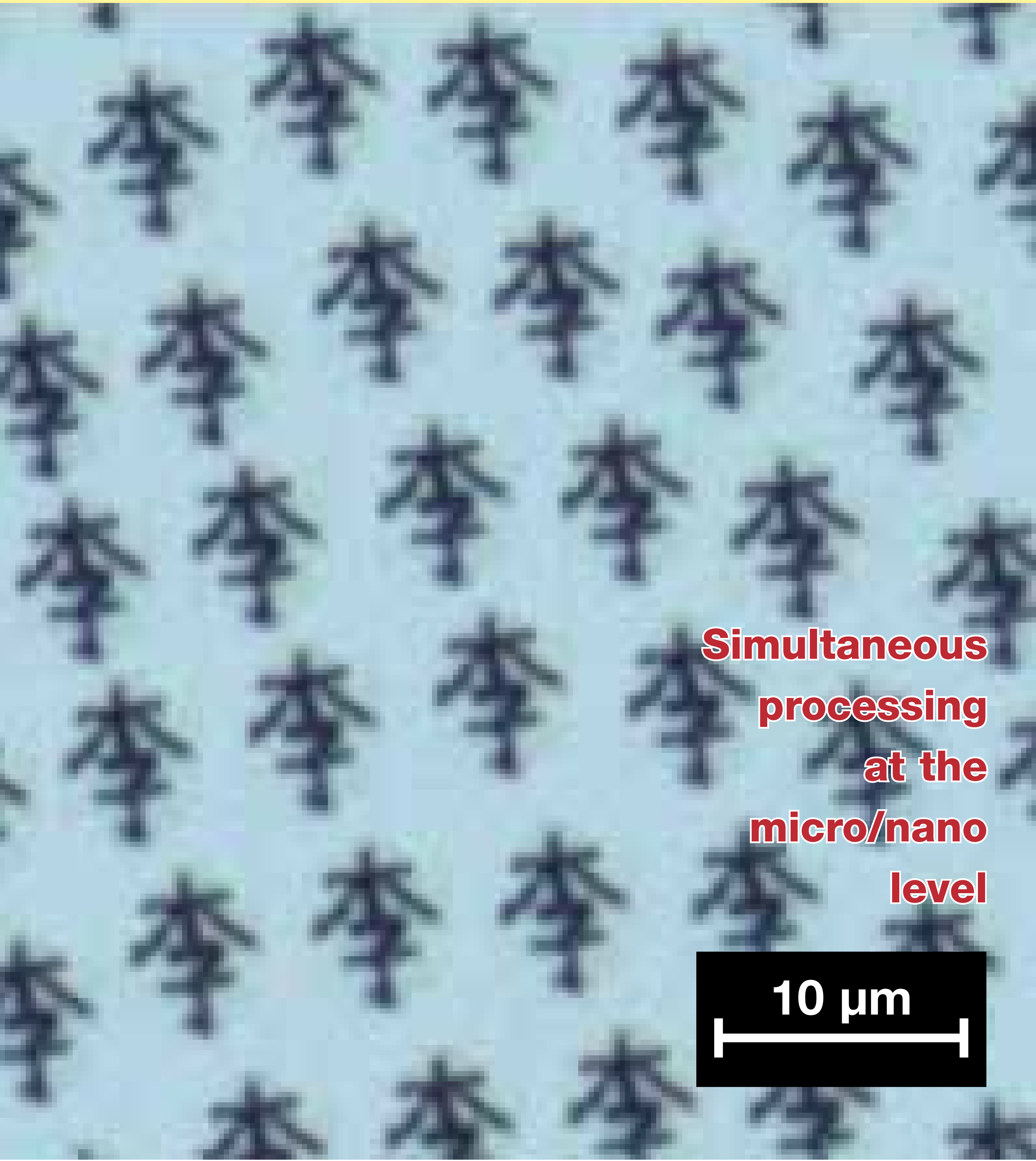
The Laser User

Issue 68 Winter 2012



Simultaneous processing at the micro/nano level

The AILU objectives

The principal objectives of AILU include:

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

Benefits of membership

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

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

the association of AILU laser users

Helping you make the most of laser technology

What does AILU membership mean to me?

I have been a member of AILU since we started our company back in 2000 and I can honestly say it has opened many channels.

The high quality workshops organised by AILU are a good chance to catch up on new developments and offer excellent networking opportunities. A good example of the workshops was the recent Job Shop meeting held at JCB Rocester. As well as a very interesting day of presentations and discussions there was a tour of the site at the end of the meeting which was one of the best I have been on. As a supplier we find the lunchtime exhibitions during the AILU workshops are a great opportunity to show our product range and we try to get to as many of these as we can as we have made some excellent contacts there.

I think the ILAS conference has found its' place and is developing an excellent reputation both in the UK and abroad. Both our German suppliers are very keen to attend due to the quality of the speakers and events being organised.

The magazine and website are also a great resource of information and interesting articles, ensuring that important developments and trends are brought to your attention without constantly having to seek out the information.

I would say that AILU membership is fantastic value for money and would highly recommend anyone with an interest in lasers becoming a member.

John Cocker – Laser Trader Ltd
johnc@lasertrader.co.uk

Courtesy University of Manchester

The cover picture is a SEM images of part of a repeating pattern of laser-ablated Chinese 'Li' characters, using simultaneous processing, see page 24. On the micro theme, articles on pages 22 and 26 deal with the challenge of processing with high PRF ultrashort pulsed lasers; another on page 19 addresses micro hole drilling.

Joining AILU

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

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

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

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

www.ailu.org.uk

or simply contact the AILU office at

+44 (0)1235 539595

ASSOCIATION NEWS

Three AILU awards to be presented
The winners of the 2013 AILU awards have been decided. The presentations will be made at the ILAS dinner on 12th March at the Nottingham Belfry Hotel. The winners are:

AILU Award
To an individual who has made an outstanding lifetime contribution to the industrial use of lasers in the UK.

The winner is: **John Bishop**

John Bishop (left) sponsors and presents the first AILU Young Laser Engineer's Prize, in 2002, to Emma Johnston in the presence of AILU President, Bill Steen

Back in 1979 John Bishop, proprietor of Flamecut Products Ltd., converted a computer-controlled water cutting machine into the UK's first moving optics laser profiler and established a spin-off company, Lasercut Products. He has been an evangelist for laser processing since and has been an active member of AILU and the laser job shop group. He retired from the laser business in 2003 but remained a laser processing enthusiast, only retiring from the job shop committee very recently

AILU International Award
To an individual who has provided outstanding support to AILU over many years.

The winner is: **Dirk Petring**

Dirk Petring making a presentation at an AILU laser cutting workshop in 2003

Dirk is head of Macro Joining and Cutting at the Fraunhofer ILT in Aachen, and is internationally recognised as a leading figure in these processes. A paid-up AILU member he has freely given keynote presentations at four AILU Workshops since 2001 and has provided 8 full articles for the AILU magazine, including one in this issue!

Continued ...

AILU Young UK Laser Engineer's Prize
To an individual under 30 years of age, for a significant piece of work in laser applications. The work must be conducted in the UK and have real or potential economic gain for the parent organisation and preferably for the wider industrial laser user community.

The winner is: **Sam Lester**

Sam Lester at the TATA Steel Metal Centre in Port Talbot.

Sam started his EngD at Tata Steel in 2008 on the development of laser cladding to increase the service life of critical components in the Steel Works, and is now the manager of the welding and hardfacing group at Port Talbot.

His work led to outstanding improvements in component lifetimes in severe operating conditions, and this subsequently resulted in the decision to design and build a self programming robotic production laser cladding machine. This is now successfully installed in the engineering workshops at Port Talbot. Sam's work has had significant impact on the increase of time between planned maintenance in the Works which will see a marked increase on line reliability and business profitability.

WELCOME TO NEW CORPORATE MEMBERS

Advanced Laser Technology Ltd

Air Liquide UK Ltd

C Brown & Sons (Steel) Limited

HTA Group Ltd

Lasered Components Ltd

PP Plasma

School of Mechanical Engineering, University of Birmingham

AILU to vet training courses
The are a good of courses regularly being run in the UK by academic and industrial organisations, that deal with aspects of the technology and practice of laser materials processing and that may therefore be of interest to AILU members.

At a recent AILU committee meeting it was agreed that whilst the Association was not in a position to approve such courses, a committee could be set up to identify ones that could be of interest to our members. A list of such courses would be drawn up Inclusion on the listing would simply mean that the course exists and may be of interest, and imply nothing about the quality/effectiveness of the course. A synopsis We should invite members to submit a synopsis of any such course.

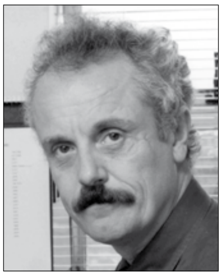
Cranfield synopsis to be abstracted for other course providers to copy.

PEOPLE AND INITIATIVES

People

Changes at Liverpool University

Professor Ken Watkins has retired from his post as Head of the Liverpool Laser Group at Liverpool University and the Lairdside Laser Engineering Centre, to taking up an Emeritus position. His position has been taken over by **Geoff Dearden**.


Ken Watkins


Geoff Dearden

"We worked hard to establish a seamless transfer of responsibility and it has gone very well," said Geoff. "I'm absorbing Ken's share of the teaching for this year, and **Stuart Edwardson**, as Lecturer, will support me in this," he added.

Contact: Geoff Dearden
E: g.dearden@liv.ac.uk
W: http://www.lasers.org.uk

After 11 years at The University of Manchester, where he held research and teaching responsibilities in laser materials processing, Dr **Andrew Pinkerton** has moved to Lancaster University as a Senior Lecturer in the Department of Engineering.

Contact: Andrew Pinlerton
E: aj.pinkerton@lancaster.ac.uk

John Lincoln, Network Manager at South of England Photonics Network (SEPNET) has recently been appointed as National Outreach Manager at the EPSRC Centre for Innovative Manufacturing in Photonics

Contact: John Lincoln
E: John.Lincoln@harlinltd.co.uk

Hamamatsu UK's new MD

Hamamatsu Photonics UK Limited has appointed **Tim Stokes** as their new Managing Director.

Tim gained a BSc (Hons.) Physics at Manchester University and has 25 years' experience within the industry.

"Hamamatsu have always adopted a 'customer first' approach to our business and I look forward to strengthening our relationships with our customers and contributing towards the future growth of the Company" said Tim.

Contact: Maria Fetta
E: maria.fetta@hamamatsu.co.uk
W: www.hamamatsu.com

New Sales Engineer at ES Technology

Following record financial results and the expansion of the company into an adjacent business unit, ES Technology recruited **Rachel Cook** in July 2012 as Sales Engineer for the sub-contract laser marking division of the business.

Since joining ES Technology in July 2012, Rachel has been busy building relationships with existing customers and also developing new opportunities within the Automotive, Aerospace and Medical Device market sectors.

Contact: Rachel Cook
E: sales@estechnology.co.uk
W: www.estechnology.co.uk

Initiatives

A new boost for AM

In October 2012 Universities and Science Minister David Willetts announced a new Technology Strategy Board investment of £7 million to accelerate the commercialisation of additive manufacturing technologies by focusing on the freedom the technology brings to the design of new products.

The 'Inspiring New Design Freedoms in Additive Manufacturing' competition for collaborative research and development projects grants opened on 3 December and closed on 30th January. We look forward to details of the successful applications.

AILU's PPI SIG provide support for Laser Shot Peening facility

Professor Lin Li at the University of Manchester is Chair of AILU's Product and Process Innovation Special Interest Group. He is also on the Steering Committee of Science and Technology Facilities Council, Central Laser Facilities, EPSRC Loan Pool; through which, on his recommendation, the EPSRC purchased in 2012 a high power ps laser for the laser processing community. He also recommended that they purchase a shock peening laser for the UK laser community.

"The situation was that no university in the UK has a suitable laser source for researching laser shot peening, but before requisitioning one the EPSRC needed to assess the potential demand from the UK academic community," said Lin. "At the time I had only 2 weeks to make the case for purchasing the laser."

Through the PPI SIG, the free-to-join group within AILU which represents the needs of researchers in laser materials processing in AILU's activities, members were asked to declare their interest in making use of such a laser for research, and to provide information on when and for what kind of research the laser would be used. A significant interest was shown and Lin made the proposal for a EPSRC national laser loan pool facilities purchase of both a ps laser and a shock peening laser. The proposal was accepted and these lasers are or will shortly be available for the AILU communities to use free of charge.

Contact: Lin LI
E: lin.li@manchester.ac.uk

Business

Gold medal opening at Trumpf

The new auditorium and a Technology Tooling Centre at the Trumpf Technology Centre in Luton were officially opened by Gold Medal Olympian, Greg Rutherford during the In-Tech 2012 open house.

The auditorium can seat 100 guests and alongside further investment in its training suites, provides TRUMPF with world class facilities for workshops, seminars and other customer events.

Contact: Gerry Jones
E: g.jones@uk.trumpf.com
W: www.trumpf.com

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

BUSINESS

Commercial spin-off from institute

Following the closure of INETI, a major R&D institute of the Portuguese Government covering many different technological areas including Optics and Laser systems, a team that includes senior researchers of INETI founded a commercial company, adLaser.

Lisbon-based adLaser is devoted to laser safety, promoting the safe use of laser and other artificial optical radiation in an expanding range of applications; providing consultancy, training, translation of technical documents and the sale of laser safety equipment. As well as being a member of AILU, adLaser is a member of CTE76 – the Portuguese Electrotechnical Commission for laser safety standardization

Contact: Margarida Calejo Pires
E: geral@adlaser.pt
W: www.adlaser.pt

Trumpf expecting further sales growth

The Trumpf Group has achieved the highest sales in its corporate history (2.33 billion Euro at the end of fiscal 2011/12), and is expecting growth to increase slightly more for the coming fiscal year. The announcement was made by the company at its Annual Press Conference in Ditzingen, Germany.

Trumpf President Nicola Leibinger-Kammüller commented that thanks to its highly flexible production systems, Trumpf quickly adjusted from recession to recovery, gaining market share worldwide in the process.

The company sees innovations as a key factor in its success and has considerably increased its investments as well as expenditure on research and development over the past year, to 153 million Euro (cf 61 million Euro in the previous year:) "It is only by making these major investments in the future that we can retain our technological lead over the long term," said Leibinger-Kammüller

Contact: Gerry Jones
E: g.jones@uk.trumpf.com
W: www.uk.trumpf.com

IPG Photonics Acquires JPSA Laser

IPG Photonics has acquired J.P. Sercel Associates Inc. (JPSA), a USA global supplier of UV excimer and diode pumped solid state (DPSS) industrial laser micro-machining systems for precision processing in high-volume manufacturing. The acquired business will operate under the name IPG Microsystems LLC.

The acquisition enables IPG to expand its integrated laser systems product offerings for fine-processing, precision cutting, drilling and micro-machining of non-metals, including glass, semiconductors and ceramics.

"Strong demand exists for better quality short-wavelength and short pulse width laser sources in applications addressed by JPSA's products," commented Jeff Sercel, CEO and Chief Technology Officer of JPSA. "While we will continue to sell our UV and excimer laser systems, as well as systems which use DPSS lasers, we strongly believe there are significant growth opportunities using advanced fibre lasers to displace traditional laser sources in high growth applications."

Contact: Stan Wilford
E: swilford@ipgphotonics.com
W: www.ipgphotonics.com

BOFA honoured with Queens Award

Duke of Kent in the factory test area factory

Poole based manufacturer BOFA International Ltd has been honoured with the UK's most prestigious business accolade The Queens Award for Enterprise. *(See TLU Issue 66, p2)*

The Duke of Kent flew into Dorset on Tuesday 23rd October 2012 to present the award, which recognises the company's outstanding achievements in overseas sales. During the visit HRH was given a guided tour of the manufacturing facility. The Duke was particularly interested to learn how new product concepts transfer through the R&D stage into full production and took the time to stop and speak to staff throughout the tour of the factory which employs 120 workers.

Contact: Marilyn Joslin
E: marilyn.joslin@bofa.co.uk
W: www.bofa.co.uk

Eight steps to success in 2012

For the financial year to end-September 2012 the turnover for the UK/Ireland operation of industrial laser systems manufacturer Rofin-Baasel UK Ltd (RBUK) were up 12% on the previous year, adding to a remarkable 3-year run since 2009 during which business up 75%.

A pre-tax profit of almost £500,000 on a group turnover of over £11M makes 2012 the most profitable year ever, as well as the highest turnover and greatest number of lasers installed. Against a fairly challenging business climate, Managing Director, Andrew May set out eight things he believes helps to set Rofin apart from the competition:

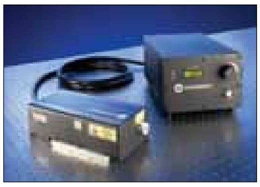
1. Service. "During office hours you'll speak to a person. We don't use an automated or menu-driven phone system."
2. Access to engineering support. "Our Technical Helpdesk is manned during office hours. Outside of working hours we can provide you with emergency contact details."
3. The lasers. "Rofin's lasers and components are made at specialist manufacturing sites all over the world. After Germany and the USA, Rofin in the UK employs the most staff."
4. Efficiency. "We use technology when appropriate but not when it's a barrier to customer contact. We operate out of functional, not flashy offices."
5. Technology independence. "We make almost all industrial laser types, so if you come to us with an application we can help you decide which technology works best for you."
6. Range of sources. "We make all the core industrial laser sources: CO_2, direct diode, fibre and YAG,Vanadate. We offer pulsed, Q-switched and continuous-wave power."
7. Application labs. "We have demo and testing lasers at 3 sites in the UK – housing a total of around 30 laser systems of all different types.
8. Experience. "The average technical staff member (sales, service or manufacturing) at RBUK has 16 years' laser experience – many have over 20."

Contact: Andy May
E: a.may@rofin-baasel.co.uk
W: http://www.rofin.co.uk

SOURCES AND SYSTEMS

Sources

Coherent's high power OPSLs



Two new Verdi™ G lasers from Coherent are the first of this product family to offer single longitudinal mode (SLM) output, delivering linewidths of < 5 MHz. They are offered with a choice of 2 and 5 W output power at 532 nm, with SLM output expected at other wavelengths soon.

Based on optically pumped semiconductor laser (OPSL) technology, the lasers are characterized by low noise, high electrical efficiency, and a small platform. Additionally, this construction provides higher stability and greater reliability than other visible laser types.

Verdi G SLM lasers are targeted at applications involving interferometry and holography, and are ideal for atom cooling and trapping.

Contact: Brandon Morioka
E: Brandon.morioka@coherent.com
W: www.coherent.com

IPG's new kW fibre lasers

IPG Photonics announced at Photonics West 2013 a new generation of Kilowatt class low-mode Ytterbium fibre lasers offering lower cost per watt of laser power and lower operating expenses and service requirements. The improved 1060 nm laser from IPG offers customers exceptionally simple operation and extends the range of applications for fibre lasers.

"Drawing from our experience from more than 5,000 Kilowatt class fibre lasers in demanding industrial applications, our goal was to create products suitable for a much broader range of applications than now, including various applications currently served by non-laser technologies," said Dr. Valentin P. Gapontsev, CEO of IPG.

The main benefits include increased wall plug efficiency (up to 33% from 28-30%), up to two times average improvement in beam quality and an increase in the estimated mean time of uninterrupted laser operation from the current 1.5 years to greater than 3 years. IPG now offers for this series an industry-leading three-year warranty.

Contact: Stan Wilford
E: swilford@ipgphotonics.com
W: http://www.ipgphotonics.com

Rofin's high fibre regime for industry

StarFibre Series

For general purpose marking and ablation of layers in photovoltaic and semi-conductor applications, Rofin's PowerLine F series offers between 20 and 50 W power from the specially optimized diode pumped, q-switched fibre laser sources.

Rofin's latest generation of ultra short pulse fibre lasers includes the StarFemto series, which produce laser pulses shorter than 1 picosecond to accomplish precise and selective ablation of work-piece surfaces for micro-structuring, drilling, cutting or scribing. Nominal power ranges from 100 to 600 W at fundamental mode beam quality and can be operated in either pulsed or CW mode. The excellent beam quality enables the efficient use of scanner systems for high-speed positioning as well as the fast and precise application of small geometries on work-pieces, reducing cycle times and increasing productivity.

OEM version of Rofin's SC CO_2 family

Self contained "sealed-off" lasers are ideal tools for light industrial applications such as cutting, drilling and marking.

The OEM 40 iX is the latest model from the successful ROFIN SC Series. With an output power of 400 W and a beam quality of K > 0.8, this sealed-off CO_2 laser, based on the industry proven Slab principle, is good for processing organic materials, plastics, ceramics, glass and metals.

With its integrated HF power supply and a total weight of 75 kg, the ROFIN OEM 40 iX is compact and lightweight. These attributes allow the unit to be easily integrated into a variety of system concepts in combination with scanners or other beam guidance components.

The OEM 40iX is also the perfect choice for those who wish to replace older laser sources with the latest technology. Furthermore, the laser distinguishes itself by its high reliability and a long lifetime of the laser unit in industrial production.

Contact: Charles Sanders (SC series) or Dave MacLellan (Star Femto range)
E: sales@rofin-baasel.co.uk
W: www.rofin.co.uk

3kW fibre laser launched by JK Lasers

A powerful 3 kW fibre laser has been launched by industrial laser manufacturer JK Laser.

The laser will help enhance productivity by processing thicker section metals at faster speeds and to higher standards.

Delivering stable output power from switch on, the JK3000FL features a consistent focused spot size and beam profile over the complete power range. It is fitted with JK Lasers' detachable 'plug in, pre-aligned' (PIPA) beam delivery fibres, offering core diameters from 100µm.

The launch of the JK3000FL has opened up new applications for the company, including remote laser welding, an application previously dominated by CO_2 lasers.

The JK3000FL can also be fitted with JK Lasers' own range of process tools for optimal performance and an optional timeshare unit that can rapidly connect up to four separate workstations.

