The Industrial LASER USER

association of industrial laser users

Issue 34 *March 2004*

2004 winners of the AILU Award and Prize

Denis Hall - 2004 AILU Award winner

Denis Hall, Co-Founder and Non-Executive Director of Rofin-Sinar UK Ltd and Professor of Photonics at Heriot-Watt University, Edinburgh has won the 2004 AILU Award for his contribution to the development of industrial lasers and their applications, especially for work on the RF-excited planar waveguide diffusion cooled CO_2 'slab' laser.

Denis' research in CO_2 lasers began as a PhD student in the USA, and continued during 9 years of post-doctoral research at NASA, where he produced the first comprehensive theoretical treatment of optical resonators for waveguide lasers, and at Avco in Boston where he worked on electron beam excited lasers. Denis continued this work at RSRE Malvern when he returned to the UK in 1976, where he developed a family of waveguide laser devices excited by dc discharges. These proved to be the basis of many UK advanced military laser systems for ~20 years.

Denis Hall with a student at Heriot-Watt's laser laboratories

Denis' university career began relatively late when, at 38, he gained a position at the University of Hull. Part of his research at Hull involved transverse RF excitation techniques to produce compact waveguide CO_2 lasers for medical, industrial and laser radar applications. In 1980 he co-founded Laser Applications Ltd in Hull, set up to manufacture lasers and laser systems for medical and industrial applications. The company was later acquired by Coherent Inc, operating as Coherent (UK) Ltd, and is now part of the Linx Industrial Group.

He moved to Heriot-Watt University in 1987, where his research group continued to pioneer new laser architectures, leading to their development of the sealed slab CO_2 laser in 1988. This technology was taken up by Coherent Inc as the basis for their Diamond© range of sealed industrial lasers. In 1997 Denis was a co-founder of Palomar Technologies Ltd, set up to manufacture CO_2 lasers based on planar waveguide technologies. The company now operates successfully as Rofin-Sinar (UK) Ltd with a staff of ~65 manufacturing slab CO_2 lasers and systems. Denis combines his laser research with the role of Pro Vice-Chancellor of Heriot-Watt University with responsibility for Research.

continued on p3

Great interest in polymer processing at the latest AILU workshop

Report on AILU's most recent workshop with contributions from Paul Hilton and Marcus Warwick

The 'Laser processing of polymer-based materials' held at TWI on 18 February 2004 proved to be among the best attended and, judging by the response of delegates, one of the most successful AILU workshops for several years. Paul Hilton from TWI chaired the day of presentations put together by his colleague Marcus Warwick.

In November 2000 when we ran a meeting on the same subject we had only 58 delegates; at this recent meeting we had 86, the vast majority of whom were users seeking laser solutions. Also, comparing with previous meetings on plastics, the number of actual production applications appears to be rising fast.

The title of the introductory talk, given by Ian Jones from TWI, 'Polymers meet Photons' set the scene for what was to follow. Because of the range of wavelengths available, the interaction of laser light with polymers provides the necessary mechanisms for a wide range of possible processes, both pyrolytic, (i.e. involving direct heating of material) and photolytic (i.e. involving direct breaking of chemical bonds) in nature. When considering potential applications, one concept that Ian introduced was the joining of polymer-based fabrics.

Gareth McGrath from Gentex Corporation, presented the subject of Clearweld ® using a wide range of samples which were passed round the audience (and which were also subjected to some impromptu NDT!) and no slides. The Clearweld ® process involves using a layer of infra-red absorbing dye at the joint interface.

continued on p 4

Speakers at the 'Laser processing of polymer-based materials' workshop at TWI on 18 February; (l to r) Bill Hogan and Rolf Schmeisser (Jenoptik), Paul Hilton (TWI, Chairman), Markus Bleher (Bielomatik Leuze), Gareth McGrath (Gentex), Alex Hofmann (Laserquipment), Scott Wastoby (Invista), Karen Henderson (Coherent UK), Ian Stewart (Lindstrand Balloons), Ian Jones and Marcus Warwick (TWI), Reinhold Martin (Ticona); Jim Fieret (Exitech) and Peter Gollmann (Fisba Optik). Missing from the picture is John Powell (Laser Expertise).

Letters to the Editor

How long to run your laser machine?

The article 'Run the old lasers into the ground..." by Jay MacFarlane in Issue 33 makes very interesting reading and on the face of it we should all be running our machines into the ground and buying new every five or six years and not every 18-24 months as we do now.

The problem lies in the basis used for his calculations and as he says himself statistics and mathematics can be used to give any result you want. Competition is very fierce these days and our customers are wise as to the type of machinery out there (*It should be noted here that we have recently bought a 5kW system for the same price we paid for a 2.6kW six years prior and the output has doubled*). They know that the latest machines are cutting faster than the older ones and they expect to be paying accordingly. They pretty soon get their own way - over eager (or frightened) competitors see to that.

The effect of that is to reduce the recovery rate of the older machines so that where £90 per hour is given, the actual rate is likely to be a maximum of £60. This would reduce the annual contribution by £720,000 leaving a balance in favour of the new machines of £578,000. Jays figures look good but our competitors would never allow us to be so simplistic. To stay ahead of the game you need the latest equipment, I don't believe that any of the leading sub-contractors in the UK are relying to any great extent on old machinery.

David Lindsey Laser Process Ltd

Jay's argument in his article 'Run the old lasers into the ground..." is similar to that concerning the purchase (or not) of a new car. Do you keep running the old model which has been paid for, you know its idiosyncrasies and you can fix yourself; but the paint's thin in places, there is a suspicion of rust starting to appear and it hasn't got a CD, or heated seats, or electric windows, or any kudos?

The new car has all the bells and whistles, really looks the part and it impresses the hell out of the neighbours; but it costs a fortune to buy, the insurance costs are ridiculously high, it is liable to get nicked, it has an umbrella in each door and it depreciates faster than a speeding bullet.

You have to do the sums, as Jay has done. Then add in the intangibles. Then decide.

Incidentally the Rofin SM2000 was a hell of a good laser.

Tim Holt Institute of Photonics

1967 Laser video on the internet

A British Pathe newsreel clip, which can be downloaded for free from *www.britishpathe.com*, shows a CO_2 laser in use at the Services Engineering Research Centre in 1967. With a Cholmondsly - Warner like voice over, scientists are seen playing with a "ray gun". The laser is described as "stranger than a hovercraft".

The clip serves to remind us all of how long ago lasers were being investigated for materials processing. Razor blades are seen being cut, the drilling of diamonds is described and an experiment shows the welding of plastic bags. The finale is using the laser to set rockets off, disappearing up a piece of guttering through the ceiling!

Martin Sharp Lairdside Laser Engineering Centre, Liverpool

AILU-driven standards?

Working on the development of CO_2 laser scanning systems for demanding applications, it has become clear to me that there are a number of quite basic aspects of laser beams and optics that would benefit from greater standardisation; and I would also like to think that AILU could assist with this. I offer scan speed as an example.

Scanning speed can be a very confusing topic. What we need is a standard for defining scan speed that will be recognised throughout the laser industry.

Most suppliers of CO_2 scanheads quote scanning speed in metres or millimetres per second. Nd:YAG scanheads are mostly marketed by the number of 1mm high characters that they can mark in a second: but then there is not much call for 1mm letter marking in CO_2 scanning applications.

The current state-of-the-art software to control galvo scanning motors operates with 16-bit resolution, ie. everything is divided into 65,536 positions in X, Y and if used, Z. If I use a f100mm lens with two-axis scanning and a field size of 70 x 70mm, I will have a resolution of 936 positions per millimetre in both directions, ignoring lost bits for correction of field distortion through the f-Theta lens . If I switch to a f2122mm lens I will have a field size of 1.5 x 1.5m, but a resolution of only 43 positions per millimetre. If I set my galvo motors to run at a mere 1000bits per millisecond, the spot will move approximately 1.07m/sec with a f100mm lens and 23m/sec with the f2122mm lens and the exact same scanhead. What is the speed of the scanhead?

Maybe we should be looking at some norm to become an AILU-driven standard. Radians per second anyone?

Steve Hastings Raylase AG

Note from the editor

'Composites are coming' says a headline of an article in a recent issue of Machiney magazine, dealing with the increasing use of composites in large civil aircraft. No mention of laser processing, mind you; though it would take more than that to dampen my enthusiasm after the recent lively AILU workshop on polymer processing.

Current market research forecasts a steadily increasing significance for laser polymer processing and the turnout and enthusiasm of delegates at our recent workshop backs this up. Opportunities abound, especially in laser welding of polymers, a process for which the match of laser wavelength to a specific feature of the polymer's absorption spectrum is a key requirement. How fortunate it is, therefore, that the spectral region of particular interest in this regard, the near infrared, is the very wavelength band where current laser technology has its greatest strengths and most exciting prospects in terms of sources and optics.

It is at times like these, when an area of technology begins to open up a new field of major commecial opportunity, that I feel fortunate to have chosen a career linked to lasers. There seems to be no end to their industrial potential!

(continued from p1)

2004 winners of the AILU Award and Prize

Adrian Orchard - 2004 Young UK Laser Engineer

The Young Laser engineer's Prize for 2004 has been awarded to 28 year old. Adrian Orchard of TRS Engineering Services Ltd Bloxwich, West Midlands, in recognition of his work in the application of laser welding to the fabrication of heat exchangers.

"Adrian has been an important part of the TRS toolmaking, prototype and precision engineering team and he has tackled leading-edge projects using state of the art laser technology," said John Shuker, Director of Engineering Services. "His work has enhanced TRS' ability to broaden its market base," added John.

The design of the unique heat exchangers that Adrian was involved in manufacturing is subject to patent action, so full details cannot be released at this time. However, the process involves the welding of two 0.25mm thick stainless steel plates in such a way that the weld pattern generates capillary channels.

The integrity of the weld, requires that the two sheets have full contact during the laser weld process; any air gaps would cause a lack of weld integrity and oxidation of the component. The weld path pattern covered almost the entire face of the heat exchanger panel so vacuum clamping was employed. "From this point on," said John, "Adrian contributed everything to the manufacturing process."

The main challenge for Adrian was that technical tables for setting the machine speed and laser parameters were not available for the welding process, so the machine settings had to be determined empirically, both in hardware and software. Furthermore, the prototype panels were required to be treated in the same way as in production, and so pre-tempering of the sheets to try and simplify the welding parameters was not permitted.

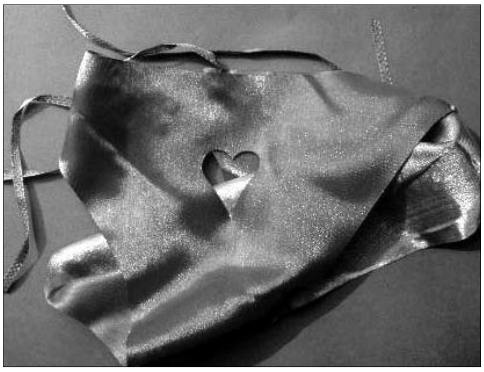
Adrian Orchard

Nitrogen/Helium was used to neutralise hydrogen around the heat affected zone during the CO_2 laser weld and prevent oxidation: the panels were later to be coated, so to ensure adhesion any surface oxide had to be eliminated.

The weld design was a series of 'dashes' 10mm in length; the short weld length necessitated ramping the laser power up and down as the head of the 7-axis machine first accelerates and then decelerates over each weld length, maintaining constant weld penetration and HAZ. The power ramping requirements for the two phases were found to be quite different.

Adrian's work is supported by Energy International Systems Ltd, who commissioned the work.

Most gorgeous part this quarter



Laser-cut in polyamide

Wicked Knickers!

Congratulations to Janet Stoyel of The Cloth Clinic, winner of this quarter's Most Gorgeous Part competition.

This item of ladies underwear was designed and produced specifically for sale as a Valentine present.

Two materials: polyester/polyamide, one gold, one ruby, cut back to back in one piece. No stitch, no uncomfortable seam lines, gusset problems or tight elastic leglines to show through slinky garments. Laser cut buttonholes at both sides with tie fastening to make pretty bows.

A cut-out heart shape in a provocative position enables the wearer to create a personal design statement!

The authors of items published will receive a complementary registration to an AILU workshop of their choice.

Greatest Cock-up

We were recently called to a customer who has many laser machines, one having cutting difficulties.

Our engineer was despatched and conducted the preliminary tests that we all do and could find no reason for the problem. On further investigation he discovered the thermostat for the chiller and asked the Operator why it was sitting on top of the cabinet. The Operator's response was that on this particular morning, after a cold snap, the machine would not initially fire up due to the temperature of the water being too low as a result of the coldness in the building. His initiative told him to remove the thermostat and hold it for some time and allow it to read a new temperature, which would then allow the machine to fire up. Unfortunately, his common sense did not prevail and he omitted to return the thermostat to its rightful position. The chiller consequently was not reading the temperature of the water cooling the resonator, it was still reading the temperature of the room.

On re-installing the thermostat, the temperature was in excess of 40°C, which led our engineer to understand the reason for their cutting problems: they were due to the high thermal temperature of the resonator.

If this had not been caught in time, this would have caused a major malfunction with obvious costly consequences.

Submitted by a laser supplier who prefers to remain anonymous.

Please send in your 'greatest cock-up'. A bottle of champagne awaits the best contribution we print over the coming year!

(continued from p1)

Polymer processing workshop at TWI

Examples were shown of how the process can be applied to both rigid and flexible plastics, including films and various forms of woven, non-woven and laminated fabrics. One example was of a dark blue ‘fleece’ jacket, in which every joint, including joining of the zip fasteners, was made using the Clearweld ® process. On this garment the only stitching involved the Clearweld® logo.

The next presentation, given by Markus Bleher (Bielomatik Leuze, Germany) focused on transmission laser welding of plastic materials and in particular the welding equipment used in various current production applications. These systems employed both diode and solid state lasers for welding, utilising fixed beams with moving parts and galvo-driven beam scanning with fixed parts, respectively. The talk concluded with interesting examples of transmission laser welded automotive parts, employing white to black and black to black component configurations.

This theme was continued by Alexander Hofmann (Laserquipment, Germany) who split transmission laser welding into three areas:

- Contour welding - where either the part or the laser are manipulated.
- Quasi-simultaneous welding - employing galvanometers to scan the laser beam over the part.
- Simultaneous welding - using several diode laser stacks together in a single point welding method.

Alexander concluded with examples of the production equipment manufactured by Laserquipment and products in or close to production, including Brita water filter containers, solar panel heat exchangers and plastic window assemblies for vending machines.

Jim Fieret (Exitech) considered the range of lasers available for micromachining polymers, including use of low M^2 nanosecond (Q-switched) Nd-YAG and Vanadate lasers (IR or UV), moderate M^2 Ti:Sapphire femtosecond lasers and high M^2 Excimer (UV) lasers. “The key is to choose the right laser wavelength, beam characteristics and process,” Jim emphasised. Applications included serial writing using galvo mirror scanning systems (including blind hole and slot drilling in Polyimide and polymer fibre composites) and Excimer laser mask fabrication of components for microturbines and GPS antennas. The drilling of inkjet printer nozzles provided an interesting demonstration of synchronised image scanning (SIS), an Excimer laser mask imaging technique for large area writing of $2^1/_2$ D-shaped microstructures. Other applications included 3-D display patterns and micro-lens arrays, including aspheric lenses.

John Powell (Laser Expertise) addressed the cutting of polymers. He ruled out CW Nd:YAG because, without the help of carbon filler, most polymers are transparent to the 1.06µm wavelength. The CW CO_2 laser is commonly used for cutting, but the mechanisms for thermoplastics and thermoset plastics are different. The former are (with exceptions) cut by the melt sheering process common to metal cutting, whereas thermoset plastics are cut by thermal degradation. Problems of cut edge quality and post-process finishing were addressed, as well as the significant fume hazard associated with laser cutting.

The weld joint requirements for technical textile joining in safety-critical components including airbags and large inflatable devices (including hot air balloons, parachutes and tunnel plugs) were addressed, respectively, by Scott Westoby (Invista - part of the DuPont Group) and Ian Stewart (Lindstrand). In both applications

Laser welding of a label to a technical textile during the TWI Labs tour

the Gentex absorber was used to provide laser beam absorption at the interface. Scott emphasised the comparison of laser welded and one piece woven seals and concluded that although the sealing potential of laser welding is good, the weld strength is currently not as high as existing airbag seal technology and leakage rates are higher. On the other hand, as Ian pointed out, for inflatable components of interest to Lindstrand, stitching is unsuitable as are some other joining techniques (such as glue). The tensile strength of the weld was acceptable for these applications but helium leakage rates, at least in part due to laser damage, remained a problem.

Developments in plastic welding with a scanner were described by Peter Grollmann (Fisba Optik). Using a post-objective scanning system a large scan area can be achieved without the limitations and aberrations of F-theta pre-objective scanning. The Fisba system, which includes a power meter, pilot beam, pyrometer and camera monitoring system, was among the many desktop items on display at the lunchtime exhibition. Peter acknowledged that for some applications the speed of movement of the focusing lens was a limitation; in other cases the fact that the beam was far from vertical at the edge of the scan field could be a problem. Successful applications with this scanner included the welding of a dial face on a meter, where the large scan area allowed parallel processing of several units, with significant reduction in process time .

Karen Henderson (Coherent UK) presented some of the work of their Laser Applications Centre in Santa Clara USA. Promising applications for laser curing adhesives in fibre optic telecommunications, microelectronics and related fields were identified and illustrated by the ‘on-bonder’ parallel and serial curing of adhesives for fixing a matrix of single emitter fibre-coupled devices. Karen also described micromachining of polymers with a Q-switched CO_2 laser, with illustrations including marking, ablative removal of polyimide from copper; with excellent precision and quality. UV (mask) marking and machining was also addressed, including marking by colour changes (photochemical change in the pigment within the plastic) and reel-to-reel direct laser patterning of flexible materials.

The talk by Paul Williams of Regenesys on the diode laser welding of utility-scale energy storage devices was given by Marcus Warwick (TWI), in view of the recent forced closure of Regenesys. The energy storage devices, stacked fuel cells, required hermetic seals within the electrode and support frame. Diode welding was the technique of choice over vibration and ultrasonic welding. A prototype robotically-controlled laser welding system had been successfully developed for this purpose at TWI. “With the correct quality control and QA procedures laser welding proved a very reliable technique,” concluded Marcus.

In his presentation of laser welding and marking of plastics, Reinhold Martin (Ticona, Germany) provided several useful tables, including degree of welding success for a wide range of methods and plastics; combinations of plastics that can be welded; and welding geometries for transmission welding. Ticona have assessed laser welding of their Hostaform and Celanex ranges of materials, homogeneous and mixed-material welds. Reinhold also reviewed the benefits of laser marking and showed YAG laser marks in various colours available in their Hostaform range of materials. He also presented tables showing the laser marking suitability of a range of amorphous and semi-crystalline thermoplastics.

The last presentation of the day was given by Rolf Schmeisser and Bill Hogan (Jenoptik). The company’s VOTAN range includes 2-D and 3-D laser perforating, cutting, engraving and welding machines, mainly for the packaging (2-D) and automotive (3-D) sectors. Sources include a 1.2kW Trumpf CO_2 laser tuned to 9.3µm wavelength to improve plastic absorption, with a working 2-D area up to 1.5 x 1.5m. Within the robotically-delivered VOTAN C range, 3-D cutting is possible within volumes of 2.8 x 1.2 x 0.3m. “One car maker has 20 different door specifications. The laser system allows any one to be dialled up for hole cutting,” said Bill. Other examples included clean cutting of technical fibres, decorative door film, floor mats and rubber lip seals. With a scanning head replacing a fixed cutting head on a robot, synchronised if necessary for simultaneous robot and scanner motion, micro-holes and large quantities of small components can be cut in thin plastics.

After the final presentation a short tour of the new laboratories at TWI was arranged, combined with demonstrations of laser welding of textiles. Delegates toured the laboratories in small groups, accompanied by TWI staff. The main engineering hall houses areas for defect and plant assessment, resistance welding, mechanical fastening, arc welding and surface engineering, as well as TWI’s high-power lasers. These include four Nd:YAG lasers and two CO_2 lasers, used for welding, surfacing and cutting. A demonstration of welding an airbag fabric was carried out using a 1.8kW 940nm Rofin direct-diode laser, mounted on a two-axis gantry system from Blackman & White. The TWI laboratories for scanning-electron and light microscopy were seen, along with the range of specimen preparation equipment.

The laboratories of the Advanced Materials and Processes group were also viewed. This group’s activities cover polymers, composites and adhesives, as well as microjoining, electronics and ceramics. The labs include a microjoining area, a reliability testing lab and a clean room. Diode lasers for polymer welding include: a 50W scanning system from Fisba Optik; 300W and 600W systems from Laserline attached, respectively, to a two-axis table and a six-axis robotic arm from Motoman; and a 1kW Rofin system attached to a high-speed single axis table. The polymer lab includes equipment to carry out a wide range of polymer joining processes, including impulse welding, ultrasonic welding, adhesive bonding, hot-plate welding, resistive implant welding and vibration welding. Finally, the 600W Laserline laser and robot were used to weld a label to a piece of mattress fabric, an application developed at TWI within a collaborative project supported by the DTI.

The Association is most grateful to Paul Hilton for a marvellous job chairing the meeting, keeping the speakers to time and stimulating questions after each talk; and to Marcus Warwick for putting together the programme of speakers. We would also like to thank the TWI organisation for their contribution to the smooth running of the event.

Tricks and tips

Materials for pulsed Nd:YAG laser weldering

The most important consideration in any welding operation is the weldability of the material - all else then follows!

The most commonly welded material is steel, and the general selection rule is to keep the carbon content under 0.12%. For stainless steels, ensure that the Cr/Ni ratio is greater than 1.7. Stainless steel alloy ANSI 303, many 400 series alloys and high carbon steels should be avoided due to a high carbon, phosphor and sulphur content. Generally, nickel alloys and titanium are highly weldable, but aluminum alloys cracking is an issue. Grades such as 3003, 4032, 5005, 4047 to 6061 are fine, others are case specific. Copper can be spot welded with attention to setup and a large pulse energy!

The plating material and method of plating can also have a significant effect on the welding process. For example, electro-less nickel plating creates welding problems due to the inclusion of phosphor and other contaminants during the plating process. The recommended plating method is electrolytic. The thickness and type of plating is also a consideration, for example, a gold coating thickness above 1 µm may induce weld cracking.

Geoff Shannon
Unitek Miyachi Lasers (Monrovia California, USA)

Job shop tip

Removing scrap from very large cutting tables

Cutting Edge Metal Processing Inc of Mobile, Alabama are somewhat unique in the laser cutting field in the size and weight of plate that they cut and weld. (As an aside, we scrap any plate that comes off the table smaller than 4' x 8' (1.2m x 2.4m): for many laser shops, this would be the ideal size to cut!)
As Bob Lewis explains:

Slag and small drop were a concern when we designed our 185’ long (56.4m) gantry system. We looked at several rather sophisticated designs involving automated removal but opted for a very simple and effective system.

We shop-built several trays 150mm deep x 3m square on "V" rollers and installed inverted angle iron tracks the length of the table. About once a week, we put a clean tray at the South end of the table and push it flush with the table end with a small fork lift. At the North end a partially filled tray is forced out. It is then emptied into a scrap trailer. This works extremely well for us and we've never had any mechanical problems as we might have with an automated system. It is normally emptied during the second shift when things are less hectic.

Bob Lewis
Cutting Edge Metal Processing Inc (Mobile AL, USA)

Members' News

Welcome to New Corporate Members
(since January 2004)

IPG Photonics

Manufacturing Service Solutions Ltd

Metal Improvement Company

Thales Laser

Universal Laser Systems GmbH

Warwick Laser Systems

News in brief

Institute of Photonics in UK FSO Consortium
A consortium of UK companies and universities are to develop a next-generation optical platform for free-space-optical (FSO) communications. The project, valued at over £720,000, dubbed 'ALFONSO', will combine advances in mid-infrared, optically pumped, vertical external cavity surface-emitting lasers (mid-IR OP-VECSEL) at the Institute of Photonics, University of Strathclyde, Glasgow, with expertise in adaptive optics at the University of Durham. Industrial partners Cablefree Solutions Ltd, Sira, Ferranti Photonics Ltd and Starpoint Adaptive Optics Ltd provide development engineering support and route to market. ALFONSO is sponsored by the Smart Optics Faraday Partnership and is supported with a grant by the UK Government's DTI LINK OSDA (Optical Systems for the Digital Age) award scheme.

LAMP lights up
The LAMP (Laser Aided Material Processing) project is an initiative by Coventry and Warwick Universities to provide a funded laser R&D facility for SMEs in the West Midlands region. Provided that they are within the Objective 2 area, SMEs can use this facility at no external cost to them, thanks to part funding by the European Regional Development Fund. As well as lasers, specialist fabrication technologies are within the project scope.

To benefit from this free service, qualifying SMEs are encouraged to email *info@lampproject.co.uk*. The service includes: telephone advice; feasibility studies; advice on design protection; type testing; development proposals; prototyping; training; technical documentation; pre-production batches.

Southern Expansion for Photonics Cluster (UK)
The Photonics Cluster (UK) has established a new base in the South of England. Located at the Hertfordshire Business Incubation Centre (HBIC) in Stevenage, the base will complement the expanding facilities and programmes delivered by the cluster from its HQ at Aston Science Park, Birmingham.

The HBIC is funded by the East of England Development Agency, and was set up last year to support and help the growth of biotechnology, ICT and the aerospace and defence sectors.

News in brief

VT Shipbuilding
VT Shipbuilding is playing a significant role, working alongside BAE SYSTEMS Marine, in the design and build of the new T45 destroyers for the Royal Navy. VT will build substantial sections, including the bow and mast modules, of the first six vessels in the new Shipbuilding Facility at Portsmouth Naval Base.

Type 45 is the first class of surface warships to pioneer a new modular construction philosophy under which sections of the ships will be built at different sites in the UK and then brought to a shipyard for final assembly. At the Portsmouth site plate panels are cut with a Messer Griesheim 4kW CNC laser plate cutting machine, prior to welding and assembly.

Laserdyne receive follow-up laser machine orders
Laserdyne® Systems, a Division of Prima North America Inc., has announced receipt of multiple follow-on orders for its multi-axis 790 beamdirector systems totalling over 1.9 million dollars from the Pratt & Whitney Division of United Technologies.

The new systems include Laserdyne's new patented Optical Focus Control (OFC). OFC has been shown to improve quality and shorten cycle times in drilling both uncoated and thermal barrier coated turbine engine parts.

Burrhart offers laser cutting consumables
Consumables for high power CO_2 laser profilers and plasma cutting machines have been introduced by Burrhart Machinery, Luton, under an agreement with the Italian manufacturer Esse A. The company is noted for its patented nozzle which optimises gas consumption to reduce running costs.

Burrhart was also recently appointed agent in the UK and Eire for the extensive Ophir range of CO_2 laser optics, marketed under the Duralens brand name.

New premises for Lasers Are Us
Lasers Are Us Ltd UK has moved to larger premises, to allow its research, design and development and production to come back under one roof at their headquarters in South Wales. The extra space will house further lasers, to broaden the range of laser services offered. Two new sales staff and one operator joined the team in January.

New web site for GSI Lumonics
GSI Lumonics have redesigned their web site offering visitors improved access to information about the company, its products and their applications. The web site at *www.gsilumonics.com* has improved navigation and provides enhanced abilities for visitors to contact GSI Lumonics for assistance. It also includes news releases, annual reports, detailed stock information, investor FAQs and more.

