The Industrial LASER USER
association of industrial AILU laser users

Issue 35 June 2004

AILU's 10th AGM

Fifty members and guests gathered at BMW's Hams Hall plant on 31 March 2004 for the annual technical meeting and AGM to hear an upbeat assessment of the future for laser use, exciting developments in rapid prototyping, new product and service developments, the annual address on the activities and plans for the association, and the presentation of awards to recognise achievement in the laser community.

The technical part of the meeting, chaired by Martyn Knowles (Oxford Lasers), kicked off with a review of the industrial laser market by Arnold Mayer (Optech Consulting) and the state-of-the-art in Rapid Manufacturing Technologies by Bill O'Neill (Institute of Manufacturing, University of Cambridge). (See p5 and p36, respectively, for further details of these presentations).

In keeping with tradition at these events, the technical programme also included a 'What's New?' session of short technical and sales presentations. (See p12 for more of the 'What's New?' details.)

AGM

The AGM presentations were particularly upbeat this year. A general optimism within the laser community has been backed by a strengthening of AILU membership over the year, with the total number of members standing at a record level of 287 (June 2004).

Summarising the various activities of 2003/4, AILU President Tim Weedon reaffirmed that the magazine was the jewel in AILU's crown, stressing that members should not hesitate to send in news, that "just because it is obvious to you does not mean it's obvious to anyone else".

Tim reviewed the events of FY 2002/03. The members' meeting at Jaguar, the Microprocessing workshop at Exitech and the Lasers and Optics workshop at UMIST were particularly well attended, but attendance at the Sheet Metal Processing workshop at Amada and at the Jobshop 03 in Nottingham were disappointing. This year, the two events will be combined in a single full day event. (See p43 for date and venue).

Tim (as Chair of the Market Development Group) and David Lindsey (as Chair of the Job Shop Group) provided summaries of their special interest group activities. In his Secretary's report Mike Green reviewed UK networking activities with UKCPO and Make It With Lasers, and European networking with EULASNET.

New members of the committee were appointed and, in keeping with the new procedure for appointing the AILU President, last year's Vice President, Paul Hilton, was approved to take over from Tim for the coming year, and Malcolm Gower was approved as the new Vice President. (See p3 for a full description of committee changes).

Recognition for laser expertise

The AILU Award for 2004 was won by Denis Hall, Co-Founder and non-executive Director of Rofin-Sinar UK and Professor of Photonics at Heriot-Watt University, Edinburgh. Ken Lipton, Managing Director of Rofin Sinar (UK) Ltd reviewed the contributions of his long-time friend and made the presentation.

Winners of the 2004 AILU Award and Prize. Prize winner Adrian Orchard (left) of TRS Engineering and Award winner Denis Hall (right) of Heriot-Watt University flank retiring President Tim Weedon.

Ken described how Denis has championed the technology of the RF-excited diffusion cooled CO_2 laser technology and has made major recognised contributions, both as an academic and entrepreneur. Pointing out that Denis's university career began relatively late, in 1979, at the University of Hull, Ken described the major role that Denis played in the establishment of Laser Applications Ltd in Hull (subsequently purchased by Coherent Inc) and Palomar Technologies Ltd (later part of Rofin-Sinar (UK) Ltd).

In accepting the AILU Award, a laser engraved glass block provided by Rofin Baasel on a laser machined and engraved metal mount courtesy of Micrometric, Denis expressed his particular gratitude to Howard Baker and to his other research colleagues for their invaluable contributions over the years.

In his last act as AILU President, Tim Weedon expressed his delight in presenting the Young Laser Engineer's Prize to Adrian Orchard of TRS Engineering Services Ltd, for his work on the application of laser welding to the fabrication of heat exchangers. The Prize included a laser marked plaque, courtesy of thinklaser, and a cheque for £250.

"It is clear that Adrian has played an key role in the success of this complex, leading-edge project," said Tim. "Undoubtedly, this work will enhanced TRS' ability to broaden its market base," he added.

In accepting the Prize, Adrian acknowledged the great support he had received from the team at TRS. "The work involved welding together two 0.25mm thick stainless steel plates in such a way that the weld pattern generates capillary channels," Adrian said. "The main challenge was that the machine and laser settings had to be determined empirically, both in hardware and software."

As the meeting was brought to an end, Paul Hilton led a show of thanks to Tim Weedon for his enthusiastic leadership of the Association over the year.

Letters to the Editor

Laser safety eyewear

For much of the Nd:YAG laser marking and engraving work that we do as a laser job shop activity the laser beam is not fully guarded. Consequently, the provision and use of safety eyewear plays a vital role in our laser safety strategy.

As laser users will know, safety eyewear is expensive, often several hundred pounds a pair, and one would expect for this money that the design and construction of the frames as well as the filters would be of the highest standard. Indeed, one could argue that good construction and ergonomic design are critically important, since the long-term comfort and good visibility of the eyewear are key to ensuring that the laser user keeps them on.

Yet having spent large amounts of money on such eyewear, what do I often find? Foam seals around goggle frames that wear out very quickly; elastic straps that rapidly perish (why can't manufacturers use something a bit wider than knicker elastic?); moulded rubber seals that perish quickly and can't always be replaced; and eyewear that is too heavy and it won't fit properly over spectacles.

Users need to be more demanding and manufacturers need to be much more responsive!

Charles Dean Fimark

Polarisation

Many laser processes are not dependent upon the need for a linearly polarised beam. Some even benefit from random polarisation. However, in most cases it can be very useful to have some element of the laser's output beam that forces a stable linear output. Such an output is much more amenable to optical manipulation and control. For example, polarisation-insensitive beam splitters are available but they have a lower damage threshold and are far more expensive than their polarisation-sensitive cousins.

I think that AILU should be pushing for a standard specification of laser polarisation : one that would be recognised throughout the laser industry. As an integrator who has supplied many sealed-off CO_2 lasers with laser marking heads, let me give some examples that illustrate the potential benefits of having such a standard.

When a laser manufacturer issues a technical specification for a laser which contains wording such as "Polarisation – Linear, Perpendicular", one would expect the word "Perpendicular" to mean 90° to the base of the laser housing. We have found that the angle can be several degrees off, requiring us to rotate the mount to compensate in order for beam splitters to perform correctly. As a result, we are now in the process of building our own compact digital polarisation meter at Raylase. If any reader would like a duplicate, please let me know.

Another example: what does "linearity >100:1" mean for a CO_2 laser? Should one expect there to be up to 1% of the output in the parallel polarisation? Is this meant to be a stable ratio, or are there further tolerances to take account of? Any 'leakage' of such parallel polarisation will have to be deflected out of the beam path or absorbed in the optics: certainly, it cannot be totally ignored. For example, if I send a 500W 100:1 output CO_2 laser beam through a polarisation sensitive turning mirror designed only for high reflectivity of the P-polarisation, then a significant fraction of the 5W of S-polarisation might be absorbed, which could be a problem.

Regardless of tighter specification by laser suppliers, I am a great fan of introducing some form of polarisation forcing element at the beam output aperture of the laser. Personally, I plump for an external, uncoated, unenhanced Brewster window, which will guarantee polarisation output orientation and further reduce the nominal 1% opposite-pol down to 0.25%.

An uncoated ZnSe Brewster window can take around 12 times the energy of the coated enhanced type, up to 6kW if the beam is large enough over the optical surface and, provided it is fixed to one orientation, the output beam should go from <100:1 down to <400:1. Uncoated Brewsters are best used in pairs to compensate for the beam's parallel deviation caused by the refraction at each surface of the optic. This further limits unwanted polarisation down to <1600:1

Enhanced coated Brewster windows are perfect for the high-speed attenuation of CO_2 energy commonly used with galvanometric scanning techniques, but their price is a limitation on the laser power that they can be used with. Careful attention must be paid to peak power and the size of the beam through the optic. Too much power and the optic will thermally lens before a catastrophic failure. Dust or other contamination will also kill the optic very quickly as the heat absorption rises.

I would urge laser system manufacturers and users of polarisation sensitive optics to make their voices heard. We need a clear and universal standard for the specification of laser output polarisation.

Steve Hastings Raylase AG

Note from the editor

More than a magazine

No doubt, like me, you have subscribed to magazines only to find that you don't have the time to read them.

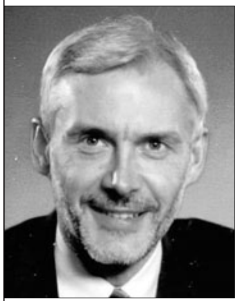
I was, of course, heartened by Tim's Presidential address at the recent AGM in which he referred to this magazine as 'the jewel in AILU's crown'; but whilst I would not be too worried if you didn't have the time to read it, I would be seriously concerned if you regarded the AILU membership subscription as buying you little more than this quarterly magazine.

Even if you lay the magazine aside largely unread, be assured that behind it, only a phone call or email away, lies access to key people in the industrial laser community and valuable technical advice and information.

Remember too that back issues of all the articles in the magazine, right back to 1995 when this magazine started, are available for you to download from the web at any time you have the need or, hopefully, the time!

On a personal note, I regard the process of publishing this magazine as a bit like attending a workshop: getting involved brings lots of spin-off benefits. In this case, it forces me to focus on where the industrial laser community is heading and what the important developments are that need to be addressed. I hope that in this you agree that we are reasonably successful.

Message from the AILU President

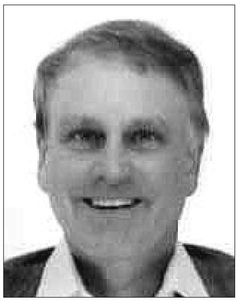


Paul Hilton

In my year as President of AILU I would like to build on the efforts of my predecessors, Bill Steen and Tim Weedon. A key factor will be to maintain membership of the association at levels consistent with the range of services provided. I would also like to see implemented a policy of continuous improvement.

Plans have already been formulated to ameliorate the AILU website, in a way that should make it more useful, and the committee always strives to better the quality of our highly successful workshop programmes. We should also be thinking to consolidate AILU as 'the' European laser related trade association and to make sure it is correctly positioned alongside existing initiatives in Europe such as ELAN and ELI. This year, I will also be looking closely at the emerging initiatives from the DTI, such as the new 'Technology Fund'. A key part of this initiative will be 'Knowledge Transfer Networks' and AILU would seem well placed to participate in this type of activity.

AILU's new Vice President



Malcolm Gower

Malcolm Gower first worked with (CO_2) lasers in 1967 while working at Perkin-Elmer Corp in the USA. Subsequently he held research and teaching positions at NASA-Ames Research Center, California; the University of California, Berkeley; the Universities of Oxford and Reading and the Rutherford Appleton Laboratory. He has conducted both experimental and theoretical research in the scientific and industrial applications of photons, lasers and optics.

Malcolm co-founded Exitech with Phil Rumsby in 1984 where he remains Chairman and Technical Director. Exitech is now a world-leading manufacturer of photon-based micro and nano-fabrication tools. Malcolm is a Fellow of the IEE, the IoP and for his services to industrial laser development was awarded an MBE in 1993.

AILU's new committee members

Kevin Brien

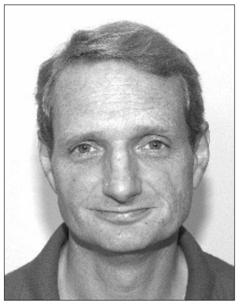
Kevin Brien is Managing Director of Pullmax Limited, who sell and support a wide range of advanced sheet metal forming equipment in the UK and Ireland, including CNC punching machines, CNC press brakes and Bystronic laser cutting systems. Kevin joined Pullmax over 20 years ago, when the company relocated to Leeds, and has been Managing Director since 1991.

Lin Li

Professor Lin Li holds a chair of Laser Engineering at UMIST and is the Director of the Laser Processing Research Centre there. He is an author of over 270 publications, 1 book and an inventor of 30 patents on laser processing techniques. His current research interests include laser drilling, laser cutting, micro-machining, micro-welding, surface engineering, HPDL applications and rapid prototyping.

Stewart Williams

Dr Stewart Williams runs a group at the Advanced Technology Centre of BAE SYSTEMS, investigating advanced manufacturing applications. This has included laser welding, cutting, surface treatment and drilling of a wide range of materials. Current topics of research are stress engineering in welding, hybrid laser conduction welding, corrosion protection of welds and laser assisted friction stir welding.



Gerry Jones

Gerry Jones has a background in mechanical engineering. For the past sixteen years he has been involved with industrial lasers and laser systems based on both CO_2 and Nd:YAG technology. He is currently at Trumpf Ltd where he is responsible for a range of laser-based products for cutting, welding and marking.

Market Development Group defines its aims

Tim Weedon

After a series of monthly telephone conferences, the steering group of the Market Development Group has achieved a clear understanding of its priorities. First and most urgent action is to enhance the website. Most particularly, this will be the host for a suite of 'standard presentations' covering a range of key subjects from understanding industrial lasers to the characteristics of manufacture by laser and the cost of laser ownership.

Most of the standard presentations will be aimed at the designers of components and products; a small number will be intended for the public at large and students in particular; these will be in the 'public' area of the site. Visitors to the site can view the presentations on screen, but members will be able to download presentations for their own use when talking to prospects and customers.

We intend to create a new area on the AILU site for 'welcome guests' to register their identity and interests, but our plans for web site development also include facilities for members to directly control their own entries on the site, and enhanced links to members' websites. The pace of our progress will be determined mainly by funding, and we are actively seeking grants to match the value of the standard presentations.

The MDG committee believe that this new special interest group within AILU will bring benefit to all members and most particularly to job shops, equipment suppliers and consultants.

We have reached the stage when we would welcome the involvement of all AILU members who support the aims of the group. We plan to announce plans for an open meeting of interested AILU members as soon as the funding situation for the web site development has been sorted out. Members can expect to be hearing more from us by mail or email over the coming period.

Tim Weedon MDG Chair

Laser Job Shop Group
Users of Lasers for Profit
An AILU special interest group

Don't miss this AILU Workshop for job shops!

Subcontract laser processing: the future

20 October 2004 at the National Metalforming Centre
Full details and registration will be released early September

New Job Shop Group Chairman seeks greater participation

Having served two years as Chair of the Job Shop Group, David Lindsey (Laser Process) handed over the reins to Martin Cook (Cutting Technologies) at a Job Shop Committee Meeting on 7 April. Under David's enthusiastic leadership the group enjoyed a 40% growth in job shop membership and a significant expansion in surveys undertaken.


Martin Cook

AILU offers a wealth of information, guidance and networking opportunities for everyone involved with lasers. Over the years it has, almost single-handedly, helped to bring the laser community together in the UK, to ensure leading edge information is available to all.

It was therefore a natural progression that, in 1998, the Laser Job Shop Group was formed as a focus tool for companies and individuals who were trying to make a profit from their use of lasers. I've been fortunate enough to be a member of the group since its inception; the things I've learned have been priceless. The group is not just about technology; it's not just about technique: both are comprehensively covered at the AILU workshops. The benefits go much deeper: it allows like-minded people to openly discuss issues of any type related to the running of a laser job shop. For example:

- I, like many others, have been stuck trying to cut a particularly awkward material. A few telephone calls to other members and the problem is solved.
- I now know there are certain materials, previously thought to be safe to cut, that could cause major problems without the correct procedures in place.
- I found out I was paying too much for my laser gases.
- I know which machine manufacturers offer the best service, and who has the most expensive spares.
- I now know the main markets for laser companies in the USA, and parts of Europe (think about the significance of that for a while).
- Perhaps most importantly, I now know that the problems I thought were unique to my company are universal, and there are certain things you can never solve!

We have many members, all contributing to the knowledge pool, and all gaining from it in a relaxed and friendly environment. We want more: fresh faces, fresh ideas.

So get in touch with Mike Green at AILU, or give me a call. It might just be the best decision you make this year. Remember, just because we compete it doesn't mean we can't enjoy it!

Martin Cook Job Shop Group Chair

Most gorgeous part this quarter

Congratulation to Neil Main of Micrometric, winner of this quarter's Most Gorgeous Part competition, with an excellent example of using laser technology to achieve a cost effective product and an ideal design.


Filter element for an environmental application. (top) initial four-post design, (bottom) two laser-cut plates that replace the four posts with a tongue and groove concept giving increased rigidity and quick and easy assembly. The design change alone resulted in a 15% saving on the overall product cost.

The photo shows a filter element designed for an environmental application. The initial four-post design, (top of the picture) has a bottom and a top plate, both laser profiled: the four posts were laser welded to both plates

The initial design was improved by introducing two laser-cut plates (bottom of picture) that replace the four posts with a tongue and groove concept giving increased rigidity and quick and easy assembly. The design change alone resulted in a 15% saving on the overall product cost.

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

Greatest Cock-up

Some time ago our company sold a laser to a customer via a certain laser machine integrator company in the UK that has since wound up and shall remain nameless. As such, the responsibility for installation was the machine integrator's although in practice they let the customer do it and left him all alone in the process.

The day after the laser arrived, I got a call from the laser engineer at the customer's site complaining that we had not sent enough coolant for the chiller and that instead of two five gallon plastic containers we should have sent at least a 100 gallons.

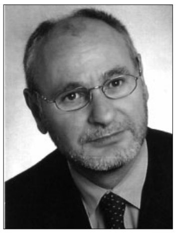
I said to him that we don't send out any coolant and asked him what he had done with the dielectric oil that we sent him for his high voltage modulator tank. Oops said he!

At the end of the day it cost him quite a bit as the dielectric oil cost a couple of hundred pounds to replace and being so fine, it was an absolute nightmare to clean out his chiller and associated pipework! Good job he didn't try to turn the laser on!

Submitted by a laser supplier who prefers to remain anonymous.

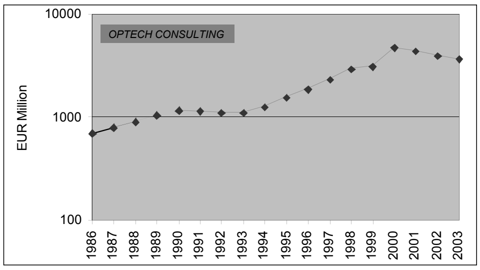
Please send in your 'greatest cock-up'. A bottle of champagne awaits the best contribution we print over the coming year!

Upbeat market forecast for laser growth



Arnold Mayer of Optech Consulting (Taegerwilen, Switzerland) opened the presentations at AILU's annual meeting at BMW Hams Hall with an upbeat assessment of prospects for the laser community.

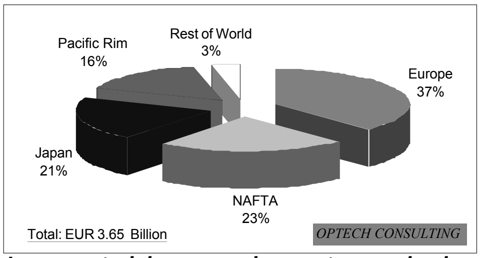
"As a technology, lasers passed their mid-point in the 1990's," said Arnold. "We may never again see continued high double digit growth in the market but there is still lots of growth potential."



World Market for laser materials processing systems. *(N.B. except for semiconductor lithography systems, the figures include the non-laser components of the system)*

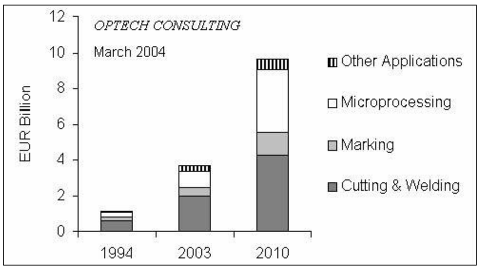
As shown in the figure (left) world sales, expressed in Euros, have fallen since 2000. Analysis of the fall indicates that it can almost all be attributed to a halving of sales in micro systems over the period.

The figure for spend on laser materials processing systems worldwide in 2003 was 3.65 Billion Euro, and the geographical distribution of this is shown in the figure below. It shows that in 2003, 37% of laser processing systems sold were purchased in Europe, well ahead of NAFTA and Japan.



Laser materials processing systems sales in 2003, by area

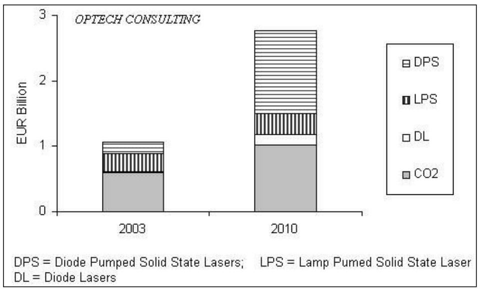
With regard to future sales, Arnold predicts that the figure for total world sales in 2010 will be 9.6 Billion Euro, corresponding to an average growth of 15% per annum.



World market in laser materials processing systems

The breakdown by application of sales in 2003 and 2010 is shown left. "We can look forward in the next few years to double-digit growth in semi-conductor laser equipment sales," he said.

Arnold noted that spend on machine tools over the last 15 years had remained at approximately 30 Billion Euro (2003 value). this is because the increased demand has been balanced by increased machine efficiency. However, Arnold predicted that within this 30 Billion Euro there is scope for a doubling of laser machine tool growth from the current 2.8 Billion to approximately 6 Billion Euro.



World market in laser sources for materials processing systems by laser type

With regard to sales of laser sources for material processing, Arnold predicted strong growth in diode-pumped solid state lasers but no growth in lamp-pumped SSLs, even in high power welding applications.