Contact: Mark Greenwood
E: sales@jklasers.com
W: www.jklasers.com

Spectra's compact Integrated Lasers

Spectra-Physics has introduced the Excelsior One CW laser series. The new line of ultraviolet, visible and near-infrared lasers integrate laser head and controller into a single, compact package. Available as free-space and fibre-coupled laser configurations, the plug-and-play Excelsior One series includes eleven different wavelengths and delivers up to 500 mW of average power. For added convenience, the integrated lasers utilize only one supply voltage for all models. These lasers are a dependable, simple solution for a wide range of fluorescence-based bio-instrumentation applications including flow cytometry, confocal microscopy, DNA sequencing, and other bio-instrumentation applications.

The Excelsior One product family includes direct diode and diode-pumped solid-state (DPSS) technology in a consistent compact footprint with a common electronics interface. All lasers deliver TEM00 mode quality and very low optical noise for highest signal-to-noise ratio.

Contact: Jon Richardson
E: jon.richardson@newport.com
W: www.newport.com/excelsiorone

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

SAFETY AND OPTICS

Optics

Mirrors with mounts can save money

Our mirrors can be designed and manufactured as one monolithic "mirror and mount": thereby overcoming the need for a kinematic mounts, which is often more expensive than the mirror. Robust design ensures the mirror remains distortion free, and can be pre-aligned for simple installation.

Contact: Mark Wilkinson
E: sales@lbp.co.uk
W: www.lbp.co.uk

Laser Optics Cleaning Kit

Supplied in a robust carry case this optics cleaning kit contains all the tools necessary to carry out general optics cleaning on your lasers. Aimed at field service and maintenance engineers the kit comprises a handbook describing lens cleaning techniques and all the materials and tools that are needed.

Contact: Adrian Norton
E: adrian@thinklaser.com
W: www.thinklaser.com

Safety

Brinell CN-G advanced laser protection technology

During this year's ILAS 2013 (March 12-13, Nottingham) we will be demonstrating our Brinell CN-G 532 nm laser blocking technology which is being used in a number of demanding applications including the latest greenlight surgery. Greenlight laser therapy is an innovative, non-invasive medical procedures that is revolutionising such treatments as enlarged prostate and the removal of cancerous tumours in treatment.

532 nm is close to the peak of the human photopic response, making the design of filters with a good visible transmission a challenge. The majority of the filters used to protect wavelengths in this region block the green and most blue light, and so appear orange in colour (see middle picture opposite). Being able to distinguish blue from red with protective eyewear is extremely important for the surgeon (and even more the patient!) More generally, distinguishing shades of colours can be the difference between success and failure.

As shown in the figure opposite, our new CN-G laser protection filter allows the user to see a balanced colour view while blocking the laser at 532 nm to levels to as high as OD6. Our demo at ILAS will allow delegates to experience the difference for themselves.

Green laser pointer dazzle hazard for pilots: (top) No 532 nm green laser protection; (middle) Standard 532 nm laser protection; (bottom) Brinell Vision CN-G 532 nm protection

Contact: Adam Brierley
E: adam.brierley@brinellvision.com
W: www.brinellvision.com

Positioning

Galvo and controller combination

Aerotech's Nmark AGV-HP advanced galvanometers use innovative optical feedback technology to increase resolution to greater than 24 bits.

With Aerotech's Nmark CLS controller the ability to accurately place a laser spot as a function of X/Y axis position, a key feature of Aerotech's linear positioning tables, is now available for scanner applications. The controller comes with Position Synchronized Output functionality, allowing true position-based triggering, removing the need to program mark, jump, and polygon delays.

The Infinite Field of View feature of the Nmark CLS seamlessly synchronizes servo and scanner motion under one controller environment to allow fast scanner positioning over the entire servo travel, eliminating galvo field of view constraints.

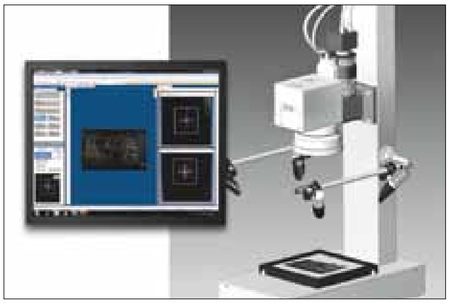
Contact: Simon Smith
E: ssmith@aerotech.co.uk
W: www.aerotech.co.uk

The scanalign vision system: automatic precision alignment for laser processing

The SCANalign® vision system is tailored specifically to the demands of laser processing, facilitating high-precision laser processing in low-precision environments. Fiducial markers and other features on work pieces are automatically recognized for precise positioning of the laser beam; an approach that is more precise than any part or mechanical fixture in the machine itself. In addition, the vision system allows calibrating the working field and checking the result of the laser process. Users can follow the processing online, or on a PC or remote terminal. In simple terms, SCANalign® provides self-aligned laser processing.

The new vision system takes pictures through the laser scan head and is easy to use and set up. By observing the workpiece through the scan head, the system effectively corresponds to a camera with over 100 million pixels, yielding a precision for measuring features across the complete working field that is higher than can be achieved by typical vision systems.

The SCANalign® system is an integrated solution that saves the user man-years of engineering effort. It comprises



a software package with an intuitive graphical user interface, a camera and adapter, an illumination system and a high-precision calibration plate. The user does not need to write or check computer code. All components are reliable and industry proven. The vision system interfaces seamlessly with SCANLAB's laserDESK® software.

SCANalign® is perfectly suited for solar cell and medical part processing, micro-machining, high-volume engraving of small parts and many other applications. The system will also be available for the intelliWELD® scan heads used for high-power remote welding in the automotive and other industries.

Contact: Anne Konrad
E: A.Konrad@scanlab.de
W: www.scanlab.de

Measurement

2012 R&D 100 Winner

To aid productivity and quality in industrial applications, thermal detectors are used to measure the power and energy of lasers. But to complete the picture of the laser's performance, a measurement of the beam's profile.

The BeamTrack Laser Power/Position/Size Sensors Development Team from Ophir Photonics Group: (l to r) Yaakov Pechman, Jonathan Feust, Shimon Elstein, Eliyahu Bender, Ilan Haber, Mark Ivker, David Okun

BeamTrack Laser Power/Position/Size Sensors from Ophir are the first laser detectors able to collect six different metrics in the same unit: power, position, size, energy, centring and wander.

Contact: Gary Wagner
E: gary.wagner@us.ophiropt.com
W: www.ophiropt.com/photonics

Newport Integrating Spheres

The Newport Corporation Series 819C/D high power silicon-based integrating sphere detectors operate from the UV region through the visible to the near-infrared and can handle up to 10 W of optical power. They are calibrated and traceable to NIST standards. The new CAL2 models feature a built-in temperature sensor and OD1 attenuator sensor. Newport power meters (the 1830-R, 1918-R, 1936-R or 2936-R) automatically recognize the attenuator On/Off position and the detector head temperature.

Available for both diverging and collimated input beams, the line extension to UV and higher-power features make this series an essential tool for critical optical power measurement applications.

For added functionality, all spheres come with a fibre optic connector that picks off some light for further analysis (e.g. wavelength measurement) without affecting the overall system calibration.

Contact: Jon Richardson
E: jon.richardson@newport.com
W: www.newport.com/819

Lasermet's meter checks laser pistols

Lasermet laser power meters were used to help ensure laser pistols used in the Modern Pentathlon provided competitors with a level playing field.

Modern Pentathlon is five events, one of which is shooting. Laser pistols replaced pistols firing pellets in competitions throughout 2011, including the World Cup and World Championships. "There were some issues around the new technology and for the London Olympics we wanted to eliminate as many as possible," said Steve Candy, the combined event manager for LOCOG.

'In 2011, an agreement was made on the laser specifications so that different suppliers could provide different kit for the pistols and the targets and for them all to work. Because there hadn't been any real testing at competitions up until that point, the laser shooting was open to both abuse and safety concerns."

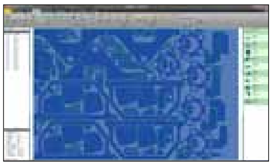
'With Lasermet's laser power meter, the laser power and length of shot can be displayed on a PC, but also on the meter itself, which was ideal for testing on the field of play."

Contact: Paul Tozer
E: paul@lasermet.com
W: www.lasermet.com

SOFTWARE, MATERIALS PROCESSING

Software

Sigmanest version 10



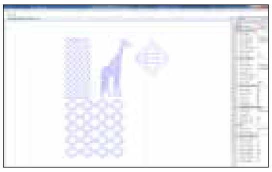
SigmaTEK Systems has released SigmaNEST version 10.

"An example of what makes version 10 special is improved cutterpath planning that reduces machine cutting cycle time and consumable wear extending tool life," said SigmaTEK President & CEO, Ben TerreBlanche.

SigmaNEST Product Manager, James Lindsey added that "While 3D CAD model import is certainly nothing new to SigmaNEST this latest release boasts enhanced functionality in that area as well as the ability to tap into engineering data. We don't impose a workload on the engineering department to save work as an IGES, STEP, DXF or any other neutral file format before being handed off to manufacturing. Companies select SigmaNEST not only for its superior functionality but also because it can drive multiple cutting, punching and bending machines and import data directly from a number of popular CAD/CAM systems."

Contact: Chris Cooper
E: chris.cooper@sigmanest.com
W: www.sigmanest.com

Motion programs direct from CAD



CADFusion bridges the gap between part drawings and motion control. Users need only import a vector-based DXF drawing into this easy-to-use environment to see the resulting tool path graphically on CADFusion's canvas. Part optimization is easy and intuitive with shape re-ordering, feature scaling, and rotational/translational features at your fingertips. Overall process management, including local and global feed-rate control and lead in/out moves, can be automatically configured in advance so that every import file produces a consistent motion control program.

For export, CADFusion compiles a full motion control program, automatically inserting user-defined initialization and process trigger events. Laser/process definitions and firing events can be specifically tailored by the user and called automatically by CADFusion during program compilation.

Contact: Simon Smith
E: ssmith@aerotech.co.uk
W: www.aerotech.com

Drilling

Supply agreement for Laserdyne

Prima Power Laserdyne, a manufacturer of precision multi-axis laser machining systems, has made a long term multi-system supply agreement with Dynamic Precision Group – Turbo Combustor Technology (TCT) of Stuart, Florida. Laserdyne will supply new Laserdyne 795XL laser systems and remanufacture TCT's existing Laserdyne 890 systems. Laserdyne have had a close relationship with TCT since 1994, and with this agreement they will become one of their largest customers in terms of number of systems. The expansion of TCT's laser drilling capability comes at a critical time for the turbine engine community, with new designs dramatically increasing the requirement for laser drilled holes.

TCT has also joined with Laserdyne in a collaboration with IPG Photonics on fibre laser drilling of all types of cooling holes in turbine engine components.

Contact: Mark Barry
E: LDS.SALES@primapower.com
W: www.primapower.com

Passion for Perforations

Rofin-Baasel has been active in the flexible packaging market for over 10 years and an ethos of continuous product development has resulted in a series of innovative laser based systems, with many different configurations, designed to support customers requirements in scribing (scoring), perforating and cutting packaging materials. The testament to this is the 200 plus customers already using Rofin systems within the packaging industry.

The Flexible Packaging industry is supported by Rofin's CO_2 systems department. Using in-house winding systems and laboratory equipment, a dedicated applications team specifically focus on developing laser processes for the packaging industry, ensuring that lasers will remain a key technology in flexible packaging systems for easy opening and perforation applications

Contact: Jamie Costello
E: sales@rofin-baasel.co.uk
www.rofin.co.uk

Marking

Sienna 800 Duo on display

Spectrum Technologies Plc, based in Bridgend, exhibited the latest model in their SIENNA range of laser wire stripping systems – the SIENNA 800 Duo - at the MD&M Minneapolis show at the Minneapolis Convention Centre (31 October to 1 November 2012).

The SIENNA 800 series brings new capabilities to the standard SIENNA range with the introduction of high speed single side scanning optics for the ablation (including stripping and marking possibilities) of a variety of insulation materials.

The SIENNA 800 Duo version contains two laser sources – a 50 Watt CO_2 and a 30 Watt YAG scriber. It provides a 118 by 118 mm process area. The material to be ablated is processed from above and a rotating jig is available to turn the part over to accurately process the underside. Processes include: Removal of insulation from hard to strip wire and cables; Stripping of magnet wire (patented process); Stripping of flat laminated cables (FLCs) and other products where the insulation is bonded to the conductor; Scribing metal shields; Marking onto various surfaces R&D applications.

Contact: Peter Dickinson
E: pdickinson@spectrumtech.com
W: www.sprectrumtech.com

More affordable laser marking

The new CombiLine Basic from Rofin offers the ideal technical solution for efficient, high-quality laser marking: a stand alone workstation with a large working chamber, fully integrated laser marker and smart operation technology.

A wide motorized door provides easy access to the spacious working chamber. A motorized z-axis positions the marking head to accommodate different work-piece heights. All components, including the laser marker are controlled by an integrated computer system. Using "VisualLaserMarker", Rofin's industry-proven laser marking software, the definition of simple as well as complex marking layouts can be achieved in a matter of minutes

Contact: Mike Batchelor
E: sales@rofin-baasel.co.uk
W: www.rofin.co.uk

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

Heat treating with high power direct-diode lasers

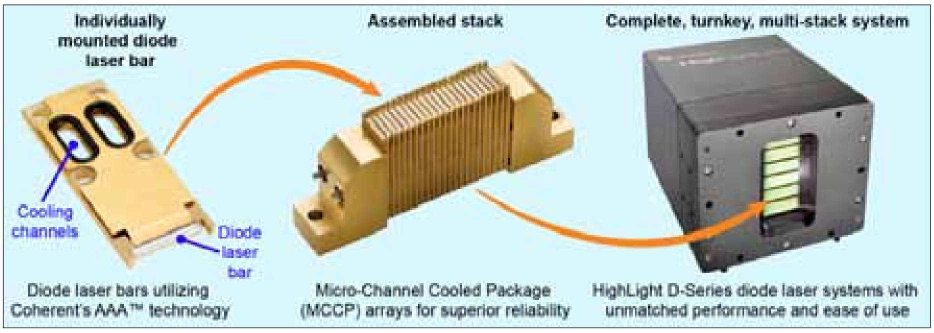


Figure 1: Single laser diode bar to compact 8 kW diode laser system the size of a shoe box.

Lasers have been used for heat treating applications for over 30 years but various practical and cost limitations have kept them from widespread employment. But over the past few years, a new approach for heat treating based on the highpower direct-diode laser has emerged which avoids the limitations of traditional laser technology.

Benefits of laser treating

In laser heat treating, a spatially well-defined laser beam is used to illuminate a work piece. This radiation is absorbed near the surface causing rapid, localized heating. Typical penetration depths into the bulk material are from 0.5 to 2.0 mm. The bulk heat capacity of the material acts as a heat sink thereby enabling self-quenching. Thus, no oil or water is needed for quenching, which is an advantage over traditional induction or oven heat treatments. However, the main benefits are rapid processing, precise control over case depth and point of application, and minimal part distortion. Part distortion is typically low enough to eliminate the need for post processing steps to restore dimensional accuracy, and compared to legacy methods, the laser induced surface transformation often creates a smaller grain structure due to the rapid quench, resulting in superior wear resistance.

Heat treating lasers

Although the CO_2 laser has historically been the laser of choice for heat treating it has three significant drawbacks for this application: (i) Its far infrared output (10.6 µm) is not well absorbed by steel, requiring surfaces to first be "painted" with an absorptive coating; (ii) Its output is typically a round beam of just a few millimeters in diameter, which must typically be expanded and homogenized to match the dimensions of the area to be treated; and (iii) Its wall plug efficiency is relatively low, which translates directly into increased operating cost.

An alternative laser technology for heat treating is the high power direct-diode laser. A typical individual diode laser emitter might produce at most a few Watts of output power at a wavelength in the near infrared (e.g. 0.975 µm). However, as shown in figure 1, numerous emitters can be fabricated on a single, monolithic semiconductor substrate or bar with a total output of 100 W or higher. These linear bars can, in turn, be combined in horizontal and vertical stacks to produce a high power direct-diode laser system with total output power in the multi-kilowatt range. Its small size makes it easier to integrate and allows it to be cooled with a small volume of circulating water and a chiller.

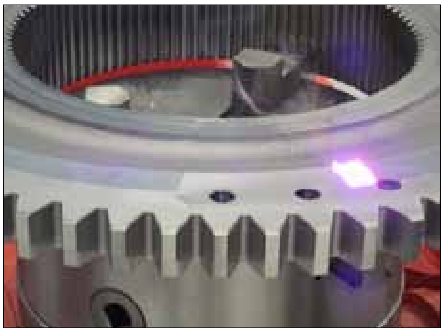


Figure 2: An industrial gear component face is selectively heat treated by a direct-diode laser.

Diode laser advantages

High power, direct diode laser systems address all the previously mentioned disadvantages of CO_2 lasers for heat treating: (i) Their shorter wavelength is well absorbed by metals; (ii) They offer output power and beam characteristics that are well matched to the needs of heat treating, and which enable a high degree of flexibility in terms of their implementation*; Thy offer an electrical efficiency about four times higher than that of the CO_2 laser and provide an instant "on" capability so there is no standby power consumption.

As well as savings from higher efficiency, direct diode laser systems offer greatly reduced maintenance costs; for example, a Coherent direct-diode laser system typically costs about ~30% less to own and operate over a five year period than a CO_2 laser of similar output power.

*For example, Coherent HighLight D-Series lasers are available with output powers from 2.8 to 8 kW (all at 975 nm) and a range of beam dimensions. The 6 kW and 8 kW models are each offered with line beam dimensions of 1 mm width, and either 6 mm, 12 mm or 24 mm length. An optional beam shaping accessory can expand the 1 mm beam over a range of values up to 12 mm, for easy optimisation to process requirements. Another option is a pyrometer for monitoring work surface temperature, enabling closed-loop control of laser power during heat treating, and avoiding over heating of the processed part.

Heat Treating with Diodes Lasers

For the majority of hardening applications, the diode laser output beam illuminates an area that is smaller than the total area to be processed, so to achieve total coverage either the work piece or the beam must be moved. For example, figure 2 shows a gear face being selectively heat treated; the beam remains stationary and the component is rotated.

Figure 3: Diode laser heat treated tool jaw.
A 4kW HighLight 4000D, beam size 8 x 12 mm, processes the part in 4.5 sec (= 1.4 m/min). The material is 3055 NiCr, the surface hardness: 60 HRC and the case depth is 1 – 1.3 mm below the teeth.

Figure 3 shows how diode laser hardening delivers very localized results that are uniform and consistent. Specifically, this is a tool jaw (3055 NiCr) that was heat treated with the Coherent direct-diode laser.

In conclusion, the Coherent HighLight laser family is a unique source for heat treating that delivers a number of advantages over traditional technologies as well as other laser sources. In particular, this diode laser offers maximum flexibility via field interchangeable beam shape options, a large working distance of ~270 mm, and reliable and industry proven diode technology. Plus, its attractive cost of ownership characteristics, optional closed-loop process control and small size make it easy to integrate directly with existing production equipment.

Heiko Riedelsberger Coherent Inc
E: heiko.riedelsberger@coherent.com
W: www.coherent.com/

Compact laser marker

The new Rofin PowerLine Prime 12 ultra-compact laser. complements the current PowerLine Prime Series.

The new PowerLine Prime 12 is a diode-pumped laser marker with a wavelength of 1064 nm. The laser operates in TEM00 fundamental mode. This ensures optimum focus and high marking resolution. With excellent pulse stability, the PowerLine Prime 12 is aimed at demanding marking applications on a range of different materials.

The PowerLine Prime 12 is configured with standard interfaces and a 19” supply unit. The compact laser head and the detachable connections guarantee a high degree of flexibility in integration. The new laser also offers prime technology at a very attractive price. Low operating costs and a flexible service concept turns this laser marker to an efficient alternative for many challenging marking applications.

Contact: Mike Batchelor
E: sales@rofin-baasel.co.uk
W: www.rofin.co.uk

Cutting

Gold medal for laser cutting machine

A flatbed laser cutting machine integrated with a 400W fibre laser from JK Lasers was awarded a gold medal and diploma at the 2012 International Technical Fair in Bulgaria.

Designed and manufactured by ISL Photonics, a division of IKIS, the Gladus400 impressed show judges with its flair and manufacturing performance. Filip Shkembov, Manager of IKIS, said: “Our award-winning Gladus400 is the culmination of many months of hard work. JK Lasers worked closely with us, delivering the outstanding service we needed to build the machine."

Mark Greenwood, General Manager of JK Lasers, said “We look forward to building on this positive relationship and wish the team all the best with the launch of their ISL Photonics division.”

Contact: Mark Greenwood
E: sales@jklasers.com
W: www.jklasers.com

LVD at 60 unveils new laser cutter

LVD celebrated its 60th anniversary in business with an innovative press brake automation system, a new laser cutting product, and a new control and interface technology.

The laser cutting system was the Electra FL. Powered by a fibre laser source, it provides fast, accurate thin sheet processing of traditional sheet metal materials with the added versatility to efficiently process metals such as copper and brass at processing speeds up to 50% faster than CO_2 laser sources in thin sheet metal. It features a lightweight, high rigidity beam delivery system to allow for highly dynamic processing.

Modular automation options for the Electra FL include a compact material warehousing tower (CT-L) that provides full capabilities for loading and unloading and includes a shelving unit for storage of raw material and finished parts.

<u>LVD adaptive laser cutting system</u>

The LVD patented Adaptive Laser Cutting (ALC™) system provides real-time monitoring and feedback control of the laser cutting process to achieve high productivity, consistent processing accuracy and reduced scrap.

ALC uses dynamic feedback to monitor key parameters in real time during the cutting process and automatically optimize the cutting parameters to ensure a consistently accurate cut. It is particularly useful when processing thicker mild steels in an unmanned environment, where machine speed is often restricted to ensure reliability and account for potential variations in material properties; all of which limits productivity and increasesw the cost per part. ALC automatically adjusts to process at the highest speed and efficiency, providing up to a 10% increase in productivity. Consistently accurate processing also eliminates scrap or rework of expensive thicker materials.

ALC is now a standard feature on select models of LVD’s Impuls series laser cutting machines.