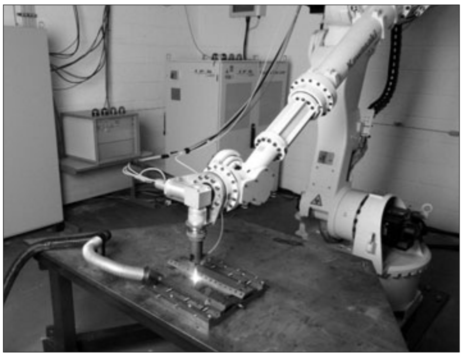
Camtek signs up new agents
Camtek, Malvern, UK has appointed ScotCAM Limited, based in Wishaw, Lanarkshire as, an agent of its CADCAM products in Scotland. They have also appointed JETCAM s.a.r.l, based in Brétigny, near Paris, as an agent of its CADCAM products in France.

7kW Yb-fibre laser operational at TWI Technology Centre (Yorkshire)

As part of TWI's regional development plans, a new 7kW Yb-fibre laser was recently delivered and installed in record time at TWI Technology Centre (Yorkshire) Ltd. The YLR-7000 Yb-fibre laser, manufactured by IPG Laser GmbH, was installed in a fully enclosed, CCTV monitored, 6 x 6m cell. This cell, modelled on those used in TWI Cambridge for Nd:YAG laser processing, encloses the laser, a four-way optical switch, a 6-axis articulated robot arm and a worktable, which can be replaced with alternative manipulating equipment if required.

The YLR-7000 comprises a series of 200W fibre units, the outputs of which are combined using proprietary technology, into a 10m long single fibre of 200µm core diameter. From the end of the fibre the laser power enters a four-way optical switch, manufactured by Optoskand, which allows simultaneous processing of up to 3.5kW of laser workpiece power through beam paths 1 and 2, or up to 7kW of laser workpiece power using beam paths 2, 3 or 4. An average beam parameter product of 18.5mm.mrad and laser workpiece powers of up to 7.2kW were measured during commissioning.

The laser beam is transmitted from the optical switch to the beam focussing systems, through 20m long by 300µm diameter optical fibres. Three Optoskand beam focusing systems are available for material processing: one has a 120mm collimating lens and a 250mm focussing lens, the other two have a 120mm collimating lens and a 160mm focussing lens. These options produce minimum laser spot diameters of 390µm and 610µm respectively, as measured using the PRIMES FM-35 Focus Monitor. The 610µm spot with the 250 mm focusing lens will allow a good comparison to be made with the processing performance of the 3kW and 4kW Nd:YAG lasers currently at TWI Cambridge.



6-axis articulated Kawasaki robot arm

Each of the beam focusing systems can be mounted on the ZX130L, a 6-axis articulated robot arm manufactured by Kawasaki. The robot has a 130kg payload and an extended reach of close to 3m, allowing components as large as 3m by 1.5m to be welded. The Kawasaki D42-controller has been equipped with INTERBUS-S to ensure high-speed communication between the robot and the Yb-fibre laser. It will also link with any additional peripheral equipment to be used in the cell, such as cold wire feeder, seam tracker or arc welding source. It is believed that this is one of the few research laboratory laser systems where all laser and process functions are set and controlled entirely at the robot control.

Following a very rapid and efficient commissioning, a three-month study is currently underway, assessing fibre laser performance for a range of materials, thickness and joint configurations. Further work on welding (laser and laser hybrid i.e. the laser plus arc), cutting and surface modification or cladding is planned for a number of applications/industry sectors, including medical, high-temperature materials, spring manufacture and airframe structures.

Contact details for members' news items

Aerotech
Contact: Andrew Moore
T: +44 (0) 118 940 9400
F: +44 (0) 118 981 5022
E: amoore@aerotech.co.uk

Bavarian Photonics GmbH
Contact: Stephan Geiger
T: +49 89 89407 226
F: +49 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.com

BLM Group UK Ltd
Contact: Paul Lake
T: +44 (0) 1525 402555
F: +44 (0) 1525 402312
E: paul@blmgroup.uk.com

BOFA (UK) Ltd
Contact: Derek Roberts
T: +44 (0) 1202 666789
F: +44 (0) 1202 649922
E: sales@bofa.co.uk

Burrhart Machinery
Contact: William Burrell
T: +44 (0) 1582 563400
F: +44 (0) 1582 493993
E: w.g.burrell@burrhart.co.uk

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

Coventry University
Contact: Peter Hancocks
T: +44 (0) 2476 888036
F: +44 (0) 2476 887697
E: cex432@coventry.ac.uk

Fisba Optik AG
Contact: Ralph Gschwend
T: + 41 71 282 3330
F: +41 71 282 3130
E: ralph.gschwend@fisba.ch

GSI Lumonics
Contact: Riccardo Tomassoni
T: +44 (0) 1788 570321
F: +44 (0) 1788 579824
E: tomassonir@gsilumonics.com

Institute of Photonics
Contact: Tim Holt
T: +44 (0) 141 553 4120
F: +44 (0) 141 552 1575
E: tim.holt@strath.ac.uk

John Tainton
Contact: Roy Harwood
T: +44 (0) 1562 740477
F: +44 (0) 1562 68765
E: roy@johntainton.co.uk

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

Laser Lines (I&M)
Contact: Gary Broadhead
T: +44 (0) 1295 672500
F: +44 (0) 1295 672550
E: garyb@laserlines-im.co.uk

Laser Optical Engineering
Contact: Rob Roach
T: +44 (0) 1509 228733
F: +44 (0) 1509 223948
E: robroach@laseroptical.co.uk

Laser Resale
Contact:Steve Smith
T: +44 (0) 1924 223038
F: +44 (0) 1924 223054
E: sales@laser-resale.com

Lasers Are Us
Contact: Simon Lau
T: +44 (0) 1656 745090
F: +44 (0) 1656 749611
E: sales@LasersAreUs.com

Micrometric Ltd
Contact: Neil Main
T: +44 (0) 1522 509999
F: +44 (0) 1522 501901
E: neilmain@micrometric.co.uk

Photonics Solutions plc
Contact: Douglas Neilson
T: +44 (0) 131 664 8122
F: +44 (0) 131 664 8144
E: doug@psplc.com

Photonics Cluster (UK)
Contact: Glenn Barrowman
T: +44 (0) 121 260 6000
F: +44 (0) 121 250 3567
E: glennb@astonsciencepark.co.uk

Prima Industry UK
Contact: Joe Attuoni
T: +44 (0) 2476 645588
F: +44 (0) 2476 645115
E: joe@primauk.com

Pro-Lite Technology
Contact: Peter Blyth
T: +44 (0)1908 730085
F: +44 (0)1908 269991
E: peter.blyth@pro-lite.uk.com

Purex International LLP
Contact: Jon Young
T: +44 (0) 1709 763000
F: +44 (0) 1709 763001
E: jon.young@purexltd.co.uk

Pyramid Engineering Services
Contact: Glenn Higgins
T: +44 (0) 20 8 776 5545
F: +44 (0) 20 8 776 5546
E: glenn.higgins@pyramideng.com

Rofin-Baasel UK
Contact: Andy May
T: +44 (0) 870 990 1020
F: +44 (0) 870 990 1030
E: a.may@rofin-baasel.co.uk

Rojac Engineering Ltd
Contact: Jonathan Cox
T: +44 (0) 121 773 3536
F: +44 (0) 121 771 2148
E: mail@rojac.co.uk

Thales Laser SA
Contact: Antoine Duret
T: +33 1 6933 9443
F: +33 1 6933 9458
antioine.duret@fr.thalesgroup.com

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

TWI
Contact: Paul Hilton
T: +44 (0) 1223 891162
F: +44 (0) 1924 223054
E: pahilton@twi.co.uk

Umicore Laser Optics Ltd
Contact: Paul MacLennan
T: +44 (0) 1438 767500
F: +44 (0) 1438 767555
E: paul.maclennan@umicore.com

UMIST
Contact: Lin Li
T: +44 (0) 161 200 3800
F: +44 (0) 161 200 3803
E: lin.li@umist.ac.uk

VT Shipbuilidng
Contact: Ian Perryman
T: +44 (0) 23 9288 3668
F: +44 (0) 23 80 426010
E: lian.perryman@vosperthorny-croft.com

Winbro Group
Contact: Helen Taylor
T: +44 (0) 1530 516000
F: +44 (0) 1530 516001
E: htaylor@mjt.uk.com

Fine laser machining from Pyramid

Pyramid Engineering has recently delivered an LMS3000 laser-machining centre for fine welding and cutting applications, to a major UK corporate customer.

LMS3000 fine laser welding and cutting centre

In keeping with the customer's standard factory requirements, a Heidenhain motion controller was coupled with Aerotech motion tables to provide a very accurate and flexible package. The specified laser supplied was a Lasag model SLS200 pulsed Nd:YAG providing a maximum output of 200W delivered by fibre beam into a Class 1 safety enclosure..The laser incorporates quick change welding and cutting options to suit the customer's small-batch manufacturing requirements.

The above system is the latest addition to a growing portfolio of specialised turn-key systems designed and manufactured by Pyramid Engineering, covering hermetic encapsulation, welding, cutting, marking and general machining operations.

Aerotech's automation publication

Aerotech has released a publication that details its expertise across a variety of demanding, high-precision industries. The 40-pages of automation solutions for the automotive, machine tool, assembly and packaging industries highlighting how Aerotech's advanced motion systems have helped major manufacturers attain and maintain a competitive advantage through the use of matched, high-precision motion systems.

The new A3200 digital automation platform is the core of many of Aerotech's modern motion systems. Other products include linear and rotary stages, servomotors and drives, robots, actuators and industry-specific motion systems. Other examples include high-speed point-to-point movement systems for automated drilling operation, higher precision motion systems for electro discharge machining (EDM); and pick and place, marking, printing and high-speed registration systems for assembly and packaging applications, to name but a few.

Laser resale expand waterjet activity

Recently established Waterjet Technology, a division of Laser Resale, had invested in a second waterje. It has twin cutting heads and a 4000mm x 2000mm table. The model being shown at MACH will be smaller, also equipped with a rotary axis; and offers superior cutting speeds due to the new design of intensifier and an innovative cutting head.

Waterjet MD Steve Smith commented, "We have enjoyed great success since establishing Waterjet Technology with many components produced both in metals (up to 60mm) and a wide range of non-metals such as plastic, granite and composite materials."

Solutions for laser welding of polymers

ROFIN-BAASEL has a complete laser family for polymer welding: lasers and laser systems with innovative scanning technology as well as compact diode lasers, which can be easily integrated into existing systems by fibre coupling.

Polymer welding with scanner heads

The newly-launched StarWeld Diode laser family comprises diode lasers (SWD) and diode pumped Nd:YAG lasers (SWD-Y) for polymer welding. Every laser is equipped with galvo deflection (scanner) heads as standard. 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.

According to the application, users can choose between highly focussed micro welding lasers (HQ series, welding spot diameters of 0.15 mm and wider) and powerful high-speed lasers (HP series). Typical applications are either quasi-simultaneous welding or contour welding of two-dimensional welding paths.

DLx diode laser

The diode lasers are offered with wavelengths of 808 and 940 nm, providing significant advantages in particular for the welding of pigmented polymers. The main application is polymer contour welding, usually with laser powers between 30 and 120 W. What is new is the additional fibre coupling for these modules, which homogenizes the beam. For precision welding with powers of up to 30 W, a 400 µm core diameter fibre is available.

Company founder and CEO Carl F. Baasel said, "Approximately half of the more than 7,000 Baasel lasers and systems have been delivered with galvo heads. Ideal technological preconditions for the laser polymer welding are opening up here for us."

Expansion at John Tainton

John Tainton, a specialist supplier of fully flattened steel sheets, distributes in excess of 100,000 tonnes per annum. The company processes full prime quality steel coils supplied by some of the worlds leading producers.

Over the last year, Tainton's has expanded by opening a new Service Centre in Cross Keys in Gwent. With five networked locations they can deliver a fast nation wide service. MD Peter Carpenter said, "There is a future for progressive steel suppliers that are prepared to invest".

The company produces decoiled sheets and plates from two Service Centres based in Kidderminster and Crosskeys. The stock range consists of coils in hot rolled dry, hot rolled pickled and oiled, cold reduced, electro zinc coated and hot dipped galvanised and is available in standard widths and thicknesses from 0.6mm to 6.4mm. Coils can be cut to customer's required lengths and a close tolerance multi strand blanking service is also available.

In addition, John Tainton offer QUICK STOCK® to meet the requirements of customers for a same day/next day delivery. In conjunction with the Service Centres at Kidderminster and Crosskeys QUICK STOCK® is also available from warehouses in Braintree Essex, Eastleigh Hampshire and Stockport Cheshire.

Firstek cuts 5-axis programming time

Firstek Limited, manufacturers of prototype automotive components are based in Basildon, Essex, UK and currently run two Prima 5-axis laser machines: an Optimo and a Rapido. After installing PEPS SolidCut Laser to drive these machines they have achieved substantial savings.

Their previous 5-axis CAM system was purchased along with the first machine in 1997, but in 2001 Prima withdrew the product from the market, along with product support and updates. Subsequently, Firstek decided to install PEPS SolidCut laser in the CADCAM department.

"Programming was at least 50% quicker than the previous system, mainly because PEPS is solids-based and can utilise the solid information stored against the part," said Rob Blackwell, Technical Manager. "Previously we would pull in an IGES or other format file with an inner/outer surface. We then had to delete all of the inner surfaces on the old software. PEPS takes in the solid model, so we just pick the edge and one click of a mouse generates NC code. A part that might have taken 5-6 hours to take from drawing to code can now be done in 2 or 3 hours, which over the course of a week saves me about a day."

Every company has their own preferred methods of working, and in the case of Firstek they wanted to change the visual format of the output NC code. Rob added, "My experience of Camtek's support department is that they always provide a swift response; a matter of minutes in this particular instance."

"It cannot be underestimated how important support is," said Iain Tennant, General Manager. "The data from customers is not always formatted consistently, and unless you are a large company with a big IT department you will need people like Camtek to hold your hand through the initial learning curve," he added.

The Prima Optimo can handle larger jobs, which accounts for around 10% of Firstek's business. These jobs require fixtures that previously were impossible to generate manually, requiring alternative part holding methods to be used. PEPS includes automatic 'egg-box' fixture generation, nesting each plate onto a sheet.

With the company's business progressing more towards low volume production work as opposed to purely prototyping, the requirement for fast and reliable throughput of jobs on the 5-axis lasers is paramount. Firstek plan to recruit a new machine operator who will also make use of SolidCut Laser.

"PEPS is important for our business. It not only saves us substantial time but it is easier to use. We can now recruit an operator and train them on the system rather than a specialist CAD operator, which would come at a much greater expense," said Iain.

Consistent investment at NSI brings its rewards

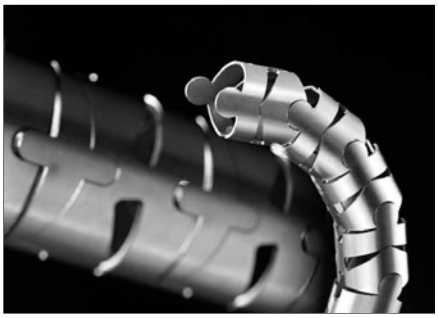
When Lee Bates and Steve Owen established their steel stockholding business in 1986, they had no idea that their NSI Group would eventually include one of the largest laser profiling facilities in the UK.

Initially adding value by providing a profiling service based on oxy-propane cutting, NSI decided to build on the success of this facility during the late 90s. A Trumpf L2530 heralded a substantial programme of investment. Eight further Trumpf laser machines followed and with them a massive rise in the company's laser profiling business; this currently accounts for nearly 85% of turnover.

NSI has applied a simple but hugely successful formula. Rather than secure work and worry about how it's machined afterwards, it has consistently invested in machinery to attract new work. As a result, it has entered five different areas of laser profiling: general, high-speed, heavy-duty, five-axis and tube.

Early success with the Trumpf L2530 and the L3030 flying-optic laser profilers for flat-blank production made NSI aware of opportunities in three-dimensional profiling. Moreover, the company's Midlands location has meant that it is ideally positioned to meet the automotive industry's need for trimmed pressings. Satisfying this need led to the installation of three Trumpf TLC five-axis laser cells over the last three years.

With five laser machines working 24 hours five days a week, further investment beckoned but NSI wanted not only more production but also, greater productivity. MD Lee Bates found the answer in a Trumpf HSL 2502C: a twin resonator, twin head high-speed laser machine. The acceleration and speed achievable by the linear drives on the HSL 2502C enables its two CO_2 lasers to make full use of their 3kW of power, even on thin components. This allows NSI not only to produce parts faster, but also offer high-quality, bright-edged, oxide-free, mild steel parts by using high-pressure nitrogen. However, the company has not confined its HSL machine to thin-sheet applications. It is also using the machine in the 3 - 6mm 'light plate' field. The machine's twin-head format virtually halves the cutting time per part whilst its power and speed save even more time. And although some factors such as unit material cost and the hourly running cost per laser stay the same, the HSL's productivity has enabled NSI to reduce component costs by as much as 30% in some cases.



Laser tube cutting works its magic

Last year NSI became the first subcontractor in the country to purchase a Trumpf L6030 to profile medium to heavy gauge material up to 6 x 2m in size. This investment has already brought benefits over and above those originally expected with the manufacture of products as diverse as railway rolling stock and canal narrow boats. Both benefit from the use of sheets up to 6m long in their manufacture, because the use of fewer but larger sheets reduces downstream assembly costs. It also minimises the welding and dressing requirements and improves the aesthetics of the products by eliminating unnecessary weld seams and associated thermal distortion.

Because, in general, the larger the raw sheet or plate size, the better the material utilisation that can be achieved, NSI not only use this machine for large components, but also for kits of parts and nests of smaller and even unrelated items that can be nested around and within larger parts to be cut.

Because NSI is also a stockist of tubes and secrions, it is not surprising that its latest acquisition was a Trumpf Tubematic. This brings its total of Trumpf machines to nine, enabling NSI to undertake an wide range of profiling work.

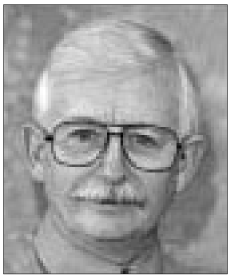
Micrometrics' seamless transition

The management team (left) Neil Main, Rosie de Smit and David English

Micrometric Techniques, the specialist laser job shop in Lincoln, has formed a new company and management structure to take the business forward into the decade ahead and beyond. This follows the retirement of Dr Maurice Gates MBE, managing director, who founded Micrometric Techniques 21 years ago.

The company now trades simply as Micrometric Limited. At the helm of the new company is a management team comprising Neil Main, David English and Rosie de Smit. All have been actively engaged at a senior level with the business.

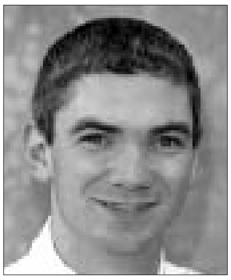
As part of the reorganisation and consolidation, two new business cells have been created to provide clear direction and focus for two key elements of the business, and managers have been appointed to lead them.



Dave Burrell

Dave Burrell has been appointed manager of Laser Profiling and Kevin Johnson, manager of Precision Cutting, Laser Marking, Engraving and Welding.

Alastair Lloyd, who has considerable experience in the electronics industry, has joined Micrometric as a sales engineer. Alastair, who spent 10 years as an electronics engineer with Marconi and latterly worked for a Hampshire-based electronics distributor, is looking forward to developing relationships with Micrometrics customers particularly in the electronics, medical instrumentation, automotive and defence industries.



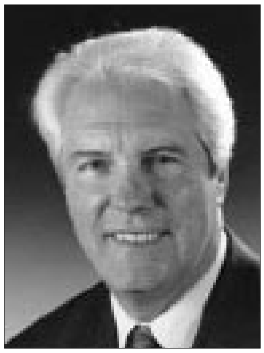
Alastair Lloyd

Situation Vacant

Powerlase Ltd, Crawley, UK have a position open for an 'Applications Technician/Engineer'. Duties will include undertaking short to medium term customer specific applications projects, assisting the sales effort, equipment set-up and maintenance, and feedback to the laser design team. Candidates must be educated to degree level or equivalent, and have multiple years laser processing experience. They must be highly motivated, flexible, willing to work in a team and alone as required. Salaries are competitive and will be commensurate to experience.

Please send a covering letter and CV to Matt Henry, Applications, Powerlase Ltd, Imperial House, Link 10, Napier Way, Crawley, West Sussex. RH10 9RA, or email *matt.henry@powerlase.com*

Micrometric's founder steps down



Maurice Gates

Maurice Gates, who founded Micrometric Techniques in 1982, has retiring from day-to-day involvement in the company. A founder member of AILU, he remains an active committee member and a leading figure within AILU and in the industry in general.

Maurice received the MBE in 1987, an Honourary Doctorate in 1997 and the AILU Award in 1999.

He is also a member of the Engineering Employers Federation's Management Committee and the CBI's Technology and Innovation Committee. He intends spending more time pursuing his many interests including motoring and photography.

A Brighter LAMP

Peter Hancocks

Mike Keough

Industry veteran J.Peter Hancocks and established practitioner Mike Keough have joined the Laser Aided Material Processing (LAMP) project team at Coventry University as Senior Project Officer and Project Officer, respectively.

The LAMP team is led by Edmund du Bois of the Coventry Centre for Advanced Joining and Brian Bryden, Project Manager for the Warwick Manufacturing Group's team. (See 'News in Brief' for more LAMP details).

New additions at Umicore Laser Optics

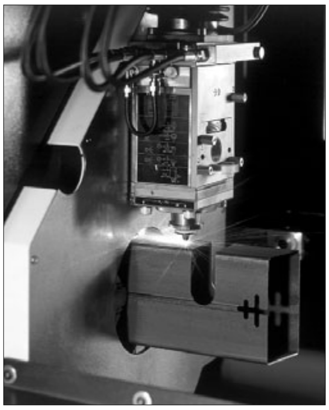
Tom Krekel

There have been several additions to the personnel at Umicore Laser Optics in recent months, a reflection of Umicore's rapid growth and its desire to keep its levels of service at the forefront of the market.

Tom Krekels has taken over as Managing Director of Umicore Laser Optics. Tom holds a Ph.D. in materials science and joins Umicore Laser Optics from their Hoboken (Belgium) establishment, having worked for three years in business development of Thin Film Materials.

The sales team of Paul Maclennan, Richard Lawson and Kay McCormack has been bolstered by the additions of Patrick Apélian, Keith Warters and Brad Smith; each bringing their own technical skills. Patrick is a graduate from France with a logistics background; Keith brings a wealth of experience in mechanical engineering, including time spent in the telecommunications, aerospace, military and automotive industries. Brad complements his sales role with a strong IT skill-set, having recently graduated from Sheffield Hallam University.

Laser Tube Cutting System at MACH



Adige will be exhibiting their very latest Laser Tube Cutting machine at Mach 2004 in Hall 5 on Stand 5290. The LT702D has been purpose designed and refined for the laser job shop environment.

In a survey of it's laser job shop customers, Adige found batch sizes were much lower than they had assumed, the spread was in fact between 50 and 1000. With such short runs, dead time for changeover was a significant cost. In its latest generation of machines Adige has therefore incorporated fully automatic adjustment of all settings activated through the CNC. Remarkably, the LT702D can typically be completely reset from one job to another in less than 3.5 minutes, so even the shortest of batches or sample pieces can be managed efficiently. Another exceptional feature for job shop applications is the machines refined yet simple-to-use CAD/CAM software. For ease of operation, all the programming is done in 3D using software purpose-written for tubular applications.

Programming a part from scratch to producing the first component can be completed in less than 4 minutes. The optimum cutting line and cutting parameters are set automatically by the software. Accuracy cycles can be selected to automatically compensate for out of square or twisted tube.

“The cutting rates and positional movements on the LT702D are spectacularly fast,” said Paul Lake of BLM Group UK. “Adige's 54 years of experience in tube handling is evident in the very slick loading , handling and unloading systems,” he added.

Laser tube cutting is an obvious companion to laser plate cutting in the job shop, offering an opportunity for added value work for existing customers and markets and new customers and markets.

LOE offer extended services

Laser Optical Engineering is now offering, as an extension to its existing laser safety services, of consultancy, policies, training and auditing, the addition of laser shield testing to BS:EN12254 1998. “This ensures that shielding for laser systems is correctly specified and that all the components of a laser system comply with the relevant regulations,” said Rob Roach of LOE.

“The provision of this service is logical for LOE, which prides itself on providing pragmatic laser safety solutions, based on practical experience in such areas as laser fume characterisation and daily laser classification to BS EN 60825”, Rob added.

Winbro Technology Innovation Centre

Winbro’s new Technology Innovation Centre provides a unique facility for the special process equipment industry

Technology Innovation Centre

The TIC offers a service using EDM (Electro Discharge Machining), ECM (Electro Chemical Machining) and Laser processing; and Works in partnership with customers to develop innovative new manufacturing processes.

The TIC Facility is occupied by both the Customer Relationship Management Team for Sales/Process Development solutions and the Customer Care Team for after sales care and support. WinbroGroup’s belief is that the location of these teams is critical to the Technology Innovation Center’s role in being close to the process and our customers at every stage of the investment life cycle.

Features and benefits offered at the Technology Innovation Centre include: contract Research & Development; EDM, ECM & Laser Process Development; applications engineering; process development; prototype & batch production; tooling design and manufacture; EDM cartridge tool & nose guide design & manufacture; integrated inspection through contact & non-contact methods; adaptive machining; CAM system development; repair & overhaul methodologies.

Situation Wanted

Simon Pogson, currently completing his PhD at The University of Liverpool, Department of Manufacturing Engineering, is seeking to further develop his career in either Material Science or Manufacturing Engineering. He is currently researching laser-based Rapid Prototyping technology into the production of functionally graded structures using, amongst other, bio-compatible metals. He is looking for a role where he can use his existing skills and knowledge to assist in the development of new technology and would be happy to work anywhere in Europe.

Having graduated in Mechanical Systems and Design Engineering, he worked for two years as a Design and Development Engineer. He then obtained an MSc (Eng) in Product Design and Management, which led to his current position as a Research Assistant and PhD candidate.

Please contact the AILU office for a copy of his CV.

FOR SALE

IN-LINE LASER CUTTING SYSTEM

Preco PL-15 Laser Cutting machine

This machine was designed and built to operate as an in-line cutting system for polyester flex circuits.

The machine features and capabilities include:

- 100 Watt CO_2 Synrad laser
- GSI Lumonics galvo head and field lens
- Cutting area 13.25“ x 30” in two stages
- Cutting speeds up to 300 inch per second
- Conveyor with lift plate and vacuum hold down
- Smema compatible on inbound and outbound side
- Flat screen monitor
- PC used for operator interface and file storage
- DOS computer for operating laser
- Affinity Model RAA 007C-CE01CB closed loop chiller

Initial cost $220,000 USD and less than 30 hours use. Offers in the region of $45,000 USD would be considered.

Contact Gary White on +1 630 718 5993 or email Gary.White@molex.com

JETCAM Expert v15 at MACH 2004

JETCAM International will be demonstrating the latest version of its sheet metal fabrication CADCAM software, JETCAM Expert on the Press and Shear stand at MACH 2004.

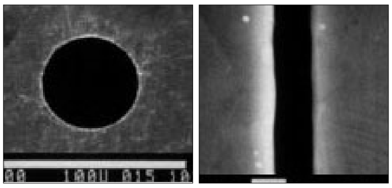
Version 15 now includes substantial improvements for laser users. These include mass skeletal destruction, intelligent lead-ins, heat avoidance and common-line cutting, each of which ensure that parts are made quicker and at a higher standard of quality while optimising machine cycle time and saving material. The new version also offers better networking and file handling; and RCP (Remote Control Processing) that allows JETCAM Expert to be used as a 'black box' to generate nests and NC codes remotely. A new optional nesting module delivers further enhancements over the existing free-form nester.

