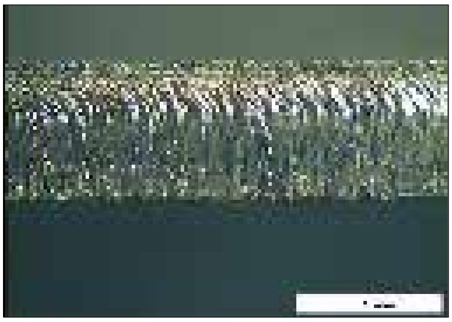

Fig. 1: 1mm C-Mn steel sample cut at 30 m/min using nitrogen assist gas and spot size of 37 µm.
Courtesy of Fraunhofer IWS Dresden

One of the most important parameters in laser processing is the depth of field of an optical system, or the Raleigh range. The ability to maintain the intense focal region of light over an extended distance from the focus is extremely enabling for cutting, drilling and welding applications. For example, if an application requires a 400 µm spot size then laser operating at 1 µm wavelength with a BPP of around 8-10, would have a depth of field <10 mm. In contrast, a laser with a BPP of 2-4 would have a depth of field of around 40 mm. One would expect that the laser with the lower BPP would perform better and this will indeed be found to be the case in the following sections on cutting and welding.

High brightness laser cutting

For those currently involved with CO_2 laser cutting the key questions are: Can I cut faster with a high brightness source? What are benefits in terms of quality?

High power, fast axial flow CO_2 laser beams are widely used for cutting and they remain the dominant source in this application. Commercial cutting speeds have steadily increased over recent years as the beam quality and reliability of industrial CO_2 laser sources have improved. Recent developments have demonstrated performance levels at around 40 m/min for oxygen-assisted cutting of 1 mm C-Mn steel sheet at 2.5 kW power level, a high beam quality, M^2 <1.4, and a spot size of ~ 80 µm. The results are impressive, although the process window reduces as the speed is increased, largely due to the drive for smaller spots and higher intensities resulting in small depth of fields and extreme sensitivity to focal height positioning. Limitations in the dynamic response of stand-off control systems currently limit the implementation of high speed CO_2 laser cutting machines.

Compare the results for the CO_2 laser with those achieved using a single mode (BPP ~ 0.34) Yb fibre laser operating at 1 kW, as shown in figure 1. The cut quality is quite good given the operating conditions (less than half the power of that used by the CO_2 laser and no exothermic assist from the oxygen jet). The cut is typical of a high speed cut sample; note the complex striation pattern caused by an unstable melt ejection process. In this instance it appears that brightness is providing a significant benefit to the user; a higher speed for lower power.

<u>Effect of focal position</u>

Figure 2 shows results of high speed micro cutting of thin sheet using a single mode Yb fibre laser, comparing the cutting performance at different positions of the beam waist in relation to the top surface. The movement of the focus inside the sheet dramatically reduces the cutting speed. At the highest speed (all powers) at the cut aspect ratio is ~ 9.

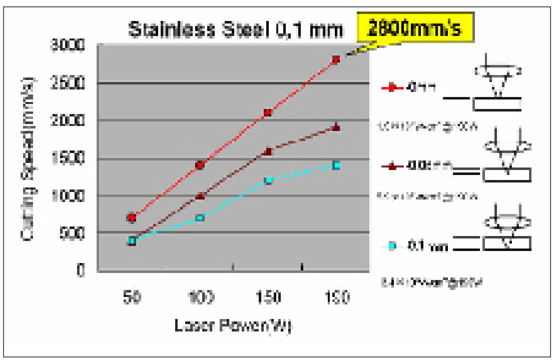

Fig. 2: High speed micro cutting using a single mode Yb fibre laser, spot diameter 11.4 µm. [1]

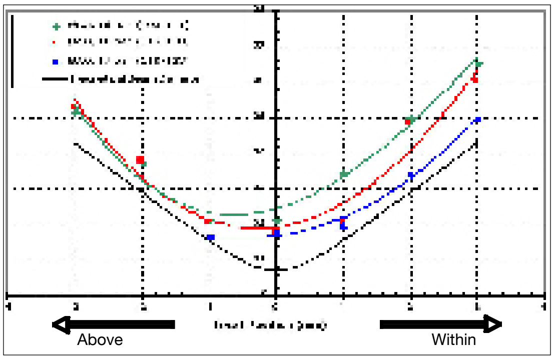

Fig. 3: Kerf width against focal position for cuts produced with a 2.2 kW Yb fibre laser on 6 mm thick stainless steel, nitrogen gas assist. Nozzle diameters and pressures as shown.

Figure 3 presents data relating to the cuts produced with a 2.2 kW Yb fibre laser on 6 mm stainless steel sample using nitrogen assist gas [2]. In this case there is a requirement to create a wider kerf for better melt ejection.

The best dross free cuts were achieved with the focus placed 3 mm inside the plate for all pressure settings. In this case the laser had a BPP of around 2 and a theoretical minimum focal spot diameter of ~ 80 µm. The aspect ratio of the best quality cut was ~ 12. It was necessary to open up the kerf in order to provide an opportunity for efficient melt eject, but this requirement effectively removes the principal benefit of high brightness. This conclusion is typical of cutting trials that have been undertaken using high brightness laser sources, including high brightness CO_2 slab lasers. An example of the best quality cut achieved for the Yb fibre laser is shown in figure 4.

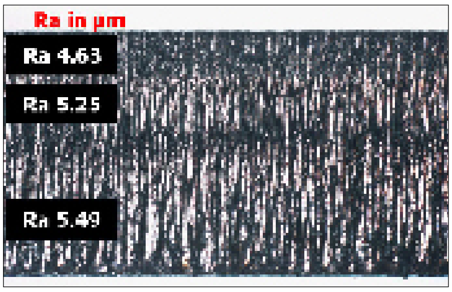

Fig. 4: Typical cut surface on 6 mm stainless steel using a 2.2 kW Yb fibre laser [2]

Attempts to model the associated melt flow have revealed a complicated melt flow pattern for high aspect ratio kerfs. Gross et al [3] modelled a range of kerf widths from 450 µm to 650 µm and 6 mm depth. Wave structures in the melt flow were identified and the idea of a "melt wave" was introduced to explain the complex striation patterns that are often found on cuts generated at high

Fig. 5: Re-solidified overlapping wave structures observed in the lateral cross section of a high aspect ratio stainless steel cut.

speed or high aspect ratios, see figure 5. This mechanism matches observations in surface topology and microstructure of cut cross sections, such as figure 1.

Laser Cutting Performance Comparisons

There has been much debate in recent years regarding the cutting performance of various high power laser sources, e.g. fibre, disc and CO_2. Direct comparisons are difficult to make since they are often not made with equivalent conditions; and are often biased, largely due to circumstance rather than intent.

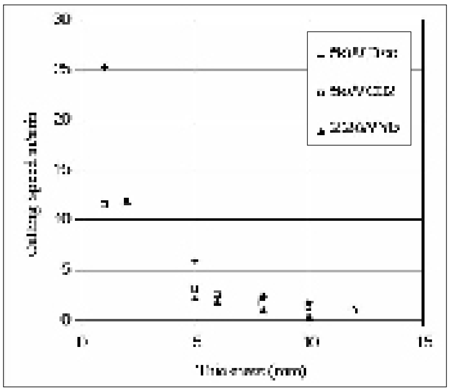

Fig. 6: Nitrogen assisted stainless steel laser cutting comparison of a 5kW Disc laser, 5kW CO_2 laser, and an IPG 2.2kW Yb fibre laser.

In order to determine the cutting behaviour of three of the principle cutting lasers, a series of experiments were performed on stainless steel with:

- Trumpf 5 kW Disc laser (BPP ~ 4.5, fibre diameter 100 µm)
- Trumpf 5 kW CO_2 laser (BPP ~ 6)
- IPG 2.2 kW Yb fibre laser (BPP ~ 2).

Cutting with these lasers was carried out using a high speed Aerotech positioning stage (ALS20000 series) and a Precitec YK52 cutting head (lens focal length 150 mm, nozzle diameter 1.7 mm).

Figure 6 presents the cutting speed comparisons. At the time of writing a 5 kW Yb fibre laser was not available for test, although given that the disc laser offered the same beam characteristics as the intended 5 kW fibre laser (BPP ~ 4, and delivery fibre diameter of 100

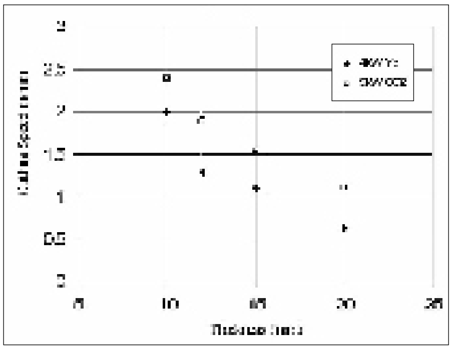

Fig. 7: Oxygen assisted laser cutting of mild steel , a comparison of a Trumpf 5 kW CO_2 laser, and an IPG 4kW Yb fibre laser (data published by both companies).

µm) the authors do not expect there to significant performance difference between the two 1 µm sources. In fact the performance of the 2.2 kW fibre laser is around 50% of that achieved by the 5 kW disc source.

It is clear from figure 6 that the high brightness sources offer considerable process improvements on thinner section materials. However, as the section thicknesses increase above 7-8 mm the performance of the CO_2 laser matches that of the solid state competitors although there remains the obvious benefit of operating efficiency. The authors believe that the reason for this trend is associated with the higher absorption levels at 1 µm wavelength. Waveguiding through multiple reflections down the kerf work against the shorter wavelength and concentrate energy distribution in the upper regions of the cut. The higher reflectivity for the 10.6 µm wavelength serves to distribute the laser energy deeper in the cut perhaps offering greater levels of melt fluidity in this case. The very complex and quite distinct striation patterns observed with the deeper cuts produced at 1 µm is perhaps an indication of this effect. Further trials are planned that will effect greater control of energy distribution within the kerf to see if the melt flow can be stabilised.

Figure 7 provides a comparison of CO_2 and Yb fibre laser performance on thicker section oxygen cutting of mild steel using data made available by IPG Photonics and Trumpf for a 4 kW Yb fibre laser and a 5 kW CO_2 laser.

Unlike the results in figure 6, the Yb fibre laser with only 20% less power that the CO_2 laser is seen to perform less well at these higher thicknesses. It can be argued that this is an unfair comparison as processing conditions are not matched in any way. However, we have found difficulty when attempting to cut mild steel plates in oxygen assist gas with 1 µm sources e.g. the cutting kerf width for 1 µm laser cutting sources needs to be considerably greater than for the CO_2 laser. It may be that optimum cutting parameters for oxygen assist gas have not been found in this case. Further trials are in progress to explore these phenomena in greater detail with the view to providing a comprehensive comparison of all three laser types up to a maximum power of 5 kW.

High Brightness Laser Welding
The increased intensity in the focused output of high brightness solid state lasers reduces the threshold power for deep penetration laser welding [4] and enables higher welding speed. In all cases, deeper and narrower welds with reduced heat affected zone and distortion can be obtained, bringing improved productivity and product quality [5]. It is generally agreed that welding results are determined simply the brightness of the source, not whether it is a disc or fibre laser [6].

Multi Mode Fibre and Disc Laser Welding
Penetration depths previously unattainable with conventional lamp and diode pumped solid state lasers have become easily achievable with modern high brightness lasers as illustrated in figure 8. For example, it is evident that full penetration of 12 mm was reached at a welding speed of more than 5 m/min when using a 17 kW laser. However, the data also shows that only at very low welding speed does laser power alone determine the penetration depth.

For this data, bead-on-plate welds were made at the BIAS laboratory in Bremen, Germany, with similar boundary conditions to those in figure 8. For example, all welds in aluminium AA6082 were made using a 200 mm focusing optics

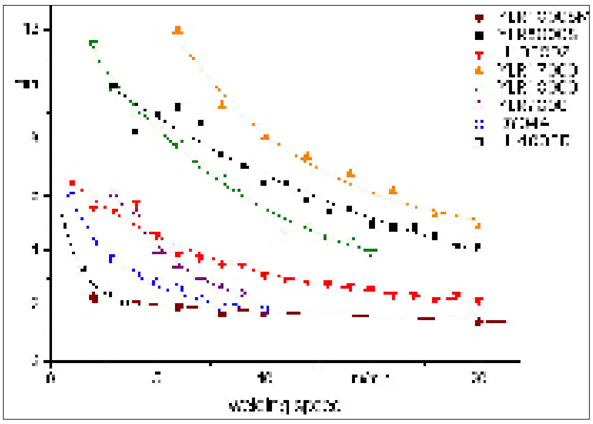

Fig. 8: Penetration curves in AA6082 Aluminium for a variety of solid state lasers from 1 kW to 17 kW

Laser	HL4006D	DY044	YLR-7000	YLR-10000	YLR-17000	HLD6002	YLR-8000S	YLR-1000SM
Type	YAG	YAG	fibre	fibre	fibre	disc	fibre	fibre
Year	2002	1999	2003	2004	2005	2006	2006	2006
Power [kW]	4	4	6.9	10	17	6	8	1
BPP [mm*mrad]	23.9	15.7	18.5	11.7	11.6	8	4.2	<0.4
Fibre dia. [µm]	600	400	300	200	200	200	100	15
Collimation [mm]	200	200	120	150	150	200	160	150
Focal length [mm]	200	200	200	200	250	200	500	200
Spot diam. [µm]	574	434	510	360	420	200*	320	20*

Table 1: Laser and focusing data

* nominal projection

(except for the YLR-17000 and YLR-8000S where focal lengths of 250 mm and 500 mm were used, respectively), and the focus was kept on the top surface of the plate. The laser system data are given in Table 1. (N.B. The optical parameters used were chosen to demonstrate as clearly as possible the effect of power and beam quality and will not necessarily represent the optimum configuration for each laser source from the point of view of practical welding performance or weld quality.)

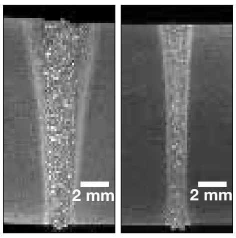

Fig. 9: Laser welds in 11.2 mm thick X70 pipe steel

(left) CO_2 laser (13.5 kW, 1.8 m/min)

(right) Fibre laser (10.2 kW, 2.2 m/min)

In the high power range, solid state lasers start to compete with well established CO_2 lasers for thick section welding applications such as shipbuilding [7] and pipe welding. For example, figure 9 illustrates autogenous laser welding in X70 pipe material. Compared to a state-of-the-art CO_2 laser, the same welding task was realized at higher welding speed using a fibre laser of lower power. Clearly visible is the narrowness of the weld and heat affected zone of the fibre laser joint.

Apart from better welding performance, solid state lasers may be particularly suitable for outdoor mobile welding applications, due to their compact and robust set-up which makes them insensitive to a hostile working environment, and due to their exceptionally high efficiency which reduces requirements for power supply and cooling [8]. For example, an application scenario in onshore pipe laying shows a clear cost advantage for laser welding compared to today's most competitive MAG orbital welding technology, which is mainly due to a reduction of the number of welding tents, the personnel and logistics cost, and also an increased daily output [9].

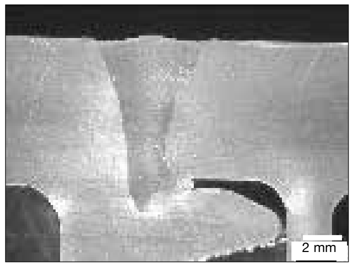

Fig. 10: Laser-GMA hybrid weld in AA6008 for a railway application

Another example is fibre laser-GMA hybrid welding of extrusion aluminium profiles for railway applications shown in figure 10. In this case the required penetration depth of 8 mm was achieved with a very good weld quality using a laser power of 10 kW at a welding speed of 6 m/min. The combination of laser and arc leads to an exceptional gap bridging ability and a very stable process behaviour at high speed, providing a substantial increase in productivity over today's arc welding, combined with an increase in product quality by a significant reduction of line energy and distortion.