As the figure above shows, CO_2 sales are predicted to enjoy a healthy growth, largely as a result of there being no solid state replacement laser for general flat sheet metal cutting. Also, Arnold predicts that 30 - 40% of welding will still be done by CO_2 lasers in 2010. The predictions also assume that direct diode lasers will not prove a cost-effective source of good beam quality.

For further information Arnold Mayer can be contacted at Optech Consulting T: +41 71 667 0990; E: info@optech-consulting.com.

The case for European support of photonics and optics

One of the consequences of the maturing of laser technology and laser applications has been the drying up of funds that were once available for basic laser-related research from the European Commission through its various framework programmes.

Germany, the dominant European player in this area, is enjoying a nationally-funded 10 year program in the field of optical technologies; thanks in part to a report 'Optics21: Key technology for the 21st century' produced in 1999 by the WLT (German Scientific Laser Society) which sets out how photon technologies are bringing major benefits to society. Now, led by the WLT, a similar process is being undertaken for the EU. A joint Strategy Paper "Photonics for the Benefit of EUROPE" is being prepared, which will recognise AILU and all other contributing institutions equally, with the goal of implementing optical /photonics technologies in the next (7th) EU framework program.

In formulating the strategy paper, AILU and other organisations around Europe have been asked to make their inputs under 5 headings: general political goals (including its impact on the EU commitment that by 2010 it will be "the most competitive and dynamic knowledge-based economy in the world"); action areas (including production technology); launching innovations and benefiting from the research; core competencies to be developed; fundamental research topics.

Key elements of AILU's strategy include its dedication to maximising the effectiveness, efficiency and competitiveness of manufacturing industry, its support for the work of researchers, developers and manufacturers of lasers and laser systems to improve the efficiency of products; and its active promotion of best practice.

AILU's response to the WLT was undertaken largely by the standing committee and has proved most useful in providing the opportunity for us to clarify the Association's position in various key areas. AILU is now in its 10th year, and it has been no bad thing for us to have this incentive to focus on our future strategy.

The joint Strategy Paper will be presented to the European Commission in a one day seminar in Autumn this year in Brussels. Many members of AILU will be keeping their fingers crossed!

? QUESTION & ANSWER

Are laser beam shutters good enough?

We are seeing a number of cheap imported lasers having no physical beam shutter, simply software that inhibits the fire signal to prevent exposure, the laser source remaining powered. As a machine integrator, we would like to know what the requirements are for beam shutters.

The laser safety standard BS EN 60825-1 includes two Clauses addressing requirements for laser beam stops or attenuators (shutters): Clause 4.7, which requires that Class 3B and Class 4 laser system must incorporate a beam stop or attenuator; and Clause 9.1, which outlines the general requirements for tests to claim compliance. Tests must be made under each and every reasonably foreseeable single-fault condition.

None of the above even hints at the form of the beam stop/attenuator. The beam stop may be a metal cap that fits over the laser output aperture and secured with a chain to comply with the "permanently attached" requirement or it may be a manually-operated flap that moves to cover the laser aperture. These solutions may meet the laser standard requirements but they have little relevance to use within many automated configurations, passing the onus for safety of the laser onto the end user or integrator. By contrast, many laser suppliers to the industrial market provide beam stops (often called shutters) that can be remotely operated, are fail safe and incorporate a range of safety features that give heightened confidence in the security of operation of the device.

This is not the end of the story when putting laser systems into the marketplace in Europe. If the laser is part of a machine, then the Machinery Directive needs to be met. If the end equipment is not a machine, then almost certainly the requirements of the Low Voltage Directive (LVD) need to be satisfied. If the laser is to be considered a component for incorporation into an arrangement by the end user, then the Provision and Use of Work Equipment Regulations (PUWER) requirements will need to be met.

The Machinery Directive requires that any failure or incorrect functioning of components guaranteeing a safety function, should not compromise the safety or health of persons in the working area. In particular, where embedded Class 3B and 4 lasers within machines remain on (in order to maintain their stability) during access to the processing zone by the machine operator (e.g. for piece part loading or unloading), the shutter is required to provide the same level of safety, and with the same integrity, as would be expected of the process zone guard during laser processing. That is, the shutter must tolerate the full laser beam radiation without deterioration or damage and have an adequate lifetime. Other requirements include monitoring the beam shutter for damage, monitoring that the shutter is closed when it is intended or commanded to be closed and controlling its operation by safety-related control circuits

The LVD and PUWER are not so explicit but are consistent with the requirements of the Machinery Directive.

Whilst many high power CO_2 and Nd:YAG laser machines incorporate shutters that satisfy these requirements, a surprisingly high number of those incorporating lower power CO_2 and Nd:YAG lasers appear to have totally inadequate shutter systems. My recommendation is that system designers and integrators need to be aware of the risks that may be presented by inadequate shutter provision or a shutter failure and the consequences of injury that may result. They should also be aware of the duties and responsibility placed on them to meet the relevant safety legislation and thus make the necessary provisions based on individual risk assessments. Many laser manufacturers, especially those from outside Europe, may not have had to consider the safety of this part of their product. Thus, additional features may need to be incorporated by the laser user when the product is integrated especially when intended for an industrial application.

Mike Barrett Pro Laser

New deal for Canadian laser job shop

AILU members might be interested to hear that Capital Laser Inc, a Canadian laser job shop, has signed what is being hailed as a ground-breaking licensing agreement for the transfer to them of new laser precision manufacturing knowledge and expertise from the The National Research Council (NRC), Canada's premier organization for research and development.

Capital Laser plans to manufacture fully integrated laser precision manufacturing systems and to provide a manufacturing service to industrial sectors from biomedical to automotive and electronics.

TIP for laser beam visualisation

Highlighter pens provide an excellent fluorescent dye for laser beam detection, much less expensive than a detector card. The pen can be used to coat a variety of materials including card, masking tape and metals.

We use a card marked with a Stabilo violent pink marker (Ref No. 275/58) for detecting a femtosecond 800nm Ti Sapphire laser beam. Members with other lasers might like to try the technique.

Alex Ellin Renishaw plc

The MACH and SUBCON exhibitions in pictures

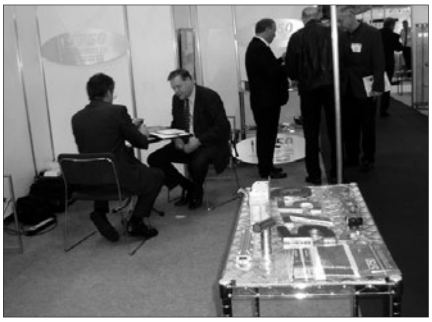
- for a written summary see page 43

SUBCON

Peter Hancocks and Tim Weedon ready for visitors

The AILU stand in Subcon focused on providing laser design information, job shop capabilities and displaying laser-processed parts.

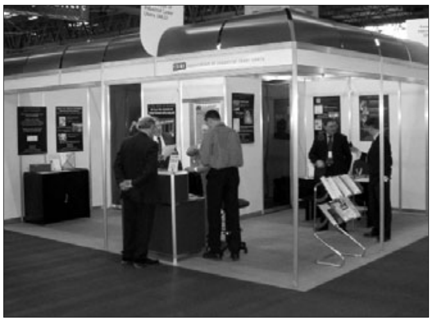
Highlights included a superb laser cut model of Tower Bridge (provided by Charles Day Steel) and a PowerPoint show on laser cutting provided by Kevin Brien.



5750 Components was the only AILU members exhibiting at SUBCON.

Andy Murphy said that they were very pleased that they had taken a stand at the show.

MACH



The AILU stand in Hall4 attracted a steady stream of visitors.

In addition to AILU information packs, the stand displayed a wide range of laser-processed parts, a PowerPoint show of AILU web site features and information on EULASNET and UK regional activities.

Trumpf described the results of this year's event as phenomenal, with sales 200% up on sales in MACH 2002.

On the first day of the show, Pulmax announced that it had an order valued in excess of £400,000 from EPS Laser for its Bystronic Byspeed 3015.

A laser welding Audi A2 (Zinc-coated aluminium) chassis on a Trumpf stand, in the Engineering Lasers area of Hall 4.

The photo shows Steve Ingram of Trumpf showing the chassis to Sinéad Deery from the adjacent GSI Lumonics stand on the quiet first day of the show.

Engineering Lasers Area within MACH

Powerlase showed their range of Q-switched DPSS lasers and their milling and drilling capability.

"UK manufacturers needs to be more open to laser applications," said CEO Terry Newell, shown here with Marketing Manager Annette Jones .

Among the many laser items on their stand, Telesis Eagle displayed a 20W fibre laser, fibre delivered to a robot-mounted scanning head for maximum flexibility in marking applications.

Included on the Laser SOS stand were the their diode-pumped (20W), lamp-pumped (120W) and 250W Q-switched YAG lasers.

"The better location of 'Engineering Lasers' between Halls 3 and 4 contributed to much better visitor numbers than in 2002," said Jim Leach.

Marking systems seemed to be particularly popular with visitors:

New AILU member Hans Jobst shows off the NWL Mistral diode-pumped Q-switched YAG laser marking system.

This robust mobile Class 1 unit is designed for heavy industrial use. It can be supplied with either front or side access.

The guisilaser APF from Tullio Giusi is a laser marker with automatic feeder that can accommodate tags in a wide range of sizes and mark them in a wide range of formats.

The flexible automation makes the product particularly well suited to job shop use.

Malcolm Payne, MD (left) of Electrox, shown here displaying the Scriba laser in a customised workstation.

Malcolm was delighted with the interest level of visitors to MACH.

Apologies to the many other AILU members who had stands at the show not shown here

? **QUESTION & ANSWER**

Bulk gas supply for laser cutting

We are purchasing a third laser cutting machine for our laser job shop and we wish to move from bottle banks to a more economic and convenient supply of high pressure (up to 30 bar) nitrogen gas. Which option should we go for?

Of all the elements of supply mode selection, the provision of high pressure nitrogen for laser cutting is perhaps the most difficult. A lot depends on the customer's true needs; both for the present and for the future. Consequently, the selection is particularly difficult for laser job shops because the gas demand is hard to predict; both week to week (e.g. 1mm mild steel one week, 20mm stainless the next) and in the longer term.

Compressed cylinders in Manifolded Cylinder Packs (MCPs) offer the most flexible supply option, but as gas demands increase, the cost and space demands of MCPs and time lost for MCP changeover can become problems.

Cryogenic tank

For cutting requirements below 20 bar, small cryogenic tanks represent an excellent supply option. They offer hands free installation and the gas is provided constantly on tap. They can be manifolded to increase storage on site to match demand and external vapourisation can be provided to meet higher gas flow requirements. For larger volume requirements, bulk cryogenic supply options offer a good solution, but standard versions of such vessels can only deliver up to approximately 16bar so either a high pressure cryogenic tank, or a standard pressure tank with separate pressure build-up systems must be used.

High pressure cryogenic tanks are simple, very reliable (have no moving parts) and easy to use. They store the liquified nitrogen at up to 37 bar and can deliver at pressure up to 34 bar. Consideration must be given to the filling process for the tanks, as UK road tankers, used to transport the cryogenic liquid, are normally governed to suit the operating pressure of standard pressure tanks, pumping at a maximum pressure of 14bar. As this is below the operating pressure of the high pressure tank, the tank has to be taken off-line and de-pressurised before filling can begin: this can interrupt production in a busy job shop, and a certain amount of cold gas has to be vented to atmosphere.

However, some logistics fleets have specialist high pressure road tankers, which can fill at pressures > 30 bar, allowing the tank to be continuously on-line and eliminating downtime and product loss associated with the high pressure cryogenic tank. (Only Air Products currently offer this service in the UK)

Trifecta

The Trifecta is a thermodynamic pressure intensifier, manufactured by MVE/Chart Industries Inc. and purchased by a number of gas companies. A Trifecta takes low pressure liquid from a standard pressure bulk supply and passes it through a skid-based unit comprising two 200 litre liquid vessels that are sequentially filled and pressurised to provide high pressure (32bar) liquid to a vapouriser, which then supplies the laser machine. Developed primarily to cater for the specific needs of the laser market these units have been widely used by both BOC and Air Products in North America and a high number in the UK, the first of which was installed by BOC at Micrometric in 1998. The Trifecta provides a continuous high pressure gas flow by means of a number of solenoid valves: no pumps are used.

Mini Cryo-Pump

Some time ago, Air Products withdrew the Trifecta from its equipment range in favour of an alternative high-pressure solution, the Mini Cryo-Pump. The Mini Cryo-Pump is offered to customers requiring an uninterrupted supply consuming over and beyond 10 tonnes liquid per month. Air Products has a number of these installations in North America and the UK, the first of which in the UK was to Malton Laser Ltd in 2002. Air Products advise that it is extremely reliable and cost effective in production and that it was introduced due to the growing reliability problems and escalating maintenance costs of the Trifecta. The Mini Cryo-Pump utilizes a standard pressure cryogenic tank in conjunction with a small cryogenic pump to deliver high pressure (up to 150bar) liquid through a vapouriser. The vapouriser output fills a high-pressure reservoir, which is then used to supply the house pipeline at high flow (205Nm3/h) supply. The system is modular in that additional pumps can be added to increase flow capability.

Nitrogen generator

PSA nitrogen generator systems are most commonly sold for producing volumes of nitrogen far in excess of the requirements of a laser cutting application. However, there are PSA nitrogen generators designed to operate on the smaller scale required for laser cutting, providing flows from 1 Nm^3/hr to over 100 Nm^3/hr.

The modern PSA systems claim a totally non-welded construction, requiring no periodic safety inspection or "topping up" of the adsorbent; and to be of a modular construction for simple future expansion should gas consumption increase. We have received no reports from laser job shops using this form of gas supply, but it seems clear that the technology is improving al the time and that the nitrogen generator is providing an increasingly attractive alternative to pressurised bulk-storage options.

Summary

We conducted enquiries among AILU job shop members. Some but not all expressed satisfaction with the Trifecta system; none expressed an opinion about the promising alternatives.

Additional reading: 'Supply and use of gases in laser materials processing' by Stephen Ainsworth. Issue 32, p32.

Thanks to Jack Gabzdyl (BOC), Andy Jordan (Hydram), Neil Main (Micrometrics), Peter Watts (NJ Bailey), and Aaron Williams (Air Products) for their contributions

GAS TIP

To make sure we don't get unnecessary gas tanker deliveries (which are expensive), we email the level of the bulk tank to the suppliers sales office daily. In this way they can monitor our usage and send a tanker only when we need it. This system generally works well, although there was one time when our usage shot up and the delivery was only just in time to keep us going. So it is best to keep the supplier informed if you know you are suddenly going to be using a significant amount of gas.

Andy Jordan Hydram Engineering

Members' News

Welcome to New Corporate Members
(since March 2004)

NWL Lasertechnologic GmbH

Pacer Components plc

CKE Engineering

Croft Engineering Services Ltd

DW O Brien Ltd

Brian Phillips Consultancy

Laser Physics UK

Bigneat Containment Technology Ltd

InnoLas (UK) Ltd

LVD UK and Ireland Ltd

ABC (Stainless) Ltd

Energas

SEI S.p.A.

News in brief

New African Laser Centre established
The CSIR in Johannesburg, an AILU member since 2000, has recently established a new .African Laser Centre to help co-ordinate laser research throughout the continent. It is hoped that the new centre will help to attract researchers back to Africa, and encourage them to pursue research that will improve the quality of life of its population. Six institutes in Algeria, Egypt, Ghana, Senegal, Tunisia and South Africa, with specialities ranging from materials processing to bio-photonics, have already signed up to join the ALC.

Basic Facts 2004
'*Basic Facts*', the MTA pocket guide to trends in the manufacturing technology sector is available free from the Manufacturing Technologies Association by contacting *info@mta.org.uk*

News in brief

Trumpf wins with TrumaForm
Trumpf won the Metalworking Awards (Physio-Chemical Category) at MACH 2004 with its TrumaForm LF direct laser forming (powder deposition) machine. One of the first users of this technology in the UK will be TWI. Trumpf is currently completing the installation of a machine at TWI Sheffield where it will be used on a variety of research projects.

BAE SYSTEMS awarded £4M laser contract
BAE Systems has opened a £4.0m Laser Centre of Excellence at its Avionic Group's Sensor Systems Division (SSD) in Edinburgh, Scotland. The new facility will design and produce 3000 lasers that are needed for the targeting system in F-35 Joint Strike Force Fighter.

Lockheed Martin awarded the contract for the laser system to BAE last September. The facility will have 4000sq. ft. of manufacturing space and 21 test rooms for Class 4 lasers.

Newport acquires Spectra-Physics Lasers
Newport Corporation is in the process of acquiring Spectra-Physics Lasers & Photonics from Thermo Electron Corporation, Waltham, MA, USA. Pending regulatory approval and other customary conditions, the agreement is expected to close in the third quarter of 2004. Spectra-Physics has emphasised its commitment to business as usual for their customers.

2004 CLEO/IQEC has record attendance
Attendance at the 2004 Conference on Lasers and Electro-Optics/International Quantum Electronics Conference (May 16-21, San Francisco) grew by 7% over its 2003 figures. CLEO/IQEC also had a 31% increase in papers.

II-VI YAG Laser Lens Debris Shields
At a fraction of the cost of a YAG laser focus lens, II-VI's new VLOC high quality laser debris shields provide the cost-saving protection for lenses, from back splatter and other harsh workshop environments. These high quality windows provide a cost-effective solution to lens protection and are backed by world-class service and customization.

Pro-Lite distribute for Coherent and Quintessence
Pro-Lite Technology has signed a sales distribution agreement with Coherent Inc to act as distributor for Coherent's range of laser measurement & control (LMC) products in the UK and Ireland, including laser power and energy meters, laser wavelength meters, spectrum analysers, and laser beam profilers. Pro-Lite also has an exclusive agreement with Quintessence Photonics Corporation, to distribute throughout the UK and Ireland its range of high efficiency laser diode arrays and bars used in materials processing, military and DPSS applications.

And finally...

Spend a penny
In preparation for joining the Single European Currency, all citizens of the United Kingdom of Great Britain and Northern Ireland must be made aware that the phrase "spending a penny" is no longer to be used. The correct terminology is "Euronating".

Record breaking science

Two of the CCLRC's facilities - the Vulcan laser and the ISIS pulsed neutron source at the Rutherford Appleton Laboratory - feature in this year's Guinness World Records. A presentation of certificates by David Hawksett, Science and Technology Editor, Guinness World Records commemorated this achievement on Friday 23 April.

The Vulcan laser is the highest-intensity focused laser in the world, capable of producing a beam with a focused intensity of 10^{21} watts per cm^2 (that's a thousand million million million watts - equivalent to all the sunshine falling on the Earth focused onto the end of a single human hair).

ISIS is the world's most powerful pulsed neutron spallation source. Covering the size of a football field, it produces 4 x 1016 (40 thousand million million) fast neutrons per second. These are focused into beams in a 'neutron microscope' allowing scientists to study, at a microscopic scale, the atomic and molecular arrangements that give materials their unique properties.

From left to right: Ian Gardner (ISIS), David Hawksett (Science and Technology Editor, Guinness World Records) and Colin Danson (Lasers)

During the celebration staff from the Central Laser and ISIS facilities came together to hear short talks by Professor Henry Hutchinson, Director Lasers and Dr Andrew Taylor, Director ISIS on the successes of their respective facilities and their future hopes for the facilities. David Hawksett, the Science and Technology Editor for Guinness World Records then presented certificates to Colin Danson (Lasers) and Ian Gardner (ISIS). On presenting the certificates he commented, "The good thing is that I did not have to travel across the Atlantic to make the presentations. It is usually in the USA where this sort of work is done".

New Laser Engineering courses at Liverpool

The Laser Group in the Department of Engineering at Liverpool has been at the forefront in offering training programmes in engineering applications of lasers for some time. Some new developments now make these courses more available to AILU members and the wider laser processing community.

From September this year, University of Liverpool will be resuming its policy of opening access to its postgraduate level modules in laser engineering. Each module is of one week duration and contains traditional lecture elements, presentations from distinguished visiting lecturers and practical hands on activities. In recent years visiting lecturers have included Bill Steen, John Powell, Roger Crafer, Bill O'Neill and many industry-based experts.

The one week modules for the period September to December '04 are: Introduction to Laser Engineering; Optics and Optical Systems; Medical Applications of Lasers; Economics of Laser Applications; and Laser Welding and Drilling.

One week modules in the period January – April '05 are: Laser Cutting and Marking; Laser Microprocessing; and Laser Surface Treatment.

The fee for attendance for each module is £650.

In the coming year (in an initiative sponsored by NATEC - The Northern Aerospace Technology Exploitation Centre) up to 20 personnel from small companies will be able attend at the reduced rate of £250 per module.

It is also possible to register for the part-time version of the MSc(Eng) degree in Engineering Applications of Lasers over a 2 –3 year period.

