The Industrial LASER USER
association of industrial AILU laser users

Issue 30 *March 2003*

Rapid Tooling by Laser: a recipe for survival

Bill O'Neill reviews AILU's lively first meeting of 2003

The rate at which industry can deliver products to market plays a large part in determining the profitability of a company. In the search for speed, traditional manufacturing processes are replaced by new approaches that are emerging from the relatively young field of rapid prototyping. Laser-based prototyping techniques such as stereolithography, selective laser sintering and fused deposition modelling were first considered as quick means of checking component design, fit or function. Recent developments, however, have seen these and other processes mature into small batch production techniques capable of producing final components in a range of materials.

Speakers at the Rapid Tooling workshop (l to r) Chris Bocking (CRDM), Bob Bennett (MCP Equipment), Stuart Jackson (Electro Optical Systems Ltd), Gordon Freeman (Ferranti Photonics), Bill O'Neill (University of Liverpool), Leo Sexton (Laser Age Ltd) and Simon Pogson (University of Liverpool). Missing from the picture are Geoff Dearden (University of Liverpool), Carl Hauser (University of Leeds), Greg Gibbons (University of Warwick) and Jiwie Xie (University of Liverpool)

It is always worthwhile bringing new ideas and process developments to the wider community, and so on March 4th AILU presented a rapid tooling workshop hosted by the University of Warwick. The event brought together around 70 delegates from industry and universities all with a common interest in finding out how the manufacturing technology landscape will look in the coming years as a result of this new and impacting suite of technologies.

The UK has a thriving research and development community in the field of rapid manufacturing, and this event showcased some of the best examples of research from UK universities in addition to the latest commercial developments in the field of rapid manufacturing. As laser users we often think of the changes that have been brought about in industry by the introduction of laser cutting, welding and heat treatment processes. These generic processes are used universally.

Continued on p4

2003 winners of the AILU Award and Prize

Damian Adams - 2003 Young UK Laser Engineer

Damian Adams

The Young Laser Engineer Prize for 2003 has been awarded to Damian Adams for his role as project manager for the specification, tender, installation and commissioning of a 5-axis laser profiling machine for cutting titanium and aerospace alloys at BAE SYSTEMS, Samlesbury.

Many months of trials were required to assess the laser cutting of stressed aircraft components to ensure that the process conformed with aerospace design standards, before potential suppliers could be short-listed and invited to tender.

Following the competitive tender process the machine finally chosen was the Trumpf Lasercell TLC 6005. From a wide range of Laser types and powers Damian chose a Trumpf 1.8 kW CO_2 laser to handle their relatively thin materials. Considerable consideration was given into cutting thicker materials with a 3 kW laser but this option was dismissed at an early stage of the project. The machine forms part of a £2.9 million facility, which in turn is part of a £17 million plus Eurofighter Typhoon manufacturing facility investment within the Fabrication Business, Samlesbury.

"The whole project team, which includes many disciplines, has delivered a facility to be proud of: fast, accurate and repeatable parts are the norm and the machine will serve the profiling of parts formed within the Fabrication Business for many years to come," said Damian.

"Laser technology was chosen for its significant advantage over other technologies and the laser machining facility is the fruition of many years of work," he added.

Since its successful installation and commissioning, the machine is now being used in the production of Eurofighter Typhoon aircraft parts of varying material type and thickness, with the capacity to meet the peak demand for these parts, expected in 2007.

AILU member Chris Lane, the BAE SYSTEMS Laser Safety Officer, who worked closely with Damian on the project, made the nomination.

"Over the years I have been involved in many large procurement programmes for laser related equipment but what impressed me most was Damian's professional approach and enthusiasm throughout the project, achieving the right balance between engineering and safety considerations. Added to this, laser processing in the aerospace industry is still in it's infancy and he had to overcome not only the difficulties of selecting the correct solution but also qualifying that components could be manufactured to the stringent aerospace standards," said Chris.

continued on p3

Letter to the editor

Efforts to improve M^2 beam measurements

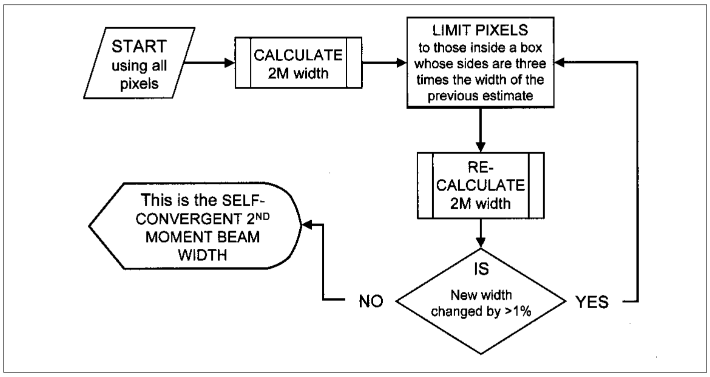
I would like to make a few comments concerning the measurements of M^2 reported in your last issue (*Femtosecond laser beam quality for percussion drilling* by Jonathan Magee, Issue 29, pp28). It appears that Dr Magee's laser has a very low value of M^2 and as such, should be amenable to measurement according to the procedures recommended in the standard ISO 11146 'Test methods for laser beam parameters: beam width, divergence angle and beam propagation factor'. However, extreme care has to be taken with a very high peak-powered laser to make sure that the measurements are not corrupted by noise and environmental effects.

Scattering from dust and scratches will always degrade the beam quality, so too will spurious reflections from the optical components in the beam line. One of the greatest problems is in the use of in-line filters for beam attenuation. Multiple internal and external reflections in the filters and the focusing optics used in these measurements will surround the main beam with a number of converging and diverging "noise" beams that will interfere with each other and with the main beam. On top of this, for measurements on high peak-powered laser pulses there are the non-linear interactions of the beam with air in its path.

My own preference for beam attenuation is to make use of the multiple internal reflections from a wedge prism. Each successive reflection represents a further attenuation of the beam and the wedge ensures an angular separation of the reflected beam from the main beam. The other problem is how to bury the excess main beam. High efficiency beam dumps are hard to make and the reflections from a dump can illuminate the laboratory, providing an enhanced baseline for the CCD signal. A Rayleigh Horn may be the answer.

Personally, I am unhappy with the method of calculating M^2 from the ratio of beam diameter to that at the waist, especially when waist diameter measurements are difficult and suspect. M^2 is meant to be a constant of propagation and if it varies, as reported by Magee, then something is wrong. My own preference is to apply the final technique mentioned in the current edition of ISO 11146, which involves taking a series of measurements around a waist and using weighted least-squares curve fitting to find the most probable hyperbolic envelope to the measurements, which sounds difficult but isn't. I have found this technique to be very powerful and have used it to determine M^2 and the other propagation parameters, even for poor quality laser pointer and LED outputs.

ISO 11146 is an evolving standard. ChocLab, the Eureka programme on laser characterisation, has addressed the characterisation of beams of lower quality and greater complexity than those susceptible to the existing standard, and a revision to 11146 is at an advanced stage. One of the main recommendations that is relevant to the problems of measuring beam widths is a new procedure for subtracting the effect of background noise. The revision will recommend that ten measurements of background (scattered and environmental) radiation be made, but for this to be done the main beam must be prevented from entering the beam profiler (camera); not an easy task. The next step is to deal with the effect of noise from the wings of the beam profile. Strictly speaking, second moment method of calculating beam width involves "integrating out to infinity". The revision to 11146 will suggest a



Decision path for a practical way of dealing with the effect of noise from the wings of the beam profile in the second moment (2M) measurement of beam width.

neat way of limiting the window of integration. Unfortunately, the name for the procedure, the "self-converging second moment width measurement" is not quite so neat. What I have found in the use of this technique is that it may not give you a strictly accurate measurement of M^2 but it does give you a precise and reproducible value. By the way, M^2 will no longer be called the 'beam quality factor' but the 'beam propagation ratio'.

Brooke Ward
Europtics.

Response by the author

I note Brooke's comments on reflections from filters and other components in the beam path. All had optimised anti-reflection coatings but I suspect that Brook is right about stray reflections as the main source of background noise. Regarding the proposed method of averaging 10 measurements and subtracting the result from the main signal, we found that the background is not reproducible but that the average value is a constant, so subtraction doesn't improve the look of the beam profile distributions. We did consider making a best hyperbolic fit but, as Brook points out, the technique as presented in the standard is far from straightforward.

continued on p3

Note from the editor

March has been a month of deadlines for organisations wishing to submit outline proposals for research funding under Framework 6 (FP6), with another deadline looming in late April. One effect of this has been to delay the completion of the magazine. My apologies for this.

It is easy to be cynical about the activities of those involved in FP6. The mountain of paperwork, the twisting of project aims to fit priority themes, the mad scramble to pull together partnerships with the required mix of nationalities, sizes and types of organisations and, last but not least, the creation of an appealing acronym for the project. It does, however, bring much needed research funding and helps maintain an active European research network.

Laser technology may have had its day as far as direct EU research funding is concerned, but it remains a key enabling technology, especially in nanoengineering, and lasers remain a significant part of many of the current submissions. So, we hold our breath and hope that the proposal assessors' response reflects the claim that this is indeed the 'photon century'.

2003 winners (continued)

Colin Webb to receive the 2003 AILU Award

Colin Webb, Chairman and Founder of Oxford Lasers Ltd and recently-retired Professor of Laser Physics at the University of Oxford and President of the UK CPO (Consortium for Photonics and Optics) is to receive the 2003 AILU Award for his outstanding contributions to the industrial use of lasers in the UK.

Over his long career at Oxford University and Bell Labs USA, Colin has made many contributions to the understanding of the physics of the laser process and the engineering of practical laser sources; in particular the Argon Ion, Metal Ion, Excimer and Copper Vapour Lasers. His contributions include the first practical device for discharge-excitation of excimer lasers, the introduction of cryogenic gas purification techniques for extending the working lifetime of the gas mixtures of excimer and VUV lasers and to understanding the stability limits of excimer laser discharges. He was made a Fellow of the Royal Society in 1998.

Many of these laser developments have been taken through to commercial production at Oxford Lasers, where Colin has been a tireless champion of the applications of CVLs in industrial diagnostics, isotope enrichment and micromachining. In 2000 he gained an MBE for his contributions to the UK Laser Industry.

Colin has done much to promote the laser research in the UK and throughout the world. He has championed the need for funding for applied laser research and the development of the UK laser industry. In recent years he spearheaded the establishment of the UK CPO. He continues to be Chairman of Oxford Lasers and an active member of the Optoelectronics Advisory Committee of the Rank Prize Funds.

A young Colin Webb heads for the USA in 1964 to begin work at Bell Labs

The presentation of the award will be made in November during the AILU workshop on developments in laser sources and optics.

letters (continued)

Our aim in making these measurements was to estimate the effective diameter of the beam for laser drilling. In this context the energy in the wings of the beam distribution, which makes an important contribution to the "integration to infinity" involved in the second moment calculation of beam width, contributes little if any useful energy to the ablation process. It seems to us to be probably more sensible for an industrial laser user to use Mylar film burns i.e. measurements of hole diameter with varying pulse energy. For Gaussian beams, the square of the diameter of the char or hole depends on the natural logarithm of the pulse energy (see note below) and the method would seem to circumvent the need to resort to the more difficult second moment method. It is a moot point though!

Estimating beam diameter from film burns for short pulse lasers
For laser ablation with a beam having an approximately Gaussian spatial intensity beam profile a simple relation can be derived between the diameter, D, of an ablated crater and the material-dependant surface damage threshold fluence ϕ_{th}, the Gaussian beam radius ω_o ($1/e^2$), and the peak fluence in the beam, ϕ_o i.e.

$$D^2 = 2\omega_0^2 \ln(\phi_0/\phi_{th})$$

The peak fluence and the pulse energy, E_p are directly related by

$$\phi_0 = \frac{2E_p}{\pi\omega_0^2}$$

It follows that a plot of D^2 versus ln E_p should be a straight line with a slope of $2\omega_o^2$.

Jonny Magee
National Centre for Laser Applications (NCLA)

Final comment by Brooke Ward
A few points of response.

1. Filters The trouble with thin-film attenuating filters (also the CCD window) is that they are usually designed for normal incidence so internal reflections emerge parallel to the main beam.

2. Background subtraction Not only is there a non-uniform response across a CCD frame and usually some missing pixels, but there is always background light. Recording 10 frames of noise and averaging before subtracting the result pixel-by-pixel from the main beam frame (recorded using the identical set-up) can have a critical effect on the final beam width estimate.

3. Propagation calculations The appropriate width measurement for M^2 is the second moment width (=87% power content width for a TEMoo beam). The measurement is difficult to make on a non-TEMoo beam and this width is always been greater than the damage/drilling width, so workers in the field over the last 30 years have used alternative definitions of beam width. As a result, for example, there is still a considerable gulf between groups of biophysicists trying to determine the relationship between retinal damage threshold and spot diameter on the retina. This is partly due to different definitions of damage but I suspect that different definitions of spot diameter are also to blame.

At last, the self-converging truncated second-moment width measurement seems to be reproducible and applicable to a wide range of beams. I would like to think that the emerging ISO definition of width becomes widely adopted and that efforts will be devoted to identifying the relationship between a drilled hole diameter and the truncated second moment diameter.

Brooke Ward Europtics

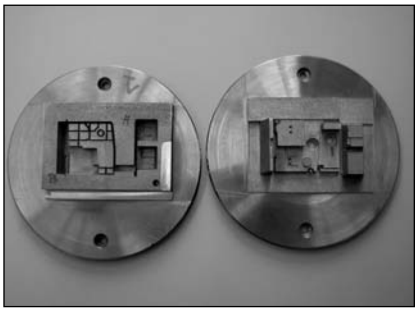
Rapid Tooling comes of age

(continued from p1)

I have observed rapid prototyping technologies, that were largely seen as “cute processes that help the designer”, mature into full-blown manufacturing processes for metals, polymers and some ceramics. This may come as surprise to some readers as it did to some of the delegates at the meeting. It became clear by the end of the event that the designers have got more than a new toy to help them; they have been given unprecedented design freedoms that will see an explosion of creativity in the manufactured products of the future.

I had the pleasure of chairing the event and was glad to see a good-sized enthusiastic audience who were keen to participate in the stimulating discussions generated by the presenters. The day kicked off with a scene-setting talk and overview of rapid manufacturing by Gordon Freeman of Ferranti Photonics. Chris Bocking of CRDM, Buckinghamshire Chilterns University College, gave the background to the new rapid tooling activities being developed by his team and a number of case studies showing some typical application areas. Two excellent speakers, Stuart Jackson of EOS UK Ltd, and Bob Bennett of MCP Ltd covered the commercial realisation of functional metal parts and tools. It became clear after these talks that the future manufacturing of metal parts will rely far less on restrictive Victorian engineering concepts and much more on flexible, reconfigurable and tooless production systems.

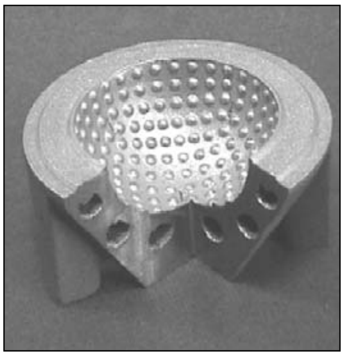
Greg Gibbons of Warwick University, gave two talks, one on behalf of Prof Wimpenny, of De-Montfort University, in which the future for laser based rapid manufacturing techniques was discussed, the other on the work he and his team at Warwick have carried out on the production of laminated sheet tooling systems. Tooling systems that utilise laser cut sheets that stack up to form large or small scale tools for a wide range of production techniques show considerable promise and are slowly being taken up by industry.



Courtesy of MCP Equipment

Die core and cavity ‘made in a day’ by selective laser melting

Leo Sexton of Laser Age Ltd, gave a talk on the long established process of laser cladding which is finding application in the repair of expensive and exotic components such as turbine blades and tooling systems. The final session before lunch was given by Geoff Deaden of Liverpool University who concentrated on the developing application of laser forming or bending, presently a laboratory curiosity but sure to become an important process in the tooless fabrication of sheet metals.



Courtesy of Electro Optical Systems Ltd

Golf ball die with internal cooling channels by direct metal sintering

Lunch break gave the delegates a chance to discuss the morning presentations and a chance to see and talk to those providing the first commercial solutions in this new and important field. Several new companies took the chance of exhibiting their products as services, one of the important features of any AILU meeting!

The three sessions that completed the day were from young university researchers, Simon Pogson (Liverpool), Carl Hauser (Leeds) and Jiwie Xie (Liverpool). The presentations provided a peek into the future of laser-powder metal build processes including some challenging work in the field of graded material systems.

I hope that AILU will see their way to organising more events on this subject. For those of you who want more, make a point of going to the international conference on Design and Rapid Manufacturing, Time Compression Technologies 2003, to be held at the NEC during Manufacturing Week in November this year.

Bill O’Neill

Courtesy of Laser Age Ltd

Worn tooth repair by laser cladding

LIA Celebrates 35th Anniversary

Laser Institute of America

35 Years 1968 - 2003

In 1968, a group of visionaries predicted the future importance of lasers and founded the Laser Institute of America (LIA) in California. Today, 35 years later and located in Orlando, the LIA represents hundreds of corporate and thousands of individual members and is the premier source for information in the USA on laser safety and applications. To that end, LIA is the secretariat and publisher of the ANSI Z136 series of USA laser safety standards.

LIA is an international society, with a board of directors that represents eight different countries and had its first international president in 2002. As well as providing laser safety training, LIA sponsors conferences (including ICALEO®), produces short courses and publishes instructional publications and the Journal of Laser Applications®.

For more information, visit *www.laserinstitute.org*

Changes at CLP

After 20 years dedicated to the development of IREPA Laser and the dissemination of industrial applications of laser in France, Olivier Freneaux, President of the French laser association CLP (Club Laser et Procedes) has taken on the General Management of a new company in the south of France. Jean-Pierre Billon takes over as the new CLP President.

Olivier Freneaux

Another key change at the CLP is the appointment of Wolfgang Knapp of the CLFA (Cooperation Laser Franco-Allemande, a collaboration between France and the Fraunhofer ILT in Aachen, Germany) as Vice Président of International Relations. Dr Knapp is also playing a major role in the formation of a European Laser Institute.

British optoelectronics associations merge

A major step forward into consolidating the United Kingdom's position as a leading global player in opto-electronics has taken place with the announcement that the Midlands Photonics Cluster, based at Aston Science Park near Birmingham and the UK Laser and Electro-Optics Association (UKLEO) have joined forces, integrating members of the UKLEO into a unified Photonics Cluster.

The MPC was established in November 2000 to offer a focal point for photonics companies and academic institutions in the Midlands, where it continues to assist businesses in the region and create jobs.

The merger will create a focal point for supporting business opportunities for manufacturers, distributors and relevant research institutions. The cluster, which already comprises some 50 companies and organisations, hopes to develop overseas networks and to further integrate into defence, automotive, aerospace and health care groups.

Glenn Barrowman of the MPC made a presentation on the current role and future activities of the cluster to over 60 representatives from throughout the EU and enlargement states present at the recent European Business Network Seminar (13/14th March, Vienna). The event presented an opportunity for greater internationalisation of the cluster with the linkages to the Optics Valley, France and the German community centred around the Thurringhia Region.

The cluster is exhibiting at Laser 2003 in Munich in June.

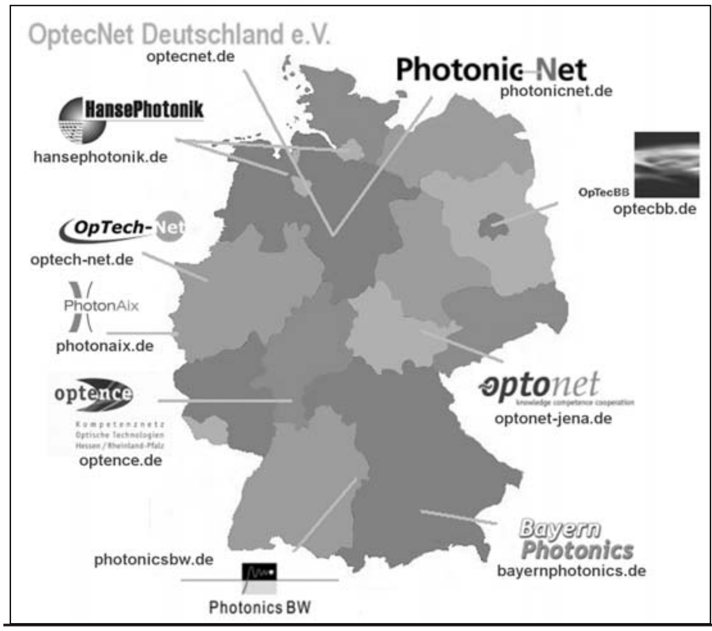
Challenges and chances of running both EOS and OptecNet Deutschland

In September 2002, Klaus Nowitzki, the ex-CEO of WLT, took over the management of Germany's supraregional network OptecNet Deutschland e.V; taking along the European Optical Society of which he has been the Executive Director since July 2000. Once again, Nowitzki has a split responsibility for a national and an international organisation.

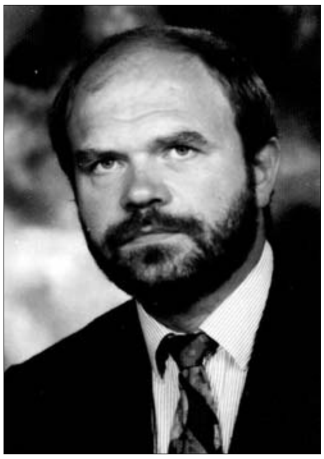
Now, after six months experience, he reports on the challenges and chances of running both a federal network as OptecNet and an international society as the EOS.

AILU: First, could you briefly introduce OptecNet Deutschland to our readers?

Nowitzki: Of course. OptecNet Deutschland e.V. is the supraregional network of the nine regional German Competence Networks for Optical Technologies. Seven of these, OptecNet included, are funded by the Germany Ministry for Education and Research (BMBF). BMBF has a very clear vision of the outcome: the aim of the regional networks is to speed up the development and application of Optical Technologies in strategically important fields. OptecNet Deutschland, though, focuses on supraregional tasks, such as PR, exhibitions and conferences, training and further education, and, last but not least, the creation of a powerful 'internal' network.



AILU: And how does the EOS fit in these activities?


Klaus Nowitzki

Nowitzki: The aims and activities of EOS are not too far from OptecNet. Both organisations aim to promote and support the development and application of Optical Technologies and both offer benefits and services to their members. The biggest differences are in the number of members and the structure: OptecNet's members are the nine regional networks which unite about 300 companies and institutes, and the EOS has about 600 individual and 70 corporate members.

AILU: What do these organisations have in common in terms of tasks and activities?

Nowitzki: Quite a lot. Both want to bring together partners from industry, research, education, finance and public authorities. Also, the main task of both organisations is disseminating target-group specific information on optics ranging from breaking research results to funding opportunities, and many information resources are of great importance for both organisations. In addition, their most important communication instrument is the internet and email. Further, EOS and OptecNet serve as an interface between the optics community and the public.

AILU: What do you see as the challenges?

Nowitzki: The challenge is to always clearly distinguish the aims and visions of the two organisations, which I think we can do. Our long-term goal for Optical Technologies is to strengthen the network and establish unique consulting competencies based upon the current structure of the nine networks, so that OptecNet will become the first place to go .for optical technologies made in Germany. EOS on the other hand has the long-term goal of achieving 'Coherence for Europe' i.e. uniting those working in optical technologies and bringing together the different cultures and backgrounds from around Europe to make a united Society, for the benefit of everyone within Europe and Worldwide.

For further infomation contact Klaus Nowitzki at: European Optical Society (EOS) (T:+49-511-277-1295 E: eos@optecnet.de W: www.europeanopticalsociety.org) or OptecNet Deutschland e.V. (T: +49-511-277-1291 E: nowitzki@optecnet.de W:www.optecnet.de)

Members' News

New Laser Processing Development Centre at Corus, Rotherham

Building upon several years of experience with laser processing on several sites, including the 25kW laser at Scunthorpe, Corus have recently established a new centre for practical developments, aimed at enhancing industrial exploitation of laser manufacturing with metals. Based at the Swinden Technology Centre near Rotherham, it will be developing a comprehensive range of laser processes to establish robust techniques that can be applied directly to manufacturing.

Initial applications studies will be based around a Ferranti 5 kW CO_2 laser with a beam quality suitable for welding, cutting and (with lens modification) multi-spot welding, surface hardening and weld overlay. Currently, movement is by a traversing table under a static laser, which is ideal for establishing optimum parameters for laser/MAG and laser/plasma hybrid welding. A large processing bed is shortly to be installed that will allow high-speed cutting to be evaluated and a demonstration of cut then weld manufacture to tight tolerances.

Nick Longfield (left) with Alan Thompson

5 kW laser being sited within laboratory

Machinery for rotating components will also be acquired to prove the cost benefits of rapid laser surface hardening or weld overlay on items such as shafts and gears.

Corus are keen to partner external customers in their evaluation of more efficient laser processing technologies and supply the processing knowledge required to initiate immediate production with a turnkey system. In addition, the facility is available for specific customer developments and for trial production runs.

Members interested in knowing more about the activities at the centre are encouraged to contact Alan Thompson (E: alan.thompson@corusgroup.com T: +44 (0)1709 825224).

Exitech wins Eureka funding

Exitech may be the exception, but it it certainly good news that they have received DTI funding for their part in the EUREKA project 'FOLIA' (flexible organic illuminators for the automotive market) Exitech's contribution to E!2541 is to develop a laser patterning method for the thin films and the DTI grant amounts to over £250k.

This successful grant application, the first for quite some time for laser processing, should provide encouragement for others in the laser business who may be interested in applying for EUREKA funding. (See *www.bit.ac.at/eulasnet/* for existing projects)

Exitech have been particularly successful at attracting UK government funding, with a total of 10 supported projects, plus 2 Framework 5 projects.