Contact: Chris Phillips
E: c.phillips@lvduk.com
W: www.lvdpullmax.co.uk

Welding

Laserdyne 430 fibre laser system

Fluiten Italia S.p.A. of Milan has taken delivery of a Laserdyne 430 four-axis fibre laser system.

Fluiten, a designer and manufacturer of mechanical seals, recently acquired a Laserdyne 430 to precision weld high-pressure and temperature resistant components used in the manufacture of Fluiten seals.

"Fluiten will be utilizing the full array of Laserdyne hardware and software features integrated with the latest high power fibre laser,” said Terry VanderWert, President of Prima Power Laserdyne.

The Laserdyne 430 is a four-axis system designed for precision cutting, welding and drilling two and three dimensional components. The system operates at speeds up to 20 m/min in the X, Y, Z axis with bi-directional accuracy of 12.7 µm. This accuracy is throughout the system’s 585 x 408 x 508 mm work envelope, making it ideal for laser processing a broad range of Fluiten components. These include helical spring seals, bi-directional seals, and seals with integral flanged and jacketed casings.

Contact: Mark Barry
E: LDS.SALES@Primapower.com
W: www.primapower.com

Precision welding, cutting and drilling

The Lasag PWS Mini desktop workstation offers a compact design whilst maintaining great flexibility.

The workstation is designed for laser processing precision miniature components and offers single or multiple fibre optic delivery to the workpiece.

Primary applications for this system can be found in the medical, dental, electronics, computer, communications, and micro machining industries. The Lasag PWS Mini is ideally suited for components that may require spot and seam welding or cutting and drilling.

The workstation can be equipped with any standard Lasag laser source and it is therefore extremely flexible in use.

Contact: Dave MacLellan
E: sales@rofin-baasel.co.uk
W: www.rofin.co.uk

CASE STUDY

Powder Deposition at Stanley Black & Decker

Powder deposition by laser is setting new standards in knife blade technology at Stanley, where sharper for longer is the new mantra. Running unmanned and continuously for three days, the application at Stanley Black & Decker is now the longest, uninterrupted, single-run laser deposition process in the world.

But as amazing as this may seem, it's little more than a first step for this progressive manufacturing company. The Stanley brand is synonymous with workplace utility knives. The blade itself is remarkably simple, selling in two major formats: trapezoid blades preferred by UK and US customers; and snap-off segmental blades for the European markets.

An edge of dust

"Carbide" is the next generation of Stanley knife blade. At its core is a high-performance Trumpf laser solution, depositing a carbide powder to the blade edge. It was developed and installed at the Stanley Black & Decker UK facility near Sheffield, and adds to existing "conventional" knife blade manufacturing capacity.

At present, Carbide blades are manufactured using six inline, purpose-built application centres, each housing a Trumpf laser deposition head and camera systems with coiled strips of blades fed automatically below the nozzle. Trumpf TruDisk technology provides the laser source, while Trumpf TruMark laser marking stations are integrated into each centre. The blades are subsequently ground in a separate operation to produce the required edge angles. The result is knife blade technology redefined. The process boosts hardness from 800 Vickers Hardness for a standard blade, to 1200 Vickers Hardness. Surprisingly, this caused a dilemma for the Stanley marketing department in that a claim that a blade offered 10 or 12 times the life of a standard Stanley blade would not be believed,

The Stanley Black & Decker marketing team was insistent on a product that "looked different" in the marketplace. The special look of the black edge created by the laser deposition process was just what they needed, even though it could be removed by introducing more argon shielding gas.

The project demonstrates that laser deposition technology is not the sole reserve of high value parts produced in low volume, such as jet engine turbine blades for example, but can be applied to simple products manufactured for mass markets. "We are no different than any manufacturing company'" said Stanley's R & D Manager, Peter Culf. "Each expenditure has to be meticulously justified, but our driving motivation was that we wanted a superior blade," he explained. "Advanced technology of this type obviously carries a cost, but we believe that our customers will readily appreciate the performance benefits that result."

Contact: Gerry Jones
E: g.jones@uk.trumpf.com
W: www.trumpf.com

CASE STUDY

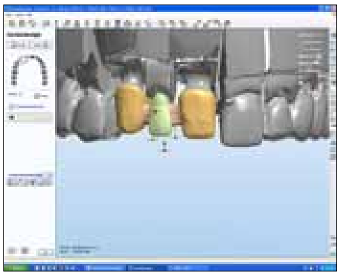
Taking denture production to industrial levels

When it comes to manufacturing dental restorations, the prime conventional techniques are mould-based casting and milling, which is currently the most widely used technique. These manufacturing methods have weaknesses in terms of quality, they take time, but above all tend to be expensive in relation to the unit costs. A milled unit costs approximately 19.90 EUR. According to Andreas Laufer, managing director of Mannheim based dental laboratory Laufer Zahntechnik GmbH, his dental laboratory is able to offer the same unit, manufactured using metal laser melting, at a cost of just 9.90 EUR. He has managed to achieve this fine balancing act with the aid of an entirely new view of the production process.

Laser Fusing – The key to cost reduction

Andreas Laufer has been a pioneer of CAD/CAM technology since the latter part of the 1990s but in 2003 he took an interest in generative metal laser melting technology. "The possibility to move from skilled production using a traditional method to an industrial scale was now achievable," says Laufer. This technology, which at the time was still in its infancy, promised, thanks to its tool-free manufacturing method, a high degree of efficiency and economic viability taking into account the costs of employees, material consumption and machine costs. In addition, the process has allowed the time taken to process an order from receipt through to delivery of the product to the dentist, to be drastically reduced.

A generative structure also means that less rework is required. Finished products are of the highest quality coupled with high precision, high density and a great fit. A further benefit is the greater freedom of design available when using this technology. Today Laufer works with Concept Laser Mlab cusing, LaserCUSING® machines. Thinking outside of the box and having the courage to focus on manufacturing on an industrial scale has paid off for the company.



Paradigm Shift to Industrial Fabrication

The switchover to LaserCUSING® paid off for Laufer, whose aim, from the outset, was to transform traditional artisan fabrication into industrial production. With fully automatic generative fabrication, on average 80 units are produced simultaneously on one build plate each day. The enormous cost advantages of this method lie in the batch size, and the automatic fabrication overnight

The achievements to date at Laufer have demonstrated that it is possible to deliver high quality coupled with high speed. But Laufer also see lots of other opportunities for improving the production process, including generating data via a "mouth scan" to replace the traditional plaster-cast model with a printed plastic model? "This would make the processing of orders even faster," says Laufer;"scan in the morning and then fit the denture the very next day – simply 'overnight' production."

Contact: Colin Cater
E: c.cater@estechnology.co.uk
W: www.estechnology.co.uk

JOB SHOP CORNER

New precision levelling line

United Steels has successfully decoiled and levelled 20mm structural grades of mild steel. Feedback from laser users has been excellent; they are delighted that the product has little or no residual stress after laser cutting.

The new precision levelling line at United Steels is unique in the UK and the configuration is designed to reduce residual stress after processing. United are still gathering data and are working with industry experts to make sure they lead the market in providing reduced residual stress in both mild, structural and high strength steel grade sheet and plate from 4 to 20 mm in sizes up to 2.1 x 10 m.

United Steels has already proven that the inconsistent results experienced by some when laser processing heavy gauge sheet and plate can be cured by their new levelling line, which can process steel in thicknesses and strengths not previously possible in the UK.

Contact: Glyn Costigan
E: glyn.costigan@unitedsteels.com
W: www.unitedsteels.com

The UK's first Trulaser 1030 fibre

Rather than upgrade to a newer version of its existing CO_2 laser, the desire to bring thin sheet laser cutting in-house led the East Anglian subcontractor, Electronic Metalwork Services (EMS), to chose a Trumpf TruLaser 1030 fibre, fibre-guided solid state laser. It has the distinction of being the first in the UK to install this model. "The Trumpf fibre-guided laser offered us the best productivity for materials under 5mm," explained Julian Long, Director of EMS.

This new acquisition was specified with a semi-automatic pallet changer to maximise productivity. "Cutting downtime by removing components whilst the machine is running the next sheet helps us remain competitive," Julian Long added.

Contact: Gerry Jones
E: g.jones@uk.trumpf.com
W: http://www.trumpf.com

Laser Process saves time and cost

Cannock-based Laser Process has invested £50,000 in a new Dugard ECO1000 vertical machining centre, for performing a range of secondary machining operations on parts they have laser cut. The operations made possible by this machine include drilling & tapping, chamfers, rebates, countersinking and counterbores.

Managing Director Dave Lindsey said "The machine will enable us to provide a one stop shop for our customers, at the same time adding value to our sales."

Laser Process has also taken a 3000 square feet unit opposite their base on Keys Park. This unit will house assembly operation in order for the firm to run a smooth operation. This is a relatively new but rapidly growing part of the business which is hoping to expand in the future. To keep up with the growing demand, the company has taken on extra staff to operate the new machine and for the assembly operations.

Contact: David Lindsey
E: dl@laserprocess.co.uk
W: www.laserprocess.co.uk

Investment for City Engineering

City Engineering (Bristol) Ltd has recently invested over £500,000 in laser equipment with funding secured from Lombard.

Chairman Robert Davies said "We took a strategic decision to invest in the Trumpf Fibre Laser because it provides increased efficiency and allow us to work with a broader range of materials including copper and brass. "

"This is the second piece of machinery that we have purchased through Lombard," said Robert. "Having used asset finance rather than cash provided us with greater flexibility and allowed us to preserve our capital, so it was a logical funding solution for us. The machinery will more than pay for itself during the contract period, and we take ownership at the end of the term."

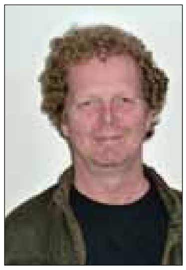
"We took out a Key Asset policy that covers us for accidental damage. In the event of user error or damage to such a complicated piece of equipment, the policy safeguards us against this kind of unexpected cost," said Robert.

Contact: Robert Davies
E: rdavies@cityengineering.com
W: www.cityengineering.com

Chairman's report

Job Shop Spring

Notes from Captain John



Cherished readers:
Is it just me or did we all have a great spring followed by a quieter summer in 2012? How can a lot of hurdling and high jumping have had such an effect of the laser cutting industry? I know a lot of us had to stay off work to watch the beach volleyball but even so it seems an odd correlation.

As autumn arrived things seemed to pick up – I suppose all those wet leaves on the beach had something to do with it… and with autumn came the AILU jobshop meeting – which was a great success as usual. This year the meeting was held at the JCB factory in Uttoxeter. There were about 55 in attendance – including several new jobshops – who then joined AILU – hurrah! We had talks on whether or not to buy a fibre laser, leasing v buying and the availability of grants amongst other things. The survey results section was a particularly lively affair (no – I am not kidding) and the afternoon general discussion raised several items which could save us all some cash.

All in all, a great meeting – and if you missed it try to make the next one.

So - later this year don't think 'Autumn – season of mists and mellow fruitfulness', think instead 'Autumn – it's time for the bleedin' jobshop meeting – innit?'

The autumn of 2012 was, unfortunately, followed by the usual winter of discontent but the new year looks a little brighter – and, once again, I solemnly declare that the recession will definitely be over by my birthday (6th of March).

Onward and upward …

Cheers

John Powell

E: jpowell@laserexp.co.uk

See also a brief summary of the JS '12 business meeting on p 31.

JOB SHOP CORNER

Building a new factory

Dean Cockayne

Midtherm Laser, Dudley, West Midlands

Building a new factory' loosely translates as 'engineering your own nervous breakdown'. In my case this project started back in 2007 when I enquired about buying some waste land from the local council. The small area of land is next door to my current premises.

Expecting the council to respond was my first surprise. They were not interested in listening to me; in fact they came across as not being interested in anything! It took nearly two years for me to convince them to part with their piece of waste land and to obtain planning permission. This came along with strict rules regarding the environment and compliance to what is know as 'section 106'.

Section 106 is about planning obligations seems to be just another way of taxing employers. In my case compliance cost me approximately £200k. Fortunately, I managed find a way to reduce this in the end but still had to pay out several thousand pounds.

So it was January of 2012, after several meetings with the bank to discuss funding, that we were able to start clearing the ground.

It seems that the council had dumped lots of their rubbish in that area over the last few years and then covered it over, obviously with a deep regard for the environment!

With costs rising and eating into our reserve budget we finally managed to get the steel frame up and the roof on: progress at last. Well, it seemed like progress until it seems someone realised that there were some incorrect dimensions and that things had to be changed before more progress could be made. This resulted in another dip into the reserve budget.

The design was for a simple steel frame building with some bricks and cladding. Cladding! From this experience the only conclusion I can reach is that cladders would dissolve in the rain and melt in the sun, which is why they spend most of their time sitting in the van drinking tea and sleeping.

July was a fantastic month. We had the roof on, the cladding done and the floor in: now all we needed was some power. Luckily I had a tip off earlier in the year and had already purchased as much of the extra KVA as was available. I had the substation modified and we had power in the new building.

My elation only lasted as long as an electrician's working day! This turns out to be about 6 hours: their day starts at about 10 am, breakfast at 11 for an hour (usually off site at the café), lunch at 1 o'clock in the van (quick snooze for an hour or so) and then home for 4 pm.

The new building during the early stages of construction and (bottom) close to completion

Health and safety comes first of course, which is why they never have time to clear up after themselves. It is too risky for them to answer a mobile and of course they never work on the same job for more than two days straight.

By October the machines were installed and just about working, the offices were plastered, most of the electrical work was complete and now the bank wanted to split the mortgage because they were not confident we would finish the building! I know, I know….bankers! I was told by many colleagues and friends but you're always prone to take what someone tells you as gospel if they are wearing a pin stripped suit.

As I write this (November), the building inspector has just been. I talked him out of the lift he expected to see installed but we still have a list of ridiculous things to correct. The builder has been fantastic but we are still waiting for the electrician: now promised for Thursday, but he didn't say which one. I think that with a little paint and tarmac we should just about by the end of the year. So at last I will be able to have my nervous breakdown.

To sum up. The building is fabulous, it looks and works superbly. For us it is spot on; but would we do it again?

No way! I'd look for a finished building that suits and move the whole lot regardless of cost and downtime.

Contact: **Dean Cockayne**

E: dean@midthermlaser.co.uk

The difference between a fibre laser and a fibre delivered laser

Tony Hoult

There is a sea-change underway in the laser industry: it is now clear that there is a shift from the conventional technique of assembling lasers using free space optical components to a technique based on splicing together fibre based components.

It is now very widely accepted that the shift from free space to fibre brings a range of benefits, not least of which are dramatic improvements in reliability, stability and ease of use. These can be seen across the whole spectrum of the laser industry from multi-kilowatt lasers to low power ultra-short pulse length lasers, with more and more lasers using the key word 'fibre' in their descriptions.

But let us take a step back; the phrase fibre laser (or the US spelling 'fibre' laser) arrived in the laser lexicon in 1962 with the invention of the earliest devices by Elias Snitzer. He was the first to show that a laser beam can actually be generated within the fibre itself, hence the term 'fibre laser'. Despite a slow start low power fibre lasers developed rapidly to play a key role in the telecom boom (and bust) in the late 90's. Since then rapid progress has been made in scaling up laser power: only recently it was announced that a 100 kW fibre laser is being developed! This scaling up of power, and with it performance and reliability, has brought rapid penetration of the industrial laser market at the expense of the incumbent 'old technology' lasers. Commercial success has come to those leading this technology - fibre lasers have become and remain a hot topic.

Fibre or just fibre delivered?

As a result, it is clear to me that the phrase 'fibre laser' and even the word 'fibre' is being applied far too loosely in the multi-kilowatt laser market to associate some laser products with this success that are clearly not truly fibre lasers but are simply fibre delivered' lasers. So let me clarify what a 'fibre laser' is and what it is not.

A 'fibre delivered' laser beam is one that is generated using conventional free space optics technology via other solid state media such as rods, discs or slabs. The output from such a laser is then focused down into a fibre and delivered to the workpiece via this flexible optic cable. This 'fibre delivery' technique, which has been in use with flashlamp-pumped solid state lasers for almost 30 years, does indeed reduce many problems that are associated with building lasers systems, especially where the laser should be remote from the point of application of the beam. More recently the 'fibre delivered' technique has been employed to combine the beams of very many individual direct diode lasers into a single fibre for delivery to the workpiece. Although these lasers are still 'free space' devices in one sense, the complex optics that squeezes the output of several individual diode lasers into a much smaller 'free space' allows the benefits of fibre delivery to be maintained.

Other solid state free space laser resonators based on slabs or discs of doped optical crystals have also been developed to avoid some of the issues associated with large diameter rod lasers but NONE of these other high power laser types are fibre lasers.

A real fibre laser is a totally different disruptive technology that has many major attributes that none of these other laser types can match. The essence of a real fibre laser, and this does bear repeating, is that the beam is actually generated in the fibre itself. This is achieved by writing optical gratings into the fibre and these gratings act as the partially and totally reflecting mirrors required to make up the laser resonator. This active fibre or gain medium within which the laser beam is generated is actually drawn down contiguously with layers of cladding. Pump light is introduced into the cladding layer by splicing larger core diameter fibres from laser diodes into the cladding and the outer cladding, thus confining the pump light. This elegant solution to the problem of generating laser beams is scalable simply by increasing the length of the active fibre, by increasing the number of pump diodes or for applications where focusability is not so important, using optical combiners to join many beams together.

Tony Hoult is General Manager of West Coast Operations for IPG Photonics

E: thoult@ipgphotonics.com

Comments:

I sent Tony Hoult's piece out to a range of laser users and suppliers and was surprised to receive so few responses. To add to the two I did relieve (see below) I would add my own, which is more supportive of Tony's view.

I don't think there is any doubt that the fibre laser represents a major advance in laser technology, with IPG still leading the way in high brightness output, both multi-mode and, even more amazingly, single mode. But I think the point that Tony is making concerns the fact that the technology is so stable and reliable. We will have all heard the story of customers taking delivery of high power fibre lasers and, despite all the rough handling, temperature fluctuations and vibration they were subjected to during transit, they worked first time.

Industrial users should always enquire about a laser's robustness, efficiency and reliability as well as its output power and should not be misled by the fact that the output is fibre delivered.
Ed.

Well I don't think anyone can argue with Tony's main point that you can only call a fibre laser a fibre laser. But I am not sure what the point of the point is. Are other companies going round pretending they are selling a fibre laser when actually they are not? If so, surely we should be told who they are or they should be reported to the trading standards body
Stewart Williams Cranfield University

'What Tony says is perfectly true – but it's a small point as far as laser cutting is concerned. A fibre delivered laser beam cuts exactly the same as a fibre generated/delivered laser beam.'
John Powell Laser Expertise

French experience

I had the pleasure of making two business trips to France in 2012: to Besançon to view the Micronora, a biennial micro-technology and precision trade fair (25-28 September); and to Mulhouse to attend the JNPLI, the Club Laser et Procédés (CLP) annual 2-day national industrial meeting (28 - 29 November).

Micronora

The CLP, a similar organisation to AILU, organised a 'Laser Zoom' at Micronora, a 400 m^2 area organized in 6 main booths, each dedicated to a different process, with cases displaying samples of laser processed parts, posters, presentation slides and videos running on large screens and, on some booths, a laser machine. AILU supported the Zoom by providing slides from the Design for Laser Manufacture web site.

The micro-machining booth in the Laser Zoom. The Zoom proved especially popular with school and college students (see right)

I was only able to attend on Day 1 of this 4-day event and was impressed by:

- The large number of attendees at Micronora on a wet and windy first day. There was a real buzz at the show.
- The large number of laser product and service suppliers that had taken stands many of which I was unfamiliar with.

JNPLI

The JNPLI took place in Mulhouse Exhibition Centre at the same time as ESPACE, a 2-day laser exhibition. Key insights for me were:

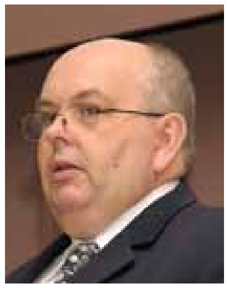
- Simultaneous French-English translation work very well for English- speaking presenters and audience alike.
- Translation facilities provide great opportunities to hear fresh viewpoints, approaches and experiences.

La cuisine française: the lunch breaks were marvellous!

I've learned a lot from these trips to France; they were useful and enjoyable. I wholeheartedly recommend both.

Mike Green
E: mike@ailu.org.uk

PRESIDENT'S MESSAGE



Happy New Year everyone! I hope you all had a good Christmas break and start this year in good spirit. Initial soundings show that while there Is some business confidence, companies are still having to work very hard to maintain their financial position let alone build upon it. I hope this hard work pays off and come year end we are seeing some real business growth and associated confidence.

This year for AILU is dominated by ILAS 2013; see the website at www.Ilas2013.co.uk for the current details and in particular the program. We had a wide range of offers to speak and this has allowed us to put together a programme that Is really quite impressive. There Is an increasing international content, and there is good coverage of all the major sectors of laser materials processing. Put simply, there is something for everyone, and I'd hope everyone can find the time to be there!

ILAS is a significant event for AILU. As well as providing the opportunity for our community to meet, to hear about the latest in laser materials processing, to network and to talk business, a successful ILAS helps secure AILU's finances. So please make the effort and set aside the time to attend.

Finding time Is often the biggest hurdle to attending any event let alone ILAS, even more of a hurdle than finding the registration fees and travel costs. But in providing the premier Laser Materials Processing event in the UK this year I believe that attendance will bring you a good return for your support.

ILAS 2013 continues to grow as an event. It will be bigger than its predecessors in 2009 and 2011 and more international. This is especially important since an increasing overseas participation provides visibility to the laser industry based in the UK, which is seeking to grow its exports. This is also important for AILU itself; indeed, maintaining and increasing the visibility of AILU has been a core activity for me during my time as president. Last year we made great efforts to improve visibility at home and abroad, mainly through trade shows. It is important that AILU Is seen as the voice of the UK laser processing community. In this way it can promote the industry and its needs wherever possible.