DPSS laser finds micro applications

The DIVA from Thales Laser has successfully been incorporated into the production lines of several leading industrial companies to carry out high precision micro machining applications. This compact air cooled DPSS laser offers multiple advantages; including a unique combination of high beam quality and high pulse energy (20mJ at 20Hz) and a short pulse duration of 10ns.

Bio and nano technologies

A common application in biotechnology is cell or bacteria sorting. This is usually done by means of micro channels that are wide enough to allow only the desired species through.



50µm dia. hole and a 1µm wide slit

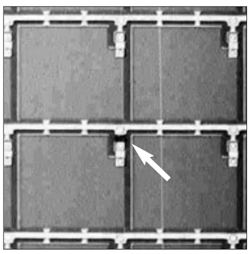
Thanks to its excellent beam quality, DIVA makes possible the manufacturing of micro slits of less than 1µm wide, or 50µm holes with perfect roundness. The SEM photos show very good edge condition and minimised thermal damage on stainless steel foil.

Repair

Several high tech industries such as Flat Panel Displays or Semiconductors are moving to ever smaller feature size with increasing density per plate or wafer. Consequently, defects are common and in view of the manufacturing costs involved, repair operations are essential.

LCD screens are a typical example: with the high number of pixels, it is not unusual to find faulty pixels that have to be disconnected to avoid further electronic problems. The faulty pixel must be disconnected without damaging the adjacent pixel, which may be as close as 30µm.

The figure shows a 5µm wide cut to disconnect a pixel in a 2D silicon array, made with a 532nm DIVA. As a result of the very short laser pulse duration, the neighbouring pixels were not damaged.



5µm wide cut in 2D pixel array

"The compactness, air cooling, long diode lifetime and computer control of the DIVA are particularly well adapted to the high throughput and reliability needs of these industries, making this laser a favourite repair tool," said Antoine Duret, Application and Marketing Engineer at Thales.

M rated eyewear for pulsed lasers

Lasermet, in conjunction with LaserVision, are now offering M-rated laser safety eyewear conforming to EN 207 for laser pulses of less than 1ns duration. Until recently users had been unable to purchase eyewear which was specified to protect against femto & pico-second lasers.

Eyewear is available for ultra short pulsed lasers operating in the 700 to 900 nm wavelength region in either goggle or spectacle frame style. "As far as we are aware this is the only eyewear in existence with an M rating under EN 207," said Lasermet's Paul Tozer.

For further information visit:
http://www.lasersafety.co.uk/eyewear/Femto-Pico-QF.html

Improved safety of Excimer laser

TuiLaser has optimised the ExciStar S-Industrial, its high repetition rate Excimer UV laser, to improve performance and minimise safety concerns.

ExciStar S-Industrial

Firstly, the use of a solid-state switch on the ExciStar provides performance benefits whilst at the same time lowering the maximum voltage within the ExciStar S-Industrial to only 1.5 kV.

The handling of halogen gases is also a primary safety concern. The discharge tube, which is constructed from metal and ceramic components, is supported by a newly re-engineered gas management system. TuiLaser has incorporated a microprocessor-controlled, failsafe manifold to ensure a safe work environment. A vacuum pump works with a halogen exhaust filter to prevent halogen leakage into the environment. The use of premixed laser gases not only mean more regularity in laser performance, but also reduce risks to the operator.

The ExciStar S-Industrial lasers meet SEMI standards of safety and reliability and have been incorporated in many SEMI-certified process devices. Tui have also obtained FDA, UL-CSA and IEC 61010 certifications.

The integrated corona preionisation technique enhances performance. Designed without ionising pins, hefty electric fields which can cause arcing are avoided. Instead, working in conjunction with the solid state switch the corona preionization produces a "soft" discharge which not only produces better beam quality, it results in less wear and tear on the system and less down time.

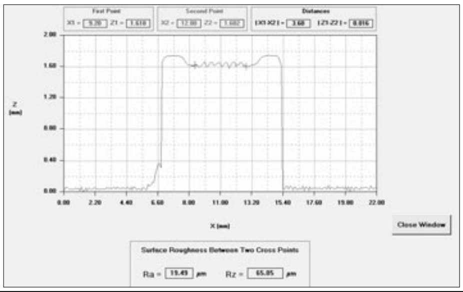
Different versions are available that vary in repetition rate (200, 500 or 1000 Hz) and wavelength (157, 193, 248, 308 or 351 nm). The ExciStar S-Industrial at 248nm reaches 18 mJ per pulse and performs with an energy stability of σ (Standard Deviation) less than 3 %. The ExciStar S-Industrial worldwide installed base of over 200 units is already hard at work on the mezzo- and micro scales. This light source is primarily used in applications including micro drilling, optics testing/inspection, direct writing and micro machining.

UMIST offers laser surface profiler

The University of Manchester Science and Technology is offering for sale a laser surface profile-scanning machine designed for high precision surface profile and surface roughness (Ra and Rz) measurement.

At the heart of the scanning system is a non-contact laser distance sensor, which is based on the principle of triangulation. The sensor has a 30µm diameter beam spot, ±5 mm measuring range and 1µm resolution.

Other components on the profiler include: a digital display with a signal processor that converts the sensing signal into digital format; height adjustment to locate the sensor position in the Z axis (vertical) direction; a horizontal X-Y motorized table that moves the object over a 90 mm x 90 mm range with 4µm resolution; and a computer with software to collect the sensing data and control the X-Y table movement. The maximum scanning speed (single step) is 24 mm/s, the minimum 1 mm/s.

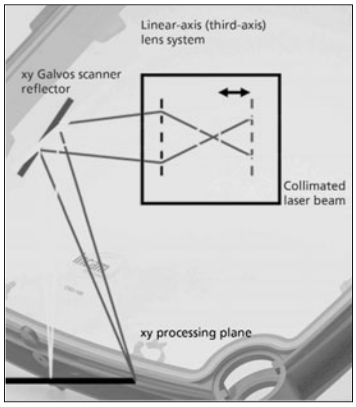


Profiler results, showing (l) typical cross section and (above) a simulated 3-D view

Fisba offer new dimension welding

The new FLS inlineScan from Fisba Optik is a multifunctional diode laser system for welding of plastics over an area up to 500mm square. Its modular design includes as optional components: a pyrometer to measure and control the welding temperature; a CCD camera for observation of the welding process; and a pilot beam for precise visual alignment of the workpiece.

In its basic function, FLS inlineScan uses a dynamic post-objective scanning system, thereby overcoming the limitations of weld width control and working-field area imposed by the use of a fixed F-Theta objective lens; and the time consuming alignment of pyrometer, CCD camera, and pilot beam. The third, linear, axis of the new FLS inlineScan allows larger working areas and dynamic focus control of the weld width. The inline arrangement of optical paths facilitates easy integration of a CCD camera, pyrometer, and pilot beam; and overcomes the need for external adjustments and calibrations.



Dynamic post-objective scanning on the FLS inline Scan

Go to www.fisba.ch/presse_English to download an illustration

BFi's new beam measurement products

Laser beam profilers

The Firewire CCD Laser Beam Profilers are the latest generation of profilers and offer a larger aperture (9.6mm by 7.6mm) and spectral ranges 260-1100nm (standard), 193-266nm and 1500-1600nm.

OPHIR BeamStar FX

Features include:

- 10 bit true system dynamic range
- Automated gain and shutter control
- Exclusive automated photodiode synch with pulsed lasers
- User friendly but sophisticated software for accurate measurement
- Firewire interface for multi camera and multi PC operation

Sensitive photodiode for laser pulses

The Ophir PIN 1Z02822 is a highly sensitive silicon photodiode, is responsive over the wavelength range 0.2 – 1.1µm and offers:

- Surface reflectivity: 30% approx.
- Aperture: f10mm
- Energy Scales: 100nJ to 200pJ
- Lowest meas. energy: 10pJ
- Noise on lowest range: 2pJ
- Max. pulse width: 50µs
- Calibration accuracy: ± 5%
- Linearity: ±1% (10% full scale
- Max. Av. Power: 0.5mW
- Max. Av. Power Density: 5W/cm²
- Damage Threshold: 0.1J/cm²

Photodiode energy meter for low pulse engines

Bavarian Photonics' long pulse laser

The Aion Industrial 1064-16-V-LP, a long-pulse Nd:YVO4 laser system from Bavarian Photonics is available in power levels of 8W and 16W, with energy per pulse up to 1mJ at 10kHz repetition rate. This Nd:YVO_4 laser has a pulse width around 50ns at 20kHz, 90ns at 70kHz. The laser has a high beam quality, an excellent pulse-to-pulse stability and precise power control.

Aion Industrial 1064-16-V-LP

Typical applications for this laser source include surface micromachining of metals, roller structuring for the printing industry, deep engraving and solar cell structuring.

Laserdyne's new optical focus control

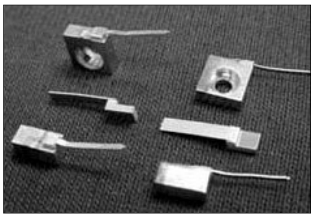
Laserdyne's new Optical Focus Control (OFC) feature is now available for all 790 BeamDirector® systems (and as a field retrofit to existing 790 systems), for laser processing of 3D non-metallics.

OFC senses part surfaces inaccessible to conventional AFC nozzles and it eliminates side sensing problems that can occur with nozzle based sensors.

Most important, it can be used on a wide range of materials, both metal and non-metal, and with different surface finishes and colours.

OFC enhances laser processing of thermal barrier coated (TBC) and uncoated metals along with other non-metals

Pro-Lite diodes and DPSSL software


High power diodes from Axcel

High power laser diodes
The Axcel Photonics LambdaLok™ series of high power laser diodes encompass exploit Volume Bragg Grating technology to "lock" the wavelength, narrow the spectral linewidth (to typically 0.3nm) and improve the wavelength stability (to 0.01nm $^oC^{-1}$). These diodes are ideal pump sources for solid-state lasers and Raman Spectroscopy.

Axcel Photonics manufactures laser diodes from 785nm to 980nm both single mode emitters from 3µm aperture to broad area multimode emitters 50-460 µm. Axcel's singlemode emitters are achieving 150mW – 500mW depending on wavelength and 20-40mW per micron stripe width from their multimode series. Recent data has shown 15W output from a 100µm 965nm emitter prior to COD.

Software to model thermal lensing processes in laser resonators.
New PC software developed by LAS-CAD GmbH models the complex thermal lensing processes occurring in laser resonators, showing modal patterns and cavity stability; and providing the laser engineer with real-time tools for such applications as diode pumped solid state laser design.

LASCAD offers: thermal and structural finite element analysis; ABCD Gaussian Beam Propagation code; wave optics beam propagation code; numerical eigenmode analysis; beam propagation outside the cavity. Optical elements e.g. mirrors, lenses and crystals can be added, combined or removed with a mouse click.

Finite Element Analysis is used to solve partial differential equations used to compute the temperature distribution, deformation and stress in laser crystals and materials affected by pumping geometries and cooling techniques. This powerful tool can model both end pumped and side pumped rods, disks, slabs and thin disk lasers.

Users have reported very close simulation to actual results and can design laser cavities or optimise existing designs in minutes rather than weeks or months in the laboratory. Pro-Lite would be pleased to arrange a free of charge evaluation copy of the LASCAD software to interested laser manufacturers and designers.

Bofa's unique two-stage pre filter


New 2 stage pre filter

Bofa (UK) Ltd are claiming a new and unique concept in pre-filtration of LGAC's (Laser Generated Air Contaminates). The key to this filtration is an expansion chamber, which causes the velocity of the air sucked in through the sealed inlet to drop. The larger particulates fall to the bottom of the cartridge chamber and the remaining particulates hit the filter surface at lower speed. Once the particulate has built up and become heavy, gravity breaks it away, thereby extending filter life. Breakaway particulate are captured within the filter cartridge.

By contrast, in traditional filter units the particles hit the filter at speed and lodge within it; causing it to lose efficiency after a few weeks of operation.

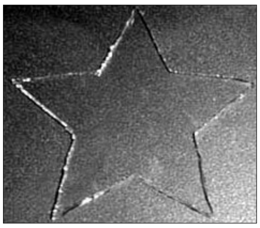
When a filter is used to capture sticky LGAC's, such as are generated when laser processing PET and other polymers, surface area is critical as the particulate sticks to the filter face on contact. To address this problem of diminishing filter area, the Advantage 180 and 400 2-stage pre filter cartridge has a 9m² of media surface area, whilst the 1500 and 400 have 20m². For more information visit *www.laserfumeextraction.com*.

Dedicated web site
Bofa's new website *www.laserfumeextraction.com* is dedicated to laser fume. The site offers information on health and safety issues, poor quality marking or cuts due to LGAC's and how to minimise reject products. The site also addresses the extra precautions that need to be taken into consideration when laser processing polymers, including PVC.

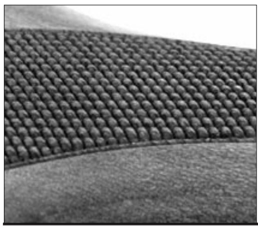
To coincide with the launch of the site an interactive CD-ROM has been made available. It contains unit data sheets, 3D models of extractors and technical information. Both the web site and CD-ROM have been designed to help end users as well as Bofa's OEM partners.

CO_2 laser applications from Synrad

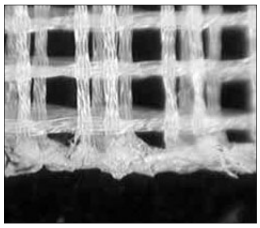
The Synrad web site at *http://www.synrad.com* is a repository of interesting CO_2 laser applications, including the following selection.



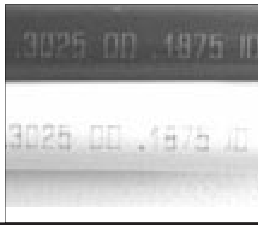
Laser cutting of float glass. Fracturing and edge cut quality are problems when cutting glass, but as this example shows, using 200W power with high pressure gas assist at low speeds minimises fracturing. This application depends on the ability of lasers to cut with no mechanical force.



Laser engraving of wood. This handgrip pattern on a sycamore handle was engraved using 60W power. Total cycle time for engraving the 1-inch by four-inch pattern was 62 seconds.



Cut and weld operations. A compromise must be made between process speed and weld strength. In this example, 0.4mm Polyester weave was processed with 10W power at 130 cm/min. No clamping or pressure forces were applied, aside from the action of an assist gas, which pushed the sheets together and sheared the melt through the cut to enhance joining of the material.



Laser marking of PVC. In this example, contrasting marks were produced using 10W power at a marking speed of $1ms^{-1}$. Cycle time for the 14-character mark was 0.13 seconds.

In the UK, Synrad are represented by Laser Lines (Industrial & Medical).

Purex's labyrinth filter and new fume web site

Laser generated air contaminants (LGACs) are produced during materials processing and should be controlled by an extraction and filtration system. The cost of replacement filters can be a concern for the end user but the new patented Labyrinth filter from Purex may just be the answer.

The capability of a filter to capture and retain particles depends on the cross sectional area of filter media 'in which' and 'on which' particles can be contained. Traditional pleated paper filters only capture dust particles on a single thin face of materia , whereas Purex's new patented Labyrinth filter is deep and graded and so has a much greater dust holding capacity throughout without, affecting airflow.

The greater dust holding capacity means fewer filter changes and lower annual replacements costs, in some cases over 10 times less. Further savings are made by the customer in shipping costs, as compared to bulky rigid filters which may be expensive to transport, the Labyrinth is small, compact and lightweight; and is less likely to be damaged in transit.

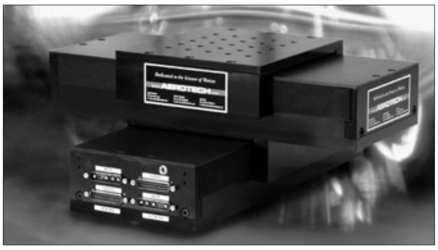
Another positive and important point for the customer is that Purex machines are front loading, so the operator can simply open the door and push the small replacement filter into place in seconds without having to disconnect the machine from the process. Although small for shipping and storage purposes, the Labyrinth filter delivers massive performance once inside the machine.

New website for extraction specification

To help laser users identify the correct extraction system requirements, Purex International has developed a new website at *http://www.laserfume.com* containing on-line process survey forms; separate forms for laser marking, engraving, welding and cutting applications as well as resources such as links to Health and Safety information and other laser-related sites.

"Even seemingly harmless materials such as cardboard and paper labels can produce respirable dust and formaldehyde," said Jon Young of Purex International. "To make sure your lungs aren't the first filter that laser fume meets, visit http://www.laserfume.com", he added.

Low-cost stage with high performance


Aerotech's new ALS1000

Aerotech's new direct-drive linear motor stage, the ALS1000, offers the accuracy associated with direct-drive architecture in combination with a compact and sealed design, internal cable management and impressive performance.

With its small footprint and environmental protection in combination with outstanding contour accuracy and smooth velocity profiling; offering, the ALS1000 provides a cost-effective solution for precision markets such as laser machining and medical device manufacturing.

The linear motor drive provides high force with no attractive force, zero cogging, zero backlash, zero friction, no windup and outstanding system response. The motor's magnetic field is totally self-contained.

The metal way cover of the stage and tabletop are treated with a Teflon-impregnated scratch-resistant protective cover; other stage finishes are also available as options. Users also have the option of an air-purge fitting that can be used to create a positive internal pressure - preventing particulate ingress in heavy applications.

The cable management system (CMS) is optimised for millions of cycles of maintenance-free operation; and in single and two-axis systems the CMS is completely internal. An external CMS is available for three-axis systems.

Non-contact linear encoders with sub micron-level resolutions are standard on all ALS1000 series stages. Motor power and feedback signals terminate at the stage's endplate, creating a simple, clean interface. Aerotech also manufactures a wide range of matching drives and controls to provide a fully integrated and optimised motion solution.

The system is then backed up by comprehensive local technical support throughout its life, no matter where it ends up.

Photonic Solutions' fs and SPC systems

The Integra-C

The Integra-C from Quantronix, the compact version of the Integra, is an oscillator to output system that provides high energy femtosecond pulses; supplying over 2.5mJ in pulses that are less than 100fs.

Applications for this high peak energy, short pulse, temperature stable and now small size source, include ultrafast spectroscopy and dynamic studies as well as precision micro-machining with minimum heat affected zone.

The system is based on patented, field-tested regenerative amplifier/multi-pass power amplifier architecture. A complete redesign of the optical train has allowed the entire high energy source, including the oscillator, stretcher, amplifier, compressor and pump laser to be housed in a small enclosure. The system has been designed to accommodate the compact IMRA fibre oscillator but a variety of third party oscillators can also fit within the housing.

Another key to the reduced size and high energy of the Integra-C is the newly redesigned Quantronix Darwin series of green lasers used to pump the amplifier. The new Darwin head is also reduced in size while simultaneously providing more energy per pulse. The Integra-C is aimed at both scientific and commercial markets.

Time-resolved fluorescence

Since their broad introduction in the early 90s, confocal and two-photon laser scanning microscopes have initiated a breakthrough in biomedical imaging. The applicability of multi-photon excitation, optical sectioning and superior contrast, makes such instruments an ideal choice for fluorescence imaging of biological samples.

Recording time-resolved fluorescence images can be achieved by combining a Laser Scanning Microscope with pulsed laser excitation and a new Becker & Hickl Time Correlated Single Photon Counting (TCSPC) Imaging technique available in the UK through Photonic Solutions plc.

Opinion

Birmingham manufacturer argues for a level playing field

Jonathan Cox, Managing Director of Rojac Engineering Limited, makes the case

There is no future as a true world player if all one supplies is services, because services simply redistribute wealth: they don't create it. Taking raw material of various types and making something that can be used, that is true added value.

One has only to look at the big global economies, existing and burgeoning, to see that most are manufacturing led, producing goods for domestic market consumption and for export. This is particularly true in the Far East. The UK should take heed.

Rojac Engineering Limited is a Birmingham-based major supplier of sheet metal components, welded assemblies and fabrication. Like many other manufacturers, we have invested in state-of-the-art plant and equipment and systems and striven to be awarded relevant quality marks. So when it comes to tendering for manufacturing contracts we can compete well on quality. And because we are also highly flexible we can compete well on delivery too.

Where we face the challenge is on price. As a result, like other manufacturers in the Birmingham area, particularly if they occupy a position in the supply chain below the first tier, we lose work in the face of foreign imports, with the lion's share coming from the near and far East. Given the low labour costs in the Far East, we find it challenging to compete. However, I predict that if we allow our manufacturing sector to decay we will be held hostage to higher prices in years to come as workers in the Far East demand higher wages.

Meanwhile, British manufacturers should have no difficulty in competing with imports from European competitors, but we do. This is because the playing field's surface is uneven. Take the foundry industry as an example. Health and safety and environmental legislation in the UK increased the cost burden to foundry owners, and many went under. This is not to say that the charges were inappropriate or without merit, simply that some other EU member countries' foundries were not faced with similar bills, so they continued trading and submitting tenders for UK business with the playing field sloping to their advantage. Their quotes did not have to reflect the cost of the UK legislation. This situation could, of course, be rectified by restricting quotes for contracts to those from plants based in the UK or if they too either adopt similar legislation or paid a tax to equate to the charges levied upon the UK operators. This would need government intervention, but successive governments appear to have lacked the will.

The manufacturing sector, like the UK's workforce as a whole, is suffering from an ageing workforce. Those of my staff, whom I would regard as young, i.e. less than thirty years of age, tend to work on the CAD side of the business. In common with other manufacturers, we find it increasingly difficult to attract young people who want to work on the factory floor. Thus skills die out or have to be imported from outside the region or even outside the country.

To address this problem, we have to improve the image of manufacturing in the UK and persuade students to study engineering – at school and at university. This calls for those who run UK plc to value and be seen to value the manufacturing sector. It also calls for a sea-change in the way engineers are regarded in society. Engineering and manufacturing really are sexy!

Jonathan Cox, MD of Rojac Engineering

Think about leading your life without manufacturing: where would you live, how would you travel to work, what about your TV, your kitchen appliances, your mobile phone and PC, the plane to take you on holiday? OK, many of these products are currently manufactured overseas. But believe me, Birmingham manufacturers are among the best in the world. If only they and others would recognise it!

Birmingham manufacturing businesses need to make the most of their opportunities and work together to improve the situation. They could do worse than my four point plan: trade with other Birmingham and the Black Country businesses; employ and train people from this region; export from this region to the rest of the UK and beyond, and lobby for the creation of a level playing field on which UK plc manufacturing can compete.

I'm not just saying this, I practice what I preach. I employ local people, I deal with local suppliers, and I contribute to the local economy. The benefits are numerous, including easing the strains on our national transport infrastructure.

Birmingham can manufacture its way back on to the industrial map. Organisations simply have to make others aware of their existence and make the most of available support, particularly Birmingham Business Link and the Birmingham Chamber of Commerce.

It's not easy to be a UK manufacturer but it's important. Manufacturing is the lifeblood of modern life: it started here in the Midlands and it should and must continue here. It's up to me and other like-minded manufacturers to make sure it does.

This feature is based on an article that first appeared in the Birmingham Post on 23 October 2003

An introduction to Lean Manufacturing

Steve Baker
The Manufacturing Institute

2nd Floor Quay West Trafford Park Road Trafford Park Manchester M17 1HH
T: +44 (0)161 872 0393 F: +44 (0)161 877 3094 E: steveb@manufacturing institute.co.uk

As the barriers to trading between European countries are eroded, the ability of overseas manufacturers to export products to the UK has become much easier. The advantages of exchange rates in recent years have reduced the disadvantages of transportation costs. Now, in 2004 the threat of losing major UK customers to European competition is moving from a possibility to a reality.

The challenge for the manufacturing industry is not new. Many different approaches have been used. As far back as the early twentieth century Frederick Taylor was pioneering the "one best way" and the art of scientific management. Time and motion study, MRP, MRP2, TQM, JIT, TPM, 6 Sigma and many "new" manufacturing philosophies have come and gone, some with more success than others.

Underlying our fascination with many of these techniques has been our curiosity at the success of Japanese manufacturing through a period of general decline in Western Manufacturing. Japanese manufacturing was revolutionised by the work of Taiichi Ohno, Eiji Toyoda and Shigeo Shingo at Toyota – they developed the Toyota Production System (TPS) and introduced us to the concept of Lean Manufacturing. Many proponents of manufacturing change in the West have imported various component parts of TPS and often married them up with the latest Western thinking.

Lean manufacturing focuses on the elimination of waste, and the promotion of flow, on processes that add value for the customer. The organisation is viewed as part of an "extended enterprise" of suppliers and customers and the process involves using less of everything – manpower, capital, facilities, inventories, time – in all aspects of production, design, distribution, and marketing. This is achieved by harnessing the effort of all employees, using a range of tools and techniques in a powerful conceptual framework, or business logic.

The Toyota Production System

The term 'lean manufacturing' was first coined in The Machine That Changed the World (Womack, Jones and Roos, 1990) to describe the revolution in manufacturing that was initiated by the Toyota Production System (TPS). The forerunner to TPS was the Ford motor company and it was Eiji Toyoda's visit to the Ford plant in Detroit back in 1950 that initiated the concept. What Eiji found in the Rouge plant was mass production, with an output of 7,000 cars a day.

In the early days Toyota's entire production was a few thousand vehicles per year, and the presses that Toyota employed had to be capable of producing many different stampings and making changeovers frequently; unlike the western alternative where one press could be making the same part for many months. Toyoda's production specialist Taiichi Ohno relentlessly practiced the changeover techniques until, in the late 50's, he had reduced the changeover time from a day to three minutes and it was production workers not specialists that undertook the changeover. This was typical of the actions taken by Toyota in taking western best practice, removing waste and then empowering the workforce to give a more cost effective, flexible system of production. The Toyota method also involves helping their external suppliers, encouraging them to implement as much of the entire Toyota Production System as possible.

As for Ford, the company was very successful but flow production became mass production as 'process villages' pushed batches from operation to operation and plant to plant. At that time demand outstripped supply and anything that was built could be sold. In recent times the situation has changed, competition has become fiercer and Ford realise that they must move away from mass production and become Lean: . Ford is using the 'Ford Production System' (FPS), based on the Toyota Production System, to make this transition.

Lean Thinking – Womack and Jones

Womack and Jones (1996) refer to Lean thinking as 'the antidote to muda', where muda means waste. The waste they refer to is 'any human activity which absorbs resources but creates no value'. Lean production focuses on eliminating waste in processes. There are seven key wastes: transportation; inventory; unnecessary motion; waiting; over-production; over-processing; defects.

The process of eliminating waste, and creating a Lean environment, is through the application of five Lean principles: specify value; identify the value stream; create flow; pull the product; strive for perfection. A description of these principles is given below.

<u>Specify value</u>

Value is specified by the producer, from the customer's viewpoint i.e. 'through the eyes of the customer' and is concerned with understanding exactly what the customer needs, not what the producer thinks he needs.

Womack and Jones (1996) cite the German engineers who add features and refinements to products without considering if they are what the customer's want. These features may enhance the product or add more functionality, but if the customer is not willing to pay for them, do they add value?

<u>Identify the value stream</u>

The value stream refers to a set of specific actions that bring a product through the three critical management steps of any business: problem solving task – concept, design, engineering, product launch; information management task – order, scheduling, delivery; physical transformation task – raw material, finished product, customer.

Identifying the value stream is step two in the approach to Lean thinking and will almost certainly expose staggering amounts of muda. The activities within the value streams are expressed as one of three different types and these are: value adding – an activity that adds value to the product; non-value adding, but necessary – adds no value but is required to complete the product; non-value adding – adds no value to the product and can be ceased.