In figure 11 the achievable penetration per kilowatt of employed laser power is plotted, underlining the important role of beam quality. It is evident that particularly for welding at elevated speed, beam quality (expressed as BPP) is becoming a decisive parameter. Obviously, high penetration per kilowatt can offer an economic advantage. Moreover, it also allows for a reduction of the heat input, less heat affected zone and less distortion and hence, improved weld quality.

The message here is that a low BPP is essential wherever the requirements are for highest aspect ratio welds and minimal heat input. The one limiting factor is that the reduced weld width requires

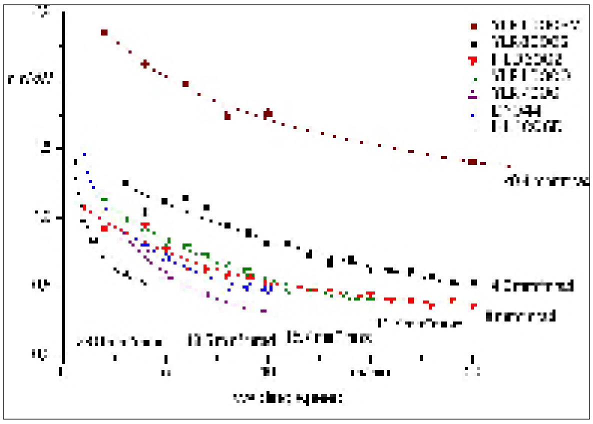

Fig. 11: Dependence of the penetration depths per kilowatt laser power on the beam quality for welding of Aluminium (AA6082).

a joint preparation to within very narrow tolerances and excellent beam control. Typical examples are automotive power train applications, which can generally fulfil these requirements, and aerospace structure applications that require particularly narrow welds in aluminium materials, figure 12. For such applications high brightness CO_2 lasers have generally been preferred. Recent studies indicate, however, that solid state lasers potentially have advantages with respect to productivity [10] and product quality [11].

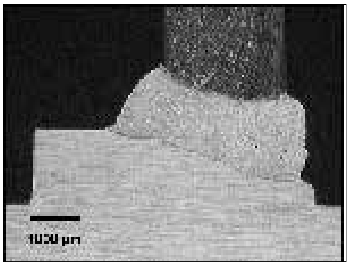

Fig. 12: Disc laser welded skin-stringer joint in AlMgSc alloy (courtesy of Airbus)

Limitations arise when the beam quality provided by the laser source is "too good" for a particular application. For example, the 8 kW fibre laser installed at BIAS has a BPP of 4 mm*mrad. Delivered from a 100 µm delivery fibre and collimated with 160 mm lenses, the nominal focus diameter can be as small as 125 µm for a standard 200 mm focusing lens. For the majority of welding applications in the macro world, such a small spot size is likely to cause gap bridging, beam adjustment and process stability issues. In this case, using longer focal length optics can be a remedy, with the additional advantage of a better protection of the optics from spatter and fume. Many such welding applications (e.g. in body-in-white production) typically require a beam diameter of more than 500 µm in order to achieve a sufficient strength of the overlap joint. This focus spot diameter corresponds to a focal length of around 500 mm for a typical thin disc laser (BPP 8 mm*mrad), which is frequently used in scanner welding systems [12]. However, in many other 3D applications a stand-off distance that is too large can be undesired since it may add to the requirements for the handling system.

Single Mode Fibre Laser Welding

Single mode fibre lasers provide a near diffraction limited output (M^2 <1.1 is typical, corresponding to a BPP < 0.4 mm*mrad at 1 µm wavelength). Such beams can be focused to a diameter of just a few microns, reducing the laser power threshold for deep penetration welding to the order of 10 W [1]. At a power level of 200 W a penetration depth of more than 0.5 mm can be obtained in steel at a welding speed of 10 m/min as shown in figure 13.

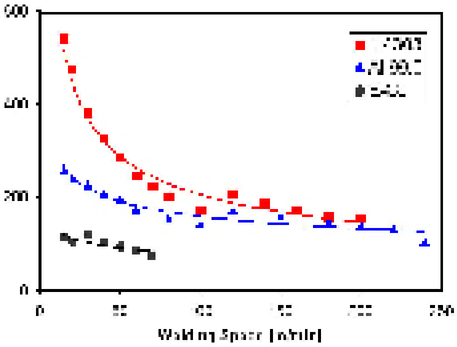

Fig. 13: Penetration in different materials using a YLR-200SM single mode fibre laser P = 200 W, f = 50 mm

Welding aluminium and copper at normal incidence requires an optical isolator to be used. Nevertheless, in these high thermal conductivity materials a lower penetration depth is observed and the high reflectivity of copper limits the coupling of the beam into the material at increasing the welding speed, preventing deep penetration. By contrast, Aluminium can be deep penetration welded at high speed with a penetration that is then close to that of steel.

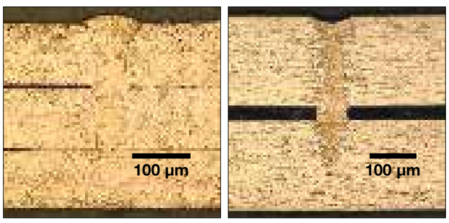

Fig. 14: Overlap welds in 1.4303 stainless steel P = 100 W, f = 80 mm: (left) t = 0.1 mm, , v = 40 m/min; (right) t = 0.2 mm, v = 30 m/min

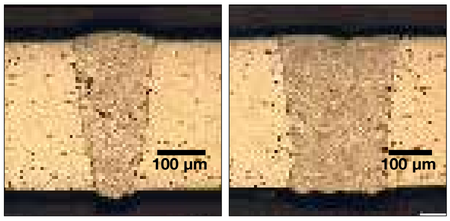

Fig. 15: Welds in $AlCuMg_2$ aluminium alloy (t = 0.3 mm, P = 200 W, f = 50 mm) at two welding speeds

(left) v = 30 m/min; (right) v = 15 m/min

Single mode fibre lasers in this power range are very well suited for precision micro welding [13]. Figure 14a shows an overlap weld of 3 sheets of stainless steel (t = 0.1 mm) that were nearly penetrated with 100 W at 40 m/min. The width of the weld was approximately 40 µm. Even with such a narrow weld a gap can be bridged as illustrated in figure 14b, providing it does not exceed approximately the weld width.

In aluminium alloys, the aspect ratio of the welds is much smaller than in steel, and by reducing the welding speed the width of the welds can be further increased as shown in figure 15. As a result, reasonable seam geometries can be obtained. Considering the laser power, welding speed and the dimensions of the weld, it is safe to say that here the high brightness of the laser has indeed opened up a new window for processing small thickness aluminium in a CW regime which was simply not accessible before.

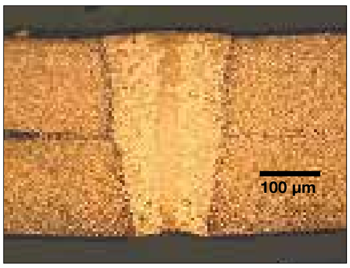

Fig. 16: Overlap weld in E-Cu58

t = 0.15 mm P = 200 W f =50 mm v = 4 m/min

Copper is one of the more difficult materials to be laser welded. The main issue is a high initial reflectivity combined with a substantially increasing absorption when the material is molten. Here, the high intensity of the beam is of advantage since it strongly supports the coupling into high reflectivity materials even at a low power level. Nonetheless, the use of an optical isolator is mandatory to avoid damage to the system from back reflection. Figure 16 shows an overlap weld in copper with a full penetration of 0.3 mm achieved at 4 m/min.

Another promising application is the welding of dissimilar materials. In the

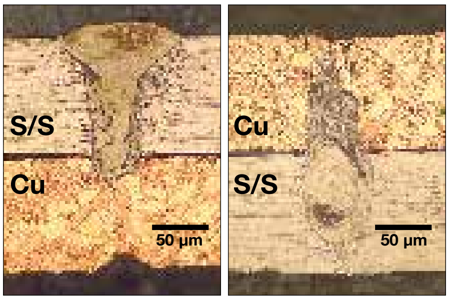

Fig. 17: Overlap weld of 1.4303 stainless steel and copper E-Cu58, t = 0.1 mm, P = 200 W, f = 50 mm, v = 30 m/min

example shown in figure 17, stainless steel was welded onto copper and vice versa using 200 W at 30 m/min. In the former case, the total thickness of 0.2 mm was fully penetrated, as indicated by the root formation in figure 17a. Apparently there was no dilution of the steel into the copper, and the weld seam was almost invisible in the copper. With copper on top, the lower sheet was not fully penetrated, figure 17b, and an upward dilution of steel into copper was clearly visible.

Single mode fibre laser systems in the 200 W class have now been in use for a few years and they have increasingly found application in industry, including cutting and rapid manufacturing. For micro welding in the thickness range of tenths of millimeters (typically up to half a millimeter) they overcome some of the former limitations and enable applications in a variety of materials and material combinations, both at moderate and at high welding speed.

By contrast, and despite their tremendous potential for welding applications, today's generation of kilowatt class single mode systems is often considered as equipment for laboratory use rather than for production since there are still some of shortcomings which need to be addressed. For example, the optical fibre length is limited to a few meters due to

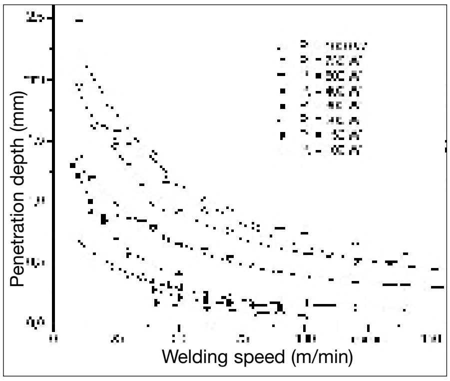

Fig. 18: Penetration in 1.4301 stainless steel using a YLR-1000SM fibre laser, P = 1 kW, f = 200 mm

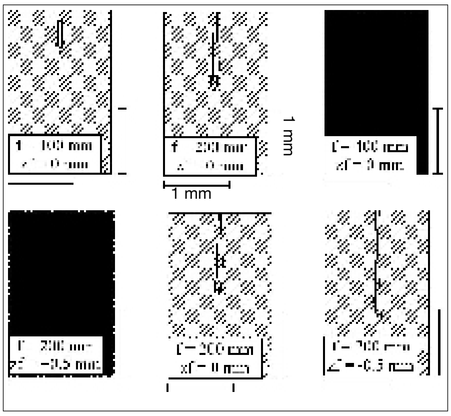

Fig. 19: Calculated keyhole geometry for single mode fibre laser welding at 1 kW. in 1.4301 stainless steel as a function of the position of focus relative to the workpiece surface. P = 1 kW, v = 10 m/min

detrimental nonlinear optical effects that appear in longer fibres. Moreover, these lasers are susceptible to back reflection due to the lack of commercial optical isolators at the kilowatt power level. Furthermore, process phenomena that occur at very high intensities are not well understood. Consequently the multi-mode versions of disc and fibre lasers are currently preferred in the kilowatt range.

Figure 18 plots penetration depth vs welding speed using the 1 kW single mode fibre laser. As the figure shows the laser is capable of achieving a remarkable weld penetration of up to 2.5 mm in stainless steel at a welding speed of 10 m/min, and > 0.8 mm at 100 m/min.

All these welds are extremely narrow, with a typical aspect ratio of up to 15. However, the challenge now is to identify applications that can take advantage of this type of weld seam, and then to be able to apply this welding process in a production environment, which is probably the more difficult requirement. Practical considerations associated with these welding parameters and weld geometries are how to manipulate the beam or the work piece at such speed, how to position the beam correctly, and how to deal with work piece tolerances and gaps.

A view at the keyhole can help to understand how critical is, for example, the choice of focusing conditions and the role of adjustment and tolerances under the chosen welding parameters. A self-consistent analytical keyhole model [after 14] was employed to calculate the shape and depth of the keyhole for welding with single mode fibre laser at 1 kW. The first observation was a difference between the calculated depth and the experimental result, indicating some limitations of the established model that will need to be worked on. Nevertheless, the model reveals that the focal length has a significant impact, with a smaller spot diameter resulting in a wider and shallower keyhole as shown in figure 19. This is consistent with observations made by other research groups [4]. Moreover, it was found that a variation of the focal position by 0.5 mm relative to the top surface of the material results in a dramatic change of the keyhole geometry, and affects the penetration depth to almost the same extent as does a doubling of the focal length.

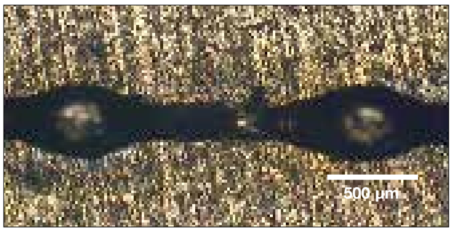

Fig. 20: 'Humping' in single mode fibre laser welding of 2.5 mm thick 1.4301 stainless steel shown in plan view. P = 1 kW, f = 200 mm, v = 10 m/min

The melt pool dynamics also set limitations to the utilization of high power and speed for single mode fibre laser welding. As shown in figure 20 the humping effect causes periodic droplet formation at the weld bead at comparatively low welding speeds. It also gives rise to severe undercuts. As illustrated in figure 21, at very low laser power the onset of humping was found to be at welding speeds well above 80 m/min for the given laser parameters (and according to [15] might be pushed much higher by reducing the focus diameter), at high laser power the onset of humping is at less than 10 m/min, leaving only a small process window available if the effect is to be avoided [16].

Conclusions

The development and understanding of laser cutting processes for 1 µm sources

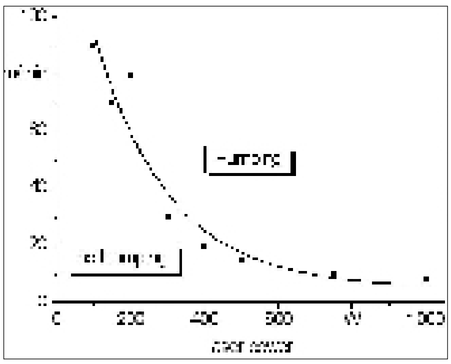
Fig. 21: Humping limit curve for 1.4301, f = 200 mm using a YLR-1000SM single mode fibre laser, P = 1 kW, f = 200 mm

is still in its infancy. There is a need to further explore the interactions of wavelength and absorption for deeper section if the high brightness offered by these sources can be usefully applied beyond thickness levels of 7-8 mm. It is clear that thinner sections do benefit greatly from high brightness, although at powers below 1 kW.

Welding at 1 µm has been used in industry for many years now, but things have changed dramatically with the advent of high brightness lasers. The higher efficiency and increased performance of these sources offer economic advantages and enable applications previously out of reach of cw solid state lasers by providing high beam power and beam quality simultaneously. The former is essential for thick section welding, whilst the latter enables higher welding speed for increased productivity and product quality. Commercially available multi mode disc and fibre laser systems are capable of covering a wide range of macro applications, while low power single mode systems can be ideal tools for micro welding up to about 0.5 mm thickness. Further processing research into how best to exploit the high power single mode systems is particularly needed.

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See Observations p51

Fibre news from optics.org...

(abridged reports)

Stuttgart opens Euro 1.825 M fibre facility

A new speciality fibre production facility in in Stuttgart's Institut für Strahlwerkzeuge (IFSW) will target materials processing applications. It will focus on developing passive and active fibres for high-power, high-brightness materials processing applications.

"The goal is to produce new fibre structures that deliver multikilowatt fundamental mode laser radiation over distances of 10–100 m for materials processing applications," Thomas Graf, director of the IFSW, told optics.org. "The fibres will also be used for the generation and amplification of high-brightness fibre lasers with average powers in the multikilowatt range. We will also work on flexible, high-power beam delivery of pulsed and continuous-wave high-brightness radiation such as that produced by fibre or thin-disk lasers."