Just a week ago I attended a meeting to discuss leadership in Photonics in the UK. It was interesting and thought provoking. One key issue remains in my mind: should we keep using the word 'Photonics'? Do people understand what it is, the way it pervades modern life and thence Its Importance to industry.

Various organisations, associations and other agencies have been set up over the years to support Photonics. Within this, AILU has consistently represented the laser processing community and sought to promote it as a sector of importance. Other photonics associations have mainly referred to LMP when the impact of Photonics needs to be demonstrated. Their main interest is either regional or in another sector of photonics. Without AILU then, LMP might find itself relegated to the provision of spark filled pictures! We have managed to provide AILU visibility throughout the last few difficult years, indeed I'd like to think that the last year was one of the best, with a pavilion at MACH, and AILU stands at a number of exhibitions here and overseas in Germany and France.

Maintaining and increasing this visibility is crucial, despite the difficulty with current resources, but as members you can do your bit too. A good attendance at ILAS will add legitimacy to LMP and AILU, and increased recognition from the government and it's agencies.

ILAS is also an important event for me at a personal level: at the AGM I hand over the presidency to Neil Main of Micrometric. Neil has been a brilliant Vice President to work with and I could not have done near as much as I have without his help, support, guidance and vision. In handing over the presidency to Neil, I wish him every success and my ongoing support.

It seems a bit early to be saying thanks, so I am going to leave these perhaps for another small article in the magazine and to be said on the day at ILAS.

I hope to see you at ILAS. Six weeks away! Please make a decision now to attend and register. AILU is important, it is the Association that agencies want to talk to , let's show them why!

Martin Sharp
E: m.sharp@ljmu.ac.uk

Some questions, answers and open issues in laser cutting

Dirk Petring, Frank Schneider and Norbert Wolf

The advent of fibre and disk lasers a few years ago really shuffled up the conventional CO_2 laser cutting market. System suppliers, customers and researchers became aware of new threats or opportunities, depending on their point of view. It needed some time, but now the high system efficiency and availability as well as reduced floor space, operating costs and maintenance requirements of fibre-coupled 1 micron laser technology is attracting strong market attention. No warm-up time of the resonator and no beam guiding system to be purged or re-adjusted are strong arguments for afflicted users of traditional laser systems. However, limitations of fibre-coupled 1 micron systems in thick section cut quality are recognized, partly accepted by some customer markets and continuously shifted to higher thicknesses by ambitious research efforts. [1]

To be entirely mastered a process must be calculable. This point is increasingly recognized as a precondition for sustainable success in manufacturing technologies in a global market; and it is true also in the laser cutting business. If speculations are replaced by trustworthy calculations, a new quality of process understanding can be created.

Disputed statements

There is currently an ongoing debate about the specialities of the 1 micron laser beam fusion cutting process in comparison to the established 10 micron variant, and in particular some distinct statements and speculations about beam coupling and energy redistribution over recent years should attract attention (listed below in chronological order):

- "…the differences in absorption between the two wavelengths, with the beam at one micron wavelength suffering greater absorption higher up the cut than the CO_2 laser beam, which therefore enjoys better waveguiding and thereby better spreads the absorbed laser power down the cut."
  O'Neill et al 2008 [2, 3]
- "…the energy absorbed from the CO_2 laser is used for increase the process temperature, leading to a lower viscosity of the melted material, whereas when cutting with a disk laser the absorbed energy is used to melt a higher amount of material with a lower average temperature and thus a higher viscosity."
  Scintilla et al 2010 [4]
- "…increased laser beam absorption in the cut kerf is realized through the multiple reflections of the laser beam in the thick-section cut kerf."
  Wandera et al 2011 [5]
- "Recent studies show that the efficiency of fibre laser cutting is higher than of CO_2-laser cutting, also for thick section cutting. Even though some multiple reflections can improve the Fresnel absorption, this cannot explain the observed high absorption in laser cutting of metals."
  Olsen 2011 [6]
- "…the lower part of the cut front […] became curved or kinked and extended in the cutting direction. This effect is explained by greater interaction of the reflected beam with the lower part of cut front and in particular highlights the role of the multiple reflections in the process."
  Scintilla et al 2011 [7]
- "According to experimental results, the degradation of the surface roughness in the case of a 1 μm beam starts at 1–2 mm below the top surface, where the laser beam absorption from multi-reflected components is not supposed to be important. Consequently, multi-reflections cannot be the main mechanism."
  Hirano and Fabbro 2012 [8]

All the above result from an expert background and are based on plausible considerations. But how can the right conclusion be drawn from these contradictory and speculative propositions?

Open questions

Reviewing the above cited arguments together with the underlying practical experience, the following questions might lead to the right answers:

1. How does the beam coupling and propagation within the kerf differ between 1 micron and 10 micron wavelength?

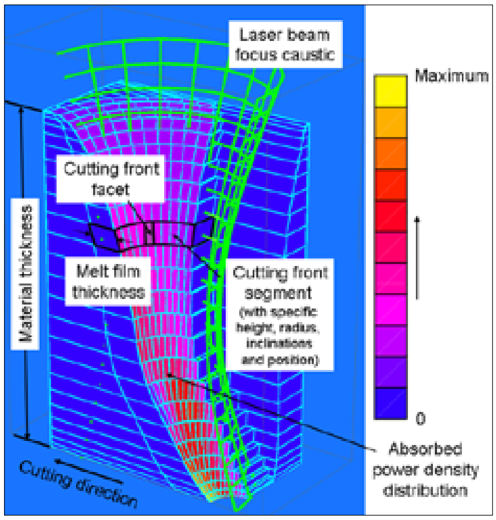


Figure 1: Laser cutting simulation of the cutting front with CALCut

2. How does 1 micron radiation influence the energy redistribution within the kerf?
3. Why do cutting kerfs produced in steel with 1 micron lasers show wider and more irregular cross-sections and more recast than those produced with CO_2 lasers under similar conditions of focus geometry?
4. Why does the cut surface get abruptly rougher and irregular typically 1-2 mm below the top surface?

In fact, answers to these questions were given some years ago [9, 10, 11], when the importance of multiple reflections (MR) in 1 micron laser beam cutting was explained by the authors. Here, we will show that all phenomena raised by the four questions above can be ascribed to MR. The well-known irregularity of melt flow and thermal radiation observable during trim-cut experiments fits in, too.

Calculating with CALCut

The computer simulation 'CALCut' has been used to predict, analyse and optimise the performance of various cutting applications for the past 20 years (see [11] and references therein). Its wide range of validity has been demonstrated experimentally, varying material, sheet thickness, laser beam power, cutting speed, focal length, focal position and polarisation.

As part of this work, three cutting process regimes were identified: the heat-conduction-controlled process at low speeds; the melting-controlled process in the medium speed range; and the evaporation-controlled process above a critical cutting speed (see [11] and references therein). Similarly, the influence of CO_2 laser beam quality on cutting speed has been analysed and explained by means of CALCut.

The steady-state model provides a unique insight into laser cutting and allows forecasting cut quality features by calculating, for example, cut front shape, kerf cross section and melt film thickness (see figure 1). CALCut has also been used to calculate the practical implications of changes in beam quality and wavelength [11].

Answers to open questions

Taking the above four questions in turn and referring to the respected arguments which they raise:

1. Answer to question about beam coupling and propagation [2, 3, 5-7]: *How does the beam coupling and propagation within the kerf differ between 1 micron and 10 micron wavelength?*

Thick sections benefit from the larger Brewster angle[1] at the 10.6 µm wavelength of CO_2 lasers i.e. an increased absorptance in metals at grazing incidence. This is a stroke of luck for CO_2 lasers.

While the importance of the Brewster angle is evident, some authors nevertheless assume better wave-guiding through multiple reflections for 10.6 µm than at 1 µm (see [2, 3]). It is demonstrated in figure 2 that the physics of Fresnel absorption[1] bring about something else. This was discussed first time in [9, 10, 11].

Figure 2 presents two curves of maximum cutting speed versus power calculated with CALCut for the same application. In the lower curve only the first absorption step is taken into account whereas in the upper curve all reflection and absorption steps on the self-adjusting cutting front are taken into account.

In accordance with the assumptions in [5, 7] and in contrast to the assumption in [6], the beam coupling improves further down the cutting front due to multiple reflections. A correct simulation taking MR into account provides realistic results regarding cutting depth and maximum achievable cutting speed.

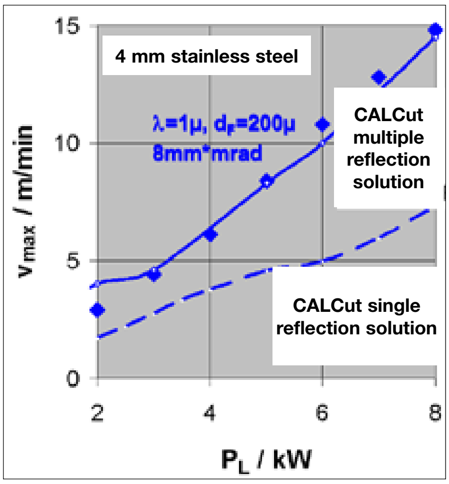


Figure 2: Taking into account multiple reflections makes 1 micron cutting results explainable [10].

The absorption at 1 µm would be much lower (especially but not only in thick sections) if this “wave-guiding” did not occur. In the example in figure 2 the coupling efficiencies differ by a factor of 2 [10, 11].

The effectiveness of an MR contribution at 1 µm can be made plausible with the simplified illustration in figure 3 [12]: The first point of incidence of a ray is characterized by a relatively large angle of incidence, with low to medium absorption; then, during numerous MR steps the angle of incidence continuously reduces and the surface absorptance increases. Only at the finite radius of the kerf entrance (not included in figure 3) where the transition from sheet surface to kerf entrance takes place, do smaller angles of incidence result in high absorptance of the outer (low intensity) boundary of the beam.

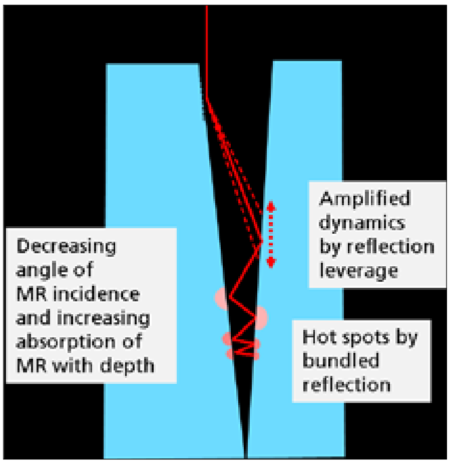


Figure 3: Effects of multiple-reflections are getting more pronounced at 1 micron wavelength due to low absorption at grazing incidence and increasing absorption with decreasing angle of incidence (simplified for illustration only) [12]

CALCut simulations also predict hot spots due to self-focussing effects in the kerf (figure 5, [10]). The hot spots can even reach the kerf walls behind the cutting front and cause irregular front and kerf shapes and induce melt flow irregularities with related quality losses [11, 12].

2. Answer to question about energy redistribution [4]: *How does 1 µm radiation influence the energy redistribution within the kerf?*

The simulated cutting fronts in figure 4 reveal similar changes in temperature with speed for both wavelengths [12]: the variation of speed has a much greater influence than wavelength. Nevertheless, typically a slightly higher temperature at 1 micron is calculated, in contrast to the assumption in [4], where a lower temperature is predicted.

3. Answer to question about wider, more irregular kerfs [4, 7]: *Why do cutting kerfs produced in steel with 1 micron lasers show wider and more irregular cross-sections and more recast than those produced with CO_2 lasers under similar conditions of focus geometry?*

At the edge of the kerf entrance the higher absorption of 1 µm radiation at small angles of incidence becomes effective. Even the lower intensity regime of the beam boundary, normally wasted in the case of 10 µm beams, can melt the material and leads to a wider kerf entrance. This can also be inferred from the simulated cutting fronts in figure 4 [12].

Much more obvious are the partly “curved and kinked” cutting front geometries predicted for 1 µm cutting compared to the smooth shapes for 10 µm cutting. This result has been observed experimentally in an excellent investigation [7]. Their assumption that MR could be responsible for these effects is confirmed by the simulations in figure 4 [12].

Figure 5 presents a cutting front geometry calculated with CALCut for thicker section cutting [10], taking into account all multiple reflections and absorption steps on the self-adjusting cutting front – partly visible as “hot spots” in the energy flux distribution seen in the right half of the simulated front. Accordingly, an irregular and locally widened kerf geometry occurs. This is also visible at the real cut edge in figure 5 [11].

Also the experimental findings regarding the kerf cross sections from [4] in figure 6 are in excellent agreement with the corresponding CALCut results. The

1. In the present context, Fresnel absorption is the angle-dependent absorption of laser beams at metal surfaces, an effect described in terms of angle and polarisation by what are termed the Fresnel equations. These equations show that at a particular angle of incidence, the Brewster angle, so-called p-polarised light is maximally absorbed in the metal.

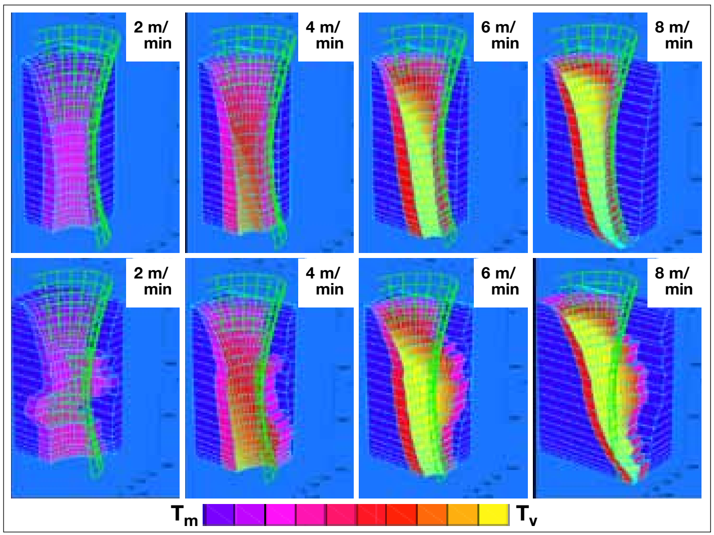


Figure 4: CALCut simulations of cutting fronts in 3 mm stainless steel. More expanded and irregular cutting fronts are predicted at 1 micron (bottom row) than at 10 micron (top row) [12].

experimentally produced width of the recast is wider than the represented melt film thickness of the cutting front calculated with CALCut, because additional melting (by MR) and stochastically accumulated recast is produced; this phenomena, which takes place behind the cutting front, is outside of the represented calculation regime i.e. it does not contradict the simulation results [12].

4. Answer to question about abrupt increase of roughness [8]: *Why does the cut surface get abruptly rougher and irregular typically 1-2 mm below the top surface?*

Careful evaluation of simulations such as those in figures 4 and 5 reveal that MR contributions typically start below 1-2 mm cutting depth. This is in good agreement with experimental findings of the transition between fine and rougher cut edge regions. In this context it is important to note that multiple reflections can destabilize the lower cutting zone and lead to coarser striations [11]. This is also illustrated in figure 3, where amplification of dynamics by the reflection leverage is sketched [12].

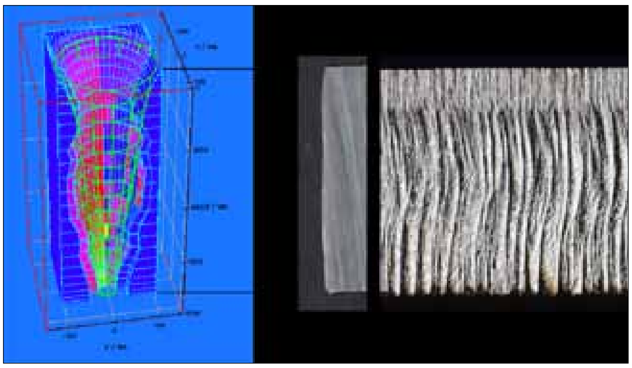


Figure 5: Theoretical and practical evidence of multiple reflections (laser TruDisk 8002 @ 8 kW, combi-head Laserfact F2-Y, 8 mm structural steel, cutting speed 2.4 m/min, cutting gas: nitrogen) [10]

Conclusion

The CALCut MR solution makes explainable the comparison of 1 micron laser beam fusion cutting of steel compared to the CO_2 laser beam cutting variant, in terms of:

- real coupling efficiency (V_{max}),
- wider kerfs,
- amplified dynamics,
- hot spots,
- quality issues

An answer to the next question that follows is under way: What would be the appropriate measures to counter the negative effects of multiple reflections without giving up the benefits of a significantly increased coupling efficiency?

References

[1] Petring, D: More about laser cutting - A mature laser application still has something up its sleeve. LIA Today, Vol. 19, No. 1, 6-7 (2011)

[2] Seefeld, T, and O'Neill, B: Cutting and welding with the new high brightness lasers. The Laser User, Issue 50, Spring 2008, 32-37

[3] O'Neill, B: Laser cutting: a technology with some surprises in store. The Laser User, Issue 51, Summer 2008, 34-36

[4] Scintilla, L D, Tricarico, L, Mahrle, A, Wetzig, A, Himmer, T, Beyer, E: A comparative study on fusion cutting with disk and CO2 lasers. 29th International Congress on Applications of Lasers and Electro-Optics (ICALEO 2010), paper #704, Anaheim, CA, USA, September 2010

[5] Wandera, C, Kujanpää, V, Salminen, A: Laser power requirements for cutting of thick-section steel and effects of processing parameters on mild steel cut quality. Proceedings IMechE Part B, Journal of Engineering Manufacture, Volume 225, 2011

[6] Olsen, F O: Laser cutting from CO2 laser to disc or fibre laser – possibilities and challenges. 30th International Congress on Applications of Lasers and Electro-Optics (ICALEO 2011), paper #101, Orlando, FL, USA, October 2011

[7] Scintilla, L D, Tricarico, L, Mahrle, A, Wetzig, A, Beyer, E: Experimental investigation on the cut front geometry in the inert gas laser fusion cutting with disk and CO2 lasers. 30th International Congress on Applications of Lasers and Electro-Optics (ICALEO 2011), paper #105, Orlando, FL, USA, October 2011

[8] Hirano, K, Fabbro, R: Possible explanations for different surface quality in laser cutting with 1 and 10 µm beams. Journal of Laser Applications, Vol. 24, Number 1, February 2012

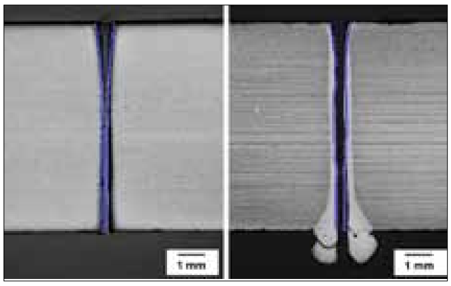


Figure 6: CALCut (blue lines) explains the experimental comparison of cross sections produced with 10 micron (left) and 1 micron (right) laser radiation (experimental data [4]: 8 mm 90MnCrV8, 0.95 m/min, 3 kW, focal position 4.5 mm, 14 bar nitrogen, CO_2 laser (with M^2 = 1.35, r_F = 76 µm, z_R =1.3 mm), disk laser (with M^2 = 14, r_F= 76 µm, z_R = 1.2 mm)) [12].

[9] Petring, D: Observations to [2], in: The Laser User, Issue 50, Spring 2008, 52

[10] Petring, D, Schneider, F, Wolf, N, Nazery, V: Theoretical and Practical Impact of Brightness on High Power Laser Cutting and Welding Applications. 4th International Symposium on High-Power Fibre Lasers and their Applications, St. Petersburg, Russia, June 2008

[11] Petring, D, Schneider, F, Wolf, N, Nazery Goneghany, V: How Beam Quality, Power and Wavelength Influence Laser Cutting and Welding Processes. Proc. of LAMP2009 - the 5th International Congress on Laser Advanced Materials Processing, Kobe, JP, June 2009

[12] Petring, D, Schneider, F, Wolf, N, Molitor, T, Nazery Goneghany, V: Cutting with 1 micron wavelength lasers: An intermediate assessment of speculations, simulations, diagnostics and facts. Proc. of Stuttgart Laser Technology Forum SLT'12, June 2012, Stuttgart, Germany

The authors are with the Fraunhofer Institute for Laser Technology ILT, 52074 Aachen, Germany

Contact: Dirk Petring
E: dirk.petring@ilt.fraunhofer.de

Dirk Petring established the Department of Laser Cutting at the Fraunhofer ILT in 1989. Since 1998 Dr. Petring has been in charge of the welding activities at ILT as Head of Macro Joining and Cutting. In 2006 he co-founded Laserfact GmbH

See Observations p 28

This edited paper appears in full in the Proceedings of ICALEO, 2012. It is published with the kind permission of the Laser Institute of America.

Helical drilling of high quality micro holes

Christian Fornaroli, Jens Holtkamp and Arnold Gillner

Small diameter holes drilled reproducibly to high standards roundness, diameter and aspect ratio are required for a wide range of modern components and products from fuel injectors to spinning nozzles. Laser-beam helical drilling has shown great promise to meet this requirement. The process involves rotating a laser beam at high speed. This is achieved by means of a Dove prism that is mounted in the hollow shaft of a high speed motor.

Laser drilling technologies are primarily used in situations where conventional manufacturing technologies, in particular mechanical drilling and EDM (electrical discharge machining) are unable to provide an acceptable solution [1]. Situations where this arises include drilling in very hard and/or non-conductive materials, or where the requirement is for holes of high aspect ratio and/or high quality. The main limiting factor for conventional technologies is the performance of tools for drilling small hole diameters [2].

Helical drilling

There are several laser drilling techniques and technologies, the main ones of which are presented in figure 1. In a first step it possible to distinguish drilling processes according to whether the laser beam moves or not. Together with trepanning, helical drilling belongs to processes requiring a moving beam. Some of the available non-rotating beam drilling techniques are very productive but are limited in precision and quality, one reason being their dependency on the stability and circularity of the laser beam profile.

Laser-beam helical drilling enables manufacturing of high quality micro holes with various conicity, high aspect ratios and minimal heat affected area [3]. Because of these unique features helical drilling is beginning to establish itself in several sectors of industry, such as the automotive, energy and textile industries [4].