Mapping tools are deployed to identify and understand the value streams and to identify actions to remove waste. Standard and Davis compared value adding to a round of golf whereby a typical round of golf takes longer than 4 hours, and the club is only in contact with the ball for 1.5 seconds. The rest of the time consists of 2 of the 7 wastes: waiting or transport.

Create Flow

Once the value has been specified and the value stream mapped, the next stage is to make the remaining value-creating steps flow. Many traditional organisations tend to pass products from department to department and undertake tasks in large batches. The reason for this is often to reduce the need for changeovers and therefore keep the equipment running. The reality is that this approach results in high work in progress (WIP) and long lead times.

Reducing batch sizes to create continuous flow quickly places attention on the time taken to achieve a changeover. Functionalised organisations with departmental boundaries can often be an obstacle to achieving flow; the organisational layout may need to be considered.

Pull the Product

The concept of pull is to make exactly what the customer wants just when the customer wants it. In this way the product that a customer consumes is pulled through the production system rather than pushing product into the system in batches, hoping that this product will be sold at a later date.

Strive for Perfection

When the previous four stages have been undertaken, tremendous gains will have been made in giving the customer what they want, exactly when they want it and the product has also been produced at a lower cost.

It then becomes evident that there is no end to the process and that it is a process of continuous improvement: as waste is removed, yet more is revealed. A number of mapping tools are available to assist in this process of eliminating waste. Hines and Taylor suggest six tools and where they are best applied (see text box).

Literature survey

The Lean method of manufacturing and business improvement is spreading rapidly throughout the UK, but there are many different ways of approaching and applying it, not only in its physical application, but also in recommended approaches within industry literature. For a long time Lean was directly linked to the auto industry, but now it is clear that Lean can be applied to any environment.

Every application of Lean will vary according to the situation i.e. the industry, culture and environment. This indicates that it would be unwise to follow a pre-prescribed method of application and that a certain amount of pre-analysis is required to understand the implementation environment, this is critical in respect of cultural and ‘people’ issues. However there are certain ‘key’ elements that are common to any successful Lean application and these should be included in all Lean implementations: Senior management support; Middle management involvement; Immediate results; Non-sporadic approach; Change agent; Shop floor involvement; Flow; Team based activities; Just do it; Quick changeover; Clear communication; Organisational structure; Value stream mapping; Workplace organisation; Guiding coalition; Pilot line; Strong use of measures; Driver / lever / crisis.

A case study of a laser-user manufacturing follows:

Hines and Taylor six most useful tools and where to use them

	Process Activity Mapping	Supply Chain Response Matrix	Production Variety Funnel	Quality Filter Map	Demand Amplification Mapping	Value Adding Time Profile
Overproduction	Maybe	Maybe	No	Maybe	Maybe	Yes
Waiting	Yes	Yes	Maybe	No	Maybe	Maybe
Excessive Transportation	Yes	No	No	No	No	Maybe
Inappropriate processing	Yes	No	Maybe	Maybe	No	Maybe
Unnecessary Inventory	Maybe	Yes	Maybe	No	Yes	Maybe
Unnecessary Motions	Yes	Maybe	No	No	No	No
Defects	Maybe	No	No	Yes	No	Maybe

(i) Process activity map

The process activity map originates from industrial engineering, this can clearly be seen from the use of times and step-by-step analysis. There are different formats to the layout, but they all have the basic fundamental approach: to map each sequence of the process, measure the time it takes and attribute the type of activity i.e. operation, delay etc. They also record distance moved and number of people involved.

(ii) Supply chain response matrix

This tool aims to portray the critical lead-time constraints for a process. It can include its suppliers and customers in order to show in one diagram both the lead time and inventory, in time. From this diagram lead times and inventory amounts can be targeted for improvements.

(iii) Production variety funnel

This tool is visual in that it plots the number of product variations at each stage of the manufacturing process. It can be useful for identifying where buffer stock should be held prior to customisation.

(iv) Quality filter map

This tool looks at the area of quality defects and where they are produced. If looking at the complete value stream then this could take in several tiers of suppliers. If using this tool within an organisation then the suppliers can be replaced by different departments, which are viewed as internal customers.

Three types of defects are recorded: Product defects; Scrap defects; Service defects.

(v) Demand amplification map

This map is very simple to produce, and is very powerful for anticipating trends, seasonal or promotional allowing the opportunity to predict demand and produce in line with it. The map which plots forecasts, demand, production and inventory graphically, can be used for a single organisation or for the complete supply chain and is excellent at identifying any dislocations that occur.

(vi) Value adding time profile.

This tool shows the accumulation of both value adding and non-value adding costs. One of its strengths is that it allows you to see where costs are being wasted. It is very useful at indicating how much cost is being attributed to non-value adding activities as opposed to the activities that add value to the product.

Case Study: Lean manufacturing at CHK Engineering

Crewe based CHK Engineering, established in 1964, employs 150 people at its Crewe base – using laser profiling on the manufacture of metal fabrications for commercial vehicles, trailers and suspension systems, agricultural, construction and materials handling machinery, and electrical distribution and switchgear.

The need for change

Eighteen months before it made the leap into lean manufacturing, CHK paved the way for radical change by creating a flatter structure and introducing new leadership. The receptive culture was also assisted by the company's pledge that productivity improvements would not result in compulsory job losses. The spirit of change was afoot, but traditional manufacturing systems still prevailed. The focus was on reduced cycle-times by engineering improvements with no focus on waste reduction.

Production of frame brackets, which is the company's largest product family, was organised by process function – with four managers each responsible for their separate laser profiling, forming, welding and painting sections. They worked in isolation, with little involvement in the other processes.

Since the laser profiling machines represented a large investment, the focus was to keep the machines operational to recover investment. Consequently, the lasers were often used to produce ahead of schedule, resulting in excess work in progress (WIP). Further down the line, there was a bottleneck within the welding operation, where there was more limited capacity.

The organisation of machines within four separate functions, coupled with WIP coming and going from the stores, also resulted in a convoluted materials flow, involving many unnecessary transport movements around the factory.

Making the lean leap

CHK took advantage of The Manufacturing Institute's Master Practitioner Experience, which offers free diagnostic advise and subsidised consultancy support to Small and Medium sized companies.

From the one-day diagnostic visit, CHK got some ideas how to progress further. The main tool used to determine this approach was Value Stream Mapping analysis, which identified where the glitches were in the business and provided a clear path to engage all manufacturing functions and implement a leaner, more efficient way of doing things.

The analysis showed clearly that CHK were carrying excess stock due to over-production and schedule changes, that operations were unbalanced and flow inhibited and that materials and information flow was convoluted. It also demonstrated that capacity and process capability were sufficient to meet customer demand by manufacturing to order on a two-day leadtime. Based on initial analyses, there was an overwhelming case to change the layout of the factory and make to order using a cellular approach.

A seven-strong CHK cross-functional project team was selected to drive and implement the project. The team changed the layout of the factory to accommodate cellular production, enabling materials to flow smoothly and releasing more than 50% of the floor space for future expansion.

Frame brackets cell employing laser cutting

Out went the old way of doing things within isolated units and in came: team working, multi-skilling, re-training, reduced batch sizes, Kanbans, Six Sigma and 5S techniques, excellence in communication and reorganisation of shifts. As a result, 5 people were required to do the work that 9 people had previously accomplished, allowing four to be redeployed to other areas of the business. In driving down levels of WIP and waste, the team found that a number of quality issues had been hitherto masked by using spare parts from the stores. These problems were quickly addressed and overcome.

Another issue that came to the fore was the need to address Overall Equipment Effectiveness. To achieve significantly faster product turnaround, the team has had to ensure that its machinery is continually maintained and kept in full working order to avoid down time.

Training

An essential part of the empowerment process, was ensuring that team members had the necessary training in lean principles and tools and techniques. Key staff participated in the Manufacturing Institute's practical learning programmes on lean manufacturing, Six Sigma and team leader development. As part of this ongoing development process, CHK is also one of a number of companies testing the Institute's Lean Online programme. This pioneering programme comprises a suite of practical internet-based training modules, designed to equip key manufacturing personnel with the skills and knowledge they need to implement lean manufacturing.

Reaping the real benefits of lean

It took CHK just three months to fulfil the objectives of its restructuring, which were to improve financial control, operational efficiency, capital investment and people development. Through going lean, the company has exceeded its expectations. The powerful benefits are evidenced by: the reduction of lead times from two weeks to two days; a 60% increase in people productivity and 26% increase in their value added contribution; impressive reductions in stock and WIP from £71,000 to £5,000 and significant improvements in quality and waste control.

The Manufacturing Advisory Service (MAS) and the Manufacturing Institute

The MAS is an integrated service providing free information and advice for all UK Manufacturers large and small; the service is delivered in co-operation with the DTI Small Business Service network of Business Links. In the North West the MAS is delivered by the Manufacturing Institute.

The Manufacturing Institute is a registered charity, re-investing its surpluses in its work of expanding UK industry's best practice knowledge base. In the past 18 months The Manufacturing Institute's practitioners have helped the region's companies reap productivity benefits totalling more than £10 million.

Laser welding of polymer and wood composites

Heinz Haferkamp, Alexander von Busse, Stephan Barcikowski* and Jens Bunte

Laser Zentrum Hannover e.V

Hollerithallee 8 Hannover D 30419 Germany

* T: +49 511 2788 377 F::+49 511 2788 100 E: bk@lzh.de

In laser beam transmission welding, a joint between optically dissimilar materials is made by overlapping the materials and applying a laser beam of a wavelength that it is transmitted by the first material and absorbed in the second, causing heating and welding at the interface. This innovative and promising technique has already been applied in the automotive, electronic and medical sectors for welding plastics using near infrared lasers (including the high power diode (810 nm, 940 nm) and Nd:YAG lasers (1064 nm)); and the recent extension of the technique to joining wood components is proving to be of considerable interest to the woodworking and furniture industry.

In comparison to conventional joining techniques, laser beam welding of polymeric and wooden components provides several advantages including: high flexibility, contact free application and processing in places that are hard to access.

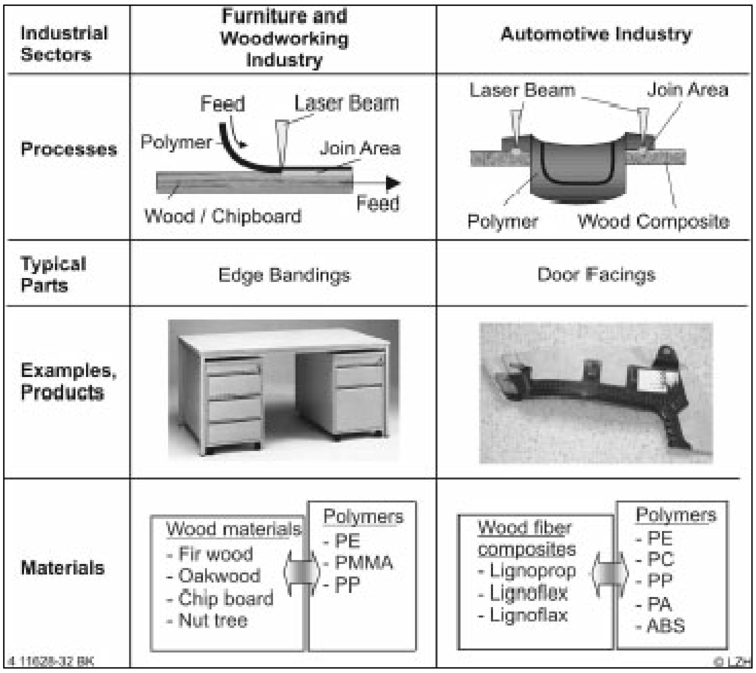


Figure 1: Industrial sectors, processes and materials relevant for laser welding of polymers and wood composites.

Applications in the woodworking market

Applications in the woodworking market niche remain to be investigated. The investigations considered here focuses on the two applications shown in figure 1, 'edge banding' applications of interest to the furniture and woodworking industry, and 'door facing' applications of interest to the automotive industry.

Up to now, edge bandings for furniture parts are glued to a chipboard plate with a typical feed rate of 40 m/min. Gluing has the disadvantage of comparably high operational costs and poor reliability, the adhesion of the particle-bonded glue sometimes not satisfying the customer. Figure 1 illustrates the concept of the laser welding process and lists relevant material combinations for laser assisted edge banding.

In the automotive industry, wood fibre composites are of increasingly importance for use in automotive interior parts. Figure 1 presents a typical product and the relevant material matrix for this application. Ultrasonic welding techniques are usually applied, but this requires specific sonodes for each part, which decreases the flexibility of the process. The typical cycle time of the process shown in the right column of figure 1 is 30 seconds.

Laser material processing of wood

Laser cutting, drilling and welding of wood and wood composites is commonly used in industry. At typical focused laser intensities of 10^6 to 10^8 W/cm^2 the process is mostly thermal and the thermal decomposition products of wood and its composites are known, as well as pyrolysis products and mechanisms of the lignin and cellulose components.

The wood polymer structure starts to change at 100-190°C for lignin, 170-210°C for hemicellulose and 220-350°C for cellulose. At temperatures in excess of 250°C significant decomposition of the bulk material takes place, so for laser welding of wood to polymers it is best to restrict the temperature range to 100 to 250°C, or even better 200°C.

Lignin starts to melt at about 100°C. During laser treatment of wood, a charring (carbon black residue) is widely observed and analysis of the surface shows a hydrophobic character, assumed to be due to the lignin. This plays an important role for the laser transmission welding process.

Thermographic investigation of polymers

The selection of materials for laser transmission welding is primarily based on two properties: (i) thermo-physical properties (e.g. heat conduction, viscosity) and (ii) optical properties (i.e. high transmittance for the laser-transparent partner (in this case the polymer) and high absorption for the laser-absorbing partner (in this case the wood composite)).

By way of illustration, figure 2 shows transmission and heating rate values for two polymers of interest for edge banding; PA6 (polyamide 6) and PBT (polybutylene terephthalate), in both natural form and with glass-fibre reinforcement. For both materials there the transmittance is almost the same at both wavelengths.

The scattering effects and changes of the absorption properties due to glass-fibre reinforcement are clear in figure 2: for PA6, there is an increase of the heating rate of a factor of about 5 with 30% glass-fibre reinforcement, a factor of about 10 in the case

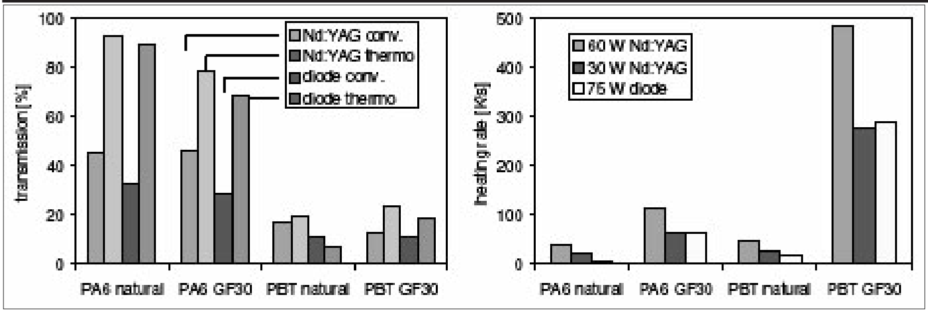


Figure 2. Transmission (left) and heating rate (right) of 2mm thick samples of natural PA6 and PBT, showing the influence of glass-fiber reinforcement at diode (810 nm) and Nd:YAG (1064 nm) wavelengths. The 'thermo' and 'conv' terms in the left hand legend refer, respectively, to thermographically determined (i.e. by measuring transmitted laser power, which includes reflection losses of the beam as well as absorption) and conventionally determined (i.e. total laser power absorbed).

of PBT. In consequence, the parameter range for processing glass-fibre reinforced PBT is more restricted than in the case of PA6.

In addition to glass fibre content, the optical transmission of PA6 is strongly dependent on material composition (e.g. pigments, fillers, foaming agents). Tests showed that even keeping the same (black) pigment and same glass fibre reinforcement, infrared transmission varied greatly e.g. 810nm (diode laser) transmission through a 2mm thick strip varied between 20% and 50% depending on manufacturer as a result of the different different parameters used when producing the material; for example, the raw granulated material can be black on delivery or the colour pigment might be added to the natural material while it is being injection-molded in the extruder. Also, the microstructure (crystallinity and density of spherulites)of the polymeric part depends on the injection molding process, and this too affects the laser beam transmission.

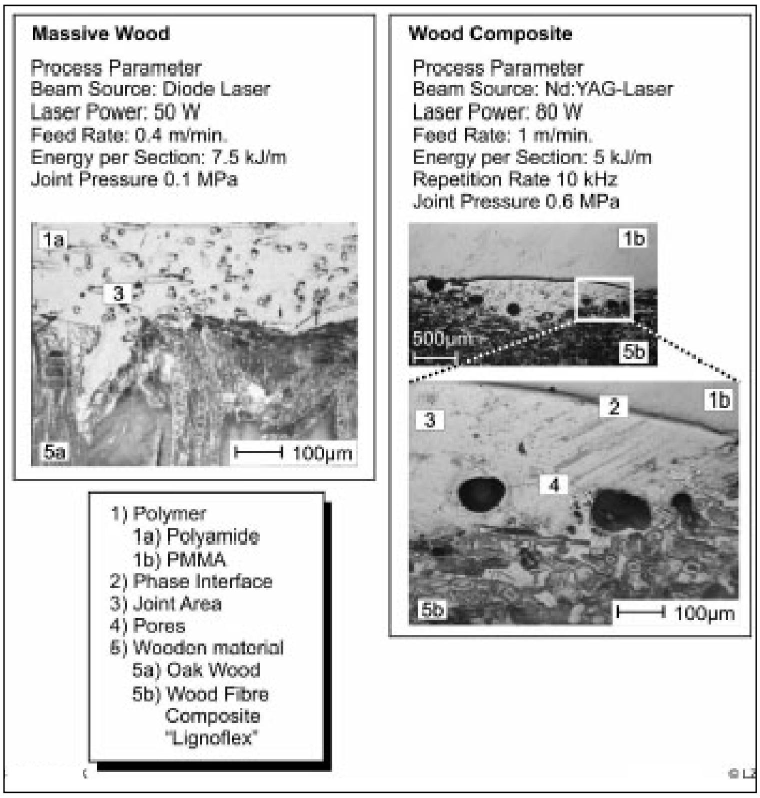


Figure 3. Cross sections of joints realized using laser transmission welding. Left: Oak wood and polyamide 66. Right: PMMA and the wood fiber composite lignoflex.

Laser welding to wood and wood composites

Joining mechanisms

Figure 3 shows representative cross sections of joints realised during laser transmission welding of oak wood and polyamide (PA 66, on the left of the figure) and PMMA and lignoflex (on the right). The surface of the massive wood shows typical re-processing (sawing) damage to a depth of 200 µm. In these areas, the polymer melt may infiltrate the wood, providing mechanical clamping of the materials after recrystallisation. In the heat affected zone (HAZ), the concentration of lignin (the wood thermoplastic) changes and a melt pool of the thermoplastic components (polymer and lignin) may provide a second joint mechanism. The proof of the latter may require chemical analysis of the composition of the joint area, but preliminary results of UV-spectroscopic scanning microscopy analysis support the thesis and mechanical characteristics of the joint area and base materials are clearly different.

Visual differences between the cross section of the joint area and that of the base materials are clearly seen in figure 3. Referring to the number scheme in the figure: at (2) the phase interface is clearly seen and pores (4) are also observed. The pores could not be avoided simply by control of laser energy deposition (the chosen joint was realised using 50 J/cm, but the pores also persisted at lower (40 J/cm) and higher (60-80 J/cm) values), but there arrears not to be a correlation between joint strength the presence of pores.

In summary, the joint mechanisms observed were: mechanical clamping; thermoplastic components melt pool; lignin in wood; thermoplastic matrix in natural fibre composite; thermoplastic polymer. Shear tension tests confirmed that the joints were stronger than the base material i.e when cracks occur under tension, they originate within the base material releasing wood fibres at the polymer.

Process Stability

Computer tomography (CT) measurements were carried out to characterise the polymer-wood laser transmission weld with a view to increasing process stability and reproducibility.

Since natural fibre composites have strong material inhomogeneities and anisotropic structures, an inhomogeneous weld contour is to be expected. Figure 4 shows the result of the CT analysis of representative joints between polyamide 66 and oak, chipboard and wood fibre composite, using a 105W Nd:YAG laser welding at 1m/min. For each material combination five pictures of longitudinal CT layers are presented. Regions with lower density appear dark, whereas those with higher intensity appear bright in the CT pictures.

Referring to figure 4, the CT layers sample the density distribution of material parallel planes covering the 600-800µm-thick welding zone, starting from a layer in the polymer (i.e. in the upper part of the joint) and finishing with a layer representative of the base wood or wood composite material which is unaffected during the welding process. Looking at the laser weld in a combination of PA 66 and oak wood, it can be clearly seen that a continuous weld is

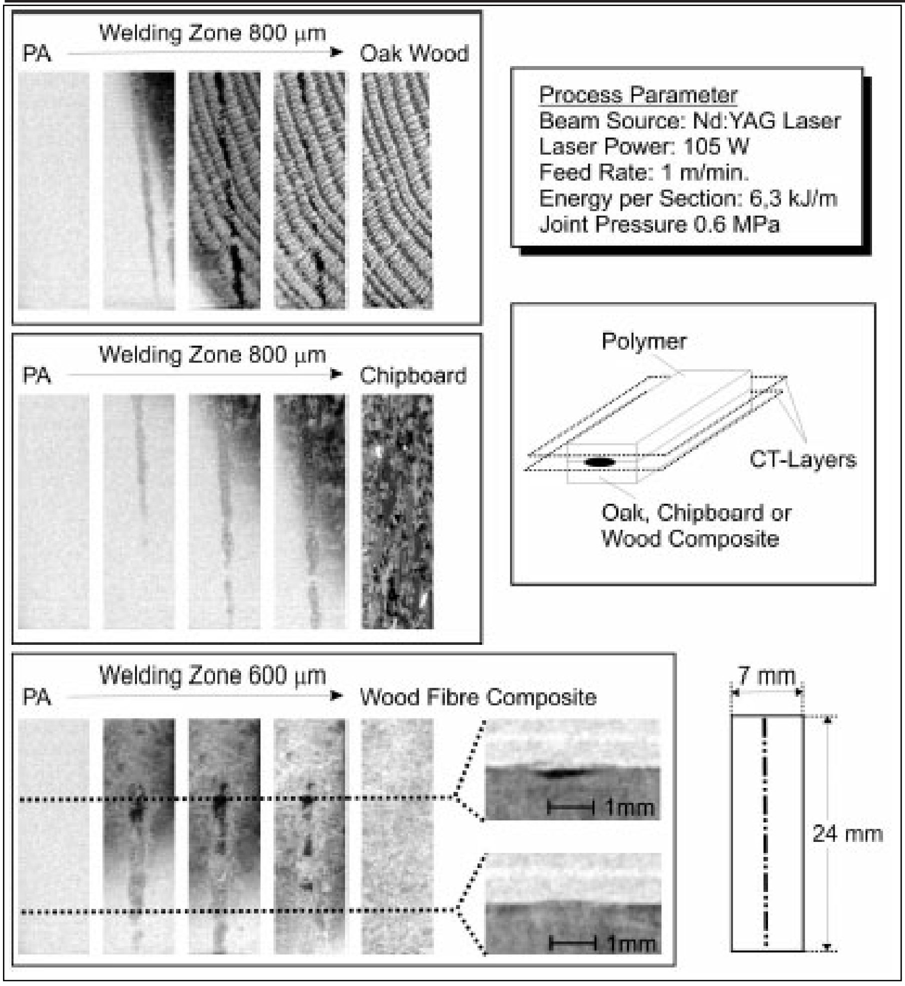


Figure 4. Computer tomography of laser transmission welded joints bonding Polyamide to oak, to chipboard and to wood fiber composite. Regions with lower density appear dark, whereas those with higher density appear bright

achieved along only part of the path of the weld contour. This absence of bonding becomes particularly noticeable in areas where the radial wood grain crosses the weld. In other regions the annual rings of the wood influence the continuity of the weld. It is known that the thermal properties of wood strongly depend on the density of the specimen and the material section. Thus one cause of the non-uniform welding might be the higher density of wood grain and the latewood in comparison to the early wood.

The CT layers of chipboard (middle part of figure 4) demonstrate that in this case the weld contour is more homogeneous than the weld contour of oak wood, but this contour too is interrupted where chips with the size of about 1 mm are crossed during welding.

The CT of a laser transmission welded joint with polyamide and wood fibre composite is shown in the lower part of figure 4. For this analysis, an extremely inhomogeneous weld was chosen and two transverse cross sections of the weld are included in the lower part of the figure. The upper of the two cross sections represents a deep penetration of the wood fibre composite without visible bonding of the materials, whereas the lower cross section represents a suitable bonding layer.

We conclude that even with quasi-homogeneous wood fibre composite there remain irregularities in the resulting laser weld seam. Furthermore, we note that the melt temperature (270°C) of the laser-transparent polyamide PA 66 is higher above the decomposition temperature (200°C) of the hemicellulose within the wood fibres, so temperature monitoring of the process, or some other appropriate technique for reliable process control, will be required for the further development of laser transmission welding of polymers and wood or wood composites,

Conclusions

Laser beam welding of polymer and wood composites is a promising new machining process for many manufacturing sectors including the automotive, electronic, medical, woodworking and furniture industries. Welding velocities up to several m/min can be reached, and a thermographic system has been developed for the qualification of the different materials for laser weldability. With this, influences of glass-fibre reinforcement and material composition on transmission, absorption and scattering of the polymeric and wooden materials under investigation has be quantified.

Natural fibre composites have strong material inhomogeneities and anisotropies, so special process strategies have had to be developed for their application. It is speculated that the primary joint mechanism of wood with polymers involves a change in material composition within the HAZ and a common lignin-polymer bond but the proof of this still remains to be established. To test the joining mechanism a UV-spectroscopic scanning microscopy analysis will be undertaken at an excitation wavelength of 280nm to achieve basic knowledge on the weld partner available within the HAZ.

For process stability and quality assurance when welding wooden components, suitable process control has to be employed during the welding process. Moreover, process strategies and clamping devices dedicated to industrial laser transmission welding in the furniture and automotive sector have to be, and are being developed.

The main task in the future will be, of course, the qualification of a reliable means of process control during laser transmission welding of the homogeneous wood composites and natural polymers.

Acknowledgments

Parts of this work was supported by the *Arbeitsgemeinschaft industrieller Forschungsvereinigungen* (AiF, AiF-Nr. 12.627 N resp. 13.346 N) and *Deutscher Verband für Schweißen und verwandte Verfahren e.V.* (DVS) and *Deutsche Gesellschaft für Holzforschung* (DGfH) with financial contributions from the Federal Ministry of Economics and Labour. The authors would like to thank the AiF as well as the project partners for their support. In addition, the authors would like to thank Mr. Sattari at LZH for carrying out part of the investigations regarding the weldability of wood.

This article is based in part on a paper presented at ICALEO (Jacksonville 13 - 16 Oct 2003) and is published with the kind permission of the Laser Institute of America

Also see ‘Observations’ on p39

Attention to detail in CO_2 laser scanning

Steve Hastings
Raylase AG
Argelsrieder Feld 2-4 Wessling/Oberpfaffenhofen D-82234 Germany
T: +49 81 53 88 98 20 F: +49 81 53 88 98 10 E: s.hastings@raylase.de

No sport comes close to Formula One in terms of the demands placed on technical engineering, and top designers know, above all, that winning and loosing is more often than not, weighted more towards the attention to detail, than to the driver. A perfect example of this is Damon Hill's exceptional drive at the 1997 Hungarian Grand Prix. Being more a technically accurate driver than an out-and-out racer, he took the underpowered Arrows past Michael Schumacher's Ferrari and into the lead on a circuit which demands precision driving. On course for an incredible win against all the odds, he lost the lead two laps from the end of the race because of a mechanical failure. Every car is stripped down after each race to gain valuable analysis: in this case, it was discovered that the mechanical failure on a multi-million pound piece of engineering was a 50 pence rubber oil ring.