Coherent acquires Molectron

As a result of Coherent's recent acquisition of Molectron Detector, Inc. (MDI) a new business unit within Coherent 'Laser Measurement and Control (LMC)' has been created. The entire Molectron organization has been retained and the Molectron team, headed by MDI founder and president, Don Dooley, has been combined with Coherent's Auburn-based test and measurement group.

Coherent can now reasonably claim to offer the industry's broadest selection of laser measurement and control equipment.

Situation Wanted

I am a laser materials processor who is coming to the end of my current contract at UMIST and therefore I am looking for a position within the laser materials processing industry. I have been working at UMIST for over five years, first as a PhD student and then in a post-doctoral capacity. My previous experience includes a Materials Science/Laser MSc, a Chemistry BSc and a Eurolaser Academy Diploma.

My main research interests are laser ablation/marking and laser drilling. Recently, I have also been working on a combined laser and ECM process. I am keen to continue such interests, but would also be interested in new and exciting challenges.

For further details, please contact me at: R.Stewart@umist.ac.uk

Raster to vector software enquiry

Keith Withnall is currently evaluating raster-to-vector conversion software for generating laser cutting and marking programs from bitmaps, drawings and scans of existing parts or logos.

He is keen to talk to anyone who has an interest in such software or experience of using any existing packages.

Keith can be contacted on:
T:+44 (0)7751 012001
E: keith@kwa.biz

Welcome to New Corporate Members

(since December 2002)

ABR Specialist Welding Ltd

Bavarian Photonics GmbH

BMT Reliability Consultants Ltd

El En spa

Forschungszentrum des Deutschen Schiffbaus and Meyer Werft

HACO Laser Tech

Hospital Metalcraft Ltd

IFSW, University of Stuttgart

JLF Electro Mechanical Ltd

Lantek Systems Ltd

Laser It

Laserweld 2000 Ltd

Rojac Engineering

OUT FOR PUBLIC COMMENT

New UK measurement system programme

The proposed 2003 - 2006 National Measurement System Programme for Electrical/Electromagnetic Metrology can now be viewed and downloaded from the DTI website:
http://www.dti.gov.uk/nms/consult/electromagnetic_draft_for_comment.pdf

Theme 8 Laser Power and Energy Standards, which is Section 4.8 of the document, will be of particular interest to AILU members. The proposed programme aims to incorporate the requirements that were identified during the consultation phase but the DTI would welcome any further comments on the Programme.

Comments should be addressed to John Lee at the National Measurement System Directorate, DTI (151 Buckingham Palace Road, London SW1W 9SS; T: 020 7215 1416; F: 020 7215 1978; E: john.lee@dti.gsi.gov.uk)

Members might also like to view background material at:
http://www.dti.gov.uk/nms/consult/electromagnetic_formulation.htm

2003 Descartes Prize - 1,000,000 Euro

The Descartes Prize is the European prize for outstanding scientific or technological results from European collaborative research. The competition is open to all fields for scientific endeavour including the social and economic sciences. The Descartes is one of a number of activities supported with a view to raising public awareness of science and its importance in daily life.

The new call for entries to the 2003 Descartes Prize was published on 17 December 2002, with a closing date of 13 May 2003. For more information: *www.cordis.lu/descartes*/

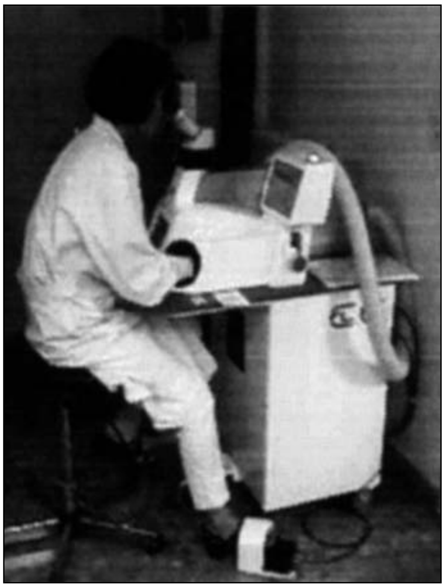
Laser SOS provide laser welding to assist art conservation

A new field of application in laser techniques devoted to solve conservation and restoration problems has been opened up with the success of laser welding in the conservation of artworks at the "Opificio delle Pietre Dure" laboratory in Florence.

In its first major application, laser spot welding was employed to restore a precious ostensory of the 17th century made of gold, silver, gilded silver, painted enamels and diamonds, which was broken in to approximately 400 fragments of various sizes. Since the object arrived in the laboratory, it was clear that conventional restoration techniques could not be applied because of the large number of pieces and their varying (small) size and thickness. In fact, glue could not be considered for joining such small pieces in view of the joint strength required to support the weight of the reassembled structure. On the other hand, the use of conventional soldering techniques were hindered by the presence of enamels, gems and gilding.

The reconstruction of the ostensory was carried out by using a Laser SOS Nd:YAG laser welder equipped with a stereomicroscope for precise control of the operations. The laser provided 1-20 ms pulses of variable duration at a maximum average power of 40 W and maximum pulse energy of 50 J, with pulse repetition rates up to 10 Hz. The focal spot diameter of the laser beam could be varied from 0.25 to 2.5 mm.

The laser workstation provides a closed (Class 1) working chamber that allowed the operator to introduce both hands in order to manipulate the objects to be welded. The chamber included an adjustable platform to hold the objects and two nozzles for gas assistance.



Operator with the Laser SOS welding station

Significantly different behaviours were observed between pieces produced by rolling and by casting, due to their different density and microstructure. To date, about 300 laser-welded joints have been produced and many parts of the object have been reconstructed and reassembled into their original position.

New facilities for Oxford Lasers

In January 2003 Oxford Lasers relocated its main manufacturing facility from Abingdon to Didcot. The previous facility had been configured to support the manufacture of lasers, principally copper vapour lasers. However with the shift in recent years to integrated systems that incorporate a broader range of lasers (CVLs, Nd:YAG and diode lasers) a new facility was required. The new building offers more flexibility and the company has been able to optimise the layout to accommodate their growing systems business in both their Industrial and Imaging Divisions.

New address: Unit 8, Moorbrook Park, Didcot, Oxon. OX11 7HP.

Switchboard: T: +44 (0) 1235 810088 F: +44 (0) 1235 810060

Divisions T: +44 (0) 1235 then 814433 (Industrial), 814433 (Photonics) or 812255 (Imaging)

Oxford Lasers new premises at Didcot

Laserdyne move to new facilities

Laserdyne Systems Division, a world leader in multi-axis laser machining systems have recently moved into new facilities in Champlin, Minnesota.

Paolo Cigna, President of PRIMA North America, announced the move stating that it strategically positions the company to focus on customer needs for multi-axis, high precision, high speed laser machining systems.

With over 250 multi-axis laser systems in use world-wide, Laserdyne's new facilities and location are designed to support the company's commitment to its current markets and to markets that can benefit from the company's unique capabilities. Laserdyne's BeamDirector® products, for example, are widely used in the aerospace industry and used in turbine engine manufacturing across North America, Europe and Asia.

Laserdyne has been an innovator of both software and hardware for laser drilling and cutting 3D parts, such as turbine combustors for aircraft engines using multi-axis CO_2 and Nd:YAG BeamDirector lasers.

Laserdyne Systems' new address is 8600 109th Avenue North, #400, Champlin, Minnesota 55316, USA. T: +1 763-433-3700; F: +1 763-433-3701.

Contact details for members' news items

Associacion Industrial de Optica
Contact: Jose Ramos de Campos
T: +34 (0)96 131 80 51
F: +34 (0)96 131 80 07
E: jramos@aido.es

Bavarian Photonics
Contact: Stephan Geiger
T: +49 (0)89 89407 226
F: +49 (0)89 89407 168
E: stephan.geiger@bavarian-photonics.com

BFi Optilas Ltd
Contact: Andy Turner
T: +44 (0) 1908 326326
F: +44 (0) 1908 221110
E: Andrew.turner@bfioptilas.avnet.com

BOC Gases
Contact: Jack Gabzdyl
T: +44 (0)1483 244629
F: +44 (0)1483 244657
E: jack.gabzdyl@uk.gases.boc.com

Camtek
Contact: Carol Hart
T: +44 (0) 1684 892290
F: +44 (0) 1684 892269
E: sales@camtek.co.uk

Coherent (UK) Ltd
Contact: Robert Lewis
T: +44 (0)1353 658833
F: +44 (0)1353 659110
E: Keith_Hilliard@cohr.com

Cutting Edge Metal Processing
Contact: Robert Lewis
T: +251 431 8015
F: +251 431 7948
E: LEWS@bendership.com

Club Laser et Procedes
Contact: Pierre Billon
T: +33 03 88 65 54 12
F: +33 03 88 65 54 01
E: jpbillon@clfa.fr

Corus
Contact: Alan Thompson
T: +44 (0)1709 825224
F: +44 (0)1709 825337
E: alan.thompson@corusgroup.com

Element 6
Contact: Thomas Schaich
T: +31 (0)485 395 700
F: +31 (0)485 316104
E: thomas.schaich@e6.com

Exitech Ltd
Contact: Malcom Gower
T: +44 (0)1865 290400
F: +44 (0)1865 290401
E: m.gower@exitech.co.uk

Ferranti Photonics/Photosynergy
Contact: Gordon Freeman
T: +44 (0) 1382 518200
F: +44 (0) 1382 518228
E: sales@ferrantiphotonics.com

IRIS
Contact: Milan Brandt
T: +61 (0)39 214 5651
F: +61 (0)39 214 5050
E: mbrandt@swin.edu.au

Keith Withnall Associates Ltd
Contact: Keith Withnall
T: +44 (0)7751 012001
E: keith@kwa.biz

Kentek
Contact: Simon Hargrave
T: +1 603 435 7201
F: +1 603 435 8901
E: tmacmullin@kenteklaserstore.com

Lasermet
Contact: Paul Tozer
T: +44 (0)1202 770740
F: +44 (0)1202 770730
E: Paul@lasermet.com

Laser Optical Engineering
Contact: Simon Hargrave
T: +44 (0)1509 222900
F: +44 (0)1509 223948
E: simonhargrave@laseroptical.co.uk

Laser SOS
Contact: Jim Leach
T: +44 (0)1480 460990
F: +44 (0 1480 469978
E: sales@lasersos.com

LIA
Contact: Beth Cohen
T: +407.380.1553
F: +407.380.5588
E: bcohen@laserinstitute.org

Licom Systems Ltd
Contact: Andrew Harfield
T: +44 (0)2476 713434
F: +44 (02476 713449
E: aeh@uk.licom.com

MJ Technologies
Contact: Helen Taylor
T: +44 (0)1530 516034
F: +44 (0)1530 516001
E: mjt@mjt.uk.com

Oxford Lasers Ltd
Contact: Martyn Knowles
T: +44 (0)1235 810088
F: +44 (0)1235 810060
E: martyn.knowles@oxfordlasers.com

Powerlase
Contact: Duncan Cooper
T: +44 (0) 1293 456234
F: +44 (0) 1293 456222
E: duncan.cooper@powerlase.com

Prima Industry UK
Contact: Richard Baxter
T: +44 (0)2476 645588
F: +44 (0)2476 645115
E: richard@primauk.com

Pro-Lite Technology LLP
Contact: Robert Yeo
T: +44 (0)1908 730085
F: +44 (0)1908 269991
E: info@pro-lite.uk.com

Rofin-Baasel UK Ltd
Contact: Dave MacLellan
T: +44 (0) 870 990 1020
F: +44 (0) 870 990 1030
E: D.Maclellan@rofin-baasel.co.uk

Scottish Optoelectronics Association
Contact: Chris Gracie
T: +44 (0)1506 497228
F: +44 (0)1506 497229
E: soa@cablenet.co.uk

SEI (UK) Ltd
Contact: Ian Croft
T: +44 (0)1480 309802
F: +44 (0)1480 461366
E: sales@cutandmark.com

Spiricon
Contact: Larry Green
T: +1 732 735 2060
F: +1 435 753 5231
E: larry@spiricon.com

thinklaser limited
Contact: Adrian Norton
T: +44 (0)1737 778000
F: +44 (0 1737 789245
E: systems@thinklaser.com

Trumpf Ltd
Contact: David Foulks
T: +44 (0) 1582 725335
F: +44 (0) 1582 399250
E: sales@uk.trumpf.com

Unitek Miyachi Lasers
Contact: Geoff Shannon
T: +1 626 930 8448
F: +1 626 599 9636
E: geoff@axiasys.com

PhotoSynergy formed in joint venture

A joint venture company, PhotoSynergy Limited, has been formed by the University of St Andrews and Ferranti Photonics Limited. The business of PhotoSynergy is the development and commercial exploitation of solid-state lasers and associated equipment based upon technology originating within the Photonics Innovation Centre (PIC) of the School of Physics and Astronomy of the University.

The University is an acknowledged world leader in the field of photonics. With Ferranti Photonics' long experience in the development, manufacture and marketing of lasers and laser based products, PhotoSynergy aims to be an important route for bringing the leading edge technology to market.

MJT and Amchem amalgamate

Following the acquisition of Amchem Limited as part of the Winbro Group, the company will now work with MJ Technology to serve the existing customer base and to develop new business globally, exploiting and building on their joint strengths in the design and manufacture of EDM, ECM and laser equipment.

“The combination of technical expertise within Amchem and MJT is a major breakthrough for our business and will encourage a more focused strategic vision to develop our designs, to heighten product performance and quality and to respond effectively to our customers' growing needs,” said John Stackhouse, Director. of MJ Technologies, “The increased wealth of experience in our industry that comes with the restructuring, will enhance our technological advancement and to encourage business development in aerospace, power generation, automotive and various industrial sectors.”

“The new structure will not only significantly broaden our engineering capabilities, but will also enhance our established global network of experienced, qualified and reputable agents who are familiar with our market sector, offering highly trained personnel to provide an extensive sales & service support for both the MJT and Amchem products,” John added.

“The businesses have grown to be world leaders in the supply of special process systems to the global market of aero-engine manufacture,” he explained, “and this new strategic investment by The Winbro Group is a demonstration of our long-term commitment to the industries we serve.”

BFi Optilas' new European agreement

BFi OPTiLAS, a pan-European specialist distributor, and Exitech have signed a collaboration agreement for the distribution by BFi OPTiLAS of Exitech systems in the territories of Belgium, Denmark, Finland, France, Holland, Italy, Norway and Sweden.

Exitech provides a range of high-end products for pulsed laser micro-processing. The agreement enables BFi OPTiLAS to provide not only the laser source by also a fully automated laser system solution for a number of demanding applications.

Trident becomes thinklaser

As of 1 January 2003 Trident Systems Limited has been trading as thinklaser limited, offering Laser Marking Systems for purchase and subcontract

The new M series from thinklaser has a revolutionary modular design. Customers can specify a range of configurations including wavelength, power output, markfield size and operator interface. With its completely programmable beam power, pulse energy and marking speeds the M series can mark a wide range of industrial materials.

M Series

The thinklaser markers are available in both CO_2 or Nd:YAG configurations. Nd:YAG at 1064 nm and at power outputs from 35 to 100 W can be used for marking a wide range of materials. In addition to metals the laser will also mark coated metals, plastics and ceramics. All systems are fitted with motorised aperture changes providing both multimode and TEMoo configurations.

At a wavelength of 10.64 µm the RF-excited CO_2 laser systems will mark materials such as wood, plastics, glass, coated metals, paper and ceramics. Two power ratings are available in this category, 25 Watt air cooled and 50 Watt water cooled.

Using the industry standard Windows NT as the operating platform, the control software allows the user to edit a wide variety of functions, select text with TrueType or single stroke fonts, enter or select logos, barcodes and 2D matrix codes.

Designed and packaged to offer a high degree of flexibility the M-series laser markers can be supplied as stand alone process tools or fully integrated into automated production lines with full handling solutions from thinklaser.

The new web site at *www.thinklaser.com* offers a range of reference information about the different aspects of laser marking. An applications library contains a picture gallery showing a wide variety of laser marked materials and provides detailed process information. General information is also available on laser material additives and links are provided to associated organisations.

MIWL offers free case studies

Anyone interested in laser applications can receive a free set of case studies that provide an overview of how lasers can be used to improve manufacturing. The case studies are offered on the new Make It With Lasers web site at *www.miwl.org.uk*.

Titles of the case studies include:

Manufacture of MIS Instruments	Coding Toiletry Products
Remote Materials Analysis	Forgery in Pharmaceuticals
Decorative Textiles	The Gillette Sensor
Military Ship Building	Hydraulic Solenoid Valves
Road Sweeper Manufacture	Circular Saw Blades
Real Gold Credit Card	Cooker Hob
Borescope Manufacture	Multi-Fuel Heating Stoves

Trumpf In-Tech 2003

In-Tech 2003 is the biggest open house event that Trumpf UK has ever staged. Over £2million of new production machines will demonstrate the range of Trumpf's technologies. The theme of the event is Integrated Solutions.

In Tech 2003 at Trumpf UK in Luton

Monday 31 March – Friday 4 April 2003

Cutting Edge hits new record

During the week ending 16/2/03, Cutting Edge Metal Processing, Inc., Mobile, Alabama, USA, hit a new one week record of over 783,000 pounds of plate cut on its 185-foot Laser cutting table. This table is served by a Tanaka LMXIII 6kW and a Tanaka LMXV 4kW laser. The vast majority of the material cut was 1/2", 9/16" and 5/8" A-36 plate in 8, 10 and 12-foot wide sheets, 40 and 45-feet long. Some plates had over 100 parts cut from them. All of this material was coated with pre-construction primer on both sides, requiring a "vaporizing" pass before cutting. All plates were also extensively laser etched with part assembly marks.

Part of this volume included cutting about 60,000 lbs of 10" x 3/4" x 480" and 540" flatbar to length with sniped end cuts on both ends, and several internal shaped cuts. The flat bar was set up on the table in groups but not aligned. The end positions were entered into the controller manually by sighting the alignment beam and scheduled for cutting as if the bars were plates.

EUREKA! Prima's laser robot

EUREKA project E!1784 EUROLASER PUBLICS has devised a fully automated, high power laser-cutting robot which is capable of continuously cutting metals up to 20mm thick in 2-D and 3-D. The system employs sensors capable of recognising and correcting anomalies in the cutting process to achieve precision cutting. It enables the use of lasers to expand beyond supervised, small-scale applications into highly-automated volume manufacturing, and at much the same price as traditional laser-cutting systems.

"Laser technology has, to date, failed to fulfil its full potential as an industrial metal-cutting tool partly because of the sensitivity of the process to external disturbances and partly because of the intrinsic difficulties in controlling and tuning the variables of the laser-cutting process," said Piero Chiabra of Italian lead partner Prima Industrie SPA. "The two frontiers of laser-cutting machinery are quality and robustness and our solution advances both of these," he added.

"Prima Industrie SPA is marketing the machines for use all over the world. Before the project started we forecast that sales of the system would reach 60 a year by 2006, but this prediction is already out of date," said Piero. " Industrial laser-cutting will now have a higher presence worldwide and is expected, over the next 5 to 10 years – and partially as a result of this project – to achieve ever better performances, to the point of eventually replacing existing punching machines in the thin metal sheet market."

BOC's LASOX success

The first commercial use of the LASOX process, co-developed by BOC and the University of Liverpool in the UK, took place at the Bender Shipbuilding yard in Alabama where a series of laser cuts through steel plate using a LASOX cutting head at less than 2kW of power were made.

LASOX is the result of eight years research between BOC's UK-based Fabrication Technology Centre in Wolverhampton and Dr Bill O'Neill of Liverpool University. The process uses oxygen to provide the cutting power while the laser is used to maintain a pre-heat, in a similar way to the fuel gas flame in oxy-fuel cutting.

Dr Jack Gabzdyl, BOC's market development manager, said "The LASOX process was originally envisaged extending the thickness capability of laser cutting. However, based on the initial success of the trial and with further refinement, the LASOX process could become a modern alternative to traditional thick section profile cutting methods such as oxy-fuel."

Pat Cahill, research and development manager for Bender Shipbuilding, said: "A year ago, cutting steel thicker than 50mm would have been unheard of with a 2kW laser. LASOX has the potential to cut steel plates as thick as 100mm. Currently high-powered plasma cutting is limited to 75mm. This development opens up the possibility of a new generation of steel ships that are stronger and cheaper to build."

BOC provided the basic technology and process license for LASOX. Alabama Laser Systems carried out the commercialisation of the process and the integration into the existing laser cutting system at Bender. After a year of evaluation and development, the system is now in full production at Bender Shipbuilding. The installation at Bender has been so successful that the programme is being brought forward by three months and in early 2003 full installations at Caterpillar, for their heavy duty mining equipment, and General Dynamics – Electric Boat, for use in the building of submarines, are expected.

(see article on page 25)

Camtek celebrates 20 years

Camtek, based in Malvern, Worcester, is celebrating its twentieth year of trading during 2003. The company, which specialises in CADCAM software for the programming of CNC machine tools used in milling, turning, wire EDM, and multi-axis laser cutting, has seen it's business grow such that it has become one of the Internationally recognised companies in this field.

Strategic alliances have been formed between Camtek, Worldwide machine tool manufacturers and a range of distributors throughout 60 countries, supplying their customers with the well known and respected PEPS system as standard and specially branded variations

Brian Warner, Managing Director; said "We've come a long way since 1983, with resellers and users in 60 countries around the world. This is thanks to a loyal customer base that has continually benefited from our development methodology. We want to assist engineers by showing them how they can get the very best out of their existing or new machine tool and start saving money, something that is becoming of paramount importance with the tough business climate in manufacturing at present."

Expansion at LOE

The recent recruitment of Dr Rob Roach to Laser Optical Engineering pushes the number of employees into double figures. Rob gained his doctorate at UMIST and worked as a postdoc with John Tyrer at Loughborough University. He also brings to LOE over 5 years of commercial experience gained at Laser 2000 and joins the team as a sales and marketing engineer, assisting the company to develop its commercial activities.

Rob Roach

"This is an exciting year for LOE," said Simon Hargrave, LOE's business manager, "we are looking to expand both the company's commercial profile and its products and services."

Simon also announced that plans had been agreed for LOE to move to the new Loughborough University Innovation Centre. The move, which is planned to take place after Easter 2003, will provide LOE with over 200 m^2 of floor space. This will enable all the elements of the company's diverse laser capacities to be brought under one roof.

Licom's new Marketing Director

Paul Monte has been appointed sales and marketing director of Licom Systems.

Paul Monte

Paul was previously Sales Director at Bonas Machine Company, an engineering organisation producing machinery, CAD and electronic control systems for the textile and upholstery industries.

"Licom is an innovative organisation developing software of considerable benefit to a wide range of manufacturers. The future is very bright indeed," Paul commented.

Marked Change at Trumpf

To meet increased demand for Trumpf's solid state laser products the company has made changes to its sales structure. The customer bases for Nd:YAG lasers for marking and for spot welding have a high degree of overlap, so the sales operations for pulsed and marking lasers have been combined and two Product Managers appointed to support the initiative.

Dawson Holloway

Dawson Holloway, an industry veteran of 18 years, brings considerable experience in pulsed laser applications to the company. He will partner Tony Dain, Trumpf's existing Product Manager–Marking. Together they will represent Trumpf's solid state interests in the UK.

Terry Wanderwert rejoins Laserdyne

Laserdyne Systems, a division of PRIMA North America, Inc. and a world leader in multi-axis laser machining systems, announced the appointment of Terry VanderWert to the position of vice president.

Terry VanderWert

Terry will be responsible for defining the future direction for Laserdyne Systems and will directly oversee product and applications development efforts. He rejoins Laserdyne Systems where he previously served for over 15 years in product line management positions. During that time, he was responsible for the introduction of many of the company's Beam Director products including the models 780 and 890. He was a key member of product teams that successfully established Laserdyne BeamDirector products as a standard in the aerospace industry. He was also responsible for initial sales in China, which today is one of the company's most important markets.

Scotland's first opto packaging centre

Plans to develop Britain's first optoelectronics packaging centre have been given the go-ahead by Scottish Enterprise.

News of the green light for the £4M Integrated Optoelectronics Encapsulation Centre is a major boost to the optoelectronics and microelectronics sectors in Scotland.

The Centre, which will be run by the Scottish Optoelectronics Association, will address the key issues surrounding packaging novel components, particularly transitioning optoelectronic devices from the laboratory to real world applications.

SOA Chief Executive Chris Gracie, said "this is excellent news. A great deal of work has gone into planning the centre. It will be extremely important to the long-term success of the sector in Scotland."

Fibre laser emits record power

At the recent Photonics West conference, Johan Nilsson, a researcher with Southampton Photonics (SPI) and Southampton University's Optoelectronics Research Centre, announced that his team had built a singlemode fiber laser with an output power of 270 W. This output, achieved from a ytterbium-doped fiber laser operating at 1080 nm, is alleged to be a new world record.

"The cladding-pumped fibre lasers have a M^2 beam quality value of around 2, but this can be improved and we expect that singlemode fiber lasers with kilowatt level output powers will soon be achievable," said SPI's director of business development Stuart Woods.

The company is planning to release a range of high power fiber lasers for industrial applications such as marking, cutting and welding at the LASER 2003 show in Munich in June.

"In terms of price and performance, fiber lasers will offer very strong competition to other laser technologies," Stuart added.

AILU's International Members

Some of the Association's members from outside the UK report on aspects of their current activities

Associacion Industrial de Optica, Spain

The Associacion Industrial de Optica (AIDO), based at the Technological Institute of Optics, Colour and Image, is a private, non profit making association formed by businessmen and institutions to develop their professional activities in the applications of optics in industry. The Institute started its activity in 1998 as an initiative of the Valencian Government, through the IMPIVA, the Institute of small and medium size enterprises of Valencia.

AIDO headquarters

The main purpose of AIDO is to encourage the investigation and technological development of industries within the fields of optics, image, colour, design and the newest communication technologies, to raise the quality of production and, in general, to support industrial development.

AIDO has been registered by the Ministry of Science and Technology as a Centre of Innovation and Technology (number 26) since 1997 and as a Technological Research Transfer Office (number 63) since 1996.