In the work presented in this paper, helical drilling optics was used with a nano-second-pulsed laser source (Nd:YVO4 laser: Edgewave Innoslab IS4II-DE 10ns, 532 nm, 18 W @ 20 kHz) to drill micro holes in stainless steel. The objective of this work was to investigate the main factors that influence quality and productivity, such as fluence, shape of the rotating beam and rotation speed.

In addition to the laser and the helical drilling optics (see text box and figure 2 below), a control cabinet and a clamping device for the workpiece was used. Everything except the control cabinet was mounted on the x-y-z-stage of a laser-machine tool.

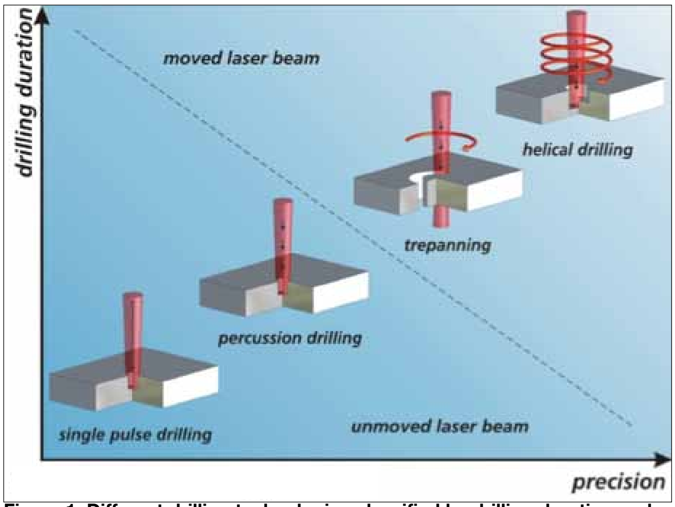


Figure 1: Different drilling technologies classified by drilling duration and precision

<u>Beam rotation</u>

Figure 3 describes the operation of the spinning Dove prism, a technique that has two fundamental attractions. First of all, the beam is not just rotated, but actually imaged. As shown in figure 4, it is possible to distinguish two superposed rotations: first, a rotation of the laser beam on a helical path and, second, a rotation within itself (proper rotation) synchronized with the helical path, which means that the hole roundness is almost independent of the beam profile. Secondly, the laser beam is rotating twice as fast as the prism itself. This offers higher optical rotational speeds and synchronization between polarization and beam rotation. Especially when drilling micro holes with high aspect ratios (more than 1:5), control of the polarization of the laser beam becomes very important if high hole quality is to the attained [6]. This is dealt with by rotating the half-wave plate and the prism in synchronism, thereby ensuring that the orientation of the beam polarization is maintained constant in relation to the hole wall. The latter is achieved because the spinning half-wave plate also rotates the polarization at a speed of 2ω. (Note that the half-wave plate at the input of the optical arrangement for helical drilling ((1) in figure 2) has to be adjusted relative to the half-wave plate inside the hollow shaft motor.)

<u>Beam focus</u>

Figure 5 shows the caustic around the focus of the f = 60 mm focusing optics

Helical drilling optics

In helical drilling, the laser beam is rotated relative to the work piece. In this case, the rotational movement is produced using a Dove prism, mounted in a high speed, hollow shaft motor, as shown in figure 2.

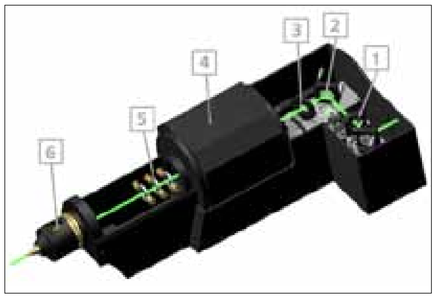


Figure 2: Optical path inside the helical drilling system and relevant components

Figure 2 shows the setup of the helical drilling system and relevant components inside, numbered from (1) to (6).

After a deflection mirror at the entrance, the beam passes a half-wave plate (1) in a rotatable mount. A second mirror (2) deflects the beam into the hollow shaft motor (4). Together with a motorized rotating wedge prism (3) the deflection mirror (2) is mounted on a motorized moving stage. This allows the beam to be translated and tilted relative to the axis of rotation of the hollow shaft motor.

The laser beam enters the hollow shaft motor and the internal Dove prism. Subsequently, the laser beam is rotated and passes a balancing holder (5), which is essential to compensate for the geometrical error created in the manufacture of the Dove prism. The balancing holder (5) consists of two wedge prisms and a laser A final optical component, a focusing lens (f = 60 mm), is located in a brass nozzle (6) connected to a coaxial process gas supply.

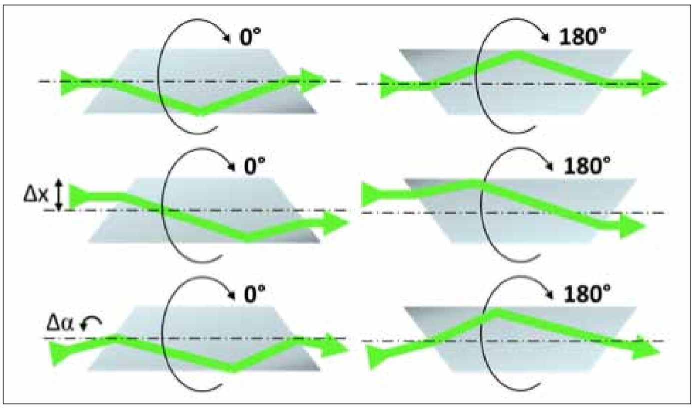


Figure 3: Principle of imaging inside the Dove prism. Effect of parallel shift and angle modification

At the entrance and exit of the prism, the beam is refracted and inside the prism a total reflection takes place. A centred and straight incoming beam (upper illustration) exits the prism centred and straight and rotates exclusively around its own centroid. If the beam is shifted parallel (Δx, centre illustration) to the optical axis, the outgoing beam moves on a circular path; if, however, it is tilted (Δα, lower illustration) in front of the prism, the outgoing beam traces the shape a cone.

NB: the laser beam is rotating twice as fast as the prism itself i.e. after a mechanical rotation of 180° the optical rotation is already 360°

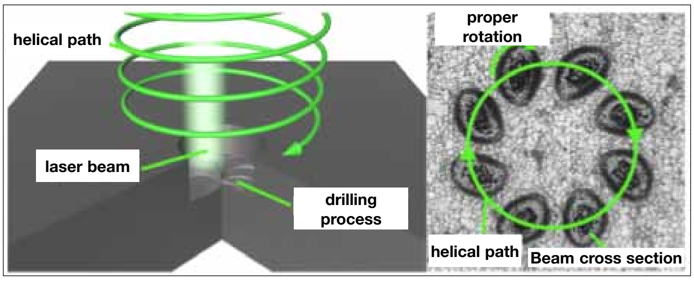


Figure 4: Diagram of helical drilling and illustration of the rotating motion (proper rotation and helical rotation).

(left) Spatial drilling progress when the laser beam is penetrating the workpiece. Full perforation only occurs after multiple rotations, since the ablation rate is quite low. Nonetheless, the ablation mechanism offers high precision, because of very small recast layers and homogeneous wall surfaces.

(right) The laser beam is not just rotated, but actually imaged. Consequently, the envelope of the laser beam describes a perfect circle, independent of the geometry of the beam cross section, thereby making the hole roundness almost independent of the beam profile.

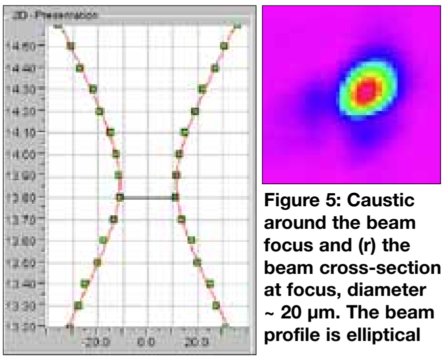


Figure 5: Caustic around the beam focus and (r) the beam cross-section at focus, diameter ~ 20 µm. The beam profile is elliptical

and the beam cross section at focus. The measured beam quality (M^2) is 3.05 and the Rayleigh length (Z_R) is 0.25 mm.

Experimental results and discussion

During the experiments, the influence of pulse energy, wedge prism angle and deflection mirror position was investigated, while other parameters were fixed (see summary in Table 1 opposite).

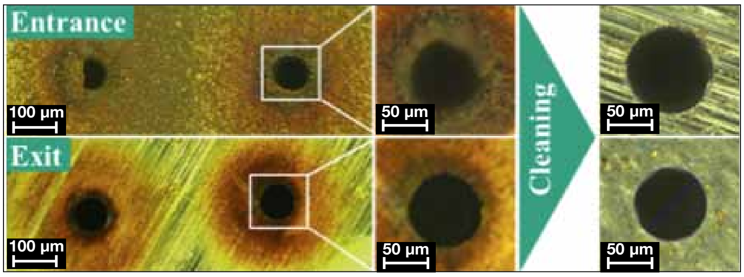


Figure 6: Contamination of drilled holes before and after ultrasonic bath cleaning. The ultrasonic bath contained 10% hydrochloric acid at 30°C and the cleaning time was 15 min.

As noted in the table, drilling times varied from 20 to 60 seconds dependent on experimental parameters.

During drilling the material volume is removed from the hole and both entrance and exit sides of the hole end up contaminated, the entrance side especially because before the hole breaks through the assist gas drives the melt and vapour out through this side. However, ultrasonic bath cleaning removes the contamination, see figure 6. The success of the cleaning process indicates that the ablated material is simply sticking to the edge and surrounding surface.

The diameter of the drilled hole is mainly determined by the diameter of the helical motion, but also by the pulse energy as shown in figure 7. At a pulse energy of 0.3 mJ the entrance diameter is about 65 µm and the exit diameter 30 µm. With pulse energies over 0.75 mJ the exit hole is larger than the entrance hole. One explanation is that multiple reflections from the walls inside the hole cause additional ablation on each reflection, causing extra enlargement of the exit hole and making its dimensions more sensitive to changes in pulse energy than the dimensions of the entrance hole.

Small angle modifications of the pivoting wedge-prism in front of the hollow shaft motor cause the raw transmitted beam to be tilted out of the vertical direction of rotation; see figure 3 (lower figure). After passing the rotating Dove prism the tilted beam traces a conical shape with an aperture angle equal to the initial deflection. The focusing optics convert the angle modification of the incoming into a linear shift of the focused outgoing

Fixed parameters		Variable parameters	
Repetition rate	f = 10 kHz	Pulse energy	0,3 - 0,95 mJ
Focal position	Workpiece surface	Wedge prism angle	-25 - 15 °
Wavelength	532 nm	Deflection mirror position	-2,0 - 2,0 mm
Pulse duration	10 ns	Drilling time (depending on other experimental parameters)	20 - 60 sec
Material	X5CrNi18 -10 1 mm thickness		
Process gas	2,5 bar O_2		

Table 1: Fixed and variable experimental parameters

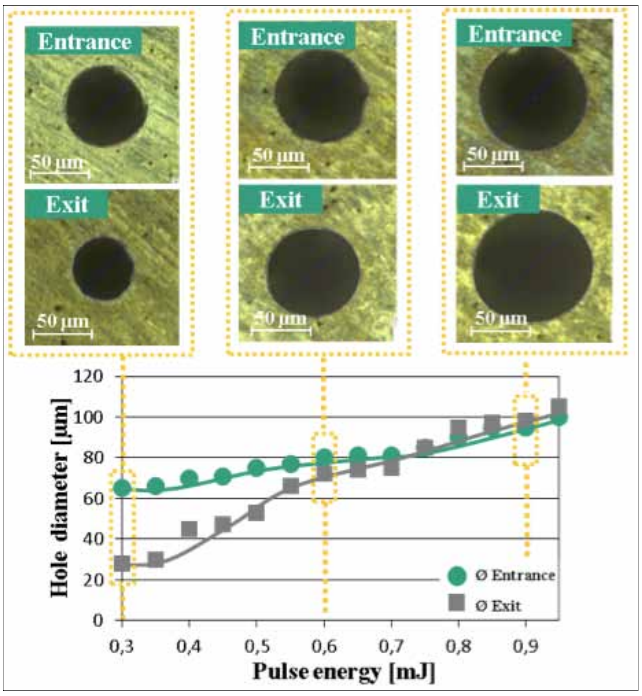


Figure 7: Correlation between pulse energy and hole diameter of entrance and exit side

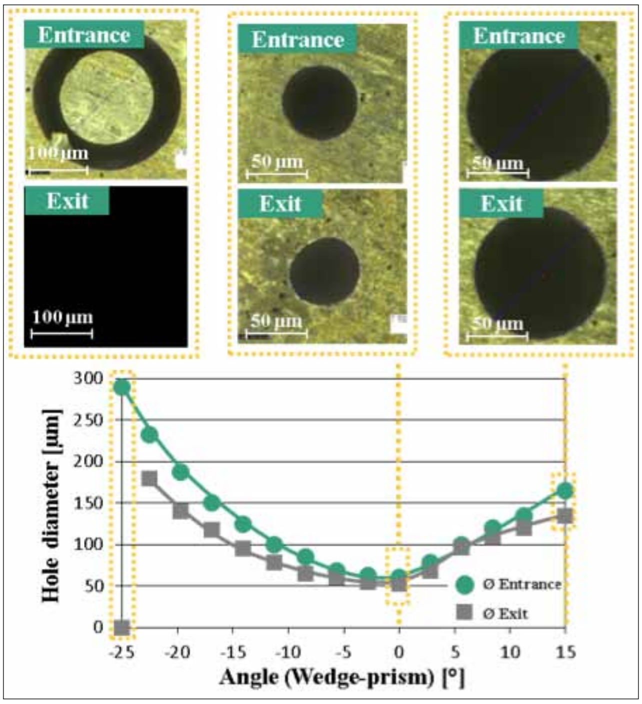


Figure 8: Correlation between angle position of the wedge prism and hole diameter of entrance and exit side. The trials were carried out at a pulse energy of 0.7 mJ and a deflection mirror position of 0.5 mm.

beam, thereby determining the helical diameter of the rotating beam. Figure 8 shows the correlation between modification of the wedge-prism-angle and the resulting hole diameter. The angle varies in a range from -25° up to 15°. The position 0° is the setting with the minimal (almost zero) helical diameter.

At an angle position of -25° the entrance diameter amounts to about 280 µm and the hole is not completed. The top view of the hole obviously shows a remaining core. At 0° the entrance diameter is about 70 µm and the exit amounts to 60 µm. In comparison to larger holes the roundness appears a little worse.

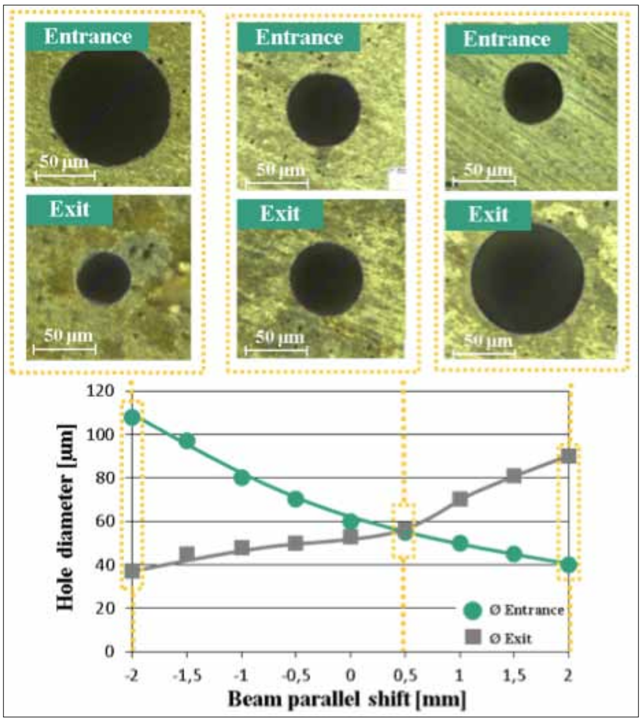


Figure 9: Correlation between parallel shift and hole diameter (taper). The trials are carried out at a pulse energy of 0.7 mJ and wedge angle 0°

In order to influence the taper of the resulting hole, the raw beam must be shifted parallel to the rotating axis in front of the hollow shaft motor. The influence of such a beam shift is shown in figure 9. In the position 0 mm, the point of deflection on the mirror matches the rotation axis exactly. While the position of the beam is constantly shifted, the pulse energy is set to 0.7 mJ and the wedge prism angle amounts 0°. At the position 0.5 mm, the hole has an exactly cylindrical shape. Both entrance and exit diameter is round and about 55 µm.

When the deflection mirror is moved to the left, the entrance is enlarged significantly while the exit diameter decreases in size slightly. At maximum parallel shift of -2.0 mm, the taper ratio is about 2.5:1, which means that the entrance is 110 µm and the exit diameter amounts to 40 µm. To reverse the taper ratio, the deflection mirror must be moved in a positive direction. In this case, the maximum negative taper ratio is 1:2.3 at a mirror position of 2.0 mm. Entrance diameter amounts to 90 µm while the exit is 40 µm.

Conclusions

Laser-beam helical drilling of high quality micro holes in stainless steel are investigated for helical drilling and a ns-pulsed laser with a wavelength of 532 nm.

The hole diameter does not only depend on the helical diameter, controlled by the wedge prism, but is also influenced by the pulse energy of the incident laser light. In particular, the exit side reacts very sensitively to changes of the pulse energy. Modifications of the wedge prism position in front of the hollow shaft motor have an immediate effect on the helical diameter and thus on the hole diameter. The investigations have shown that it is possible to control taper ratio of the drilled hole if the deflection mirror is moved parallel to the rotational axis. In addition to a positive shaped cone, it is even possible to increase the exit, while the entrance remains small.

In the future an ultra-short pulse laser will be used for this work to further reduce the heat input and, it is hoped, make subsequent cleaning superfluous. It will also be interesting to investigate drilling results in other materials including titanium and ceramics.

References

[1] Huegel, H.; Graf, T. (2009) Laser in der Fertigung, GWV Fachverlage, Wiesbaden. 352

[2] Foehl, D.(2011) Einsatz ultrakurz gepulster Laserstrahlung zum Präzisionsbohren von Metallen, Herbert Utz Verlag, München, 27

[3] Wawra, T. (2004) Verfahrensstrategien für Bohrungen hoher Präzision mittels Laserstrahlung, Herbert Utz Verlag, München, 29

[4] Walther, K.; Brajdic, M.; Kelbassa, I.; Poprawe, R. (2008) Drilling with pulsed laser radiation – A flexible, precise and productive manufacturing technique, Werkstatttechnik Online, Düsseldorf. 523

[5] Wawers, W.; Gillner, A. (2010) Device for drilling and for removing material using a laser beam, Patent number US7842901, Fraunhofer Gesellschaft, München

[6] Nolte, S.; Momma, C.; Kamlage, G.; Ostendorf, A.; Fallnich, C.; Alvensleben, F. von; Welling, H. (1999) Polarization effects in ultrashort-pulse laser drilling, Applied Physics A: Materials Science & Processing, 68, 563–567.

The authors are with the Fraunhofer Institute for Laser Technology ILT, Steinbachstr. 15, D-52074 Aachen, Germany

Contact: Christian Fornaroli
E: christian.fornaroli@ilt.fraunhofer.de

Christian Fornaroli studied mechanical engineering and economic sciences at RWTH Aachen from 2004 till 2010, when he moved to Fraunhofer ILT where he is investigating micro-structuring and ablation processes with (ultra) short pulsed lasers.

See Observations p 28

This edited paper appears in full in the Proceedings of ICALEO, 2012. It is published with the kind permission of the Laser Institute of America.

High repetition rate femtosecond laser ablation of metals

Joerg Schille, Lutz Schneider, Lars Hartwig, Udo Loeschner, Robby Ebert, Patricia Scully, Nicholas Goddard and Horst Exner

The recent commercial availability of high average power, high Pulse Repetition Frequency (PRF) ultrashort pulse lasers offers industry the prospect of high quality machining at high throughput. However, heat accumulation and particle shielding in laser matter interactions have been identified as limiting effects at high PRF and have first to be overcome before the full industrial potential of these laser sources can be realised.

Particle shielding

Studies of the laser micro processing of stainless steel have found that metal removal rates decreased at PRFs above several hundred kilohertz [1-3]. This is caused by particle shielding i.e. insufficient time for the ablation products (particles and droplets) to clear between pulses, causing partial shielding of the workpiece from incoming laser pulses.

Heat accumulation

Even for ultrashort pulse laser ablation a significant fraction of the absorbed energy remains in the material, and at high PRF (i.e. ~ 1 MHz) the time between consecutive incident pulses is too short for complete heat dissipation into the bulk, causing enhanced residual thermal energy deposition to take place [4]. This is particularly the case for low-heat conductive metals such as stainless steel, where surface temperature rises strongly, giving rise to both higher laser beam absorption and lower ablation thresholds. As the temperature rises to the melting point, additional changes in thermo-physical material properties further influence the ablation process. Material melting is generally considered to be detrimental to process quality.

Conversely, these heat accumulation effects have been found to be negligible for high conductivity metals such as copper, even in case of PRFs up to the megahertz range. Furthermore, in comparison to stainless steel, laser beam shielding can be neglected for copper because of the reduced superheated layer that causes particles ejection by homogeneous nucleation [1, 5].

Laser parameters

In this study a high repetition rate femtosecond fibre laser (IMPULSE, Clark-MXR) was integrated into a micro machining work station, as shown in Figure 1.

The laser emits a linearly polarised Gaussian beam of 1030 nm central wavelength, 180 fs pulse duration (sech²), at up to 25 MHz PRF. The average laser power was ≤13 W with the maximum pulse energy of 7.2 µJ.