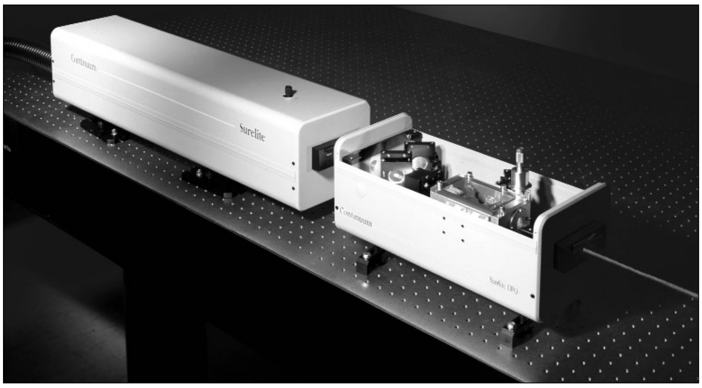
Further details, including precise dates and on-line application forms can be found at <u>*http://www.lasers.org.uk*</u>

Photonic Solutions ranked one of UK's fastest growing privately-owned companies

Edinburgh-based optoelectronic supplier, Photonic Solutions has been ranked one of the UK's fastest growing privately owned firms, according to a recent survey published in Real Business magazine. The survey, called the Vantis/Real Business Hot 100, ranks the UK's 100 fastest-growing private firms by sales-turnover growth over a four-year period and is sponsored by national accounting and business advisory firm, Vantis.

The 2004 Vantis/Real Business Hot 100 is created from data supplied by business analysts Jordans. It shows Edinburgh based firm Photonic Solutions, started in 1999 and run by Douglas Neilson was ranked 80th in the survey. The laser and equipment supplier achieved an average annual sales growth of 66%, with turnover of £3.1 million and profits of £0.3 million.

Douglas Neilson, Managing Director of Photonic Solutions says: "Building a growing and profitable business is always a challenge. Happily, our business has gone from strength to strength and we are delighted that our achievements have been recognised in this prestigious survey."



Continuum laser distributed by Photonic solutions

Cutting Technologies order new laser

Just 12 months since establishing Cutting Technologies Limited and the initial investment of a 3 kW Bysprint, directors Martin Cook and Barry Proctor have invested in a second machine, this time a Byspeed equipped with 4 kW resonator. This represents an overall invest value of £650,000.

"We wanted to take laser cutting business back to basics, working on small, fast orders and have had a fantastic first year with many of these small orders developing into bigger markets. Cutting Technologies has positioned itself as a "cutting centre", actively supporting the smaller customer. We will handle any job, regardless of size and if we cannot do it ourselves we will find someone who can,"said Martin Cook

"The Bysprint is working to capacity and whilst we prefer to offer lead times of 2 – 3 days, it was becoming 4 – 5 days. We could have opted for a second Bysprint but felt the Byspeed would provide us with another dimension. It is 30% faster, it loads from the side which makes it easier for cutting tubes; and the 4 kW resonator has given us the option to cut up to 15mm," Martin added.

Laser-cut stair rails

Laser Cutting Co orders tube cutter


Paul Lake (l) of BLM-Adige with John Stalker at MACH

The Laser Cutting Company, Sheffield signed up for a new Laser Cutting machine on the stand of BLM Adige UK at MACH 2004. The Tube cutting machine is specifically designed for the sub-contracting industry. The deal forms part of a £500,000 investment in new equipment and upgrading of operations and opens up new markets since it enables Laser Cutting to process aluminium as well as mild and stainless steel.

John Stalker, MD of Laser Cutting who bought the business in December 2003 said, "This now brings our total tube cutting facilities to 4 machines, two of which are capable of multiple shapes; making us probably the largest sub-contract tube cutter in the UK".

"The introduction of state of the art machinery allows for much more reliable turnaround times" said John. "This is essential for our manufacturing partners who in the main are offering finished items, on just-in-time principles".

Paul Lake, MD of BLM Adige said "We are particularly delighted to be selling our latest technology to Laser Cutting since they were the first sub-contractors in the UK to invest in a BLM machine over 4 years ago."

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'What's New in 2004?'

The "What's New in 2004?" presentations at the AGM meeting at BMW's Hams Hall plant on 31 March was as frantic as usual, packing nine presentations into fifty minutes.

The presentations included two technical papers ('Spectacles for diode stacks' by Denis Hall (Heriot-Watt University), 'Gap bridging with hybrid laser/arc welding' by Paul Hilton (TWI)), two university initiatives ('LAMP initiative for West Midlands SMEs' by Ed du Bois (University of Coventry) and Brian Bryden (Warwick University) and 'The Laser Initiative' by Anthony Walker (LLEC)), and 5 commercial presentations. Of these, the presentation 'laser cladding' by John Cocker (Laser Trader) is covered in an extended feature on p19. The remaining non-technical presentations are summarised below.

The Laser Initiative

'The Laser Initiative' at the Lairdside Laser Engineering Centre is supported by Wirral council and the ERDF (objective 1 funding) for the creation of sustainable industry in Merseyside. The LLEC activities include project work and application trials and the generation of new laser users in the Merseyside area.

Lairdside Laser Engineering Centre

Illustrations of recent activities include: solving a machining problem for a textile cutting company that was not getting its expected cutting results, resulting in improved performance and creation of a new job; linking a non-metallic cutting company with a laser job shop to carry out an urgent piece of work; production of prototype samples of a component for a HF lighting company, which allowed it to win a contract.

Current and future activities include laser awareness seminars themed to industry sectors. AILU member involvement in presenting and in demonstrations is invited.

The LAMP project

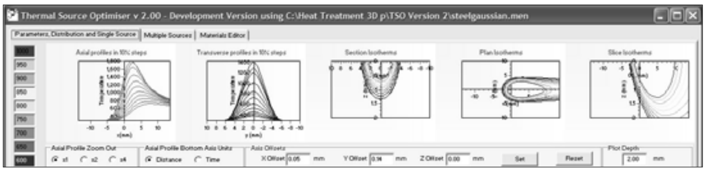
The LAMP (Laser Aided Material Processing) project is an initiative by Coventry and Warwick Universities to provide a funded laser R&D facility for SMEs in the West Midlands region. Provided that they are within the Objective 2 area, SMEs can use this facility at no external cost to them, thanks to part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

COVENTRY UNIVERSITY

The service includes: telephone advice; feasibility studies; advice on design protection; type testing; development proposals; prototyping; training; technical documentation; pre-production batches.

Improved software for laser heating

TSO2 (Thermal Source Optimiser – version 2) is a surface heat source modelling package from Abington Consultants. The package provides surface and sub-surface temperature distributions for a range of laser beam cross sections (including line, circular, eliptical and multiple source arrays), power distributions and scanning geometries. It provides a rapid visual result on a standard laptop computer, allowing the user the facility to optimise beam and scan parameters for welding and heat treatment by making changes and quickly observing their effects.



Sample of the visual output of TSO2

A key feature of TSO2 is its improved graphs: all graph axes can be selected with the mouse for measurement of individual graphs, setting of measurement planes (x,y,z) and expansion for close viewing. TSO2 also offers limited keyhole weld modelling.

Extruded coldformed laser cutting nozzles

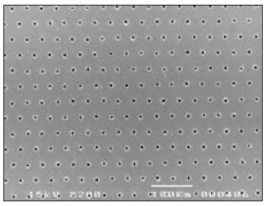
Dawson Shanahan specialise in cold forming and finish of copper components. Over a period of 2 years a unique process has been developed to produce both simple and complex laser nozzles with highly polished internal forms for both CO_2 and YAG lasers.

A CO_2 laser cutting nozzle

Generally speaking, machined nozzles have an internal surface finish of around 1µm. Cold-formed nozzles have a surface finish of around 0.1µm. This gives better, less turbulent gas flow resulting in the improved cut quality and speed. Additionally it has been found that feedrates can be increased by up to 10% and still achieve improved cut quality. These advantages are a direct result of the mirror finish and curved internal nozzle profile.

High Speed Drilling Systems

Oxford Lasers offers a high speed drilling system based around a high PRF DPSSL, pick & place automation and a high speed galvo. The machine is designed for holes of 5 to 30 µm diameter and up to 500µm deep in metals. A video shown during the presentation showed drilling at up to 300 holes per second.



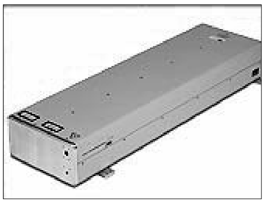
300 hole per sec drilling

Applications requiring large numbers of holes and moderate tolerances (± 10%) include micro-filters, catalysts, fuel filters, sensors.

Synrad's new 400W Sealed CO_2 laser

Laser Lines are UK agents for Synrad lasers, a company specialising in low cost, long-life sealed CO_2 lasers that are simple to use and integrate.

The firestar f400 (400W) is the highest power member of the Synrad family. It is robust, compact and complete with built-in gas purge system, integrated laser/RF and 400 watts of power in a high quality (M^2 <1.1) beam for mounting on robotic arms, and integrating into flatbed cutting machines and high-speed marking systems. Operating off 96V DC, the Duolase design includes a free space resonator and integrated RF power supply; and offers cw or pulsed operation and excellent power stability from cold and after warm up.



Synrad's new 400W laser

Performance results include: cutting 316 stainless steel 0.91 mm thick at 120 mm/sec (100 PSI O_2 assist); cutting dieboard 19 mm thick at 19 mm/sec and spot welding 1.3 mm 304 stainless steel.

Air Products receives royal recognition for laser resonator gases

Air Products plc, Special Gases Group, has recently been granted the Queen's Award for Enterprise: Innovation 2004 for its BIP® technology. This technology involves a patented method of removing impurities as the gas is withdrawn through a self-contained purifier built into a gas cylinder (see figure 1). The award recognises Air Products' Special Gases Group for its outstanding efforts in developing cylinder technology to meet customers' requirements in a wide range of applications including Gas Lasers.

BIP cylinders of both Helium and Nitrogen have ultra low moisture and hydrocarbon impurities down at low part-per-billion levels. This is dramatically below the impurity levels from conventional gas cylinders that are typically 100 times higher. These ultra low impurity levels also remain constant as the cylinder empties, unlike the situation with conventional gas cylinders where impurity levels increase (see figure 2).

Fig. 1 The BIP purifier attached to a gas cylinder to deliver ultra-pure gas

With BIP Helium and Nitrogen, the user can significantly reduce the rate of formation of deposits on mirrors – this improves laser reliability and reduces the need for expensive mirror maintenance. Overall operating costs are typically reduced by the application of the BIP® technology.

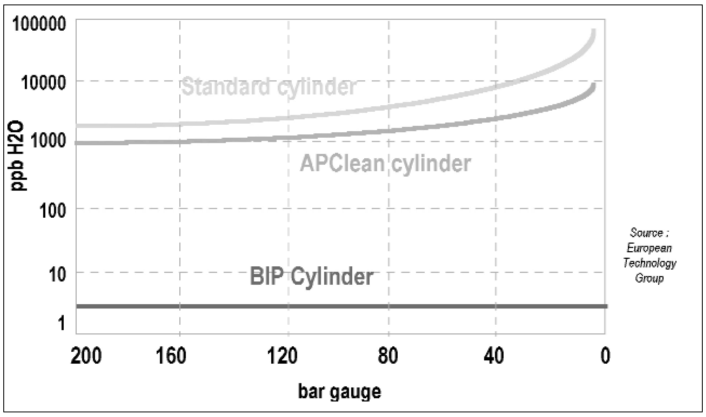


Fig. 2. Illustration of how impurity levels increase as a cylinder empties; and the dramatic improvement achieved by BIP® technology

The Queen's Awards for Enterprise are the UK's most prestigious awards for business performance. The continuous innovation category rewards UK companies that have demonstrated outstanding achievement and commercial success through innovative products or services. This innovation award demands that real commercial success must have been demonstrated and sustained over at least a five-year period, proving the value of the innovation, rather than just its technical success.

FireWire motion control takes off

Aerotech raised a few eyebrows when it unveiled the world's first servo motion control system that was entirely software driven from a standard PC. If software lay at the heart of the new Automation 3200 motion controller, it was the choice of FireWire for the networking that gave the arterial system its breathtaking performance.

According to Aerotech's Simon Smith there really should have been no surprise that FireWire should create such a revolution in motion control, but the IEEE1394 (FireWire) standard has been slow to find applications.

"Automation, control and design engineers are spoilt for choice when it comes to the selection of high performance communications networks, control hardware and languages. The sheer range of protocols - from device to enterprise levels - is overwhelming," said Simon. "However, one FireWire, based on a proven architecture, is steadily emerging as a clear leader."

FireWire exploded onto the scene in a big way in 1995, when it was accepted, by the IEEE, as a bona fide communications standard. However, the industrial world has been distinctly lax in its adoption, possibly as a result of the powerful members of the industrial consortium backing USB - FireWire's biggest competitor.

"When you consider the capabilities FireWire has to offer, it is difficult to fathom why it is not the de-facto standard," said Simon. "Not only does the latest wire based version offer an 800Mbps bandwidth but its next hardware layer is defined in a fibre version which will allow up to 3Gbps, allowing Aerotech to offer more complex functionality without future redesigns."

JLF Engineering expands laser use

Following its relocation to more efficient and larger new premises in September 2003, JLF Engineering, the Croydon based precision sheet metal firm has installed two new Bystronic Byspeed lasers in an investment totalling £0.7M.

The high speed machines are capable of working larger sheet sizes, (3 x 1.5m), which will reduce handling time and improve cost effectiveness as more parts can be cut per sheet.

JLF has a history of heavy investment in Bystronic laser profiling technology and the new machines are two of only six of their kind currently in operation in the UK.

This production system is supported by a Pullmax Laser QC 800 digital scanner that can scan artwork, as well as flat sheet metal products. The scanner speeds up the inspection stage and can also be used for reverse engineering. Typically the equipment scans a 500 mm square part in 45 seconds, verifies the results against a drawing and reports any discrepancies.

Nick Manaton retires

Technical director Nick Manaton has announced he is retiring after 30 years service with Pullmax. Throughout his time with the company Nick has been an influential member of the management team providing help and advice to both the company and its customers.

Nick has been responsible for the growth and development of the after-sales, training and product support departments that has been integral to the continuing success of Pullmax.

"After spending so many years with the company and watching it grow and develop into one of the leading players in the industry it will be very difficult leaving", said Nick.

"Many changes we have made throughout the years have now become industry standard and I have been proud to be part of its development. I am leaving at time when Pullmax is in the enviable position of having one of the best of reputations in terms of professionalism and product support."

Nick's duties will be handed over to John Clarke and Mark Balance, both of whom have been with Pullmax for many years and have worked very closely with Nick in the past.

Nick Manaton flanked by John Clark (l) and Mark Balance

Steve Ebdon joins Innolas UK

Innolas UK has appointed Steve Ebdon as their new Managing Director. With over 20 years experience in the laser industry, Steve brings a wide range of skills to the company.

Steve Ebdon

A loyal supporter of AILU throughout his previous positions with Spectra Physics, Uniphase, AMS and more recently Elforlight in Daventry, Steve recently signed up Innolas as an AILU Corporate Member.

Innolas manufactures Nd:YAG systems for industry and research, and provides spare parts and service for a wide range of industrial lasers.

Purex appoints new engineer

Paul Schofield

Purex International, manufacturer of fume extraction products for industry and education has appointed Paul Schofield in the role of customer support - Applications Engineer. Paul has gained engineering experience at the sharp end during his time with the Royal Navy, GEC Marconi and BAE Systems.

"It is commonly accepted that if a process or task generates hazardous fume then to comply with occupational health and safety regulations a fume extraction system should be utilised," said Paul. "However, our customers are increasingly asking for engineering support as they try to reduce process costs, increase productivity and eliminate downtime."

Purex have actively promoted this close relationship and have seen the benefits for both the customer and supplier: hence the expansion of the department and the new appointment.

Situation Vacant

Applications Development Manager based in Guildford

BOC Industrial and Special Products (ISP) is consolidating its capabilities in the area of Advanced Materials Processing Technologies. Reporting to the Global Technology Director for Industrial Product this role will focus on the definition and development of future products and applications, with key responsibility for implementing and supporting new products and applications introduction.

Candidates will have extensive technical knowledge of advanced materials processing technologies, including applications of industrial lasers. Educated to degree level, with business qualifications or experience, the successful candidate will demonstrate clear vision and the ability to deliver major product and service programmes.

Please apply on-line at *http://www.BOCjobs.com*, registering with Job Opportunities Section under Job id 839012.

Situation Vacant

Laser Scientist

The **National University of Ireland –Galway** invites applications for a **Lectureship in Experimental Physic**s (34k-71k). This permanent post is targeted in the research areas of the **National Centre for Laser Applications** (*http://www.ncla.ie*), which plays a central role in one of the research clusters in the Department.

The NCLA is committed to fundamental and applied research, focused on the applications of lasers in material science, in laser micro-fabrication, and in optical characterisation. Candidates whose interests include laser material processing, laser technology, material characterisation, or spectroscopy will be particularly welcome.

For full details of the post, visit: *http://www.nuigalway.ie/news*

Closing date 5.00 p.m. on Friday, 6th August, 2004

El.En's Compact Series of CO_2 lasers for metal cutting and welding

The El.En. Group, a leader in Italy in the field laser sources and applications, has recently launched five new CO_2 laser sources for cutting and welding. These lasers, the Blade600 (600W) and Blade 1500 (1500W) of their Blade Semi-sealed Series, and the C4000 - C5000 - C6000 (4000, 5000, 6000W) of their Compact fast axial flow series, were unveiled at Lamiera in Bologna 12-15th of May 2004.

El.En's Compact C4000 - C5000 - C6000 range

All lasers claim state-of- the-art characteristics in terms of beam quality and other laser characteristics in their power range

"The great thermo-mechanical stability of the El.En. laser resonator allows use in the most extreme industrial conditions," said Martino Burlamacchi of El.En. "The innovative double kinematic support system guarantees total isolation of the laser performance from the mechanical and thermo-mechanical movements of the chassis. This patented solution gives to the resonator an exceptional stability (long and short term) and repeatability."

Modular switch-mode power supplies
The use of modular direct current semiconductor power supplies, entirely and specifically designed by El.En. guarantees an exceptional compendium of performances, electrical efficiency, simple and economical handling. All El.En. laser sources are designed with a modular concept, with great advantages in reliability and simplicity for service.

Oil free radial compressors
The laser sources of the Compact series are equipped with oil free radial compressors that guarantee long maintenance intervals.

Low operative costs
The high electrical efficiency and the high reliability of the El.En. lasers place them among the most effective and economic on the market

One beam for each application
The large range of models and the proven experience of El.En. in the design of optical resonators makes it possible for the user to select the best combination of beam quality and power for the application of interest. For example, the C5000 offers $M^2=2$ for cutting applications.

A view of the El.En Compact laser resonator

Third Bystronic laser for Belmar

Belmar Engineering, a specialist fabrication and engineering company, provides a wide range of sub-contract and complete manufacturing services. With type approval from Lloyds Register for the manufacture of aluminium and stainless steel fuel tanks, Belmar are suppliers to some of the top international yacht and boat building companies. Over the years the company has established a reputation for on-time delivery of high quality components and in order to help meet these demands has recently invested in a third Bystronic laser.

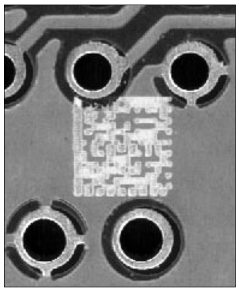
A first Bystronic was commissioned in 1999 followed by a Bysprint in 2001. This latest machine, a Bystar equipped with 4 kW resonator and rotary axis, provides Belmar with the ability to cut thicker materials and take advantage of laser cutting tubes.

Jim Whitehouse of Belmar said "We needed extra capacity due to a strong order book and chose Bystronic. Not only are we proficient with Bystronic technology, but we felt that their rotary axis was easier to operate. Importantly, we have a good relationship with Pullmax who provide us with an excellent service response despite the distance between the two companies."

"The Bystar has had a fundamental effect on Belmar's business in terms of manufacturing times. The company produces a disabled persons lift and its production time has been halved thanks to the rotary axis."

Synrad tip for tight matrix marking

The most common method of marking 2D Data Matrix codes is to raster fill each cell, by steering the laser beam top to bottom, left to right across the substrate. This method works very well until the 2D Code is reduced to fit tighter spaces, such as on high-density circuit boards. Then the diameter of the focused beam fills a larger percentage of the cell so that marked cells grow proportionately larger than unmarked cells. This effect is shown in the photo right. Although the code may read properly when scanned, the Association for Automatic Identification and Mobility standard grade will fail.



To solve this issue, WinMark Pro provides the ability to create 2D barcode cells by drawing an unfilled vector circle. The advantage of this "circle" tool is that the circle radius can be adjusted from 100% down to 1% of the cell's size. Decreasing the circle radius compensates for the diameter of the laser beam at the point of focus. To achieve optimum results in this particular barcode application, Synrad further reduced the barcode circle radius to 75% as shown in photo left.

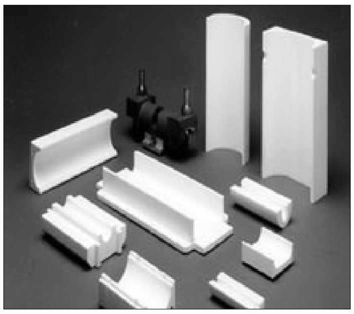
In addition to the normal marking adjustments, 2D Barcode Bitmap and 2D Barcode Circle Radius properties allow the user to 'dial in' marking parameters to obtain consistent marking and verification results. Another important benefit is that "circle" barcodes mark much faster, often reducing cycle times by 30 to 40%.