So to it is with the subject of CO_2 laser beams: scanning optics, targeting and polymer processing, the attention to detail can make the difference between a fully functioning system and a problematic one. The cost of not ensuring a fully functioning system more often than not turns the "sexy" world of the laser into a nightmare that will cause a first time or potential user to probably not invest in the technology again.

Challenges for CO_2 laser processing

To fully understand 'attention to detail' in the context of CO_2 laser processing it is important to grasp the range of laser output parameters that need to be considered. Variables for the laser source output that are to be measured and perhaps monitored include output power and power stability, wavelength and wavelength stability, mode and mode stability, the Gaussian profile, pointing stability, output collimation, beam waist position, polarisation and polarisation stability, pulse rise and pulse fall, peak pulsing, continuous wave and quasi-continuous wave output. The analysis required is further complicated by a paucity of suitable measurement and testing instrumentation for the far infra-red spectrum.

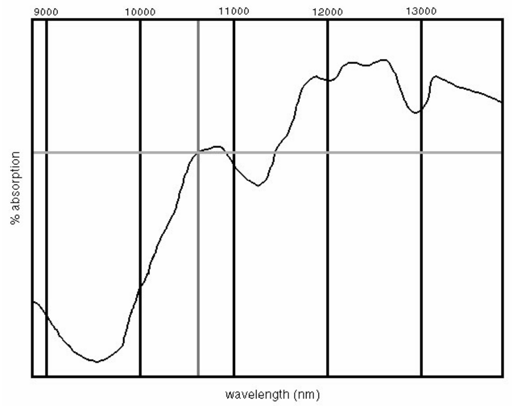
Then we have to take into account what may be termed 'conditional factors' on the laser output parameters; cooling, gas purging, process-shutter bounce, vibration and control effects; input modulation, active DC power supply control, pulse period, pulse width and combination driving. In an exacting application this must all be tested, measured and verified before we can begin to work on the optical delivery and final focusing onto the workpiece. It is here that there may be opportunities to introduce alternative methods of beam control that are far superior to direct control of the laser source itself.

'Conditional factors' on output and beam delivery

Chiller

Poor cooling can compound power and wavelength instabilities in the laser source, thereby.affecting the stability of laser power reaching the target and, because absorption in polymers is wavelength sensitive, the level of absorption of the target material.

Figure 1. The absorption spectrum of polypropylene, revealing a structure typical of polymers. In this case, the absorption within the sample is only 65% at 10.6 µm



The choice of a chiller for a laser may seem simple, but it is fraught with extra little complications. Take a 200W laser: the technical specification sheet clearly states that we require a cooling capacity of 4kW at 16 litres per minute. But are there any other optics or components, such as beam dumps, that need to be cooled? If so, the cooling requirement may rise to 4.2kW.

One method to increase cooling capacity from a chiller is to increase the coolant reservoir size. In warmer climates I have seen the system exit coolant pumped into a larger tank which then feeds directly to the pump within the chiller. The use of a larger reservoir generally helps to keep the overall temperature more stable within the entire cooling system. I have also seen alternative coolant mediums such as liquid silicone.

Gas purging

Gas purging of the beam delivery line is important, even imperative in dusty or humid conditions. In addition to thermal blooming, failure to ensure a clean-dry, non-absorbing gas to the beam line will lead to the build-up of contaminants on the delivery optics. The absence of gas purging can give rise to pointing instability, beam divergence and mode to deterioration. The output coupling mirror and beamline components may distort or damage due to increased surface contaminant absorption.

Vibration

Vibration can cause massive problems in beam delivery. and in order to maintain constant processing, it is essential that the vibration from nearby heavy plant and machinery be dampened.

Process-shutter bounce

In the early 90's I designed a fixed laser beam targeting system for a machine that ran a web of thin electronic foil at 150 metres per minute. The laser beam was split to produce four focus points, and had to process slits of specific length in the material. A fast process shutter was employed for slit length control and the only problem was the appearence three diminishingly small streaks at the end of every line caused by the process shutter bouncing off its bottom (closed) position, allowing a small part of the beam to pass. Simply adding a small damper cured the problem.

Laser output control

Laser output control becomes a critical issue when it is applied to modulated laser processing of thin polymer sheet. To put it another way, cutting through a metal at relatively slow process speed is easy compared to part-depth cutting of polymers at speeds where pulse separations can be seen as feature separations in the material.

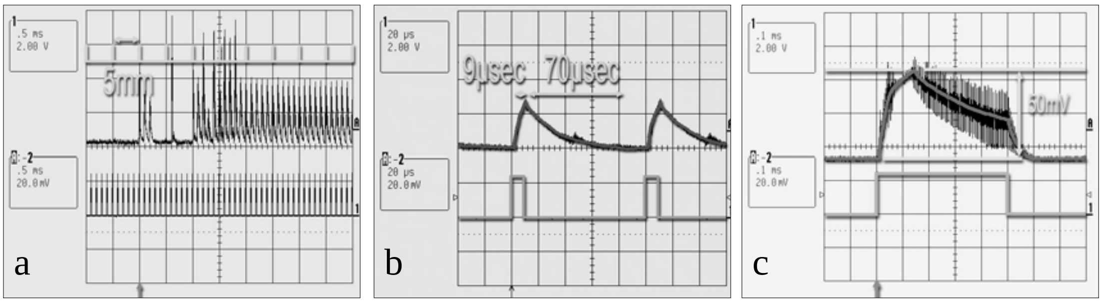
Applying modulation to a CO_2 laser can be as tricky as igniting a spark-plug to explode a petrol-air mixture within a car engine. There has been more than eighty years development to improve motor combustion, and still room for improvement, so we shouldn't expect miracles from activating a relatively large volume of gas within a laser cavity.

I like to think of the gas within a laser cavity being similar to that within a fluorescent strip-light. Go to the light switch in your kitchen and turn the strip-light on and off a few times. Does the light start the same way every time? Is there the same delay? The answer of course is "No".

To address the problem, many commercial CO_2 lasers now include a 'tickle' signal to maintain a low discharge current in stand-by, but laser output modulation will never be as uniform as the electrical input modulation. To improve start-up performance, other CO_2 laser manufacturers are actively developing the opposite of the Nd:YAG first pulse suppression technique, whereby the first excitation pulse is made more powerful in order to increase the speed at which the laser output ramps up and maintain a better uniformity at the beginning of processing sequence.

As shown in figure 3, the modulated laser output pulse is far from 'top hat' and, as PRF is reduced so the peak power increases. The peak power at 1kHz 50% duty cycle may be up to four times the maximum CW output, and this will affect all beam delivery optics and other components that come into contact with the beam.

Figure 3. The challenge of modulation as revealed by a comparison of input modulation signal (bottom trace) and, above it, typical laser output from a diffusion-cooled slab CO_2 laser. Modulation rate and duty cycles are: (a)10kHz, 10% (500 µs/division); (b) 10kHz, 10% (20 µs/division); (c)1kHz, 50% (100 µs/division. The bottom arrow marks the first trigger point.



Scanning the laser beam

The optimum laser modulation frequency for materials processing varies from material to material, with some materials preferring high peak power whilst other materials are not so restrictive. In a scanning laser processing system, this and field size will limit the scope of scan and processing speeds (for example, a preference for processing at a high laser modulation frequency prevents operation at the higher scanning speeds). Also, the laser output modulation must be directly coupled to the speed and acceleration/deceleration of the focused beam or 'spot' at the target.

Laser scanning forms the basis of the Raylase product range, and a 70mm field targeted by an f100mm lens is about as small as I have seen used with a CO_2 laser. For such a lens, maximum spot velocity across the target will be anything up to 4 metres per second depending upon the galvanometric motor performance, control electronics, and especially the mirror masses.

Translating the same figure through a three-axis post-objective scanning system to a 2m field, and we are able to scan with maximum spot velocities over 100 metres per second. At just 10 metres per second a 50% laser duty cycle implies a 5mm streak of power followed by 5mm of no target processing: at these kinds of scanning speeds the laser output needs to be at reasonably constant during the 'on' periods. For a diffusion-cooled slab CO_2 laser optical pulse seperation is lost somewhere around around 15 kHz and full 'quasi-CW' operation is reached at modulation frequencies around 50kHz.

Figure 4 shows the improvement in power stability of a diffusion-cooled CO_2 laser from start-up. Such plots were obtained by monitoring the output power every 25µs, calculate the average power over a period and assessing all fluctuations above and below the average as a percentage instability. As a general rule of thumb, providing the chiller has the correct capacity and is maintaining the coolant at ±0.1C and the laser is switched on at a constant output settings, power instabilities should be within ±7% (i.e.14% overall) after 10 minutes. How many processes require the laser to be on for 10 minutes before starting?

The operation of X-Y galvanometric laser scanning traditionally involved first making a 'jump' to the starting co-ordinates with the laser off, which involves mirror movement time plus a 'settling time' to ensure that the mirrors have reached their required positions and are stable, generally under 0.5ms in total. At this point the laser is turned on and the mirrors begin their acceleration up to the desired scan speed with the laser energy reaching the target. If the path changes direction or is discontinuous then there will also be a mirror deceleration period and additional settling delays to account for.

However, this traditional approach does not work well with a fast-modulated CO_2 laser, where the modulation laser output can fluctuate; nor does it counter the the reduction in power that

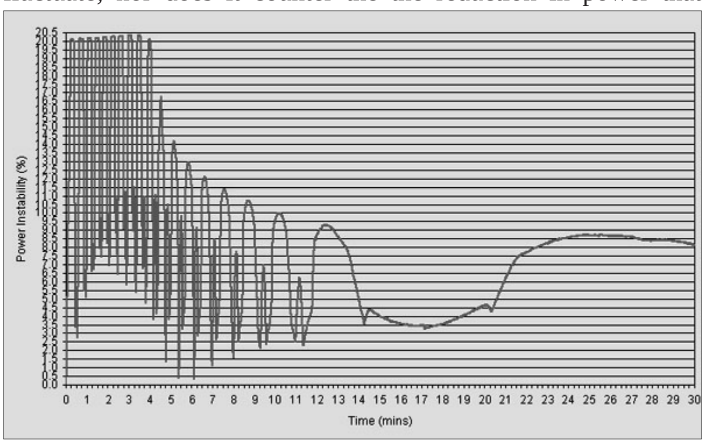


Figure 4 Low pressure cavity laser instabilty measured with Ophir 20C-A thermal head at 5kHz 75% duty cycle. Note: over 30 mins ±10%. After 10mins <±4%.

Figure 5 Raylase AG first generation Power Control Device

should occur during acceleration and deceleration phases. Within the past decade there have been several attempts to counteract the problem of over-processing during acceleration and deceleration. Pushing up and pulling down the DC power supply to the RF amplifier, pulse width, pulse period and combination pulse width and period driving, can ease the problem; but by its very nature, influencing the electronic signal input generally increases laser output instabilities.

Power control

In 2000, Raylase launched the Power Control Device (PCD) shown in figure 5, to optically control laser power to target in direct relationship to scan velocity. It is complicated and expensive but we believe that it remains the only 100% repeatable process to maintain accurate fine processing of polymers.

With the PCD the laser remains on and the PCD maintains constant output from zero to 99.98%. It is an optical device providing stable transmission control characteristics, which calculates the scan spot velocity and provides a stable energy deposition on the target to better than 0.1% stability. By the same technique, fluctuations in the CO_2 laser output fluctuations can be monitored and controlled to ±0.01%. This became the basis for the Raylase PowStab shown in figure 6, currently being used successfully in the CO_2 security glass marking industry.

The scan head design

CO_2 laser scanning scanning is now taking over from inkjet coding and chemical processes, and for security marking, welding, ablating, scoring, cutting, perforating and treating.

Pre-objective, flat-field, two-axis, or f-Theta scanners add a corrective lens after the XY mirrors to adjust for field distortions. Post-objective, or three-axis scanning uses an active expander lens, also driven by a galvo motor, and then an objective focusing lens before the XY mirrors. The directional movement of the expander is known as Z-axis. I will refer to the two different types as “Two-axis” and “Three-axis” scanning.

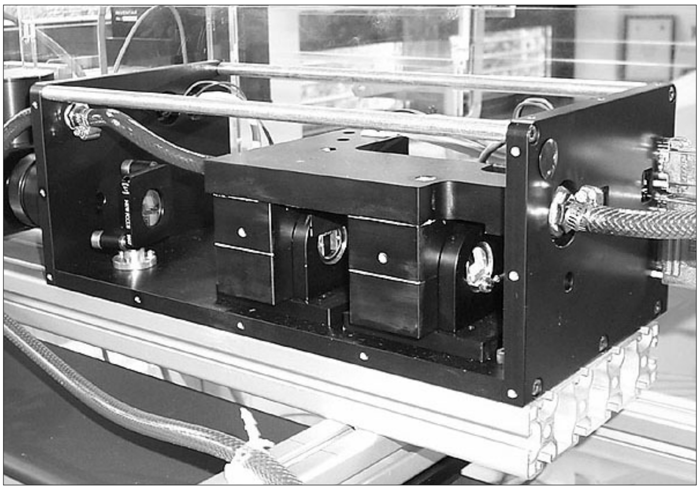


Figure 6 Raylase AG PowStab-10 prototype system.

Two-axis scanning is the less expensive, but three-axis scanning has the advantage of on-axis focusing, thereby maintaining a minimum spot size and one that remains more constant over the target field. Two-axis scanning fields can be changed by replacing the f-Theta lens, whereas in three-axis scanning, moving the distance between the Z motor positioned expander lens and the objective has the same effect.

Mirror inertia limits scan speed in the same way for both two and three-axis scanning. Larger aperture mirrors give a smaller spot but their larger inertia compromises scan speed. In two-axis scanning, the larger the mirror, the larger the f-Theta lens diameter must be.

The optics available to scanning technology continues to advance and three-axis scanning equipment that can target in microns spot diameter (at 64% peak) of the field size in millimetres eg. a 320µm spot to a 500mm^2 field. Compared to the 850µm spot diameter produced by a 15mm two-axis scanhead with an f720mm f-Theta lens to target to the same area field, the spot area is some seven times smaller, meaning that a considerably lower power laser can process at the same speed, with the added benefits of lower heating of the target and lower fume generated.

Two-axis scanning used for cutting is at its best with small field sizes in cramped mounting conditions, and of course not every customer wants to cut as efficiently as possible. Some want to mark, for example jeans. Here a two-axis system is perfect for ablating the unwashed indigo dye from the surface of the material with a relatively large spot and field.

Forecasts point to a healthy growth both in CO_2 lasers and in galvanometer scanning units. I often wonder when the threshold will be crossed where organisations, authorities and ancillary suppliers see this potential and start standardising, accommodating and optimising; and when will we be able to gain those valuable laser output details that are still missing?

A full version of the 2003 David Greening Memorial Lecture can be found at www.raylase.de/40_news/bilder/dgml03.pdf

A younger Steve Hastings as Incident Officer on the Silverstone Emergency Services Incident Team, where he learned first hand the benefits of paying attention to detail.

Steve began R&D in digital post-press in 1988 and developed fine CO_2 laser processing of print-packaging-materials. He is currently Applications Manager and CO_2 systems integration specialist at Raylase.

Back to basics

An occasional series of laser technology and application reviews

f-Theta scan lenses for CO_2 lasers

Gary Herrit
II-VI Inc
375 Saxonburg Blvd Saxonburg PA USA
T: +1 724-352-5272 F: +1 724-352-5703 E: gherrit@II-VI.com

F-Theta (F-θ) scan lenses play a key role in many applications today, including marking, engraving, and via drilling. Typically the F-Theta lens is used in conjunction with one or two axis galvanometer mirrors to allow fast positioning and precision focusing of the laser beam.

Figure 1 illustrates a typical pre-objective scanning system. The laser beam is first conditioned in size and shape before being reflected off one or two galvo mirrors, which deflect the beam into the scan lens, to produce a scanned focused spot on the work piece. It is called a pre-objective scanning system because the scanning of the laser beam takes place before it enters the focusing (or objective) lens.

In this paper we list some of the key application issues that first time scan lens users should consider when designing a scanning system and purchasing a scan lens. We also provide(opposite) an introduction to terms used in the design of scanning optics.

Scan Lens Selection

Scan lens selection is usually determined by the application. Applications vary from simple engraving systems to high performance direct drilling of via holes in circuit boards. The applica-

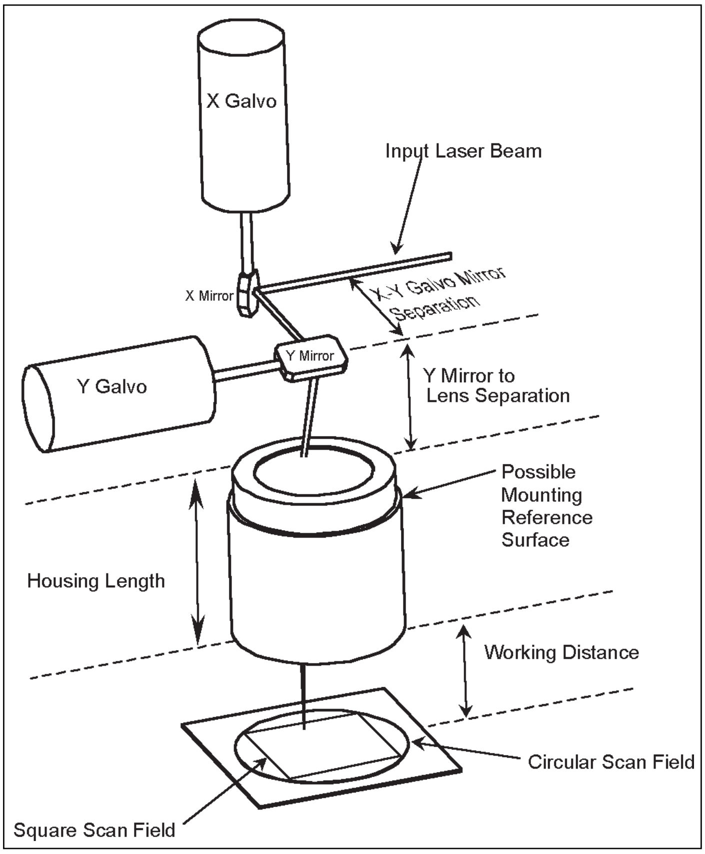
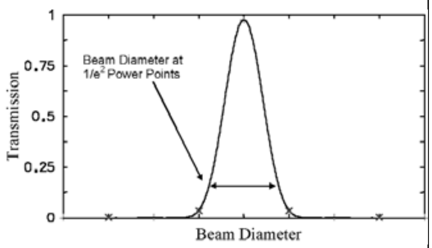


Figure 1 A typical pre-objective scanning system

Some CO_2 laser scanning optics terminology

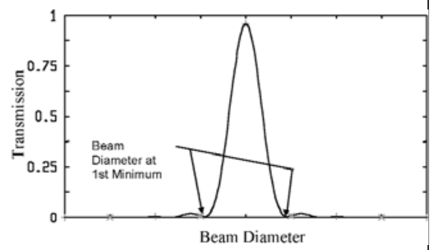
Beam diameter

There are a number of ways of specifying beam diameter. For most untruncated laser beams the beam diameter is specified by encircled power (energy) i.e. the smallest diameter of the circular aperture that contains u% of the laser power (energy), written d_u. The normally-quoted value is for 86.5%, which for a Gaussian beam is equivalent to the beam diameter measured at the 1/e² power points.



Intensity distribution for a Gaussian beam profile

For truncated beams that take on the airy disc pattern (i.e. a series of concentric circles generated by diffraction through a pinhole) the beam diameter is often quoted at the first minimum.



Intensity distribution for an Airy disk profile

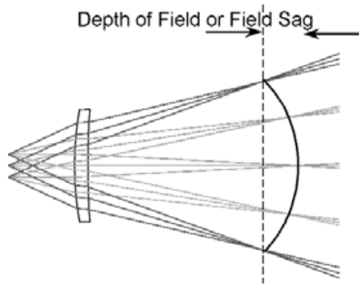
Beam diameter at Galvo is the diameter of the laser beam as it enters the input aperture or port of the galvo head. This may be quite different to the diameter of the beam as it leaves the laser; for example, if the laser beam is transmitted through a small mask or, commonly, if the system incorporates a beam expander.

Beam divergence

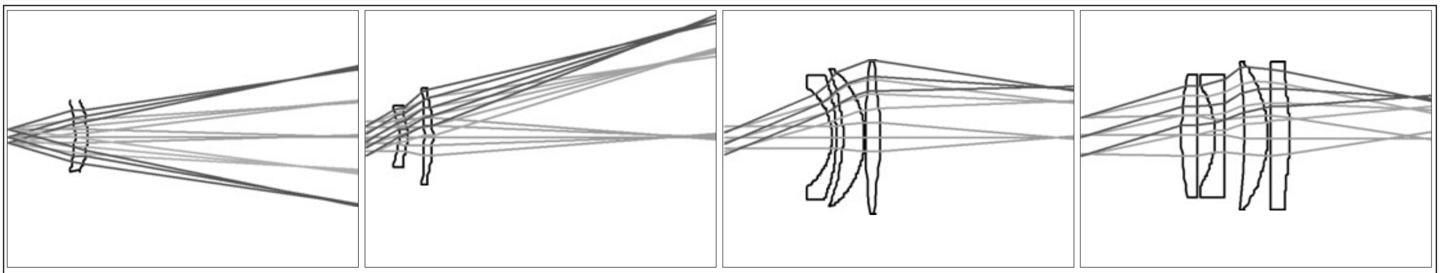
The beam divergence is the apex angle formed by the cone of the increasing beam diameter. Beam divergence should be specified as full angle or half angle, with a subscript to indicate the relevant diameter (see beam diameter above). It is usually measured in milliradians (mr).

Depth of Field

The position of the best focus spot, in the direction perpendicular to the plane of the workpiece, varies across the scan field. This is also known as field sag or field depth. At some point in the field the beam may focus just before the nominal focal plane (workpiece), and at some other point the beam may focus just beyond the nominal focal plane. The distance between the most extreme focus points is the Depth of Field. For simple lenses this curvature is often spherical in shape and it is curved backward towards the lens. CO_2 scan lenses may have depth of fields as large as several millimetres for simple singlet designs and as small as <100 µm for more complex 3 or 4 element telecentric designs.



Continued on p28



Singlet (Marking) **Doublet (Marking/Drilling)** **Triplet (Via drilling)** **Quadruplet (Via drilling)**

tion specifications that determine the design of a scan lens include the field size, focused spot size, input beam size, and input beam divergence.

Engraving systems usually require large fields and large focused spot sizes. Consequently, scan lenses for these applications are simple one or two element lens systems that are non-telecentric. Lasers for engraving and marking are usually low power (10 to 100 watts CW). Since such lasers emit small diameter beams, a beam expander may be used to expand and collimate the laser beam prior to entering the galvo/scan lens systems. Beam quality is not so critical because large focused spot sizes are required.

At the other end of the spectrum are the more complex lenses for via hole drilling. Via drilling systems using CO_2 lasers incorporate lasers in the 100 to 500W power range, often pulsed. Laser beams from these lasers must have good beam quality (low M^2 values) or the beam must be conditioned by using a mask projection technique. Spatial filters are sometimes used to improve the beam quality; however, at the higher power levels, spatial filters can sometimes be damaged by the focused beam. In general the beam entering the galvos and scan lens must be a good quality beam with a symmetric intensity profile.

Circuit board via holes are needed in many sizes from several hundred microns to <50 µm. Via holes that are greater than 200 µm are usually drilled by mechanical drills. Via holes less than 50 µm require YAG or UV laser systems. However, the CO_2 laser systems are ideally suited for drilling vias in the 50 to 200 µm range; 150 µm is the most widely used via size. These small vias require scan lenses with short (typically 100 mm) focal lengths. In order to produce circular holes with minimum taper, telecentric lenses are usually specified, generally comprising 3 or 4 high quality optics in a tightly toleranced mount.

Beam path to the scan lens

Most beam path from the laser output to the scan lens are enclosed to protect the operator and the optics and the enclosure may be N_2-purged. The beam path usually includes beam bending mirrors, lenses or curved mirrors if a beam expander is used, and of course the galvo mirrors. Any or all of the optical elements, mounts, and beam delivery tubes may truncate the beam.

Beam truncation changes the focusing properties of the beam and scan lens; generally resulting in a loss of the laser power and an increase in the focused spot size. If it is necessary to truncate the beam then the user should be aware that the focused spot size and shape may not be as calculated or expected.

<u>Mask Projection Systems</u>

Because of the need for good quality beams in laser via drilling systems the mask projection technique is sometimes used to clean up the beam mode i.e. remove the "noise" around the periphery of the beam due to higher order transverse spatial modes.

The requirements for a mask projection system to work properly are that the laser beam be collimated when it reaches the mask and the laser beam diameter be at least four times larger than the mask diameter (see diagram below). A significantly truncated poor quality beam is approximately equivalent to a good quality beam with an airy disc intensity profile.

The divergence θ of the beam after passing through a mask can be deduced using the equation for diffraction through a pinhole i.e. $\theta = 2.44\ \lambda/A$, where λ is the wavelength of the laser and A is the mask diameter.

Alignment

The workpiece, which is usually located at the focal plane of the scan lens, must be aligned perpendicular to the on-axis beam leaving the galvanometer head. The alignment should be done before placing the scan lens in the beam path.

An easy way to accomplish the alignment is to use a visible Class 2 laser beam co-aligned with the CO_2 beam. The visible beam can be reflected back on itself (back through the galvo head) with an optically flat mirror placed at the location of the workpiece.

The required alignment accuracy depends on the application and the type of scan lens used. For marking and engraving systems perpendicularity between the beam and workpiece can be 10's of arc minutes. For via drilling systems an alignment accuracy of <5 arc minutes may be required.

Similar alignment accuracies are required for setting the parallelism of the scan lens i.e. aligning the lens housing axis along the alignment beam path. Centration of the lens to the laser beam axis should be held to less than 1 mm for marking and engraving systems and < 0.2mm for via hole drilling systems. A quick way to determine centration is to take a beam burn and then rotate the lens 90° in its holder and take another beam burn. If the two burns are displaced then the lens is not centred.

Most scan lenses have one or more outside surfaces that can be used as reference surfaces during the installation and alignment of the scan lens. During assembly of the scan lens by the manufacturer, the alignment of the individual elements in a scan lens housing is controlled to these reference surfaces. This assures that the optical centre of the lenses and the mechanical centre of the reference surface are collinear. The scan lens user can use this reference surface to control the position of the scan lens in the system.

Typical housing reference surfaces are precision machined ribs or shoulders in the housing, the input surface of the housing, or the exit surface of the housing. For new scan lens designs, users can work with the manufacturer to determine the position and shape of this reference plane.

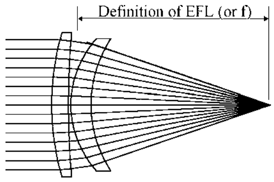
Also see 'Observations' on p39

Some CO_2 laser scanning optics terminology (continued)

Dimensions

Effective Focal Length (EFL)

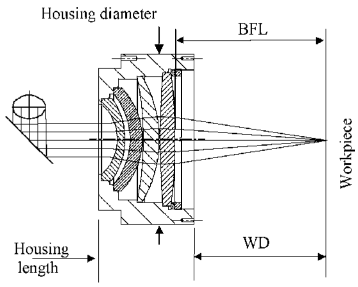
Effective Focal Length is the distance from the lens to the work piece. EFL is commonly represented in scan lens formulae using the variable f. The exact distance is difficult to measure but can be calculated by most lens design programs.