Tapered fibre improves laser performance

A tapered fibre that suppresses nonlinear effects as well as offering cost-effective pump light absorption could soon be deployed in high power fibre lasers and amplifiers.

A research team from Finland and Russia has unveiled a tapered double-clad fibre (T-DCF) that it says is an ideal active medium for high-power single mode fibre lasers pumped by diode bars. Other unique features of the fibre tailor it for use in high-power amplifiers. (Optics Express 16 1929).

"A large input diameter of up to 2 mm and a high clad pump absorption make T-DCF a unique double-clad fibre that can be pumped by sources with a poor beam-parameter product, up to 150-300 mm×mrad, such as diode bars," said researcher Valery Filippov from the Optoelectronics Research Centre (ORC) in Tampere, Finland.

"We have reported an ytterbium-doped singlemode fibre laser based on T-DCF that emits over 200W and a cost-effective 1kW system is the next target," he said.

Precision Trepanning with a Fibre Laser

Paul Jacobs

LFI, a small company located in Rhode Island, USA, is purchasing and will soon integrate a 200 watt average output power fibre laser, an automated safety enclosure, a part loading carousel, a robotic motion system and a programmable trepanning head to enable rapid, accurate, efficient, and cost effective laser trepanning of highly precise and repeatable holes for a wide range of production aerospace and medical applications. The following analysis was carried out to establish and verify optimum fibre laser parameters.

Estimating irradiance

The laser irradiance (H) on a workpiece is the single most important parameter when laser drilling. As shown in Table 1, the interaction of a laser beam with a metal workpiece can be divided into five regimes. Of these the most efficient removal of material occurs in Mode 3. Since this regime spans the range from $10 < H < 100$ MW/cm², we chose a midpoint value H = 50 MW/cm² as the design goal.

For a fibre laser the irradiance distribution is very "Top Hat" i.e. approximately constant across the laser beam spot, so the irradiance is given by:

$$H_{TH} = (E/\tau) / (\pi d^2/4) \qquad 1.$$

where:

E = laser pulse energy
τ = laser pulse duration (
d = focal spot diameter

In equation (1) 'E/τ' is the peak laser power (P_p).

The average power (P_{av}) is $f \times E$ where 'f' is the pulse repetition frequency (Hz).

Calculation for single mode fibre lasers

The following parameters are typical for a state-of-the-art fibre laser in 2008:

E = 20 mJ (= 2. 10^{-2} J)
τ = 20 µs (= 2. 10^{-5} s)
f = 10 kHz (= 1. 10^{4} Hz)

From which we calculate:

$$P_{av} = f \times E = 1.\,10^4 \times 2.\,10^{-2} = 200 \text{ W}$$

$$P_p = E/\tau = 2 \times 10^{-2} / 2 \times 10^{-5} = 1000 \text{ W}$$

The laser duty cycle (= τf) is ($2 \times 10^{-5} \times 10^4$) = 20%

Rearranging equation (1) to calculate the focused spot size (d) needed to achieve the desired value of H_{TH} (50 MW/cm²) we get:

$$d = 2\sqrt{(E / \pi\tau H_{TH})} = 50 \text{ µm} \qquad 2.$$

i.e. focusing the output from a fibre laser with an average output power of 200 W to a spot diameter of 50 µm at the work piece corresponds to "Mode 3" drilling, and is very nearly the optimum laser irradiance for precision trepanning. H_{TH} is sufficiently high to assure full vaporization of the substrate material and yet is well below the level where plasma self-absorption will be a problem.

Furthermore, if required we can easily achieve a smaller focused spot diameter for micro drilling (in medical applications, for example) by using shorter focal length focusing optics.

To estimate what can be achieved we use the fundamental optical relationship:

$$d = (4/\pi) F \lambda M^2 \qquad 3.$$

where:

F = F-number
λ = laser wavelength
M^2 = beam propagation constant

As an example:

F = 10 (a large value)
λ = 1060 nm
= 1.06×10^{-4} cm
M^2 = 1.1

yields

d = 1.5 10^{-3} cm
15 µm

Optimising focal spot size and overlap

From prior experience at LFI we know that when trepanning holes by drilling a series of smaller holes there is an optimum value of the ratio of the diameter of the laser spot (d) to the diameter of the trepanned hole (D).

$$\alpha = d / D \qquad 4.$$

As α increases the amount of material to be heated, melted, vaporized, and ejected increases, as does the energy to trepan the hole. Conversely, if α is too small the remaining cylinder of material at the centre of the hole, which resembles a tiny hockey puck, may remain lodged within the hole. Generally, the best trepanning results occur when $\alpha \approx 0.1$. For D = 500 µm, the value of particular interest here, this suggests that optimum laser trepanning occurs when d ≈ 50 µm.

Consider an actual process for precision trepanning a 500 µm diameter hole, using a 50 µm diameter laser spot, as illustrated in figure 1. We define a dimensionless ratio β:

$$\beta = \delta / d \qquad 5.$$

where

δ = distance moved by laser spot along the perimeter of the hole between laser pulses.

If β =1 then each laser spot would be tangent to that of its neighbour, as seen in figure 1. This resulting trepanned hole would have an edge in the form of a

H< 1 MW/cm²	Simple heating of the workpiece	Mode 0
1 < H <3 MW/cm²	Melting of the workpiece	Mode 1 drilling
3 < H <10 MW/cm²	Vaporization of the workpiece.	Mode 2 drilling
10 < H <100 MW/cm²	Superheated ejection of workpiece vapour.	Mode 3 drilling
H > 100 MW/cm²	Ionization of the workpiece.	Mode 4 drilling

Table 1. Operating regimes for drilling [5]
From references 1 - 5. H = laser irradiance on the workpiece

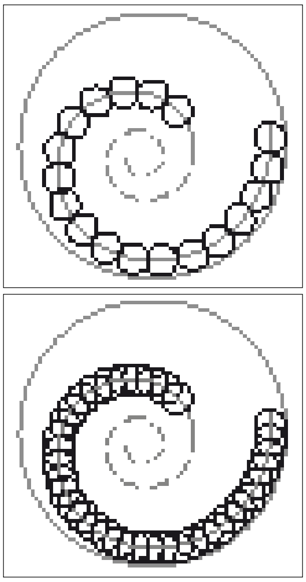

Figure 1. Illustration of tangent spiral trepanning.
(top) no overlap of neighbouring laser spots, creating a rough-edged hole.
(bottom) neighbouring laser spots overlapping half their diameter, creating a much smoother edge to the hole.

series of cusps each of height $\Delta = 20$ µm, a very rough-edged hole and not one that would satisfy many of the specifications required of work performed at LFI.

If we set β =0.5, such that each laser spot is only moved half of its own diameter prior to the next laser pulse, a more exact calculation shows that the cusp height decreases to $\Delta = 3.3$ µm. However, if we set $\beta = 0.2$ it can be shown that the cusp height is then $\Delta = 0.5$ µm.

Further benefit in hole quality by reducing β is quite negligible and it will directly increase trepanning time. Clearly there is a balance to be struck between hole-quality and productivity.

At LFI we set β =0.2 corresponding to an 80% overlap of neighbouring laser spots. For d = 50 µm with β =0.2 then δ = 10 µm. The perimeter of a hole with D = 500 µm is 1570 µm, so for optimised trepanning (i.e. with 10 µm steps) the required number of pulse locations (n) per circular orbit of the perimeter of the hole is 157.

The total number of laser pulses required per hole (N) can be written as N = n M, where M is the number of trepanning orbits executed per hole. One can of course generate a hole with M=1, but our experience at LFI is that a laser pulse directly adjacent to the perimeter of the desired hole often causes damage associated with laser "breakthrough". For this reason it is not advisable to start the trepanning process with the first laser pulse striking directly adjacent to the desired perimeter of the hole. Rather, it is best to start the trepanning sequence *inside* the perimeter of the hole and gradually spiral outward, reaching the point where the outer edge of each laser spot is tangent to the desired hole as illustrated in figure 1, which shows the process for $\beta = 1$ and $\beta = 0.5$.

The optimal trepanning process proceeds though the first orbit to physically trepan the hole, then proceeds though a second orbit to "clean up" the hole, and finally spirals slightly inward prior to conclusion of the trepanning sequence, to avoid any final artifacts on the perimeter of the hole. From experience, increasing M beyond about 2.3 increases the time to trepan the hole without any measurable improvement in hole quality, so we typically set M at this value. This results is a very high quality hole in materials of thickness less than 1 mm.

Time considerations

The number of pulses required per hole is given by:

$$N = \pi M / \alpha \beta \qquad 6.$$

Substituting:

$M = 2.3$
$\alpha = 0.1$
$\beta = 0.2$

Gives

$N = 361$

A state-of-the-art fibre laser operating at f = 10 kHz would trepan a 0.5 mm diameter hole in (361/ 10,000 =) 0.0361 s. We refer to this number as the "pulse sequence interval".

The pulse sequence interval calculation assumes that the trepanning head kinematics can keep up with the arrival of laser pulses. To do this at in the example above the trepanning head must be able to execute a single (δ =) 10 µm step in (1/ f =) 100 µsec.

Material removal

A significant benefit of trepanning is the reduced volume of material that must be heated, melted, vaporized, and ejected from the substrate.

For trepanning the volume of the annulus being vaporized is:

$$V_A = \pi Ddh \qquad 7.$$

where

h = hole depth

From Equation 7, for the case D = 0.5 mm and h = 1 mm, $V_A = 0.078$ mm^3.

In general $V_A / V_H = 4\alpha$. For $\alpha = 0.1$ only 40% of the hole material needs to be vaporized when trepanning. Other benefits of trepanning over percussion drilling are improved precision and repeatability [4]. Another major benefit of trepanning with a fibre laser is the ability to easily achieve a very small laser spot diameter. This enables operation in the optimal Mode 3 irradiance regime with very modest peak power levels, thereby dramatically reducing the fibre laser average power, size, and cost.

Absorbed Energy Considerations

From the fibre laser specifications the energy delivered per pulse is 20 mJ. Some of this energy is reflected by the workpiece, but because the inter-pulse interval of these high pulse repetition frequency lasers (10 kHz) is so short (100 µs in this case) the material remains molten between pulses. Since the spectral absorptivity of most metals is greater in the liquid phase [1], we assume for Hastalloy X that 70% of the energy emitted by the laser is absorbed in the workpiece

The minimum mass of material (m_T) to be removed during trepanning is given by:

$$m_T = \rho V_A \qquad 8.$$

Where:

ρ = density of material

The minimum absorbed laser energy required (e_T) to remove this material energy is made up of 5 elements:

(i) To adiabatically heat the material from ambient temperature to its melting point;
(ii) To melt the material;
(iii) To adiabatically heat the material from its melting point to its boiling point;
(iv) To vaporise the material.
(v) To eject the material.

$$e_T = m_T[C_p(T_v - T_o) + L_F + L_V + E_K] \qquad 9.$$

Where:

C_p = Specific heat (assumed constant)
T_v = Temperature of vaporisation
T_o = Ambient temperature
L_F = Latent heat of fusion
L_V = Latent heat of vaporisation
E_K = Specific kinetic energy of the exhaust vapour (i.e. $^1/_2$ (velocity)^2)

Estimate of energy requirement for drilling in pure nickel

Thermal properties:

ρ = 8.9 gram/cm^3

T_o = 293 °K

T_m = 1728 °K

T_v = 3005 °K

C_p = 0.44 J/gram-°K

L_F = 300 J/gram

L_V = 6392 J/gram

Calculation of E_K

With a nickel vapour temperature of 3005 K then the speed of sound is ≈ 960 m/sec.

$$\begin{aligned} EK &= (2 \times 960)^2/2 \\ &= 1.84\ 10^6\ m^2/s^2 \\ &= 1840\ J/gram \end{aligned}$$

Energy requirement

Specific hole dimensions:

D = 0.05 cm

d = 0.005 cm

h = 0.1 cm

Substituting into equations (8) and (9):

$$m_T = 0.7\ 10^{-3}\ g$$

Substituting into equation (7):

$$\begin{aligned} &C_p(T_v\text{-}T_o) + L_F + L_V + E_K \\ &= 1193 + 300 + 6392 + 1840 \\ &= 9725\ J\ /\ gram \end{aligned}$$

$$\begin{aligned} e_T &= 0.7\ 10^{-3} \times 9725 \\ &= \underline{6.8\ J} \end{aligned}$$

Table 2 Sample calculations of energy requirements for trepanning in Nickel

A detailed calculation of E_K would require knowledge of the velocity distribution of the exhaust vapour. We know from high speed digital CCD array photography [5] that the vapour is supersonic, approximately Mach 2 i.e. a velocity of twice the speed of sound in the hot vapour.

This approach is illustrated in Table 2 with a calculation for nickel. Taking the results of this calculation and assuming 70% absorption of the laser pulse energy (20 mJ per pulse, of which 14 mJ is absorbed), the number of pulses required to remove trepan the hole is (6.8/0.014 =) 486 pulses, corresponding to approximately 0.05 seconds per hole at a fibre laser pulse repetition frequency 10 kHz. Initial test results showed an actual measured time for spiral trepanning of 0.050 seconds for D = 0.5 mm and h = 0.76 mm (cf 1 mm in the calculations above) in good agreement with these calculations.

Robot indexing time

Increasing the laser output power will reduce the trepanning time; however, when the trepanning time is itself a small fraction of the "robot indexing time" required to accurately move the work piece to and settle at the centre of the next hole, then further increasing the laser power will have a minimal effect on overall cycle time.

There are three potential approaches to trepanning. The first involves a continuous circular motion around the perimeter of the hole to be drilled without stopping and starting. However with this approach the initial laser penetration occurs on the perimeter, often producing an undesirable artifact.

The second approach involves acceleration – translation – deceleration for each laser pulse. This approach requires additional time, but has the benefit of enabling "spiral trepanning" where the initial laser penetration occurs within the perimeter, and the circular trepanning orbit is completed M times. Also, this approach is compatible with generating holes of different diameters on the same part.

As an example, if M = 2.3, this might involve initially spiralling outward, then executing one orbit to cut the substrate material, and a second orbit to clean the hole. At the conclusion of the second circular orbit the path also then spirals back inside the circular perimeter. The drawback of this approach is that additional time is required for acceleration and deceleration at each laser pulse location throughout the trepanning orbit, increasing unit time and reducing productivity.

The third approach is to use a Continuous Motion Automatic Trepanning Head (C-MATH), which overcomes the need for the trepanning head to make hundreds of small incremental steps around the perimeter of the hole. To achieve this the robot moves the head only to the centre of the next hole in a speedy and accurate manner, leaving the rotational speed of the C-MATH, which is synchronised with the fibre laser pulse output, to advances one fifth of the spot diameter around the perimeter of the hole between pulses.

A limitation of the C-MATH approach occurs in applications that require two or more different hole-diameters on the same part. For such situations a programmable continuous motion automatic trepanning head, or PC-MATH is required.

The programmable feature enables both spiral trepanning as well as the generation of trepanned holes of different diameters on the same part. The benefits of the PC-MATH approach are: (1) faster cycle time; (2) simpler continuous motion; (3) no laser drilling artifacts are generated near the perimeter of the hole; and (4) the ability to pre-program different trepanning orbit diameters on the same part. The only drawback of this approach is that the desired trepanning orbits must indeed be pre-programmed for each part geometry. This needs to be done directly from a CAD model of the part.

Trepanning Cycle Time

In general, the time required to trepan a single hole can be expressed as:

$$T_{total} = T_{center} + T_{trepan} + T_{acc}$$

T_{center}: the time for the robot to move the trepanning head from the location of the centre of one hole to the location of the centre of the next hole.

T_{trepan}: the time to accomplish continuous circular trepanning

T_{acc}: the time to accelerate and decelerate between laser pulses.