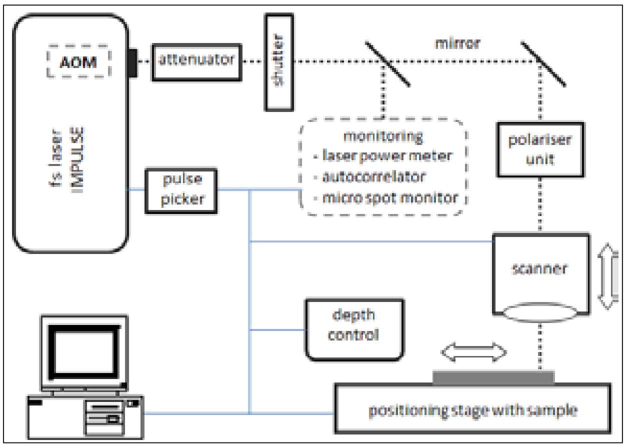


Figure 1: Schematic of the laser micro-machining workstation

A galvanometer scan system (intelliScan, Scanlab) with a telecentric f-theta objective with a focal length of 56 mm deflected and focused the laser beam across the sample surface. The focal spot diameter was 30 µm, corresponding to a maximum laser peak fluence of 2.0 J/cm².

The machining setup was equipped with a pulse picker to separate discrete pulse separation, monitoring systems to control the process parameters, a confocal point sensor for depth measurement, and a unit to change the direction of beam polarisation.

Simplified temperature calculation model

A simplified temperature calculation model can provide useful insight into the contrasting behaviour of a relatively low thermal conductivity material, stainless steel, and copper, a high conductivity material. The model assumes: the laser acts as a uniform surface heat source; that the fraction of the laser pulse energy that does not contribute to material ablation transfers into the bulk; the penetration depth is related to the thermal diffusion length (l_d); all other heat losses (e.g. convection, radiation, plasma/particle shielding) can be neglected; the temperature dependency of the thermo-physical material properties can be neglected.

Table 1 presents the thermal diffusion lengths obtained in copper and stainless steel for different time interval corresponds to the period between two consecutive incident laser pulses, which depends on repetition rate i.e. 20 µs – 50 kHz, 5 µs – 200 kHz, 1 µs – 1 MHz.

	copper	st steel
Thermal Diffusivity	107 mm²/s	3.9 mm²/s
l_d Δt = 20 µs	92.5 µm	17.6 µm
l_d Δt = 5 µs	46.3 µm	8.8 µm
l_d Δt = 1 µs	20.7 µm	3.9 µm

The temperature rise caused by a single laser pulse is determined by the heat affected volume, the fraction of incident energy converted into heat, and the thermal properties of the material. In the case of a higher number of laser pulses impinging the same area, the thermal impact of each preceding incident laser pulse is taken into account in the calculation. An example of the calculations is shown in figure 2. Calculated surface temperatures for stainless steel are shown in figure 3 for a pulse energy of 5 µJ (optimised for ablation), corresponding to an average laser power of 5.0 W @ 1 MHz. It shows that at this PRF the surface temperature rise approaches 450° C. Similar calculations for copper yield a surface temperature rise of only 11°.

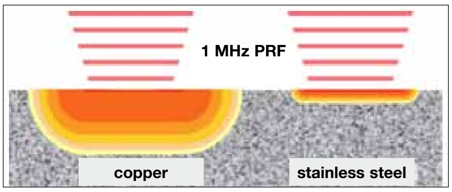


Figure 2: Heat distribution after 5 incident laser pulses

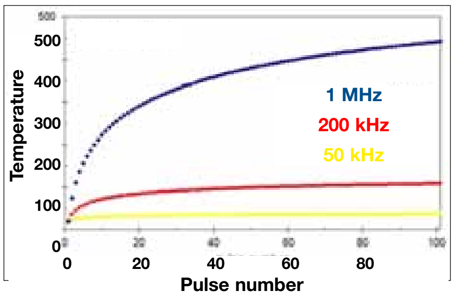


Figure 3: Calculated surface temperature rise vs number of 5 µJ pulses on stainless steel

Ablation depth vs. repetition rate

In the study three different industrial grade metal sheets were investigated: 0.5 mm thick stainless steel (AISI 304), a 0.45 mm thick polished 99.9% pure copper metal sheet, and a block aluminium alloy (Aluminium 6082-T6).

Ablation depths were determined using a non-contact surface measurement system (µsurf explorer, nanoFocus) and investigated as a function of the repetition rate with optimised laser parameters for minimised surface roughness, as determined by the outcomes of the parameter study presented previously [6].

The depth achieved at the lowest PRF studied (20 kHz) is expected to be unaffected by heat accumulation and particle shielding. The results presented in Figure 4 are relative to the 20 kHz values. For copper the ablation depth is seen to be essentially independent of PRF, consistent with the expectation that heat accumulation and shielding effects can be ignored up to 1 MHz PRF.

In the case of of stainless the ablation depth varies with the repetition rate. The decrease of ablation rates obtained at repetition rates up to two hundred kilohertz may be explained by particle shielding whereas the increasing ablation depth (up to 10%) at higher PRFs may be the effect of heat accumulation.

The highest increase (60%) in ablation depth with increasing PRF was obtained with aluminium and as yet we do not have an adequate explanation of this.

Micro-mould fabrication

We have fabricated micro-moulds using laser micro machining in order to produce micro-featured plastic demonstrators by micro-injection moulding.

Figure 5 presents a micro structured mould manufactured in a 15 mm x 11 mm x 80 µm plate of aluminium. The bridge width was 58 µm at the surface and increases in the depth. Initially a horizontally polarised laser beam was used and the wall angle formed differently depending on the polarisation direction relative to the plane of incidence. As a result the width of the bridges appeared differently at the bottom of the ablated structure between 110 µm and 116 µm in horizontal and vertical direction, respectively. But, as shown in the Figure 5 (bottom), ablating with a circular polarised laser beam resulted in a homogeneous bridge width of 112 µm at the bottom of the structure. The processing time was ~ 1 hour.

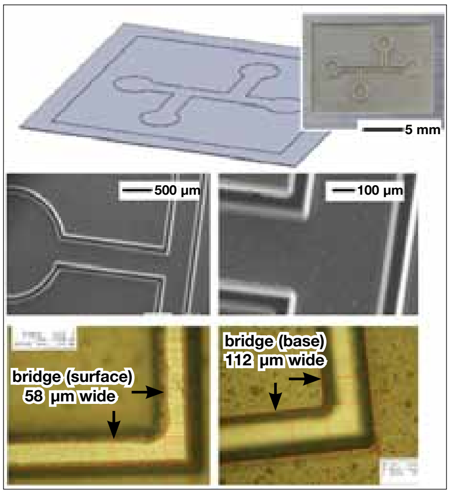


Figure 5: Micro-featured mould processed in aluminium block material; the drawing of the demonstrator and the manufactured aluminium mould are shown on top, a detailed view of the micro features is given by means of both SEM images (centre) and optical microscope images (bottom).

The plastic replica of the micro featured aluminium demonstrator mould is shown in Figure 6. The width of the microfluidic channel is 116 µm at the surface and 60 µm at the bottom, and therefore it fits very well to the bridge dimension of the mould. The optical microscope images confirm that laser processed micro structures can be highly detailed when moulded in plastic.

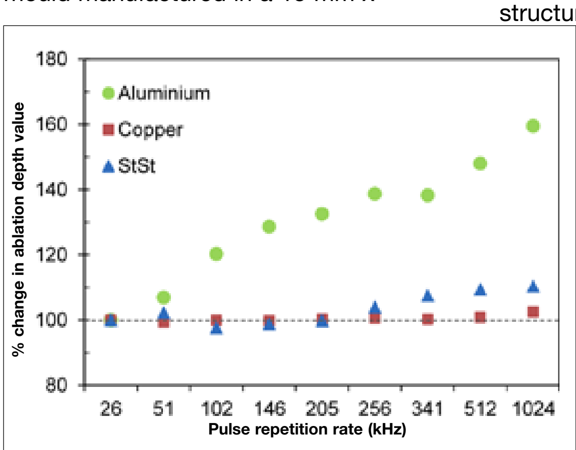


Figure 4: Ablation depth vs PRF, shown relative to valued obtained at 20 kHz.

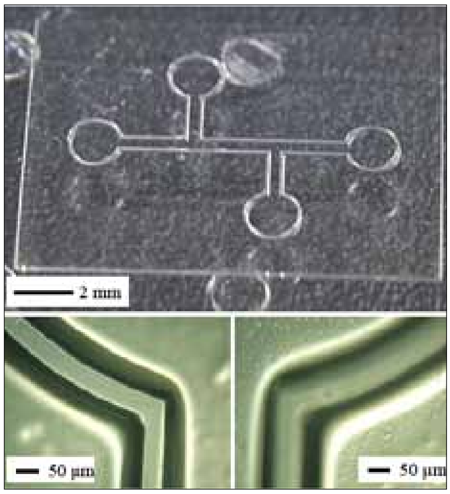


Figure 6: Plastic replica of the microfluidic demonstrator mould; the channel was 80 µm deep with a width of 60 µm at the bottom (left) and 116 µm at the surface, respectively.

References

1. Ancona, A., et al., High speed laser drilling of metals using a high rep. rate, high average power ultrafast fibre CPA system. Opt. Express, 2008. 16(12): p. 8958-8968.
2. Döring, S., et al., Microdrilling of metals using femtosecond laser pulses and high average powers at 515 nm and 1030 nm. Applied Physics A: Materials Science & Processing, 2010. 100(1): p. 53-56.
3. Schille, J., et al., Micro structuring with highly repetitive ultra short laser pulses, in LPM2008 - 9th Symp.on Laser Precision Micromachining. 2008: Quebec, Canada.
4. Vorobyev, A.Y. and C. Guo, Direct observation of enhanced residual thermal energy coupling to solids in femtosecond laser ablation. Applied Physics Letters, 2005. 86(1): p. 011916-3.
5. König, J., S. Nolte, and A. Tünnermann, Plasma evolution during metal ablation with ultrashort laser pulses. Opt. Express, 2005. 13(26): p. 10597-10607.
6. Schille, J., et al. Micro processing of metals using a high repetition rate femto second laser: from laser process parameter study to machining examples. in Proc. of 30th Int. Congress on Appl. of Lasers and Electro-Optics (ICALEO 2011). 2011. Orlando FL, USA.
7. Nolte, S., et al. High Repetition Rate Ultrashort Pulse Micromachining with Fibre Lasers. in Fibre Laser Applications: Optical Society of America.

Joerg Schille, Lutz Schneider, Lars Hartwig, Udo Loeschner, Robby Ebert and Horst Exner are with the Laser Institute at the University of Applied Sciences Mittweida, Technikumplatz 17, 09306 Mittweida, Germany

Joerg Schille, Patricia Scully and Nicholas Goddard are with The Photon Science Institute, The University of Manchester, Oxford Road, Manchester M13 9PL, UK

Contact: Joerg Schille
E: schille@hs-mittweida.de

Joerg Schille graduated in engineering from the University of Applied Sciences Mittweida (Germany) in 2003 and after 3 years in industry has returned to the university as a PhD student in the Rapid Micro Tooling research group to investigate pulsed laser micro processing.

See Observations p 28

This edited paper appears in full in the Proceedings of ICALEO, 2012. It is published with the kind permission of the Laser Institute of America.

Large area laser nano-texturing

Lin Li, Wei Guo, Zeng Bo Wang, Zhu Liu, David Whitehead and Boris Luk'yanchuk

As the electrical-mechanical and optical devices are getting smaller, the need to consider surface tomography becomes more important. Tribological characteristics, optical absorption, wettability, cell interaction with surfaces and even aerodynamic and hydrodynamic properties of micro devices are dependent on surface characteristics and surface textures. To tailor surface characteristics for specific properties through texturing requires high efficiency micro/nano fabrication technology. Under normal optics the smallest feature size for laser patterning on surfaces are diffraction limited to the laser beam wavelength for direct beams and to half of the laser wavelength if interference technique is used; which means > 100 nm unless the laser wavelength is in deep UV where optics become expensive and are easily damaged. Electron and ion beams, whilst capable to writing with resolutions down to 10 nm, is too slow for large area (>1 cm^2) series surface texturing.

Writing nano-sized features less than the diffraction limit of the lasers can be achieved using near-field optics (NFO). The technique described here uses a self-assembled particle lens array to write millions of nano-sized user defined features, such as letters lines and curves, *simultaneously* by angular beam scanning. A area 5 x 5 mm can be written with a single shot or a few scans of a laser beam, to produce up to 100 million identical nano or sub-micro scales features.

Near Field Optics

NFOs deals with optical phenomena where evanescence wave or plasmonic field enhancement becomes significant and the sizes of the scattering objects in the laser beam path are of the order of wavelength or smaller [1]. Several near-field patterning techniques exist: laser integrated scanning near-field optical microscopy (SNOM); laser-assisted AFM/STM-tip patterning; micro-lens arrays (MLA); and contacting particle-lens array (CPLA) [2-4]. In particular, MLA and CPLA are parallel processing techniques that can allow many identical features to be produced simultaneously.

One of the common problems of most NFO systems is that the processing optics are very close to the target surface giving the opportunities for contamination and damage by the surface debris generated during the materials processing. In addition, most NFO techniques require precise control of distance and orientation between the processing optic/tip and the target surface. Compared with other near field laser patterning techniques, CPLA has the advantages of low cost and simple/fast setup. Also, as a contact optical system, it eliminating the need for precise distance control and allowing patterning on a curved surfaces.

CPLA involves the self-assembly of a two-dimensional lattice of optically transparent micro-spheres. Such lattices can focus the light through multiple internal reflections in the spheres, generating evanescent waves, with high energy localization on the surface below the particle [5]. An important development described here overcomes a major limitation of the common CPLA technique, that of the micro-sphere array surviving only a single shot laser i.e. it causes most of the particles become thermally deformed and are ablated off the surface [6]. The technique we have developed to overcome this involves angular laser beam scanning (ALBS) [7].

Angular laser beam scanning

Figure 1 shows the laser beam scanning the YZ plane with an incident angle θ. Because the intensity peaks on substrate are shifted away from the contacting point, the ablative forces do not react strongly with the micro-spheres and they remain on surface after processing, allowing multiple shots of the laser beam. Thus, to form a continuous line, single laser pulse was used for every small angle ($\pi/36$) scanned through the spheres, with the beam at normal incidence on the final shot of the process

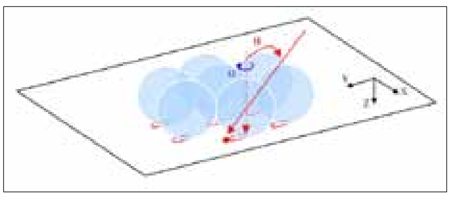


Figure 1. Schematic diagram of the experimental configuration for direct laser writing of nano-line arrays on substrate surface.

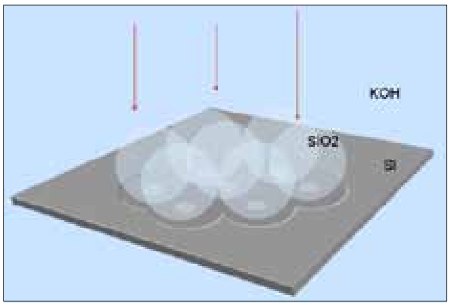


Figure 2. Schematic of wet chemical assisted laser nano-patterning using particle lens array.

to avoid blasting off the micro-spheres earlier in the scanning sequence. As the laser intensity on the target at various scanning angles is different [7], the laser beam intensity adjusted to enable uniform feature sizes.

Experimental Procedure

A 248 nm KrF excimer laser (GSI-Lumonic IPEX848) [15 ns, 1-10 Hz; non-polarised output] was used.

Dry CPLA processing

The target material for texturing by dry processing was a 20 nm thick, semi-conductive Sb70Te30 thin film on a polycarbonate substrate. A close-packed monolayer of 1 µm diameter SiO_2 spheres (supplied by Duke Scientific) was formed by self-assembly onto the thin film surface over an area of 5 x 5 mm^2. The threshold fluence for thin film ablation was about 200 Jm^{-2}.

Wet CPLA processing

The target material for wet chemical assisted CPLA processing was a n-type single crystal Si (100) wafer. A close-packed monolayer of 0.5 µm diameter SiO_2 spheres was formed by self-assembly onto the Si surface by self-assembly, as shown in figure 2. About 10^8 spheres can be formed in an area of 0.5 m^2.

N-Type silicon can be etched use 30%wt KOH solution. The reaction between Si and OH^- is weak at room temperatures, but much faster at the elevated temperatures effected by the laser beam.

Complex user defined nano patterns

The optical near-fields around the particles were simulated by a rigorous particle on surface (POS) model, illustrated in figure 3. The electromagnetic modes, including the evanescent modes, were taken into account in the model. The peak enhancement of over 30 times is

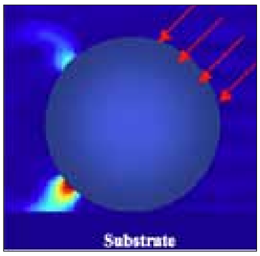


Figure 3. 2-D view of the calculated Poynting intensity distribution Sz. (λ = 248 nm, incident angle θ=30°; SiO_2 sphere n = 1.51, radius = 500 nm; SbTe substrate (n = 1.80, k = 2.07).

predicted, decaying rapidly with increasing angle θ.

Angle θ controls the position of intensity peak point in the radial direction, while angle θ moves it in circumferential direction. Moving θ by a small angle (π/36) each time and then scanning (π/36) at that particular angle setting allows easily fabrication of user-defined patterns, as illuminated in figures 4 and 5.

Wet chemical assisted nano-patterning

Two examples of wet chemical laser assisted particle lens array textured n-type silicon in an aqueous KOH solution are shown in figure 6 for processing using two different laser fluences. At a relatively low laser fluence (5.9 J/m^2), a ring shaped structure was produced with the central island nano bump size around 50 nm in diameter, whilst at a higher fluence (7.3 J/m^2), dents were produced with an average diameter of 200 nm. With the aid of atomic force microscopy we compared to theoretically determined optical energy intensity field distribution in the chemical solution to the structure of these features, which had a typical depth of 20 nm. At the lower fluence the surface structure approximately followed the energy density field profiles, but not at the higher fluence.

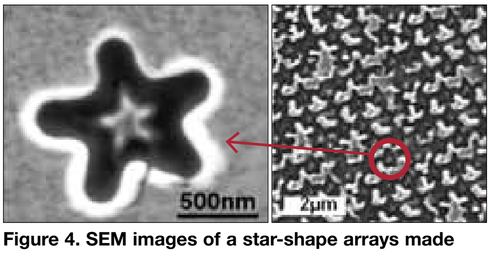


Figure 4. SEM images of a star-shape arrays made by scanning beams with designed angles [8]. Tens of millions of those features were generated simultaneously by 72 laser shots at different locations. The features are 20 nm deep. The dimensions of the very small star-shaped 'island' has a tip feature of size less than 30 nm.

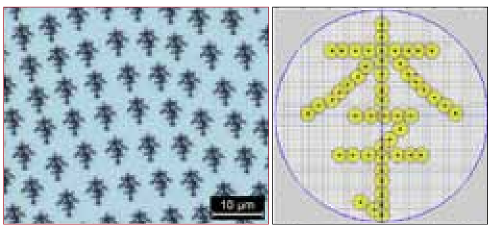


Figure 5. SEM images of millions of the Chinese 'Li' pattern ablated simultaneously with a fluence of 1-20 mJ/cm^2 using 5 µm silica spheres

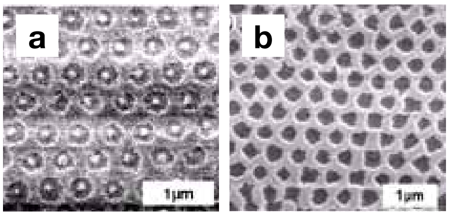


Figure 6. SEM images of structures produced by wet chemical assisted laser particle lens array surface texturing in 30% KOH, with (a) laser fluence 5.9 J/m^2 and (b) laser fluence 7.3 J/m^2

Conclusions

A new laser based nano-texturing technique has been demonstrated by the use of self-assembled mono-layer particle lens array and angular incident laser beams and the use of a chemical solution. The method has shown to produce complex user defined nano-scale structures over a large area with structure sizes below the diffraction limit of the laser beams. Several million identical nano- patterns have been produced simultaneously.

By avoiding normal incidence illumination by the laser beam, we have overcome the problem of keeping the micro-spheres for multiple shots and have demonstrated the production of user defined patterns. In particular, the spacing between the patterns is no longer limited by the diameter of the transparent the micro-spheres and the depth of patterns has been increased by repeated laser pulses. This represents a useful advancement of the near field parallel nano patterning technique; and combining it with reversed patterning by using chemical assisted patterning (also demonstrated here) we have a means of providing user defined textured surfaces on small objects such as MEMs (for improved tribological characteristics), LEDs (for improved emission efficiency), and medium sized objects such as moulds and dies that may potentially be used to produce textured surfaces (for wettabilitiy control, optical reflectivity control etc.) on plastic materials through injection moulding.

One issue that would need to be considered carefully is reliable production of uniformity of self-assembled mono-layers of micro-spheres (currently limited to 0.5 µm diameter), a key requirement. Careful work piece preparation is an essential element.

Micro-lens array near field parallel patterning is a competing technique to the particle lens array technique for economic large area nano-patterning/texturing. The uniformity of patterns produced by the micro-lens array can be excellent providing the lens array can be made highly parallel to the surface of the work piece.

References

[1] Girard C and Dereux A 1996 Near-field optics theories Rep. Prog. Phys. 59 657-99.

[2] Arias-Gonzlez J R, and Nieto-Vesperinas M 2000 Near-field distributions of resonant modes in small dielectric objects on flat surf aces, Opt. Lett. 25 782-84.

[3] Denk R, Piglmayer K and Bauerle D 2002 Laser-induced nanopatterning of PET using a-SiO2 microspheres Applied Physics A, 74 825-26.

[4] Brodoceanu D, Landstrom L and Bauerle D 2007 Laser-induced nanopatterning of silicon with colloidal monolayers, Applied Physics A 86 313-14.

[5] Hong M H, Huang S M, Luk'yanchuk B S and Chong T C 2003 Laser assisted surface nano-patterning Sens. Actuator A-Phys. 108 69-74.