Since its creation, AIDO has been known for its marked multi-sectorial character, acting as a R+D consultant to SMEs that require optical technologies to increase their competitiveness, encouraging the quality of their final products and production processes and promoting industrial innovation.

Currently the centre represents the technological interests of more than a thousand associated firms from different industrial sectors such as Ophthalmic Optics, Audiovisuals, Lighting and Signposting, Graphic Arts, Paints and Varnishes, Equipment, Telecommunications, Computing, Electronics etc. AIDO has at its disposal modern facilities of 2.300 m^2 including 5 testing laboratories, all of which are accredited by the National Entity for Accreditation (ENAC), 2 workshops, 1 training centre and 8 technology departments with more than 60 professionals specialised in Graphic Arts, Image, Machine Vision, Laser, Audiovisuals, Quality and Environment, Colourimetry, Development and Product Engineering, Photometry and Training.

In 1997 AIDO adopted an expansion strategy to offer technologic solutions not only to the SMEs in Valencia but also nationally, and a branch office in Seville has been opened for organisations in the South of Spain. The Institute, as a member of the Network of Technological Institutes of the Valencian Community (REDIT) and the Federation for Development and Technological Innovation (FEDIT), keeps improving year after year with the aim of promoting the competitiveness of the Spanish SME in the national and international markets.

For more information on AIDO, see the web site *www.aido.es*

Bavarian Photonics, Germany

TuiLaser has a long history of innovation and leadership in the production of sophisticated mini excimer lasers in the medical, industrial and scientific markets which goes back to 1993, and with the recent foundation of Bavarian Photonics in 2002 TuiLaser completed its challenge to expand into the diode pumped solid state (DPSS) laser business.

The Aion™ Industrial-V DPSS laser system

The new AionTM Industrial-V DPSS laser offers high laser peak powers at repetition rates up to 100 kHz, with excellent beam quality, excellent pulse to pulse stability and precise power control. It is currently available in four different models offering a choice of 1064 nm and 532 nm wavelengths, with an output power of more than 16 W and 8 W, respectively. Applications for the laser include marking, micromachining, semiconductor manufacturing, scientific and medical use.

For more information, see *www.bavarian-photonics.com.*

For information on the TUILASER family of excimer lasers, see *www.tuilaser.com*

Element Six, The Netherlands

Element Six, formerly known as the De Beers Industrial Diamonds group, is a world leading supplier of high quality superabrasives and industrial diamond materials, including both diamond and the complementary superabrasive cubic boron nitride (cBN). These materials are available both in their single crystal and polycrystalline forms, for abrasive and non-abrasive industrial uses.

Of particular interest to industrial laser users will be E6's Chemical Vapour Deposited (CVD) diamond manufacturing capabilities, which have now reached the stage where windows for applications such as IR imaging systems and high power lasers can be routinely produced.

Diamond has unique attributes as an optical material. It has the widest spectral bandwidth of any known material, extending from UV to microwave. Its extreme hardness, high thermal conductivity and chemical inertness make diamond the ideal window material for many industrial, R&D and military applications.

For CO_2 laser applications, the thermal, mechanical and optical properties of CVD diamond (including thermal lensing and laser damage) are dramatically superior to zinc selenide. Indeed, the increase in performance is so great that CVD diamond enables a new generation of higher power laser systems to be developed.

For further information visit the web site *www.e6.com*

AILU's International Members

IRIS, Australia

Profile cut obtained in 40 mm thick, 250 grade mild steel plate with a Nd:YAG laser power of 2 kW.

One of the many laser research areas being pursued at IRIS, the Industrial Research Institute Swinburne, is laser cutting.

Laser cutting offers unique advantages in terms of cut quality, speed, absence of tool wear and minimal or no clamping of parts. The lasers used for cutting are predominantly CO_2 and more recently Nd:YAG lasers. The technology is now considered mature, particularly for thin and medium thickness (~15mm) steels. There is, however, industrial interest to cut thicker mild steels in the 20 – 50 mm range while maintaining cut quality.

One approach to increasing the thickness of the material that can be cut is to increase laser power. This approach has been adopted by laser suppliers and over the last ten years the power of CO_2 cutting lasers has increased to 6 kW. While there are a number of advantages to this approach there are also significant challenges. At higher laser powers (3.5 kW and higher) the beam quality becomes poorer, the lifetime of optical components is reduced due to thermal loading, equipment and running costs are high and cutting precision deteriorates. Another approach involves a change in the cutting process itself as in the LASOX process with CO_2 lasers.

Researchers at IRIS, with the support from the Co-operative research Centre for Intelligent Manufacturing Systems and Technologies, have developed a new beam manipulating laser cutting head for cutting thick mild steel plate with Nd:YAG lasers.

The work at IRIS is showing very positive results. In particular, a relatively low power (~0.5 – 2.0 kW), fibre delivered Nd:YAG laser has cut mild steel plate up to 50 mm thick. Illustrated in the figure above is a profile cut in 40 mm thick, 250 grade mild steel plate at 150 mm/min. The surface of the cut is very smooth compared to conventional cutting and shows little or no oxide layer.

Associate Professor Milan Brandt who leads the research said that this technology is particularly suited to laser job shops that want to increase the thickness of mild steel plate that they can cut but can not justify the purchase of a higher power laser. In addition, the technology would allow such job shops to cut materials that they would normally have to subcontract for plasma, oxy-fuel or water jet cutting. Interest in the new cutting technology has already been expressed by Bob Urquhart from Lasermax, a laser cutting job shop based in Wollongong, NSW, Australia.

Research activities are currently directed at determining the optimum laser cutting conditions for a range of mild steel thickness, improving the cutting head design and material piercing. This work in laser cutting is part of IRIS's strategy to develop new processes and industrial applications for lasers.

For further information contact Milan at *mbrandt@swin.edu.au.*

Kentek, USA

Kentek laser safety screens

Kentek provides customers worldwide with custom and stock laser safety products, accessories, components, service and technical support. Their comprehensive line of products include: eyewear, signs, labels, custom enclosures, curtains, partitions, replacement parts, measuring devices, re-work services, and custom laser head design and manufacturing.

Laser Safety Division recently announced a partnership with Purex International for the sales and marketing of Laserex brand fume extraction and air purification equipment in North America. These highly efficient and economical systems used in virtually any laser application.

Kentek's historic strength in laser components for industrial and research applications now extends into the medical field and their Laser Parts Division has significantly increased both inventory and manufacturing capability for replacement parts for medical lasers. Kentek stocks laser rods, flash lamps, flow tubes and other parts for many popular medical lasers. Kentek is also offering design and manufacturing services for laser pump chambers and cavity reflectors.

For further information see *www.kentek-laser.com*

Laser Mechanisms, Belgium

Advanced laser cutting head

Founded in 1980, Laser Mechanisms, Inc. is a leader in the design and manufacture of laser beam delivery components and articulated arm systems for high power lasers.

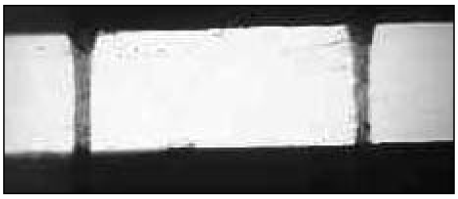
A recent addition to their product range is the Advanced Laser Cutting Head. The head is based on their 5.0" / 7.5" multi-focal length design that increases processing capability, decreases downtime and eliminates the need for a second head. With a 48 mm clear aperture, the Advanced Laser Cutting Head easily accepts beams from even the largest multi-kilowatt resonators. And with the ability to accept both 1.5" and 2.0" diameter lenses, the head will satisfy both current and future processing requirements.

The Advanced Laser Cutting Head uses FIST capacitive height sense electronics for noncontact metallic cutting, maintaining a constant standoff, even if the material is warped. The head also features springloaded, safety-interlocked crash protection. Should a crash occur, the head references back to its standard operating position with no realignment or refocusing required. The cartridge-style lens holders allow the user to easily remove lenses for inspection or cleaning and replace them without the need for realignment in a matter of seconds.

For further information see *www.lasermech.com*.

AILU's International Members

NCLA, Ireland



10 µm diameter holes drilled in a 50 m thick stainless steel sheet using an ultra-fast laser

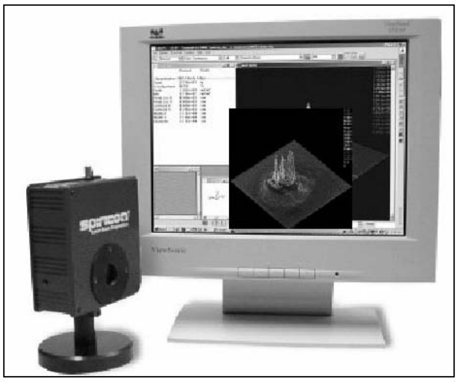
The National Centre for Laser Applications is a state-of-the-art resource in laser technology located in the National University of Ireland in Galway. NCLA sees AILU as a key networking and training resource for the centre, keeping it up-to-date with the latest UK and European developments.

The centre has a dedicated research team which applies its extensive laser resources and related instrumentation for industry-sponsored research, in training, and in technology transfer – mainly with companies in the electronics, medical device and aerospace sectors. The centre has state-of-the-art femto-second and DPSS lasers (for micro-machining of metals, semiconductors, polymers, and ceramics), excimer and frequency doubled DPSS lasers (for micro-processing of advanced materials) and high-power YAG and CO_2 lasers (for etching, welding, cutting, and drilling). Activities are supported by up-to-date characterisation techniques, including nanosecond-scale imaging of laser material interactions.

Current research topics include laser-assisted surface activation and the production of micro-sized features on advanced substrates. The Centre has close working relationships with various automation companies and develops and transfers laser drilling, welding, cutting and etching processes for industrial use.

For further information see *www.ncla.ie*.

Spiricon, USA



Spiricon CO_2 laser beam analyser

Spiricon are a leading manufacturer of laser beam diagnostic (beam profiling, M^2) instrumentation for industrial and scientific applications.

The Spiricon Pyrocam III camera for IR beam measurements combines the highest performance, resolution and stability. Spiricon's Laser Beam Analyzer (LBA-PC) Software simplifies data logging.

A recent development is real time imaging of unfocused CO_2 laser beams in a portable, lightweight yet rugged package. For laser resonator tuning, the Spiricon CO_2 analyser allows operators to view short-term fluctuations and the laser beam structure with a level of detail never before available, eliminating the inferior and time-consuming procedure of taking mode burns. Users can reduce the time necessary for laser tuning and data can be archived to make fault diagnosis easier.

The CO_2 Industrial Beam analyzer is self contained and can be moved easily from one laser workstation to another. Powers up to 1 kW continuous exposure.

For further information see *www.spiricon.com*

Unitek, USA

LM5G Diode-Pumped Laser Marker

Unitek Miyachi Corporation is based around Los Angeles and has three distinct operating groups: Unitek Peco offers resistance and laser welding equipment for precision metals joining; Miyachi manufactures resistance welding and process monitoring equipment for applications ranging from sheet metal to component parts manufacturing; Unitek Miyachi Laser builds a family of pulsed Nd:YAG lasers with up to 7kW peak power and multiple output beams for OEM's or as turnkey systems with multi-axis CNC motion hardware for laser welding applications.

Geoff Shannon completed his PhD at Liverpool University and moved to the US in 1998 to work as a laser applications engineer for Synrad. Two years ago he moved to Unitek Miyachi Laser where he has been involved in the development of Nd:YAG laser welding applications and systems. The systems are used to manufacturer photonic devices for fibre optic networks and typical applications require the manipulation, alignment and fixing of optical elements, such as lenses, filters and fibres, to submicron tolerances.

The challenges for photonics based systems revolve around parts design for weldable fibre support structures. Minimizing the fixing tolerance misalignment or weld shift caused by the welding process and designing tooling to hold and manipulate the tiny parts are the key areas. The customer typically has an optical design, and Unitek Miyachi then help to make the design laser welding friendly and accessible for tooling. From there, a feasibility program is undertaken to investigate the welding shifts and CAD modeling of the tooling before the customer commits to purchasing a system.

The current climate of the photonics industry in the US is depressed, with no immediate signs of a pick-up. Unitek's current focus is to optimize machine capability and flexibility as well as striving for innovative low cost solutions. The heady days of 2000 where "I don't care what it costs, just get it here " are long gone. To this end the company are developing innovative component support structures that minimize fixing tolerances, and squeezing the cost/performance ratio of the systems. The market slow-down has given Geoff the opportunity to investigate challenging aspects of laser welding (such as gold coatings and dissimilar materials, weld shift/fit-up implications of joint designs) and to dip into laser soldering and other new technology.

For further information see *www.unitekmiyachilasers.com*

On a personal note from Geoff:
The US laser scene has a fair number of Brits, which is great at shows and conferences, and it's also amazing how you become attuned to zoning in on a British accent! One thing that is a little surprising over here is the lack of institutes and universities undertaking laser materials research compared to Europe.

Oxford Lasers' new particle analyser

The Oxford Lasers Eexp VisiSizer system is designed for on-line analysis of particle size distributions in pharmaceutical production plants.

The size of particles in pharmaceutical formulations is a key quality and safety measurement. The system measures particle size and velocity distributions using a technique called Particle/Droplet Image Analysis or PDIA. In this technique, a laser is used to illuminate the region of interest from behind and shadow images of the subject are taken with a digital camera. The laser and camera are triggered so that a single laser pulse freezes the motion of the subject during each frame capture.

The images are read from the camera by the VisiSize software, which has an analysis rate of 15 frames per second (fps). After background subtraction the pixel area of the particles is measured and prior calibration of the system allows the equivalent particle diameter to be reported for up to 250 particles per frame.

The system can analyse images singularly or analyse a sequence of images. In real time the system analyses images from the camera at 15 fps and builds up a particle size distribution. It is also possible to store a sequence of images in memory and then to disk for later analysis. The reporting format for the particle size distributions can be customised to suit the user requirements and it is also possible to record the individual particle data from the analysed images if required.

The system is designed for use in potentially explosive environments, hence its Eexp rating and ATEX accreditation.

Lasermet's new beam shutters

Laser safety specialists Lasermet have launched a new range of laser beam shutters for safety and beam control applications. The shutters are designed to operate in conjunction with their popular ICS-1 laser interlock control system and adds to Lasermet's extensive range of laser interlock equipment. They are available for OEM applications.

The LS- range of beam shutters act as a combined shutter and beam dump to absorb the beam. Intelligent electronic design minimises the current required to operate the shutter. 'Open' and 'close' buttons are situated on the shutter itself but the remote switching and switch bypass facilities which come as standard enable the shutter to be used inside enclosures in remote locations or for OEM applications. The shutter is designed for reliability and the close shutter operation is gravity fed, making it suitable for safety applications.

The LS- 10-12, the first shutter in the range, is a 12 V DC shutter specified for up to 10 W of laser power. It has a 15 mm aperture and draws a maximum of 120 mA when open. A 100 W and a 40 mm aperture version are expected to be available later this year.

Thin profile thermopile head

Ophir Optronics, a leading manufacturer of laser measurement instruments has released the Model S250W, a thin profile water-cooled thermopile surface absorber head for CW and long pulsed laser.

With a dimension of 90 x 90 x 20 mm and a 50 mm diameter aperture, the L250W head is suitable for applications where space is a constraint. It can measure powers from 4W to 250W and energies from 200mJ to 200J. The L250W is compatible with all Ophir smart displays.

Laser Marking at the Cutting Edge

For Geo H. Greensmith and Co., the purchase of a Trumpf VMC 5 laser marking workstation has enhanced the service it offers existing customers and opens up a wide range of new markets.

The company manufactures heat-treated blanks for professional knives and, according to partner Dave Greensmith, first started thinking about laser marking when asked to put a special design on some finished cutlery. After looking at the alternatives he realised that for the quality, complexity and quantities required, laser was the only answer.

"One of our contracts was to produce a variety of Celtic knot patterns on Skean Dhu knife blades. The patterns were too large to be etched and process considerations meant that engraving wasn't an option," said Dave, "We arranged for the parts to be laser marked by a subcontractor, saw what was possible and decided to set up our own subcontract marking service."

The VMC 5's Vanadate laser source efficiently delivers a high quality beam, giving maximum power density and control in a tightly focused spot. The end result is high quality marking.

According to Greensmiths, the Trumpf software is easy to learn, easy to use and fully comprehensive. "Everything you need is there. Some suppliers wanted me to start writing my own programs. I'm not interested in being a software programmer, I just want to use the machine."

Areas where Greensmiths expect to make an immediate impact include the personalisation of giftware and high quality marking on cutlery. The optional rotary axis means they can mark cylindrical components too.

Greensmiths also see potential in the growing demand for traceability, as the VMC 5 can produce a unique data matrix code on almost any component.

Trumpf VMC 5

"Because the laser is so versatile we can cover a whole range of industries. You probably don't realise how many things you see are already laser marked: and there are a lot more things that aren't currently laser marked that could be."

Powerlase extends laser range

Powerlase Ltd has extended its range of High Power Solid State Diode Pumped Nd:YAG lasers. Average powers range from 35 to 420 Watts, beam quality (M^2) values of ≤ 30 and wavelengths of 1064 and 532nm.

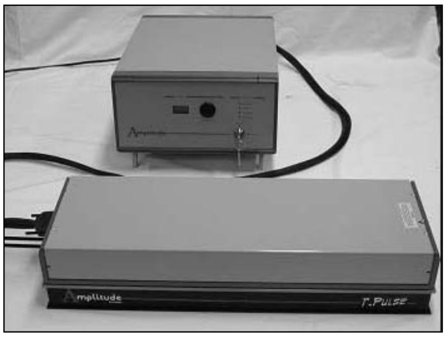
These systems are designed to enable economic high volume production use, for laser applications in aerospace, automotive, micro-electronics, PCB production, ablative lithography etc.

All Powerlase lasers combine high average power with high pulse intensities, a combination not usually available together. The lasers also feature energy conversion efficiencies up to double that of industry norms.

In addition Powerlase has adapted its modular designs to provide scaleable and stable energy sources for Laser Produced Plasmas, specifically to produce extreme ultraviolet (EUV) light for the lithographic production of next generation microelectronics.

Pro-Lite offer femtosecond source

Pro-Lite Technology LLP (Milton Keynes, UK) has released the T-PULSE from Amplitude Systemes (Bordeaux, France).



T-PULSE femtosecond laser

The T-PULSE is a novel femtosecond laser source based on a Ytterbium-doped gain medium directly pumped by laser diodes. The femtosecond oscillator achieves exceptional performance from a small, reliable single box at a significantly lower price than a traditional Ti:Sapphire oscillator pumped by a DPSS or Argon laser.

The T-PULSE provides an output of >1 Watt average power at 1030nm wavelength, with <200 fs pulses at a pulse repetition frequency of 50MHz. The spectral linewidth is <8nm FWHM with an energy per pulse energy of 20nJ. The laser head footprint measures only 60 x 20cm. Contained within the compact laser resonator are an internal thermal management system, a self starting solid-state mode locking system and high performance optics. This laser has low electrical power consumption and has been engineered for simple day-to-day use, providing long-term stability and excellent repeatability with a short warm-up time. T-PULSE applications include precision machining and explosives machining.

Amplitude Systemes are collaborating with the University of Bordeaux and have recently reported a method of spectrally broadening the 1030nm output using a short micro-structured or "holey" fibre to enable simple external tunability in the range of 950-1200nm without recorse to adjustment of the laser itself. Amplitude expects to offer this extension commercially in 2003.

Amplitude Systemes' mission is to design and manufacture the next generation of ultra-fast lasers. They work in close partnership with the University of Bordeaux CELIA Laboratory and other leading teams in femtosecond technology. Amplitude Systemes is represented in the UK & Ireland by Pro- Lite Technology.

Laser marking at Cambridge Precision

After many years of outsourcing their laser marking, Cambridge Precision decided that, in order to meet stringent quality and time constraints prevalent in today's market place, they needed their own in house laser marking facility.

SEI MIRO II marking machine

Nigel Rata, director of Cpi approached SEI of Italy through their sister company SEI (UK) with a specification for a machine, with ease of use and flexibility at the top of the wish list.

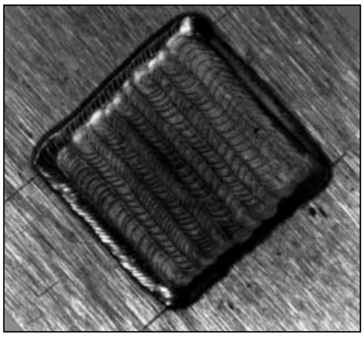
Tests were carried out a SEI (UK) demo room in St Ives Cambridge and a MIRO II system was configured incorporating a rotary 3 axis for the marking of medical tubes. This 40 W pumped diode based machine was delivered in May of 2002 and to date has performed without fault.

Mr Rata and his colleagues at CPi have been more than pleased at the performance of the MIRO II but like all machines good technical support is essential. "We work 24/7 here," comments Mr Rata "so we need to know that our suppliers can assist us to the same degree as we support our customers".

SEI (UK) have now installed a demonstration unit at their St Ives base to test and quantify sales enquiries. Companies requiring laser marked metals, plastics or other substrates are invited to send samples and data to SEI (UK) who will gladly conduct feasibility trials. Small batch pre-production runs can also be produced prior to customer's own facility being ready.

Tool repair at Moeller

Electrical component producer Moeller Manufacturing has confirmed that installation of a Trumpf PowerWeld facility in its Worksop plant has enabled key injection moulding tools to be repaired within minutes, rather than the hours, or even days it would have taken previously.



Laser repair of a moulding tool

The use of a Trumpf NdYAG laser not only speeds up the process, but also improves the work quality. It is precise, predictable and obviates the thermal distortion or metallurgical damage problems of earlier techniques of metal deposition – such as TIG welding.

"Our existing TIG welders find it much easier to use," confirms MD David Howell, "and its use has virtually eliminated the need for follow-on dressing. Subsequent dressing takes only a couple of minutes with a diamond file- in fact the total time to repair a 50mm long worn tool edge is not more than five minutes."

The PowerWeld has in-built fume extraction. The work is viewed through a 25x magnification stereomicroscope, enabling precise targeting of the worn or damaged area of the tool.

Rofin's new range of laser products for polymer welding

Euromold (Frankfurt, December 4 to 7, 2002) saw the first presentation of the Rofin-Baasel's expanding family of lasers for polymer welding.

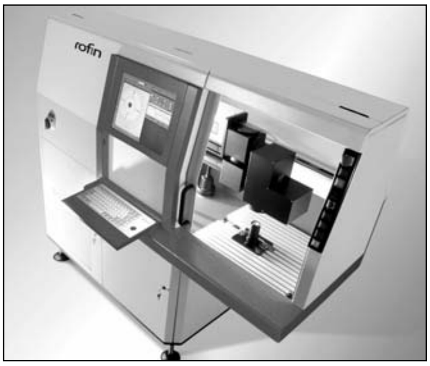
StarWeld

The StarWeld Diode laser family comprises diode lasers and diode pumped Nd:YAG lasers for polymer welding. All laser models are equipped with galvo deflection (scanner) heads as standard. All common laser wavelengths such as 808, 940 and 1064 nm are available for polymer welding.

According to the application, users can choose between highly focused micro welding lasers (HQ series, welding groove spot diameters of 0.15 mm and wider) and powerful high-speed lasers (HP series) up to 150 W.

The diode modules for direct processing were developed by the Rofin subsidiary Dilas. They use a patented beam shaping technique to achieve the beam quality required for galvo head scanning. The other StarWeld family members, the diode-pumped solid-state lasers, incorporate a Baasel Lasertech patented pump cavity for the laser crystal to achieve high efficiency and good beam quality. One attraction of the overall design is that the diode modules can easily be exchanged if the laser power is subsequently upgraded.

PolyScan



The PolyScan is the new turnkey laser system for polymer welding, into which any laser with a galvo head from the StarWeld Diode series can be integrated. Choosing between diode and Nd:YAG lasers allows the flexibility to cater for different requirements. Applications using contour welding and quasi-simultaneous welding are easily implemented.

The system has been ergonomically designed for ease of loading and unloading and system programming, all of which is achieved from a comfortable sitting position, with extensive legroom and good access to all essential components.

DLx diode laser with fibre coupling

The DLx is based on the Dilas diode laser series. The compact design of the diode modules aids their integration into tight system solutions or onto robot arms.

What is new to the DLx series is the additional fibre coupling for these modules, offering an homogenized beam and significant time saving for 2 dimensional welding. For precision welding with powers of up to 30 W, there is even a fiber with only 400 µm core diameter available.

Outlook

Since October 2002 polymer welding within the Rofin group came under the responsibility of Baasel Lasertech.

Baasel Lasertech is also responsible for the laser micro business. The product spectrum comprises among others: - lasers and laser systems for precision welding, precision cutting, micro structuring and micro drilling.

According to Thomas Merk, CEO of Baasel Lasertech, Baasel's established access to the micro technology market has provided them with very good contacts for polymer welding; in the medical device, electronics, automotive, tool and mold making industries, for example.

Background to polymer welding

Laser welding is a relatively new joining technology for thermoplastic polymers. Its advantages over conventional welding methods include:

- superior optical quality of the weld
- non-porous surface quality
- minimal surface contamination (no crumbs)
- minimal thermal stress of the component
- high tear resistance of the weld

Almost all industrial laser welds are realized according to the overlap principle, in contrast to the welding of metals where butt-welding is equally significant.

In overlap welding of polymers, the upper cover layer is transparent to the laser beam and the lower layer is absorbing. As the diode laser wavelength is outside the visible range (400 – 700 nm), there is, in principle, no restriction (opaque, coloured or clear) on the visual appearance of the upper and lower layers and developments of different kinds of polymers are under active consideration. In the case of optically non-transparent components the weld seam, which forms inside the material is invisible.

There are currently four different processes for laser welding of polymers: contour welding, simultaneous welding, quasi-simultaneous welding and mask welding; of which contour and quasi-simultaneous welding are the most popular.