The average linear speed of trepanning U_{av} can be estimated using Equations 4 and 5 to express the distance moved (□) between pulses and the inter-pulse interval (= 1/ f) i.e.

$$\begin{aligned} U_{av} &= \square f \\ &= \square\square Df \qquad 10. \end{aligned}$$

Since the actual motion is limited by the kinematics of the trepanning head, which has a maximum possible speed of U_{max}, it is important to select parameters such that

$$\square\square Df \leq U_{max} \qquad 11.$$

From Equation (10), subject to the kinematic limit of the trepanning head, the time taken for the head to traverse the perimeter of the hole (= □D) M times, is:

$$T_{trepan} = \square M / \square\square f \qquad 12.$$

Note that the trepan time is independent of the hole diameter! This occurs because both the perimeter to be trepanned and the continuous circular trepanning speed are proportional to the hole diameter.

A state-of-the-art PC-MATH trepanning head offers U_{max} = 100 mm/s, but this is exactly the value of U_{av} calculated when the desired values of □ (= 0.1), □ (= 0.2), D (= 0.5 mm) and f (= 10000 Hz) are substituting into Equation (10)

We definitely do NOT want to operate the trepanning head at its maximum limit, so it is important that we reduce the value of U_{av}. Clearly, we do NOT want to further decrease α (raising the issue of the release of the central plug), nor do we want to reduce β, since at 0.2 no further improvement in measurable hole-quality would result. So we have decided to reduce the laser pulse repetition frequency to f = 7000 Hz. Substituting this value into Equation 12 gives an expected trepanning time per hole of 0.052 seconds.

Preliminary Test Results

Preliminary work using a fibre laser to trepan a series of test holes was undertaken to evaluate potential system performance. However, the work-piece was NOT positioned using a robot, nor was a robot used to move to the location of the next hole, and especially significant, the holes were trepanned using an X-Y stage (requiring acceleration, translation and deceleration to move from the location of the center of one hole to the next, plus a series of very small steps around the perimeter of each hole) rather than utilizing a PC-MATH.

The fibre laser trepanned holes were generated through:

A. 380 µm thick Hastelloy X sheet stock
B. 760 µm thick Hastelloy X sheet stock
C. An actual Hastelloy X jet engine baffle

The selected hole-diameter was 0.46 mm and the trepanned holes were subsequently measured on an OMIS II optical measurement and inspection system located at LFI.

Despite being preliminary data, the test data from the 50 initial holes trepanned through 380 µm thick Hastelloy X revealed an error relative to the specified diameter of only 11.4 µm. The standard deviation in diameter was 10.2 µm. This is a surprisingly good result in view of the fact that a PC-MATH was not employed.

For the holes drilled through 760 µm thick Hastelloy X, the error in mean diameter was only 7.0 µm and (especially significant) the standard deviation in hole diameter was only 4.8 µm, an outstanding result! Very recent test data (March 2008) again involved trepanning with an X-Y stage rather than an optimized PC-MATH. Here fifty holes were trepanned to a nominal diameter of 560 µm, through 635 µm thick Hastelloy X test coupons, and resulted in a standard deviation in hole diameter of only 2.37 µm. With the use of a properly calibrated PC-MATH unit it is not unreasonable to expect that LFI may achieve hole diameter standard deviation values as small as 2 µm! To the best of our knowledge this would represent a new worldwide standard for precision laser drilled holes.

Conclusions

1. A value of α = 0.1, corresponding to a 50 µm laser spot diameter is close to optimum for precision laser trepanning 500 µm diameter holes.

2. A value of β = 0.2 provides a good balance between trepanning time and hole quality.

3. Spiral trepanning is advantageous to avoid undesirable artifacts on the perimeter of each hole.

4. An average fibre laser output power of 200 W should more than suffice for trepanning applications where h < 1.5 mm.

5. A "programmable continuous motion automated trepanning head" or PC-MATH is recommended.

6. Operating the fibre laser at F = 7 kHz allows a 2008 state-of-the-art PC-MATH to safely remain below its rated linear speed limit.

7. For applications where hole-depth exceeds 1.5 mm, an average fibre laser power greater than 200 W is needed to achieve optimum performance.

8. Preliminary test results obtained *without* utilizing a PC-MATH show a standard deviation in trepanned hole-diameter as small as 4.8 µm!

A fibre laser system is particularly attractive for this application. Its use simplifies installation, reduces the operational footprint, reduces electrical power consumption and enables job-site portability. Its low power consumption opens up the option of air or water cooling (water cooled version is recommended for industrial applications) and its long lifetime should significantly reduce repair costs. The laser is essentially zero maintenance and its excellent pulse-to-pulse repeatability, even when turned off for hours, will reduce the laser trepanned hole diameter standard deviation.

Additional data will be gathered at LFI using an optimized PC-MATH in the near future, to determine the level of precision attainable with such a system. We will then provide an update to this paper.

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See Observations p51

The Clearweld® process for plastics' manufacture

Gareth McGrath and Katie Rushforth

The use of welding with near infrared (NIR) lasers has become a well-established processing method for joining thermoplastics in industrial applications. Transmission laser welding is the recognised procedure within this field, where the upper part is transparent to the laser and the lower part absorbs laser energy converting it into heat. Most plastics in their natural state do not absorb near infrared (NIR) light, so the plastic used for the lower part generally contains an additive such as carbon black. This restricts plastics to dark colours. What is so special about Clearweld® is that it enables a flexible solution for joining transparent, coloured or opaque thermoplastics components. Clearweld® has many other advantages in addition to colour flexibility, enabling it to be used in applications from textiles to medical products.

Gentex has developed a series of materials that strongly absorb in the NIR while remaining virtually colourless. These absorbers are used to create two product forms, coatings and resins as shown in figure 1.

Technical considerations

Substrate/Materials

To laser weld successfully the top substrate must be transmissive at the laser wavelength, while the bottom substrate must absorb the laser energy either throughout the bulk of the material or at the surface only. The two substrates must be in contact and miscible when heated in order to generate a weld.

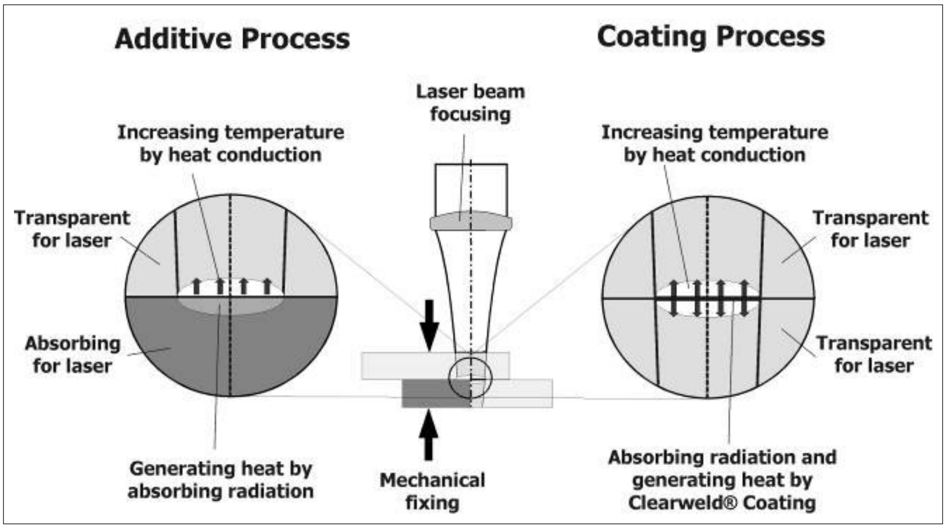

Figure 1. Laser welding plastics using Clearweld additive or Clearweld coating

Clearweld additives absorb only at the targeted wavelength ranges to weld efficiently while minimising visible colour. They can either be applied to the substrate as a coating or put directly into a resin to form a resin. Figure 2 presents a selection of the Clearweld absorbers that are available.

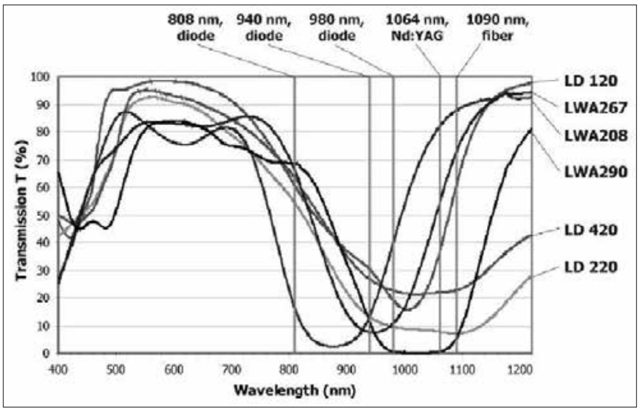

Figure 2. Transmission of Clearweld® absorber, as coating (LD) or as additive for resins (LWA)

Fixturing/Clamping

Intimate contact and pressure is required at the joint interface of the heated materials to allow sufficient melt flow to create a weld. The amount of pressure depends upon the materials being joined and their surface conditions at the weld interface. This pressure is typically generated using a clamping device. It may be possible to use a compression joint design to eliminate the need for an external clamping device.

Resins

Weldable resins are created by incorporating the absorbing additives directly into the base resin. Such resins are then used to form the absorbing substrate of the parts. Welding of the resin compounds works the same way as with coatings. Resins are custom formulated for applications, taking into account material, colour and process requirements.

Coatings

Clearweld absorbing coatings contain absorbers for use in the wavelength range of 940 to 1100 nm. These coatings are low viscosity liquids, formulated to take into account substrate materials, part design and process requirements. They are applied to the joint interface only where a weld is desired. The accurate delivery of the coating to the joint interface is critical to the success of the Clearweld process and the coatings are tested and certificated for use with specific delivery methods.

The thin consistent Clearweld coating, after drying, has a slight colouration. However, during heating the absorber decomposes and the visible colouration is lost completely resulting in a clear and transparent weld joint without affecting the original colouration of the plastics.

Applications in the medical sector

Laser weldable tubes

A new application for Clearweld is laser weldable tubes for medical applications, developed in cooperation with Natvar. These tubes are manufactured by a co-extrusion process to place the Clearweld additive on the outside for enabling laser welding of luers* to each end of a tube. The tubes and luers have to be transparent and colourless to allow the survey of liquids flowing through the tube.

*Luer: A joint of two components that twist and lock together to form an airtight connection between tubular parts e.g. for connecting hypodermic syringes with their needles.

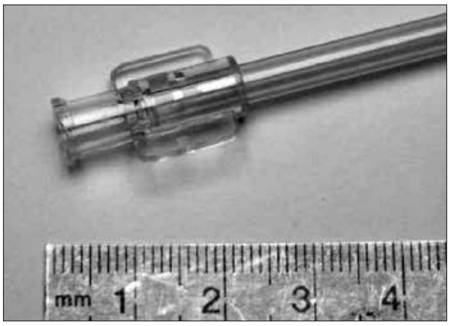

Figure 3. Laser weldable tubes for a medical application

The preparation for laser welding is done by pushing the luer on to the tube. The luer is fixed to the tube by a press fit and can be laser welded by one pass for small tube diameters and rotating the tube under the focused laser beam for thicker tubes. Because of the press fit, no additional clamping is needed. Positioned at the end of the tube, the laser weld generates a hermetic sealing without any change in the transparency of the components.

Common joining methods for such devices are UV bonding or solvent bonding. In both cases the process is time consuming and adds a chemical to generate the joint. UV and solvent need full surface contact for the entire length of the lure, typically 7 to 12 mm. The main advantage of laser welding over these processes is in creating a mechanical bond with no additional solvents or adhesives.

Bottles tubes and containers

Numerous medical products are marketed in plastic bottles, tubes or containers. Production of such containers must take into account a wide range of variables (e.g. material, shape, size, wall thickness, physical strength) and usually some type of lid or closure that must seal in the contents. Manufacturers of containers have various requirements,

Courtesy of Barkston Plastics

Figure 4. Medical devices from transparent PMMA, welded using Clearweld Coating (both lids welded simultaneously).

such as leak-proof seals, tamper-resistant closures and cosmetically appealing tubes or fittings. Creating a strong joint between the lid and the container body while maintaining its aesthetic appearance, can be a challenge, see figure 4.

The typical methods of bonding large surface areas have problems: adhesive bonds degrade over time, require long cure times, pose aesthetic problems and the adhesive can contaminate channel areas; applying heat to melt the plastic to form a bond is time-consuming and limits design flexibility; ultrasonic welding can generate particulates which may present problems in medical devices. By contrast, infrared laser welding provides: strong hermetic seals; welds with low mechanical and thermal stress; little or no flash to impair channel integrity; and pre-assembly of parts, high weld speeds and three-dimensional contour joints

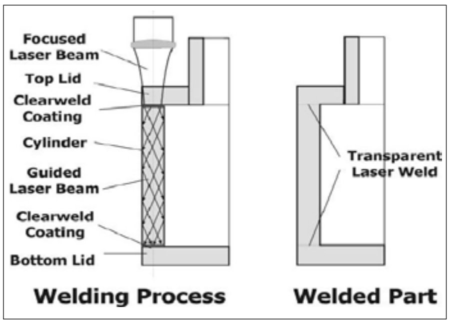

Figure 5. Schematic of the welding process

The arrangement in figure 5 shows the final production approach. For colourless parts a thin Clearweld coating can be applied to the lid or the internal edges of the container where the lid is to be welded. For transparent coloured parts an IR absorber can be added to the resin that is to form one of the substrates.

Applications in fuel cell manufacture

Fuel cells are now used for applications such as powering vehicles, providing electricity to buildings and operating electronic equipment such as computers. Analogous to storage batteries, fuel cells utilize an electrochemical process that converts chemical reactions into electricity. And whereas batteries die when the chemicals are consumed, fuel cells continue to provide electrical energy as long as fuel is supplied to them. Many fuel cell programs are currently in the development stage, and designers are seeking to optimize cell construction. Significant obstacles in this effort include joining discrete layers within a fuel cell, and joining individual fuel cells into stacks to increase the voltage output.

Thermal bonding and ultrasonic welding, commonly used joining techniques, must overcome significant challenges in fuel cell applications: speciality plastics to withstand chemical attack can be difficult to bond; incorporated small channels may collapse during manufacturing; fuel cell membranes and electrical wiring are sensitive to vibration (e.g. during ultrasonic welding); adhesive bonds susceptible to chemical attach and have poor long-term stability. By contrast, infrared laser welding provides strong, hermetic seals with low mechanical and thermal stress; introduces no vibration; allows pre-assembly of parts, high weld speeds and three dimensional contour joining; and provides control of collapse and flash to maintain the integrity of fluid path channels.

The design of fuel cells varies with the type of cell and its end use. However, all cells consist of multiple layers; these must be joined and the plastics used must be chemically resistant. In proton-exchange-membrane fuels cells, most commonly used to power small appliances such as laptop computers, the electrolyte is a film separating the anode from the cathode. These components are contained in separate layers, which must be hermetically sealed to insure proper operation. A number of individual cells are then stacked to provide sufficient voltage output to power the final device. The Clearweld process can be used to join most common thermoplastic materials. The materials of choice for fuel cells should be chemically inert, such as polysulfone, high- density and ultra high molecular weight polyethylene, or fluoropolymers such as PVDF.

Conclusions

The advantages of Clearweld include: colour flexibility; clean, optically colourless high strength joints; repeatable and consistent joining; hermetic sealing; and biocompatibity. Applications include medical products and fuel cells, but the process can also be used in packaging, automotive components; micro fluidics; electronics and textiles.

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The new edition of EN 60825-1:2007

Mike Barrett

Late 2007 saw the publication of EN 60825-1:2007 – Safety of Laser Products Pt1: Equipment classification and requirements. This revised prime standard for laser products accurately reflects the revised IEC 60825-1:2007 and supersedes the earlier version of 60825-1:1994 together with subsequent amendments and corrigenda.