EFL is closely related to Back Focal Length and Working Distance, which can be directly measured. Generally, a greater the EFL the longer the Working Distance and the larger the focused spot size.

Back Focal Length (BFL)

The Back Focal Length is the distance from the vertex of the last lens surface to the workpiece. (see figure below)



Working Distance (WD)

The Working Distance is the distance from the work piece to the closest edge of the scan lens housing. If the scan lens is a single element and is unmounted then the WD is defined to be the distance from the edge of the second or last surface of the lens to work piece.

Housing dimensions

The length of the scan lens housing is determined by the number of optical elements in the lens and the distance between the elements. The lens design program establishes the optimum distance between the elements, but the user may specify a maximum length according to system needs.

Similarly, the housing diameter depends on the optic diameter optimized by the lens design program, but the user may specify a maximum housing diameter according to system needs. A smaller diameter will be less expensive, but if the optic diameter is less than the optimum design then the lens performance may be degraded.

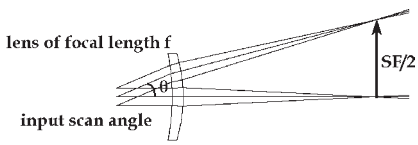
The user should also specify any other requirements of the housing, such as flanges or bolt holes, for mounting the housing in the system.

Flat Field Lens

Many lenses, including F-theta lenses, are designed so that their foci lie on a flat image plane. When a lens has been designed to minimize the Depth of Focus it is called a Flat Field Lens. Ideally all scan lenses or F-Theta lenses should be designed for the minimum depth of field possible.

Input scan angle

The input scan angle (measured in degrees) is the extent of angular movement of the laser beam (produced by the galvo mirrors) needed to scan the beam over the dimensions (SF) of the desired scan field. The maximum input scan angle is limited by the maximum mechanical turning angle of the galvo mirrors.



The input scan angle (often termed the optical scan angle) is related to field size and focal length of the scan lens by

$$SF = 2f\theta$$

where f is the focal length of the scan lens, and θ is the input scan angle (N.B. Sometimes galvo manufacturers provide scan angles as the mechanical angle through which the galvo mirror turns. The input scan angle is twice the mechanical angle).

Users may choose a smaller design scan angle. Scanning at smaller angles will increase the speed of operation but may result in a smaller scan field or a longer working distance.

M^2 value

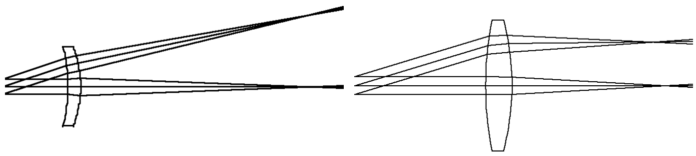
The beam propagation factor, M^2, is a measure of the quality of the laser beam. An M^2 value of 1 is the theoretical best, and anything greater than 1 will give a larger focused spot size. This parameter is particularly important for non-mask projection systems i.e. ones that do not truncate the laser beam. Typical values for CO_2 lasers range from 1.1 to 3.

Mask

The use of a mask is optional; it is not a part of all scan lens systems. If used, the mask is usually positioned several meters before the galvo head.

Output Scan Angle

The output scan angle is the angle between the laser beam and the optic axis as the beam exits the lens. Smaller output scan angles give more circular spots and less beam size variation across the scan field, but lenses that give smaller output scan angles are more expensive. Lenses with output scan angles less than 1^0 or 2^0 are termed telecentric.



Non-telecentric **Telecentric**

Power and energy

A Continuous Wave (CW) laser emits a steady and uninterrupted beam of radiation and the output is specified as a power (Watts). A pulsed laser emits a beam of radiation as a train of pulses: in such cases, average power can be quoted, together with the pulse energy, peak power and pulse repetition frequency (PRF). Most scan lenses are used in applications that require pulsed lasers.

Spot Circularity

Circularity is a measure of the ellipticity of the focused spot. The shortest diameter across the shape of the spot is divided by the longest diameter. A circularity of “1” would be the best possible, and a circularity of “0.5” would be poor. Telecentric lenses give the best circularity and lowest beam size variation across the field. The circularity is often calculated for a specified number of samples throughout the field. The minimum or lowest circularity value found in the sample is the one used in the specification summary for that lens.

Spot Size

On Axis

The spot size is the diameter of the focused spot. It is calculated by lens design programs at the $1/e^2$ power points. The user may specify some other measure of the spot, such as the Airy Disk diameter or the Full Width At Half Maximum (FWHM- the 50% power points). The spot size on axis is always the smallest and most circular of any in the scan field.

In general it is best to model the laser beam in a lens design program to determine a realistic expectation of focused spot diameter. However, feature sizes cannot be accurately predicted from calculated spot sizes: the relationship between the two is complex, so trial-and-error testing is required.

Corner of Field

The spot at the corner of the scan field is usually the largest and least circular of any in the scan field. Again it is important to point out that the spot size value calculated by an optical design program is not the same as the feature size produced by the lens in the user’s application.

Wavelength

A CO_2 laser emits radiation at a number of different wavelengths between 9.2 µm and 10.8 µm. Two of the most common wavelengths are 9.3 µm and 10.6 µm.

Emerging applications for Q-switched DPSS lasers

Matt Henry
Powerlase

Imperial House Link 10 Napier Way Crawley West Sussex RH10 9RA
T: +44 (0)1293 456221 F: +44 (0)1293 456233 E: matt.henry@powerlase.com

Nd:YAG Flashlamp-Pumped Solid State Lasers (FPSSLs) have been widely used in industry for over twenty years, whereas industrially rugged Diode Pumped Solid State Lasers (DPSSLs) appeared only relatively recently. Q-switched DPSSLs are now available at comparable average powers to pulsed FPSSLs, offering pulses with durations of 1-100s of nanoseconds at kilohertz pulse repetition frequency. Typically comparable figures for conventional pulsed FPSSLs are a pulse duration of order 1ms at a repetition frequency of a few hundred Hz.

We believe that the ns - kHz (1ns = 10^{-9}s, 1 kHz = 1000 pulses per second) regime of operation has the potential for much improved processing: short pulses diminishing thermal effects and high peak intensities improving material coupling and process efficiency. Combined with the excellent beam quality, high efficiencies, rugged construction and long diode lifetimes; this makes DPSS lasers a very attractive option for both macro and micro scale manufacturing.

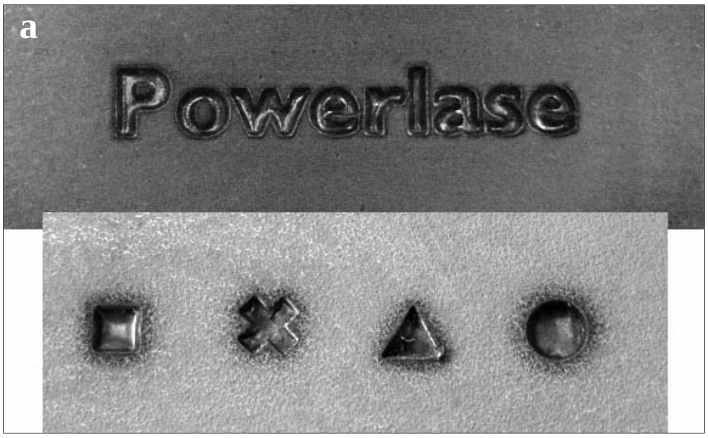
In this paper we consider two emerging processes enabled by the latest state-of-the-art Q-switched DPSSLs. The first is laser milling of Nickel superalloys, a process by which complex 3D shapes can be machined in aerospace alloys to improve cooling and therefore performance and lifetime of turbines in both the aerospace and power generation sectors. The second is high aspect ratio, fine hole drilling of stainless steel fuel injectors for the automotive sector; offering the potential to radically improve engine efficiencies by producing ever-finer fuel aerosols from smaller hole sizes. The high peak power densities in the focused beam results in plasma formation when processing metals and an explanation is given as to why we believe this to be critical to the success of both processes.

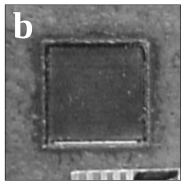
Laser milling

The laser milling of Hastalloy and other Nickel based superalloys is of increasingly significant commercial interest in the aerospace and industrial gas turbine sectors. It offers, for example, the potential to rapidly machine complex shapes in the leading edges of turbine blades.

With high power DPSSLs complex shapes can be created in times that compete with EDM, with the added advantage that the processing can take place on surfaces that have already had Thermal Barrier Coatings (TBC) applied to them. Cooling vanes have long been drilled by flash lamp pumped solid-state lasers: it is now possible to laser mill 3D shapes at the exit of these vanes, offering improved cooling by more effective flow control.

We have already successfully demonstrated the laser milling of ceramic (TBC) with a Q-switched DPSSL, so the potential exists to mill and drill dissimilar laminar materials in a single pass with the same laser e.g. drill cooling vanes and mill alloy turbine blades: a very attractive option for those companies at the forefront of gas turbine technology.





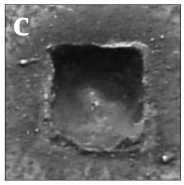


Figure 1. Examples of laser milling of Hastalloy X, demonstrating the balance between material removal rate and acceptable feature quality:
(a) Fine shapes achieved with optimised parameters (4.6.10^7 W/cm^2 and 23 mm^3/min).
(b) Milling at high peak intensity (6.7. 10^8 W/cm^2), showing a high quality finish but suffering from a low material removal rate (2.5 mm^3/min).
(c) Milling at a low peak intensity (1.2.10^7 W/cm^2)showing a high material removal rate (49.4 mm^3/min) but feature quality is poor.
Feature size for shapes and lettering is 4mm

For this laser milling work a Starlase AO4 Nd:YAG Q-switched DPSSL was used at the fundamental (1064nm) wavelength. This laser offers average powers up to 430 W, repetition frequencies from 3-50 kHz and pulse durations of 35-200 ns. The output beam passed through an external attenuator* to provide fine control of pulse energy, was.collimated through a Galilean telescope; and was directed into a galvanometric scanner (ScanLab HurryScan25) with a 254mm focal length f-theta telecentric lens, a working field of 115x115mm and a maximum velocity of 10m/s. All samples were Hastalloy X.

The performance of the Q-switched DPSSL is such that if average power is maintained constant, the pulse duration increases as the pulse frequency is increased i.e. the peak intensity decreases. In the high peak power regime, material removal rates are found to increase exponentially as power density diminishes, an effect that we associate with plasma shielding of the workpiece (see below) i.e. the density of the plasma increases with increasing incident power density, increasing its shielding effect. This implies that there will be an optimum set of laser parameters for which the material removal rate is maximised. For this removal rate to be commercially attractive, our work suggests operating the laser at higher frequencies, 30-50 kHz, where pulse widths are longest,

*Such an attenuator is necessary to control pulse energy, for unlike FPSSLs, Q-switched DPSSLs have distinct stability regions that are optimised by reference to the diode drive current. A consequence of this is that stable power output cannot be controlled simply by adjusting power input. Fine power control is better achieved with an external attenuator.

120-200 ns, in order to reduce the ratio of peak intensity to average power and thereby reduce plasma shielding effects.

A further consideration is surface quality. It is observed that at high power density, material is removed in the form of a fine molten spray. This produces the finest surface finish. At a constant average power, the molten spray becomes denser and the surface quality deteriorates as the power density diminishes. Clearly a balance must be struck between material removal rate and acceptable feature quality. Figure 1 above demonstrates this balance. It may be possible to combine different regimes to improve laser milling: for example, a two-stage process could involve low intensity processing for bulk material removal, followed by high intensity processing to produce fine features and surface quality. Indeed, it can be argued that plasma effects are beneficial if appropriately controlled, acting as a balance between quality and milling rate.

Plasma effects

At focused beam intensities of between 10^7 and 10^{10} W/cm^2 at a metal workpiece, typical for DPSSL processing, plasma formation occurs. Understanding the effect of the plasma is therefore critical in controlling the metal removal process.

Such effects are already well documented in the field of laser welding; for example, plasma suppression is essential for consistent keyhole welding, where CW lasers in the kW range achieve focussed intensities approach 10^7 W/cm^2.

Laser plasmas from metal substrates are produced predominantly via multiphoton ionisation and the inverse bremsstrahlung mechanism, by which free electrons can extract energy from the laser beam. The effect of the plasma is three-fold: (i) some of the incident laser beam will be absorbed, heating the plasma and being partially conducted through to the substrate, and some of the absorbed power will be re-radiated via bremsstrahlung emission; (ii) the laser beam will suffer optical distortion as it passes through the plasma, serving to defocus the beam– the so called ‘plasma lensing’ effect; (iii) when the plasma reaches a critical density, a value set by the laser wavelength, it will act as a ‘plasma mirror’ serving to reflect the beam. This critical density is inversely proportional to the square of the laser wavelength i.e. the density at which the plasma becomes a mirror to the laser beam is one hundred times higher for a Nd:YAG (1.06 µm) than for CO_2 (10.6 µm) laser. A consequence of this is that deeper hole formation is achieved in metals by using shorter wavelength lasers.

The plasma is rapidly formed at the surface, and expands away from the substrate. The substrate at the plasma-solid interface is heated by conduction and the plasma pressure causes material ablation at the interface. As the plasma expands away from the substrate its temperature rises and its density falls. Incident light begins to be reflected away at the point at which the critical density is reached in the plasma.

The plasma density that is achieved will affect processing, and its value is proportional to the peak laser power density at the workpiece. It is therefore proportional to pulse energy and inversely proportional to pulse duration and spot size. Controlling these parameters will control plasma density and its effects upon processing.

Fine hole drilling

Laser drilling of cooling vanes in aerospace and industrial gas turbines with flash lamp pumped Nd:YAG lasers is one of the great success stories in the field of laser materials processing. The emergence of high power industrial DPSSLs opens up new and exciting markets for laser drilling, particularly automotive, where the need for ever more efficient engines drives the demand for improvements in fuel injector design.

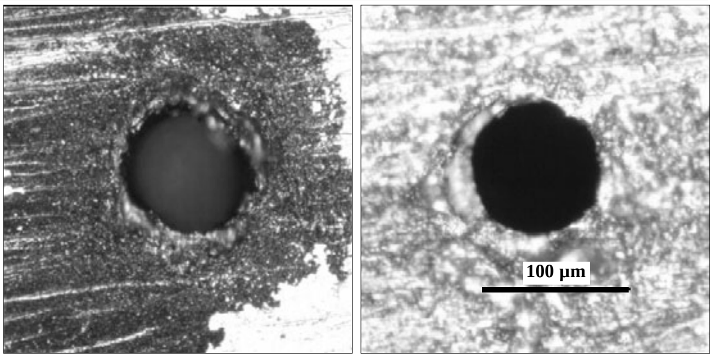


Figure 2 Comparison of percussion (left) & trepan drilled entrance holes, demonstrating the unsuitability of the former for fuel injection holes.

In order to improve engine efficiency, fuel injectors are required to produce ever-finer fuel aerosols in the cylinder. This can be accomplished by reducing the diameter of the holes through which the fuel is volatilised. Conventional manufacturing methods such as EDM are unable to produce holes small enough for the next generation of engine designs, particularly diesel engines. Therefore the challenge for the laser industry is to meet and exceed these exacting standards for high aspect ratio hole drilling.

The current industry target is to drill <100µm diameter holes in 1mm thick 316 stainless steel. These holes must be devoid of dross, demonstrate consistent circularity throughout their bore, have an acceptable level of recast, and have a taper as close to zero as possible - reverse taper may be desirable for flow control if possible. High quality holes have been successfully demonstrated using both harmonic wavelengths (532 & 355nm) and femtosecond lasers, but not at commercially attractive process rates. The challenge is to successfully apply fundamental wavelength Q-switched DPSSLs and meet hole quality requirements at a commercially interesting process rate.

The choices of laser for this work was dictated by automotive industry research that suggests that sub-20ns pulse durations are an enabling parameter for this application. A Starlase EO12 Q-switched DPSSL was used: this laser offers >30W average power output at 1064nm, at a fixed pulse repetition frequency of 3.5 kHz and pulse duration of 10ns, at near diffraction limited beam quality. A precision Cartesian XYZ motion stage was employed with linear drives offering micron accuracy at high velocities (up to 2m/s). As for the laser milling work, an external attenuator controlled the pulse energy at the workpiece.

It would offer significant advantages if it were possible to percussion drill these holes whilst meeting hole quality requirements, since then hole diameters and process times could be significantly reduced. However, the accepted wisdom is that trepanning offers superior quality over percussion drilling, so both methods are examined. As figure 2 shows, the quality of percussion-drilled holes was found to be unacceptable.

As in laser milling discussed above, plasma shielding is also found to play a primary role in fine hole drilling. In this application pulse width is fixed and therefore intensity can only be adjusted by external attenuation. Again, a bright plasma is observed at the workpiece, and hole dimensions and taper are found to be a function of the incident laser intensity. Figure 3 shows how critical the intensity is in controlling hole quality.

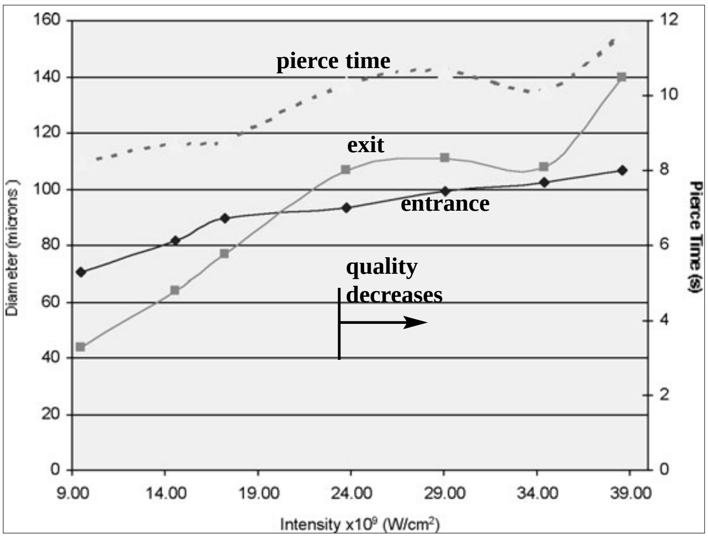


Figure 3 Entrance and exit hole diameter and pierce time in 1mm stainless steel as a function of power density. Focused spot size, trepan diameter and exposure time were held constant at 20s throughout.

Since focused spot size, trepan diameter and exposure time were held constant in figure 3, the data suggests that the plasma effects (defocusing of the beam combined with plasma heating) may be responsible for the general trend of increasing entrance and exit hole diameters with increasing laser power density. During the drilling the plasma sinks into the forming hole, widening the hole it as it goes and thereby accounting for the absence of a strong positive taper. If so, the drilling is at least in part a plasma machining process and could explain why the taper diminishes and eventually reverses as power density increases. This interpretation is consistent with the pierce time increasing with power density and with the strong correlation between pierce time and exit diameter.

Figure 3 suggests an optimum power density for creating a sub-100µm hole with minimal or negative taper of around $2x10^{10}$ W/cm^2. Unfortunately, hole quality deteriorates as power density increases much above this threshold: circularity diminishes and dross formation becomes uncontrollable. So simply increasing power density is not in itself a solution for achieving reverse taper.

for the hole data in figure 3 the maximum pierce time was 12s, yet the data relates to holes drilled with a constant exposure time of 20s, since additional laser exposure after piercing is required in order to minimise taper. Data for this is shown in figure 4.

Figure 4 shows clearly that as exposure time increases so taper diminishes, the exit diameter increasing consistently whilst

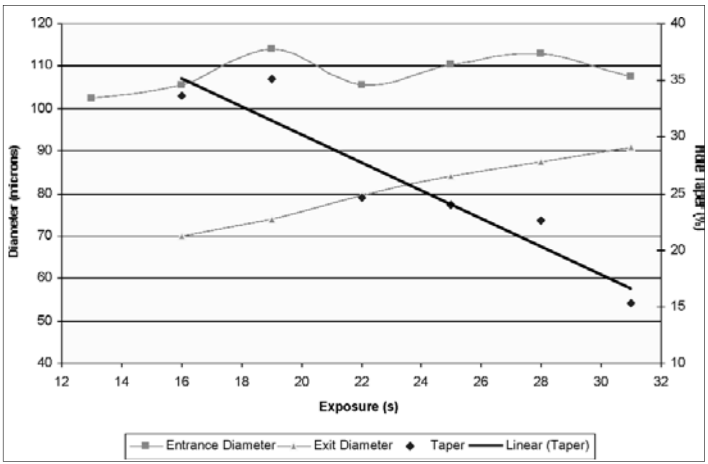


Figure 4. Fine hole characteristics in 1mm stainless steel vs. exposure duration

entrance diameter remains relatively constant. Therefore in order to achieve minimal taper, it is necessary to expose the substrate for a number of seconds beyond initial penetration to allow the laser to 'bore out' the hole.

By choosing an appropriate power density, exposure duration and trepan diameter it is possible to achieve high quality holes in stainless steel with high repeatability, as illustrated in figure 5.

Each hole in figure 5 is drilled in 20s; taper is <10%, hole circularity is better than 5%, and maximum variation is 6%. In this example, only 20% of the available laser power was used, so by beam splitting it would be possible to drill four to five holes simultaneously, offering a throughput of >12 holes per minute.

Fuel injector drilling is an evolving application, with .targets becoming increasingly stringent; and Powerlase is working to meet these targets for the next generation of diesel engine technology.

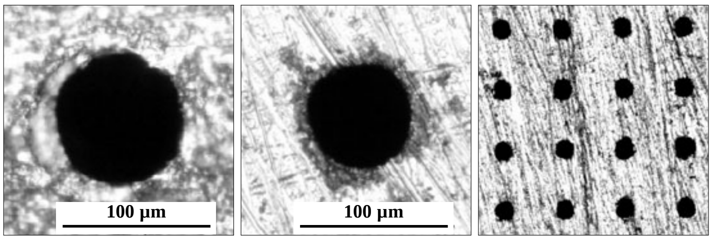


Figure 5. Sub-100 µm holes drilled in 1 mm stainless steel; and (right)grid of holes on a 250 µm pitch

Conclusion

High quality laser milling of Nickel-based super-alloys can be achieved using 1064nm Q-switched DPSSLs; offering fine surface finish and high resolution detail at commercially attractive material removal rates.

Laser milling is critically dependant upon plasma formation. Above the optimum power density, plasma shielding reduces the material removal rate, but results in fine quality machining. Below the optimum power density, the material removal rate is higher, but machining quality deteriorates. At the optimum power density laser milling becomes a robust process, and offers a good compromise between feature quality and process rate.

Fine hole drilling of steel is possible with 1064nm Q-switched DPSSLs. It is possible to drill high aspect ratio holes >10:1 in 1mm steel at commercially attractive rates of >12 holes/minute. Highly repeatable holes of diameter <100µm can be produced with low or negative taper, good circularity at both entrance and exit and negligible dross. Fine hole drilling is also found to be influenced by plasma formation: for a given hole diameter an optimal processing power density must therefore be identified. At high power densities it is possible to achieve reverse taper, but in such regimes hole quality quickly diminishes and hole diameter becomes excessive. Taper reduction in fine drilling requires overexposure of the hole.

The latest generation of high power Q-switched DPSSLs are industrially robust tools capable of commercially enabling the important industrial applications of super-alloy milling and fine hole drilling. With proper process understanding they can match and exceed the performance of alternative technology solutions such as EDM, and can significantly better the performance of flashlamp systems.

This article is based in part on a paper presented at ICALEO (Jacksonville 13 - 16 Oct 2003) and is published with the kind permission of the Laser Institute of America

Also see 'Observations' on p39

The effect of beam shape in laser surface treatment of ceramics

Dimitrios Triantafyllidis[1,2], Lin Li[1] and Howard Stott[2]

University of Manchester Institute of Science and Technology (UMIST)

Manchester M60 1QD U.K

T: +44 (0)161 200 3816 F: +44 (0)161 200 3803 E: lin.li@umist.ac.uk

[1] Laser Processing Research Centre, Department of Mechanical, Aerospace and Manufacturing Engineering

[2] Corrosion and Protection Centre

Laser surface treatment of ceramics with melting and re-solidification is generally associated with the development of thermally-induced cracks (see TILU Issue 33, pp23). These cracks result from the low thermal conductivity of ceramic materials, their brittleness and high melting temperatures, which lead to the built-up of large temperature gradients.

Crack formation can be minimised by controlling cooling rates and thereby thermal gradients; and one of the main advantages of the laser over other power sources for ceramic processing is the capability that it offers to control surface cooling rates and temperature gradients. This can be achieved by applying pre- and post-heating methods or by scanning the laser beam at a relatively slow speed; the latter technique having been successfully applied for the development of crack-free surfaces in alumina-based refractory ceramics.

The majority of laser surface processing to date is performed using circular or rectangular beam profiles. Other beam shapes may offer advantages, and whilst the degree of simplification necessary to achieve an analytical solution to beam shapes effects may produce unrealistic results, modern computer technology allows complex numerical methods, especially finite element analysis, to be applied. This paper investigates the effects of beam profile on the cooling rate and, hence, maximum processing speed.

Computational Model for laser heating

A commercial three dimensional finite element package program (ADINA) was used to simulate the laser heating of a refractory ceramic. Processes incorporated in the simulation include heat conduction in the material, together with radiation and natural convective cooling of the surface.

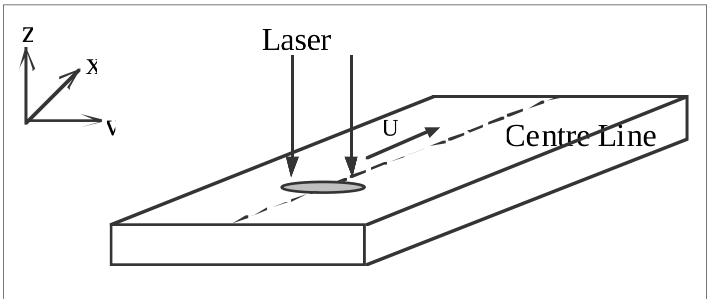


Figure 1 shows a schematic representation of the physical model of the process; the heating and cooling (and therefore the temperature profiles) are assumed to be symmetrical about the centre line.

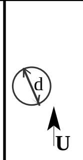
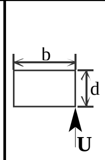
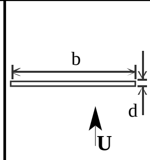
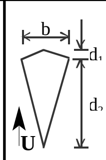
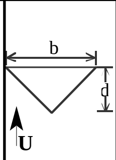
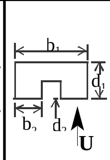
Shape	Circle A	Rectangle B	Line C	Rhomboid D	Triangle E	Greek Pi π F
Geometry						
Dimensions (mm)	d= 12	b= 14 d= 8	b= 112 d= 1	b= 10 d_1= 2 d_2= 20	b= 10 d= 22	b_1= 16 b_2= 6 d_1= 8 d_2= 4

Table 1. The investigated laser beam shapes.

Six different laser beam shapes were simulated, as listed in Table 1. The effective surface area (about 112 mm^2) and power density of the beam was uniform over its area and the same for each shape. In this way, a comparison could be made between laser beams of different shape for similar scan speeds.

The properties of the refractory ceramic and the processing parameters are shown in Table 2. The properties of the material were assumed to be independent of temperature. The environmental temperature was set at 20 C.