Contour Welding means that the laser moves over the welding contour via an axis-system or a robot. In this case, the compact design and fiber coupling of the diode lasers are outstanding advantages. The technique allows welding of components of almost any size, but gap tolerances between the parts to be welded have to be maintained.

In quasi-simultaneous welding the laser beam is moved rapidly over the workpiece several times using scanning mirrors. The welding path heats up gradually and evenly, so that a quasi-simultaneous melting of the entire welding track occurs. The disadvantage of this technology is that a considerably larger laser power is required in comparison to contour welding; quasi-simultaneous welding is therefore best suited for smaller components with shorter welding paths.

Dealing with Laser Generated Air Contaminants

Jon Young

Purex International LLP

Purex House Farfield Park Manvers Rotherham S63 5DB www.purexltd.co.uk

T: +44 1709 763022 F: +44 1709 763001 E: jon.young@purexltd.co.uk

Laser Generated Airborne Contaminants (LGACs) is a term used for the dust and smoke that is generated when a material is processed with a laser. Lasers are increasingly used to mark, etch, cut and weld a wide variety of materials, and coupled with the right fume extraction system they deliver excellent results. Fume extraction is required for most laser operations in order to protect personnel, but it can also have the added benefit of enhancing the performance of the laser process. It is therefore of paramount importance that the correct fume extraction system be specified.

What happens during laser processing?

The majority of laser processing involves removal of material. This material, in the form of solid particles, vapour and/or droplets, possibly swept up by the heated and rapidly expanding ambient gas (air) expand, travels at high speed and preferentially normal to the workpiece surface, which is generally the direction of the focusing optics, see figure 1.

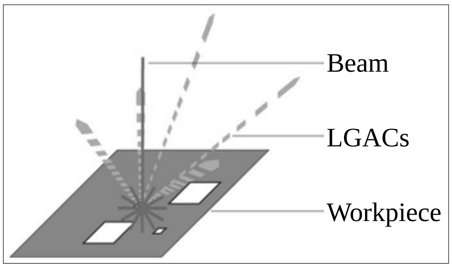


Figure 1: The material removed during laser processing preferentially travels normal to the workpiece, which is generally the direction of the focusing optics.

LGACs may include a variety of vapours, some of which may be noxious (e.g. benzene, phosgene during the processing of some plastics), together with the solid (small particle) products of complete and partial combustion, which may include some toxic oxides (e.g. chromium and nickel oxides from stainless steel).

In addition to safety concerns, airborne particles can cause problems for the laser if they are allowed to be deposited on the lens or remain in the processing area, causing beam distortion and attenuation, see figure 2. Deposition of particulates within the laser enclosure can contaminate the product and creates the need for regular cleaning of associated equipment. The only practical method of overcoming the above problems is to remove airborne contaminants as quickly and completely as possible by the provision of an efficient fume extraction system.

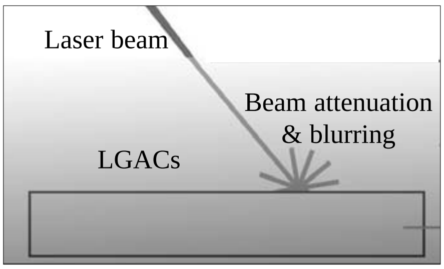


Figure 2: In addition to contamination, LGACs can cause beam attenuation and distortion

Purification system design

The range of materials that are processed with lasers is wide and varied so if flexibility is required then the purification system must cope with a range of volumes and types of contaminants.

Airflow rates of between 80 and 5000 m^3/hr will ensure the correct level of extraction from most laser processes. The optimum rate depends on many factors as does the shape and location of the extraction nozzle or enclosure. These aspects of specification and design are best left to an experienced professional.

Filters are the main purification system consumable and one method of prolonging the life of a main filter is to use a pre-filter to remove larger particles (> 1µm) from the air stream. These are supplied in different forms, ranging from pads to bags to a patented concertina design that, due to its larger effective surface area, offers around 10 times the life of a normal pre-filter. Pre-filters are made from a variety of filter media and it is vitally important that the correct type is specified by the supplier, otherwise the life of the main filter may be significantly reduced. This is especially true if the material that is processed releases oily or sticky particles.

Many purification systems work on the “top down” filtration principle, which has been proven not to offer the best filter life and may cause filters to split. A filter for laser processes generally contains HEPA (High Efficiency Particle Arrestor) media to filter out harmful particles (99.997% at ≥0.3µm and 95% at ≥0.01µm) plus a chemical layer to filter vapours, and in the low pressure, “top down” purification systems the contaminated air enters the purification unit at the top and takes the path of least resistance, straight down through the filter at a high velocity, see figure 3a. Only part of the HEPA and chemical filter media is used in this way and the contaminated air is allowed to pass through the filter too quickly. Both of these factors lead to reduced filter life and particles can also collect in the pleats of the HEPA media, possibly causing it to split, especially if the particles are moist, releasing hazardous material into the workplace without the operator’s knowledge.

A solution to the limitations of “top down” filtration is found in the Reverse Airflow Principle shown in figure 3b, whereby the contaminated air has to slow and turn through 90 degrees when entering the purification machine. This action causes larger particles to drop out of the air-stream, thus preventing premature filter blockage, and particles can no longer collect in the pleats of HEPA media, because the air is travelling upwards. Air equalisation plates containing an array of holes with a combined cross sectional area equivalent to that of the pump air inlet, used in conjunction with the reverse airflow system, cause the air to slow to the speed at which the filter media is most effective and ensure that the full area of filter media is used. Such plates also increase the rigidity and security of the filters themselves.

Some materials release corrosive vapour when processed with a laser, for example, PVC produces hydrochloric acid vapour, which coalesces inside the purification machine. In "top down" systems, the liquid HCl can travel through the filters and may collect on the electrical wiring and the motor below, causing corrosion and a possible fire risk. Reverse airflow systems on the other hand, allow the acid to drip onto an absorbent pad where it can be safely dealt with, see figure 3b.

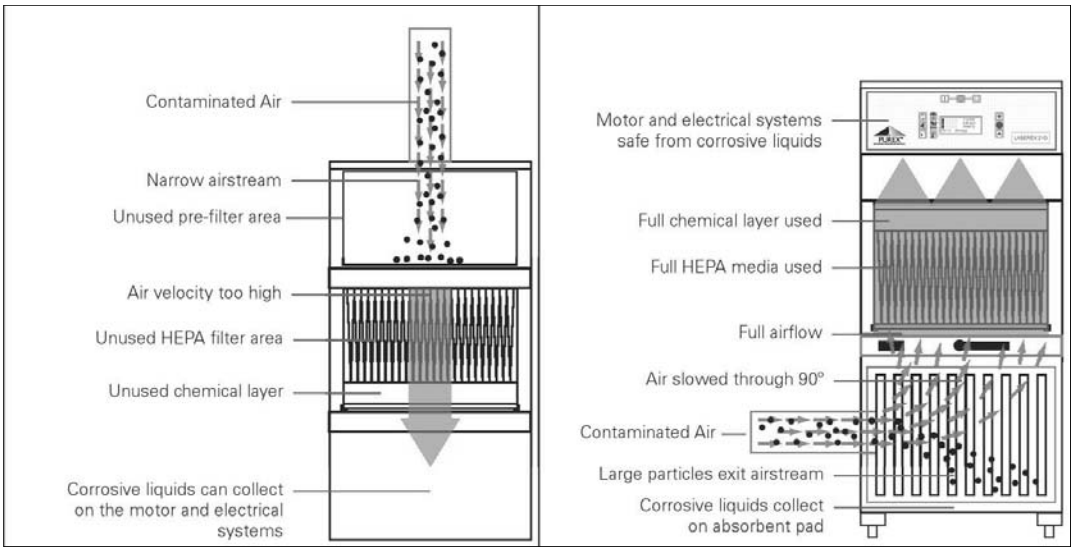


Figure 3. Designs of purification systems. (a) top down and (b) reverse airflow, pointing out the benefits of the latter.

Another method of greatly increasing filter life is to utilise high-pressure pumps that are able to overcome the resistance in a filter as it becomes blocked, extending its useful life for far longer than a low-pressure system is able to. In such cases, reinforcement is needed between the pleats of HEPA media to prevent them from splitting.

Health and Safety

To aid preventative maintenance and ensure the provision of a replacement filter when needed, a pressure monitor should be employed to alert the user when a filter is nearly full. However, the pressure sensor alone would not alert the user if (i) a filter is ruptured or otherwise damaged, (ii) there is no filter fitted, (iii) a seal is broken or (iv) the chemical layer that filters out noxious gases is exhausted.

Although the use of reinforcing guarantees that filters do not split and a pressure sensor indicates when a filter is full, it is vitally important for the exhaust of any purification system that re-circulates air into the workplace to be constantly monitored. Many commercially available laser fume purification systems rely on the operators nose to tell if a filter is blocked or there is a problem with the system. Automatic gas sensors should be used to identify if a chemical filter is exhausted and particle sensors should be employed to ensure that the operator is alerted if, for example, a filter has not been fitted or it is damaged and is allowing hazardous particles to pass through. If these monitoring systems are not in place, conformity with the COSHH regulations will be prejudiced and the user's health is at risk. Such purification systems should also be annually certified by the installer and be well maintained to ensure compliance with the COSHH regulations.

Helping the environment

Perhaps the first thought of many is to vent contaminated air from a laser process out to atmosphere. This method of extraction is not environmentally friendly and there are regulations that govern what and how much can be released into the atmosphere. Apart from regulations, it costs money to heat a factory and venting the warm air to the atmosphere can represent a considerable energy loss and may therefore not be economical. Furthermore, external venting does not usually offer precise control of airflow rates: if the rate is set too high then small components can be sucked into the pipe-work and if set too low, then LGACs can escape into the workplace.

In a modern production environment, it is necessary to build flexibility into production lines, so that the lines can be moved as the factory grows or the production emphasis is altered. Vent to atmosphere extraction requires extensive, fixed pipework that should not be moved, since it can harbour contaminants, without first cleaned up and made safe. Also, planning permission is often required to cut holes in the factory roof or walls and these holes must be sealed again if the pipe-work moves! This lengthy, expensive process interrupts valuable production time.

A re-circulating system avoids any regulations that govern external emissions. Purified air is returned to the workplace in virtually the same conditioned state/temperature, as when the air entered the machine, therefore air conditioning costs do not rise. Vacuum levels can be set and altered easily for each individual process and most systems can be easily moved, should the process move. Altogether a re-circulating system is much more cost effective, flexible and environmentally friendly than an external system.

Closed loop flow control

The air resistance of the filter increases during its life, and the optimum motor speed increases accordingly. A closed loop flow control system can automatically adjust motor speed to provide a constant extraction rate throughout the life of the filter with a variance of less than 1%. By contrast, with a motor of fixed speed the extraction may either be correct when the filter is new but not cope adequately as the filter becomes blocked or be far to high while the filter is new, which leads to reduced filter life. Another benefit of flow control is that energy usage is kept to a minimum, a particularly welcome benefit in view of the climate change levy.

Summary

Fume extraction and purification is not simply a matter of buying a pump in a box; it requires careful thought when specifying any system. The performance, economic features and benefits offered by a good unit can, and do, outweigh any minor increase in the initial capital cost of the equipment, especially when compared with the overall cost of the laser system.

The rising cost of insurance

One of our members, a supplier of laser equipment, has recently expressed concern at the sudden skyrocketing of their employers public liability, service indemnity and product liability insurance. Certainly there have been rapid rises in industrial insurance rates, a reflection of an increasingly litigious population. Added to which, some insurers regard anything to do with lasers as dangerous and quote totally unreasonable rates. We asked our members about their experiences and, in particular, if they have any advice on how to reduce their premium. We had a good response to the enquiry and here we summarise their replies.

The majority opinion was that the recent rises in insurance premiums are high and across the board. More than ever, premiums represent a major cost to a business ("...our premiums are more than phone, electricity and rates combined..."). The insurance industry has taken some big hits recently and some members suspect that 'must have' insurance is regarded as an easy target for increases. ("..the insurance industry also seems to have taken a renewed interest in risk and any uncertainty or misunderstanding is a reason to put up the premiums first and talk later..."). One member pointed out that the variation in insurance requirements around the world is inconsistent resulting in some countries being able to produce cheaply.

Members report that many insurance companies do not understand the practicalities of the laser business, assessors seem incompetent when it comes to understanding the risks posed by lasers, which certainly seem to create the perception of high risk ("...we have found it impossible to obtain insurance when the term 'laser beams' was mentioned and we are having to use clients' company insurance for cover..." "...we have agreed a figure of £23,887 for the 12 month period Jan-Dec 2003. Other quotes were £86,000 and a whopping £132,000, and several companies would not even quote!...")

The way forward

Some suggestions by members include:

- Encourage manufacturing trade organisations to get together and voice their objections to some of the insurance regulations and the premiums charged.
- Go for a group policy. We understand that the EEF (Engineering Employers Federation) may team together for insurance quotations.
- Insist on a site visit by a risk assessor before setting the premium. During the visit, try to work with this person to gain a proper perception of the risk.
- Get a good insurance agent, one who will understand and work with you, and who is known, respected and trusted in the market.
- Be prepared to be honest and open about the risks and the management of those risks. Prepare a few pages of description of risks and the steps you undertake to minimise those risks. Your agent can pass this information on to insurance companies.
- Be prepared to argue back through an agent, possibly offering them retention of the whole portfolio of your insurances (for buildings, contractor's third party liability, travel, car insurance etc) in return for a limited increase in your employer's and product liability.

Possible key submission phrases to use in any description of activities and risks include (mainly for job shops):

- Lasers are not dangerous things.
- We do not design the product that we make.
- The things we do make are very simple and compliance (e.g. material specs) can be easily proved.
- Most of what we make is fabricated, assembled or generally mucked about with by our customer.
- If things end up in America, it is sold there by a larger (and richer) concern than ours (and therefore would be the target of any litigation).

More disjointed jottings

Define your objective

Peter Charnley

RE Cooke & Son (Burton) Ltd

Several years ago now I set about studying, part-time, for a post graduate qualification in business studies. Quite apart from the fact that this was hard work, (I kept reassuring myself about that link between pain and gain), it was also extremely satisfying. Not just because of that inner confidence that comes with enhanced knowledge, nor even the sense of achievement. What I found really satisfying was the commitment to learning across the whole of my student group.

Without exception, each student was enthusiastic and keen to get involved in active and lively debate. There was a definite synergy, and we all tapped into it. What impressed me particularly was that these were adult women and men from a wide cross-section of business disciplines including production, engineering, commercial, sales, marketing, personnel and financial. This wide knowledge base was systematically employed to the benefit of the group. There was no politics, just a genuine wish to achieve a common goal.

But my own experience in the world of work made me doubt if this same, diverse group of people would be equally committed to cooperating within their "teams" back at work. It seems to be a universal truth that there are tribal splits in the work place. "Sales" and "Production" are the classic cat and dog combination. The poor old "Finance" team are seen as the party poopers etc., and each functional grouping seems to have its own special agenda. Each group competes for available resource and each believes that it alone sees the "true" picture.

You know the sort of scenario: "Sales" brings in a great new order, which has been won on the basis of a quick delivery. "Production" says that it can't possibly achieve the delivery without laying on extra shifts at premium rates. "Finance" feels compelled to point out that these extra costs will result in the job being manufactured at a loss. In between all of this, senior management are trying to meet bigger, strategic targets and simply haven't got time to get involved with routine operational bickering.

So why on earth can cross-functional teams work so well in a student/learning context, but revert to type in the context of the workplace?

Define your objective. I think that the answer is simple: clarity of objective and open communication.

Consider those MBA students for a moment. Their objective was to obtain a degree. (Each student shared the same objective, surely?) Since this objective was clearly understood, the team's effort towards a common goal was quite natural. A strategy of co-operation pretty well defined itself, because it was the easiest way to reach the objective. Communication in an open classroom is very simple too; no need to post notices, have meetings or send out memos.

There is no inherent reason why cross-functional teams cannot cooperate to the general good of the company, so how can we achieve the same level of enthusiasm and cooperation within the workplace? Drawing from experience, I'd cite the following as the key principles to start to obtain better working cooperation:

Define your business objectives – not as easy as it sounds! The MBA students wanted their degrees; no room for equivocation there. Do you want a bigger turnover? A bigger profit? Both? Are any of these objectives really achievable or perhaps mutually incompatible? Can you finance a bigger turnover right now? Have you modelled the impact of increased overhead costs on your bottom line? It may be that you think that better profitability will come from increasing your prices – but will the market stand them? Or perhaps you feel that the bottom line can be improved by increasing productivity: OK, but how will that be achieved? And how do you quantify the improvement in productivity that can be achieved without capital expenditure?

Or perhaps a widening of the product range? OK, have you researched the market? Never underestimate the value of market research. Not too many years ago, 35mm film sales had an enviable year-on-year sales increase. The market was clearly booming and on the face of it investment in a new production plant wouldn't have seemed silly. But with the advent of digital cameras, film sales are falling fast. Perhaps the investment wasn't so clever after all!

It should be clear from the above that defining your objective(s) needs to be much more precise than a broad brush statement. To make it understood by everybody, your objective has to be quantifiable and achievable, with very clear boundaries. It also has to be measurable: how else will you know if you're on target?

Communicate your strategy. Once you have determined your objective(s) and strategy it needs to be communicated throughout the business. This allows all the functions to prepare to work to the common goal. And then there must be measurement of key aspects of performance against the plan, which must be communicated too.

Be prepared to change things. Objectives and strategies must be flexible and realistic because things outside your control will change. If you set things in stone, it's a recipe for problems ahead.

In summary then, my contention is that if all the players in the company know where the goal is, there's a good chance of a team effort towards success. Well, speaking as a salesman, I suppose that you can anticipate that the production department will let you down – no change there then!

E-Mail: peter.charnley@recooke.co.uk

Food for thought.....

Applications for laser metal powder deposition

Hugh Bisset

Laser Process Solutions

932 Forks Of The Credit Road Belfountain Ontario L0N 1B0 Canada

T: +1 519 927 5813 F: +1 519 833 2904 E: hhbisset@aol.com

The applications market for laser metal powder deposition (LMPD) processes is still a matter of discussion, with only a few application areas forging ahead (see 'Food for thought' in Issue 29, p24, December 02). As usual, the question of time and cost is all important in the increasingly tight market place.

Repair of turbine blades

One thing that is clear is that gas turbine blade repair in the aerospace sector is currently showing the greatest potential for utilisation of LMPD technology.

Turbine blades wear at the tips and when ready for repair they require to be built up in length by about 1 to 2 mm, and of course the wear is never even. This is not a new problem technically, but with the cost and delivery of new blades remaining prohibitive, the shear volume of repair is driving the development of a new cost-efficient method. New designs and the use of blisks in engines also spurs this effort. (A blisk (integrally bladed disc) combines the rotor and blades in a single piece, in contrast to the removable blade design that has been used in the past.)

Repair methods used to date have involved arc welding, with tungsten inert gas (TIG) and plasma arc welding (PAW) being the preferred techniques. They all involved using excess build up and then machining back to the correct contour. With laser powder cladding it is easier to come closer to the original contours and reduces cost on the basis of faster build up and less post-process machining. Huffman Corporation in the USA has for many years produced good equipment for laser powder cladding with the five axis capability that is needed for blade repair. The aerospace industry took a long time to issue the necessary paperwork to allow laser repair procedures and there are more developments to be completed before full acceptance, but with this being in hand the process is becoming more attractive for investment.

MTU Aero Engines in Germany has a registered process called LPAiK, which is a form of laser powder cladding but involves enclosing the worn tip in a mould to reduce time in build up and post machining. Whilst this goes a long way to solving the problems of tip build up it is not the complete answer. The remaining problems are how to accurately measure the blade damage/wear and how to accurately laser deposit the powder to the net shape of the blade.

The first step in assessing blade damage/wear is to determine if the Z notch is worn. If it is, then this is the first repair. To do this the blade is mounted in a jig in a CMM system with a laser measuring head, and loss of material is plotted in all planes. The blade is then set up accurately in the laser deposition system and the material deposited to the net shape except in length, which will be slightly greater, to allow machine grinding to length. The illustration provided in my previous feature (Issue 29, p24) shows the high quality finish that can be obtained with the powder deposition process. The technique will have to be developed to meet the demand for cost-efficient repair of new generation blisk technology and is being actively researched and developed in Canada. A general comment at this juncture might be worthwhile: whereas the general thrust of LMPD is to lay down as many lbs/hr as possible without heed to quality of finish, turbine blade repair is one of the cases where this is not the answer.

Aerospace alloys

The other main thrust in the aerospace industry is the large scale deposition of titanium and its alloys. This has come about by the active research funding policies of the US government in laser deposition of metal powders. The basic research carried out at Sandia Labs is being commercialised by Optomec while at the same time the laser deposition work at ARL of Penn State University was willingly accepted by MTS Systems Corporation, which in late 1997 formed a subsidiary called Aeromet Corporation to exploit direct laser deposition under the title of Lasform. The object of this process was to manufacture large scale titanium components for aerospace use. This in turn led Lockheed Martin into the business of large scale deposition.

The main interest in this type of technology is one of cost control, rapid manufacturing techniques and the ability to integrate components such as ribs and offer the possibility of local graded metallurgical structures. At this scale there has to be direct government funding to get the process into industry. It is interesting to note that Liverpool University developed its direct laser casting (same process - different name) in the same time frame.

Repair of cutting dies

One of the other areas in which LMPD is evolving is in the manufacture/repair of cutting dies, also illustrated in my previous feature, which can take one of several design forms, depending on the end product. One is the rotary die shown in the last issue of this magazine, where the width of the die is made to match the width of the paper stock and the diameter is dependent on the step and repeat pattern: the overall size is limited only by the size of the deposition chamber and the CNC system. The core is made from tool steel, which is hardened and ground in order to provide a good surface for deposition, and the die rule material is a specialty alloy which has the capability of holding its ground edge.

Dieboard manufacture

Flat dies for cutting and creasing materials such as cardboard are made using the same technology but the base is made from hardened and ground plate instead of thick plywood. Dies of this type are made for cutting printed stock, labels, cards, plastic films ,rubber and cardboard. This is not a well known sector of industry and tends to be overlooked, but in most countries it has a surprisingly high monetary value and tends to have a relatively high profit margin due to its rapid turnaround time requirements.

Injection mould tools

The use of LMPD technology for producing or repairing injection mould tools is another active application area. The main interest is in creating integral cooling channels within the mould, in whole or in part. The comments made in the earlier section dealing with the repair in gas turbine blades are applicable here.

In injection moulding the cycle of events is as follows: close mould, fill mould, pack and hold, cool part and eject. The cooling part of the cycle can account for up to 44% of the cycle time and it has been shown that 33% of this can be saved. A reduction in scrap due to fewer sink marks has also been found.

Using the LMPD technique to produce dies can have a real productivity benefit. The use of copper or brass for cooling has been shown to be successful and it is also possible to incorporate a transition layer between the copper and the alloy of the mould or insert. The main thrust in this field has been made by Precision Optical Manufacturing of Michigan USA. This is a distinct step forward from using SLS in that direct metal deposition will develop the full mechanical properties in the deposited material.

Prostheses

Titanium is of particular interest for surgical implants, mainly because of its uniquely high strength to weight ratio and its anti-corrosion properties towards blood. It is used mainly in hip and knee implants, where the number of these implants between now and 2005 is estimated to be 450,000 in the USA alone.

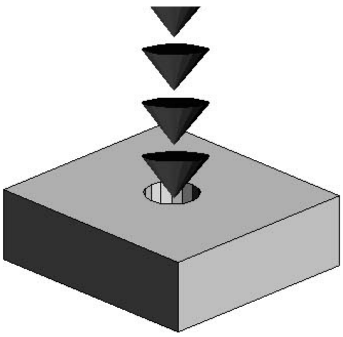
Thanks mainly to the strong aerospace interest, a main thrust of LMPD development has been towards titanium and its alloys. The concept of grain direction control, which is possible in LMPD only made it more attractive for the manufacture of implants and the possibility of creating controlled surface finishes is appealing. It has been suggested that short pulse and short wavelength lasers could produce surface dimpling in the order of 3-5 microns, to aid bonding. The coating of implants with hydroxyapatite using laser pulse deposition (LPD) has been found to yield good smooth coatings in the order of 1-3 microns and such coatings are now being offered by a company in Germany.

Other types of implants are now being considered (especially as coatings and other add-on processes become more available) and the direct manufacturing of parts, using LMPD to deposit such high strength materials as tungsten, tantalum, rhenium and molybdenum on titanium and stainless steel alloys, in a variety of combinations for surgical use, is being pushed by funding bodies in the USA.

? QUESTION & ANSWER

Effect of focal length on hole drilling

In Nd:YAG laser percussion drilling, what is the effect on hole shape and metallurgy when increasing the focal length from 100mm to 200mm whilst keeping the same unfocused beam diameter of 15mm? I realise that the power would have to be increased to achieve the same power density due to the increased spot size.



When the focal length is increased from 100 mm to 200 mm, the beam spot size will be doubled. The power density will therefore drop by a factor of 4 and so the peak power will have to be increased by a factor of 4 in order to achieve the same power density.

Assuming that the increase in peak power can be achieved then the hole size will be more than doubled, the taper will be reduced and the hole circularity improved and the amount of recast will be less.

If, as is more likely, the laser cannot achieve a four-fold increase in peak power then the pulse length will have to be increased in order to achieve the same drilling rate. As a result, the hole size will be more than doubled, the recast layer will be thicker, the taper will be increased and the repeatability of the process will get worse.

Lin Li UMIST.

Blind holes in quartz

Is it feasible to laser-drill blindholes in quartz? We are interested in holes of approximately 0.7 ± 0.03 mm to a depth of 5.0±0.1 mm.

Drilling quartz with a CO_2 laser is a possibility. In the past I have successfully drilled smaller holes with a sealed CO_2 laser. There is a little debris left but this can be wiped away. The problem is that for this diameter of hole trepanning would normally be used but blind trepanning is probably out of the question.