Spectralon reflectors from Pro-Lite boost laser cavity efficiency

Pro-Lite Technology has announced the availability of Laser Grade Spectralon from Labsphere; a thermoplastic with diffuse, high reflectance which promotes increased powers and improved beam quality when used as a cavity reflector in lamp and diode pumped solid state lasers and lamp pumped dye lasers. Spectralon offers a combination of high reflectance (for example, >99% in the pump band of Nd:YAG at 808nm) and near-perfect diffuse reflectance, providing laser engineers with a solution to the conflicting design objectives of high output energies combined with a high beam quality with reduced hot-spots.

Independent tests have shown that a flashlamp-pumped Nd:YAG laser equipped with a Spectralon cavity reflector exhibits a 30% increase in slope efficiency and output energy compared with the same laser fitted with a ceramic chamber. This gain results from the multiple reflections that take place within the chamber, amplifying the effects of differences in the reflectance of the pumping chamber.

Laser output power and energy are not always the most important considerations for laser designers. For many applications in materials processing and scientific research, the quality of the laser beam is a priority. A laser equipped with a Spectralon cavity provides a significantly enhanced and more predictable beam quality compared with less diffusely reflecting materials as a direct result of the more uniform pumping of the laser medium.


Spectralon Laser cavity reflectors

The laser output parameters that are affected include: improved spatial uniformity; reduced non-symmetrical optical aberrations (coma and astigmatism); and reduced 'hot-spots'. At the same time, a diffuse reflector will suffer from a much reduced risk of parasitic oscillations, allowing the designer to exploit the full output potential of the laser.

Spectralon is a thermoplastic that is machined according to customer-supplied drawings. Pro-Lite welcomes enquiries for customised fabrication of laser cavity reflectors which are produced in the company's dedicated Spectralon machine shop.

Trumpf's UV marker for plastics

Plastic marking with the VectorMark

TRUMPF's new VectorMark compact 6 is a new precision laser marking system that achieves high-quality, high-contrast marks on most plastics and synthetic materials without the need for substrate additives. The marker's 355nm UV wavelength is ideal for applications such as marking electronics where photo-sensitive pigments are generally added to change the materials' dielectric properties.

The frequency-tripled, diode-pumped, solid-state VMc6 laser system marks plastics at higher quality and at faster speed than traditional marking methods. Also, on most plastics the VMc6 achieves a much darker contrast than infrared lasers and without damaging the material or altering the part's surface finish.

The system's UV wavelength offers several advantages in the material processing of plastics. For example, the high-contrast marking occurs through a photo-chemical process, rather than a thermal process. This 'cold marking' ensures minimal heat is introduced to the part and creates crisp high contrast marks without engraving or burning.

The UV wavelength also greatly increases the range of synthetic materials that can be marked with high quality and contrast. Excellent results have been confirmed on a wide range of materials that previously could only have been marked clearly with the addition of photo-sensitive pigments.

The VMc6 is designed for highly efficient and low cost operation. Its vanadate crystal is mounted to a frame that is automatically moved at regular intervals. As a result, wear is spread out over the entire crystal and its life is prolonged dramatically.

In common with other models in the VectorMark compact laser range, the VMc6 is available as an OEM system for integration and as a stand-alone Class 1 workstation.

Photonic Solutions offer ps OPO

Photonic Solutions are pleased to announce that High Q Laser Inc. are offering a picosecond Optical Parametric Oscillator (OPO) LEVANTE.

The completely electronically tuneable LEVANTE OPO system has a wide tuning range from 1550 nm to 2000 nm. With frequency doubling a signal range from 775 nm to 900 nm can be accessed. The output power of the LEVANTE OPO reaches up to 2 W in a 70 MHz pulse train with pulses of 7 ps duration.

The LEVANTE is optimized to be pumped by the picosecond laser oscillator picoTRAINTM from High Q Laser. The OPO is available at two different power levels: 1 W tuneable LEVANTE output power pumped by a 5 W picoTRAINTM and 2 W LEVANTE output pumped by a 10 W picoTRAINTM.

Both pulse train from the pump laser and the OPO are designed to be perfectly synchronized. This makes the system especially suitable for two-colour pump-probe experiments and CARS microscopy. For both applications at the present time, researchers have to employ two actively synchronized ultrafast lasers, a complex and expensive solution. The usage of the picoTRAINTM / LEVANTE combination means higher simplicity and ease of use for users, resulting in optimum cost effectivity and more time for the actual application.


High Q's Picosecond Optical Parametric Oscillator (OPO)

Trumpf's new multi-axis laser cutting centre for 3D and formed parts

TRUMPF's new five-axis laser cutting centre, the TLC CUT 5, made its UK debut at MACH 2004. Designed for 3D and formed parts cutting, the machine is equipped with the TLF CO_2 laser in a choice of powers for 3D cutting and automatic focus adjustment for different materials and thickness. Trumpf's Autolas plus® is provided as standard.

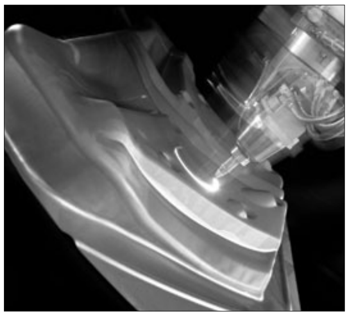
A continuously-rotating C axis and ±100° swivel of the B-axis provides flexibility for processing almost any application on the new machine, including undercuts on spun or formed parts. This improves process accuracy as the operator does not have to stop and reposition the part or laser head. Trumpf's flying-optic design allows the machine to maintain high speeds and tight tolerances regardless of part-weight. The stationary workpiece reduces tool set-up time and requires less complex fixtures and tooling.

This laser cutting centre has a number of ergonomic features including a wide door at the front of the safety enclosure to facilitating access for load/unload; even large aerospace, automotive and white goods components can be accommodated. The machine's design also allows worktables to be accessed from the front and at any time, regardless of where the cantilever may be positioned.

The worktables are designed to support base bridges or fixtures to carry three-dimensional objects. An optional exhaust unit, or the available shop exhaust system, can easily be connected to the worktables.

The new TLCCut 5 5-axis laser cutting machine

The machine's teaching pendant, a handheld programming device, can be used to jog the machine axis for set-up work or to programme or teach the machine.



3D laser cutting of a part

Purex special products

Purex are asked to make a lot of special products and 'one offs'. Two of these are described here and readers may find they have a use for the same or a similar product.

The first product is a back-draught table attached to a Powerflow 2000i fume extractor.

Purex back-draught table

This table is used to draw fumes away from the user, who might be working with powders or hazardous fumes. It could equally well be produced as a downdraught version if required or made smaller / larger.

The other product reviewed here is a containment unit for waste that generates odour and/or hazardous fumes.

The user can empty waste into the bin during the working day without having to worry about odours or hazardous fume.

The Purex extractor filters out the odour and returns clean air to the workplace, and at the end of the day the waste can be disposed of in the usual way.

Purex can adapt this design to customers' specific requirements.

Purex Waste Extractor

Lasermet safety shutter

Lasermet's new 20w laser beam shutters for safety and beam control applications are gravity assisted for fail safe operation and come equipped with a range of user-safety features including LED shutter status indication, options for interlocked safety shutdown or manual operation, remote switching option and a safety latch to prevent accidental beam switch-on.

The LS-range of laser beam shutters are designed to be driven by a safety control system such as the Lasermet ICS-1 laser interlock control system, for use as a means of shutting down the laser beam automatically during unauthorised access, or manually when the beam is not required. They are also available as OEM components for laser or laser product manufacturers.

Pro-Lite's new safety eyewear

Pro-Lite Technology has launched the latest laser safety eyewear style from GPT Glendale, the Encore™. Recognising that laser eyewear is only safe if it is actually worn, GPT designers have made the Encore a comfortable and stylish alternative to a traditional goggle.

The Encore is a wraparound spectacle with a wide field of view that is available in two frame sizes to ensure that a good fit is obtained with all wearers. The larger frame has been tested to offer a comfortable fit over most popular styles of prescription spectacle, while either frame provides a comfortable fit for non-spectacle wearers.

Encore eyewear

New Laser Cutting Fume Extractor

Advantage 1500

Laser fume control specialist, BOFA International Ltd., have just released details for the new Advantage 1500 and 4000 laser cutting fume extraction and purification systems. Designed in consultation with leading laser manufacturers, both systems incorporate Bofa's 2 stage pre filter technology offering long filter life. Chemical and 99.997% HEPA filters are also fitted to ensure that exhausted air is suitable to be re-circulated into the working area.

Automatic flow control comes fitted as standard on the Advantage systems. This allows the user to set the airflow required by the laser cutting system. This flow is then automatically maintained by increasing motor speed as the filters block.

Cost of equipment and ownership were a major consideration throughout the design process. This has resulted in a cost effective, yet fully comprehensive range of systems. More details can be found at w*www.laserfumeextraction.com*

Other news from BOFA is the change of name from BOFA UK Ltd to BOFA International Ltd. This change has come about due to a large number of overseas OEM contracts being won since last years launch of their Advantage range of laser fume elimination systems. Export sales are now well over half of BOFA's annual turnover.

BFi new products

Laser diode controllers

Now available from BFi Optilas Ltd is the Laselec LYDYA range of high power laser diode controllers designed to prolong diode lifetime and optimise performance.

These high power laser diode drivers are available in both CW (150 to 3000 W) and Quasi-CW (driving up to 40 diode bars), with or without TEC controller. A very low overshoot and a number of integrated specific features ensure the user gets the highest lifetime from the laser diodes.

Several options are available, making it an ideal driver for R&D labs, diodes test benches and DPSS lasers manufacturers.

With drivers from ILX and Analog Modules, BFi Optilas offer a complete solution for driving diodes at any power.

M-rated eyewear for ultra short-pulse lasers

LaserVision, a leading manufacturer of laser safety eyewear, filters and curtains have recently released more M-rated laser safety eyewear, this time for ultrafast Nd:YAG lasers. This new rated eyewear is the latest addition to the M-rated eyewear already available from LaserVision.

Currently, LaserVision claim to be the only company in the world able to offer M-rated products for femto- and pico-second lasers, certified to EN207.

Aerotech's new rotary stages

ABR1000

Aerotech's new ABR1000 Air Bearing Rotary Stage is designed to meet the exacting demands of high precision electronics, optical and nanotechnology manufacturing industries

This ultra-high precision rotary stages combine air bearing technology and direct drive, slotless/brushless servomotors to provide unsurpassed error motion, wobble performance and velocity stability for high-throughput production and test applications such as MEMS (Micro-Electro-Mechanical Systems). It is also well suited to other demanding manufacturing and test applications such as wafer inspection/singulation, DVD mastering, disk drive test/servo writing, optical inspection and fabrication.

The ABR1000's brushless, direct drive motor features a patented magnetic circuit to produce high torque with minimal heat which is essential for nanometre positioning applications. The motor's slotless design provides zero-cogging and torque-ripple free performance resulting in exceptionally smooth velocity control throughout its 0 to 500 rpm speed range. In addition it's high acceleration capability, in-position stability and inherently zero backlash is perfectly matched to high throughput electronic manufacturing applications.

With a nominal diameter of 175mm and overall height of just 100mm, the air-bearing surfaces within the low profile design have been maximised to ensure high-stiffness and high axial and radial load capacities of 650 N and 350 N respectively with an overhung loading of 28 Nm (tilt).

A wide range of options available for the ABR1000 include integral wafer chucks, disk chucks and clamps, accessories for ESD (electro static discharge) wafer fabrication and rotary unions for air and vacuum service. Customisation options include rate table and inertial guidance test-stands. In many applications the stage would form a part of fully integrated automation systems supplied by Aerotech and would typically include other positioning stages, motion and machine controls.

New ADRS range

In response to manufacturing industry's demands for cost efficient production systems with increased accuracy, elevated duty cycle and faster throughput, Aerotech have developed a new range of competitively priced, precision rotary positioning stages featuring direct drive, high torque, brushless servomotors with a low profile design that out-performs conventional worm/wheel tables and will minimise stack height related errors.

The new ADRS range takes advantage of Aerotech's brushless, direct-drive servo technology and has a slotless stator with no iron laminations. This eliminates torque ripple and allows "cog free" ultra–smooth velocity control comparable to that of a high quality brushed DC motor. They are completely self-contained with motor and encoder feedback connectors integral within the housing, keeping the overall footprint to a minimum.

A co-axial cladding head with integral sensors

Bert Schürmann[1] and Andres Gasser[2]

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[2]Fraunhofer ILT Aachen Germany

The potential for cladding in process engineering is well recognised. An advantage of processing with laser radiation is that the component is subject to less thermal load, thereby minimising distortion and structural damage. This is particularly advantageous where expensive, delicate components are to be repaired or coated. Such applications range from tool and mould construction, to coating valves and valve seats in car manufacture.

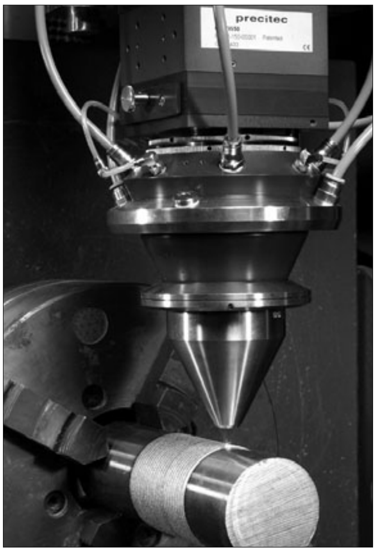


fig 1. The YC50 cladding head in action

In collaboration with the Fraunhofer Institute for Laser Technology, Precitec has developed the YC50 co-axial cladding head shown in figure 1, and has tried and tested it in various applications. Surfaces were coated with the head aligned both vertically and horizontally with strip widths of up to 6 mm and 3D geometries produced with seam widths of approximately 1 mm, as shown in figure 2.

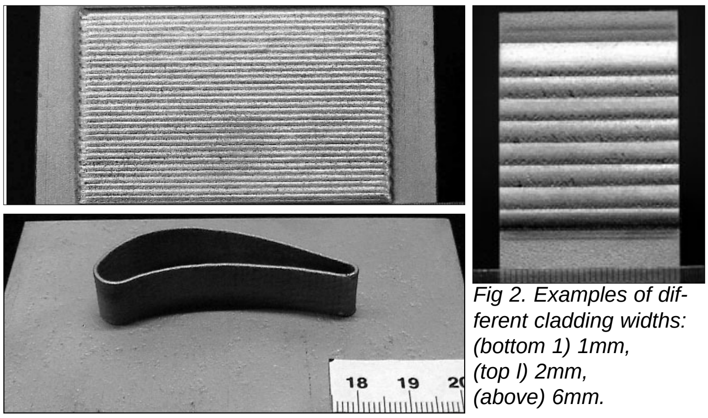


Fig 2. Examples of different cladding widths: (bottom 1) 1mm, (top l) 2mm, (above) 6mm.

During development great emphasis was placed on the simple, safe operation of the cladding head. This resulted in a practical design that enabled laser and powder beams to be aligned in a few minutes without time-consuming cladding tests.

Sensors were incorporated for monitoring both the optical components (the protective window in particular) and the process, so that the cladding head could be used in automated production. The laser beam power coming into the cladding head can also be measured and monitored. It has been demonstrated in countless experiments at ILT that the known benefits of monitoring a deep welding process using optical sensors could also be transferred to cladding. Indeed, the core sensor components inside the Precitec YW50 welding head can be easily converted by the customer for use in the YC50 cladding head.

In addition to monitoring the cladding head components the radiant heat emitted by the process can be registered with an in-built sensor and used for process control.

Repair of a cutting roller that is used in paper processing for example is shown in figure 3. With powder deposit welding, any cutting shape can be deposited onto a roller or an incorrect blade removed and a corrected cutting shape restored with the same outer diameter.

Fig 3. Repair of a cutting roller: (top) cutting roller after two layer coating (bottom) after reworking by a machining process to produce a new blade.

A further consideration is powder efficiency. During cladding a high powder efficiency minimises powder loss and contamination of the machine. Powder efficiency depends on factors including laser power and strip width. For example, 82% was measured when cladding a 2mm wide strip with 309L stainless steel (20 - 53µm powder grain fraction). With increasing strip width, powder efficiency approaches 100%.

Another development aim was to be able to use the cladding head even in extreme positions and as a demonstration of this a surface was coated at ILT in which the cladding head was used in the horizontal position. Even in this extreme position an even cladding result was achieved regardless of the direction. Cladding has also been achieved in difficult-to-reach places by employing greater standoff distances. This is illustrated in figure 4.

In using powder rather than wire leaf, the direction of travel of the YC50 is relatively easier to program because the cladding does not depend on the direction of feed and so the alignment of the cladding head does not have to be adjusted to the direction of the wire feed. Consequently the cladding head can also be used for robot machines.

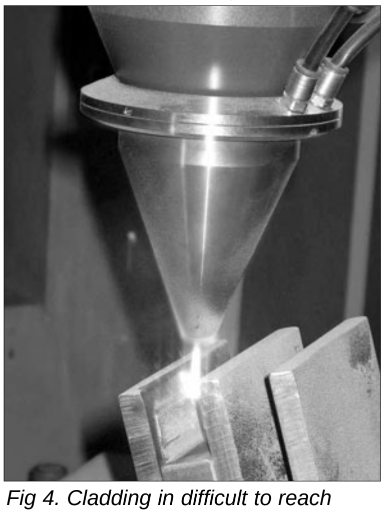


Fig 4. Cladding in difficult to reach places with greater standoff distance

Because of the cladding head's modular construction the powder feed nozzle can also be fitted to a variety of lasers including high power diode and CO_2 lasers This option opens up a large number of uses especially for job shops regardless of the laser systems available.

TuiLaser's excimer lasers fit perfectly for sensitive surface cleaning

Within science and industry there is a growing interest in automated, non-polluting cleaning devices. In particular, laser cleaning units, which have proven successful and have found many new applications, avoid the use of wet chemical reactions and thereby significantly reduce environmental contamination.

Most current laser cleaning units are designed to completely remove the top layer of a surface or the surface itself; for example, their use in the aircraft and car industries for removing paint as a preparatory step for a new sealing of the surface. Another example is the cleaning of stone facades, antiques or other objects suffering from dust and environmental damage.

In addition to a lower environmental impact, lasers offer significant additional advantages over conventional cleaning mechanisms:

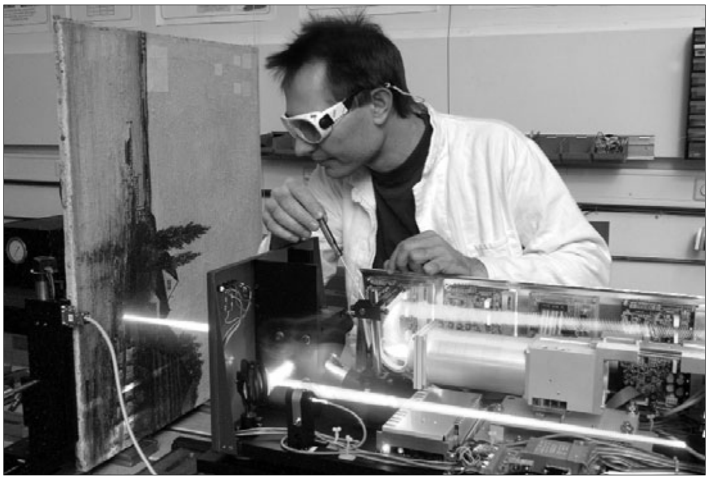
- Soft and sensitive surfaces, such as paint and plastics, may be treated to ablate a few micrometers of the upper layer, removing the adherent impurities without destroying the protecting function of the layer or the underlying structure;
- Substrates used in semiconductor epitaxial or optical coating fabrication can be irradiated to remove surface monolayers of water or oxygen, even under ultrahigh vacuum conditions;
- Toxic chemicals can be cracked and vapourised, medical instruments can be sterilised by removing hazardous surface bacteria;
- radioactively contaminated equipment can be decontaminated.

Current Studies

Scientists at the Helmut-Schmidt-University (University of the Federal Armed Forces) in Hamburg developed a laser cleaning unit designed for automated processing and cleaning of contaminated samples. In particular, dust, chemicals and radioactive isotopes sticking to varnish, lacquer or plastic protective coatings have been cleared away together with a few micrometers thin film of the surface, without destroying the sealing itself.

Whereas for complete removal of a coating it may be favourable for the laser radiation to penetrate more deeply into the material, ablation of only a thin film requires the laser energy to be highly absorbed in the top surface layer. This is best realised with lasers operating in the UV, where paint and plastics show high absorption. With this in mind, the laser-group in Hamburg are working with a KrF excimer laser.