For compliance purposes within the EU either version of the standard (i.e. 2007 or 1994) may be used up to September 2010, at which time the earlier version of the EN standard must be withdrawn. However where the IEC standard is used for compliance purposes (presumably at least for compliance claims on equipment going outside the EU) then IEC60825-1:2007 must be used as IEC withdrew all earlier editions of the standard immediately on publication of the 2007 document. This latter situation will also mean a revision of other IEC documents where individual requirements and clause numbers references have changed as a result of this new edition. For example, IEC 60825-4 for laser guards will be reissued with revised references when the next Annex is published later in 2008.

Why the change?

Standard 60825-1:2007 has changed for two major reasons: to remove light emitting diodes (LEDs) from the requirements of the standard, and to remove the User's Guide, which underwent a major revision some years ago and is issued separately as TR 60825-14:2004 – Safety of Laser Products Pt14: A users' guide. However there are also a number of other changes, some of which are important.

<u>Non-laser sources</u>

The LEDs that have been removed from the scope of the safety standard are those that are derived from semiconductor devices having large sources sizes and producing optical radiation that may not be coherent. It has been widely felt that these devices were generally not hazardous in practice and that classification requirements were inappropriate.

In general LEDs are now to be assessed using the standard IEC 62471:2006 (CIE S009:2002) - Photobiological safety of lamps and lamp systems. However, despite this change there remains considerable concern over high power LEDs, especially those producing ultraviolet light on account of the cumulative effects of UV exposure. Semiconductor devices that may generally be known as LEDs but produce spontaneous or stimulated coherent radiation are still covered by the 60825-1 standard.

<u>Users' guide</u>

Despite the removal of Section 3 (User's Guide) of the older 60825-1 standard, not all user information has been removed from the revised Part 1. Annex A now collects together most of the information relating to Maximum Permissible Exposure (MPE) values. Annex B still gives examples of calculations. Annex D describes the biophysical considerations with Annex E giving additional information to aid the expression of MPEs and Accessible Emission Limits (AELs) as radiance.

Additional requirements

<u>Measurement for classification</u>

Although the laser classification system remains unchanged in terms of definitions, there has been a significant change in the measurement geometry for classifying lasers emitting highly divergent beams. To address concerns that the measurement of power and energy for assessing the Class of high divergence sources was unduly restrictive (i.e. through a 7 mm aperture located 14 mm from the source to simulate the use of a hand-held magnifier) the measurement condition has been relaxed by moving the location from 14 to 70 mm in the new edition, meaning that some high divergence sources can be given a lower classification. However, there is an additional labelling requirement for some such sources to warn the user of skin hazards close to the source.

<u>Embedded products</u>

There are new restrictions on the level of accessible laser radiation that is permissible with embedded laser products. In particular, for user maintenance of products that are Class 1 must not permit access to levels of laser radiation of Class 3B or 4.

There is also an additional requirement for "walk-in" enclosures, that where access during operation is intended or reasonably foreseeable, engineering means must be employed to prevent emission of Class 3B or Class 4 laser radiation if someone is inside the enclosure.

Another new requirement is for Class 4 laser systems to be equipped with a manual reset, to enable resumption of operation following use of the remote interlock or interruption of the power source.

Definitions

Some terms have been added to the list of defined terms and others have been expanded. One newly defined term is "accessible emission", a term used both in the context of measurements for classification and also for quantifying "human access", one of the terms that has been expanded in the new edition.

The definition of human access is particularly important for designers of fully enclosed embedded laser products (e.g. laser machines) since in this case the product's classification (Class 1) is based on non-accessibility. In this context the revised definition makes the following changes:

a) (for enclosures of lasers of 3B and below) an assessment is made of the capability of a cylindrical probe with a diameter of 100 mm and a length of up to 100 mm (previously 12 mm diameter and a length up to 80 mm) inserted though an opening in the protective housing to intercept hazardous radiation;
b) (for enclosures of Class 4 lasers) an assessment is made of the capability a human hand or arm to intercept hazardous laser radiation. Previously there was no requirement to assess this.

The other condition for gaps remains i.e. the assessment of laser radiation that could be reflected out by a single reflection from a hypothetical flat surface.

Structure
The standard is not now divided into Sections. In the new edition:

Clause 4 still lists the engineering requirements (including 4.2.1 dealing with access during maintenance and 4.12 dealing with "walk-in" enclosures)

Clause 5 specifies the labelling requirements for laser products.

Clause 6 gives the requirements for information including that information for the user and that intended for servicing and for purchasing.

Clause 7 deals with additional requirements for specific laser products and refers readers to EN 60601-2-22 for medical laser products and EN ISO 11553-1 for laser processing machines.

Clause 8 describes the classification rules and includes direction on the responsibility for classification.

Clause 9 specifies how accessible emission levels are assessed for the purposes of classification. In this context it should be noted that the Tables of AELs for various laser classes (Table 4 to 9) now provide two tables for each of Class 1/1M, 2/2M and 3R – one where the constant C_6 equals 1 (the usual case) and the other for where C_6 is greater than one (i.e. extended sources). The interpretations when considering the measurement geometry for extended sources has been expanded, though many on the safety committee feel that this is still not clear and further work is going on to improve understanding.

As the User's guide has been removed, the requirements within the standard end with Clause 9. However for information purposes only, MPE values are still included within the standard and are described in Annex A together with the relevant tables (giving MPE limits for various wavelengths and exposure durations).

There have been no changes to the MPE limits, which are a reflection of the levels specified by the International Commission on Non-Ionising Radiation Protection (ICNIRP).

The future
Will this standard change again? – probably not greatly. There are a few typos, which will need a correction. There is still concern about the treatment of extended sources and, of course, there is the continual discussion to produce a labelling system that does not require the use of language (a discussion that has been going on for over ten years and seems no nearer to a satisfactory resolution).

There are rumours that MPE levels may be amended by ICNIRP but this is not firm. The current MPE levels are felt to be very conservative and have proved themselves by years of practical application. Test houses are still concerned that the sequence of specification used for the requirements in this standard do not lend itself readily to the sequence of testing and this may influence any further editions of this standard. (Try looking at the checklist specification in IEC TR 60825-5 and the concern in understandable.)

Whatever else, this standard is a worthwhile edition if only for the removal of LEDs from the scope and the final transfer of the user guide to Part 14.

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Associated hazards of laser use

One of the hazards associated with laser use is the electricity, especially for gas and flashlamp pumped lasers and particularly because in many such lasers there is a potentially dangerous combination of electricity and cooling water present.

The picture below was sent to Mike Barrett by Mike Shearer of Coherent UK with the comment "I thought this picture might be useful to illustrate your laser safety talk!" As Mike S pointed out "Yes, that is a power cord floating on flip flops" Ed.

Mike Barrett has addressed the importance of mechanical and other non-beam hazards of laser machines in the previous two issue (Issue 48, p50; Issue 49, p40). However, the following news report sent in by Martin Sharp of the Lairdside Laser Engineering Centre will help to reinforce this message, and the importance of assessing the mechanical and other hazards associated with a laser machine as well as that of the laser beam.

Reported by Phil Trexler of Ohio.com 16 January 2008
Portage County jury awards widow $3M in wrongful death suit

(abridged) When James Hizer found himself laid off after 27 years, he did what a lot of middle-aged men do; he took a low-paying job to get by. And after just five weeks of working for about $12 an hour at a Streetsboro steel-cutting company, Hizer died.

Hizer was on the midnight shift, operating a laser cutting machine. Whenever a sheet of steel shifted inside this machine, a worker ventured inside to straighten it. While performing this task on the fateful night he became trapped, his chest pinned against a part of the machine. He died of compressional asphyxiation and was found the next morning by co-workers; the crooked sheet of steel still inside the machine.

In submitting this news item Martin added that he personally knows of another case where a laser marking unit, suspended well above the floor in a cereal factory, killed a process worker when it fell on him.

Motion control requirements for hermetic seam welding

Ron Rekowski

Advances in electronics and battery technology have led to an increase in the number and sophistication of electronic devices that are implanted in the human body to treat a growing number of medical conditions. This technology has been used successfully for many years in pacemakers, defibrillators, and other cardio-rhythm management devices.

The growth of medical implants

All implantable pulse devices (e.g., neuro-stimulators for the treatment of chronic pain) share a common packaging technology consisting of two titanium half-shells that are joined together with a hermetic seam weld.

A hermetic seal, an airtight interface, is critical to protecting the patient from a potential source of infection throughout the lifetime of the device. The application of the seal around the periphery of the package is a critical task that has been limited principally by the capability of the motion control platform.

The welding hardware

The hermetic sealing of titanium shell medical implant package is typically executed using a Nd:YAG-based laser welding system with the titanium half-shells affixed to a three-axis X/Y/rotary system. An additional linear axis may be required if not all the seam is in one plane, which is typically the case if the weld is required to wrap around features on the device to accommodate the attachment points of the leads that transmit the electrical stimuli to treatment areas in the body. The X/Y/theta system can be a single stack (see figure 1) or a split design with different combinations of the linear and rotary axes in two separate assemblies.

Figure 1. An Aerotech X/Y/theta system for use in laser seam welding

The welding process consists of coordinated motion between the X, Y, and rotary axes to maintain the weld point on the part in the focal position of the laser. Only a single-axis move is required for straight sections of the weld, but when radii are encountered in the profile, the part must rotate in proportion to the change in angle along the surface with both linear axes moving to maintain weld focal position, as illustrated in figure 2. The speed along the weld seam must also be held constant to ensure consistent spot overlap and to maintain the integrity of the hermetic seal.

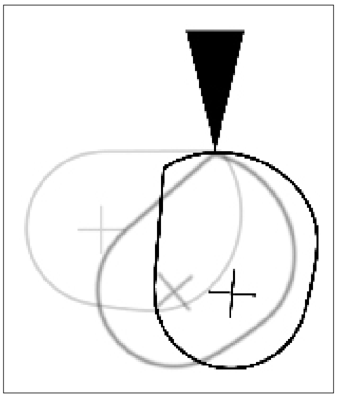
Control programming

The required movement of the axes along with the specification of axis velocity must be created off-line using a CAD/CAM package that has been configured to support this specific mechanical configuration. The CAM package breaks-up the weld profile into small, discrete steps along the weld seam path and calculates the required X, Y, and rotary positions to maintain focus and constant surface speed. The small segment sizes required to maintain good weld quality can result in a very large motion program with hundreds of lines of code.

One significant drawback to the CAM-generated approach is the loss of a direct correlation between a line in the program and a feature on the part. This makes it impossible to manipulate the program by hand to optimize weld quality by adjusting the motion profile or the weld velocity over a specific region of the part. All changes must be made in the CAD/CAM software and a new program created to run on the controller. The CAD/CAM software often is not installed on the machine controller, which results in additional delays in processing as files are transferred back and forth on company intranets or the reliable (but slow) “sneaker-net”.

An alternative method of implementing the hermetic seam-welding process retains the connection between part geometry and programmed tool path.

Figure 2. Centre of rotation translation for fixed focus



For many years robotic controllers have used on-line kinematics that transforms X/Y/Z positions into angular joint positions. The application of these transforms can be defined by a closed-form function – position and velocity commands in the 'part coordinate' space are run through a series of matrix-based multiplications (with boundary checks to avoid invalid and redundant robot positions) to create position and velocity commands for the robot. The user programs in the part coordinate space and the controller converts this information into robot coordinate space in real time.

An approach similar to the robotic control technique can be applied to the hermetic seam-welding application. The controller implementing the transformation in this case must have knowledge of the type of motion being commanded, as there are distinctly different transformation functions for linear and circular movements. Modern open-architecture motion controllers, such as Aerotech’s Automation 3200 software-based system, support this functionality. The mathematical relationship that defines the movement of the part in X/Y/Z space to motion on the X/Y/rotary subsystem is run in a task on the controller. The user program is written in the coordinate system of the part and contains only as many program lines as there are arc and line segments in the actual part geometry. Because there is a one-for-one correspondence between lines in the motion program and features on the part adjustments to part orientation or weld speed can be made on the welding machine without having to re-post the program.

The point in space about which the part rotates can be changed on a part-by-part basis if desired. The identification of the rotation point relative to the part can be automated with a vision system before welding. This reduces the accuracy requirements of the fixture, resulting in reduced tooling costs.

A critical advantage of programming in the part coordinate frame is that the commanded positions of the Cartesian space can be used to trigger the laser at precise locations along the periphery of the part to ensure the integrity of the hermetic weld. Because weld speeds are relatively slow compared to the motion control interpolation rate, the repetition rate of the laser can be adjusted in real time by calculating the vector displacement around the part during the welding process. In this way, if the programmed welding speed is modified to improve positioning tolerance over critical features on the package, the repetition rate of the laser will be automatically adjusted to maintain the desired weld spot overlap. In traditional welding processes, the weld speed is held constant and is set to the lowest speed that ensures good weld quality around the part. Having the flexibility to weld faster over straight segments and slow down for small arcs, while maintaining spot overlap, can result in a significant reduction in overall weld time.

Conclusion

Advances in control technology show great promise in reducing the programming complexity and weld cycle times while improving the quality of the hermetic seal. As the number of implantable devices proliferates and more suppliers begin to enter the marketplace, this technology will become an important factor in ensuring high quality, cost-effective manufacturing processes.

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Based on the article "Motion Control Requirements for Hermetic Seam Welding" by Ron Rekowski, published in Today's Medical Developments, a GIE Media Inc. (Richfield, OH. USA).

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Advances in lasers and delivery

cations, leading off with a review of recent work on high brightness cutting and welding by the Chair, Bill O'Neill (see article on page 32). Benefits of fibre lasers included faster cutting of thinner section material and improved welding efficiency and increased performance.

Sergei Popov of IPG Photonics reviewed applications for multi-kW CW and Q-switched fibre lasers. Among the many applications highlighted was scanner-based ultra-high speed remote cutting painted (finished) automotive steel up to 0.8 mm thickness with a 1 kW single mode fibre laser, remote micro and macro welding, and high speed hole drilling (e.g. 640 conducting holes/second (50 µm dia.) in solar cells.

Jack Gabzdyl of SPI Lasers highlighted the development of a directly modulated MOPA pulsed fibre laser for nano-second micro-machining and industrial marking. Illustrated applications included metal processing, plastic marking and thin film ablation, which could be carried out at very high processing speeds with only 20W average laser power.

Paul French of the Lairdside Laser Engineering Centre addressed the use of an ultrafast (20ps) Fianium laser and other picosecond systems. He noted that these lasers can produce a well defined structure in most aerospace materials and that their high average power makes them commercially viable in the aerospace industry for surface engineering applications, attracting considerable interest from the sector.

Mo Naeem of GSI Group in Rugby highlighted improvements in laser material processing by using the enhanced peak power feature in JK fibre lasers. These included faster piercing and higher cutting speeds for all materials tested, especially highly reflective ones.

The final presentation of the workshop was by Paul Hilton of TWI who described a new laser process. Surfi-Sculpt®, a patented power beam process originally demonstrated at TWI using electron beams, and now a fibre laser beam, involves scanning the beam to displace molten material and thereby produce raised surface features that can be shaped over a number of cycles, with a wide range of exciting surface texturing applications.

(continued from p 55)

Welding and cutting

sharing between industry and academia and is the conduit with UK government. And for European organisations the Photonics21 network is the libk to the European Commission for photonics research in Europe.

Lin Li, University of Manchester reviewed 1 kW single mode fibre laser cutting work within his research group. Most interesting was his results of striation-free cutting (surface roughness < 2 µm Ra) of 1-2 mm mild steel sheets.

In a related presentation Berndt Brenner (standing in for the original presenter, Wolfgang Danzer of Linde Gas AG, Germany who was ill) described a comparative study on metal cutting involving IPG single mode and multimode fibre lasers and a Rofin slab CO_2 laser. At the same output power 2.5 kW, on 0.5 mm electric steel, the multimode fibre could cut nearly three times faster than the CO2 slab laser, but with poorer edge quality.