Geoff Shannon Unitek Miyachi Corporation

You might like to consider using a TEA CO_2 laser. Similar work to this has been done in the past so it should work after a few trials, enough samples and some special optics. The big question is what throughput do you want to achieve?

David Bodsworth Alltec Lasers

Industrial femtosecond laser systems have demonstrated capability for fine machining in glass and other transparent materials. The process is ablative and the holes would be drilled with no thermal damage.

Andrew Turner BFi OPTiLAS Ltd.

A lesson in laser guarding

An AILU member reports a serious near-miss

The laser damage shown opposite occurred in an 8mm thick polycarbonate panel of a laser cell in which a 5-axis CNC 1800W CO_2 laser is used to trim pressed panels. The burn corresponds to an exposure of a few tens of seconds and the laser processing was taking place some 2m from the panel. If the machine had been left unattended the beam would certainly have been released into the factory.

The burn occurred as the direct result of the operator deciding to use copper strips to prevent the location jig from getting cut, but in so doing they produced the errant beam that caused the damage.

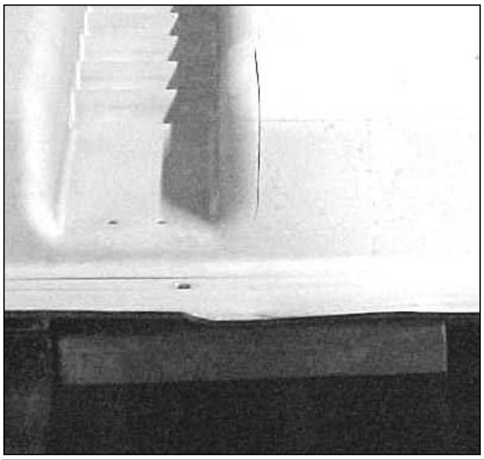
The Laser Safety Officer reports that at the time the cell was constructed he did review 60825-4 'Laser Guards' and, as part of the Factory Acceptance Test, sections of the guard were tested under worst case foreseeable exposure conditions, against the advice of the cell supplier. "At the time all of our potential suppliers were claiming that passive polycarbonate guarding was the accepted industry norm, even for multi-kW lasers," he said.

"During the acceptance tests, samples of the window and booth were put on the cutting bed and illuminated at what we estimated to be the Foreseeable Exposure Limit (FEL). With no guidance from 60825-4 on specific exposure durations, we decided to run for about 3 minutes. However, the test had to be limited to 12 seconds as a result of fume and smoke that completely filled the booth (the cell was under construction at the time so there was no fume extraction), at which time the panel had not burned though but had received some superficial damage. It was clear at the time that laser safety under worst foreseeable fault conditions was highly dependent on the vigilance of the operator, who was to view the process continuously and not leave the machine unattended. This was included in our job approval procedures."

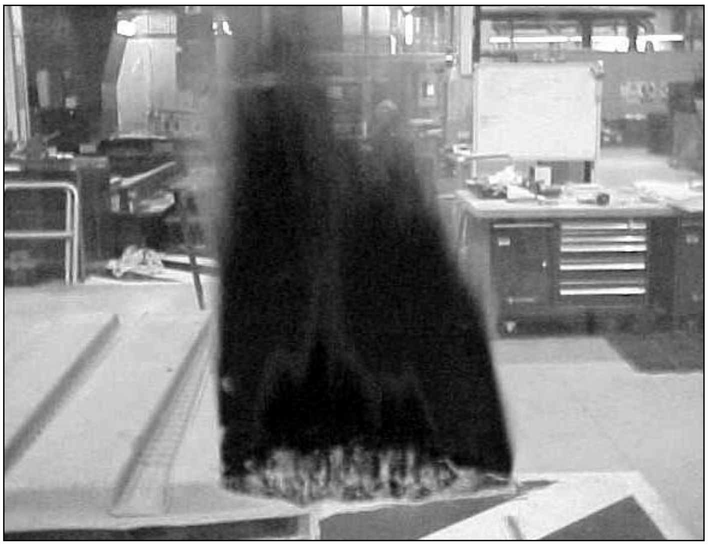
In hindsight it is easy to conclude that the operator should have anticipated the dangers of using copper as a screening method and should have been more vigilant in monitoring the condition of the guard during trials, but it remains true that:

(i) human monitoring is not reliable, especially for large enclosures.

(ii) Laser guarding requirements are much more severe for cells designed for multi-axis laser processing than for the more common 2-D processing.



The culprit. The edge of a protective block of copper can be seen underneath the laser-cut panel.



Close shave. Laser burn mark on polycarbonate screening

EN 60825-4 'Safety of laser products - Part 4: Laser Guards' requires that a risk assessment be undertaken to assess the FEL for the laser guarding. It is quite common to assume that an errant beam could have the full output laser power, especially in a situation like the one described here where the 5-axis machine is not dedicated to a single specified task.

This incident would seem to support the general recommendation not to use simple panels in 5-axis machines, except under close process monitoring, unless a sufficient passive protection time at the FEL can be achieved. Active guarding of the more vulnerable areas of the enclosure should also be considered.

The forthcoming amendment to EN60825-4 will recommend exposure durations for the testing of proprietory guards of 30,000s for automated machine applications, 100s for machines with short cycle operation and intermittent inspection and 10s for machines under continuous inspection by observation. This incident clearly underlines the unreliability of human monitoring and justifies the approach of the 60825-4 standard not to permit human monitoring as an acceptable means of meeting the requirements for Class 1 operation.

"The whole incident has been a real eye opener for us, and the fact that unauthorised and untrained operators were running the machine at the time of the incident has brought home to us the need to be vigilant in implementing administrative controls, including operator training and procedures for restricting laser use inside the cell," said the LSO.

Back Issues

For more information on laser guarding see:

A new standard: EN60825-4 laser guards
M Green, 10, 25, Feb 98
http://www.ailu.co.uk/membersonly/magazines/1025.pdf

Applying laser welding to heavy engineering
Alan Thompson 22, 18, Mar 01
http://www.ailu.co.uk/membersonly/magazines/2218.pdf

Current status of the laser guards' standard
Mike Barrett 22, 32, Mar 01
http://www.ailu.co.uk/membersonly/magazines/2232.pdf

Cutting 50mm plate with 1 kW of CO_2 laser power

Jack Gabzdyl[a]*, Wayne Penn[b], Pat Cahill[c] and Justin Koch[d]

a **BOC Ltd UK** 10 Priestley Road The Surrey Research Park Guildford GU2 7XY
b **Alabama Laser Systems** 55 Laser Blvd PO Box 55 Munford AL 36268 USA
c **Bender Shipbuilding and Repair Co Inc** 265 S. Water St Mobile AL 36603 USA
d **Caterpillar Technical Center** PO Box 1875 Peoria IL 61656 USA

*T: +44 1483 244629 F: +44 1483 244657 E:jack.gabzdyl@uk.gases.boc.com

Shipbuilding requires the accurate and consistent cutting of a large number of plate parts varying in thickness from several millimetres to over 100mm. As technology has developed, the hand-operated gas torch has given way to computer numerical control oxy-fuel systems, CNC plasma cutting systems on water tables, multi-headed systems on a single gantry, dry plasma, and, more recently, laser cutting. U.S. shipbuilding has recently adopted laser cutting as a primary method of steel plate cutting with the installation of two high-powered laser cutting systems (4kW and 6kW) at Bender Shipbuilding in Mobile, AL, and a 5kW system at Electric Boat in Quonset Point, RI.

Recently, Bender became the first company in the world with a production LASOX cutting system (see *The Industrial Laser User Issue* 29, p10) The process, in which an oxygen stream provides the cutting force while the laser merely preheats the surface of the plate, extends the cutting thickness beyond the 25 mm limit of laser cutting. This process complements traditional laser cutting and offers a single machine that can cut thin sheets to thick plates in excess of 50mm.

The demand for thick section cutting in shipbuilding

The laser offers a versatility that is unmatched by any other cutting process. In the context of the shipbuilding industry, the only gap in the laser's cutting capability is for steels over 25mm thick. This limit stems from the fact that as a narrow gap process laser cutting is constrained by both fluid and thermodynamics in thicker sections and hence a commercial limitation of 25mm is generally accepted. Cuts in materials up to 38mm have been reported but these are very sensitive to material composition and plate surface condition. The narrow gap can also give rise to problems in removal of parts from the plate skeleton.

Typical shipyard applications for plate parts greater than 25mm are limited, but are important parts of the vessels. The primary use of thicker sections is for main engine girders and foundations, and for other heavy equipment foundations and insert plates. The traditional process for fabricating a main engine girder is to cut the parts with an oxyfuel system, grind the slag of the edges and grind the kerf angle back to a flat surface, complete weldments in a machine shop or girder fabrication area, install the girder in the ship unit during a pre-outfitting stage, and then template and drill the holes for the mounting bolts. Drilling 12-24 bolt holes in 50mm steel plate is no small task, and is time consuming and expensive. The deslagging and grinding process is non-value added, but is necessary to obtain a useable part. A cutting process which can deliver a slag free part with a small kerf angle, and with holes cut rather than drilled, offers a tremendous savings in a critical ship construction process.

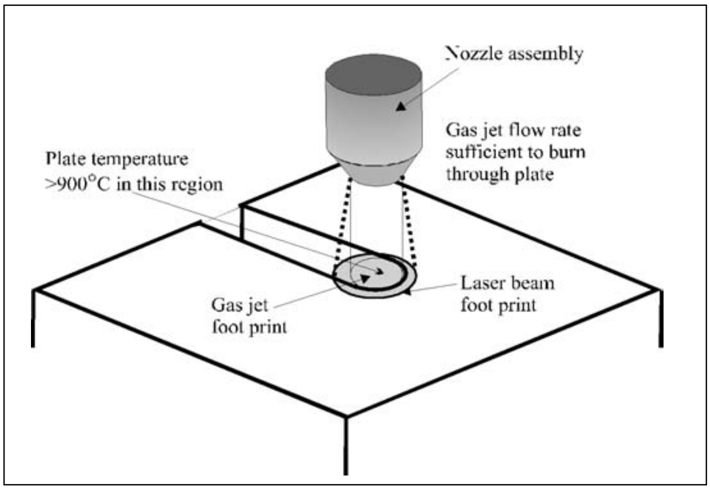


Figure 1. Schematic of the LASOX process. The process is coaxial with the laser beam passing through the gas nozzle. Using an appropriate optical arrangement, the diameter of the laser beam on the plate is made larger than the gas jet.

Laser Assisted Oxygen Cutting – LASOX

In the LASOX process the oxygen stream provides the cutting force while the laser merely preheats the surface of the steel plate. This process complements traditional laser cutting and offers the potential of a single machine that can cut thin sheets to thick plates in excess of 50mm.

In traditional reactive laser cutting the laser beam provides the governing input and the process efficiency and cut quality are a direct function of the key laser parameters. Use of an oxygen gas jet provides an important additional heat input from the exothermic reaction (see below) and removes the molten slag. However, the laser cutting process becomes increasingly sensitive to assist gas flow and pressure as the thickness of C-Mn steel increases, such that for 25mm thick plate a variation of ± 0.1bar can bring on a condition of uncontrolled burning, which manifests itself as fluting on the cut face. The narrow kerf width of the laser cut (<1mm even for 25mm thick plate) makes coupling the gas into the kerf and the removal of the molten slag increasingly difficult and this eventually compromises the stability of the process, creating an upper boundary in terms of thickness capability.

The LASOX process has more in common with the oxy-fuel gas cutting process than conventional laser cutting in that it uses the laser beam in a preheating capacity similar to the flame. The oxygen gas stream is the key process driver and the thermal input is dominated by the iron-oxygen exothermic reaction:

$Fe + 1/2\ O_2 = FeO \quad \Delta Hc = -257.58$ kJ/mol

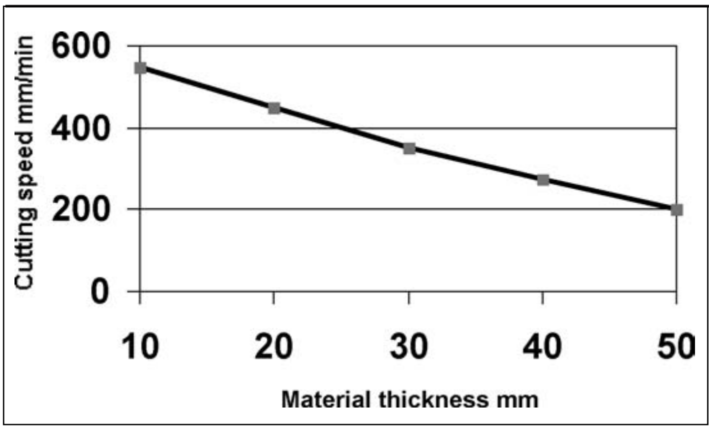


Figure 2. Cutting speeds achieved to date by LASOX process

Assuming complete combustion this amounts to 4600 kJ/kg, meaning that, for example, for a cut made in 40mm steel at 0.5m/min with a 2.5mm kerf, over 23kW of chemical exothermic power is available.

The LASOX process is illustrated in figure 1. The minimum laser power requirement for the process is dictated by the need to provide a surface temperature to in excess of 900 C over the whole of the gas jet interaction zone. This requirement can typically be satisfied using only 1kW of laser power. Additional laser power fails to give any benefits to the process in terms of productivity, in fact it can be detrimental leading to top edge melt.

Careful balancing of the laser energy input with the process requirements ensures that the oxidation reaction will be initiated across the whole width of the oxygen jet. Failing to meet this condition results in an intermittent and uncontrolled reaction with very poor edge quality.

The ability to profile cut is essential for any cutting process and the coaxial nature of the LASOX process means that its cutting performance is omni-directional and independent of the laser beam polarisation.

Cutting speeds achieved to date by LASOX process are shown in figure 2 and are comparable to those achieved with oxy-fuel. The width of the kerf is related to the nozzle diameter and is governed by the impinging jet diameter with values of 2.5mm being typically achieved in the 20-50mm thickness range. Taper is generally low at less than 2^{o} and the cut edge quality is similar to oxy-fuel with a smooth cut face from top to bottom exhibiting little variation in roughness through the thickness. The process does not exhibit the striation features that are characteristic with conventional laser cutting.

Figure 3. LASOX cutting in action

The key benefits that LASOX offers over plasma is the squareness of the kerf, while the main benefit over ox-fuel is that there is no need to preheat the plate before cut initiation which, in 40mm plate, can take over 20sec.

Producing thick section cuts in material thickness up to 80mm has been successfully conducted under experimental conditions; however, the process has yet to make the transition from the laboratory to an industrial environment.

Process integration

The National Shipbuilding Research Programme (NSRP) in the USA has sponsored a project to commercialise LASOX within the shipbuilding sector, moving it from laboratory to industry. The project involves the integration of the BOC LASOX technology with Bender Shipbuilding's 6kW Tanaka LMX III laser cutting system (see members news in *The Industrial Laser User* Issue 26, p5), the aim being to allow the operator to switch easily between laser and LASOX cutting on a single machine tool. Alabama Laser is undertaking this element of the project.

Key elements in the development project have been:

- Parametric process study
- Development of a robust LASOX nozzle assembly
- Cutting table modification
- Development of piercing techniques for >20mm plate

<u>Parametric study</u>

The LASOX process has been successfully demonstrated in several laboratories around the world, using a variety of CO_2 lasers. The results make it clear that the processing parameters need to be tuned to the laser being used. With this in mind, Alabama Laser carried out an extensive parametric study using their in-house 6kW Fanuc laser, the same laser used in Bender Shipbuilding's Tanaka system.

Key developments were made in optimising the optical arrangement to achieve the LASOX condition. Several iterations in nozzle design were made to arrive at an optimised nozzle-beam combination giving the widest range of operating parameters. Cutting routines were used to verify the stability of the process with laser on cutting times in excess of 5mins.

As shown in figure 3, a key feature of this process is the relatively high stand off distance compared with conventional laser cutting, which helps protect the nozzle from the high levels of infrared radiation from the cut zone.

An assessment has been made of the cutting accuracy and feature size that can be achieved in thicker materials. The LASOX process has demonstrated a capability in producing trepanned holes of less than 10mm diameter with tolerances of ±0.25mm, with minimal taper angle (see figure 4). Web widths as narrow as 3mm have also been cut in 40mm.

<u>LASOX nozzle assembly</u>

In order to achieve the integration of laser and LASOX cutting on the Tanaka system a robust LASOX head has been developed that can be readily exchanged with the conventional laser head.

Figure 4. LASOX cuts showing 10 mm diameter holes in 40 mm plate.

Cutting table modification

The Tanaka LMX III at Bender has an operating envelope of 4 x 45 m and the intention is to only apply LASOX cutting to a specific portion of the bed. Bender Shipbuilding's cutting table is of an extremely robust design and has been in use 24/7 cutting plates up to 30mm thick for three years. The table has a plate support structure in the form of a 150mm square grid of interlocked 12 mm thick slats. It has held up exceptionally well under the laser cutting process, but early concerns with the more destructive nature of the LASOX process have proven to be true during process development trials.

The destructive power of the LASOX gas jet was found to extend over 10 cm below the lower surface or the plate being cut. Placing plate directly on the cutting table proved highly destructive to the 12 mm slats and trial cuts demonstrated that a greater offset was necessary. In order to achieve this a support pin concept has been adopted, as shown in figure 5. The pins are made from 2mm box section with slots cut in them so that they can be slipped onto the nodes of the support slats of the existing table design. These pins are in effect consumable items that can be replaced as required.

These modifications can cope with the increased weight of the thicker plate and with the additional amounts molten slag that are generated by the LASOX process. The pins should be positioned to avoid the cut path and eliminate the risk of affecting the cut edge as the cutting process passes over. As can be seen in figure 5, if the pin is placed in the cut path, it will sustain significant damage.

Development of piercing techniques

Piercing thick plate generates a special challenge for conventional laser cutting. Current laser pulsed piercing techniques in 25mm plate can take up to 60 seconds per hole. However, regardless of the time factor, the amount of ejected material and the thermal intensity that the "splat pierce" process generates creates a significant risk of damaging the nozzle and laser head, particularly when low (<3 mm) nozzle standoffs are used. Cross jets have been used to blow away the ejected material with limited success.

With the LASOX process significantly higher standoffs are used, offering more room for the molten material to be expelled from the pierce zone. Rapid piercing in material thickness less than 40mm can be readily achieved using a rapid oscillating motion of the head to facilitate dispersal of the molten material in a radial direction away from the nozzle. This technique can achieve pierce holes in 40mm plate with typical top face diameters of 8mm and bottom face diameters of 4mm. Using trepanning techniques this can be widened to produce a hole of less than 10mm diameter.

Process benefits for Bender Shipbuilding

LASOX technology offers a low capital option of extending the process capability of the existing LMX III cutting system. The new facility allows Bender to cut all of their plate in house, thereby eliminating additional material handling and shipping and reducing lead times.

Rapid piercing of thick section steel is a key deliverable. Current pulsed piercing techniques used at Bender on 25mm plate can take up to 60 seconds per hole. We estimate that over a year, 100hrs of production time is spent in piercing, representing over $20k in lost production. Reducing the pierce cycle to less than 5s by using the LASOX based rapid pierce technique could save $18k pa.

The superior edge quality offered by LASOX and its ability to cut finer features that other thick-section techniques will provide a range of benefits including tighter nesting for improved material utilisation and the use of tab and slot techniques for reduced fit-up and assembly times. An additional benefit will be the possibility to LASOX cut "bolt holes" in thick plate that are currently drilled. This drilling process is time consuming and extremely costly.

Acknowledgments

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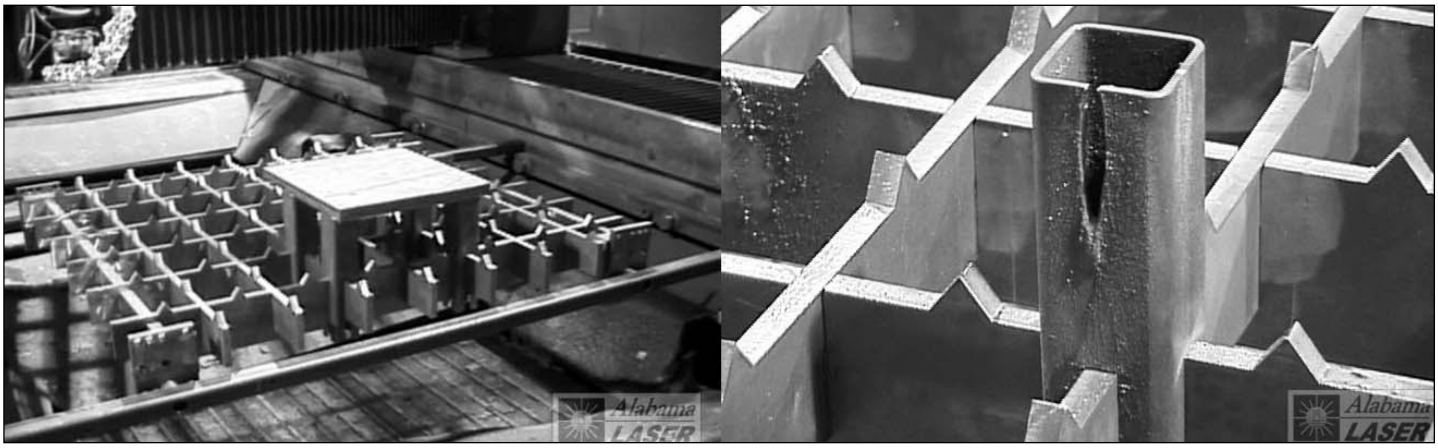

Figure 5. Box section table supports for LASOX cutting. (left) Pins supporting a part ready for LASOX cutting and (right) damage to a pin placed in the path of the LASOX cut.

Effect of steel composition on laser cut edge quality

Ariane Lugan, Paul Hilton and David Taylor*

Laser and Sheet Processes Group, TWI Ltd

Granta Park Great Abington Cambridge CB1 6AL

T: +44 1223 891162 F: +44 1223 890661 E: ariane.lugan@twi.co.uk

*now with JCB Ltd

It has been known for some time that material composition can affect the achievable edge quality when laser cutting. Steel suppliers have launched 'laser grade' steels, whose compositions and properties are designed to produce improved edge quality, cutting speed and reproducibility. Operator and machine effects can also influence laser cut edge quality. By conducting trials at a series of UK based laser job shops, using laser grade steel and trials in its own laboratory, using steels with a range of composition, TWI has attempted to quantify the effect of steel composition on the quality, in terms of roughness and squareness, of laser cut edges.

Factors affecting cut quality

The issue of laser cutting quality is complex, with a variety of parameters that can affect the process. Some of these parameters are:

- Variable laser related parameters - including power, speed, assist gas pressure, lens focal length.
- Fixed laser parameters - for example, laser beam quality or beam polarisation direction.
- Machine performance - such as focus position control or stability of motion.
- Operator influence - both at individual and company level.
- Material composition - such as levels of carbon, manganese, silicon, phosphorus and sulphur.
- Surface condition – such as mill scale and surface preparation methods.
- Material dimensional effects – such as flatness and material thickness control.

Greater understanding of the influence of the above factors should allow steel makers to supply steel plates with improved cutting characteristics, leading to greater consistency and reproducibility of the laser cutting process. To provide some of this understanding, a study of how the material composition and surface condition of carbon and C-Mn steels can affect the quality of laser cut edges has been implemented at TWI. Here we present the results of the work investigating composition, and the results of trials conducted at a series of UK based laser cutting jobbing shops.

Cutting machines have characteristics that can affect the quality of laser cutting. Laser parameters such as beam quality or pulsing capability can have a major impact on cut quality. In addition to the laser beam properties, machine characteristics, such as focal position control, motion stability and gas nozzle characteristics, also influence laser cutting quality. Although modern cutting machines offer improved process automation and control, the skill of the machine operator will have some effect on the laser cut edge quality that can be achieved through his control of the variable laser and machine parameters to compromise between cutting quality or cutting speed. The 'operator effects' described in this paper relate to how individual operators and laser job shops select these parameters to balance speed against quality and is an assessment of what is subjectively determined to be acceptable quality. Laser system operators affect laser cut quality at both an individual level and a company level, through the subjective determination of acceptable cut quality. This paper combines these two factors together and describes them as 'operator effects'.

Special 'laser grade' steels have recently been developed with compositions which are claimed to be beneficial for laser cutting. These 'laser grade' steels are steels generally marketed as providing improved cutting speed, quality and reproducibility. However, a lot of the evidence for factors that affect how well these steels perform is anecdotal, from end users and, more particularly, from steel suppliers who have launched 'laser grade' steels.

The Industrial Trials

A series of industrial trials were carried out using a laser grade steel of two thicknesses, 6 and 12mm. To attempt to quantify any variability due to machine and operator effects, five laser job shops were supplied with material and asked to reproduce a standard test piece. All lasers used in the trials were fast axial flow CO_2 lasers in the power range 2-3kW, some using RF excitation and some with DC excitation. The 6mm thickness material was selected to provide a wide processing window well within the capacity of the laser cutting equipment. The 12mm thickness material was selected because of its generally much narrower processing window, approaching the maximum thickness capacity of some of the lasers used. The cutting procedures and parameters used were not defined or monitored. The job shops were selected to allow three comparisons to be made of the variability between:

- three different operators using the same laser cutting machine.
- two different laser cutting machines used by the same operator.
- three different laser cutting machine/operator combinations.

The cut components were assessed at TWI to determine the laser

DIN 2310 standard'Thermal Cutting'. Parts 1-6, 1986.

The standard has two quality levels, I and II. In the DIN standard, edge squareness, u, is defined in Fig.1 and is measured in mm.

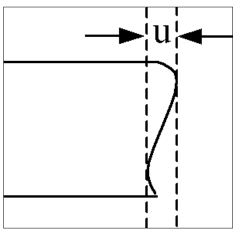

Figure1. Definition of edge squareness.

For a quality I cut in a material of thickness *a*, the maximum deviation *u* from cut squareness is given by:

$u = 0.1 + 0.15a$

where *u* and *a* are in mm.