The 3-D finite element model consisted of 2000 heat conduction elements, 400 surface convection elements and 400 surface radiation elements. The dimensions of the model were 20x20x5 mm^3 for shapes A, B, E and F, 30x20x5 mm^3 for shape D (600 surface elements) and 10x60x5 mm^3 for shape C (600 surface elements).

Material Property[a]	**Value**
Basic Composition	82% Al_2O_3, 8.5% SiO_2, 5.5% Cr_2O_3 and 1.9% P_2O_5
Density	3180 kg/m^3
Thermal Diffusivity per Unit Volume	3.5x10^6 JC^{-1}m^{-3}
Porosity	13.5 %
Melting Temperature	1700 C
Coefficient of Heat Transfer[b]	150
Emissivity[c]	0.6
Optical absorption	0.85

a. All parameter values are taken from the manufacturers spec sheet (Resistal KR85C Technical Data Sheet No 593, RHI Dinaris GmbH); except:
b. The value of the coefficient of heat transfer was taken from 'Factors Affecting Thermal Stress Resistance of Ceramic Materials' J. Am. Ceram. Soc. Vol. 38: 1955; 3-15
c. The value of emissivity was taken from The Pyrometer Handbook. IMPAC Electronic GmbH. 2000

Table 2. The material properties used in the model

Results and Discussion

Figure 2 shows pyrometer data for the predicted (by the finite element model) and measured temperature variation in surface temperature of a refractory ceramic exposed to a scanned CO_2 laser beam. The pyrometer limit was 2000 C

The initial heating and cooling rates after the beam has passed are compared in Table 3, at the centre of the laser beam and at its edge. We conclude that the model can predict the time-temperature history of the process with acceptable accuracy.

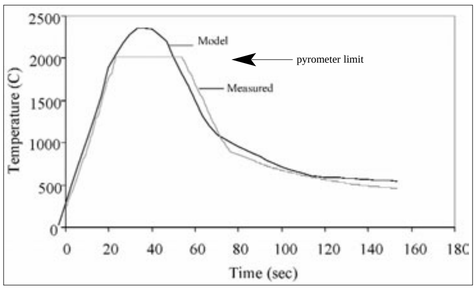


Figure 2. Comparison of measured and model-predicted temperature vs. time curves for the centre of a circular beam (Power density: 6.10² W/cm²; Speed: 0.4 mm/sec)

	Heating Rate (C/sec)		Cooling Rate (C/sec)	
	Centre	Edge	Centre	Edge
Measured	76	58	58	35
Model	75	61	60	32

Table 3. Comparison of the measured and predicted constant heating and cooling rate values

Figures 3 shows the temperature vs. time curves for scans by the six beam shapes listed in Table 1, using the same laser power and scan parameters as for the circular beam shape. The following observations can be made:

- The temperature rise and fall for a rectangular cross section laser beam are similar to those for a circular beam, though the maximum centre temperature is higher.
- The maximum temperature for the line scan is the lowest in the series and the cooling rate has the highest initial value and the shallowest 'tail'. This is to be expected: the 'line-shaped' beam has the smallest dimension in the scan direction and the greatest width; the former implying that the duration of direct heating will be the smallest of the series; the latter that heat losses transverse to the scan direction will be the lowest.
- This rhomboid beam shape is interesting has a long trailing end in the centre of the beam scan. As expected, this results in a lower cooling rate: the temperature curve is flatter and the cooling rate is slower than others in the series.
- The temperature rise and fall for a triangular cross section laser beam are similar to those for the circular and rectangular sections, but the longer trailing end of the rhomboid section extends the direct laser heating period.
- For the 'Pi' shaped beam the cooling of the centre line temperature decreases rapidly at first and then more smoothly, presumably due to heat flow in to the centre from the 'side arms'. At the centre of the 'side arms', the maximum cooling rate is seen to lie between the centre line maximum and minimum cooling rates.

Based on these model predictions, the rhomboid and Pi-shaped cross sections appear to offer advantages over the circular laser beam shape for processing ceramic, in that lower cooling rates are achieved. Conversely, for a given maximum permitted cooling rate, a beam with one of these profiles allows a higher scan (= processing) speed a beam of circular profile.

Figure 4 shows the predicted temperature vs. time relationship for the rhomboid beam profile, where the scan speed is increased from the 0.4 mm/s in fig 3 to 2 mm/s, the power density being increased to 1x10⁷ W/mm² (from 6x10⁶ W/mm²) in order to cause melting. The shapes of the curves are approaching those for the rectangular and triangular beam profiles in fig 3, implying that the effect of the long trailing end diminishes at higher scan speeds.

Conclusions

A theoretical investigation into the effect of the laser beam shape on surface cooling rates, based on finite element analysis, has revealed that for the given beam parameters (the same area and constant irradiance) and material; the circular, rectangular and triangular beam profiles give rise to similar cooling rates; the 'line' profile cause more rapid cooling and the rhomboid and Pi profiles resulted in significantly lower cooling rates. By using these latter shapes higher processing speeds can be used: the processing speed for the rhomboid profile can be increased by a factor of about 5 and that of Pi profile by a factor of about 2.5 to produce cooling rates similar to those for a circular beam. This has a great advantage in certain applications, such as crack-free surface processing of ceramics, where processing speeds are limited by the need to maintain cooling rates below critical values. By changing the beam shape and achieving higher processing speeds, these processes should become more practical.

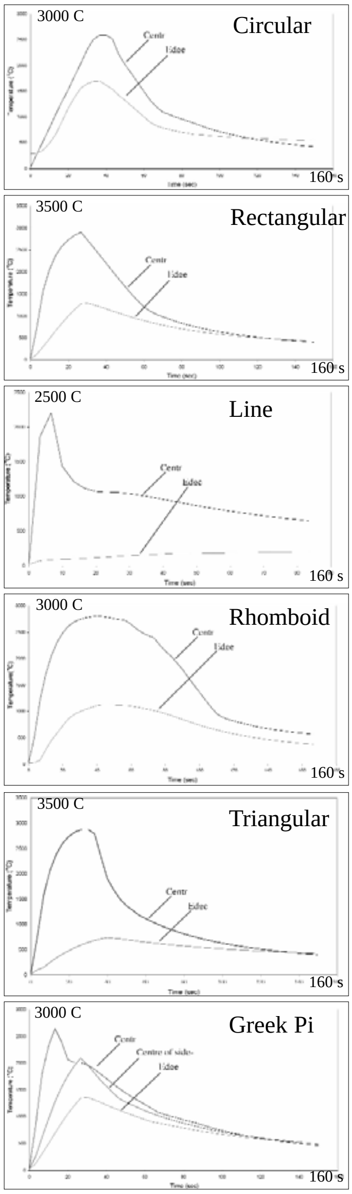


Figure 3. Temperature-time plots for various shaped beams, showing centre and edge temperatures (and, for the 'Pi' shape, also the temperature along the centre of the 'side arm', 6 mm from the centre line of the scan) out to 160 s.

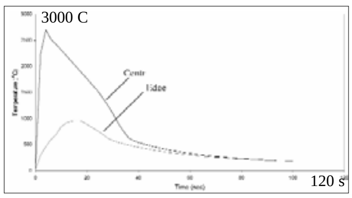


Figure 4. The temperature vs. time curve predicted by the model for a rhomboid beam shape for a processing speed of 2 mm/sec

Acknowledgments

The authors would like to acknowledge the EPSRC for funding the project (GR/N08124), Dr. C. Ashcroft and Mr. P. Rogers from Cleanaway, Dr. R. Bayliss from Morgan Materials Technology, Dr. J. Spencer from BNFL and Mr. D. Bailey from Plasma Thermal Coatings for their support to the research.

Also see 'Observations' on p39

Non-beam hazards of fs-laser processing

Jens Bunte, Stephan Barcikowski*, Thomas Puester and T. Burmester
Laser Zentrum Hannover e.V
Hollerithallee 8 Hannover D 30419 Germany
* T: +49 511 2788 377 F::+49 511 2788 100 E: bk@lzh.de

M. Brose and T. Ludwig
Berufsgenossenschaft für Feinmechanik und Elektrotechnik
Gustav-Heinemann-Ufer 130 50968 Köln Germany

Apart from primary hazards posed by the laser radiation itself, laser use also presents secondary or non-beam hazards. These non-beam hazards are either related to the laser device (e.g. electricity, laser gases, optics) or to the application. In the case of femtosecond (fs) laser materials processing applications, potential hazards include laser generated air contaminants (LGACs) and secondary radiation in the form of x-rays produced when the hot electrons of the laser-produced plasma re-enter the target material. Results of studies of these two hazards are presented here.

Laser Generated Air Contaminants

Introduction

The inhalation of particulate matter is becoming of increasing prominence in the debate on public health policy, and this includes the effect of LGACs produced by laser material processing machines on air quality in the workplace and the local environment.

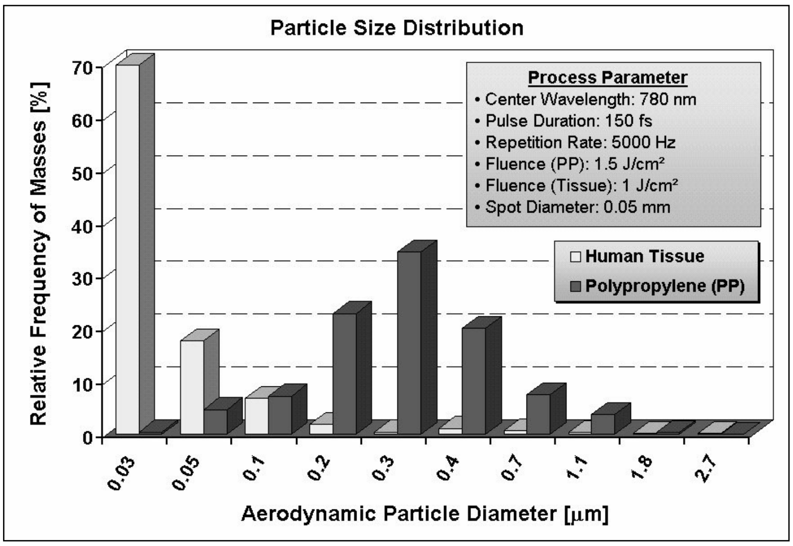


Figure 1. Particle size distribution generated during femtosecond laser ablation of Polypropylene and, for comparisn, human dermal tissue during medical treatment.

In general terms, laser manufacturers and users are obliged to identify and assess risks. For example; if LGACs are released into the workplace, regulations impose requirements on the workplace air by limiting the concentrations of harmful substances to threshold limit values (TLVs). Declaration 26 of Article 137 formulates directives which are specifically related to safety and health: occupational safety is regulated by law for chemicals (Council Directive 98/24/EG) and carcinogenic compounds (97/42/EG), including harmful aerosols. In Germany, for example, these regulations are imposed through in immission control law (BImSchG) and the hazardous substances list of the Employer's Liability Insurance Association of Institute for Industrial Safety.

It is well known that particle deposition in the respiratory tract depends upon the dimensions of the particles. The inhalation of fine particles, particularly those under 10µm diameter, can increase the frequency and severity of lung problems and even trigger premature death. Thus, in describing the particle loading of the air, information on the distribution of particle size has to be given in addition to the mass concentration.

LGACs released during material processing using more conventional lasers are well characterized and the hazardous nature of the decomposition products has been assessed (see, for example, 'The fume hazard in laser materials processing of organic materials' by H Haferkamp et al, Issue 14, pp30, Nov 99). The question is: in what ways is the LGAC hazard different during femtosecond laser processing?

Femtosecond LGAC assessment

To quantify the hazard, investigations were performed using a Ti-sapphire fs-laser system (Thales Bright: 150fs, 5 kHz, 780nm) with scanner optic. The material feed rate was adjusted to pulse-to-pulse distance of 15 µm at a beam diameter of 50 µm.

The particulate emission (PM) was captured using a semi-open process chamber. The aerosols were sucked out of the chamber and guided to the on-line-measuring unit. The characterisation of the particle size distribution was carried out by an automatic 12-level low-pressure cascade impactor (Dekati, Inc.; Typ ELPI).

Due to the high peak power density of focused of fs-laser pulses, material is ablatively removed: generally, the particles have small aerodynamic diameters, are air-borne and highly respirable. In addition to the particulate emissions, organic materials processing can give rise to toxic hydrocarbon components.

As shown in figure 1, processing of Polypropylene (PP) generates particles with a mean aerodynamic diameter of 0.3 µm, comparable in size to to those produced during conventional laser processing. Emission rates, however, will in general be relatively low during femtosecond machining.

X-rays

Laser-generated ionising radiation during materials processing is rarely considered, but the high peak intensities associated with fs-laser processes demands an assessment of this risk.

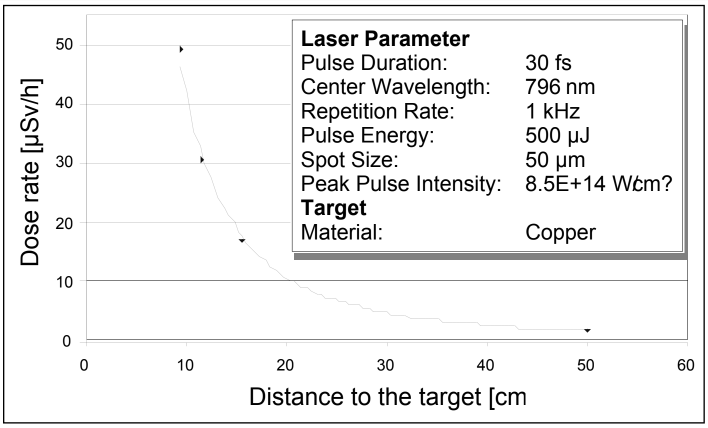


Figure 2. Results of X-ray measurements, with extrapolation to the presumed operator distance of 50 cm from the target.

Due to the extremely high pulse intensities, ultra short pulsed laser can produce a plasma and hot electrons, if interacting with matter. When these electrons re-enter the solid material, x-rays are generated. Generally, x-rays are characterized by the polychromatic continuum (Bremsstrahlung) and the characteristic line radiation. The ratio of Bremsstrahlung and line radiation depends on the physical properties of the material processed and the process parameters.

To assess the hazards of this unintentionally directly-generated x-rays for people (laser operators) one has to consider the work place and the properties of ionising radiation. Many fs-micromachining applications are carried out in an open process zone in ambient air. The typical distance of the operator to the target can be assumed to be 0.5 m and on this basis an allowance can be made for X-ray transmission in air and an inverse square law dependence of intensity decrease with distance from the source.

To assess the hazards caused by ionising radiation, the dose or the dose rate respectively and the spectrum of the x-rays were determined. The dose was measured with thermoluminescence dosimeter chips and sticks (TLDs) whilst the spectrum of the ionising radiation was measured with an Amptek x-ray detector (XR-100CR), using a thermoelectrically cooled Si-PIN Photodiode. At low photon energies the detector measuring range was limited by the 0.5 mm thick Beryllium window to 50% transmission at 4 keV and at high proton energies by the active depth of the silicon detector e.g. 50% detection efficiency at 11 keV. Investigations on the characterisation of ionising radiation have been carried out with both the Thales Bright laser previously mentioned and a Femto compactPro: 30 fs, 1 kHz, 796 nm. The spot size was adjusted in each case to 50 µm.

Investigations were carried out on copper target plates. For laser pulse intensities below 1 x 10^{14} W/cm^2, the TLD signals were below the detection limit of 2.7 µSv which corresponds to a dose rate less than 1.8 µSv/h. Analysis of the x-ray spectrum showed a Bremsstrahlung spectrum with a small FWHM at low photon energies.

With the Femto compactPro laser pulse intensities of 8.5 x 10^{14} W/cm^2 could be achieved. As shown in figure 2, TLDs signals confirmed that the dose rate decreases with increasing distance, from which a dose rate of 2 µSv/h was calculated for a distance of 0.5 m. The x-ray spectrum was dominated by a line spectrum of Ka at 8.05 keV.

The potential human risk of x-rays is influenced by a number of parameters. Apart from the material to be processed and its physical properties (electron shell/passes), the laser parameters (e.g. pulse intensity, repetition rate, spot size) have a major impact on the doze rate, as does the absorption properties of the wall materials- and the distance of the operator to the emission source.

Pursuant to the German laws and legal regulations for ionising radiation, a fs-laser installation for material processing has to be categorised as “external interfering radiation emitter”. The installation is subject to legally authorisation, or notification, unless the dose rate in a distance of 0.1 m to the touchable surface is less than 1 µSv/h. Similarly, operators of a fs-laser system are classified into the category of non occupationally exposed persons (to ionising radiation) if the following TLV values are exceeded:

For the effective dose: 1 mSv/a,

For the dose for skin: 50 mSv/a.

Comparing the results of the above mentioned investigations with these thresholds, it can be concluded that at a typical distance of the laser operator to the x-ray source of about 0.5 m, these table-top systems do not present an acute danger. At the estimated dose rate of 2 µSv/h at a typical distance of 0.5 m, it would require 500 hours of exposure to exceed the TLV for the effective dose, 25,000 hours to exceed the TLV for the skin dose.

However, first investigation using laser systems that provide higher pulse intensities confirm an increased emission rate and dose rate, considerably exceeding TLVs. These data remain to be verified and supplemented by further measurements.

Summary

The assessment of secondary hazards for femtosecond laser applications is important with regard to safety of machinery and workplace safety. Both the manufacturer of a femtosecond laser material processing machine and the user have to be aware of the hazards and should be able to apply qualified safety measures.

Investigations reveal that the femtosecond laser technology poses hazards already known from material processing with conventional lasers, such as hazards by the generation of particulate and gaseous emissions.

However, due to the extremely high pulse intensities, x-rays can be generated when laser radiation interacts with matter. In the case of material processing, the x-rays are unintentionally directly generated. The emission rate decisively depends on the laser parameters and the physical properties of the target material. The dose rate the employees are exposed to depends on the emission rate and the design of the process zone or their distance to the target. Depending on the laser process parameters, legal TLV for exposure to ionising radiation can be exceeded. With increasing output power, legal TLVs are likely to be expected during processing with fs-laser systems. This obliges manufacturers and users to carry out a risk assessment for x-rays on the basis of which adequate safety measures have to be applied.

Also see ‘Observations’ on p39

Hazard control during laser servicing

Mike Barrett and Mike Green
Pro Laser

Oxford House 100, Ock Street Abingdon Oxon. OX14 5DH
T: +44 (0)1235 550522 F: +44 (0)1235 550499 E: mikeb@prolaser.co.uk

It's a tough job but someone's got to do it. Service is about dealing with clients and customers. It is working with panics, tempers, expectations and misunderstanding; in short, dealing with human beings. On top of this, there is the safety issue – not from people, though that can be bad enough, but from the equipment and environment. Service operations will often require many of the safeguards that are designed for protecting users during normal operation of the machine, to be over-ridden or removed, leaving the service engineer to work in an environment of heightened risk.

Within the European Union, Directives have been embodied in National Regulations, to ensure that work equipment presents health and safety risks regardless of its age, condition or origin. Emphasis is placed on Safety Management through effective organisation, planning, performance measurement and audit together with reviews to achieve continual improvement. As a result, many organisations have adopted a culture that promotes worker involvement and commitment at all levels and emphasises the unacceptability of deviating from established standards of safety .

Within the service organisation environment, customer demands are making it essential for service organisations to make preparations before attending a work site and even before negotiating the service contract. The days when the service engineer turns up and assesses the situation "on the hoof" are drawing to a close. Professionalism is being measured by the pre-planning that is done. This often has a major effect on reducing equipment downtime so it makes commercial sense as well. However the only way that this can be carried out successfully and consistently is by documenting the work methods to a level of detail sufficient to demonstrate competence and to adopt a systematic approach to the quality of safety management in dealing with the risks.

Those who own or operate the laser equipment to be serviced also have responsibilities. It is they who have control of the workplace and it is they who work in it. Customers are responsible for ensuring that their safety culture is known and understood by the service organisation, so that their controls within the organisation are not compromised. This culture awareness can only be made known by good communication and the cooperation of the workforce, who themselves should have a positive attitude and behaviour towards safety management.

Preparation

In practical terms, the customer needs to spell out all specific safety requirements and procedures that the service organisation or engineers are expected to follow. There is great advantage to be had if these requirements are well known before any actual service intervention activity is commenced, as the service activity itself can be planned with these local requirements in mind. The major topics to be defined include:

- Local safety rules regarding access to factory or operating areas, fire and evacuation procedures, special hygiene and PPE requirements, location of responsible persons in case of emergency, etc.;
- Control of the local area around the laser equipment and limits of any transfer of responsibilities;
- Control and authorisation of personnel within the area and especially of spectators;
- Methods related to withdrawal of laser equipment from production and the constraints this may have on the rest of the plant;
- Control of the equipment so preventing unauthorised operation during the service period;
- Provision of sufficient space to allow work to be carried out safely. This is particularly important if the laser equipment contains high voltage equipment. There may be local regulations that apply and require work areas to be defined under these circumstances;
- Anticipated timescales and other time constraints.

Service organisations have responsibilities to ensure that their workers are adequately prepared to meet the challenges that face them when they arrive at the customers premises and to do so in a way that does not place them or anybody else in jeopardy. Preparation is really a demand for competence and thus for continual training. Customers are increasingly asking for some documentary confirmation of competence as part of their safety management system requirements. Similarly the service organisation must provide the correct tools and equipment to allow work to be conducted safely. Establishing the safe working practices and methods beforehand not only defines the predicted way of working but also establishes the equipment that is needed.

In addition to safety benefits, the use of the correct equipment for servicing means that the job gets done correctly, effectively, consistently, more quickly giving greater cost effectivity and better margins. It is a win-win situation every time. Yet time and time again, service engineers can be seen struggling with inadequate equipment and generally having to compromise safety to resolve the work around.

The service engineer is the person generally most at risk from any latent hazards. In make-or-break situations, they can often be the people whose quality of service is used by the customer to judge the whole service organisation. Working safely is very high on many customers priorities; though at the scene of activity, time may seem to be more important!

Safe service practice

<u>Local enclosure</u>
Preventing human access to the laser hazard during laser service is a primary requirement but under service conditions, is often difficult. What can be achieved should not be underestimate, and suggesting that this strategy is "impossible" should not be accepted.

Laser designers can perhaps contribute most but seem in many cases to be completely blind to the situation. For example, only a small number of industrial laser models are modularised so that service intervention on the factory floor amounts to little more than simple substitution of pre-aligned modules that need little or no further adjustment. This means that service can be completed with complete safety and the possibility of exposure to laser radiation is eliminated. Additional benefits often include improved lifetime of components and consistency of laser performance. However, the majority of lasers are not designed like this. Where a sufficient level of protection is not achievable, access may need to be prevented by appropriate use of barriers, beam tubes and local enclosures that allow access only to those areas required by the service operation.

Peripheral enclosure

Whenever there is a laser hazard that cannot be locally enclosed, a controlled area needs to be established, with access strictly limited to authorised (trained) persons only who are either able to deal with the heightened risk correctly or are kept under close control and supervision.

The boundaries of the laser controlled area need to be well defined. Warning signs should be clearly displayed at the perimeter of the laser-controlled area using the laser hazard warning symbol and stating the restrictions imposed together with the precautions to be adopted on entry. Complete enclosure of laser-controlled area is desirable but may not always be necessary, for example: if the hazard range (NOHD) of the laser beam is within the boundary; if access into the area is adequately controlled; and if the risk to persons outside the area are tolerable.

Interlocks

Industrial machines often employ interlocks on the laser enclosures. This method of protection provides an excellent method of mitigating the laser hazard especially for machine operators. During the service activity, these interlocks may have to be overridden to allow operation for establishing (or proving) a repair. In these situations it is important to use only the minimum of overrides and to limit the duration of the override condition to a minimum, removing overrides as soon as their use is no longer required and not simply leaving them in place until it is convenient to remove them. A record of all interlocks that have been over-ridden should be maintained so that the service engineer can quickly gain an overall view of the situation.

Administrative control

Where there is risk of injury within the laser controlled area but where it is not practicable to control access by engineering means, then administrative procedures may be necessary. Signage becomes very important with illuminated warnings preferable, to indicate when it is safe and when it is not safe to entry the area. The installation of conventional Emergency Stop actuators on the inside of the laser-controlled areas should also be considered.

Any administrative controls require inclusion in the local information to ensure that workers understand and abide by the controls being implemented. This information should be reviewed on a regular basis to ensure its continued relevance and should include:

- Description and purpose of the equipment;
- Name and contact point of the local Laser Safety Officer;
- Name of person authorised and in control of the service work;
- Working procedures to be adopted when inside the laser controlled area
- Actions to be taken in the case of an emergency, such as an equipment failure of a suspected accident;
- Details of requirements for authorisation of hazardous operations, such as procedures requiring a local “permit to work”

Working with administrative controls in place, inherently means that the risk of injury is heightened. Additional steps need to be taken – these include:

- Providing adequate training to all personnel involved;
- Ensuring the security of all laser components;
- Using adequate beam stop methods to prevent inadvertent beam paths;
- Using enclosures (even temporary ones) to encase the laser beam path and to extend this encasement as far as reasonably practicable;
- Confining the beam with well-defined areas;
- Using screens or curtains to contain the laser radiation (N.B. The standard IEC 60825-4 gives guidance on this subject);
- Minimising the risk of specular reflections by careful control of all objects with shiny surfaces (tools, jewellery etc) used or worn around the beam path.

Personal protective equipment

If the risk assessment and the engineering means cannot prevent access to the laser radiation hazard, then the use of personal protective equipment (PPE), i.e. laser protective eyewear, is essential. PPE should not be used in place of other controls, but in addition to them.

In some cases (e.g. when servicing UV Laser sources) it may be necessary to provide/wear other protective clothing when working in a laser-controlled area. Masks, gloves and occasionally whole body protection may be required.

Records

As part of any risk assessment undertaken prior to the commencement of service work, any classification change to the laser that the removal of protective covers may make should be noted; together with disabling any protective features may cause a change to the performance of the laser product thereby increasing the risk of injury. Thus it is important to keep a record of all service activities and operations and any resulting changes to the performance of the laser equipment.

Beam path alignment

Servicing embedded laser products can greatly increase the risk of injury. Additional controls to reduce the likelihood of an errant laser beam should be put into place during beam alignment and other such beam path operations including:

- Limiting the range of movement of beam steering components;
- Checking beam alignment close to the laser before allowing the beam to travel into the full beam delivery system;
- Using large area beam stops to allow for misalignment;
- Using visualising alignment aids such as cameras or fluorescent or heat sensitive screens;
- Using non-reflective coating or diffusely reflecting surfaces on tools in addition to the best practice of being very tidy and keeping all tools away from the beam path area.

Examples of service improvements

During the authors' years of experience with laser use and laser servicing, many examples have arisen where failure to follow the above principles has resulted in distress or injury. Below are a few selected examples, to illustrate how it could have been done better.

Example 1

A multi- kW CO_2 laser generated a beam travelling horizontally through a beam tube 3 m above the floor level. The beam would then hit a turning mirror, directing it vertically downwards through focusing optics and onto the workpiece. The whole of the beam path was normally enclosed, but on one occasion the beam path had to be adjusted and the turning mirror was removed to allow this.

The mirror assembly was interlocked but the interlock took the form of a water pressure switch on the cooling supply to the mirror assembly. If the mirror were removed, the cooling water supply pressure would change and the interlock (switch) would operate to prevent laser action. However, on this occasion the mirror was only displaced a small distance and the water was not disconnected.

As a result of some confusion about the alignment process the laser was energised: the beam travelled across the factory and hit part of the roof structure, which caught fire. This accident caused more embarrassment than injury but was serious none the less.