[6] Zheng Y W, Luk'yanchuk B S, Lu Y F, Song W D and Mai Z H 2001 Dry laser cleaning of particles from solid substrates: Experiments and theory, J. Appl. Phys. 90 2135-42.

[7] Guo W, Wang Z B, Li L, Whitehead D, Luk'yanchuk B S and Liu Z 2007 Near-field laser parallel nanofabrication of arbitrary-shaped patterns App. Phys. Lett. 90 243101.

[8] L.Li, W.Guo, Z.B.Wang, Z.Liu, D.Whitehead, B.Luk'yanchuk, Large area laser nano-texturing with user-defined patterns, Journal of Micromechanics and Micro-engineering, Vol.19, Iusse 5, 2009, article number: 064002

This paper is largely an edited version of reference [8]. The Journal of Micromechanics and Micro-engineering is published by the Institute of Physics,

Lin LI, Wei Guo, Zeng Bo Wang and David Whitehead are with the Laser Processing Research Centre, School of Mechanical, Aerospace and Civil Engineering, The University of Manchester, Sackville Street, Manchester M60 1QD, U.K. Bo Wang has since moved to Bangor University.

Zhu Liu and Wei Guo are with the Corrosion and Protection Centre, School of Materials, The University of Manchester, Sackville Street, Manchester, M60 1QD, UK.

Boris Luk'yanchuk is with the Data Storage Institute, DSI Building, 5 Engineering Drive 1, Singapore 117608

Corresponding author: Professor Lin Li, Director of Laser Processing Research Centre, Manchester University

E: lin.li@manchester.ac.uk Zeng

Lin Li holds a chair in Laser Engineering and established the laser processing research centre at Manchester University. His laser interests include cutting, welding, drilling, surface engineering, additive manufacturing and micro/ nano fabrication.

See Observations p 28

Laser potential for CFRP machining

Charly Loumena, Minh-Hoang Nguyen, John Lopez and Rainer Kling

Because the weight to tensile strength ratio of Carbon Fibre Reinforced Plastics (CFRP) is superior to any other technical material, it is used in construction where weight reduction is important; for example in aircraft [1]. However, CFRP processing presents some challenges: it is abrasive in machining and it does not tolerate significant heat input. **Mechanical machining of CFRP requires the tool temperature to be controlled in order to avoid decomposition of the matrix material, tool wear is extremely high and the mechanical forces generated can pull fibre out and cause delamination. Waterjet cutting is more commonly used: the water acts as a coolant and the running costs are relatively low. However, the high pressure of the waterjet creates delamination forces in the fibre ply and any occlusions in the laminate structure can fill up with water and abrasive particles. For these reasons, laser machining is an attractive alternative.**

Early studies of CFRP cutting with a CO_2 laser produced poor quality cut edges [2]. Later studies using pulsed UV lasers improved absorption in the polymer matrix and produced photochemical instead of thermal decomposition [3]. In other work, high speed cutting with CW lasers at up to 16 kW power demonstrated how the shorter interaction time led to a reduced HAZ in the kerf [4]. Advanced process strategies adapted the application of laser power to the anisotropic nature of CFRP to minimise the ablation of the matrix material and cut only the fibres that are set free after the matrix is evaporated [5]. To date very few laser processes have qualified for industrial production and a well determined control of the HAZ is still to be demonstrated. In addition high demands of process speed in combination with sheet thicknesses in the range of 1 – 15 mm still pose major challenges for the laser processing.

Ongoing studies at Alphanov investigate the ablation rates and surface quality of laser processing with different short and ultrashort pulsed systems with a view to providing data for assessing the feasibility of CFRP processing (cutting, drilling and repair) in geometry-specific applications. Studies have already been carried out with a thermoplastic polymer as the matrix material [6], but in the work reported here an Epoxy based matrix (Toho Tenax) has been used. The fibres orientation is 0/90° with the fraction volume is 60-65%.

Heat Affected Zone

The main issues for laser processing of multiple component material such as CFRP are linked to highly different thermal and optical properties of resin and fibre [7]. The variation of absorption of the CFRP matrix material at different laser wavelengths is an additional factor: it is high at the 10.6 µm wavelength of a CO_2 laser and reaches a minimum close to the 1 µm wavelength of many solid state lasers.

Carbon fibre has a heat conductivity along the fibre that is ten times higher than perpendicular to the fibre axis, resulting in anisotropic heat affected zones. The text box opposite sets out the basic laser details and figure 1 shows the results for circular drilling for laser sources but with the same pulse energy. The samples are imaged without cleaning.

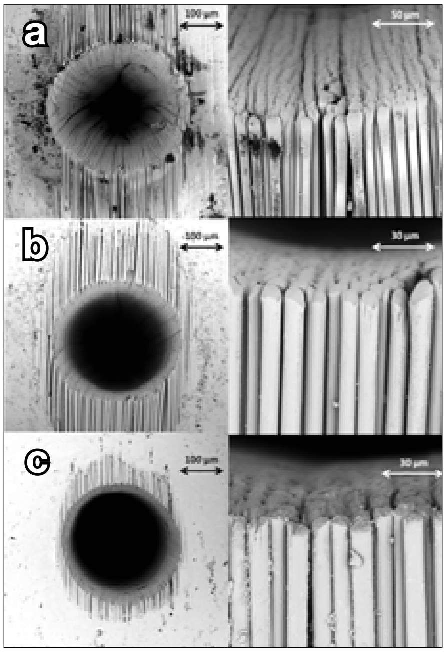


Figure 1: Laser drilled holes using: (a) IR ns pulses; (b) visible ns pulses and (c) IR fs pulses. The HAZ is dominantly in the direction of the fibres.

The HAZ is seen to be preferentially along the fibre axis and to depend on laser wavelength and pulse duration. 1030 nm (IR) ns laser processing (1a) has a slightly wider HAZ than 515 nm (visible) ns processing (1b), with the higher absorption of the resin matrix at 515 nm providing better fibre protection and presumably accounting for the fibres close to the edge of the hole in (1b) being less damaged than in (1a). For infrared fs laser processing, figure (1c) shows a smaller HAZ. This is generally the case with fs laser processing; so too is the dust that can be seen on the fibres and which is easily removed.

Graphs of fluence vs HAZ width (not included here) show a clear positive correlation between the two for ns laser processing and a smaller but noticeable positive influence of PRF on HAZ width. Throughout, for fluence higher than 3J/cm², the width of the HAZ when using a fs laser is less than that produced by an IR ns laser by a factor of ~5.

Laser workstation

Two nanosecond (ns) lasers based on a new generation of Rod-Type Fibre (BOREAS series, Eolite Systems) with the following specifications were used:

Laser	BOREAS IR80	BOREAS G30
Wavelength	1030 nm	515 nm
Pulse Width	≥ 12ns	≥10ns
Pulse Repetition Rate (kHz)	10-100	20-300
Pulse Energy	≤ 2 mJ	≤ 0.3 mJ
Beam quality	$M^2 < 1.2$	$M^2 < 1.2$
Beam dia. at focus	50µm	32µm

A new generation of compact femtosecond (fs) amplifier (S-Pulse HP², Amplitude Systemes) was also used:

Wavelength	1030 nm
Pulse width	500 fs
PRF	1-300 kHz
Pulse energy	≤ 1mJ
Beam dis.	22 µm at focus.

The beam delivery comprised a GSI LDS14 galvanometer scanning head and a 160mm F-theta lens. In order to maintain a constant pulse width, the pulse energy was controlled by a crossed polariser system. The polarisation of the beam at on the sample was maintained circular by adding a λ/4 plate.

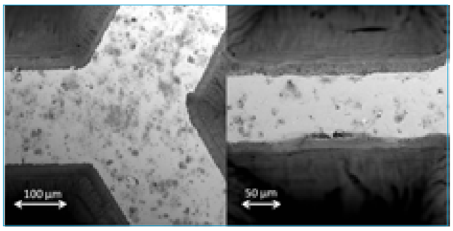


Figure 2: Focus on honeycomb cutting shape with IR femtosecond laser on carbon/epoxy sample

Reducing HAZ remains a challenge for precise laser processing of CFRP. A higher precision can be reached without delamination with a fs laser over ns laser pulse processing and even more so over conventional CFRP mechanical processing. An example is provided in figure 2.

Etch rate

Results in figure 3 for etch rate per pulse versus fluence for PRF < 20 kHz, show rates diverging only for fluence <1 Jcm^{-2}.

A similar plot of results for PRFs > 20 kHz show a similar trend but lower etch rates per pulse as illustrated in the table below; this may be a shielding effect induced by an average power (heating) effect. Despite this phenomena, the mean etch rate (the product of etch rate per pulse and PRF) increases with PRF.

	Etch rate (µm^3/pulse) at a fluence of 3J/cm^2	
	IR ns	Green ns
PRF 10 kHz	~8000	~2500
PRF 100 kHz	~5800	~1500

Cutting edge quality

Figure 4 compares the edge quality of a square depression milled in CFRP for each laser source. The milling was achieved by scanning the laser beam in a cross-hatch pattern. The caption summarises the results

Holographic effect on CFRP

Some operating conditions for fs laser processing induce bright optical effects. The colour varies with viewing angle as shown in figure 5. In pictures below, we note that this effect is linked to nm-scale

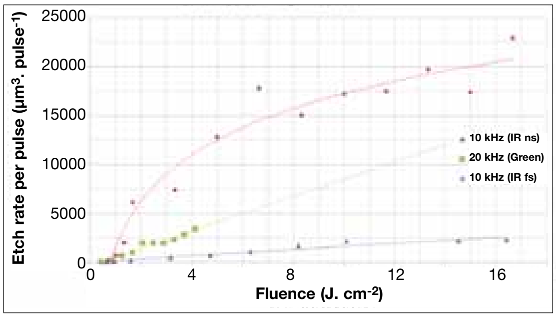


Figure 3: Etch rate per pulse vs fluence for low PRF(< 20 kHz)

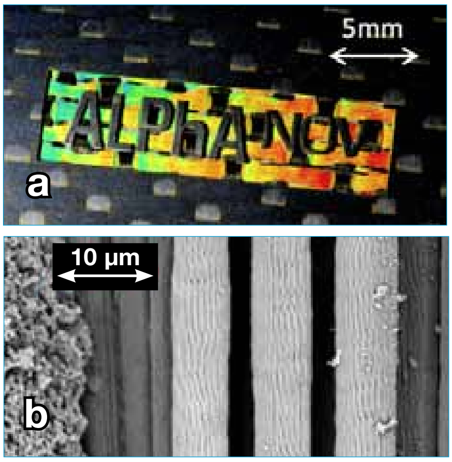


Figure 5: (a) Holographic effect on CFRP; (b) Laser-generated ripples parallel to the fibre axis

ripples formed on carbon fibres.

Such structures on carbon fibres are currently being studied in various materials for improving silicon solar cell efficiency and generating super-hydrophobic surfaces.

The period of the ripples in figure 5b is closed to 800 nm. There are also smaller ripples on the fibre (<150nm). The direction of these nanometre ripples is linked to the polarization of the laser beam as is well known from literature.

Summary and outlook

We show that the length of heat affected zones is linked to the fluence of laser beam and also to its wavelength. Smaller HAZs can be achieved by reducing the wavelength of the laser beam or by using ultrashort pulses. Cross-sectional analysis reveals neither delamination nor free-standing fibres on the cut face. The cross-sectional quality depends on the wavelength used. Laser processing leads to smooth surface on the cut edge and in fs machining the resin matrix appears to be undamaged.

Laser processing of CFRP is ahead of most of conventional techniques by avoiding all of their drawbacks. Future work will focus on UV processing, the use of assist gas (with a cutting head) and the development of a polarization converter based on holographic effects.

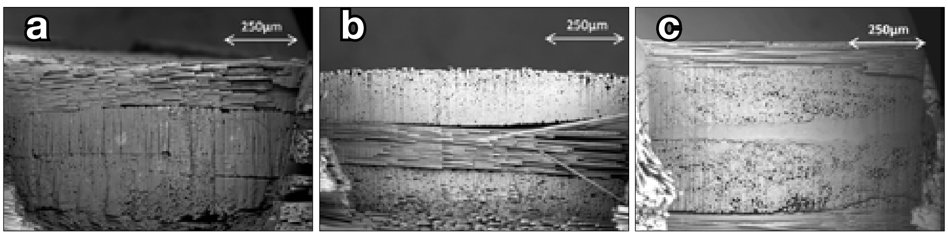


Figure 4: Comparison of cutting edge with: (a) IR ns laser; (b) Green ns laser; (c) IR fs laser
Key features include: (IR ns laser) very smooth cut edge, fibres along the cutting direction (parallel) are cut and welded by the induced heat, perpendicular fibres have same behaviour, no trace of resin remains on the cutting edge; (Green ns laser) straight flat cut edge, fibres and resin removed without thermal damage, broken fibres (possibly due to acoustic waves produced by ns processing), some layers of resin on the cutting edge; (IR fs laser) very smooth cut edge, fibres along the cutting direction (parallel) are straight and not welded, broken fibres (possibly due to acoustic waves produced by ns processing), no trace of resin remains on the cutting edge.

Acknowledgements

We acknowledge the European Commission, the French Ministry of Research and the Aquitaine Regional Council for support and funding.

References

[1] Berges DE. Hexcel Corporation Annual Report; (2004)

[2] Weber R, Hafner M, Michalowski A, Graf, (2011): "Minimum Damage in CFRP Laser Processing", In: Physics Procedia 12, pp. 302–307

[3] Voelkermeyer F, Hermsdorf J, Denkena B. and Kling R (2007): "Novel UV–laser applications for carbon fibre reinforced plastics" In: Proceedings of APT, Bremen,September; pp. 17–19

[4] Jung K-W, Katayama S, and Kawahito Y (2010): "High brightness laser cutting of CFRP" In: Transactions of JWRI, Vol.39, No. 2

[5] Negaestani R, Sundar M, Sheikh M, Mativenga P, Li L, Li ZL, et al. (2010) "Numerical simulation of laser machining of carbon fibre reinforced composites". In: Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture Vol. 224, No. 7, pp.1017-1027

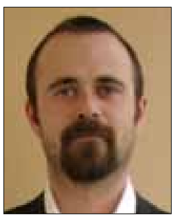
[6] Romoli L., Fischer F., Kling R.(2012), "A study on UV laser drilling of PEEK reinforced with carbon fibres", in Opt. Laser Eng Vol 50, No 3, pp 449–457

[7] Hocheng H, and Tsao C-C (2005): "The path towards delamination-free drilling of composite materials", In:, J. of Materials Processing Technology 167, 251–264

[8] C. Emmelmann, M. Petersen, A. Goeke, M. Canisius, (2011), "Analysis of Laser Ablation of CFRP by Ultra-Short Laser Pulses with Short Wavelength", Physics Procedia 12, 565-571

The authors are with Alphanov, 351 Cours de la Libération, 33405 Talence, France.

Contact: Charly Loumena
E: charly.loumena@alphanov.com



Charly Loumena is a development engineer in laser micro-machining at ALPHANOV. His main interersts relate to applications of short and ultrashort laser processing.

See Observations p 28

This edited paper appears in full in the Proceedings of ICALEO, 2012. It is published with the kind permission of the Laser Institute of America..

OBSERVATIONS

Short comments on papers in this issue

Some questions, answers and open issues in laser cutting

Dirk Petring, Frank Schneider and Norbert Wolf

Like a Christmas Cake, the expression 'the proof of the pudding is in the eating' can be applied to the paper by Dirk and his co-workers. It is a comprehensive and thought provoking discussion on the science of fusion cutting at 1 micron, but the bottom line is that those who have tried fibre laser cutting, like those who try a well made Christmas Cake, are more than happy with the experience.

Understanding the composition of the Christmas dessert is one thing; but primarily what we want to know is that it will have a delicious and salivating taste. And so it is with 1 micron laser cutting. With well over 4000 industrial fibre laser cutting systems supplied to a rapid and fast changing laser market worldwide, many end users are enjoying the benefits of much lower maintenance costs, well over 50 % reduction in electrical consumption and the elimination of laser gases to support the lasing process. In the real world of cost cutting these are the cherries that make many end users smile.

Fibre lasers in particular, and other 1 micron sources included, have helped the fiscal recovery of robot suppliers. As a result, more and more high end and high value processes that include cutting are being considered in large volumes; this is especially true in the automotive arena. These laser sources are easily integrated, very flexible and perfect for these applications, benefits that are unchallenged. They also throw a lifeline for a normal family life to laser service engineers. It has been said on more than one occasion that fibre lasers have saved marriages; less down time and more production are the key. Friday nights are for movies and dating not fixing laser faults and critical alignment!

A modest-sized fabrication shop owner Mr Ambrosio Carbone, commented in a recent article* on how he survived the recession. "First, our purchase of a fibre laser cutting system allowed us to bring in-house all the work out-sourced, saving a lot of money, since our supplier was using a CO_2 cutting system, which is substantially more expensive to run and maintain."

"At the time we purchased the system, we were told that the hourly cost was only a few Euros/hour (not tens of Euros); today, four years later, I can say that the cost of its maintenance has not been more than 1500 Euros/year"

Production across the board has increased with both small and large companies seeing the benefits at the bottom line, so rather than having high maintenance costs leaching the available funds of the December shut down, end users of 1 micron fibre lasers including their few bumps and lumps (or 'striations' as Dirk would say), were enjoying the Christmas pudding. We will leave it to the likes of Dr Petring to expound on the 'what's cutting' but until the processes are fully disrobed, the end user will enjoy the 'whys' and accept the changes that this truly remarkable technology has brought to the laser cutting industry.

Stan Wilford IPG Photonics

The research in laser cutting has experienced a renaissance in the last few years coinciding with the developments in high power fibre and disc lasers and it has now found its way into commercial laser cutting systems with a number of companies offering these as the cutting laser of choice. This has been driven in part by the significantly higher speed for fibre cutting steels less than about 5 mm thick than for cutting with the traditional CO_2 laser, and in part by the fibre optic beam delivery and the significantly higher laser operating efficiency. It is fair to say that while the benefits of using 1 micron lasers for cutting metals are clear the physics behind the process and striation formation has been an ongoing debate.

Dirk Petring and co-workers critically examine and discuss the various explanations behind the observed effects with the assistance of their developed modelling package CALCut and experimental cutting trials with CO_2 and disk lasers of the same power and beam radius dimension. Their modelling work clearly shows that the fundamental reason for the observed differences between 10 micron and 1 micron laser cutting is the effect of multiple reflections. The relatively large angle of incidence at the entrance to the cut and the resultant lower absorptance at 1 micron cause the laser beam energy to be transported further down the kerf, resulting in improved coupling. Petring and co-workers were able to explain all the differences such as the transition between the smooth and rough striations and wider kerf between the 10 micron and 1 micron lasers based on the multiple beam reflections through the kerf. Although this is perhaps the most definitive modelling study on the fundamentals between the 10 micron and 1 micron laser cutting I am sure that the debate is not over yet and we will see further research on this topic in the future. This is of course is eventually going to benefit the end user.

Milan Brandt RMIT University, Australia

Helical drilling of high quality micro holes

Christian Fornaroli et al

It is interesting article to see how ILT is extending the technology of laser material processing, in this case laser drilling. The drilling head seems very sophisticated; it allows the control of taper without altering any of the other processing parameters. Dealing with industrial clients globally I know that the question of reliability would be raised, so too the ease of setting up and using the drilling head-operator interface.

I assume that all of the work was performed normal to the surface. However, this it is very rarely the case in practice: most drilling applications require the drilling of holes at some angle to the surface, sometimes as low as 15 degrees. It would have been nice to see how the drilling head performs in such circumstances. The quality of the holes drilled in the stainless steel sheet look very good, but I would have liked to see a comparison between helical drilling and, say, percussion drilling: both can also produce a good quality hole when the parameters are correct.

The issue of recast within the hole is an important factor. Twenty to sixty seconds may not seem a long time to process these holes but I have found that industry orders are won or lost on the speed of processing.

This is an excellent article from one of the leading organisations in laser material processing in the world. One open question I would ask the AILU laser community is "JK Lasers is a UK based company interested in laser drilling for different industrial sectors: where in the UK is research work on drilling of this quality being performed?"

Mo Naeem JK Lasers

I tend to read about laser helical drilling with a heightened degree of expectancy. Of all the laser drilling processes, Drill-on-the-Fly, Percussion, Trepan, and Helical drilling, Helical always seems to be the one that should offer so much but always seems to be completely underused, despite the obvious need for such a process for the production of sub-micron accuracy holes.

* http://www.industrial-lasers.com/articles/2012/11/laser-cutting-helps-company-survive-the-recession.html

This may be because, of all the drilling processes, Helical is the one that requires the most in the way of specialised equipment; rotating Dove prisms, adjustable half wave plates etc etc. So, when asked to review the published work, I was happy to oblige.

Unfortunately, while the work is competently done and well presented, I have to admit to a certain degree of disappointment. The work is good as far as it goes, but it would have been nice if it had gone a little further, particularly in the areas of process times, material removal rates, and hole diameter and geometry control.

One thing that comes across clearly is that the laser used for these experiments is not optimum. The pictures of the holes show considerable amounts of debris around the entrance and exits together with discolouration which may be caused heat input from the edges of the focussed laser beam. Even after acid/ultrasonic cleaning, there still appears to be areas of remelted material at some of the entrances and exits.

To conclude, I would say that this is an interesting first step toward the practical use of a rotating Dove prism assembly for helical drilling. I think, as their conclusion suggest, that switching from the current ns pulse length laser to a ps pulse length laser would improve the process considerably, reducing heat input and removing the need for co-axial gas assistance and acid cleaning.

Peter Thompson
PrimaPower Laserdyne LLC

High repetition rate femtosecond laser ablation of metals

Joerg Schille et al

Schille et al. bring a significant contribution to this topical subject. Indeed, ultrafast laser processing presents a growing interest for many industrials applications since it combines the unique capacity to process any material with an outstanding precision and a reduced heat affected zone. The main drawback is the small amount of material removed per pulse which leads to a insufficient throughput for most applications. To scale up ultrafast laser processing requires this limitation to be overcome by increasing both repetition rate and average power, which could introduce both heat accumulation and particle shielding as it is pointed out in the paper. On the one hand, heat accumulation is expected to enhance ablation efficiency, on the other hand it may produce detrimental effects in the vicinity of the processed area. So, the response of the material highly depends on its thermo-physical properties and its capacity to cope with the thermal load.