For edge roughness Rz, the equation providing the limit for a quality I cut is:

$Rz = 30 + 3a$

where Rz is in µm and *a* is in mm.

The corresponding equations defining the limits for quality level II cutting are:

$u = 0.25 + 0.025a$

and

$Rz = 60 + 4a$

cut edge quality using DIN 2310, the most commonly used (qualitative) standard for determining laser cut quality (see inset box). The standard covers several aspects of quality, but only surface roughness and edge squareness are covered here.

Samples meeting the quality II levels can be generally classed as satisfactory cuts, with a good compromise between speed and quality. In general, it might not be expected to meet quality I levels unless this was a specified requirement, as this would often involve a slower cutting speed.

Work at TWI

Following this work at the job shops, a systematic investigation of plate composition was carried out to establish the importance of the various alloying elements on cut quality. This involved a range of 12 different carbon and C-Mn steel plates, all cut using the same laser parameters. The DIN 2310 standard was again used to establish cut quality, in terms of squareness and roughness, for these samples.

Table 1 lists the compositional range for some of the elements thought to influence cut quality, in the steels evaluated.

	C	Mn	Si	P	Mo
Min %wt	0.09	0.5	0.006	0.007	<0.003
Max %wt	0.14	1.39	0.48	0.024	0.016

Table 1 Composition range for the 12mm thickness steels studied.

Results

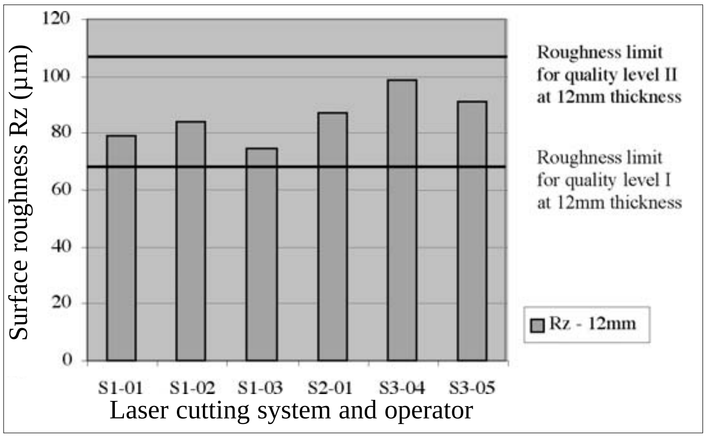

Figure 2 Laser cut edge surface roughness measurements on 12mm thickness laser grade steel. Results of the industry trials (cutting speed: 0.8m/min), with S1, 2 and 3 representing the three different laser cutting machines used, and 01, 2, 3, 4 and 5 representing the five different laser cutting job shops which took part in the work.

The industry trials showed a high level of consistency in laser cut quality between different operators and laser cutting systems. All samples easily met the requirements of DIN 2310 quality II for both 6mm and 12mm thickness laser grade steels, although only one job shop produced a class I roughness cut (on 6 mm thick material). Squareness results showed that it was much easier, at both 6 and 12 mm thickness, to achieve a quality level I cut. Typical results are shown in Figures 2 to 4.

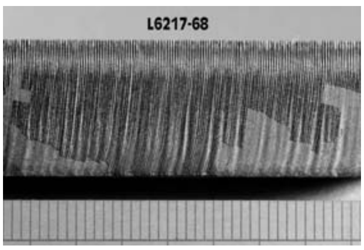

Figure 3 Typical edge quality on 12mm thickness laser grade steel at 0.8 m/min cutting speed.

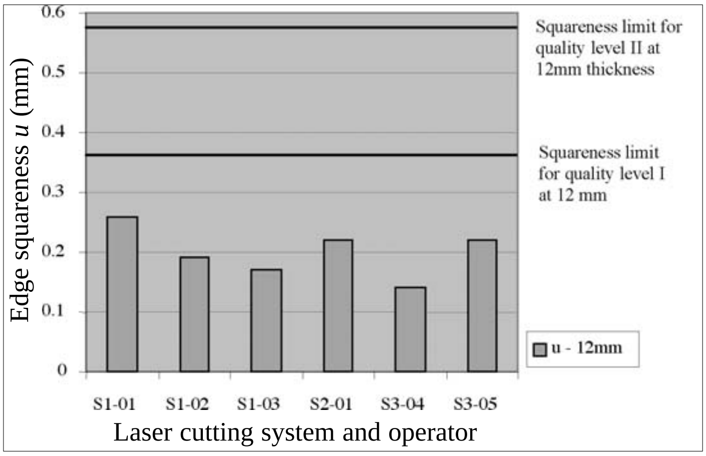

Figure 4 Laser cut edge squareness measurements on 12mm thickness laser grade steel. Results of the industry trials (cutting speed: 0.8m/min), with S1, 2 and 3 representing the three different laser cutting machines used, and 01, 2, 3, 4 and 5 representing the five different laser cutting job shops which took part in the work.

A summary of the surface roughness measurements made at TWI on 12 steels, each of differing material composition, is presented in Figure 5. Two of the 12 steels represented in this figure are marketed as 'laser grade steels' and these are indicated with a star in Figure 5.

The results shown in Figure 5 were all made with the same set of cutting parameters, at a speed of 0.8m/min, on the same equipment and, in all cases, using plates in the as-received condition, with surface mill scale. The range of the surface roughness measurements for the 12 steels was 42 µm and the range of the squareness measurements was 0.22mm.

Discussion

Table 2 presents a summary of the industrial trials for measurement of Rz and u.

The industrial trials included one make of laser cutting machine (S1) in three different job shops (01, 02, 03) and a second make of laser cutting machine (S3) in two different job shops (04, 05). In this set of results, for the 6mm thickness laser grade steel, the range in results, on either of these two types of machine, was 6mm for surface roughness and 0.04mm for edge squareness. For the 12mm thickness laser grade steel, the range in results for surface roughness was 10µm and for edge squareness 0.09mm. For both materials this represents a high degree of consistency and suggests that the individual operators/job shops had a limited effect on laser cut quality.

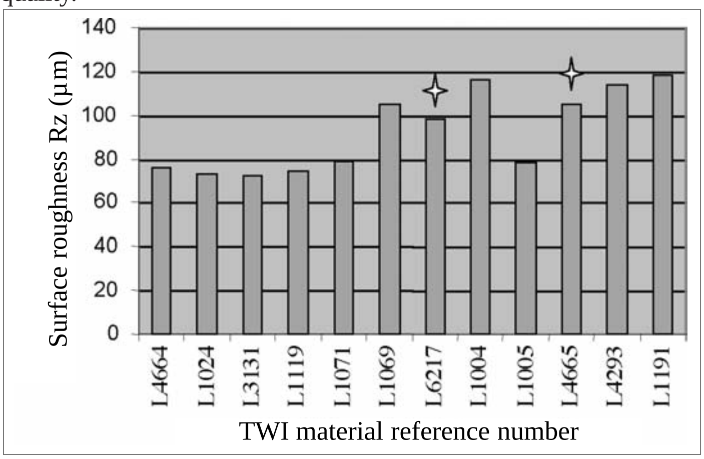

Figure 5 Surface roughness measurements on 12 mm thick C and C-Mn steels for the different compositions and surface conditions evaluated.

	6mm thickness material Rz (µm)	u (mm)	12mm thickness material Rz (µm)	u (mm)
System 1 Operator 1	49	0.09	79	0.26
System 1 Operator 2	43	0.07	84	0.19
System 1 Operator 3	49	0.11	74	0.17
System 2 Operator 1	59	0.13	87	0.22
System 3 Operator 4	50	0.09	99	0.14
System 3 Operator 5	50	0.12	91	0.22
Observed range of results	16	0.06	25	0.12

Table 2. Summary of industrial trials

One trial was carried out using the same operator (01) and different laser cutting machines (S1, S2). In this set of results, for the 6mm thickness laser grade steel the range in these results for surface roughness was 10mm, and for edge squareness was 0.04mm. For the 12mm thickness laser grade steel the range in results for surface roughness was 8mm and for edge squareness 0.04mm. This also represents a high degree of consistency between the two different makes of laser cutting machine and suggests that the machine also had a limited effect on laser cut quality.

Overall, the three laser cutting machines studied in the industrial trials and the laser system used at TWI for the final trials (not a commercial laser cutting machine), showed good consistency of results. Including the operator effects, all machines met the quality II requirements for surface roughness in both the 6mm thickness and 12mm thickness laser grade steel. All machines met the quality I requirements for edge squareness in both 6mm thickness and 12mm thickness laser grade steel.

The variations in roughness and squareness recorded in the industry trials (on the same material) can be seen in Table 2. For the 12mm thickness material, the range in all the results obtained was 25 µm for roughness and 0.12mm for squareness. These figures can be compared to the range of results obtained at TWI using the 12 steels of different compositions. The variations due to material composition are nearly twice those representing the combination of machine and operator variations. A summary of these results for the 12mm thick material is presented in Figure 6.

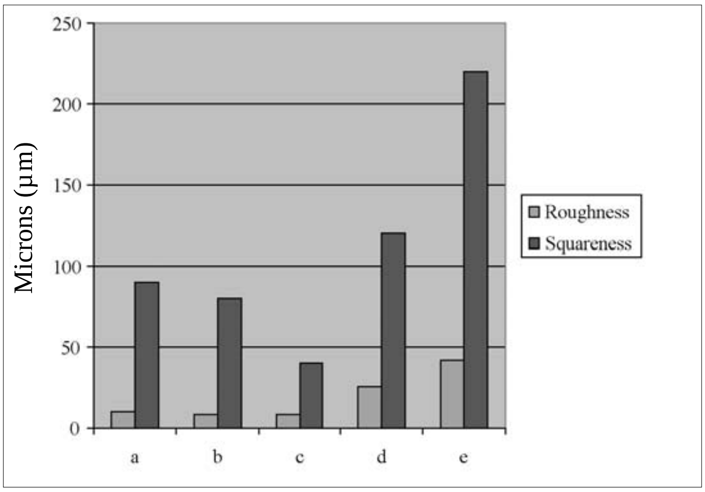

Fig.6: Variability of laser cutting edge quality due to operator, machine and material effects, on 12mm thick C and C-Mn steels.
a) S1, 01 to 03
b) S3, 03 and 04.
c) 01, S1 and S3.
d) Total range - all systems, all operators.
e) Range due to material composition.

In this work the laser grade steels did not always achieve higher quality levels than some of the non-laser grade steels in the trials. The results of the industrial trials and the trials at TWI showed that the laser grade steel did achieve good results with a range of laser cutting machines and operators. This could be a result of the wider processing window available with these steels. The results of this work (although not presented here) also confirmed that if cut edge quality is considered paramount, the silicon levels in the steel should be considered as an important factor in assessing the suitability of a material for laser cutting. Increasing silicon content was shown to have a positive effect on surface roughness and a negative effect on edge squareness. The silicon levels in the two laser grade steels used in these trials were 0.009 and 0.006%wt.

This work was designed to provide a practical guide to the effects of steel composition on laser cutting. In doing so it has raised a number of important issues that were not fully resolved. A greater understanding of chemical composition on the mechanisms of the laser cutting process would assist greatly in taking this work further and help to provide users with better information in the selection of materials.

Conclusions

The effect of material composition had a greater influence on overall laser cut quality, in terms of edge squareness and roughness, than the combined effects of the laser cutting machine and operator. The range in cut quality for a series of different material compositions was almost twice that found with the same material processed by different operators on different laser cutting machines.

Industrial laser job shops were easily able to meet the quality II requirements of DIN 2310 using laser grade steel of both 6mm and 12mm thickness.

The level of consistency in results between the different job shops and machines taking part in the trials was encouragingly high.

There was significant evidence that it is easier to meet the DIN requirements for squareness than for roughness, on both 6 and 12 mm thickness material. A revision of the quality levels I and II for roughness is therefore recommended.

Acknowledgments

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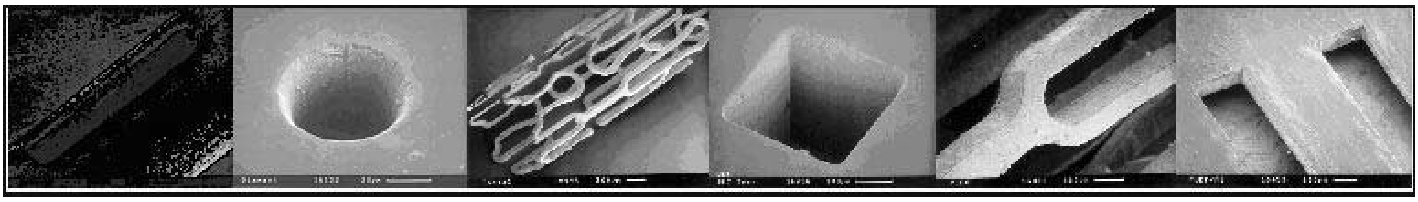
Ariane Lugan has been working as a Project Leader in the Laser and Sheet Processes Group at TWI since March 2000, involved in projects dealing with a wide range of materials for laser cutting and welding applications. Ariane is also looking at developing these techniques for medical applications, and has recently had some important activity in laser welding of Ni superalloys.

Femtosecond lasers for micron precision and nanostructuring

Andreas Ostendorf and Beatrix Rahn
Laser Zentrum Hannover

Hollerithallee 8 Hannover 30419 Germany
T: +49 511 2788 0 F: +49 511 2788 100 E: od@lzh.de



Different materials, machined with femtosecond laser pulses

Ultrashort laser pulses open up the possibility, for nearly all materials, of high precision ablation with minimal damage. Metals or materials that are transparent or temperature-critical can be precisely structured with negligible influence on the surrounding substrate. Moreover, new structures can be designed and modelled in the order of 100nm. This is leading to new products for industry and life sciences, where small structures are the key for future applications.

Ablation with ultrashort laser pulses can be described by a two-step process: First, the radiation is absorbed in the electron system of the material, leading to a strong non-equilibrium between electrons and lattice and heating up the free electrons. Second, the absorption process is followed by a transfer of energy from the electrons to the lattice, causing bond-breaking and an expansion of the material. As the processes take place on a picosecond time scale, heat diffusion into the bulk material is negligible so ablation occurs without formation of burrs. The specific properties of femtosecond laser micromachining offer new access to a variety of applications and materials that have not previously been machinable. This article gives a selection of the products and processes that have been developed at the Laser Zentrum Hannover.

Micron precision for Industry and Life Sciences

<u>Femtosecond laser drilling of fuel injection nozzles.</u>
Femtosecond laser micromachining is an excellent technique for the drilling of fuel injection nozzles.

Whereas current requirements in direct diesel injection (which include hole diameters of about 250µm in material of 1mm thickness, burr-free, produced with high reproducibility) can be fulfiled by EDM or microdrilling, future hole designs to meet the demand for less fuel consumption and higher power output will require diameters significantly smaller than 100µm and non-circular hole geometries. These designs require new tools and process techniques.

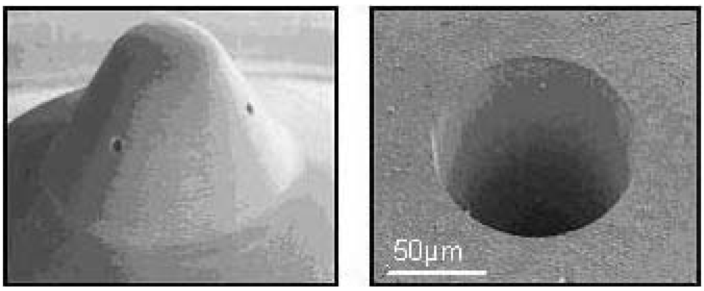


Figure 1. A fuel injection nozzle and one example of a bore in the nozzle

Due to its fine resolution and non-thermal interaction, ultrashort pulse technology can fulfil the requirements on smaller hole diameters and differently shaped hole geometries. Figure 1 shows the tip of a injection nozzle and a detailed picture of a hole in the nozzle.

Extensive research activities have produced fs-processing methods that open the possibility of generating holes of any desired diameter and shape. The technique offers hole diameters far below the limit of EDM-machined holes, burr freeness and with high reproducibility. Holes can be machined conical, cylindrical or laval-nozzle shaped. Moreover, the technique is applicable to almost all materials.

<u>Micro-machining of biodegradable materials</u>

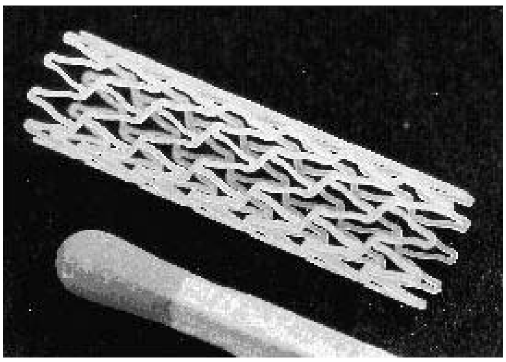


Figure 2. A stent made of biopolymers, machined with a femtosecond laser.

Stents are used as an alternative to bypass operations for the surgical treatment of arteriosclerosis. The stent is placed at the treated location and is expanded by a balloon catheter. At the present time the stent remains in the vessel to ensure the maintenance of a sufficient blood flow. It is machined from stainless steel, which has to be post-processed in order to meet medical requirements (X-ray opacity, burr freeness etc.). However, if the implant remains in the vessel, the risk of re-stenosis still exists.

New medical approaches designate stents for temporary use only. To avoid explantation, those stents have to be biodegradable, which presents new machining requirements in order to guarantee the material properties after machining.

Ultrashort pulse techniques allow minimal invasive processing of bio-degradable materials like biopolymers and special metallic alloys, meeting all the processing requirements demanded of medical implants. Figure 2 shows a stent made of a biopolymer and machined with femtosecond laser pulses.

Silicon cutting and structuring

The number of silicon chips and sensors in all kinds of products is increasing drastically and with it the industrial demand for silicon micromachining. In the microtechnology and semiconductor industry silicon is the most important material, in view of the fact that it is well understood, easy to produce and cost effective. The greatest advantage of using silicon is the possibility it offers to design complex microsystems of the size of only a few micrometers on a silicon chip.

As with any other material, silicon needs to be machined and cut. Currently, silicon is cut mechanically with a diamond blade. However, this technique reaches its limits when the thickness of the material drops to less than 100µm. Conventional (long pulse with t_H > 1ns) lasers can not be applied to high precision structuring of semiconductors, since they cause thermal melting, cracks, and deposits. So far, there is no tool available on the market that will deliver precise structures and cuts of the required quality.

Recently, however, it has been demonstrated that femtosecond laser systems are an ideal tool for overcoming these limitations, since thermal and mechanical influences are minimised. For example, figure 3 shows a cut made in a 50µm-thick silicon wafer with femtosecond laser pulses.

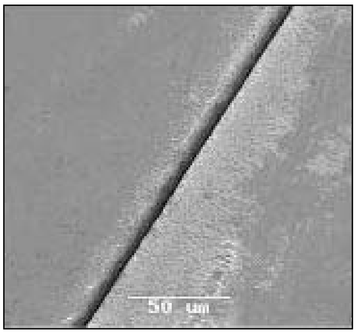


Figure 3. Cut in a 50µm-thick silicon wafer made with a femtosecond laser

Laser micromachining can also create precise structures in silicon that are almost impossible to produce using other technologies, see figure 4. Beam shaping is the key parameter to achieve structures in the required size and quality. Appearing ripples in the material can be manipulated by changing the beam shape.

By using additional optics, an almost smooth and even surface of the structure can be achieved, as shown in figure 5.

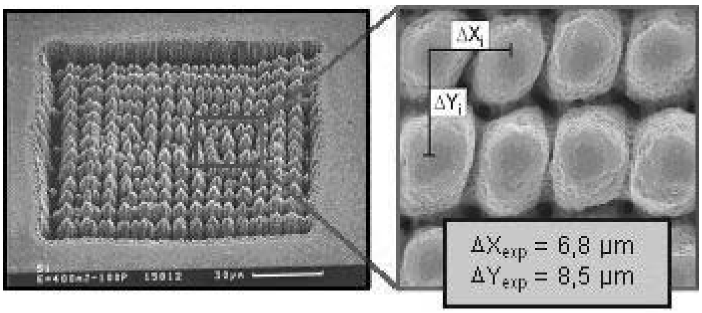


Figure 4. Surface structuring in silicon

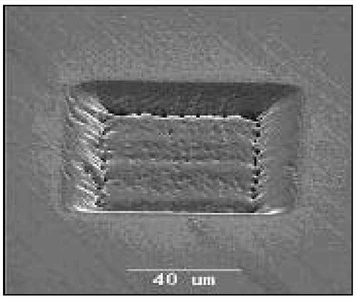


Figure 5. Surface structuring in silicon

One application of this process is the removal of defined volumes (or mass) from the material surface, for example in the trimming of microsystems.

Development of an industrial femtosecond laser micro-machining system

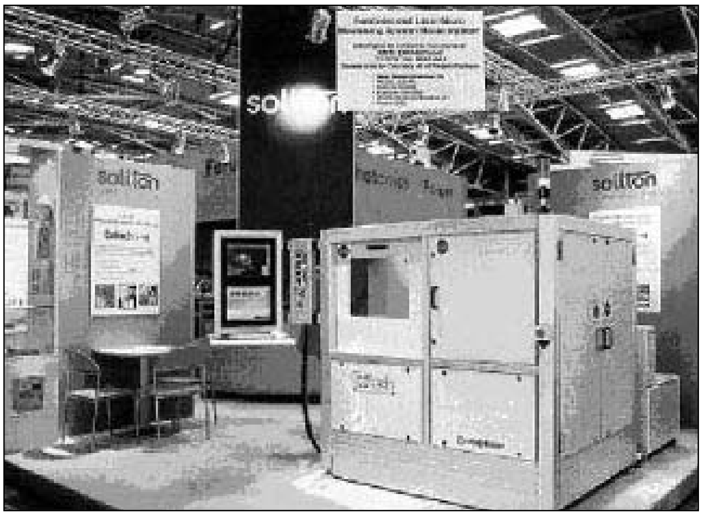


Figure 6. Femtosecond laser micromachining system at an exhibition.

Industrial demands and strong experiences with femtosecond laser micromachining have lead to the design of a complex machining system for industrial use. The system was developed for applications that can not be fulfiled using conventional machining technologies, applications such as hole drilling, structuring and cutting in all kinds of materials.

The three major parts of the system (laser, micromachining system and process) were developed in cooperation with the company Exitech.

Laser source

A compact diode-pumped titanium:sapphire laser was developed, which matches the requirements of industrial systems, such as having a small size and a stable operation. For optimum process speed combined with best cutting quality, the focus was optimised for high repetition rates and medium pulse energies. Typical average output powers from the source are around 1.5W at repetition rates up to 5kHz.

Machining system

The machining system has to fulfil such industrial requirements and specifications as flexibility, ease of use, resistance to vibration and electromagnetic shielding. Moreover, the system had to meet Class 1 laser safety requirements. This was achieved by total enclosure of the optical path and the use of vision systems for part alignment and monitoring. A picture of the machining system is shown in figure 6.

Generated Nanostructures

Nanostructures through Two-Photon-Polymerisation

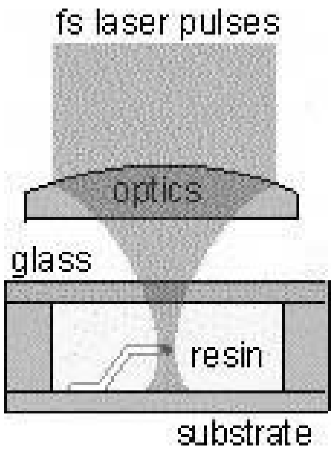


Figure 7 Principle of Two-Photon-Polymerisation (2PP)

A new technique in the application of femtosecond laser technology is the 3D-structuring of UV-sensitive Polymers. This technique allows the design of any 3D-objects with a resolution of less than 100nm.

Until recently, photosensitive polymers could only be surface hardened, using a UV-laser. Now, by using a femtosecond laser, it is possible to work in the volume of the polymer and thereby to create real 3D-structures. This process is called two photon polymerisation (2PP). Figure 7 shows a schematic sketch of the process. Using this technique, structures in the nanometer-range can be generated. For demonstration purposes, the sculpture of the Venus shown in figure 8 was produced.

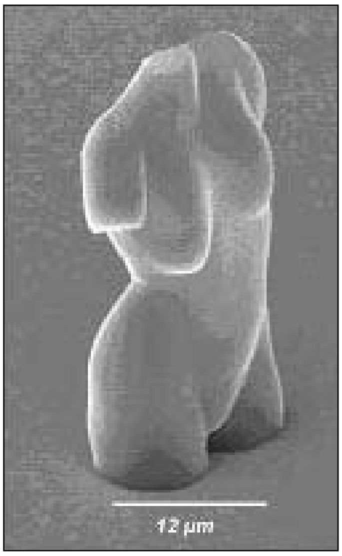


Figure 8. Sculpture of the Venus, created by two-photon polymerisation.
When the fs-pulse is focused into the polymer, polymerisation takes place through a two-photon-absorption process within the focal volume. By moving the focus through the polymer, polymerisation occurs along the focal line and creates 3D-structures

Two-photon-polymerisation has a narrow threshold fluence. The size of the hardened volume is determined by the pulse energy and the number of pulses. As a result, structures can be designed that are significantly smaller than the diffraction limit of the laser radiation. The technique has a strong potential for creating new structures, such as photonic crystals needed in the telecommunication industry, see figure 9.

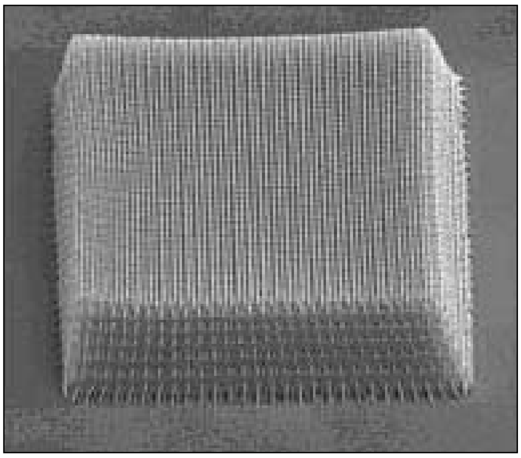


Figure 9. Photonic crystal, created by 2PP

Nanostructures through Multi-Photon-Absorption

Another femtosecond laser based technique developed at the Laser Zentrum Hannover is the design of cost-effective and flexible nanostructures in dielectric materials.