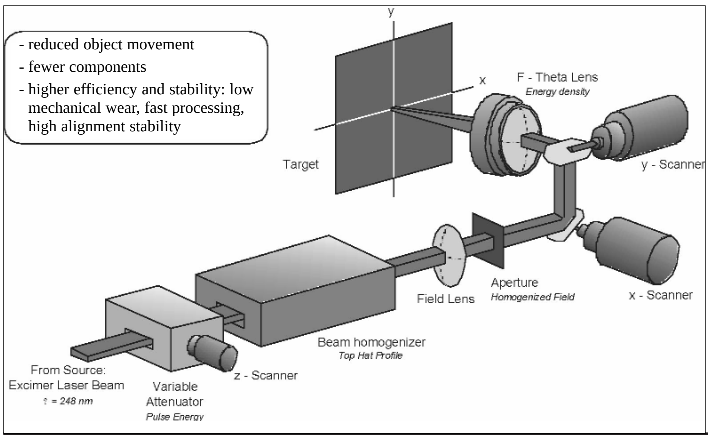
The key elements of the cleaning device are illustrated below. They include a beam homogenizer to provide a 'top hat' laser beam profile for homogeneous irradiation of samples. The beam is focused down to 2x2 mm^2 and directed across the contaminated



Researcher optimises beam former and scanner unit for restoration work

surface by a beam scanner which uses two galvo mirrors. The scan rate is adapted to the pulse repetition rate of the laser (up to 1 kHz) and can therefore achieve fast automated processing. Accurately controlled beam positioning together with the top-hat profile ensures that each surface element receives an almost identical optimum laser fluence.

Preliminary investigations with this prototype show, that after optimising the relevant laser parameters (pulse energy, peak power, PRF, number of pulses and beam profile) efficient cleaning of the surface can be achieved without damage. Computer-control guarantees uniform and continuous cleaning and ease of handling. The unit is equipped with an adapted suction nozzle to dispose the detached surface particles.



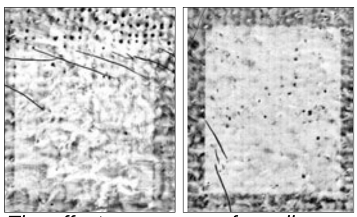
Radioactive decontamination

Tests to simulate the demanding requirements of radioactive contamination were carried out using an isotope ^{152}Eu. This isotope was chosen because it is not radioactive but can be neutron activated to a metastable configuration with a half-life of 9.5 h.

Varnished plastic plates were contaminated with the ^{152}Eu. The result was that at a fluence of 1 J/cm^2 only one or two pulses per position were necessary to reduce the initial contamination level down to less than 5%.

Artwork

As equally effective as radioactive decontamination, art work and antiques can be restored. In the photograph above the excimer laser radiation is directed onto the painting and sweeps the beam across an 6 x 10 cm area. For processing larger areas the painting could be shifted automatically by stepper motor controlled translation units.



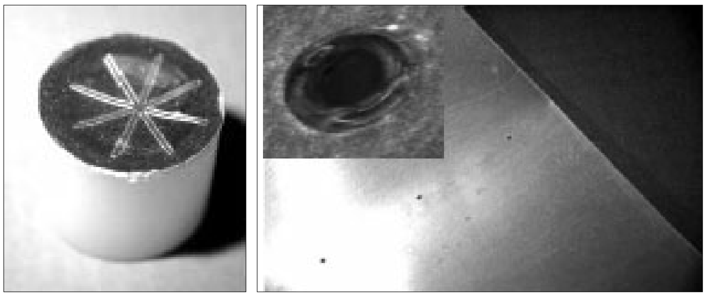
The effect on an area of an oil painting of (l) 1 pulse on painting surface, and (r) two pulses. The fluence was 350 mJ/cm^2 and the spot size = 2 x 2 mm.

The figure above shows a small section of an oil painting irradiated with one and two pulses per position. This example demonstrates the well controllable, homogeneous treatment and the effectiveness of excimer laser cleaning of art objects. The processed area is seen to have an appealing and bright appearance, showing the auspicious potential for future excimer laser cleaning applications.

Rofin Systems for Polymer Foil Processing

You are desperately trying to open a pack of peanuts and you knock the coffee cup of the person sitting next to you. Or you buy freshly packaged salad in the supermarket, which is already decaying the next day. Does this sound familiar?

These are examples where the quality of the packaging is almost more important than the actual product. Lasers open up many possibilities to further optimise the quality of packaging: selective weakening of single packaging layers (easy opening) or creating tiny perforation holes for ventilation (easy ventilation).



Examples of polymer foil processing by laser: (l) laser scribing for easy opening of a medical device package; (r) Laser-perforated polymer foil. The melted edge of the holes (insert) avoids micro-crack formation.

Easy Opening – Selective Micro Weakening

Almost all packaging foils are multi-layer structures. Each layer has a different function: PET is for stiffness and aroma preservation, PE for sealing and tear-proofing, PP for vapour impermeability, Aluminum for general light hermetic sealing and paper for stiffness. Easy opening means selective weakening of the mechanically supporting layer without otherwise affecting its functionality.

Mechanical scribing and punching methods are fast and simple, however, they cannot differentiate between the individual layers. The result may be that either the mechanically supporting layer is not completely separated (scribing depth too low) or the light or humidity hermetic layer is harmed (scribing depth too high). For some time research has taken place to find a dependable method which selectively acts on the different layers. Laser structuring with CO_2 lasers offers a new solution benefiting from the different optical properties of each foil layer.

Polymer, metal and paper layers show significantly different absorption and reflection reactions in the wavelength range of CO_2 lasers (9.4 to 11 µm). Most of the polymer materials in the packaging industry, such as PET, PS or OPA, absorb the laser beam very efficiently at the typical wavelength of 10.6 µm, resulting in the polymer layer being completely ablated in the small scribing area. A few polymers however, such as OPE or even LLPE transmit the central 10.6 µm wavelength, so in a OPP-OPE foil structure (often used for detergent packaging) the PP-layer can be structured selectively without affecting the other layer.

At low power, Aluminium layers act as perfect mirrors for the CO_2 laser beam. So, in the classical PET-Al-PE mix used in food packaging the selective absorption of the CO_2 laser allows the complete ablation of the mechanically supporting PET layer without affecting the two layers below.

Depending on the application, fixed optic or scanner optic systems may be used for structuring. In most cases processing is done on web shaped material, in which case the laser with fixed optics is positioned exactly above the web. For production reasons, many bags and pouches require structures scribed across the web, and lasers with fast scanning heads are used to compensate the web speed and can apply almost any structure even at high speeds with on-the-fly technology. Also semicircles or diagonals of opening structures on the edge of a bag may be scribed.

Typical scribing speeds are 10 -15 m/s, depending on material and technology applied. This leads to material speeds of 100-250 m/min. The minimal scribing kerf width is approximately 100 µm with fixed optics and 200 µm with scanner optical systems.

<u>Process-Related Advantages of Laser Structuring</u>

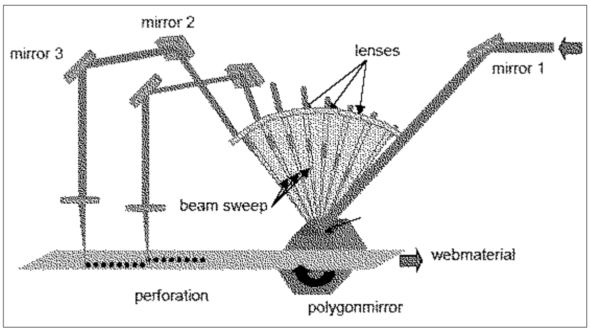
There are a wide range of typical applications where laser-structured 'easy openings' is used. Tiny traces of laser structuring can be found on the packaging of power-muesli bars, animal food, detergents and even cosmetics and medical products.

For these applications, lasers offer a number of advantages over traditional mechanical methods, such as rotating knives or barrel punches. These include all the benefits of non-contact processing (i.e. no wearing of tools, excellent reliability at high process speeds), structuring of single layers individually without affecting other layers, easy integration into industrial high-volume production. Laser technology allows considerable freedom in packaging design, opening up new possibilities for easy opening and the fine cutting means that mechanical weakening is slight and almost invisible.

Easy Ventilation – Micro-Air-Holes

The shelf life of perishable food has great influence on their economic value. Its freshness requires air ventilation and preservation of humidity. New laser perforation technologies open up new possibilities to make micro-holes into packaging selectively. The right size and number of holes can guarantee air circulation and preservation of humidity.

Principal set-up of laser perforation of web-shaped material



For perforation, a pulsed CO_2 laser ablates a micro hole through all layers. Lasers with optimal beam quality are used with laser power in the range of 100 to 2000 W, depending on the material. As shown in the figure above, the perforation pattern is generated via polygon mirrors for high-volume production or fixed optics with synchronous pulse triggering. This procedure only allows perforations in lines, but up to 16 lines can be made in parallel with the laser system on a single web. In one line, up to 50 holes/cm can be perforated, allowing not only for ventilation but also for easy-tear applications. Special optical set-ups like the patented variable pattern generator (VPG) allow one to choose the distance between holes flexibly in one line (distance between holes 4mm-500mm). Typical hole sizes in foils without aluminum layers range from 60 to 400 µm. Aluminum-coated foils require considerably more laser power, and the thermal input is correspondingly higher.

For perforating polymer foils, laser technology competes particularly with needle technologies and flame perforating. The advantages of the laser technology are smaller, crack-proof holes, due to the micro melted edge. Again, with lasers, there is no wearing of tools in comparison to needles where blunting or even breaking can occur. Due to the polygon technology and the high laser PRF, it is possible to perforate holes at extremely high web speeds (e. g. 300 m/min).

Rofin laser systems for the packaging industry

StarScribe Easy

StarScribe Easy is a mobile turnkey quasi-cw CO_2 laser (100 W max) designed for scribing applications in the web transport direction with continuous or interrupted lines. Main applications are scribing and perforating of packaging materials. The flexible articulated arm allows fast beam positioning. A double-head version can also be provided.

StarScribe Easy

StarScribe WD

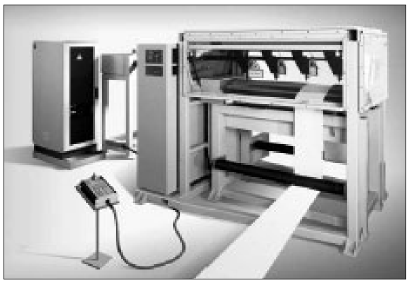
StarScribe WD (web direction) is a high performance integration module, which can be integrated as a CO_2 Class 1 laser product into existing the slit-cutters of all established manufacturers. The 2 kW maximum output can be configured with up to 8 processing heads, allowing simultaneous trace scribing. If desired, the system can also be used for foil cutting. Both continuous and interrupted lines, which are synchronous to imprints, can be applied. Maximum processed web width is 1600 mm.

StarScribe CW

The Rofin StarScribe is a Class 1 laser product containing a 1 kW CW CO_2 laser. It is designed for high-volume applications including flexibly scribing structures that are not parallel to web direction. Main applications are bags and pouches, which, due to their special production and filling method, require this set-up. Up to six CO_2 lasers with fast scanner heads (working range 1m x 1m) have been integrated into an existing winding system, not only for scribing but also for cutting flexible structures.

Perfolas Film

The Rofin Perfolas Film is a Class 1 laser product containing a CO_2 laser with a maximum power of 2 kW. It is particularly designed for high volume production lines, for perforating packaging foils. The majority of applications are for easy ventilation, but it can also be used for easy-opening applications. The core of the system is the polygon mirror set-up described earlier, which splits the laser beam into several processing heads. Circular perforated holes can also be produced at high web speeds of up to 600 m/min. The maximum web width is 1100 mm. Up to 16 parallel perforation lines can be applied in the web direction.



PerfoLas Film designed for ventilation applications in the packaging industry. With its 250,000 holes per second the main application use is in high volume production of foils.

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Web statistics: 2800 hits per day (average for April to June 2004)

KW Fibre Lasers for material processing markets

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Fibre lasers from IPG Photonics have achieved multi-kilowatt output power levels. Within the last two years, the Ytterbium fibre laser at1 µm wavelength have passed rigorous performance and reliability tests in industrial, laser materials processing environments. In the same period of time, IPG Photonics have scaled the laser power at 1 µm wavelength from a few hundred watts up to 10kW and have dramatically improved the beam quality comparing to other solid state lasers (including disk lasers) by using an all-fibre format proprietary fibre combining technology. A similar approach allows to realise fibre lasers with kW power levels in the range of eye-safe wavelengths, such as 1.5 and 2 µm, previously inaccessible with industrial lasers.

Common technology to all IPG fibre lasers is the use of highly reliable single-emitter semiconductor diodes with expected lifetimes greater than 100,000 hours of continuous or direct modulation operation. This approach allows IPG to manufacture single mode ytterbium (M^2<1.1) fibre lasers with up to 600-800 W of output (1kW is under development). Each of these lasers are based on a universal platform – a fusion-spliced, diode-pumped fibre doped with rare earth ions. Yb doped lasers operate at 1.06 µm, Er at 1.55 µm and Tm at 2 µm. The Yb kilowatt units can now be supplied with powers up to 20kW.

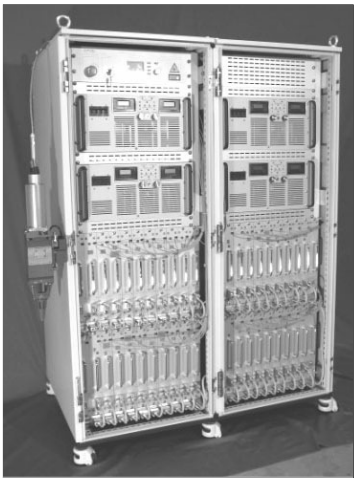
The technology involves combining multiples of the highly reliable (up to 200,000 hours lifetime) and wall plug efficient 200-300W single mode lasers in one output fibre. In the figure above, for example, a 10 kilowatt system with a 300 micron diameter output fibre is shown: the laser delivers a beam parameter product of ~12mm mrad. An enhanced 5.5kW Yb laser recently developed provides beam parameter product as small as 4mm mrad, which enables such applications as remote welding and cutting with stand-off distances of 1 to 1.5m.

The use of efficient pump diodes leads to a high overall electrical to optical wall plug efficiency of 20 to 25%.

The fibre format of the laser cavity and its parallel architecture dramatically reduce the sensitivity of the laser to back reflections and open up the possibility of high-performance processing not only of steels but also of such materials as Aluminum and Titanium.

Other advantages derive from the fibre integrated platform; such as no need for alignment, maintenance and constant monitoring of the beam quality, minimum factory floor space.

Outlook



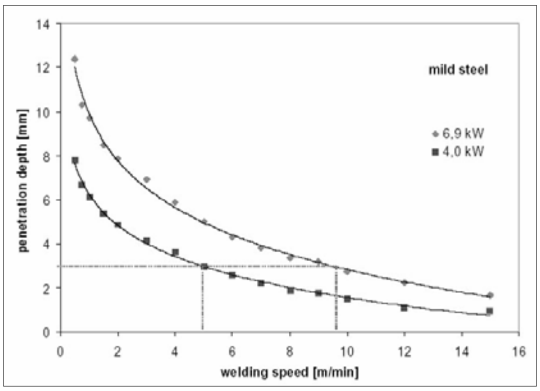
A 10.2 kW Ytterbium Fibre Laser with a 300 micron delivery fibre

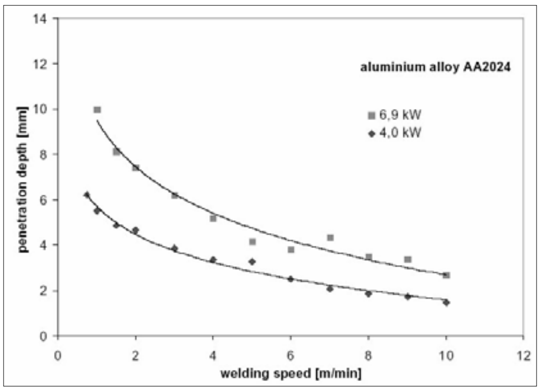
IPG introduced the first 1kW fibre laser unit in May 2002, followed by a four kilowatt laser in November 2002. The ten kilowatt laser was released in March 2003.

The first kilowatt units were installed in a variety of laboratories, selected industrial users, and integrators in Europe, Asia and the USA to gain a rapid evaluation and experience of fibre laser operation and handling at these record power levels. These installations have provided valuable feedback and have allowed critical improvements to be made in the robustness of the fibre delivery cables, in industrial control interfaces and in safety. Data on a wide range of applications has shown that the processing results in both welding and cutting not only match but in most cases exceed the quality and speeds of conventional YAG, and in some applications of CO_2 lasers also.

As of May 2004, the IPG has supplied 28 multi-kilowatt units for production applications in the US, Europe and Asia. The majority of the systems are being utilised in welding applications in the automotive and shipbuilding industries, with several also being employed for cutting and powder deposition.

An obstacle to be overcome is the tendency of engineers and industrial managers to choose the conservative, proven technology and links. However, this tendency is changing thanks to the successful trials and installation of 4 to 10kW systems at the world-renown centres of Bremen (BIAS, Germany), EWI (USA), TWI (Sheffield, UK), as well as at a number of top industrial companies. The recent supply and commissioning of a 7kW power fibre system with multi-port energy share to TWI has already shown a number of advantages of the fibre platform and is initiating joint projects at TWI which are poised to promote a widespread adoption of kilowatt-class fibre lasers in materials processing markets.





Some examples of laser welding with a high power fibre laser

Integrating spheres in laser beam power measurements

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Lasers that feature high powers, large beams, extended source sizes, high divergence or dynamic beam displacement (or any combination thereof) present a significant challenge to those wishing to determine their power in an accurate, repeatable fashion. The integrating sphere provides an elegant solution to these problems and offers an increased accuracy alternative to regular power meters used with 'difficult to measure' sources such as discrete laser diode emitters, laser diode stacks or bars and fibre-delivered beams.


courtesy of Labsphere

Compared with a bare photodiode detector, the integrating sphere captures the full beam and reduces the effect of the non-uniform spatial response that many detectors exhibit. Sphere response is polarization insensitive and serves to attenuate the optical beam onto a photodetector, allowing much higher power sources to be measured with sensitive, fast response silicon, germanium or InGaAs photodiodes. .

Detector limitations

The total radiant flux ("power") of a laser beam is often determined using a photodetector with a calibrated responsivity; a photodiode for most low power applications in the wavelength range from the UV to near IR (200-1800nm), a thermal (calorimeter, thermopile) detector for high power beams.

Photodiodes have several significant drawbacks: source to be measured must be of a low enough power not to saturate the diode and high divergence sources must be positioned very close to the detector to avoid overfilling of the relatively small input apertures. Calorimeters are used with higher power lasers but suffer with a relative lack of sensitivity. Whereas most photodiodes have a sensitivity of a few picowatts, a typical 10-20mm aperture calorimeter will exhibit noise levels that limit their use below a few milliwatts, while a typical 50mm aperture thermal detector can only be used above about 200mW. It is for these reasons that we turn to the integrating sphere as a simple solution to often challenging problems in optical radiation measurement.

The integrating sphere

An integrating sphere is a hollow, spherical chamber coated internally with a high reflectance coating that exhibits lambertian (i.e. diffuse) reflectance. Spheres are used either as directionally-insensitive collectors of light (combined with photodetectors) or as sources of uniform light (when internally illuminated). They are used to record the total radiant flux (in watts) of laser sources operating with wavelengths in the spectral range from 200nm to greater than 20µm. The radiation entering the sphere is spatially integrated, such that at almost any point on the sphere surface the light intensity measured by a photodetector mounted on the wall of the sphere is the same and directly proportional to the total flux from the light source. Because the photodiode is uniformly illuminated by the sphere, the effect of any spatial non-uniformity in the detector's response is greatly reduced. The uniform but random distribution of optical radiation within a sphere also serves to eliminate the effect of any beam polarization on the detector reading.

The simple integrating sphere shown in figure 1 has an input port through which the laser beam enters, and a second port on which the photodiode is mounted. It is common for the input and detector ports to be located with a 90 degree separation and for an internal baffle (or screen) to be fitted to the sphere to prevent direct illumination of the detector by the source. The baffle is coated with the same material as the integrating sphere wall.

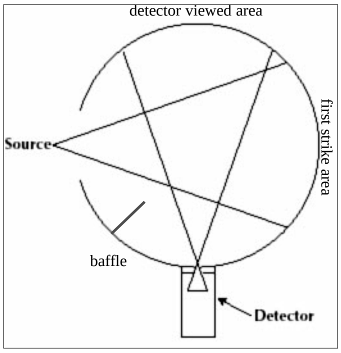

Figure 1. Simple integrating sphere

It follows that if more than one detector is mounted at the sphere wall, each will see the same light level. This principle is used to make dual-band sphere radiometers that use a silicon detector for making power measurements at up to 1100nm and either a germanium or InGaAs detector for wavelengths between 800-1800nm. Furthermore, a connector for an optical fibre can be mounted on the sphere wall which serves to couple a small amount of light to an optical spectrum analyser for source spectral analysis.

The ideal sphere has a coating with a very high level of reflectance. Most commercially available coatings for integrating spheres have nominal reflectance levels between 94 and 99%. The higher the reflectance, the greater the sphere throughput onto the photodetector, to the benefit of detector sensitivity and reduced system signal-to-noise. It is important that the "loss" of optical power that a sphere introduces is allowed for in the calibration of the photodetector mounted on it; erroneous readings will be obtained if the detector's own responsivity is relied upon.