Mark Daichendt of Laserline, Germany provided a number of practical examples of welding of metals using up to 10 kW of fibre-delivered diode laser power, providing all the benefits of laser keyhole and heat conduction welding with the lower cost and higher efficiency of diode laser sources.

Chris Allen of TWI described research into alternative welding technologies for the rail sector and the use of fibre lasers for hybrid laser-MIG welding for thick section and remote cutting with a fibre laser. He described the production of low distortion, high quality hybrid fibre laser-MIG welds in 3mm 6xxx aluminium alloys at >5m/min, stressing the importance of the design of joint geometry and the gap tolerance of the technology.

Stewart Williams of Cranfield University reported a parametric study of 100W single mode fibre laser welding of stainless steel using pulsed (0.1 - 10 ms) and CW beams. The work showed that there was some small benefit to be gained in terms of penetration depth and lower heat input by short pulse high duty cycle operation but only under well controlled conditions. Pulsed laser effects on microstructure and surface morphology were also noted.

Patterning transparent materials by laser-induced backside etching

Klaus Zimmer and Rico Böhme

There is an increasing industrial need to precision patterning of solid materials for high end applications, such as in micro-system technology and micro optics. A number of hybrid laser etching techniques offer the opportunity to etch transparent materials with standard excimer lasers [1,2,3]. Among the options available laser-induced backside wet etching (LIBWE) allows high quality patterning of transparent solids by enhancing the laser beam absorption at the liquid-solid interface. The current status and new applications of LIBWE are presented here.

The LIBWE process and the influence of processing parameters on the etch rate and the characteristics of the etched surface have been studied extensively [1,2, 4-6]. The etching mechanism involves laser-induced heating of the liquid and subsequently of the solid, softening/melting of the solid material, and detachment of the softened/weakened material by mechanical forces such as shock waves and transient high pressures. Despite the deficiencies in understanding the complexities of the etch process a number of potential applications for direct writing of precise patterns has been demonstrated [4,5]. In principle, the LIBWE technique is capable of etching micron and sub-micron structures with a high surface quality into transparent materials at low laser fluences and with a moderate etch rate [5].

Experimental

The principal experimental set-up for LIBWE is schematically shown in figure 1.

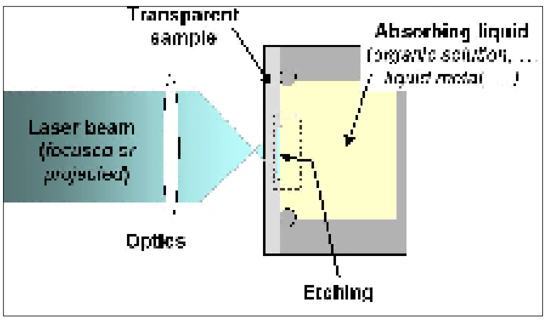

Figure 1: Principal experimental set-up for laser-induced backside wet etching.

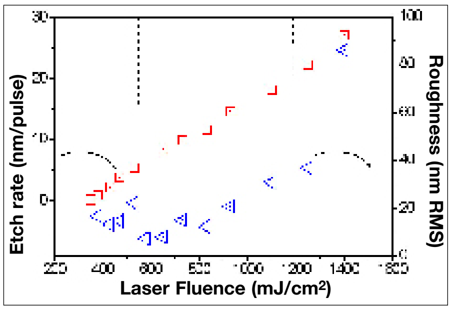

Figure 2. Etch rate and surface roughness of fused silica etched with 248 nm, 25 ns laser pulses using a 0.5 M pyrene/toluene solution. The dotted lines show the mostly used fluence range.

A pulsed laser beam that is pointed at a transparent sample penetrates the material and meets the liquid at the backside where it is absorbed and the etching takes place. In a range of experiments to investigate the process two pulsed nanosecond lasers were used, an Excimer (Lambda Physik LPX 220i) at 248 nm and a Q-switched Nd:YAG at 1064 nm. Depending on the experimental set-up the laser beam was either focused or projected to the sample backside. The laser spot was scanned over the surface using a computer controlled XYZ-stage or a galvano scanner, achieving a resolution of about 1 µm and a maximum velocity of 100 mm/s.

Results and discussion

Backside etching with organic solutions

The laser-induced backside wet etching process of fused silica and glass with hydrocarbon solutions comprising a solvent (e.g. toluene) and an absorber (e.g. pyrene) features a low threshold fluence of roughly 300 mJ/cm² and a low etch rate between 10 and 30 nm/pulse. These characteristics as well as a low surface roughness enable high precision and high quality materials patterning.

The dependence of etch depth per laser pulse and surface roughness on the laser fluence are shown in figure 2 for fused silica, identifying the optimum fluence range for etching. The optimum process parameters vary with the material to be etched, the solution used and the laser beam parameters. The etched material is almost free of cracks and surface contamination. However, incubation processes have also been observed and such effects must be considered in the machining process if high precision is to be achieved.

Note that at higher fluence the etch rate and the roughness increase significantly, in a way that resembles direct laser ablation.

Backside etching with metallic absorbers

Recently it has been demonstrated that liquid metals, e.g. gallium, can also be used as the absorbing liquid for LIBWE [7]. Liquid metals have a very high absorption, a high boiling point and do not suffer from decomposition. As a result, a higher laser fluence can be used and greater etch rates achieved, as shown in figure 3.

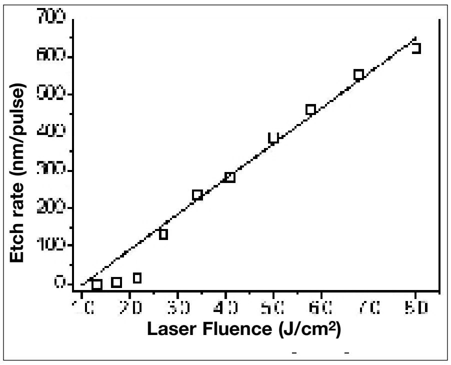

Figure 3. Etch rate of fused silica etched with 25 ns laser pulses at 248 nm using gallium as absorber.

In comparison to results using organic liquids a significantly higher threshold fluence of 1.3 J/cm² is found for the liquid metal etching, combined with an etch rate roughly 10 times higher. The latter is a result of the high reflectivity and the high thermal conductivity of the liquid metal. Taking these factors into account the absorbed laser energy is similar to that of organic liquids [8]. Despite the high etch rates a still high quality of the etched surface was found, as illustrated in figure 4. The etched groove features well-defined edges and a smooth bottom. In contrast to other

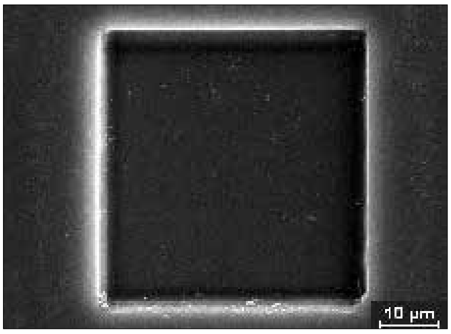

Figure 4. SEM image of a groove etched with 248 nm excimer laser pulses into fused silica using gallium as liquid absorber.

laser etching techniques almost no incubation effects have been observed and etching begins with the first laser pulse.

A further benefit of using a metallic absorber is that visible and infrared lasers can be used for etching. This has been demonstrated for 1.06 µm Nd:YAG laser pulses with a length of 18 ns and 73 ns, respectively. Etch rates as high as 1 µm/pulse have been observed. In addition to gallium, similar etch rates can be measured with mercury as absorbing liquid [9]. Compared to using gallium, the threshold fluence is significantly lower and the quality of the etched surface is higher for mercury.

Table 1 compares the results for gallium and toluene. Although thermally-driven processes dominate the etching for both liquids the etch mechanisms are presumably different. The higher boiling point of gallium allows higher interface temperatures that are probably responsible for the higher etch rate. The incubation effect observed for organic liquids is linked to secondary processes such as

Feature		LIBWE - liquid	
		Organic (Toluene)	*Metallic (Gallium)*
Threshold fluence @ pulse	J/cm²	0.3 300	~1.3 1st
Preferred fluence range	J/cm²	0.6 to 1.2	3.0 to 6.5
Etch rate	nm/pulse	5 to 30	> 500
Incubation	pulses	significant 2 to 10	marginal ≤ 1

Table 1: Comparison of typical etch rate and threshold fluence values at laser-induced backside wet etching of fused silica with 248 nm excimer laser radiation using organic or metallic absorbers.

bubble formation and liquid decomposition. In addition to the higher etch rates, metallic absorbers offer the opportunity of etching new classes of materials that are transparent to the now applicable pulsed IR laser radiation. These new capabilities allow exciting industrial applications of this technique.

<u>High resolution patterning of transparent materials</u>
The low etch rate and the high surface quality of the etched surfaces associated with LIBWE enable the etching of 3D and binary microstructures into surfaces for microoptical or microfluidic applications using a variety of techniques such as mask projection, direct writing, contour mask dragging, or grey scale mask [4,5].

By means of interference or phase mask projection techniques lateral resolutions into the sub-micrometer range can be attained not only in fused silica [6,10] but also in hard, chemically resistant materials such as sapphire [11]. However, the height of such small patterns is restricted by thermal diffusion, thereby limiting the overall contrast of the etching technique. On the other hand the same processes that lower the contrast of sub-micron patterns smooth high frequency spatial patterns [12] resulting in a low roughness of the etched surfaces. Thus, the micro roughness does not increase significantly with rising etch depth. A micro roughness as low as 10 nm rms has been observed [5]. However, with prolonged laser irradiation features associated with the inhomogeneities of the laser beam are seen. Such unwanted structures can be reduced when specific mask projection techniques are combined with laser scanning.

The high etch rates achievable with metallic absorbers make one-pulse surface patterning feasible and allow patterning "on the fly". The speed and the precision of this approach depend on the repetition rate of the laser source and the speed of the workpiece handling system. For patterning "on the fly" not only direct writing or mask projection but also more sophisticated techniques (e.g. interference) can be applied as long as the patterning can be accomplished with one pulse.

An example of "on the fly" etching of sub-micron gratings with one laser pulse is shown in figure 5. The gratings have a period of 760 nm, are very smooth and have a depth of about 130 nm. By changing the laser fluence and/or the

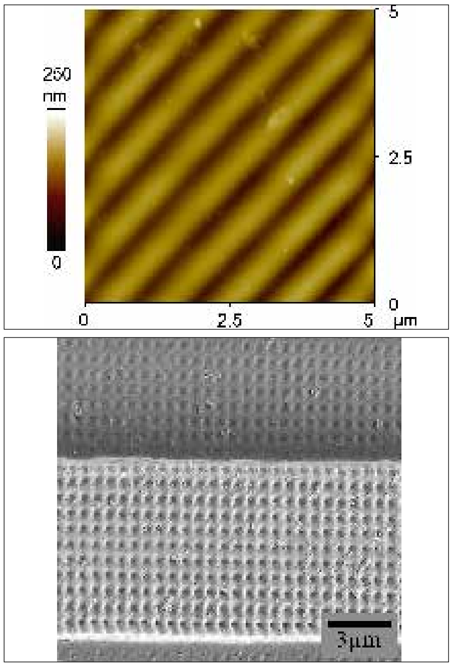

Figure 5. Gratings etched "on the fly" into fused silica by means of phase mask projection at 248 nm. (top) AFM image of a linear grating using gallium as absorber. (bottom) SEM image of a binary structure of 3 µm height with an additional laser-etched cross grating of sub-micron period.

liquid absorber the shape of the gratings can be adjusted.

Conclusion
Laser-induced backside etching enables the direct etching of microstructures such as binary patterns or sub-micron gratings into transparent materials with a low surface roughness. The threshold fluence, the etch rate, and the surface quality depend on processing parameters and the absorbing liquid used. Organic absorbers offer a low etch rate but show a significant incubation effect that must be considered for precise material processing. This effect does not arise when metallic absorbers are used and a much higher etch rate of up to 1 µm/pulse can be achieved, but higher laser fluences are required for etching mainly as a result of the higher reflectivity. Due to the high etch rates, micro- and sub-microstructures can be etched "on the fly" for high-speed surface patterning.

Moreover, the use of metals allows the utilization of infrared sources such as Nd:YAG lasers that are well accepted for industrial processes. The utilisation of these reliable low cost lasers makes the industrial application of backside etching more attractive and permits high etch rates and smooth etch surfaces to be achieved over a wide range of materials.

Continued over...

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See Observations p51

Advances in lasers and beam delivery enabling new industrial applications

12 December 2007, Cambridge Science Park

The high attendance and record number of presentations at the AILU workshop at the Trinity Centre, Cambridge Science Park on 12 December 2007 was a reflection on the high level of user interest in recent developments of new laser source and beam delivery.

Workshop speakers: (l to r) Jack Gabzdyl, SPI; Sergei Popov, IPG; Stewart Williams, Cranfield University; Bill O'Neill, Cambridge University (Chair); Mark Barry, Laserdyne; Dave MacLellan, Rofin-Baasel; Mo Naeem, GSI Group; Paul Harrison, Powerlase; Andrew Kearsley, Oxford Lasers. Not included is David Richardson, Southampton University; Alain Bierneax, Lasag; Peter Blatt, Coherent; Thomas Kaiser, PrenovaTec; Paul French, Lairdside Laser Engineering Centre; and Paul Hilton, TWI.

An exhibition and a full programme, including international speakers from the UK, USA, France, Switzerland and Germany, addressed a wide spectrum of laser source and beam delivery developments.

The opening presentation by Stewart Williams of Cranfield University, the David Greening Memorial Lecture, gave an overview of the benefits of high quality lasers and beam delivery from a user's perspective. Explaining that laser material processes depend primarily on the absorbed intensity and the interaction time, and that both are strongly dependent on the focused beam diameter, Stewart used fibre laser welding results from Cranfield to illustrate how the new high brightness lasers provide improvements to the industrial user through increased depth of field and larger spot diameters at the required intensity level, both of which lead to improved process tolerances.

David Richardson of the Optoelectronics Research Centre, Southampton University described developments in microstructured fibres and compared and contrasted the manufacture and performance of large mode area holey fibres, MM jacketed air clad fibres and hollow-core photonic band-gap fibres, with a view to high power, high beam quality laser beam delivery. He highlighted the compromised that have to be made with regard to transmission losses, band losses, mechanical strength and interconnection problems.

The remainder of the morning session included a series of more commercially oriented presentations. Dave MacLellan of Rofin Baasel UK reviewed the effects of pulse length and beam shape on laser ablation (see article on page 28). Andrew Kearsley of Oxford Lasers described micromachining short pulsed solid state lasers, illustrating how picosecond lasers were an effective solution for a wide range of materials (ceramics, dielectrics and metals) and that femtosecond lasers are a good choice for dielectrics such as crystals and glass. Alain Biernaux of Lasag AG (Switzerland) addressed laser microdrilling with a solid state (10 to 30 ns pulse) slab laser of high average power (40 W). Mark Barry of Laserdyne (USA) also addressed hole drilling, but in the context of laser processing variability in turbine engine manufacturing, highlighting the benefits of three key developments that provide more consistent holes: breakthrough detection, At Focus Drilling™ and optical focus control. Peter Blatt of Coherent (Germany) reviewed applications of mode-locked and Q-switched UV-DPSS lasers, illustrating how both are successful and complementary in serving industrial applications and highlighting the key challenges of meeting the increasing demands of higher power/ shorter wavelength, reducing the cost per Watt and developing laser designs for 24/7 operation. Paul Harrison of Powerlase addressed the use of their kW-class Q-switched nanosecond pulsed DPSS lasers for flat panel displays and solar cell manufacture, including rapid laser patterning of thin films and BM patterning and polysilicon annealing in volume industrial processing.