John Lopez
Président du Club Laser et Procédés

This is an extended summary of a work that can be of interest to laser material processing community, especially those in laser micro-machining. The authors have been investigating the response of materials to high repetition rate femtosecond laser pulses for some time and this research adds to other interesting findings on the same phenomena. I think that it is worth including this brief in the next issue of the magazine.

Stefan Dimov University of Birmingham

This article presents a short insight into two phenomena that can influence the machining rate of different metals when using high repetition rate ultrashort pulse lasers. Ultrashort pulse lasers offer many benefits to machining and are often reported to deliver pulses in a time so short that heating of the sample does not occur. However the reality is that heating effects do occur and thermal management strategies have to be implemented. As this paper suggests, this is becoming increasingly important as laser repetition rates increase. The paper presents a very simple explanation of the heat accumulation process that makes many assumptions which, as the author's results for aluminium machining show, has its limitations. Nevertheless, the paper is useful in giving an insight into particle shielding and heat accumulation and how it varies with the thermal properties of different metals. With the increasing range of ultrashort pulse lasers becoming commercially available, particularly with industrial processing in mind, it would be interesting to see how the effects discussed here varied with changing pulse duration and a broader range of materials.

Julian Burt Bangor University

The effect of plumes on laser processing has been of interest since the earliest studies of laser ablation. In particular, changes in material removal rate have been attributed to the formation of gas phase material during the early part of the laser pulse affecting the later part. This has been found to be the case even for excimer pulses of 10's of ns duration. Here, the authors are attributing effects to plumes that persist between pulses. For example, to expand sideways out of the 30 µm spot during the 20 µs between pulses requires a velocity of 1.5 m s^{-1}. I would be curious to see if such velocities are found experimentally, for example through time-resolved scattering of a probe beam parallel to the surface.

It is interesting to see the application of a simple thermal diffusion model to femtosecond interactions. Often, this is not thought to be correct and Anisimov's two-temperature model is invoked. This detailed analysis may give an insight into the mechanism of material removal but I think that the authors have correctly identified that this complexity is unnecessary to study residual heating between pulses. However, where it might be informative is to analyse the range of excited (and therefore heated) material. It could be expected that electron scattering within such a perturbed system will extend the apparent "heat affected zone" beyond that predicted by heat diffusion alone.

Howard Snelling University of Hull

Operation at repetition rates above 200 kHz is one approach to increasing fabrication speed but can lead to thermal accumulation effects in the case of stainless steel, which has low thermal conductivity, and to plasma absorption/particle shielding effects. On the other hand, no such thermal effects are apparent with copper due to its high thermal conductivity and ablation rate is nicely demonstrated to be constant up to 1MHz.

Aluminium, whose thermal diffusivity is 84% that of copper, shows a remarkable increase in ablation rate of 60% at 1 MHz over that at 20 kHz and the reason for this is still under investigation.

The studies here were applied to aluminium for fabricating a large micro-fluidic mold from which accurate polymer replicas were produced. The authors must be congratulated on this interesting article, highly relevant to industrial application of ultrafast laser processing.

Walter Perrie University of Liverpool

Large area laser nano-texturing

Lin Li et. al.

There is great scientific, medical and industrial interest in nano-patterning the surface of materials with features smaller than 100 nm i.e. less than the spatial limit achievable by concentrating a laser beam with traditional lenses or mirrors. This limit, set by the diffraction of light, can be overcome by focussing light in the so-called 'near-field'. One such near-field technique reserched over the past 10 years uses self-assembled arrays of silica microspheres to focus a laser beam onto a surface in contact with them. After passing through each microsphere the light focussed at its rear surface can have spot sizes of <30 nm at fluence enhancements of >x30 that can be then used for modifying the surface of a material in contact with it. One of the main limitations of this method for creating periodic arrays of nano-structures is the single pulse restriction placed upon it by the removal and/or damage to the micro-spheres by the laser pulse itself.

Lin Li's group at the University of Manchester describe a relatively simple technique for overcoming this drawback enabling it to be used with multiple pulses. Illuminating the micro-spheres at non-normal angles of incidence moves the material interaction site and any forces associated with it away from its point of contact with the surface. This then allows the micro-spheres to remain in position on the surface ready for illumination by additional pulses. Furthermore, using this technique they have demonstrated that by combining multiple laser pulses with simultaneously scanning the angle of incidence around the normal, arrays of nano-shapes each over a diameter scale of individual micro-spheres (typically 0.5-1 µm) can be produced. Using a relatively large excimer laser beam in combination with processes of dry ablative thin film removal and chemically-assisted etching of silicon, they have shown that arrays of tens of millions of nano-patterns can be processed in parallel over areas as large as 5x5 mm^2 with as few as 72 pulses. Quite remarkably perhaps is that with this relatively simple technique the minimum feature size they produce of ~30 nm is about a tenth of the wavelength of the light used to produce it and is somewhat similar in size and wavelength scaling to the many complex 'optical tricks' of phase shifting masks, off-axis illumination and immersion in the very expensive $40M+ excimer laser lithography step and scan tools used to produce the current generation of integrated circuits!

Since complicated shapes of nano-structures are of interest in many applications where surface engineering is of paramount importance (e.g. in metamaterial and plasmonic devices, MEMS, sensors, displays, photovoltaics, biomedicine, aerospace, etc), this work represents a major step towards extending the capability of the laser-based microsphere nano-patterning technique beyond its capability of producing only arrays of circular hole-like features. However before it can be developed into a robust manufacturing process many issues such as feature wall angles, array uniformity, defect levels, process control, repeatability and throughput will need to be quantified and refined.

Malcolm Gower
Imperial College, London

Laser potential for CFRP machining

Charly Loumena et. al.

This is another paper examining the (non) potential for laser processing of carbon fibre reinforced polymers. As pointed out in the article, CFRP is difficult to process due to the different thermal properties of the carbon fibre reinforcement and the matrix materials. Carbon fibre vaporises at 3200° whilst the matrix materials typically are degraded or removed at a temperature of a few 100°. The high thermal conductivity of the carbon fibre means that the heat gets conducted away from the edge of the cut into the material and you end up with a resin free region away from the cut edge. This is the heat affected zone with the width only dependent on the pulse length of the laser that is used. This was explained in more detail in observations I made on Paul French's article in the Autumn 2009 AILU magazine. For the heat affected zone to be less than about a micron it is only necessary to use a laser with pulse length of less than 100 ns; there is no real benefit in using femtosecond or picosecond lasers for this application; unless there are useful effects requiring highly localised average power.

Concerning this particular article all the photographs show an extensive heat affected zone, much bigger than should be produced by lasers with these short pulse lengths. Indeed, for the femtosecond laser the heat affected zone should be undetectable. Clearly, the damage shown is due entirely to the high average power in the region where the drilling has taken place. Had similar holes been drilled with a much lower repetition rate no heat affected zone would have been observed.

This really highlights the problem of processing this material with a laser: short pulses are required to avoid the heat affected zone due to transmission of energy down the carbon fibres; However to get realistic process rates high repetition rates are used leading to local heating and average power effects as shown. This can be overcome by using scanning methods for low pulse energy sources such as picosecond lasers; but when the pulse repetition rate is very high and scan speeds required are also therefore high.

Stewart Williams Cranfield University

With the recent increase in uptake of CFRP in industries such as aerospace and automotive, the use of laser technology is gaining considerable interest. One thing the paper clearly indicates is that laser material processing of CFRP and related composite materials remains to be qualified for industrial production.

Quality issues associated with delamination and HAZ are of primary concern to industry. So too are demand for high throughput and processing thicker material. Health and safety issues over the fume produced when ablating these materials also need to be dealt with.

Ali Khan TWI

This interesting article shows how much the technology has moved on since the early work of Katy Voisey on cutting carbon fibre with a CO_2 laser. The same fibre swelling that was reported by Katy is observable in figure 1, so things may not be so different after all.

A number of investigators have observed preferential conduction along the fibres (see figure 1a – 1c). My experience is that this can be greatly reduced by techniques such as beam scanning.

The holographic affect produced by femtosecond laser processing looks very interesting and I would be interested to know the authors' plans for using this in anti-counterfeiting and other such applications.

In figure 5 it looks as if the laser is processing not the body of the fibres but rather the size outer coating that is applied to make them easier to handle. If so, it shows what fine control over composite processing the team has developed. In the near future composite processing is expected to be a major market for lasers; but whether it will be one of the lasers discussed in this article, only time will tell.

Paul French
Liverpool John Moores University

Latest advances in laser processing for micro and nano-scale manufacturing

7 November 2012
Rutherford Appleton Laboratory, Didcot

The annual AILU micro-processing workshop in 2012 at the Rutherford Appleton Laboratory got off to a shaky start before almost crashing part way through but recovered and proved to be an excellent workshop! It was originally set for September but then had to be postponed, which meant a venue change: the Rutherford Appleton Laboratory generously provided its state-of-the-art lecture theatre and the adjacent visitor centre for the day. And then within a week of the event, as a knock-on of Hurricane Sandy, Mike Osborne of Optek Systems had to withdraw as Chair: fortunately Jon Blackburn of TWI agreed at very short notice to take on the job. Finally, on the day of the event but fortunately during the morning refreshment break there was a power cut. It lasted 3 hours! Trips to the Micronanics laboratory scheduled for after the workshop were brought forward, lunch was brought forward and delegates enjoyed a relaxing if much extended opportunity to meet under the dim emergency lighting. Just as we were about to abandon the workshop the lighting came back on and the remainder of the presentations were run without a further break and with each speaker losing 5 minutes.

Speakers at the workshop: (l to r) Lin Li (University of Manchester); Gideon Foster-Turner (Optek Systems); Jack Gabzdyl (SPI Laser); Uwe Stute (Laser Zentrum Hannover, Germany); Ian Musgrave (STFC Rutherford Appleton Laboratory); Paul Apte (Rideo Systens); Oliver Heckl (Trumpf GmbH, Germany): Jon Blackburn (Chair); John Clowes (Fianium)

The day began with an upbeat review of current trends and UK strategy for laser micro-processing by Jack Gabzdyl, Chair of the AILU Micro: Nano SIG. This was followed by a keynote presentation by Malcolm Gower (Imperial College), a 'state of the nation' address on laser nano fabrication in the manufacture of integrated circuits. It was followed by the second keynote of the day, by Uwe Stute of the Laser Zentrum Hannover, Germany, on developments in ultrafast laser processing. Then followed the power outage. After the extended break, and in spite of leaving himself short of time to catch his flight back to Germany, Oliver Heckl of Trumpf at Ditzingen provided some fascinating examples of cutting of transparent hard and brittle materials with picosecond lasers.

Advances in ultrafast fibre laser is key to developments in micro- and nano-processing and John Clowes described recent developments in Fianium lasers and showed how they are being exploited in precision materials processing. Undoubtedly the most radical technique to be presented was by Lin Li (University of Manchester) who described the relatively simple-in-principle laser scanning of a nano-sphere (lens) array for parallel processing of periodic nano-scale surface features. (See the article on p 24 and the front cover of this issue.)

Jack Gabzdyl presented the paper by Paul Harrison (SPI Laser) on the influence of beam quality and the optimisation of output fibre laser pulse parameters on deep engraving. The paper that was to follow, on laser-based fabrication of micro-optics by Gideon Foster-Turner of Optek Systems had to be abandoned because of computer problems.

Dimitris Karnakis of Oxford Lasers described maskless selective laser patterning of PEDOT:PSS, a technique with massive potential in organic electronic applications. More generally Paul Apte (Micronanics and also Rideo Systems) described pulsed UV laser micromachining systems and applications.

Finally, Ian Musgrave of the host laboratory gave an introduction to short pulsed laser developments at RAL, including the Vulcan system.

Overall, the meeting presented a wide range of topics within the micro/nano-processing scope of the workshop. A final big 'thank you' goes to the staff of the Rutherford Appleton Laboratory, especially for their generosity and flexibility in coping with the extended power cut; without this support we would surely have had to abandon the workshop.

JS12

October 2012
JCB World Headquarters

John Powell opens JS12 at JCB Headquarters.

The 2012 annual laser job shop business meeting at the impressive JCB World Headquarters site at Rocester, began with an introduction to JCB and "what JCB is looking for from a subcontractor" by John F Smith. Presentations by John Powell on fibre delivered cutting and Dave Connaway on his very positive experience of fibre cutting were followed by an introduction to leasing for laser machines by Stuart Mann and Neil Lloyd of Lombard; it stimulated much interest. A heated discussion of the 2012 job shop satisfaction survey findings was only resolved when a straw poll of Trumpf users present supported the recent decline shown in the survey.

Commercial presentations included introductions to the Amada AJ series of fibre cutting lasers and the Bystronic ByAutonom 3015, BySprint Pro and BySprint Fibre. Andy Waterhouse (II-VI) described good practice with CO_2 laser optics, and Simon Danks of United Steels described their new machine for leveling 20 mm plate. Finally, Neil Cressy and Adam Baker of the EIC (Energy Information Centre) described how they could help members save on electricity costs

A sumptuous lunch was followed by an open discussion on the subject of 'minimising costs', the day finishing off with a tour of the JCB production line.

Special thanks go to Dave Lindsey (Laser Process) and Dave Connaway (Cirrus Laser) for sponsoring the refreshment breaks.

(l to r) Dave Connaway (Cirrus Laser), Shaun Simpson (Onesite Solutions) and David Gattward (Microkerf) prepare to tour the JCB production line

Looking forward into 2013

"It is well worth struggling with the language barrier to attend laser event across the channel"

As this issue goes to press ILAS is only a few weeks away. The success of the event is very important for AILU, both financially and in affirming its value to the UK laser community. As things stand the registration numbers are very promising. The Presidents message on page 15 is on the same theme (i.e. the importance of ILAS), so enough said.

The mix of technical papers in this issue range from an excellent update on macro laser cutting by Dirk Petring and his colleagues at the Fraunhofer ILT to the impressive results described by Lin Li et.al. on parallel nano-scale processing. An interesting theme emerges from the remaining papers and especially the 'observations' on them: the challenge of finding the optimum laser parameters for materials processing at an industrially interesting rate. The challenge ranges from eliminating the debris in helical hole drilling to overcoming the thermal effects that undermine 'cold' machining with short pulse laser sources; the latter case being dealt with for relatively low conductivity metals (stainless steel) in one paper and CFRP in the other.

As Editor I must apologise particularly for leaving so little space in this issue to do justice to reviews of recent past events, including the two AILU workshops, which have had to share page 31. Even worse, the two events I attended in France towards the end of 2012 are condensed into a single column of page 15; but a picture is worth a thousand words and there are three of them (but small) in the column so I hope I've managed to convey some of my new found belief that it is well worth struggling with the language barrier to attend laser events across the channel.

Looking world-wide, David Belforte's 2013 economic review and forecast for the laser industry (see January/February issue of 'Industrial Laser Solutions', a Pennwell publication) predicts that revenue from the sale of laser sources and systems will be positive but low up to near the end of 2013 and then, perhaps, we will see a rapid return to the double digit growth. It's something we somehow expect from the laser business, so with that in mind and fingers crossed, I would like to wish all our readers a most prosperous 2013.

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.

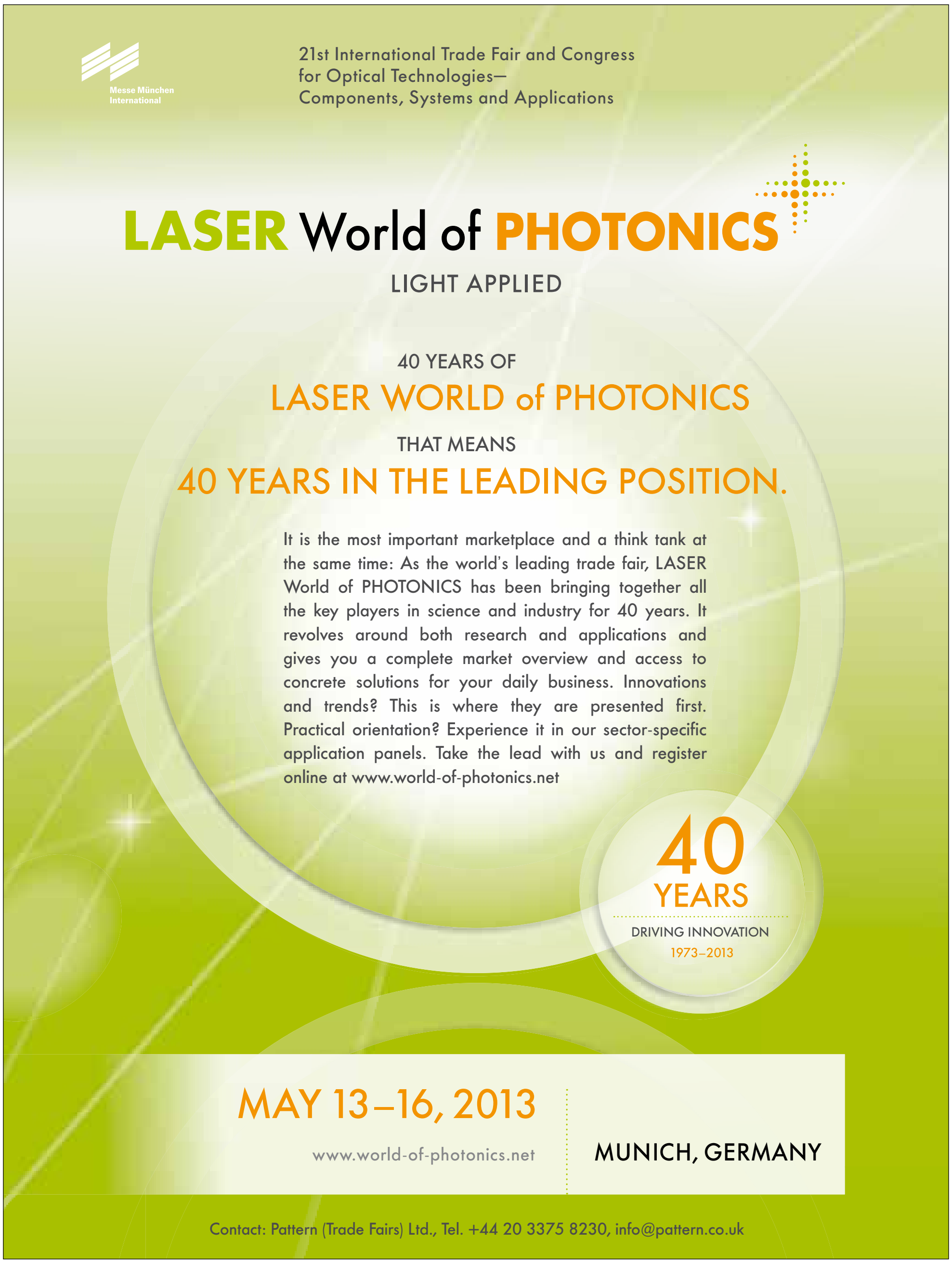
'The Laser User' is published quarterly by AILU for its members

The Laser User
Editor: Mike Green

ISSN 1755-5140

AILU
Oxford House
100 Ock Street
Abingdon Oxon. OX14 5DH

T: +44 (0)1235 539595
F: +44 (0)1235 550499
E: info@ailu.org.uk
W: www.ailu.org.uk



AILU events

March

12 **ILAS 2013 (12 & 13)**
The UK's premier event in laser materials processing.
For full details, visit: www.ilas2013.co.uk
Nottingham Belfry Hotel, Nottingham UK

12 **AILU AGM**
18th Annual General Meeting of the Association of Laser Users Members only. Details have been circulated; contact AILU office for further information
Nottingham Belfry Hotel, Nottingham UK

AILU-supported events

March

18 **ILSC 2013(18 - 21)**
International Laser Safety Conference
Orlando, Florida USA

May

13 **LiM (13 - 16)**
Lasers in Manufacturing 2013
Munich, Germany

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

CONTENTS

Members' News

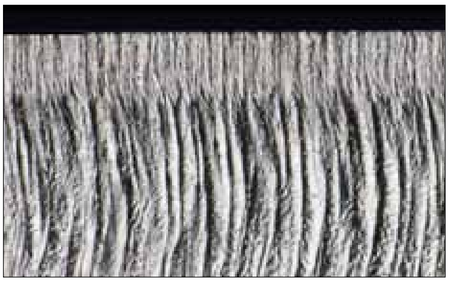
Editorial

Features

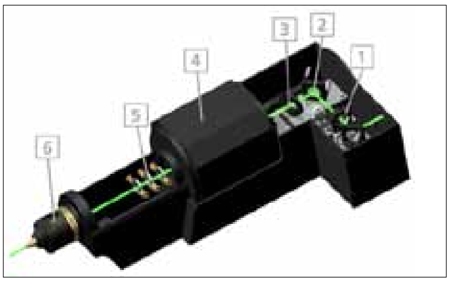
Reviews

Content by subject

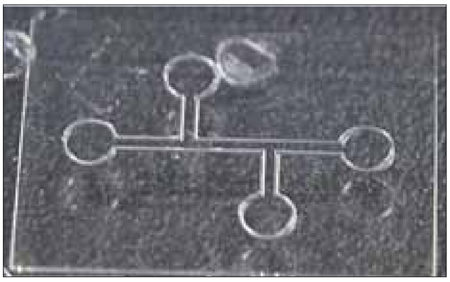
Building a new factory p 13



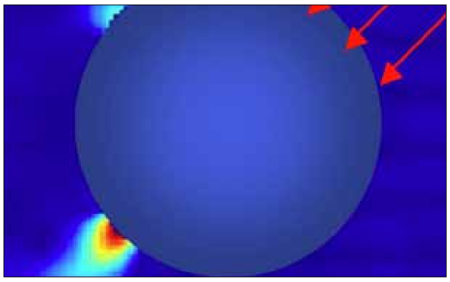
Always another question p 16



Freedom to shape holes p 19



Micro mould fabrication p 22



Beating the diffraction limit p 24

Machining composites p 26