The size of an integrating sphere is primarily chosen according to the power of the source and the size of the beam. For example, if a 25mm diameter input port is required the sphere diameter would typically be 100mm or more so as to maintain the open port fraction below 5% of the entire sphere wall area for the geometrically uniform collection of light. Furthermore, the larger the sphere the greater the attenuation of the input beam, so a larger sphere can be used for higher power beams. If we consider the case of a silicon photodiode that would have a dynamic range from about 1pW to 1mW, a sphere with a 1000:1 attenuation factor would allow the same photodiode to be able to record beam powers from 1nW to 1W. The exact level of sphere attenuation at a given wavelength is a function of coating reflectivity, sphere diameter and open port fraction, while the signal received by a photodiode will also be governed by the detector's active area and the solid angle field of view into the sphere. These parameters can all be selected to arrive at a sphere/detector combination with the desired level of attenuation for the type of sources it is required to measure.

Ideally, coatings should have a wavelength-independent reflectance. For most applications in the 250-2500nm range, coatings based on barium sulphate are commonly used. For superior reflectance, coatings based on sintered PTFE materials are available. For measurements with sources in the 1-20µm range, electroplated gold coatings are used. Water-cooled, gold coated integrating spheres are available for use with high power CO_2 lasers..

Enhanced sphere design for divergent sources

The demands of measurement accuracy and repeatability dictate that there is no such thing as a "one-size-fits-all" sphere. To function correctly, a sphere for total flux measurements must be designed to take account of the size, position, divergence, any displacement and the power levels of the laser under test.

The simple sphere model in figure 1 address the basic problems associated with using bare photodiode detectors with high power, divergent or extended area light sources. However, the signal from a photodiode mounted on a simple sphere can still exhibit a significant dependence on the position, direction and divergence of a light source. For example, the area of sphere wall opposite the input that the incident beam illuminates (known as the first strike area) acts as a virtual source and ideally this area should also be screened from the detector's field of view. For collimated beams, avoiding this overlap of illuminated and viewed areas is fairly straightforward, but for sources of high divergence, or sources of variable divergence or beam pointing, this design objective is very challenging.

A second baffle can be used for this purpose; however, baffles introduce spatial non-uniformities into the sphere response. Research conducted at Labsphere has shown that a sphere can be designed for performing more accurate and repeatable measurements on divergent and other sources without the need for baffles. The Labsphere laser power measurement sphere (LPM-040-SF) features an innovative design that positions the photodiode detector in a non-radial position just below the input port of the sphere. The photodiode is recessed and constrained to view a small area of sphere wall just above the entrance port, as shown in figure 2. As a consequence, the photodiode can see neither direct light nor indirect radiation from the first strike area for any beam that enters the sphere within an 80 degree cone angle. The restricted view from the photodiode into this sphere also serves to extend the power levels that this sphere can measure, with attenuation of approximately 10,000:1.

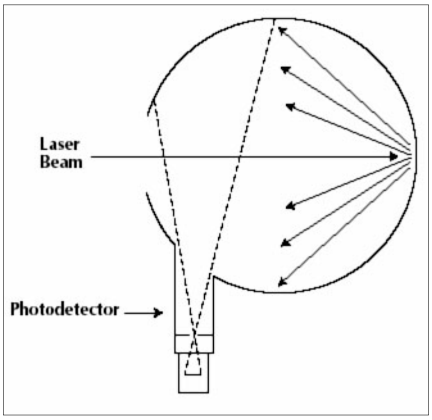

Figure 2. Baffle-free sphere design for divergent source measurements

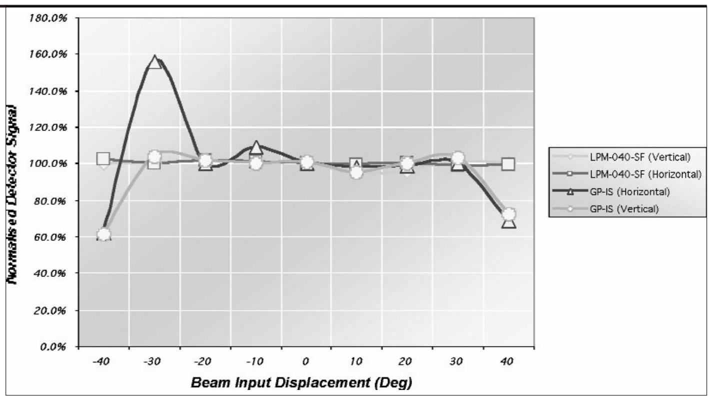

Figure 3. Comparison of integrating sphere spatial response. The GP-IS is a general purpose integrating sphere with baffle, the LPM-040-SF has the photodiode detector in a non-radial position just below the input port of the sphere.

The spatial response of a typical "general purpose" sphere was studied by illuminating the sphere with a collimated, low power laser beam. A silicon detector was fitted at the sphere wall at 90 degrees separation from the sphere input and with a baffle providing line-of-sight screening between the two. The change in detector signal was recorded as a function of angular displacement of the laser beam in both vertical and horizontal planes. The results are shown in Figure 3. For elevations of up to ± 20 degrees in both X & Y directions, the general purpose sphere was seen to be relatively insensitive to the direction of the source. At >20 degrees however, the area of sphere wall first illuminated by the beam begins to be "seen" by the photodiode, and thereafter, causes large deviations in the measurement data. The baffle also contributed to the non-linear response of the sphere. This particular sphere should therefore not be used with sources that exhibit a divergence or beam displacement of greater than ± 20 degrees to ensure acceptable measurement accuracy and repeatability.

The enhanced sphere was subject to the same tests described above and the results are also plotted in figure 3. The LPM sphere was shown to be much less sensitive to input beam variations of up to ± 40 degrees. For sources with solid angle beam divergence of up to 80 degrees, the LPM type sphere with restricted detector field of view and no baffles will provide higher accuracy results than would be obtained from a typical general purpose integrating sphere.

Further reading

Readers interested in learning more about the science and application of integrating spheres in optical radiation measurements can download the guides to "Integrating Sphere Theory & Application" and "Integrating Sphere Radiometry & Photometry" from the Pro-Lite web site (www.pro-lite.uk.com).

Robert Yeo (38) is a physicist and graduate of the Essex University Masters programme in Laser Applications. Robert entered the laser industry in 1987 when he joined Oxford Lasers before moving to Optilas Ltd in 1989. In 1996 he formed Labsphere Ltd, the UK arm of the US manufacturer of integrating spheres. In 2000, Robert joined Spectron Laser Systems Ltd where he worked until forming Pro-Lite Technology LLP in September 2002 together with his former colleagues from Optilas, Ian Stansfield and Peter Blyth.

Preventing back reflection in CO_2 Laser Systems

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If you have ever encountered rapid and sometimes unexplained power stability fluctuations in your CO_2 laser during laser processing, there is a reasonably good chance that the cause of the problem was a back reflection of the incident laser beam from the workpiece and into the laser cavity. When cutting materials such as stainless steel, brass, copper or aluminium, powerful back reflection can take place. This can have an adverse impact on the stability of the discharge and in some cases it can result in damage to the cavity optics.

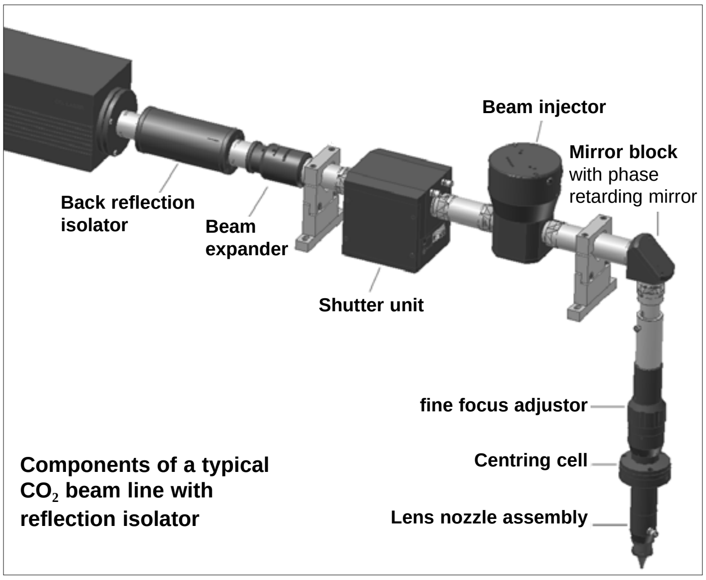
"If you damage the cavity optics of one of our 300 W sealed lasers, then you are looking at a return-to-base issue," said Keith Clark, Engineering Director at Rofin-Sinar in Hull. "If that means putting some optical kit in front of the laser then it must stack up financially. It is a bigger problem on multi-kilowatt systems where, if any cavity instability is detected, the discharge is shut-off to try and prevent expensive damage. If you can contain your back reflection, you can keep your process running."

As Keith points out, "the problem of back reflection is not restricted to highly reflective metals like aluminium. Other materials are quite capable of springing surprises. For example, when glass starts to go molten in mid-process, you start to see a change in the reflectivity of the glass. A globule of glass can become a perfect reflector of a low power CO_2 beam; not only that, the curvature of the globule can actually help to focus the beam back into the system."

The range of Rofin lasers manufactured in Hull is currently up to 300 W, although a 600 W version will soon be unveiled. The solution to the back reflection problem being considered by Keith makes use of a Phase Retarder unit in the beamline, together with a Reflection Isolator, as illustrated in the figure.

The Phase Retarder unit is designed to convert the linearly polarised laser output beam into a circularly polarised beam. Its primary use derives from the discovery in the 1970's that the efficiency of laser cutting is polarisation dependent: this discovery led to the use of circularly polarised radiation to maintain equal cut speed and quality in all directions[1]. In the present context, however, it serves a further purpose. Any of the beam back-reflected from the workpiece will still be circularly polarised, and when it passes through the Phase Retarder unit a second time it is reconverted into a linearly polarised beam, but at 90° to that of the out-going beam. The Reflection Isolator contains Brewster plates that transmit up to 100% of the outgoing laser beam but reflect the orthogonally polarised, back-reflected component out of the beam path, where it is safely dumped.

An alternative to the Reflection Isolator is called a P-Polarisation Absorbing Mirror. As with the Reflection Isolator, it is placed in the beam path before the Phase Retarder. It strongly reflects the out-going S-polarised[2] beam and strongly absorbs the returned P-polarised[2] beam. However, it must be stressed that both methods of controlling unwanted back reflection rely on the combination of a device to transmit or reflect



Components of a typical CO_2 beam line with reflection isolator

the outgoing linearly polarised beam and a device to convert that linearly polarised beam (i.e. the plane of the electric field of the laser radiation is constant with time).into one which is circularly polarised (i.e. the plane of polarisation rotates in a predictable way, once each wavelength).

The Brewster plates used in a Reflection Isolator are uncoated and are therefore capable of withstanding relatively high power. The plates are made from ZnSe, which has a Laser Induced Damage Threshold (LIDT) of 6 kW per mm of beam diameter in its uncoated and polished form. This means that it is possible to eliminate back reflections in relatively high power systems with a Reflection Isolator, so long as there is sufficient water-cooling applied to the beam dump.

Reference

ULO Data Sheet 'Principles of Back Reflection Isolators and Attenuator Devices' *http://laseroptics.umicore.com/am4/docs/pdf/tdsulo_79_80.pdf*

Footnotes

1 The common practice of using circularly polarised beams is a compromise. If a linearly polarised beam is used and the cut is in the direction of polarisation, the cutting efficiency is relatively high. If the cut direction is at 90° to the direction of polarisation, the efficiency is relatively low.

As an alternative to the simplicity of using a circularly polarised beam it is possible for some applications to steer the orientation of the linearly polarised light so that it is always in the direction as the cut. This removes the need to compromise and improves the speed and quality of the cut.

2 The terms S- and P- polarisation stem from the German words Senkrecht (which means perpendicular) and Parallel (which has a parallel meaning in English).

High power remote welding

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Laser beam welding has partially replaced many conventional welding technologies in the German automotive industry. For example, since the first use of lasers in car body roof welding, resistance spot welding has often been replaced by short laser stitches with the advantages of higher flexibility, higher processing speed and (usually) single-sided accessibility. Meanwhile, new car series are planned and designed to optimise laser usage and the total laser joint length in the body in white has increased to more then 70 m per vehicle.

Though the laser welding process itself is optimised with regard to processing speed and welding performance, time lost in repositioning the beam for the next weld seam can greatly increase the overall cycle time for robot-delivered beams. However, new technologies such as remote welding offer much greater beam positioning speeds, reducing the cycle time to almost the pure welding time.

Remote welding technology

Remote welding is a highly efficient laser process. In its common form a high power CO_2 laser is used with scanner optics to deflect the beam. The use of long focal length optics (1500mm in this study) is essential to creating a large working volume and is a key distinguishing feature of the process.

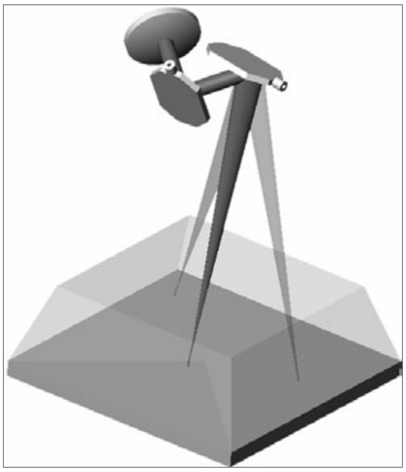


Fig. 1: Optical schematic of a post-objective scanning system for remote laser welding , illustrating the shape of the working area (source Trumpf Lasertechnik)

The working area is restricted by the maximum deflection angle and the focal length. As shown in figure1, the resulting working area for stationary remote systems has the shape of a truncated pyramid. By adding more axis of movement, the shape and working area can be extended.

Equation 1 shows how the focal length *f* of the focusing optics is restricted by the required minimum spot radius r_f, wavelength λ, beam quality M^2 and the beam diameter *D* at the focusing optics.

$$f = \frac{1}{M^2} \cdot \frac{\pi}{\lambda} \cdot \frac{D \cdot r_f}{2} \qquad (1)$$

Referring to this equation, one of the key developments that has made remote welding a reality is the availability of high power lasers with excellent beam quality (i.e. low M^2). Today we have CW laser sources with powers up to 6 kW with $M^2<2$, which allows focal lengths of more than 1000 mm.

Fig. 2: Scanner welding system with 6 kW CO_2 laser Source: Trumpf Lasertechnik)

The system used in this study was the stationary remote welding system of Trumpf Lasertechnik shown in figure 2. The system uses a 2-mirror galvanometer scanner for beam deflection and the focussing and vertical beam positioning is done by a mirror optics travelling on a high dynamic direct linear drive. The beam deflection is limited to an angle of 22° in both directions which, taken with a focal length of 1500 mm, produces a pyramid-shaped working area of 800 mm in length and width. The height of the truncated pyramid is limited to 250 mm by the maximum travel of the focussing mirror along the beam axis. Within this working range, the beam can be focussed in each position to a spot radius of r_f= 250 µm. The maximum positioning speed between two points in the working area is about 700 m/min with a position accuracy of d_x= ±0.1 mm.

Remote welding has several advantages over conventional welding technologies such as resistance spot welding. While the processing time of resistance spot welding or robot guided laser welding is often very high compared to the pure welding time, remote welding can eliminate most of the non-productive times. Especially for workpieces with numerous welds distributed over the workpiece, the positioning time takes up to 80% of the cycle time. Moreover, with remote welding the welding sequence can be optimised for minimised distortion rather than for shortest distance from stitch to stitch.

As a replacement for resistance spot welding the processing time could be decreased even more since two resistance spots can be replaced by one laser stitch with a length of about 40 mm, which corresponds to the same fusion area.

Besides reductions in the cycle time, other economic benefits can be achieved by reducing the footprint of the system. A single remote system can carry out the same welding task as numerous resistance spot welding robots.

Another advantage of remote welding (laser welding in general) is single sided accessibility. For example, the laser welding of sheet to profiles or sheet to hydro formed parts for space frame structures in the automotive industry enables new designs and constructions. Laser welding also allows the shape, direction and length of the weld to be optimised for maximum strength and stiffness.

There are also, of course, potential disadvantages of remote welding. Due to the absence of linear axes which position the laser beam usually perpendicular to the workpiece surface, the angle of incidence of the beam will change with the position of the weld or workpiece within the working area. Furthermore, the potential for supplying shielding gas and filler wire to the weld is much reduced. These issues are addresses below.

Welding performance

Welding of steel

The most significant characteristic of remote welding is the dependence of the angle of incident on position within the working area. This leads to an inclined weld seam cross section, so we have to distinguish between the penetration depth (measured in direction of the laser beam) and the welding depth (measured perpendicular to the workpiece surface), as illustrated in figure 3.

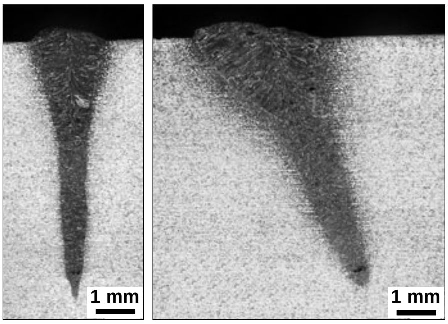


Fig. 3. Two examples for welds in different regions of the working area. The penetration depth is almost the same , but the welding depth is different.

An example for the welding performance in the centre of the working area and at maximum deflection in one direction for bead on plate welding is given in figure 4. The results show the reduced welding depth of the inclined beam, but the reduction decreases with increased welding speed. Also, for these results at maximum laser power, welding depths of more than 6 mm can be achieved.

Due to the high beam quality of the laser and the long focal length, the focused beam has a Rayleigh length of 11.2 mm, which makes the control of the focal position relatively simple. This is important especially for processing of 3-dimensional workpieces with edges and curvatures.

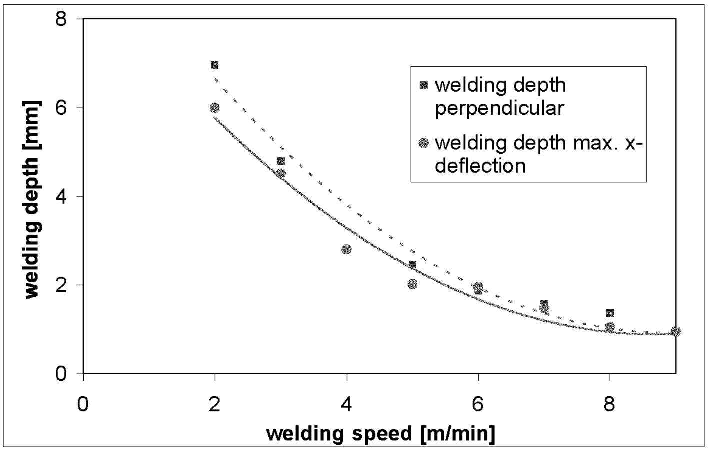


Fig. 4: Welding performance of the system. P=5.1 kW, mild steel s= 10mm

Welding of aluminium

To date, deep penetration welding of aluminium with large field remote welding systems and focal lengths of more than 1000 mm has not been possible due to insufficient power density at focus. With a laser power of more then 5 kW at the workpiece in a high quality beam this becomes possible. Figure 5 shows the dependence of the welding depth on the welding speed. At a welding speed of v= 5 m/min full penetration in a 4 mm plate could be achieved equally well for AA5xxx and AA6xxx alloys.

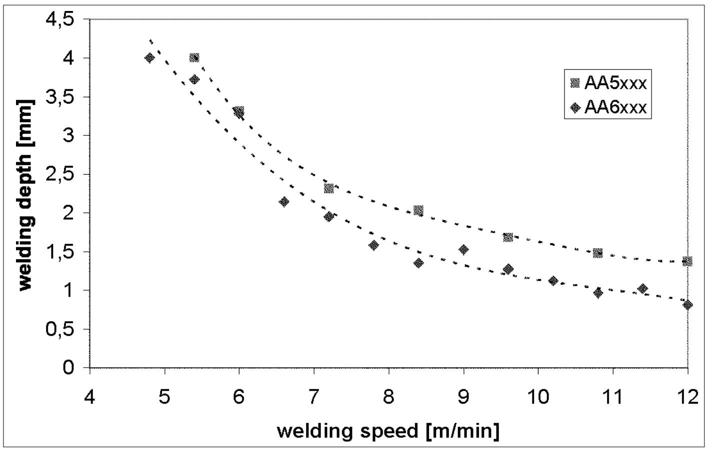
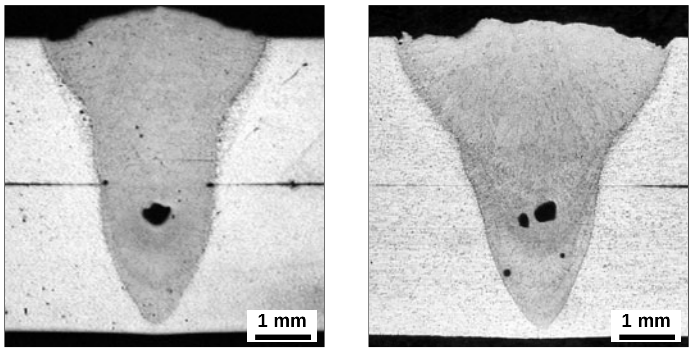


Fig. 5: Dependence of the welding depth on the processing speed for welding on 4 mm Al sheet at P= 5.1 kW

The quality of the welds in aluminium is poor compared to close proximity welding due to the absence of filler material and a sufficient and uniform covering of shielding gas. Without filler wire, the tendency to hot cracking for AA6xxx alloys is very high, however under certain restrictions remote welding of aluminium is applicable. Figure 6 shows examples for overlap welding with a perpendicular incident beam .