The afternoon session was largely given over to fibre laser technology and appli-

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OBSERVATIONS

Short comments on papers in this issue

Pulse length and beam shape: efficient material removal

Dave MacLellan

Micro lasers are certainly receiving a lot of attention at the moment. This article, giving a good summary of the current status, is hence very well timed. All the developments mentioned are interesting; however, in my opinion, it is the picosecond laser that is most exciting due to its high potential in growing markets. The short pulse duration (<10 picosecond), high energy per pulse and high average power enables such a laser to improve product quality (cold processing) at higher production rates. No wonder industry is interested! Maybe it is worthy of its own article?

Gerry Jones   Trumpf UK

This article, part of the on-going “Back to Basics” series, gives a general view of how the laser pulse duration affects certain types of materials processing. It justifies this view using some quite specific laser products and conveniently selected case studies but fails to mention other laser designs that are also capable of generating a pulsed output. The pulsed fibre laser (such as manufactured by SPI Lasers) is such an omission.

It’s a shame that the article concentrated on laser types rather than applications, as one of the more prominent laser applications described by its title was not mentioned – laser engraving (or milling). Also, the article did not provide an explanation of why pulse duration is so critical in the choice of a laser process. This can be summarised by examining the equation the thermal penetration, D:

$$D = 2 * (\kappa * t_p)^{1/2}$$

Where κ is the thermal diffusivity and t_p is the pulse duration. The equation shows that D (the distance heat will travel into the target material) is determined by only two factors: the material properties of the target and the pulse duration. As the duration becomes shorter, the heat penetration is reduced – but it isn’t a linear relationship. For this reason a wide range of pulse durations is needed and the use of a particular laser (and associated pulse duration) is dictated by the requirements of the process e.g. shorter pulses for less collateral damage.

The article continues with a description of square fibre technology, but doesn’t mention other beam shapes, in particular the gaussian – the beam shape most commonly used for materials processing. It would have made interesting reading to see these two different beam shapes compared and contrasted.

Paul Harrison   Powerlase

This article gives a tantalising glimpse at some of the interesting developments in solid state lasers and particularly lasers based on fundamental lasers around the 1 µm wavelength.

About 10 years ago it seemed that all that could be done to solid state (YAG) lasers was to replace flashlamps with diodes, and wait for femtosecond lasers to make them obsolete! What this article demonstrates is that innovation continues to thrive and that companies like Rofin – Baasel are very active in bringing these new lasers to the market.

I like the idea of shaped fibres. It is yet another technique to take us away from the round Gaussian-like beams available from many sources (although this seems somewhat odd considering the efforts laser source manufacturer’s go to in order to give us round M^2=1 beams in the first place!). Beam shaping is surely going to grow in importance.

Martin Sharp
Lairdside Laser Engineering Centre

Laser cutting of complex parts

Jean-Pierre Bergmann and Birk Ploennigs

Back in the 70’s we built a Flexible Beam Guide. This was a hand-held arrangement of small diameter mirrors and tubes arranged like this BIM system to conduct the high mode quality beam from the Ferranti MF400 CO_2 laser to a lens and nozzle cutting head. It then evolved to be attached to a robot but it soon became evident that, what a colleague called, “the tibia/fibia problem” severely restricted manoeuvrability.

The answer would be to combine the mechanical and optical axes while still purging the beam line with clean air. This is just what Jenoptik have done, using two mirrors at each rotary axis. The mass of the arm at full extension is presumably sufficiently small that inertial overshoot is negligible, even when moving rapidly.

One advance would be to halve the number of mirrors at each elbow e.g. use a “half-speed mirror” that bisects the rotary axis deflection, a concept patented in the 60’s. Unfortunately, the geometry restricts the range of deflection of each axis and complicates elbow shielding. An armadillo-like shell of metal segments could serve this purpose but might be mechanically fragile. Nevertheless, with the advent of the high beam quality and short wavelength fibre laser the diameter and mass of the whole system could be reduced to ensure minimal overshoot – if there is sufficient market demand!

Brooke Ward   Europtics.

The article outlines a flexible 5 axis robot based solution to trimming pressed parts in 3-D using a CO_2 laser, with the beam delivered through the robot arm. The modular cell offers a flexible answer for low to medium production volumes.

This approach definitely has advantages over the more conventional route (i.e. using a solid state laser with fibre delivery): it eliminates fatigue failure of the beam delivery fibre, and eliminates the need to carry the fibre along the robot arm or in a beam delivery tube.

Prior work shows that this kind of laser trimming process is economical when compared with using press tool trim dies for total part runs of up to 12000 units, with this figure increasing if complex cam movements are required within the die to trim or punch the part being processed (these cam dies can be very expensive and difficult to maintain).

The point is well made that the non contact laser process is better for processing thinner parts (0.6 mm thick steel is now used for some roof and door panels for example) and the process also allows fine features, small radii or self jigging tabs and slots to be cut into the part – something that a press tool trim die would struggle to do reliably.

Some time ago I worked with a similar type of laser beam delivery robot, and the key challenge to keeping it running was to maintain the arm joint seals intact to prevent grease, dust and dirt getting in and fouling the lenses. Removing and cleaning the lenses was a significant challenge, I recall!. The solution offered, to fill the arm with inert gas at a positive pressure, may well be economical if nitrogen produced by a nitrogen generator is used, as high leakage rates can be expected at the joints.

Finally, the fine beam quality produced by the CO_2 laser mentioned in the article further shows that this laser will remain a workhorse for such applications for many years to come,

Stephen Ainsworth
S.J.Ainsworth Consultancy

The synopsis of the work carried out by Jean Pierre Bergman and Birk Ploennigs demonstrates very clearly the advantages of using a modular off-line system to reducing the constraints of conventional gantry style laser cutters.

The authors describe the scenario of laser cutting large complex panels. In UK industry and elsewhere this activity would usually take place in the proto/pre-production phase where time to market issues are aggressive and are critical to the project timing. For such applications the value of such a system is self evident.

The expenditure that can be incurred in the manufacture of components through to the homologation stage can be extremely sensitive to design changes, and in some instances the financial impact of changes could be commensurate with the initial capital investment cost of such a robot arm.

In a fluid eco-manufacturing environment the ability and desire to create more flexible manufacturing has never been higher, and the solutions offered in this paper demonstrate that value can be added without compromising on quality, cost or customer expectation.

It would also be interesting to know, given a quoted total beam path (reflective) loss of only 5%, if the use of multiple-modular systems would lead to an exponential or arithmetic reduction. Depending on the answer, it may be possible that certain bespoke requirements could be satisfied with even more economic viability.

John Shuker TRS Engineering

Cutting and welding with the new high brightness lasers

Thomas Seefeld and Bill O'Neill

For sure the subjects addressed by Bill O'Neill (cutting) and Thomas Seefeld (welding) in their common article about high brightness lasers are currently two of the hot topics under discussion in the laser materials processing community. And this contemporary issue is truly worthy to be included in a 50th issue of Therefore I would like to take the opportunity of this jubilee to congratulate and to thank Mike Green and his team for the high quality source of information they have provided us with since 1995. The article by Thomas and Bill is a good example for a pool of results and data about an up-to-date laser subject – such as we are used to in this magazine.

Tthe term 'brightness' is often used to provide a qualitative reference to the output power and beam quality of a laser. Brightness is defined by the output power per unit area per unit solid angle, i.e. in units of W/m^2sr. Thus it is proportional to power divided by the square of Beam Parameter Product BPP. Also without this quantitative treatment of the term, the article demonstrates with numerous examples the impact of power and beam quality on present cutting and welding capabilities – particularly if judged in terms of processing speed. A main message is that for thin sheets the benefits of high beam quality as well as shorter wavelength (as compared to the 10.6 µm CO_2 laser) are much more obvious than for thicker sections. This can definitely be confirmed. The authors may kindly excuse an additional note for the reader about the current bench-mark for high-speed cutting, published in 2006 by Fraunhofer ILT: 1mm mild steel cut at 135 m/min using a 4 kW fibre laser at 2 mm*mrad (not single mode!), resulting in oxide-free edges with a roughness Rz (!) below 7 µm. The achieved speed is in good agreement with computer-simulations, which in turn provides confidence in the underlying process model.

Thick sections benefit from the larger Brewster angle at the 10.6 µm wavelength of CO_2 lasers, leading to a pronounced absorption in metals at grazing incidence. This situation truly is a stroke of luck for CO_2 lasers. And it modifies some oversimplifying statements frequently made, generalising high absorption at 1 µm wavelength. While the importance of the Brewster angle is also noted by Thomas and Bill, their presumption about improved deep wave-guiding through multiple reflections in case of 10.6 µm wavelength is at least questionable, taking into account the physics of Fresnel absorption. A process analysis using the CALCut computer simulation yields another finding: just the 1 µm wavelength range stimulates multiple reflections and thereby allows for at least fair coupling efficiency in deep penetrating interaction zones. However, the mechanisms affecting laser beam propagation and energy distribution in cutting kerfs and welding capillaries are manifold. Furthermore, the effects of gas flow conditions and melt dynamics on the achievable cut and weld quality are not sufficiently understood. These are tasks for continuing research and development with significant potential for shifts and expansion of existing laser markets as well as for the generation of completely new markets. That is why there is so much interest and impatience in academic and industrial circles concerning the current gain of new insight. Pivotal questions are: What is the optimum brightness (and wavelength) for each application with regard to technical and economic criteria? And perhaps more essential: What are the objective limits and are there new parameter options available that will overcome these limitations? To wait and see would be fatal in view of the potential impact of these hot topics.

Dirk Petring Fraunhofer ILT

This article discusses the implication of "high brightness" lasers to cutting – particularly in relation to faster cutting and better cut quality, especially in the cutting (including micro cutting) of thin section using less than 1 kW of power.

Welding is also discussed, including a comparison of a state of the art CO_2 laser and a fibre laser welding of 11 mm thick pipe. The fibre laser welds at a higher speed using less power, and its welds are narrower and have smaller heat affected zones.

The article concludes by pointing out that the new generation of high brightness solid state lasers are robust, efficient and compact and therefore well suited to outdoor mobile welding in harsh environments – something that pipeline engineers are beginning to exploit.

A "bright future" indeed ....

Janet Folkes University of Nottingham

Precision Trepanning with a Fibre Laser

Paul Jacobs

The article gives a thorough discussion on drilling with microsecond duration pulses. It is good to see all the worked examples since I think this (rather than just quoting a formula) will tend to encourage others to try calculations for themselves. As with all laser processes, there is a trade-off between quality and speed and certainly the result of diameter standard deviations in the range of 2 - 4 microns sounds impressive given the short drill times. Drilling with a nanosecond laser will typically give better hole quality albeit with longer drill times. For example, one of our customers routinely achieves diameter standard deviations of 0.2 microns in production using a 3 second drill time. I am not familiar with PC-MATH model of trepanning head but there are other devices available that would probably enable LFI to use the laser at 10 kHz.

Martyn Knowles Oxford Lasers

The Clearweld® process for plastics' manufacture

Gareth McGrath and Katie Rushforth

Selection of the right Clearweld resin or coating appears to facilitate the use of most industrial laser types (diode at 808nm and 940nm and YAG, fibre or other solid state in the range 1030 – 1090nm) for transmission welding of plastics and Gareth rightly concentrates mainly on the most difficult task of clear-on-clear plastic.

Rofin's experience is that for non-clear plastic at the absorbing side of the joint, there are many pigments or additives that can be integrated at the masterbatching stage to eliminate the requirement for an additional process to apply Clearweld in some form. A small amount of carbon black represents an inexpensive alternative, but if the colour change this brings about is not desirable in the finished product then a good masterbatcher, with experience of laser plastic welding should be able to incorporate additives that introduce negligible colour change and avoid the need for Clearweld.

Even in the application that Clearweld is best suited to; clear-on-clear, there are alternatives. Companies like BASF already manufacture additives that can be incorporated into the plastic on absorbing side, whilst leaving it clear and largely untinted. See: http://www.performancechemicals.basf.com/ev-wcms-in/internet/en_GB/function/conversions:/publish/upload/EV/EV1/products/pl/brochure/BR_Lumogen_IR_laser-transmission-welding.pdf for example.

Whilst there may be occasions when it may be preferable to apply a layer of Clearweld rather than integrate an absorber into the bulk plastics, it may be that these occasions represent quite a limited, narrow field of application.

Andy May Rofin Baasel UK

Motion control requirements for hermetic seam welding

Ron Rekowski

Falk Strascheg

I believe it was as a result of a suggestion by Falk F Strascheg of Laser Optronic, in 1976, that the Neodymium laser was first used for seam welding, and in this application. Laser Optronic represented a number of companies in Germany at the time, including Aerotech and J K Lasers. When it was found that a YAG laser was a splendid tool for the task, Laser Optronic configured a mechanical system as described by Ron Rekowski controlled by Aerotech Unidex drives. This was interfaced to the laser at J K Lasers and incidentally carried JKL into the laser system, as opposed to laser source, business.

The early systems avoided the complexity that Mr Rekowski has addressed because the joint line between shells was a circle. The leadthroughs lay off the joint line; they were planar and welded in place by circular interpolation of the X-Y table.

The spectacular reduction in temperature rise that resulted from the move to YAG laser welding reduced the need for thermal insulation inside the device and permitted the use of more energy-efficient but more thermally sensitive electronics. The latter change reduced the battery requirement and increased the operational life of the device by a factor. This all led to a massive reduction in the overall size of the devices and a desire to progress to the shapes shown by Mr Rekowski. Our initial, naïve approach to solving the control problem was to mount a miniature linear slide on the theta axis so that we could use it to ensure that the centre of rotation was always coincident with the axis of the theta table. A colleague pointed out that this was completely unnecessary if we could only establish sufficiently sophisticated control. We approached Ian Smith of Warwick Computer Designs for help. He showed that the problem bcame easily using Euclidean geometry, resulting in a little Microsoft 2k Basic program that ran on a Nascom 2 computer. This maintained the laser beam normal to the product surface to the required tolerance and generated a uniform feed rate throughout the welding cycle. I do not know when this was abandoned but it ran for many years.

The new solution is doubtless the right one, given today's sophisticated technology, but I have a lingering nostalgia for the application of Euclid!

Tim Weedon

CNC and robotics controllers contain many of the same elements and have been converging for a long time. For instance CNC features such as RTCP (Rotation Tool Centre Point) on five axis machine tools use robot style transforms to do the work. It therefore should not be too much of a surprise that a modern controller includes such features within its repertoire, possibly enabling novel machine configurations to be realised.

Implants tend to be made in families each of which has a fixed shape so once a satisfactory set of programs has been achieved they will rarely need alteration and new programs will be relatively rare. This suggests that while the extra programming convenience is nice it is probably not critical for this application. Like many advanced features ease of use, by staff for whom program preparation is probably only a small part of their job, will determine how much they get used in practice.

J Peter Hancocks
Warwick School of Engineering

This excellent article outlines 2 methodologies for tackling a complex motion program. I suspect that the use of on-line kinematic transformations will be new to many readers. The article explains the benefit of this approach in facilitating tweaking of the program to optimize the laser process. However, this mathematical-sounding technique may also put-off many users who would be happier to leave the hard work to the CADCAM system. I think it would have been helpful if an example of a simple program using the kinematic transformation method had been included. Maybe this could be developed in a future article.

Martyn Knowles Oxford Lasers

Patterning transparent materials by laser-induced backside etching

Klaus Zimmer and Rico Böhme

Laser micromachining by direct ablative etching of materials is now in widespread use for drilling microholes - from printed circuit boards and ink jet printer nozzles to scribing thin film solar photovoltaic devices and prototyping MEMS devices and microptical arrays. Its inherent flexibility for accommodating complex high-resolution 2½D spatial designs in a wide range of materials - from polymers, ceramics, glasses and crystals to metals and semiconductors is well established.

Above single pulse threshold fluences of a few tenths to a few J/cm^2, typical ablative etch rates are several tenths of a micron per pulse. Somewhat similar to the contrast behaviour of photographic film, the etch depth has an approximate logarithmic response to exposure dose. Exposure to additional pulses creates proportionally deeper etching of the material. With appropriate choice of laser and illumination matched to the material and process, ablatively etched surfaces can be produced having a roughness as low as 5 nm.