Non-linear effects during the interaction between femtosecond laser pulses and transparent materials require simultaneous absorption of multiple photons to start the ablation process. Electrons, released through multiphoton-absorption, are accelerated in the laser field, giving rise to a micro-plasma that expands and then generates small structures on the material surface. An example is provided in figure 10.

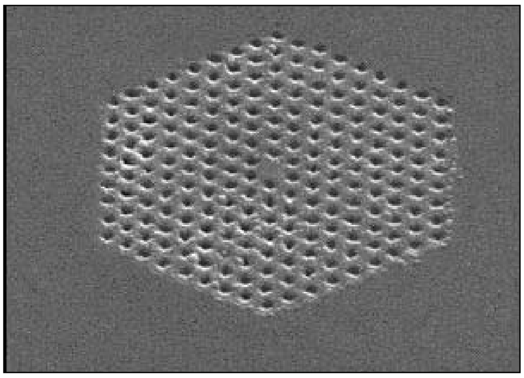


Figure 10. Example of a periodic nanostructure, produced on a sapphire crystal using a femtosecond laser

Structure sizes of less than 100nm can be realised which are relatively easy, cost-effective and fast to produce in air without additional vacuum equipment.

The Laser Zentrum Hannover e.V. (LZH) has long-term experience in femtosecond laser technology. The LZH has the knowledge, the experience and the technology for high quality product and process development for industrial applications.

CAD/CAM software for a laser micromachining tool

Ines Stassen Böhlen and Jim Fieret
Exitech Ltd
Oxford Industrial Park Yarnton Oxon. OX5 1QU UK
T: +44 1865 290 400 F: +44 1865-290 401 E: j.fieret@exitech.co.uk

The vision is old: A device is designed in a CAD-program and some clever software generates the code for the laser machine to produce your device. Such a machine can open up many possibilities for rapid prototyping and small-scale production and will finally offer the flexibility one would expect from a laser tool.

This vision was realized many years ago for mechanical tools such as mills and routers. For certain simple operations such software has also been available for some time for laser machines, but only for welding and cutting. However, a laser can be used for many other processes too, yet software techniques cannot simply be copied from the corresponding ones used for mechanical tools.

Realisation of the concept

Software developed by Exitech realises this general concept for a laser machine. The software, AblataCAM, is based on CAD/CAM software (alphaCAM by Licom Systems Ltd.) and generates the tool paths, and thereby the appropriate CNC commands, for a purpose-built laser micromachining machine, the Exitech M1000 (see figure 1).

The M1000 incorporates a Q-switched UV solid-state laser source (266 nm) and a scanning mirror head with a short focal length telecentric f-theta lens (f = 30 mm), which makes it possible to achieve a spot size of 2 - 3 µm. Beam path options include an aperture changer and imaging system (x 100 demagnification) that allows a variety of spot sizes and shapes to be generated at the workpiece and, to achieve the highest resolution, direct focusing of the Gaussian beam. Various system diagnostics such as an alignment camera, height sensor with autofocus and a power meter are integrated.

Figure 1. The Exitech M1000 laser micromachining tool.

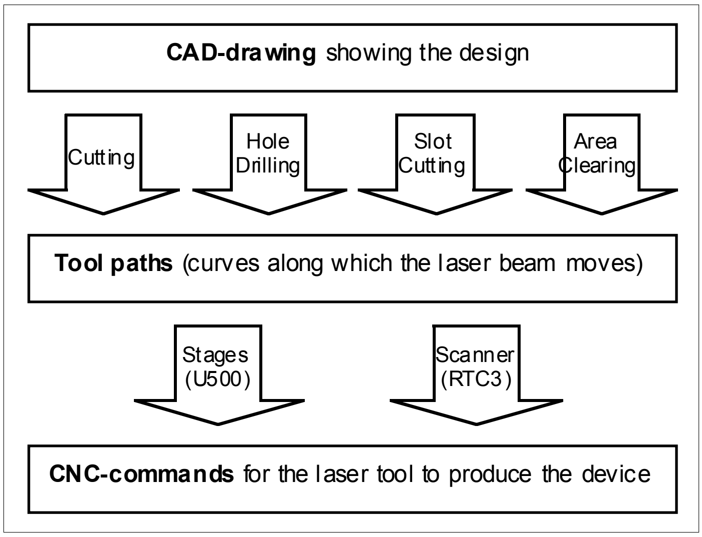


Figure 2: The process from design to manufactured part.

In the case of the M1000, the CNC commands generated by AblataCAM are RTC3 commands for the scanner head. As the scanner is not able to machine along curved lines, all the arcs in the tool paths have to be approximated by straight lines and the user can specify the maximum chord error that can be accepted.

The size of the scan field is about 10 x 10 mm. If the area to be machined is larger, it is split into “tiles” of the size of the scan area and the tool paths are broken into segments, each entirely within one of the “tiles”. In this way the total area is machined in a step and scan process, stitching the “tiles” together.

The AblataCAM software is not restricted to the use with the M1000 and has already been widely used on other systems with and without scanner head and with lasers of various wavelengths. For systems without a scanner, other post processors are available that translate the tool paths into other languages, e.g. into commands for the Aerotech UNIDEX 500 motion controller.

Figure 2 illustrates the steps to manufacture with the M1000. For the hole drilling and slot cutting operations, different machining strategies have been incorporated into the software to provide a high degree of flexibility, to make it easy for the user to experiment with different parameter sets. The area clearing function has the capability to process extensive and complex structures.

Machining operations

Cutting

In terms of tool path generation, microcutting is certainly the easiest of the machining options shown in figure 2. The key element is to compensate for the width of the cut in the path contours defined by the CAD drawing.

Hole drilling

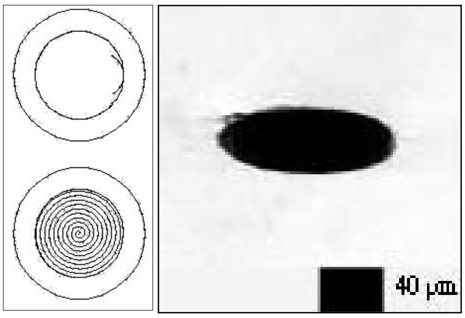


Figure 3. (left) Tool paths (grey) for holes (black), comparing the trepanning option (top) with the spiraling option (bottom).
(right) A 107 µm hole drilled in silicon.

Applications for micro-hole drilling are various, including fuel injection systems, probe cards and vias in silicon and ceramics.

Unlike a mechanical drill, the laser beam often has a diameter considerably smaller than the hole to be drilled (the exception being percussion drilling) and more sophisticated techniques are required. One approach is helical trepanning in which an incoming and an outgoing arc are added to achieve good edge quality. An alternative to trepanning is the spiraling technique in which material is removed starting at the centre of the hole; this avoids the problem with trepanning of cutting a deep narrow slot along the edge, from which it is hard to expel further material, see figure 3. Trepanning and spiraling are well known, but AblataCAM makes it easy to adjust various parameters (e.g. the number of revolutions of the spiral) and to try the new configuration by translating it directly into scanner commands.

Slot cutting

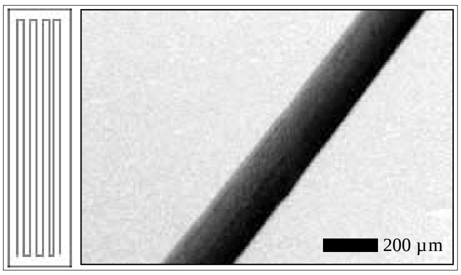


Figure 4. Tool path (grey) for rastering a slot (black) and (right), a slot cut in Silicon using the rastering technique.

In many cases, the most efficient way to machine a slot is not cutting along its edges, but rather to raster scan the whole slot. This technique is the analogue to the spiraling technique for hole drilling and has the same effect i.e.material is removed from the whole area of the slot in order to avoid a narrow cut. Again, it is not the technique itself that is innovative, but the ease of use and convenience provided by the AblataCAM software. The machining of ink feeding slots for ink jet printer heads is one application of slot cutting.

2D area clearing

2D area clearing is mainly used for single shot processes where no depth control is required, e.g. for patterning transparent conductive oxide (TCO) layers on glass or flexible substrates for flat panel display fabrication.

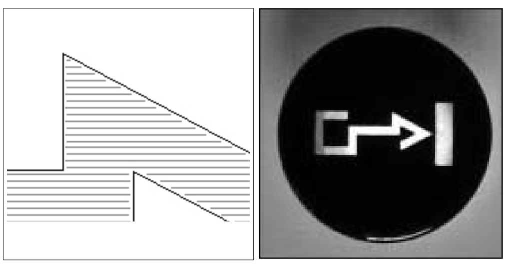


Figure 5. (right) Back-lit panel display button (black paint on clear plastic).
(left) Tool paths (grey) for machining the logo in raster mode.

Tool paths are generated that allow all the material in the areas defined by the border lines in the CAD drawing to be removed. For nested border lines, a tree structure is built up that reflects which borderline is inside which. In this way the different regions are identified, each of which is delimited by an outer border and may contain islands. The user can choose the distance between the cuts according to the size of the beam and select between a raster (Figure 5) and a contour option (Figure 6).

The AblataCAM area clearing function can deal with extensive and complex structures. For example, an 80 mm clock display containing 217 border lines and requiring about 42 m of tool paths in total.

Graphical user interface

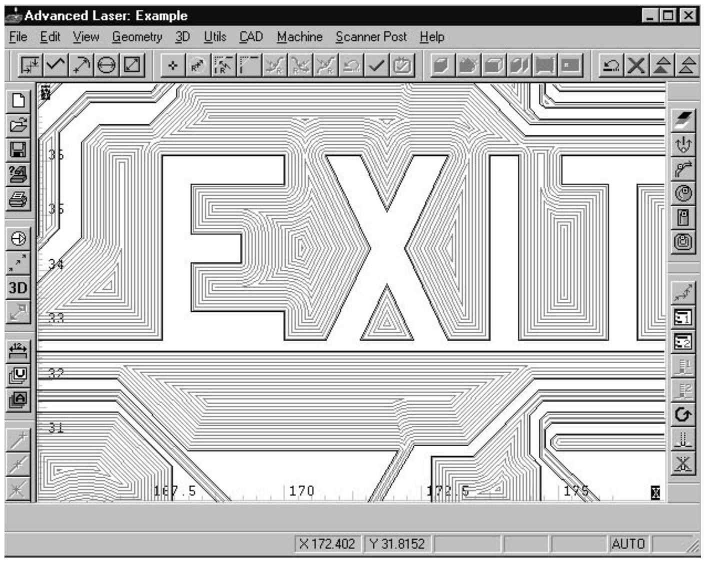


Figure 6: Screen shot of the GUI of the AblataCAM software showing a detail of another example for the area clearing operation, this time for a display (borderlines in black, tool paths in grey), contour mode.

The graphical user interface (GUI) is shown in figure 6. It was provided by the alphaCAM software, customised to allow the user to access the functionality of AblataCAM by means of menu items and buttons.

Conclusions

User-friendly CAD/CAM software for a novel laser micromachining tool concept has been developed on a commercial CAD/CAM platform. The AblataCAM software automatically generates tool paths that are then translated into motion control commands for conventional motor-driven stages or for x-y laser scanners, or a combination of both. The use of state-of-the-art scanners with short focal length f-theta (telecentric) lenses and deep-UV diode-pumped solid-state lasers (266 nm) allows high resolution, accurate micromachining of most metals, ceramics, polymers and electronic compounds. Applications include micro-hole drilling and thin-film patterning.

Acknowledgments

The AblataCAM software was developed within EU-funded project FLAME – Flexible laser-assisted micro-engineering (GROWTH program, contract no. G1RD-2000-00297). The authors wish to thank the European Commission for its support.

Manufacturing photonic devices by Nd:YAG welding

Geoff Shannon

Unitek Miyachi Corporation

1820 S. Myrtle Ave PO Box 5033 Monrovia CA 91017-7133 USA

T: +1 626 930 8448 F: +1 626 599 9636 E: geoff@axiasys.com

Photonic devices are the elemental components of the fibre telecommunications network, providing sources, means to combine and split signal wavelengths, signal amplification and restoration, receivers along with devices offering numerous other functions. The signal sources and amplification devices are referred to as' active', since they contain a light-generating component such as a laser diode. By contrast, wavelength splitters and combiners are passive devices, since they optically transform signals with no internal generation of light. Active devices require the light source to be coupled into an optical fibre with a core diameter of around 6 – 9 µm. In order to achieve the required coupling efficiencies the fibre must be located in space relative to the diode, to a tolerance of around 0.2 µm. It is to meet such demanding fixturing requirements that laser welding is implemented as the attachment technology.

The Nd:YAG laser is ideally suited to photonics welding applications, offering multi-beam output, time-share capability, highly controllable pulsed output, power feedback, and spot-size selection. For optoelectronics attachment, the pulsed Nd:YAG is used in single-shot mode. The pulse can be tailored to the need of each attachment configuration – lap, butt, edge butt, thickness etc. Typical laser-weld pulses in optoelectronic attachment applications provide 1 to 4 J over 2 to 5 ms, producing weld spots around 300 to 600 µm in diameter. There are a number of example components that are routinely welded, here the laser pump module is described.

Manufacturing pump lasers

A pump laser is used to amplify optical signals, and on long haul networks these are typically spaced around 50 miles apart. The basic construction has an outer package, known as a butterfly package, in which the optical sub assembly sits, see figure1. This subassembly generally comprises a thermoelectric cooler, a welding platform and the diode mount. In fixing these components, which is achieved by soldering, a glass fibre has to be precisely located in space relative to the diode.

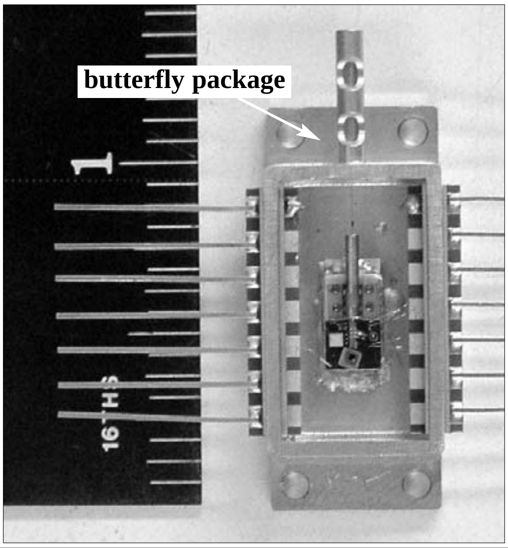
In order to make the fibre weldable it is gold metalized, then soldered into a kovar (iron-nickel-cobalt alloy) jacket known as a ferrule. The ferrule is fixed in space using a welding clip, which is made of kovar in order to match thermal expansion coefficients. The basic manufacturing sequence involves part loading, alignment of the fibre to the diode, welding the fibre in place, then post welding bending of the deformable clip to re-align the fibre and diode. The key aspects of the process are how much the fibre moves during welding, known as post weld shift, and the realigning process.

Part loading and alignment

The physical size of the parts and delicacy of the fibre tip make the initial loading of the parts time consuming. A typical ferrule is 1mm diameter, and 4-6 mm in length, a welding clip has a footprint of around 3 x 2 mm and can be only 150 µm thick. An off line pre-loading station is used where the fibre and clip are manually loaded into place on a mount. The assembled parts can be fed directly into the machine or stacked in palettes.

Once loaded the ferrule is gripped and optically aligned to the active source in 4-6 axes to a resolution of 50nm and 0.1 degrees. To increase optical coupling the optical fibres have faceted ends with a defined focus length . This implies that the fibre must be aligned along the axis parallel to the fibre, as well as in the orthogonal linear and angular axes.

The typical focal length of the faceted optical fibres lies in the range of 5-15 µm, but the fibre tip must not touch the laser, so the alignment is extremely important and is generally automated by means of optimized search algorithms.



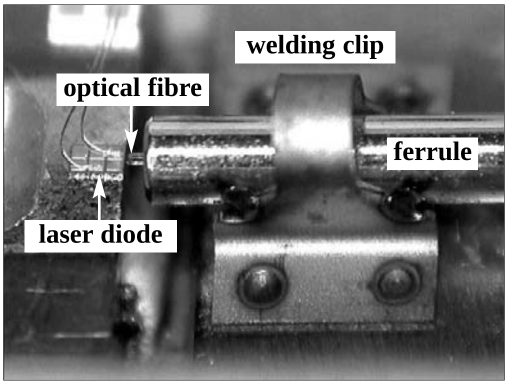


Figure 1 A "butterfly" style pump laser diode package. The magnified picture above clearly shows the ferrule, welding clip and diode, and the location of the spot welds fixing the clip to the base and the ferrule to the clip.

The welding process

The most important consideration of the welding process is the post weld shift.

After aligning the fibre to the diode to within 50nm, welds 300 µm wide and over 300 µm deep are placed on the base. these welds are followed by slightly lower penetration welds in the clip and ferrule. The likelihood of maintaining this alignment through weld solidification and thermally-induced stress is remote.

Although the size of the post weld shift is small, around 2-20 µm, this is relatively large in alignment terms.

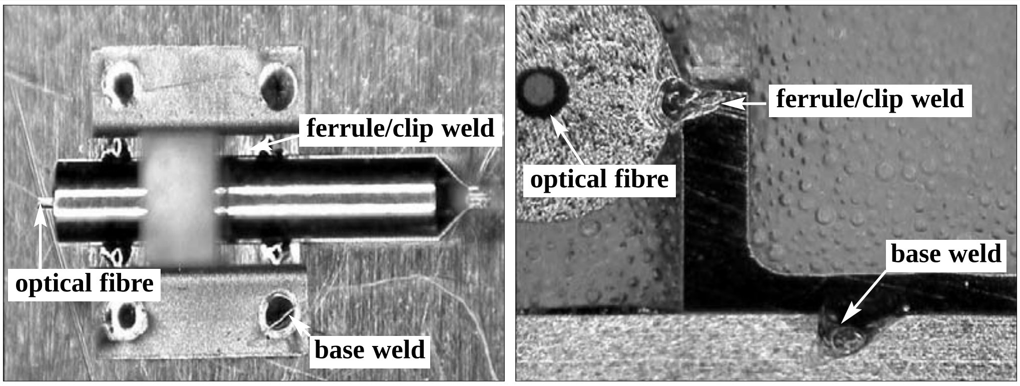


Figure 2 The left picture shows a plan view of the ferrule and clip assembly, with base welds and clips welds. The right picture is a cross section of one side of the ferrule and clip. Notice the fibre centered in the ferrule, this is 125 μm in diameter. The base lap weld and the ferrule to clip fillet weld are shown. To avoid the tooling the beams are angled typically 25 degrees from normal; this angle is apparent in the base weld.

The welding sequence and shift occurs as follows: the first welds are the base welds, as the clip and still gripped ferrule are a slip fit very little or no signal loss occurs. The second set of welds are the clip to ferrule welds, the first set are placed nearest the diode and move the ferrule downward relative to the diode. The rear ferrule clip welds then move the ferrule upward as the downward shift is translated to upward movement, since it pivots around the two front ferrule/clip welds.

Through the design of the clip and ferrule joint, and the force and location of the grippers for alignment prior to welding, the extent and direction of the shift are determined. Nominally, the majority of shift occurs in the vertical axis, which is unfortunate since this is the most optically sensitive axis, a result of the elliptical cross section of the diode laser output. The key for the welding process is to minimise the size and range of the shift.

The first step in minimising shift is to complete welds either side of the clip simultaneously. This requires the laser to provide two balanced energy-shared beams. Through design of the welding clip, the weld geometry, laser parameters and beam delivery, the shift can be characterised and minimised.

Once the shift has been characterised, the use of offsets prior to welding can be introduced. For example, if one knows that over all welds the shift occurs downward by around 7-10 μm, then the ferrule can be offset relative to the diode by, say, 8 μm upward.. This enables a percentage of the signal to still be coupled ready for the clip to be plastically deformed to fully realign the fibre and diode.

Bend Align

After the welding process, if the coupled signal is below the required specification a post-alignment process must be undertaken to locate the fibre to the laser chip. The clip is a deformable mount firmly welded to a base, with sufficient stiffness to be robust but not too stiff that it cannot be bent to re-align the fibre. With some percentage of the coupled signal typically remaining after the attachment process, the gripper tooling, motion system and control software combine to assess where the peak signal lies, and how much bending is necessary to re-align. The bending of the ferrule and clip assembly is achieved by grippers that affect the rear of the ferrule away from the diode. By successive bends of the clip a peak signal is obtained, with typically 90+% of the original signal recovered. In most cases the alignment is to a 0.3 - 0.5 μm plateau, which would appear unobtainable by such gross methods but in practice it works well.

In some of the more sensitive alignments, the package may be temperature cycled and re-bent to produce long term coupling stability. The package is then removed to go through test procedures to be concluded with hermitic sealing of the package by welding the lid to the top of the package, and solder sealing the optical feedthrough.

Summary

This brief synopsis illustrates the many steps required to manufacture a pump laser. As a system provider, Unitek Miyachi work closely with the customer from product concept through design and material selection, prototype packages and finally to production.

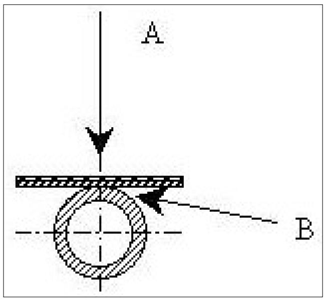
? QUESTION & ANSWER

Copper to copper laser welding

We wish to laser weld (hopefully with our CO_2 laser) a titanium coated copper sheet (0.3 mm thick) to copper tube (0.75mm wall thickness). the weld would be copper to copper, titanium face up. Do you have any advice on how we should do this? Can we coat the surface sheets with anything to increase absorption/penetration?

The question implies that you wish to direct the laser from the top, from A (see figure below).

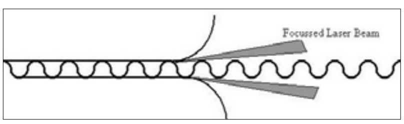
Coupling of the laser light to titanium is excellent and stable but to copper is poor and unstable (i.e. the proportion of the incoming laser power that is absorbed is very variable along the seam line and from sample to sample). There is a small chance that you could weld from A without melting the Ti but I suspect that the Cu is too thick to get away with this approach because there would be too much lateral conduction. You might be able to help this by making the focal spot larger than you would expect it to be for the joint dimensions. (N.B. 'Copper' can mean lots of different things. The purer or the higher the conductivity of the copper, the more difficult it is to get a stable process and the greater the effect of any surface contamination or oxidation.)



You would probably be more successful with a YAG laser and fibre beam delivery because this would allow you to avoid a very hot spot in the centre of the focus, which is where you are most likely to get melting. If you must use CO_2, it might be worth trying an axicon in the optics, if you have one.

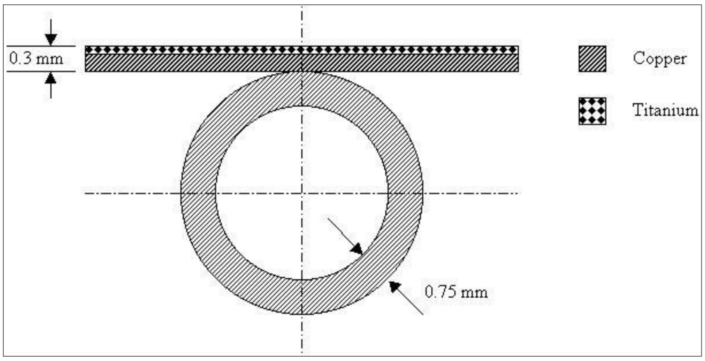
My guess is that you could weld from A with an Nd:YAG laser and obtain a stable process provided you could maintain excellent clamping of the foil onto the tube. You might get best results using a pulsed or sinusoidally modulated laser rather than cw.

The geometry B, however, is excellent because you can organise that all of the incoming laser light is absorbed; effectively it gets caught in the pinch point. It is also good because it allows you the tooling freedom to clamp the foil from the direction A, without the laser and the tooling getting each in the other's way. The welding process should be stable without melting the Ti, and should work well with a CO_2 laser.



However, if you have many tubes welded to your plate, for example if it is a heat exchanger, direction B may be a problem. A technique which is used in the shipbuilding industry (it may be patented) is to bring the components together while they are being welded, as shown in the sketch above. CO_2 is probably easier with this approach because (a) the focussed beam angle is smaller and (b) reflection helps you more if you have problems aiming the focus at exactly the right point.

Tim Weedon



With regard to the issue of a coating to increase surface absorption, spray on graphite might help. One UK supplier of an aerosol based spray-on graphite is Agar Scientific Limited (E: sales@agarscientific.com, T: 01279 813 519)

The product goes by the trade name of Graphit 33 and gives a very matt black finish.

William Rodden Heriot-Watt University

Why CO_2? YAG would be my choice. It is possible to weld Cu with a CO_2 but it needs very high power.

When welding thin materials there is often significant heat induced distortion. A way to get around is extremely rigid fixturing or to use a pulsed laser to put less heat into the weld. Either way the fit of the two parts must be very well controlled. You really must have the parts in contact.

We weld copper tubes into a perforated copper end plate to form a heat exchanger. We have found that for this sort of welding a plunged hole in the sheet that has a raised collar that fits snugly around the end of the tube welds very well.

It is possible to coat surfaces to increase absorption to enhance cutting with things like abrasive cleaners e.g. Brasso, carbon powder and suspensions e.g. Aquadag, thin paints and the like. But would you want those sorts of things in you weld? If you weld from the top the Ti would provide the absorbing coating you seek. However, if you are welding from the Cu side then differences in the reflectivity of the surface can cause major variations in the penetration of the weld.