Overlap joint in 2 + 2 mm AA5082 alloy, P=5.1 kW, v= 5.5 m/min, He 40 l/min

Overlap joint in 2 + 2mm AA6xxx alloy, P=4.5 kW, v= 3.5 m/min, He 40 l/min.

Fig. 6: Examples for remote overlap welding of aluminium

Shielding gas

For CO_2 laser welding, a shield gas (usually helium) is required not only to protect the melt against oxidation, but also to stabilise the process by preventing plasma shielding. The suppression of the laser induced plasma is normally achieved by directing a stream of helium into the interaction zone.

In the automotive industry many applications are carried out without the use of shielding gas if there are no requirements to the protection against oxidation. For remote welding, one way to avoid excessive use of expensive gases is to blow compressed air over the workpiece to eliminate the effects of the plasma.

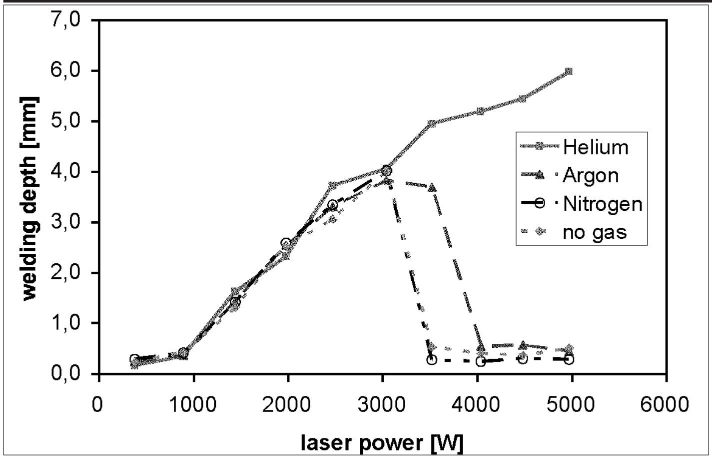


Fig. 7: Plasma shielding at high laser power; v=2 m/min, mild steel.

The influence of the processing gas at high laser power on the welding result is shown in figure 7. Up to a laser power of P= 3 kW there is no difference in the welding performance whether gas is used or not, at least as regards welding depth. At about 3 kW, corresponding to $1.5 \cdot 10^6$ W/cm^2, only with helium can the plasma shielding be suppressed. However, with remote welding there is no working head that can be used to supply the shielding gas.

To deliver the shield gas by using blowers to cover a large zone would lead to an insufficient gas supply despite high gas consumption. For these reasons the shielding gas has to be delivered over short distances; for example, by nozzles mounted directly at the welding zone to cover a special limited welding area. One possibility is the integration of the gas supply into the workpiece clamping device. However, for applications with numerous welding stitches, the expenditure of gas supplying equipment increases with the number of welds.

For short welds, conventional tube shaped nozzles can be used to direct a gas stream in the direction of the welds. For longer stitches (>25 mm) longitudinal linear nozzles with a gas stream perpendicular to the welding direction have shown good results. However, in contrast to close proximity welding, the consumption of gas depends on the length of the weld. For a 60 mm weld supplied with a commercially available nozzle of 60 mm length, the Helium consumption is about 40 l/min (about twice that typical of close proximity welding), and this consumption rate has to be sustained for the complete duration of the welding.

The absence of active clamping and force transmission (as in resistive spot welding or laser welding with roller-head) in remote welding means that for each single overlap joint stitch a separate clamp has to be installed. Such clamping is most commonly achieved by pneumatic devices. For remote welding, these devices could be equipped with shielding gas supplies, but this increases the complexity of the clamping device. Another possibility for smaller workpieces is to use clamping frames with openings for the laser access. The implementation of gas shielding can be easily achieved in this way .

Welding applications

The most commonly used joint in the automotive industry is the overlap joint. A particular attraction is its low demand on positional accuracy. In addition, for remote welding this kind of joint has the attraction of simple clamping and accessibility.

The shape tolerances of workpieces, especially of formed parts, are high, but fortunately remote welding offers a wide tolerance in focal position for welding, thanks to a long Rayleigh length.

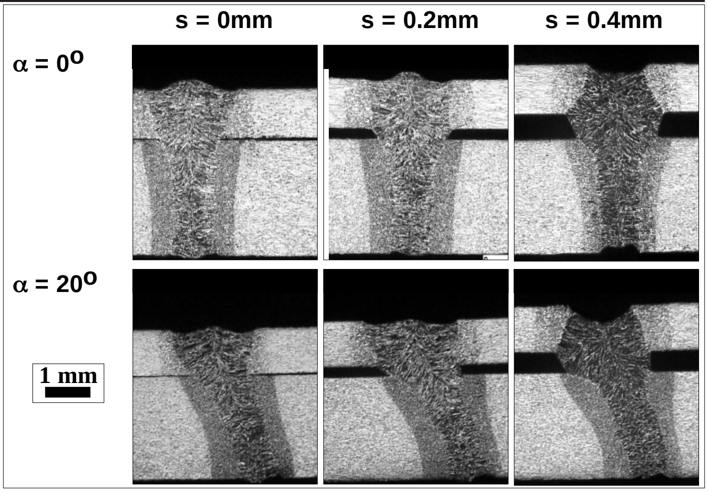


Fig. 8: Influence of inclination and gap on weld shape formation. S355Q mild steel (1 + 2 mm), P= 5 kW, v= 3.5 m/min, Helium 40 l/min

Within a wide range, overlap joint welding imposes no restrictions in beam inclination. Variations in angle during a stitch weld, for example, are either tolerable or can be compensated for. However, restrictions on beam inclination may be imposed for access i.e. by the workpiece shape and the clamping equipment.

Figure 8 shows different 1+2mm overlap joints in S355Q mild steel, for perpendicular and 20° angle of incidence. Full penetration can be achieved up to almost maximum beam deflection, as well as for gaps of up to s= 0.4 mm. This tight tolerance for gaps arises because filler material can't be used in remote welding. Overlap joining of zinc coated sheets is usually done with a defined gap in order to support the evaporation of zinc and thus to reduce the porosity. Good remote welding results were achieved.

Conclusions

Remote welding is of special interest to the automotive industry where the time intensive resistance spot welding is still the main applied welding technology. The high potential to decrease the processing times and thus the costs is driving the developments for the remote welding technology. Remote welding technology is finding its first applications in mass production. Increased laser power capability enables more efficient processing and new applications, including the welding of aluminium. Results here show that the welding depth for mild steel can be increased to more then 6 mm or alternatively a 2 mm joint can be welded at a speed of more then 5 m/min.

A limitation of remote welding is set by access to the welding position caused by complex clamping devices, the shape of the workpiece and/or the limited angle of incidence. For this reason stationary remote welding systems will not be all-purpose tools. New system concepts such as robot-guided scanner welding or flexible remote welding cells with additional axis will decrease these disadvantages, allowing flexible manufacturing over a wider range of applications including white goods, housings and even in the mass production of small parts that can be welded sequential “on the fly” under a stationary system.

Acknowledgements

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High Power CO_2 Laser Cutting

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Laser cutting has been widely accepted in industrial production, and today around 30,000 CNC-controlled laser cutting cells are installed worldwide. The working horse in laser cutting is the CO_2 laser. Since its industrial breakthrough around 1980, the laser cutting process has steadily been improving. A major trend in this development has been the ever-increasing maximum laser power. However, the CO_2 laser power applied to conventional (lens based) cutting heads are limited to a maximum of about 5 kW. There are several reasons for this, two of the most important of which are connected to the performance of transmitting infrared optics: (i) thermal lensing and damage of the laser output coupling mirror (ZnSe or GaAs) leading to beam quality degradation; (ii) power limitation for safe power transmission through the focusing lens, also manufactured out of ZnSe or GaAs.

Lens materials limit lens-based CO_2 focusing heads to a power levels of at most 5 kW, due to unavoidable residual absorption in the lens. This absorption causes thermal lensing (see 'The behaviour of optics at high power' Mark Wilkinson Issue 27, 19, June 02). In order to make use of greater powers now available in a high quality beam (10 kW and up), an all-mirror solution is required. One of the design challenges this presents is how to provide a high pressure gas out through the nozzle tip without over-pressurising the beamline. Clearly, this is not a problem where transmissive optics (i.e. a lens) are used for focusing.

One of the simplest all-mirror designs is shown in figure 1. It utilises an off-axis parabolic mirror that reflects the beam through a 90^0 angle. (See also 'A new concept in focusing systems for CO_2 lasers' D Greening, Issue 6, 11, Feb 97). As will be shown later, the use of an off-axis nozzle to deliver the assist gas can improve cutting performance above that achieved by a coaxial gas supply. However, such a configuration has two major disadvantages that make it undesirable for industrial use. Firstly, a tight tolerances on the precise alignment of the laser beam and the gas jet is essential for proper performance. Secondly, this configuration can not be used for multi-directional cutting.

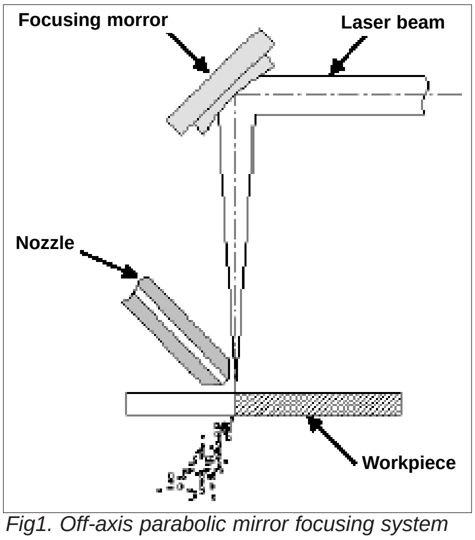


Fig1. Off-axis parabolic mirror focusing system with an off-axis nozzle supplying the assist gas

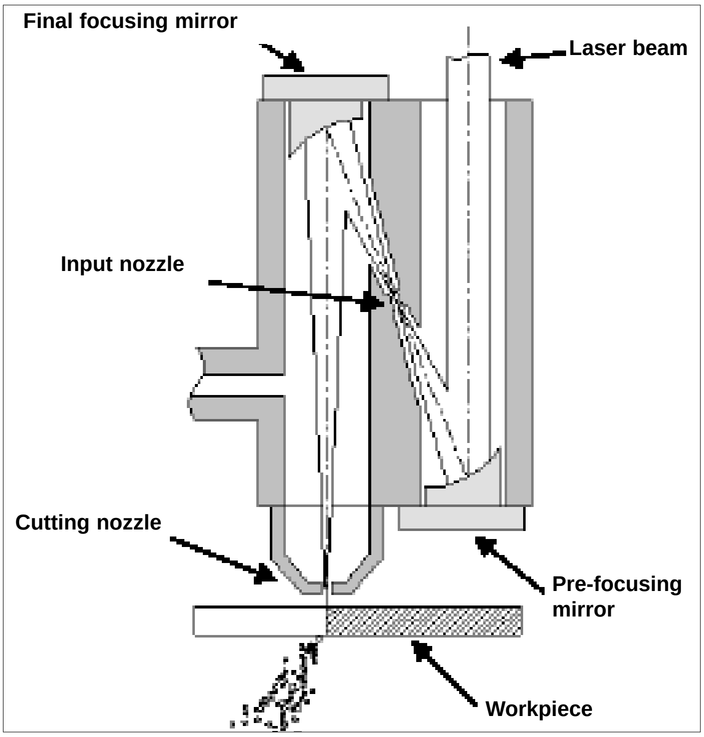


Figure 2. The prototype Powercut cutting head

One solution for providing cutting gas coaxially with the laser beam in a mirror-based focusing head is the 'Autonomous Nozzle' developed at the Fraunhofer institute ILT (See 'High speed and thick section CO_2 laser cutting', F Schneider and D Petring, Issue 25, 20, Dec 01). An alternative design is shown in figure 2. The Powercut head[1] accommodates a nozzle head as simple as that used on a normal lens-based cutting unit, and supports both subsonic and supersonic gas flow on the same head.

In this system the laser beam enters a pressurized gas chamber through a small entry nozzle by pre-focusing the beam into an intermediate focus. Subsequently the beam is again focused, leaving the chamber through the cutting nozzle, which can be set up in a similar way to a conventional lens-based cutting head.

Design and construction of the Powercut head

In general, aspheric elements are very sensitive both to manufacturing tolerances (that reduce beam quality) and to positional or angular errors (that give rise to astigmatism). However, in the Powercut optical arrangement the two off-axis aspheric mirrors compensate for one another, leading to a high quality optical performance, which is virtually independent of the entering beam angle or position. Manufacturing tolerances are compensated in a one-time adjustment during optical system assembly.

1. Olsen, F.O. (1983): Cutting head for manufacturing by means of a laser beam, Danish patent no. 149266 B

Figure 3: The 12kW CO_2 laser cutting and welding test facility at Odense Steel Shipyard in Denmark

With reference to figure 2, the first mirror is an off-axis paraboloid, designed to bring a parallel beam to the intermediate focus. The focal length is relatively short and the beam deflection angle is kept small to reduce aberrations and keep the system compact. The second mirror is required to be an off-axis ellipsoid, since it images the intermediate focus into the final focus.

The compensation of the aberrations would be almost perfect if the beam deflection angle of the second mirror is slightly smaller than that of the first mirror. From a practical point of view, it was decided to maintain the two deflection angles equal, so that the axis of the focused beam is parallel to the incoming beam. The resulting small amount of aberration was found to be quite acceptable.

With a view to cutting trials with the high power lasers of partners in the Powercut project, the focusing head was designed with an acceptance aperture of 60mm and a minimum F-number of 7 (F7).

Designs were evaluated using Opdesign, optical ray tracing design software. The relevant final dimensions chosen for the prototype optical system for F7 performance were as follows:

Focal length of pre-focused mirror:	105 mm
Distance of intermediate focus to final focusing mirror	105 mm
2nd focal length of final focusing mirror for F7	315 mm
2nd focal length of final focusing mirror for F10	450 mm
Beam deflection angle	25^0

The focal length of the final focus was determined by the choice of F7 in combination with the maximum beam diameter of 45 mm. The focal length of the intermediate focus was chosen to be 1/3 of the final focus length, and this was also chosen as the distance from the intermediate focus to the second mirror. The deflection angle was minimised, but allowing sufficient space for the intermediate nozzle construction and sufficient wall thickness to resist the high pressure in the gas chamber.

The mirrors were made of OHFC copper with internal water cooling and plasma hard-gold coatings. The intermediate nozzle was not made adjustable for reasons of space and accessibility; instead, a one time adjustment pre-aligned the pre-focusing mirror. The intermediate nozzle was chosen large enough to allow some angular error in the incoming beam. The complete cutting head was fitted to the laser beam line with external tilt hinges to ensure correct alignment.

The assembled head was assessed using a Nd:YAG laser and a Primes FocusMonitor and PowerMonitor. The results showed that the optical system created a sharp focal spot with only a small amount of astigmatism: the measured axial distance between the two focal planes was 0.7 mm, which can be reduced by fine adjustment, but is already acceptable since the Rayleigh length of the focus when used at the CO_2 laser wavelength is 3 mm.

Cutting tests at the Odense Steel Shipyard

The laser cell at the Odense Steel Shipyard, shown in figure 3, performs both laser cutting and laser welding using a 12 kW CO_2 laser developed for this purpose. The laser, which is mounted in a carriage that follows the x-axis movement of a gantry, can be operated in two different power ranges and with different laser beam qualities. Other cutting results described below were obtained on a 9 kW CO_2 laser cell at the Technical University of Denmark.

Single parabolic focusing mirror with off-axis gas jet (see figure 1)

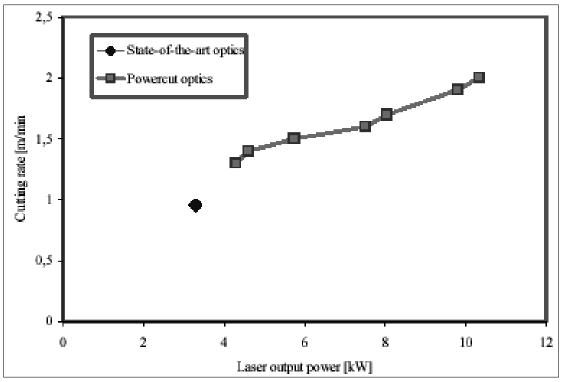
Several studies were performed applying this off-axis nozzle system. Nozzle dimensions and nozzle position were varied relative to the laser beam. The optimum nozzle position was found to be around 20^o relative to the normal to the workpiece surface.

A comparison of cutting speed between this head and a standard lens-based focusing head with symmetric nozzle was undertaken on 10 mm Raex laser-steel using the DTU laser. The laser was operated at 3.7 kW with M^2=2.9 and the results showed an almost *50 % increase in cutting performance when cutting with the off-axis nozzle arrangement* i.e. 1.2 m/min with the lens and symmetric nozzle vs. 1.8 m/min. with the mirror and off-axis nozzle.

Powercut mirror system with symmetric gas jet (see figure 2)

Figure 4 shows results obtained with the 12 kW laser source at Odense Steel Shipyard. The single data point for a lens-based focusing head was obtained with the laser operating with M^2 = 3.4; while for the higher power Powercut results, M^2 = 5. These results clearly show that, utilising the full power of the laser a 100% increase in laser cutting speed can be achieved on an industrial heavy-duty laser welding cell. As with the previous results, the reader must bear in mind that the laser was designed primarily for welding, with a much higher M^2 than a cutting laser.

Figure 4: Cutting results with the Powercut mirror-based cutting head on 13mm shipbuilding steel with shop primer coating



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Laser Trimming

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The basic principle of laser trimming is quite simple. It is well known that the resistance R is equal to specific resistivity ρ times resistor length L divided by cross-sectional area A. For planar resistors, the resistance is equal to the sheet resistivity R_s times L divided by resistor width W. Either way, when laser is cutting through the resistor, resistive material is removed and this leads to a change in its resistance value.

Laser trimming of thin film, thick film and chip resistors is a well-established technology. The majority of the systems used for these types of laser trimming accommodate relatively small substrate sizes, usually less than 254mm x 254mm. New developments in printed circuit board (PCB) design and manufacturing require systems that can handle larger panel sizes and trim physically smaller resistors to tolerances of the order of 1% or better.

Another trend in the PCB industry is the growing demand for a higher number of circuit components to be contained in smaller circuit areas. This requires that some of the passive components (resistors, capacitors, and inductors) be embedded within the board, usually close to the core material because this part of the panel suffers less distortion during the build-up process. This allows for tighter component placement with lower via counts, at the same time addressing the technical demands of high frequency analog and digital designs, increasing the reliability of the devices and potentially reducing the cost of manufacturing.

The initial placement of embedded components takes place in the earlier stages of production of a PCB at which point the components are on the top surface of the panel. Before the next lamination step, these components can be tested and trimmed to the values required by the design considerations of the circuit.

Embedded resistor materials

Two major groups of materials are currently used for embedded resistors in PCBs. The first group comprises thin film resistors made from different metal-based alloys, which are deposited on the board surface. Thin film coatings are usually deposited using a vacuum deposition technique such as sputtering, then patterned and etched away to the specific geometry. The thickness of these resistors is usually less than 1 µm. The thickness of the resistive layer determines the sheet resistance of the material. The thinner the material, the higher the sheet resistance will be for any particular alloy. At present, for most of these thin film resistors the sheet resistance falls within the range of 25 to 1000 Ω/square. For tolerances on the order of ±1%, trimming of those embedded components is required.

In the second group, thick film resistors are formed from carbon or silver-filled polymer-based pastes. Using various compositions, a wide range of sheet resistance can be obtained from 15 Ω/square to 100 kΩ/square. The paste is screen printed at the resistor location directly onto pre-etched copper traces and the dielectric of the board. It is then cured at temperatures typically ranging from 150°C to 270°C. The thickness of the polymer-carbon resistive pastes ranges typically between 15 and 25 µm.

Fig 1. GSI Lumonics EP1000 PCB trimming system

Current resistive materials and PCB photo etch and laminating techniques results in a final tolerance of approximately ± 20% of the target value while typical circuits require ± 5% or better. Laser trimming has shown to be a very effective way to bring the tolerances of these embedded components values to the required range. And increasingly, in response to the growing demands for PCBs with embedded components, this technology is being implemented in production. So, in addition to providing precision trimming, edge smoothness and resin integrity, laser trimming systems are increasingly including full automation for 7/24 operation, high throughput and precision, simple set up, and operator-friendly interface with local language support.