Since ablative etching inherently relies on the material being highly absorbing to the laser photons, optically transparent materials like glasses, fused silica, sapphire, diamond and fluoride crystals are ineffectively etched by laser wavelengths which are transmitted through the material. While focused high intensity pulses from ultrashort pico and femto-second lasers can be used to induce multi-photon absorption processes in most transparent materials, material removal rates are small so throughput is generally slow and costs consequentially high. Also current ultrafast lasers are not sufficiently robust for use in volume manufacturing applications. Dopants (e.g. dyes) can be added to an otherwise transparent workpiece to induce laser ablative etching but this may not be desirable for the end user, their application or manufacturing process.

To overcome material transparency issues various auxiliary methods such as Laser Induced Plasma Assisted Ablation (LIPAA) and Laser Induced Backside Wet Etching (LIBWE) have been developed in recent years. In the LIPAA approach a highly absorbing solid material is placed in contact with the backside of the transparent sample to be etched. The laser beam is passed through the transparent sample to illuminate and ablate this absorbing material, the resulting plasma etching the backside of the sample. On the other hand the LIBWE method, the subject of the article by Zimmer and Böhme, uses an absorbing liquid behind the transparent sample. While the exact mechanism of the etching process is not well understood, the authors present impressive demonstrations of the technique's capability for etching sub-micron features into hard transmissive materials like fused silica. With organic liquid absorbers and uv excimer laser illumination etch rates can be as small as 10-30 nm/pulse which in turn enables excellent process depth control and a surface roughness capability of less than 10 nm. The authors also demonstrate that when using liquid metal absorbers such as gallium and mercury, ten times higher etch rates can be produced and infrared Q-switched pulsed Nd lasers can be an effective source for etching hard transparent materials.

While both the LIPAA and the LIBWE processes are effective methods for high-resolution etching of transmissive materials for which direct laser ablation is ineffective, integrating them and associated parts handling into specific manufacturing processes and operations remain big challenges for the end-user applications engineer and the laser systems integrator.

Malcolm Gower
Nanophoton Technologies

The article by Klaus Zimmer and Rico Böhme on Patterning Transparent Materials by Laser Induced Back-side Etching is an informative example of the potential for realising new laser processes by considering the Surroundings (ambient) in which processes take place. While the laser community is very familiar with the benefit of using a co-axial jet of oxygen gas to increase the speed of laser cutting of ferrous metals, our knowledge of the interplay between the laser, material and ambient in short pulse laser applications is only at an embryonic stage.

Laser induced back side wet etching (LIBWE) is arguably the most publicised example of the huge potential for hybrid processing using laser pulses of short duration. The ability to structure an otherwise transparent material, with nanometre roughness, by modifying the ambient in which it is placed, is indeed intriguing. Other examples appearing more recently in the technical literature include the production of dark silicon using H_2S and various fluoride gases[1], and the recent reports of enhanced laser ablation of silicon in high[2] and low[3] pressure water ambients.

The authors state the mechanism by which the LIBWE process proceeds is complex and not clearly understood as yet. The mechanism by which the energy is coupled from the laser into the transparent material by the highly absorbing liquid polymer or metal will no doubt be very difficult to unravel. As the photo-thermo-mechanical processes involved are likely to take place on timescales that are difficult to access through experimentation, it seems that computational models will be ultimately required to elucidate the finer details. However, there appears to be significant scope to apply some real-time, fast-imaging techniques to analyse the propagation of the shockwaves and recoil of the material surface in order to investigate the material removal or redistribution mechanisms further.

While the laser material ambient interaction is fascinating, the possibility of deploying a LIBWE processes in industry will depend on cost effectiveness and its potential for providing added value. In my experience, the repetition rate at which the process operates will be most important. The recent advance from excimer based processes to those using industrially robust YAG lasers with greater etch rates is a welcome development. The health and safety issues associated with working with liquid metals may however present new barriers for implementation. Perhaps a suitable future compromise could be the application of high repetition rate (>200 kHz) UV and DUV laser sources, ultimately capable of greater precision, using various organic liquid media.

Overall the article is a welcome reminder from the authors that laser processing of materials in media which are highly absorbing offer significant benefits. It is also significant that the response of ambients which are comprised of more complex molecular structures than the diatomic molecules in air and the other monatomic gases we typically use in laser processing, offer real potential for new advances and important intellectual property.

References

1 http://mazur-www.harvard.edu/library.php

2 http://www.synova.ch/english/synova.html

3 See ICALEO 2007 (http://www.icaleo.org/) , LPM 2007 conferences (http://www.jlps.gr.jp/lpm/lpm2007/LPM2007_OralProgram_20070417.pdf)

Gerard O'Conner NCLA, Ireland

This article presents some really impressive results using liquid-assisted laser etching techniques. As noted by the authors such methods have been tried for a few years in different ways and do have distinctive technical merits. However, in my opinion, the main reason why such techniques have not become more widely adopted is purely down to the impracticalities involved in using chemicals or liquid metals. The benefits (such as high etch rates) are far outweighed by the need to handle potentially harmful liquids and I can't see such methods finding 'mass-market' uses unless they can offer something which other competing methods cannot. At present direct laser etching can do many of the same things, even if it can't match the higher etch rates for 'on the fly' etching, hence the use of chemicals remains the major barrier to the uptake of LIBWE. In addition, the scale-up issue is also a major factor. The ability to produce large samples using these methods has serious practical challenges and these would have to be solved for industrial-scale uses. The high quality results presented can obviously offer a potentially powerful method by which to produce micron-level features but whether they can make it out of the research environment into an industrial arena remains to be seen.

Nadeen Rizvi Laser Micromachining

Welding and cutting with fibre-delivered laser beams

20 February 2008, TWI, Cambridge, UK

The second AILU workshop within 3 months dealing with laser beam delivery and industrial applications took place at TWI Cambridge. It was chaired by Paul Hilton and attracted 70 delegates.

Workshop speakers: back row (l to r) Richard Hewitt, WMG; Berndt Brenner, Fraunhofer IWS Dresden, Germany; Ali Khan University of Cambridge; Stewart McDougall, Intense Ltd; Aurelie Brun, TWI; Mark Daichendt, Laserline, Germany; Charles Marine, Stadco Group; Mark Richmond, GSI Group. Front row (l to r) Stewart Williams, Cranfield University; Alastair Wilson, Photonics KTN; Paul Hilton, TWI (Chair); Markus Kogel-Hollacher, Precitec Optronic, Germany; Lin Li, University of Manchester.

AILU was honoured to have Professor Berndt Brenner of the Fraunhofer IWS Dresden, Germany to give the keynote presentation, not least because this was his first UK presentation. Speaking on new laser welding technologies and their industrial use in Germany, he reviewed many interesting industrial welding applications for hard-to weld materials, light-weight construction and distortion sensitive components; including areas where the excellent beam quality of fibre lasers opens up new application fields (e.g. for welding dissimilar materials, heat and distortion sensitive components and thick sheets) and permits new production technologies.

At the other end of the welding spectrum, the presentation by Aurelie Brun of TWI addressed the use of fibre delivered diode laser beams for the welding of technical textiles using the Clearweld® process. The use of fibre delivery in this case facilitates the application of the process to the welding of complex textile forms.

GSI Group have much experience in the design of robust laser beam delivery design for industrial applications, and Mark Richmond reviewed their unique patented design for back reflection protection. This has been applied to a wide range of fibre core sizes and for Q-switched as well as CW power, allowing material to be cut or welded at 90°.

Intense Ltd is a relatively new company currently offering fibre-integrated higher brightness diode laser sources at 5 and 10W. Stewart McDougall described their latest developments in improved high brightness power and plans to apply this technology to laser bars and stacks for high powers.

In a two part presentation, Richard Hewitt of Warwick Manufacturing Group and Charles Marine of Stadco Group expressed their belief that remote fibre laser welding is a joining method of the future, but pointed out that whereas there are several auto manufacturers who have implemented this technology there are very few system integrators currently supporting this development. They described a DTI-funded project proposal for remote laser welding at Stadco, a first tier automotive supplier.

Markus Kogel-Hollacher of Precitec Optronic GmbH, Germany described the range range of Precitec material processing tools for solid state laser and plans for future products.

Ali Khan of Cambridge University reviewed his work on supersonic nozzle design, showing that they can be beneficial in laser material processing in that the flow from a supersonic nozzle is more stable than from a sonic nozzle, and that they provide better control and offer a wider nozzle diameter. He pointed out however that the nozzle had to be accurately designed and the pressure carefully regulated to the specified pressure

After lunch Alastair Wilson, Director of the Photonics KTN, reviewed the reasons why the UK laser materials processing community should be interested in UK PKTN and Photonics21 initiatives. He pointed out that the Photonics KTN is the main photonic networking organisation in the UK; that it opens access to the science base, assists

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8 AILU AGM
University of Cranfield
Including award presentations and tour
See inside back cover for details
AILU members and invited guests only. REGISTER NOW

16 PICALO (16 - 18)
Beijing, China
http://www.laserinstitute.org
See advert page 29

21 MACH (21-25)
NEC, Birmingham
Co-located with SUBCON
http://www.mach2008.com/

22 SUBCON (22-24)
NEC, Birmingham
Co-located with MACH
http://www.subconshow.co.uk/

30 Lasers in emerging energy markets
University of Warwick
http://www.miwl.org.ukk

MAY

22 AILU Workshop
Opportunities for laser micromachining: developments and applications in the medical sector
National Maritime College of Ireland, Cork
See inside back cover.
Programme flyer to follow.
RESERVE YOUR PLACE NOW!

JUNE

4 AILU - NWLEC
2 day Workshop on laser micro and nano processing (4 & 5 June)
Daresbury Laboratory
See inside back cover.
Programme flyer to follow.
RESERVE YOUR PLACE NOW!

AUGUST

26 PHOTON 08 (26-29)
Heriot-Watt University
http://www.photon.org.uk/

Reaching fifty

"The greatest resource that this association has is the knowledge and know-how that our members are willing to share with one another, for the good of the laser community as a whole."

Reaching 50 in anything is worth a little celebration, even if it's issues of a quarterly magazine. If nothing else, it's worth a look back at the contents of the early issues and casting an editorial eye over the improvements we've made to the presentational style. The number of pages has grown too, and if this is seen as an improvement then this issue is the best yet!

In these hectic days looking back over the early issues of the magazine is a luxury I can barely afford; but this last month we have been busy populating the new AILU web site, an activity that includes adding the PDFs of all the past magazine articles, so this opportunity arose by chance.

One of the recent developments in the magazine has been the 'opinion' section and this issue contains an interesting piece by Stewart Williams. Whilst we were reviewing minor changes to the piece Stewart how mentioned how pleased he was to have the opportunity to express his opinion (on the specification of laser processes) on paper, pointed out that this magazine was possibly the only suitable publication for such material. I took this as a complement!

I firmly believe that the greatest resource that this association has is the knowledge and know-how that our members are willing to share with one another, for the good of the laser community as a whole. Since its birth the industrial laser sector (i.e. industrial users and those selling laser technology and services to industry) has managed to weather economic storms relatively well and we can be reasonably optimistic that it will do the same this time. But as the saying goes 'the whole is greater than its parts' and whilst competition is healthy so too is working together. For an association such as AILU this translates into members communicating with each other - asking questions, giving answers, expressing opinions.

This magazine is part of this communication so do please make full use of it.

Mike Green, Editor
mike@ailu.org.uk

Editorial Policy

The Laser User is the house magazine of the Association of Industrial Laser Users. Its primary aim is to disseminate technical information and to present the views of its members.

The editor reserves the right to edit any submissions for space and other considerations.

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

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LASYS

The first LASYS, International Trade Fair for System Solutions in Laser Material Processing, took place in the new Stuttgart Trade Fair Centre on the 4 - 6 March 2008.

AILU were delighted to support the launch of LASYS and took a stand at the show. An international exhibition devoted to laser machines was well overdue and full marks to the Stuttgart team for taking the initiative. The event matched its location – well integrated and very impressive!

The event provided AILU with a marvellous networking opportunity; we received enquiries from industrial users and researchers from all over Europe and beyond.

There were 195 exhibitors and the 3 day exhibition attracted 3,700 visitors, with 27% from abroad. The statistics also showed that 70% of visitors came from industry and that 88% were involved in purchasing and procurement decisions in their company.

Alongside the main exhibition was the Stuttgart Laser Technology Forum, being staged for the fifth time. This year, the focus was on the transfer of knowledge between industry and science. Speakers from either side of the debate discussed topics such as safety, precision micro-material processing, and experiences with modern beam sources, such as fibre and disc lasers.

The next LASYS is planned for 2010.

AILU Events

Opportunities for laser micromachining: developments and applications in the medical sector

Thursday 22 May

National Maritime College of Ireland, Cork

Medical Group Event: This workshop addresses opportunities in the medical sector.

Keynote speakers

Andreas Ostendorf, LZH

Arnold Gillner, Fraunhofer ILT, Aachen

Other speakers include:

Tony Flaherty, NCLA (IRE)
David Gillen, Blueacre Technology (IRE)
Frank White, Stryker Instruments (IRE)
Nadeem Rizvi, Laser Micromaching (UK)
Dermot Brabazon, Dublin City University (IRE)
Martin Sharp, LLEC (UK)
Sean Burke, Enterprise Ireland
Leo Sexton, LaserAge (IRE)
Alan Ferguson, Oxford Lasers (K)
Jonathan Magee, Rofin-Baasel Ltd (UK)
Jürgen Bock, Precitec (D)

AILU Ireland *Organised in conjunction with and supported by Centre for Advanced Manufacturing & Management Systems (CAMMS) of CIT and LaserAge.*

Industrial opportunities in laser micro and nano processing

Wednesday 4 June

Daresbury Laboratory

A 1-day AILU workshop, which is the first day of a 2-day event addressing industrial and research opportunities in laser micro- and nano-processing.

Organised in conjunction with and supported by the North West Laser Engineering Consortium (NWLEC)

Lunchtime clinic for 1 to 1 consultations

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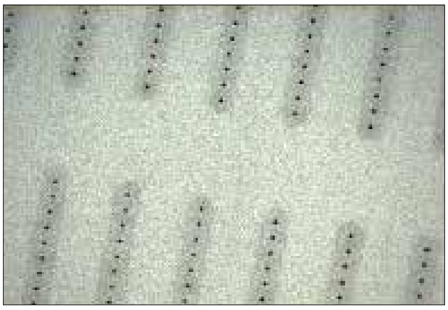

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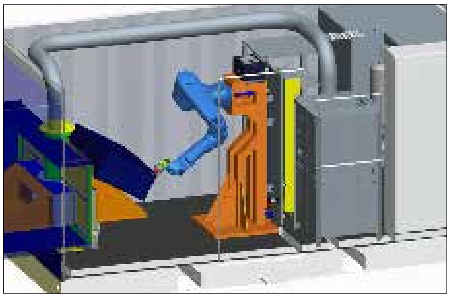

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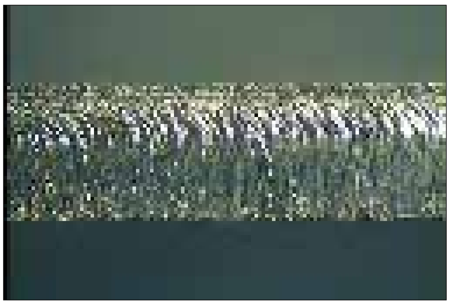

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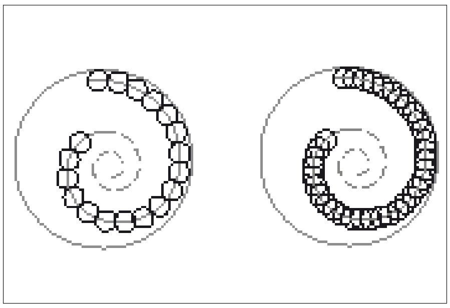

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