The lessons derived from this event are twofold. Firstly, if the mirror was to be interlocked then this should have been done directly (i.e. to ensure correct physical position) and not indirectly; and suitable interlocks (i.e. fail safe, proven design) introduced. Secondly, the administrative controls put in place were not sufficiently well thought out, recorded or understood. (Nevertheless, a beam stop was fixed to the roof structure should a repeat of the event occur!)

Example 2

A multi- kW CO_2 laser was mounted remote to a flat bed sheet metal cutting machine. The beam travelled horizontally from the laser at about 1.8 m above the floor level. The beam between the laser and the machine was enclosed within a substantial tube during normal operation.

Beam alignment necessitated removal of the tube. The service engineer had taken all the precautions that he thought reasonable, putting up signs indicating that the laser was being serviced and barriers to restrict access to the area. Both barriers and signs were put at the entranceways.

During the service activity the laser was operated with the beam tube removed and when a work break was taken the laser was left energised with the machine unmanned. Next to the laser was a bench with a kettle and tea making equipment (cups and tea bags).

During this period, a worker within the room where the laser machine was deciding that it was time for a cup of tea and, with the beam tube removed, he now had a clear path to the bench where the kettle and cups were kept. The worker walked through the laser beam, receiving a burn on his neck from the laser beam. Not only did the man suffer a serious burn and had to laid off work, but because the period of sickness was greater than three days, a report had to submitted to the local Health and Safety Executive office. In addition to the cost and time consumed in having the worker injured, the employer suffered significant amount of grief from the government enforcement agency.

The lessons learned included identifying and preventing secondary activities within the hazard controlled area (removal of the kettle and tea making facilities), the installation of improved barriers, modifications to the laser machine interface that allowed the beam tube to be removed from its normal position to a temporary adjacent position that still offered some protection from the beam, laser safety awareness training to all staff who may have access to the laser system, and improved safety awareness training throughout the Company.

Example 3

This example did not involve an injury or plant damage, but the service situation was extremely costly from a production point of view. A high power Nd:YAG laser formed part of a laser process machine. An optical fibre beam delivery system connected the laser to a focus lens assembly. The machine was situated in the centre of a production line with about 60 workers in the immediate area. The factory operated 24/7, manufacturing parts for the automotive industry. The laser worked well and the production problem only occurred during planned service in that the design of the laser was such that the protective housings had to be removed and alignment aids, held on retort stands, had to be erected. In the absence of effective peripheral guarding, all workers on the production line to be evacuated during such service operations and hence the production line stopped; placing the service engineer under extraordinary pressure to finish quickly and get the production line running again.

The driver for improved safety during service was the elimination of production downtime. Service engineers said that it could not be done and surprisingly, the laser manufacturer was not really interested in helping. Nevertheless, the user company put together a team and adopted a structured problem solving approach. The team was made up of the service engineers, the machine operators and production engineers aided by a facilitator. Their excitement was the result of actually being asked to solve the problem! They produced a solution in the form of a small amount of specialised tools and some jigs, together with some carefully worked out procedures. Their implementation allowed production to continue during the laser service activity and produced more reliable and repeatable laser operation. All costs were set aside the first time the laser was serviced because production continued.

Conclusions

During service activities, key hazard controls fall into three main categories, all of which need to be addressed:

- Organisational (involving risk assessment, training and supervisor control);
- Procedural (including definition of working methods);

and

- Equipment (including necessary tooling and jig, temporary guards or screens and signage).

Consideration of these key hazard control categories together with establishing an environment that encourages well-defined good practices and continual improvement, significantly reduces the risks to all those involved in service activities.

As a bonus, significant improvements in laser performance and reliability can be achieved at no extra cost.

Observations

'Observations' are short comments on some of the papers in this issue of the magazine, highlighting points that the general reader might find helpful and placing the paper in a broader context

An introduction to Lean Manufacturing

Steve Baker

I have five comments to make on this paper.

The theory is easy to express in a few paragraphs, the application is difficult and is a never ending journey. (If only because the goal posts keep being shifted)

We are a high diversity, highly responsive, low batch quantity (but high total volume of parts) producer, as are many of our colleagues in the Laser Job Shop business. Our process is very simple; accept the order, program, cut, ship, invoice. Most of the examples and most of the expertise available from consultants seems to be production line (often car) based manufacturing a complex multi-operation product. The manuals, examples and help in adapting the, undeniably powerful, principals to a very different manufacturing environment is sometimes less than satisfactory in our experience.

We have applied some of the techniques and we have had some successes. I would encourage people implementing these ideas to have trained and appropriate help.

There are many organisations that can offers some expertise. It is worth consulting your Business Link, the Manufacturing Advisory Service, and various Quality Clubs (the East Midlands Quality Club is valuable to us). Consider belonging to the various regional initiatives where money for training is available to members.

In the real world, when a customer says they are doing lean what they usually mean is reduce your prices. From a purchasing point of view Lean Manufacturing is not about reducing waste, co-operatively solving problems, specifying value. It is about Mean Purchasing.

Neil Main Micrometric

Steve summarises complex ideas in a short, excellent article. His golf analogy is first class, and allows us all to grasp the principles of Lean Manufacturing and general Process Improvement.

Laser “Job Shops” may think the principles don’t apply as we don’t make and remake a “product”. However, the whole basis of Lean Manufacturing is to focus on process, not product. Anything that happens in any Company is a process, from opening the mail, to delivering cut parts, and every process, in every Company, will contain waste.

However…..

From Steve’s article and the comments above it may seem that implementation of Lean Manufacturing methods is easy. Unfortunately the most critical area of implementation is also the most difficult – people. Changing a physical process is relatively easy, changing the culture of a company, and the attitude of the people controlling the processes isn’t. And it isn’t the guys running the machines who let the implementation stall – it’s usually the Management team!

As an example, a large Company in Scotland making Military components had an excellent implementation plan for Lean Manufacturing & general Process Improvement. The Company ended up bulldozing the existing factory and moving to a brand new, custom-built unit (and shedding most of the Senior Management team), just to convince its employees that it was serious about the changes. The process took 7 years!

Martin Cook Cutting Technologies

Laser welding of polymer and wood composites

Heinz Haferkamp et. al.

This paper provides a very interesting extension of the methods of laser welding most commonly used to weld two similar plastics together. The laser beam (1064nm wavelength in this case) is transmitted through the upper layer of material and absorbed at the interface by a suitable additive at the surface or in the lower material. In this case the upper material is a common thermoplastic and the lower material is solid wood or wood composite, which intrinsically heats when the laser is applied, and heat is conducted to the plastic above.

The researchers have taken on a very challenging material combination for welding, because one would not normally consider wood as a material that can be processed by melting, and then even if it could, a good weld would only be expected if the two molten materials were miscible, which is not the case for many dissimilar polymers. As they suggest, this material joining problem would normally be approached using adhesives. However, strong bonds are reported which fail by detachment in the wood. Further studies are suggested to define whether the bond mechanism is mechanical interlocking or a true weld by interdiffusion of the molten materials. Either way, this demonstration opens the possibility for improving the efficiency of processing in a wide range of applications. Wider studies need to include the longer term resistance of the joint to environmental effects.

Ian Jones TWI

This article provides an excellent introduction to a new field of application for transmission welding. Bonding wood to plastic serves to emphasise how successful such laser welding can be when applied to dissimilar materials; welding plastic to wood makes plastic to plastic look trivial.

Some of the techniques used in plastic welding currently might be successfully applied in future research to progress the aspects mentioned in the final paragraphs. For example: closed loop process control can be implemented utilising a pyrometer to measure the temperature and feed it back to the diode/YAG power (or speed of motion) control in real time, to maintain a constant weld temperature during the process. Clamping is always an issue as welds will be weak unless created under pressure, but for larger components (such as furniture), it can be feasible to use a rolling pressure wheel to apply pressure only at the point of laser heating.

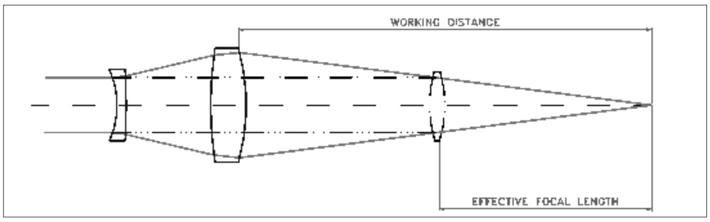
Andy May Rofin-Baasel

f-Theta scan lenses for CO_2 lasers

Gary Herrit

This is a useful paper giving a compact presentation of design tips. I appreciate the emphasis given to the need for clean, protected beam paths and careful optical alignment of the lenses with the beam axis. The need to exclude fumes, vapours and humid air from the beam lines is reinforced by mentioning N2 purging.

My only niggle with the article is in the definition of "depth of field". The conventional lens designer would call this "field curvature" and a design target for a Flat Field Lens would be to minimise it. I originally confused the term with "depth of focus", an altogether different subject.



One observation worth making arises from the figure (above) depicting Working Distance. In this lens, where the beam is expanded from its original diameter before converging to a focus, the effective focal length can be considerably less than the working distance. In other words, it is possible to give the sensitive lens surfaces a greater 'stand-off' from the workpiece than is implied by need for a small spot size and short EFL.

Brooke Ward Europtics.

The effect of beam shape in laser surface treatment of ceramics
Dimitrios Triantafyllidis et al.

This is an area that seems to have had little attention paid to it in the past and article outlines some interesting beam shape concepts. It is one of the areas of research that was shown to delegates during a November 2003 AILU event at UMIST.

The most fascinating aspect of the work is the difference in cooling rates at the edge of the focussed spot, and the affect this has on scan speed. It is also interesting to note the close correlation between the simulation model and the practical measurements for the temperature profile.

Although the surface treatment of ceramics is outside my field, the findings outlined in the article should be applicable to efficiency considerations for both laser brazing and laser welding with filler wire, particularly laser brazing in view of the affect it could have on the wetting and flow of the braze.

I am sure this would be an interesting avenue of research for someone!

Stephen Ainsworth SJ Ainsworth Consultancy

It is a sure sign of the impending maturity of a laser process that people stop worrying about how much power they can use, and concentrate instead on the subtleties of its application. Thus the article discusses applying different shapes of laser beam distribution to ceramic surfaces with a goal of increasing the processing speed without thermally induced cracking, and apparently with great success. Their approach is somewhat reminiscent of work carried out in the 1970s and 1980s on optimising transformation hardening by customising the beam distribution at the workpiece. In those days beams were customised by segmented mirrors, raster scanners and axicons. One is left to wonder how rhomboidal and triangular beams are produced.

It is also heartening to see good quality experimental data alongside the predictions of computer models, and even better to see good agreement between them. There is far too little real experimental data published these days, and the authors are to be congratulated on remedying this unfortunate trend. Perhaps in the course of time, they might like to distill the results into rules of thumb for the efficacy of differently shaped sources.

Roger Crafer Abington Consultants

Emerging applications for Q-switched DPSS lasers
Matt Henry

Nano-second pulse-length solid state lasers have inherent limitations with respect to their performance for drilling high aspect ratio holes, and Matt has explained some of the limiting phenomena. It can be expected (and has been demonstrated) that shorter pulses will result in less thermal damage. In fact, reducing the pulse length will continue to improve the process until the pulse thermal penetration depth pulse (τ) has become equal to the optical absorption depth of the photons in the metal, where

$\tau = 2 \times (kt)^{0.5}$ (k = thermal diffusivity, t = laser pulse length)

The optical absorption depth for most metals is typically a few nm (at wavelengths between 0.2 and 10 microns) and the thermal penetration depth reaches this value at a pulse length around 10ps. Using even shorter pulses has the advantage of generating no plasma (the pulses are too short - it has been demonstrated that high explosives can be safely machined with femtosecond laser pulses!), but there are no other obvious benefits for metals because their optical absorption is already very good. This is contrary to glasses, polymers and other materials where the femtosecond pulses result in non-linear effects which reduce the optical penetration depth by many orders of magnitude, down to a few nm, resulting in excellent micromachining with photons for which the material is normally transparent.

According to a German study (the PRIMUS project, see reference), ns and ps pulses can generate micro holes with similar accuracies, whereby the accuracy with ps pulses is achieved by the absence of melting, and that with ns pulses due to the strong homogenising influence of the plasma (which needs after-machining to remove the melt). Having said all this, industrially reliable femtolasers are still not available, and their power/price ratio is one to two orders of magnitude away from where they begin to make commercial sense. To a much lesser extend this is also still true for ps lasers, and the PRIMUS project concluded that for several years to come, the nanosecond process will be favoured by industry for these reasons.

Jim Fieret Exitech

Reference: D Breitling, A Ruf, F Dausinger, 'Fundamental aspects in machining of metals with short and ultra-short pulses', SPIE paper no 5339A-10, Laser Applications in Microelectronic and Optoelectronic Manufacturing IX, 26-28 Jan 2004, San Jose, CA (USA).

It is encouraging to see that Powerlase nano-second pulsed DPSS has enabled new applications for milling and high aspect ratio hole drilling. For material removal applications, shorter pulses have the advantage of reducing the heat affected zone and generating higher vapour/melt ratio. The dilemma is that shorter pulsed lasers normally have low average powers. To gain suitable material removal rate, a compromise is needed between the pulse width and average power. Powerlase lasers seem to provide such a compromise with nanosecond pulses and 430 W of average power.

The problem of plasma shielding has been well discussed in the article. It is very important for the application of short or ultra-short pulse lasers. Too higher power density simply allows more energy to be taken away by the plasma that will mess up the process. This even occurs for femto second lasers. It is known that plasma absorption and its negative effect on laser processing can be significantly reduced with shorter laser wavelengths (i.e. there is an inverse square relationship between absorption and the laser oscillating frequency, which follows from the Saha equation). Therefore, more effective use of short pulse lasers for material removal would benefit from frequency doubling and tripling or quadrupling. This may be something for the laser manufactures to consider in the future.

Lin Li UMIST

Non-beam hazards of fs-laser processing
Jens Bunte et. al.

There is growing interest in the radiation hazards associated with lasers and in particular with the ultra-high intensity systems such as those operated by the Central Laser Facility, CCLRC Rutherford Appleton Laboratory. It was interesting reading this article looking at the hazards associated with laser processing.

The legal limit for non-radiation workers in the UK (under IRR 99) is 1mSv/yr (whole body), 50mSv/yr for the skin (averaged over $1cm^2$) and 50mSv/yr for extremities; extremities being defined as hands, forearms, feet and ankles. It is possible to relax these levels significantly by designating the area as 'controlled' or 'supervised': however, it is recommended that all exposures should be kept 'as low as reasonably achievable' (ALARA).

I have not come across the 1uSv/hr at 10cm before, but these are usually limits set locally by the Radiation Protection Advisor. For a supervised radiation area, the hourly dose limit must be below 7.5uSv/hr. (For comparison, background radiation is ~0.2uSv/hr.)

The usual classification of a radiation area is based on a yearly accessible dose of 2000 hours. The document states that 500hours would be required to exceed the TVL for effective dose (1mSv/yr) – this is an important factor to state that the radiation is only present when the machine is in operation and that the machine only operates for 500 hours, otherwise the yearly dose will be exceeded by a factor of 2.

<u>Note on use of the TLD's:</u>
We are currently in discussions on the relevance of a TLD system for measuring x-rays on such a short timescale (30fs). Some badge manufacturers are not sure that they will respond terribly well and there is some debate at the moment on this.

Rob Clarke CCLRC Rutherford Appleton Laboratory

The article is a timely reminder on safety aspects of femtosecond (fs) laser material processing. While retinal and (to a lesser extent) skin hazards are properly emphasised in most laser safety courses and risk assessments, the topic of non-beam hazards are usually mentioned only in passing. The paper will alert users to the requirements contained in European directives in relation to protection from harmful laser generated air contaminants which are produced in laser material processing on all time scales, but also to the presence of collateral radiation in the form of x-rays emitted when fs-laser pulses are used.

The measurements are made on a widely-used configuration (Ti-sapphire fs laser system) under operating conditions that would be typical for many users (780 nm, 150 fs pulse-width, 1-5 kHz repetition rate) and so the data will be of interest to the fs-laser community, whether for material processing or fundamental research.

The data reported for the laser generated air contaminants is very interesting, particularly the different distributions that are observed for the synthetic and tissue samples. However, while the size distributions are very useful it should be borne in mind that they may be somewhat distorted by the measurement technique. We understand that smaller particles are more easily entrained than larger species in some measurement configurations based on electrical low-pressure impactors (ELPI). Hence, in our experience, there is value in directly sampling the airborne laser generated air contaminants close to, and at various distances from, the laser material interaction zone. To do this, we typically use a clean surface near the experimental zone, which acts like a filter to entrap the particles generated in the laser-processing environment. This is subsequently analysed using optical or scanning electron microscopes. While the technique is qualitative, it forms an easy and valuable technique for analysing airborne contaminants.

Regarding the potential hazardous x-ray doses, the paper sounds a valuable warning that threshold limit values could be exceeded as the fluences from fs laser systems increase. The measurements provided in the paper are reassuring but indicate that more data should be accumulated on the x-ray intensities emitted in different fs-laser processing scenarios. For manufacturers of machining systems incorporating fs-lasers, the paper will alert them to additional measurements that should be made to ensure that the system is not a source of harmful collateral radiation.

Gerard O'Connor NCLA, Galway

X-ray generation is a well known application of scientific Ti:Sa ultrafast systems. The applications can range from imaging to time resolved material structural dynamics study with atomic resolution. However, the peak and average powers involved to get a powerful enough X-ray source are much higher than those of femtosecond lasers used for micromachining.

To get 1mW of X-Ray average power from 20fs pulses for instance, 200mJ pulses (10TW peak power) are used at 10Hz (2W average power). At kilohertz repetition rates, maintaining such high pulse energy is impossible and peak power decreases; consequently the conversion efficiency collapses and has to be compensated with higher average power: Typically 10W average power is necessary at 1kHz (10mJ, 0.5TW pulses) to maintain the same level of X-Ray radiation. As a basis of comparison, an industrial femtosecond laser like BRIGHT will yield 1.5mJ pulses at 1kHz with a pulse duration of 150fs, resulting in 1.5W average power and 0.01TW peak power.

Antoine Duret Thales

This piece of work experimentally confirms the theories about fume emissions from fs pulse laser systems, in that for short pulse lengths the material removal process is via non-thermal shock mechanism giving rise to fine particulate of known composition. This should stengthen confidence in the efficiency of fume extraction and filtration strategies for this type of laser.

The x-ray emission gives rise to potential concern and suggestions on more pragmatic protection strategies would have been welcome. Laser processes already attract considerable safety concerns, and ionising hazards will be of further concern to potential users.

Robert Roach Laser Optical Engineering

Books and Reports

Laser Safety

Roy Henderson and **Karl Shulmeister**

With all the recent upheaval in laser classification and the rapid developments in laser technology and applications, an up to date reference source on laser safety will be greatly welcomed by laser safety professionals.

The authors have succeeded in producing a comprehensive, thoroughly up-to-date reference book, international in its approach to safety legislation, that addresses in depth many of the theoretical and practical aspects of laser safety. I was particularly pleased to see that they have not dodged difficult and contentious issues and I was delighted with their appendix of common misunderstandings.

Laser safety is a broad subject in terms of laser applications; also, it is a mix of the academic, the practical and the philosophical. The potential readership of a general book on this subject is similarly diverse, in its needs and its aspirations. Consequently there is no one approach that will suit all. Industrial laser users, for example, might find the general approach of this book too academic and wordy, and may be disappointed at the lack of specific practical detail on such topics as fume hazards, enclosure design and risk assessment of industrial installations.

The authors deserve great credit for producing an up to date reference work for the laser safety professionals, one that will influence people's approach to the subject for many years to come.

Mike Green Pro Laser

*Published by Institute of Physics Publishing ISBN 0 7503 0859 1 459 pages, Hardback £65.00 http://bookmarkphysics.iop.org*I

Handbook of laser technology and applications

Ed. **Colin Webb** and **Julian Jones**

This 3-volume set provides an excellent and useful summary of laser technology and applications. It is a vast compendium of the work of over 130 international experts, many of whom are recognised as the world leaders in their respective fields.

<u>Volume 1: Principles</u>
An introduction to the basic scientific principles of lasers, laser beams and non-linear optics. *(ISBN 0 7503 0960 1, 2725 pages)*

<u>Volume 2: Laser Design and Laser Systems</u>
The mechanisms and operating characteristics of specific types of laser including crystalline solid-state lasers, semiconductor diode lasers, fibre lasers, gas lasers, chemical lasers, dye lasers and many others as well as detailing the optical and electronic components that tailor the laser's performance and beam delivery systems. *(ISBN 0 7503 0963 6, 2725 pages)*

<u>Volume 3: Applications</u>
Case studies of applications in a wide range of subjects including materials processing, optical measurement techniques, medicine, telecommunications, data storage, spectroscopy, earth sciences and astronomy, and plasma fusion research.*(ISBN 0 7503 0966 0, 2725 pages)*

Published by Institute of Physics Publishing. Hardback set £600 ISBN 0 7503 0607 6 http://bookmarkphysics.iop.org

Industrial and Medical Applications of Adaptive Optics

Alan Greenaway and **James Burnett**

In this new report, Alan Greenaway of Heriot-Watt University and James Burnett of QinetiQ, leading experts in adaptive optics (AO), urge the adaptive optics community to shake off its do-it-yourself culture and focus on building low-cost, standardized components that can be exploited in applications as diverse as laser materials processing and ophthalmology.

Until recently, custom-designed AO systems costing upwards of $1 m have been the norm in astronomy and defence-based imaging systems. Now, however, the focus has shifted to developing smaller and cheaper components that can be bolted together to meet the needs of a range of commercial applications.

Most interest and activity has focused on industrial laser processes, since AO can play a crucial role in manipulating and controlling laser beams, either by modifying the properties of the laser resonator itself or by altering the characteristics of the output beam. Companies such as Trumpf and Diehl in Germany are already marketing commercial AO systems to provide accurate focus control of high-power carbon-dioxide lasers, while manufacturers of industrial solid-state lasers are keen to exploit AO to maintain the laser's performance over a range of output powers. In this case, AO components are incorporated within the laser cavity to compensate for the aberrations caused by thermal lensing.

According to Greenaway and Burnett, laser manufacturers would fit AO systems to almost every high-power solid-state laser if the extra cost was no more than $10,000 - around 10% of the price of a typical industrial laser system. Building an intracavity AO system with this price threshold should be feasible with bimorph mirrors, which can also be cooled to handle the high power levels. The big challenge now is to bring down the price of the high-voltage power supplies needed to control these mirrors, which can cost as much as the mirror itself. In the meantime, lower cost membrane mirrors offer an alternative for applications requiring modest power levels.

Other promising laser-based applications include the production of femtosecond laser pulses for delicate machining processes, improving the print quality in large-scale laser scanners, and boosting the range and transmission speed of free-space optical communications systems.

Greenaway and Burnett believe that industry/academic initiatives such as the Smart Optics Faraday Partnership (www.smartoptics.org) in the UK and the Center for Adaptive Optics (CfAO) (http://cfao.ucolick.org) in the US will play a crucial role in breaking the cycle of low investment in development and high-volume manufacture, due to a low demand for AO technology; itself due to the absense of a reliable supply of cost-effective devices.

Industrial and Medical Applications of Adaptive Optics is published by Technology Tracking, a collaboration between the Institute of Physics Publishing and QinetiQ. Contact Susan Curtis at susan.curtis@iop.org or +44 (0)117 930 1035 for a copy of the Executive Summary and a full Table of Contents. For more information see www.technology-tracking.com.

Meetings

MACH 2004

Over 400 companies will be on show at MACH 2004, the UK's leading event for the manufacturing sector.

The exhibition will showcase the latest technologies and products on the market, with pavilions dedicated to specialist areas of technology: tooling; measurement; inspection; CADCAM. There will also be special areas for: automation and robotics; engineering lasers; metalforming, welding and metal fabrication.

If you are attending MACH 2004, please do visit AILU on stand number 4560E in Hall 4: rest for feet in a sanctuary for laser-lovers amidst the noise and activity of the UK's largest machine tool exhibition!

SUBCON 2004

Events at Subcon 2004, the UK's premier subcontracting event, include a programme of seminars, conferences and workshops, presented by Smallpeice enterprises and AME-UK. The Smallpeice seminars will focus on the elimination of design and process failures, designing out cost and building a lean supply chain. AME-UK will run a 2-day conference on lean manufacturing.

Meanwhile, the wide range of products and services on show at Subcon will give visitors the make informed choices about potential suppliers and improving their business.

If you are attending Subcon 2004, please do visit AILU on stand number H38, which will be dedicated to 'Design for Laser Manufacture'.

Photon04

Photon04 is the largest optics event in the UK and the second in the series that began in Cardiff with Photon02. Photon04 will be held on 6-9 September 2004 at Glasgow Caledonian University and will comprise:

- Optics and Photonics 2004: the biennial conference of the Optics and Photonics Division of the Institute of Physics,
- QEP-16: the biennial conference of Quantum Electronics and Photonics Group of the Institute
- Industry Technology Programme: sessions of particular interest to those in the optics industry;
- Technical exhibition
- Seminars and workshops

Standing room only! Lunchtime exhibition at the polymer workshop at TWI

March

31 AILU Members' Meeting and AGM

BMW Hams Hall, Coleshill

Info: http://www.ailu.org.uk/events/2004.03.31.m.htm

PRE-REGISTRATION IS ESSENTIAL

April

19 MACH 04 (19 - 23) incorporating Engineering Lasers SUBCON (19 - 22)

NEC Birmingham
Info: http://www.mach2004.com
Info: http://www.subconshow.co.uk/

19 PICALO (19 - 21) 1st Pacific ICALEO

Melbourne, Australia
Info: www.laserinstitute.org/conferences/picalo/

26 SPIE: Photonics Europe 2004 (26 - 30)

Strasbourg, France
Info: http://www.spie.org/conferences/programs/04/epe/

June

24 AILU Technology Workshop

Laser-based micro-processing

Photonics Cluster, Aston University, Birmingham

Info: http://www.ailu.org.uk/events/2004.06.24.a.htm

July

5 Workshop on Laser System Technology and Applications for small and medium sized enterprises (5 - 6)

OpTIC Centre, St. Asaph, Wales
Contact: Welsh Opto Forum T: +44 (0)1745 586236

Further ahead ...

September

6 **Photon 04 (6 - 9)**
UKCPO Conference, exhibition and workshops
Glasgow Caledonian University
Info: http://www.photon04.org

29 **Step into the Light II**
Make It With Lasers
TWI, Cambridge
Info: http://www.miwl.org.uk

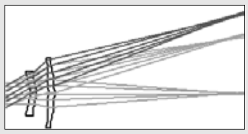
October

4 **ICALEO 2004 (4 - 7)**
San Francisco, California, USA
Info: http://www.icaleo.org

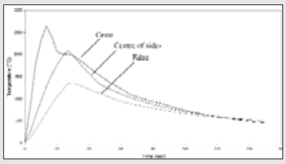
Contents

IN THIS ISSUE

Laser welding to wood p20

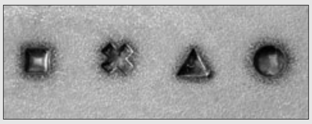


back to basics p26



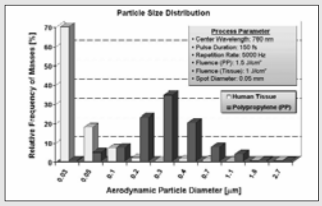
Laser treatment of ceramics p32

Lean manufacturing p17



something new with a Q-DPSSL p29

CO_2 scanning systems p23



Non-beam hazards with fs lasers p34

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.

'The Industrial Laser User' is published quarterly by the Association of Industrial Laser Users and distributed for its members only

The Industrial Laser User
Editor: Mike Green
ISSN 1366-963X
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