A consistent surface state is very important for consistent weld quality, and a consistently oxidised surface is sometimes easier to achieve than a consistently clean surface.

Ti is prone to combining with O_2 and N_2 in the weld pool forming brittle impurities. If the weld is to last or see any pressure then very good gas flushing with Argon or, if you have to use CO_2, possibly Helium will have to be used. The effect of oxide on the surface should be considered.

Neil Main Micrometric Techniques Ltd

Laser Welding of Aluminium Alloys

Friedrich Dausinger, Peter Berger and Helmut Hügel

Institut für Strahlwerkzeuge (IFSW), University of Stuttgart

Pfaffenwaldring 43 Stuttgart D-70569 Germany

T: +49 711 685 6840 F: + 49 711 685 6842 E: dausinger@ifsw.uni-stuttgart.de

Increasing demand for light-weight structures in transportation has lead to a growing use of aluminum alloys. Besides the already classical domain of air- and spacecraft industry, these alloys now gain ground in ship, locomotive and automotive manufacture. Yet whilst the productivity and quality of laser processing is very attractive for the manufacture of light-weight constructions, the specific material properties of aluminum alloys renders laser welding difficult. Nevertheless, many years of research has provided a fundamental understanding of the relevant technological and metallurgical mechanisms and we are now able to offer guidelines for a successful adaptation of the welding process to specific applications needs.

Modern CO_2 and Nd:YAG lasers have already proven themselves to be advantageous in the automotive industry for the welding of steel, where the application of in-line laser welding of car bodies is now common practice. However, compared to steel, the optical and thermo-physical properties of aluminum alloys lead to a much more complex welding process and thorough understanding of the involved mechanisms is a prerequisite to selecting the optimum process parameters.

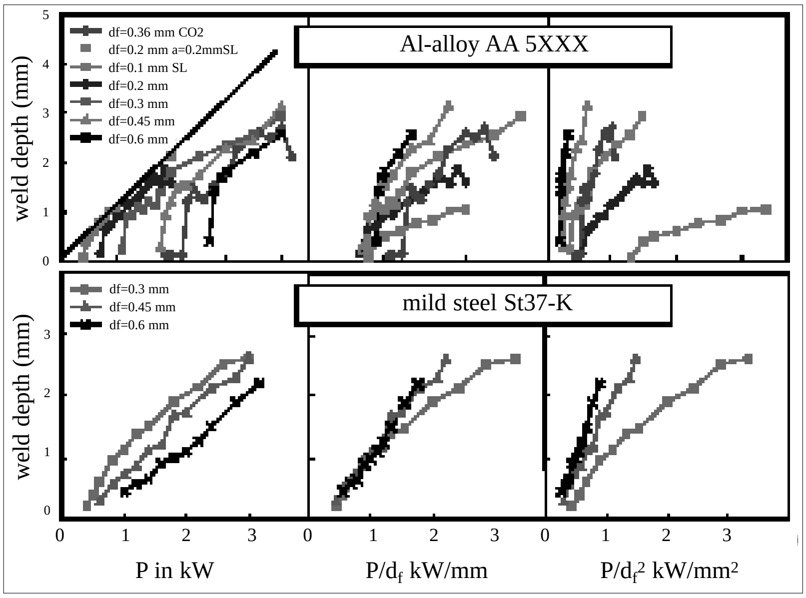


Figure 1: Penetration depth in aluminum alloy and steel at 4 m/min, for different metal thicknessed, with CO_2 , disc laser (SL) and Nd:YAG laser (unmarked). Results are expressed in terms of laser power P, power divided by focus diameter P/d_f and intensity ($\sim P/d_f^2$); the comparison clearly shows that P/d_f is the most appropriate scaling factor for the threshold for deep penetration.

Flaws of different type and origin are encountered when welding Al alloys. Some of them, such as hot cracks, hydrogen pores and hardness drop are primarily caused by the metallurgical characteristics of the material. These metallurgically-based flaws, although hard to avoid completely, can be reduced to an acceptable level. Other frequently occurring imperfections have their origin in process instabilities and it is these that we focus on in this paper.

Process Parameters

The main advantages of beam welding methods are linked with deep penetration keyhole) welding. The threshold for deep penetration is often expressed in terms of an intensity or a laser power, yet as shown in Figure 1, the results for steel and aluminum correlates with neither of these, but rather with the laser power divided by the diameter of the focused beam, P/d_f, in agreement with a theoretical analysis of Beck[2] (see box opposite).

The influence of material composition on deep penetration threshold is derived mainly from the significant lowering of vaporisation temperature caused by volatile alloying elements[4]. A thermodynamic calculation[5, 1] reveals that certain elements like Mg, Li and Zn (i.e. the volatile ones) strongly affect the boiling temperatures of alloys in the content range of technical interest. Other elements like Cu, Fe and Si, which have a higher vaporisation point than aluminum, do not affect the boiling temperature of Al alloys in this way. Pure aluminum shows a higher boiling temperature, higher heat conductivity and lower absorptivity than its alloys and it requires the highest power level to overcome the threshold for deep penetration welding.

Figure 1 reveals that, by minimising the diameter of the focused

Threshold for keyhole welding

The theoretical analysis of Beck[2] reveals the dependency:

$$\frac{P_{min}}{d_f} \approx \sqrt{\pi} \cdot \frac{T_v \cdot \lambda_{th}}{A} \qquad (1)$$

Equation 1 is an approximation that is good for welding velocities that are low compared to the thermal diffusivity, which is generally the case for aluminum. It shows that the threshold depends only on the vaporization temperature T_v, the thermal conductivity λ_{th} and absorptivity A of the material combined in what we refer to as the ‘heating triplet’ an expression often occurring in models of laser heating.

Equation (1) reveals some first reasons for the difficulties occurring when welding Al alloys:

- In comparison to steel considerably stronger thermal conductivity and lower absorptivity lead to a much higher need of laser power and/or focusability to overcome threshold for deep penetration. (The focusability is defined here as the inverse of the beam parameter product (BPP).)
- The composition of common Al alloys strongly influences the heating triplet and thus the welding process, what is not the case in weldable steels.

beam, not only is a lower laser power required to overcome the threshold for welding aluminum, but also the jump in penetration depth between conduction-limited welding and keyhole welding is reduced proportionally; thereby allowing the user to achieve well-defined welding depths around and below 1 mm.

Figure 1 also reveals that whereas in steel the weld depth scales mainly with the beam parameter ratio P/d_f, the scaling in aluminum is more appropriately with laser power i.e. the diameter of the focused beam d_f has little influence on the welding depth. An explanation for this behaviour can be found in the higher thermal diffusivity of Aluminium, about one order of magnitude higher than that of steel. Whereas in steel the welding speed will generally exceed the thermal velocity (i.e. the speed at which thermal energy is conducted away), in Aluminium this situation occurs at a welding velocity about ten times higher (i.e. > 10 m/min). For lower welding speeds the power required per unit weld depth in aluminium is determined solely by heat conduction, which accounts for the different scaling in weld depth.

The process efficiency η_P can be expressed as the product of a coupling efficiency η_A and a thermal efficiency η_{th}:

$\eta_P = \eta_A \times \eta_{th}$

The coupling efficiency measures the portion of the laser power which is available to the workpiece for the process and this can be estimated by considering the multiple reflections of laser radiation entering the (conical) keyhole. Clearly, η_A will approach unity asmptotically as the aspect ratio of the keyhole and the wall absorption increases. The aspect ratio in car body welding lies typically between 2 and 6 and a significant efficiency improvement can be achieved by using a shorter laser wavelength, to increase the wall absorption.

It also follows that in dual focus welding, where the keyhole opening is enlarged to reach better process stability or two separate keyholes are created in order to broaden the melt bead, the coupling efficiency will be significantly reduced. The process efficiency will decrease with increasing focal spot separation but at greater focal spot separations the widened keyhole will split into two individual keyholes, each with higher aspect ratio, and the coupling efficiency will rise.

The thermal efficiency η_{th} is a measure of how much of the absorbed power is used in creating the desired effect on the workpiece e.g. in producing the weld seam. Theoretical modelling of the thermal efficiency indicate that, for a constant value of η_{th} the laser power per unit depth is proportional to the 'heating triplet' expressed in Equation (1), but with the melting point temperature T_m replacing T_v. In order to achieve the same efficiency as steel, aluminum must therefore be welded with double the absorbed power, i.e. with an up to three times higher incident power than needed for steel. This means, for example, that about 2 kW/mm is necessary to weld aluminum in order to achieve a thermal efficiency greater than 40 %.

Process stability

A number of different defects can occur in the welding of aluminum. Some,like hot cracks and hydrogen pores, are primarily caused by characteristics of the material while other frequently occurring defects are thought to be caused by process instabilities i.e. cavities, irregular roots and blow holes.

With regard to cavities, these are irregular in shape and general-

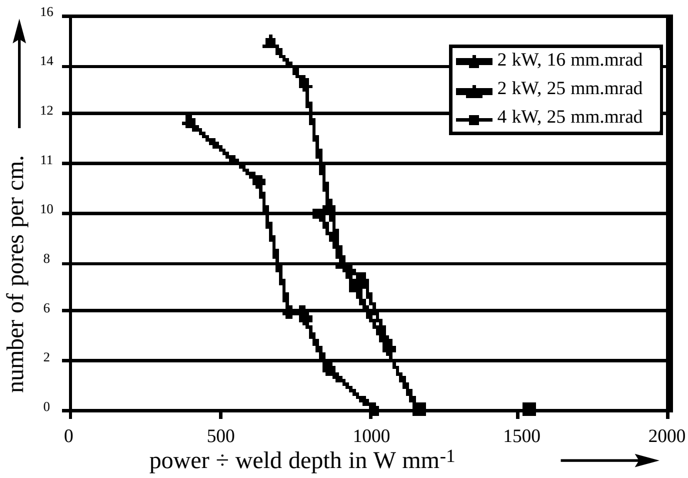


Figure 2. Plot showing the variation of the number of pores observed by X-ray analysis, with various process parameters for Nd:YAG keyhole welding of Aluminium

ly large enough in size to be visible with X-ray analysis and are located on the keyhole path. By contrast, hydrogen pores are more or less equally distributed with slight enrichment along the melt line.

A small reduction in the number of cavities can be produced by surface preparation, which is to be expected if they are caused by hydrogen contamination. On the other hand, the ratio of laser power to weld depth has a dominating influence on the number of cavities, which strongly decreases as the ratio increases and in Aluminium reaches zero at 1.8 kW/mm. This trend, first obtained using a CO_2 lasers, was recently confirmed for Nd:YAG laser welding, see Figure 2. In that case the threshold ratio for avoiding of process pores turned out to be significantly lower.

Another beam parameter shown to influence the process stability for CO_2 and Nd:YAG-lasers welding is the beam quality. As shown in Figure 2 an increase in beam quality (expressed in units of mm.mrad) leads to stabilisation of the process.

A further way to suppress these defects is the use of dual focus technique. This method was originally proposed to avoid the so-called humping effect occurring when welding steel at very high speed, but the same technique has also been found to stabilise the aluminum welding process. After the first application in series production of an automotive component several years ago, the dual focus technique became a generally accepted standard, indispensable for CO_2 laser welding of Aluminium alloys. In Nd:YAG laser welding, however, the dual focus technique is limited to applications with high quality requirements, such as the welding of structural parts of a newly developed aircraft.

A common element in all three defect types is an increase of pressure in the keyhole caused by an obstructed outflow of metal vapour. This blockage can be avoided either by creating a keyhole with an open shape (as produced by the dual focus technique) or by reducing the interaction between the partially ionised vapour and the laser beam i.e by employing a shorter wavelength laser.

Such over-pressure effects are also predicted in the welding of steel but the number of defects experimentally observed is much less, presumably because the volume of melt trailing behind the keyhole increases with the ratio of boiling to melting temperatures T_b/T_m (= 3.5 for Al compared to 2 for Fe). This melt pool can easily be deformed by laser radiation reflected from the keyhole front and by vapour jets, resulting in pores and melt ejections.

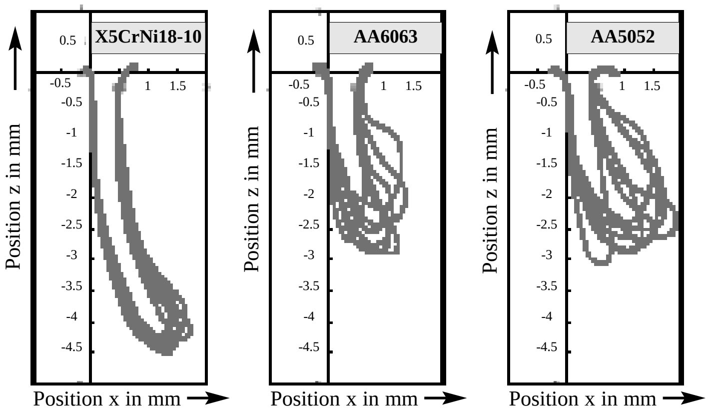


Figure 3: Overlays of the keyhole geometry taken from real-time X-ray analysis perpendicular to weld direction (x), showing increased instability in Aluminium welding. (λ=1,06 µm; P_L=3 kW; v=3 m/min; z_f=0 mm; f=100 mm; Ar)

A clear confirmation of the above speculation was achieved by X-ray analysis during welding, see Figure 3. This figure shows that whereas in welding of steel a stable and nearly cylindrical geometry was observed, the keyhole during welding of Aluminium alloys has a heavily fluctuating "soft backside" with a tendency to bulge. This bulging can lead to pore formation, to melt expulsion or remain without negative consequence.

As shown in Figure 4, it was found experimentally that the probability of defect formation correlates with the aspect ratio S of the keyhole i.e. the depth divided by its opening cross section. When the opening was increased by adequate separation of the focal spots in dual focus welding, the number of defects could be reduced to zero.

Another way to avoid defects is to reduce the amount of trailing melt by increasing weld speed, which then requires more power by unit length if the weld depth has to be maintained. This has the effect of reducing the scope of the soft backside seen in the Figure 3 results, which provides a possible explanation for the findings described in Figure 2.

A further problem when welding Al alloys at low speed is sagging of the weld bead. This is caused by the thermo physical properties of the melt (low viscosity, low surface tension, low melting temperature, high boiling temperature and high heat conductivity) leading to a relatively broad melt pool. A new method of stabilising the melt uses Lorenz forces, produced by the joint action of a a magnetic field and a current applied by an electrode.

Industrial Applications

Since 1995 laser welding has been used by suppliers of automobile components for the production of steering axles and fuel filter housings. The dual focus technique drastically reduced the number of defects and proved its effectiveness in the manufacture of millions of parts to date.

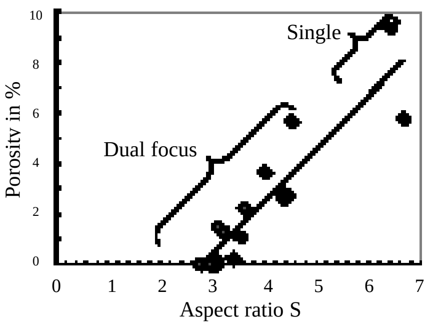


Figure 4: Reduction of pore formation by dual focus technique by adjusting foci distance (Nd:YAG-laser, AA 5052)

In 1999, a German automobile company revealed the use of Nd:YAG lasers for welding of all-aluminum car bodies. The welded seam length reaches a total of 30 m and competing techniques such as rivetting and arc welding have been substituted to a large extend. Sheet metal, extrusions and vacuum-cast parts are now welded together. After three years of positive production experience and further applications in other companies, laser welding of aluminum can clearly be regarded as "state of the art".

Conclusion

Welding of aluminum alloys requires careful adaptation of process parameters to the specific material properties.

Compared to steel:

- a markedly higher laser power and beam quality is required, the specific values depending on material composition;
- a pronounced tendency to process instability is observed.

The instability is mainly attributed to a relatively large melt pool caused by the thermo-physical properties of Aluminium. A profound improvement in weld stability is expected when welding can be undertaken at much higher speeds than are feasible today. Some progress in this direction has already been achieved by increasing beam power and quality, which allows the desired weld depth to be achieved at a higher speed and fewer defects. The excitation of instabilities, on the other hand, can be moderated by the use of shorter wavelength lasers and dual focus technique. Additionally, the application of Lorenz forces helps to stabilise the welding process.

Taking the know-how acquired to date and the problems and disadvantages of conventional joining techniques, laser beam welding is broadly regarded as a key technology for the production of light-weight structures.

Acknowledgement

The authors wish to thank their numerous co-workers who over the years produced the results presented in this paper. At first J. Rapp has to be mentioned, who's work is regarded as a real brakethrough for welding of aluminum, then in chronological order: M. Beck, C. Glumann, F. Faißt, R. Hack, M. Kern, C. Schinzel, B. Hohenberger, M. Müller, W. Gref, A. Ruß, M. Leimser and G. Ambrosy. Furthermore, the authors thank H. Shibata and his co-workers T. Iwase and H. Sakamoto as well as A. Matsunawa and his student N. Seto who made possible the real-time X-ray observations. The support of the companies Audi, DaimlerChrysler, Nissan Motor, Robert Bosch and Trumpf as well as the funding from the European Commission and the German Federal Ministry for Education and Research is greatly acknowledged.

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Listing of laser processing standards (1/3/2003)

Note: (1) Listing includes draft (pn) standards; (2) Only EN references are given; (3) The series 'Acceptance tests for CO_2-laser beam machines for welding and cutting' is currently under critical review, with the national standards bodies of UK, USA and Japan among those critical of these documents.

Safety of Laser Products

Safety of laser products series:
-Part 1: Equipment classification, requirements and user's guide ***incorporating amendments 1, 2 and 3***
EN 60825-1 1994
Product standard plus user guide. Includes new classification scheme. Revision came into force January 2001, available since October 2002.

-Part 4: Laser guards ***incorporating amendment 1***
EN 60825-4 1997
Product standard plus user guide.

-Part 5: Manufacturers checklist for IEC 60825-1
EN IEC TR60825-5 1998

-Part 9: Compilation of maximum permissible exposure to incoherent optical radiation
EN IEC TR 60825-9 1999

Safety of machinery - Laser processing machines - Safety requirements*
EN12626 1997
Harmonised to the Machinery (Safety) Directive Currently under revision to extend the application to laser processing machines which do not have Class 1 enclosures. Revision will also give fuller cross references to related standards.

Laser safety equipment

Personal eye-protection series:
Filters and equipment used for personal eye-protection against laser radiation (laser eye-protectors)
EN207 1999
Product standard and user guide. Under revision to increase size of test area.

Eye-protectors for adjustment work on lasers and laser systems (laser adjustment eye-protectors)
EN208 1999
Product standard and user guide (visible radiation only). Under revision to increase size of test area.

Screens for laser working places - Safety requirements and testing
EN 12254 1998
UK edition contains a foreword cautioning users on limitations of test requirements.
Amendment A1 issued as a document for public comment. Under revision to increased size of test area exposed.

Laser Product Standards (other)

Lasers and laser related equipment - Lifetime of lasers
ISO 17526 2002

Lasers and laser related equipment - Laser devices series:
-Minimum reqts. for documentation
EN ISO 11252 1994
-Mechanical interfaces
EN ISO11253 1994

Fibre optic connectors for non-telecommunication laser applications
EN ISO 11149 1997

Optics and optical instruments - Laser and laser-related equipment - Vocabulary and symbols
EN ISO 11145 2001

Laser beam measurements

Power and energy measuring detectors, instruments and equipment for laser radiation
IEC 1040 1990

Lasers and Laser Related Equipment - Test Methods for laser beam parameters series:
Beam width, divergence angle and beam propagation factor
EN ISO 11146 2000
Amendments to the ISO Standard are about to be issued

Laser beam power, energy and temporal characteristics
EN ISO 11554 1998
Amendments to the ISO Standard are about to be issued

Laser beam positional stability
EN ISO 11670 2000
Amendments to the ISO Standard are about to be issued

Laser beam parameters: Polarization
EN ISO 12005 2000
Amendments to the ISO Standard are about to be issued

Laser beam power (energy) density distribution
EN ISO 13694 2001
Amendments to the ISO Standard are about to be issued

Test methods for spectral characteristics of lasers
EN ISO 13695*
** Currently available as a prEN draft*

Laser and laser related equipment - Test methods for determination of the shape of a laser beam wavefront series:
-Part 1: Terminology and fundamental aspects
ISO 15367-1 2001
-Part 2: Hartmann-Shack sensors
ISO 15367-2 2001

Optics and optical instruments, lasers and laser-related equipment. Test method for absorptance of optical laser components
EN ISO 11551 1997

Laser processing performance

Acceptance tests for CO_2-laser beam machines for welding and cutting series:
Part 1: General principles, acceptance conditions
EN ISO 15616-1 1999

Part 2: Measurement of static and dynamic accuracy
EN ISO 15616-2* 1999*
** Currently available as a prEN draft*

Part 3: Measurement of the process orientated gas parameters
EN ISO 15616-3* 1999*
** Currently available as a prEN draft*

Specification and qualification of welding procedures for metallic materials series:
Part 4. Laser beam welding
EN ISO 15609-4* 2002*
** currently available as prEN draft*

- Specification of welding procedures
-Part 2: Aluminium. Electron and laser beam welded joints
EN ISO 15614-2* 1999*
** Currently available as a prEN draft*

-Part 11: Electron and laser beam welding
EN ISO 15614-11 2002

Lasers and laser related equipment - Laser materials-processing machines - Performance specification and benchmarks for cutting of metals.
EN ISO TR 11552 1997

Imperfections in oxyfuel flame cuts, laser beam cuts and plasma cuts. Terminology
EN ISO 12584 1999

Welding and allied processes - Electron and laser beam welded joints - Guidance on quality levels for imperfections Part 2: Aluminium and its weldable alloys
EN ISO 13919-2 2001

End

Meetings

Highlights

Laser Opto Ireland

Lasers and optics specialists gathered in Galway in September 2002 for Opto Ireland. This was the first in the SPIE series of Regional Meetings on optoelectronics, photonics, and imaging to be held outside North America.

The conference call attracted over 280 abstracts under 10 separate themes and over 70% of the abstracts came from Ireland. The National Centre for Laser Applications (NCLA) in NUI-Galway played a major role in the local organisation and in the coordination and planning of the meeting.

Prof. Tom Glynn (NCLA Centre Director) was conference chairman, while Dr. Gerard O'Connor chaired a half day session on Lasers in Material Processing. The conference, held over two days in early September, had 5 presentation sessions running in parallel and a large poster session on the evening of the first day. It was attended by over 480 delegates (75% from Ireland) and included a comprehensive technical exhibition in which 44 companies were represented. New photonics start up companies in Ireland were also well represented.

The meeting brought together physicists, engineers, chemists, imaging specialists, as well as biomedical researchers - all with an interest in the applications of lasers and photonics in fundamental research or in product development. The materials processing session (complemented by a satellite course on Laser Machining for Manufacturing from Marc Nantel in Photonics Research Ontario) included presentations on laser-assisted material processing and on studies of the associated laser plasmas.

NCLA personnel presented papers on the application of their new femto-second source in micro-machining of advanced materials and on accurate beam characterisation of their diode-pumped solid-state system. Proceedings of the meeting are now available (SPIE Vol. 4876).

Vendor exhibition at ICALEO 2002 - a great success!

April

9 AILU Members' Meeting
Annual meeting, with presentations, AGM and factory tour
Jaguar Cars
Castle Bromwich Plant, Birmingham
Contact: AILU

10 Make It With Lasers
Lasers - the competitive and cost effective solution
GSI Lumonics
Rugby
Contact: Lucille Patterson (lucille.patterson@twi.co.uk)

15 Assoc. of Manufacturing Excellence
Annual Conference (15 & 16)
NEC (Running along side Subcon)
Birmingham
Contact: www.ame-uk.org

May

21 AILU Open Workshop
Efficient use of lasers in sheet metal working
Amada UK, Kidderminster
Contact: AILU (flyers not yet issued)

June

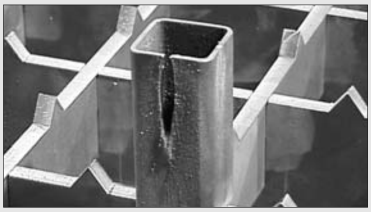
18 AILU Open Workshop
Applications of laser micro-processing
Exitech Ltd
Yarnton, Oxon
Contact: AILU (flyers not yet issued)

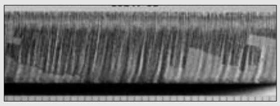
19 4th National Conference on Rapid & Virtual Prototyping and Applications (19 & 20)
Buckinghamshire Chilterns University College
High Wycombe
Contact: Dr Chris Bocking (chris.bocking@bcuc.ac.uk)

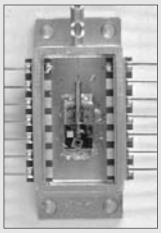
23 LASER 2003 - World of Photonics (23 - 26)
Lasers in Manufacturing 2003
WLT International Conference
CLEO/Europe-EQEC 2003
Munich Exhibition Centre
Munich, Germany
Contact: www.laser.de

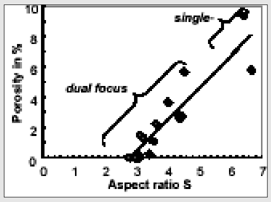
Contents

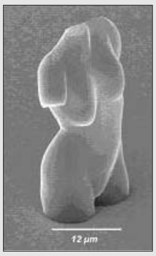
IN THIS ISSUE

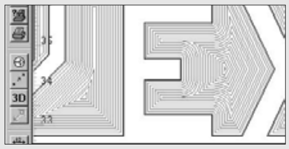












Editorial Policy

The Industrial Laser User is the house magazine of the Association of Industrial Laser Users. Its primary aim is to disseminate technical information and to present the views of its members.

The editor reserves the right to edit any submissions for space and other considerations.

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

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Editor: Mike Green
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AILU, Oxford House, 100 Ock Street, Abingdon, Oxon. OX14 5DH
T: +44 (0)1235 539595 F: +44 (0)1235 550499 E: admin@ailu.org.uk