Trimming embedded components

The work reported here was undertaken with a GSI Lumonics PCB trimming system EP1000 as shown in figure 1. The system incorporates galvanometer laser technology and a Q-switched Nd:YAG laser operating at 1.064 and 0.532 µm. The laser beam is focused through a telecentric scan lens to a spot size in the range of 20 to 30 µm. A through-the–lens vision system is provided for ease of calibration of the scan field as well as panel alignment. The system also incorporates a X/Y table capable of handling panel sizes of 534mm x 625mm. The ohmic measure-

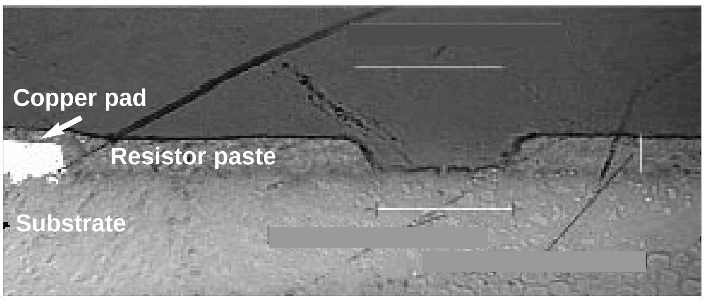

Figure 2. Cross section of a laser-trimmed film resistor

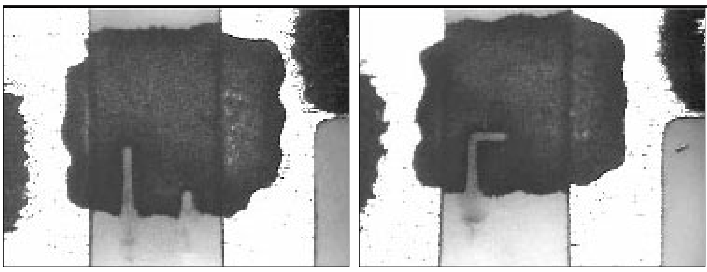

Figure 3. Laser trimming a thick film resistor (l) double plunge cut ,(r) L-cut.

ments are performed using a four wire forced voltage current nulling bridge, plus a full Kelvin probe arrangement for resistors below 100 Ω.

Trimming of thick film resistors

In general, for thick film resistors, the average power required for trimming is on the order of several watts. The exact power level strongly depends on the resistor thickness and material. Figure 2 shows a profile of the laser cut between the copper traces, for an typical, average-sized thick film resistor.

Laser trimming thick resistors at different speeds reveals that different paste compositions show different thermal responses to the deposited laser energy. Higher resistivity paste shows markedly higher sensitivity (increase in resistance caused by temperature rise) during laser trimming.

The thick film resistors used in this work were made by screen printing and curing PTF pastes. Several different pastes were used with resistances from 100 Ω/sq to 100 kΩ/sq. For some panels, resistors were printed on one side of the panel and for others on both sides. The panel thickness varies from 0.2 mm to 3 mm depending on the circuit layouts. The thickness of the polymer-carbon resistive pastes ranges between 15 and 25 µm; in most cases this was determined by the thickness of the copper pads. After curing, the resistor profile was found to be non-uniform i.e. thinner at the edges, and different according to the length of the resistor. Obviously, thickness variations present a challenge to selecting laser parameters that provide good quality of all trims. This is particular true when the profile across the current flow is strongly bell-shaped with maximum thickness in the centre of the resistor. such thickness variations are clearly visible in figure 3.

For effective trimming, it is obviously necessary that the initial resistor values be designed so that all pre-trim resistor values for the entire panel fall below the target value, after the printing and curing process steps. The spread of pre-trimming resistance values reflects variations in resistor shape, local distortions of substrate dielectric, and variation in paste density. Additional spread in resistor values also comes from the screen-printing process, panel-to-panel variations, and thermal distortion of the panel during the resistor curing cycle.

The final spread of the trimmed resistor values depends on several parameters including trim cut type, laser power, laser repetition rate, etc. the final spread of resistor values and device performance can be evaluated only after the complete lamination process. Nevertheless, results have shown that the trimming of thick film embedded resistors can be achieved with better than 1% accuracy and no substrate damage.

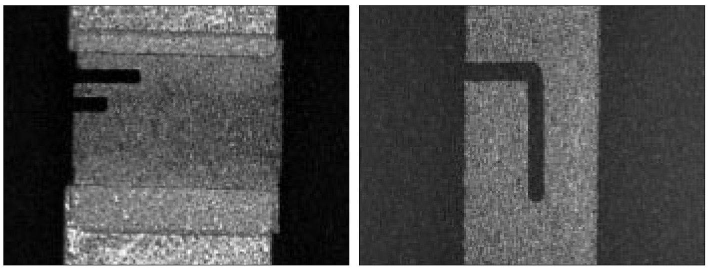

Figure 4. Laser trimming a thin film resistor (l) double plunge cut ,(r) L-cut.

Trimming of Thin Film Resistors

Figure 4 shows examples of typical laser trimming cuts in thin-film resistors. In the left hand figure some thin film material is seen to have been deposited over the copper pads and the board. Trims were visually inspected with a microscope and no damage on the PCB substrate or to the regions surrounding the cuts was found.

Experimental work carried out in this study has identified that trim performance is strongly affected by resistance probing conditions i.e. going from standard to full-Kelvin probes improved the post-trim distribution of resistance values by one order of magnitude (the standard deviation decreased from roughly 0.5% to 0.05%). Full-Kelvin probes are commonly used in the test industry as they virtually cancel the contact resistance between the probes and the pad material, which we estimate to be in the 1-10 Ω range

Testing PCB Laser Trimming

Testing correctly is of the utmost importance for laser trimming. Major requirements are speed and accuracy: measurement times must be less than 0.1 ms to match the 10 kHz trim speed, accuracy is set by the tolerances (±1% or better) of the PCB design. Probing accuracy is also required, as probes need to move precisely in X, Y and Z in order to make contact with the testing pads.

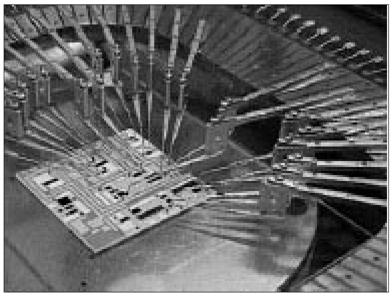

Figure 5. Cantilever-type probes for trim testing. This design is generally preferred over vertical probes for laser trimming applications since they they do not block the laser beam.

Probing speed is also important as it affects the overall throughput and cost of ownership of the system. In this regard, there appears to be a break-even point in the cost analysis comparison of flying probes and fixed probes, depending on production volumes i.e. a flying probes are more flexible and economical but a fixed probe system can test several components simultaneously and becomes economic if a few hundreds boards or more are to be produced.

To ensure electrical contact during probing, it is necessary for the probe action to scrub through any surface oxidation in order to reach the underlying base material, reduce contact resistance and ensure reliable measurements. The geometry of cantilever type probes ensures that they scrub forward when a vertical movement or overdrive is applied to the probing system.

Conclusion

Laser trimming technology is destined to play an important role in the manufacture of PCBs with embedded components. Laser trimming of these components on large format PCB has been investigated and a number of specific issues have been addressed, including probing and testing technology. Results show that both thick and thin film resistors can be trimmed to be within the expected tolerance specifications without damages to either the substrate or surrounding area.

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

Trends in the development of femtosecond lasers

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In recent years, femtosecond Ti:Sapphire lasers have been established as powerful tools for a wide range of scientific applications and are irreplaceable devices in many research laboratories around the world. This was made possible by the invention of dispersive dielectric mirrors [1], which allowed the construction of prism-free oscillators that were capable of generating pulses of only a few femtoseconds duration and with an unprecedented stability and reliability [2]. Such systems usually operate at a repetition frequency of around 100MHz and deliver output powers of up to 1W when pumped with up to 10W out of a frequency doubled solid state laser. The 1W output corresponds to a pulse energy of 10nJ (Femtosource compact PRO); and if this is not sufficient for a particular application then amplifiers are available.

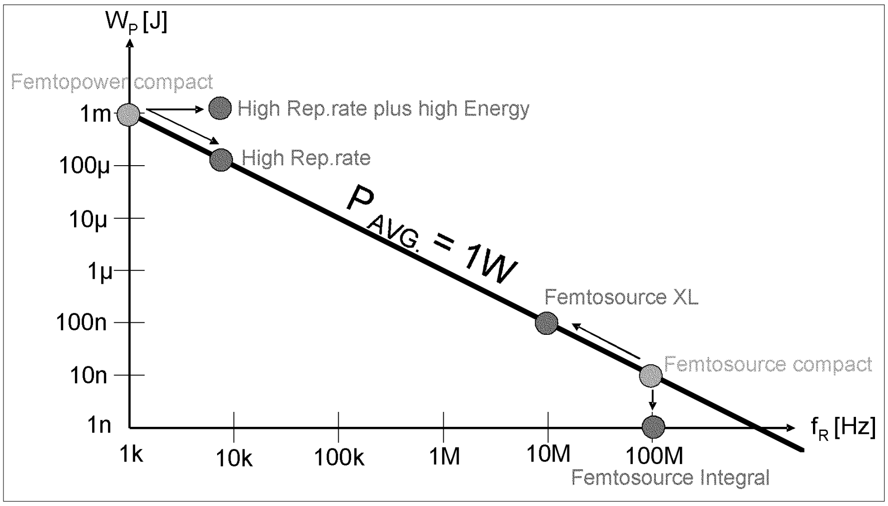

Figure 1. Established femtosecond laser sources and trends in their further development

The most common fs amplifier scheme utilizes the Chirped Pulse Amplification (CPA) technique [3], where single femtosecond pulses out of the train emitted by the oscillator are selected, then stretched to some picoseconds (thereby reducing peak power to avoid damage of the amplifier crystal), amplified and recompressed. Typical output parameters of such systems are 1mJ pulses at a 1kHz repetition rate, which again corresponds to an average output power of 1W (Femtopower compact PRO) (Figure 1).

However, if one also wants to focus on industrial or medical applications, custom-designed laser systems have to be developed. As examples, applications in optical coherence tomography (OCT) and high precision material processing are presented.

Optical coherence tomography

Optical coherence tomography (OCT), the optical analogue of ultrasonic pulse-echo imaging, enables non invasive, in vivo 2D or 3D cross sectional imaging of retinal tissue by measuring the echo delay and intensity of back reflected infrared ultrashort laser pulses. This technique has already been applied by commercially available OCT systems based on super luminescent diodes, resulting in 15-20µm transverse and axial resolution, as compared to 150µm axial resolution achievable by ultrasonography. Both axial resolution figures are not sufficient to resolve details of the (about 10) intraretinal layers, some of them only a few µm thick. But only a clear visualization of these layers and of subtle changes in retinal morphological features is sufficient for early diagnosis and fine tuning of therapeutic efficacy.

Recent improvements in modelocked femtosecond solid state-lasers (mainly involving spectral broadening) have led to the demonstration of Ultrahigh-Resolution OCT systems with an axial resolution of under 1µm. This result has allowed imaging of the nucleus of a single cell for the first time utilizing the OCT technique [4] and commercial OCT systems with an axial resolution of as low as 3µm have been introduced, allowing full visualization of intraretinal layers (Figure 2). As this method is very sensitive, only a few tens of mW of output power are needed to guarantee an excellent signal-to-noise ratio: and, of course, damage to the human eye sets an upper limit on the amount of the incident radiation that can be used. In this way, smaller, lower-cost pump lasers can be directly integrated into the femtosecond laser cavity. This allows the laser source to be more compact (500 x 260 x 80 mm), robust and user-friendly, while maintaining an extraordinary broad bandwidth of around 100nm. (Femtosource Integral).

There have been extended studies to verify the results achieved by Ultrahigh-Resolution OCT by histological findings on the same samples and to demonstrate the clinical relevance of the Ultrahigh-Resolution OCT results in patient care.

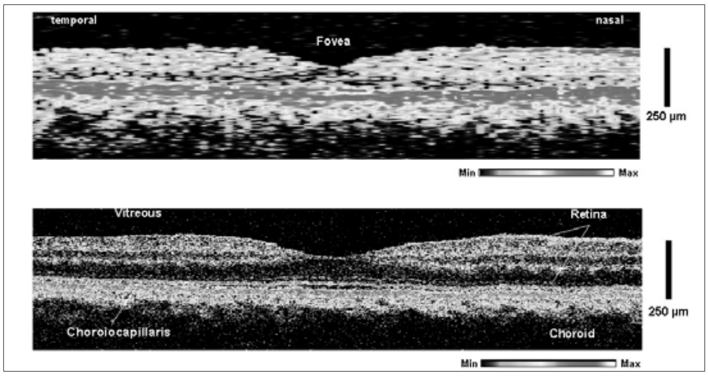

Figure 2. W. Drexler et al: Conventional (top) and ultrahigh resolution (bottom) in vivo OCT images of the foveal region in a normal human subject. Axial resolution is 15 µm (top) and 3 µm (bottom). Light-source (top): 20 nm SLD; (bottom): FEMTOSOURCE 100 nm FWHM @ 800 nm

High precision material processing

Femtosecond lasers are excellent tools for the microstructuring of nearly all kinds of solid material. The main features of material processing with femtosecond laser pulses are an efficient, fast and extremely localised energy deposition, low deformation and ablation thresholds and minimal or no thermal and mechanical damage of the substrate material. This allows one to produce microstructures with very high precision and reproducibility. Due to the extremely short pulse duration, heat formation is limited to surface layers in the nanometer range, the surrounding area remains cold. By applying a train of femtosecond pulses, the processed area can be extended in size, laterally as well as axially. Besides avoiding thermal damage, this division of the entire process into a large number of steps offers great flexibility in the geometry of the structure to be generated. Also, virtually any kind of material can be machined, including biodegradable materials, ceramics and even explosives!

Metals processing

A large number of investigations have been carried out in an effort to elucidate the mechanisms by which femtosecond laser pulses interact with matter. In metals, the free electrons absorb the incident laser light and establish an electron temperature in a time of the order of a few picoseconds, which is then communicated to the lattice on a comparable timescale. Hence, for metals, the use of lasers with pulse durations significantly shorter than 1 picosecond brings no substantial benefit.

Dielectrics processing

In dielectrics, however, the situation is fundamentally different. In such media, (almost) no free electrons are available for absorbing the incident radiation, as the conduction band is virtually unoccupied. Therefore, the first step in initiating the ablation process is the generation of a high density of free electrons in the conduction band by the electric field of the (high intensity) laser light itself. Then, the electron plasma can be heated by the external field via inverse bremsstrahlung absorption; and the energy is subsequently transferred to the lattice, leading to ablation.

In the nanosecond and picosecond regime optical damage in dielectrics has been found to have a highly stochastic nature, whereas in the femtosecond range it becomes much more deterministic. Moreover, experiments have shown that the fluence threshold for damage is considerably lower at shorter pulse durations, so less energy has to be deposited into the material [5]. This fundamentally different damage behaviour can be explained by the mechanism for generating carriers in the conduction band. If ultrashort pulses are used, nonlinear effects such as multiphoton absorption play an important role, leading to much more reproducible and superior quality results (Figure 3).

Throughput considerations

For industrial material processing applications, a high throughput is essential. The amount of ablated material per laser shot is in general proportional to the incident energy. However, for realising ultrahigh precision it is necessary to operate above but close to the damage threshold of the material concerned. By proper choice of the process parameters it is even possible to generate sub-diffraction limited structures [6]. To implement such results in industrial applications it would be desirable to have a laser source with an energy in the order of about 100nJ (the damage threshold of almost any material can then easily be reached) and with a repetition rate as high as possible, to maximise the throughput. These considerations have led to the development of long cavity, high energy femtosecond oscillators. The idea behind this concept is to increase the resonator of a standard Ti:Sapphire laser by a factor of around 10, which can be realised by insertion of a multipass cell [7]. Using this approach, our Femtosource XL can achieve the same 1W average output power as before, but with a pulse energy of 100nJ, as shown in figure 1. The generation of feature sizes well below 500nm have already be demonstrated using such commercially available systems.

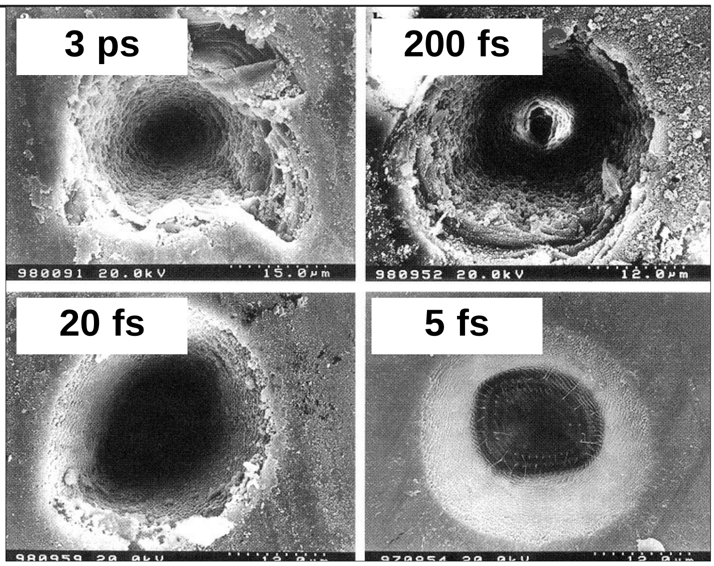

Figure 3. M. Lenzner: SEM micrographs of pulse laser ablated fused silica at air using a Ti:Sapphire laser system, operated with different pulse durations

Another direction in the development of laser sources, especially targeted for micromachining applications with less demands on the obtainable resolution, is to increase the repetition rate of CPA amplifier systems and to reduce the pulse energy at the same time to keep the average output power constant. In this way, the pump power requirement is the same and the overall thermal load can be kept constant. For applications with even lower demands on the resolution and higher demand on the throughput, systems with high output energies and high repetition rates are under development. However, such systems remain quite complex and a careful and thorough approach to thermal management is essential.

Conclusions

Femtosecond lasers are well established tools in various scientific fields, ranging from physics and chemistry to medical research. The technology is beginning to mature to the point where these lasers are attractive for industrial and clinical applications. This is made possible by the development of robust and reliable laser systems, custom designed to be ideally suited to the specific task.

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The role of lasers in Rapid Manufacturing

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The application of laser technology in industry is still dominated by cutting, marking and welding operations. Aside from our usual view of the "laser" industry, there are a growing number of laser applications that have firmly positioned themselves at the heart of the design process and on the critical path of innovative product development. Rapid prototyping is one of them.

Rapid prototyping processes have used the properties of laser light to produce complex objects via laser induced polymerisation (Sterelithography, SLA), laser fusion of polymers and metals (laser melting or the incorrectly named selective laser sintering, SLS), or the laminated object manufacturing approach that uses stacked laser cut blanks to form an object, LOM. All routes have advanced the state of product development by providing flexible production technologies that deliver complex forms within hours of the request. The driver for the rapid prototyping industry was desire to produce manufacturing solutions rather than design aids and pre-production models.

Exponents of Rapid Manufacturing technologies (RM) aim to replace conventional fabrication routes by eliminating tools, jigs, fixtures or any other engineering overhead required to produce a component. There has been considerable activity across the world over the past ten years, with the usual acquisitions and mergers of the early players resulting in a few large brand leaders now dominating the markets. Laser based polymer or metallic RM technologies are sold now for around $0.5M, with the metals technologies demanding the higher premium prices.

Polymer processing has reaped the rewards sooner than its metallic counterpart; and it is now possible to produce production quantities with high levels of precision and functional performance from polymer based SLS. EOS Gmbh, the world leader of sintering technology, has sold a number of the polymer systems to produce high volume components in place of the traditional tooling and moulding approach (spectacle frames, hearing aids, instrument fittings etc). Readers may think that these examples represent limited cases, but the economic arguments are moving in favour of RM solutions because of the cost and time advantages, and not forgetting the increased capabilities of RM technologies themselves. Given this improvement in the production technologies for polymers it is not too difficult to predict that a significant volume of polymer processing through injection moulding will be replaced by high speed high RM solutions.

It is likely that SLA technology will slowly be replaced by non-laser variants such as those provided by Objet, and Envision Technologies. These are systems that provide similar functionality to that of SLA models with system prices substantially lower than SLA (around 1/10th). In fact, it is safe to say that in the world of RM, laser based technologies are being edged out of the application space in favour of cheaper and often simpler technologies; examples being jetting and squirting systems than gain precision from high accuracy industrial ink-jet technologies and are capable of depositing polymers, waxes, metals and ceramics.

The laser still has a role to play, perhaps in the form of high-value and high-performance industrial systems. SLS application developers like the Dutch design house "Freedom of Creation" have surprised the industry with imaginative steps like those shown in figure1, which shows examples of nylon powder that has been laser fused to form woven "cloth". The material is still too crude to replace nylon garments but the design and fabrication routes have been proven. Is it possible that local production of clothing can be offered from systems such as this? In principle, yes; in practice, we need extensive research into materials that work with this approach and yet still produce comfortable clothing.

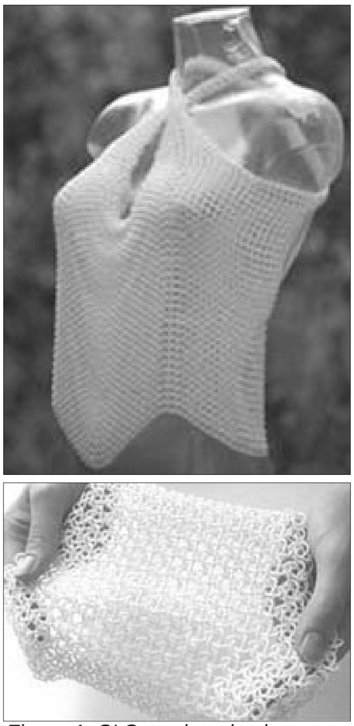


Figure 1. SLS-produced nylon garments by Freedom of Creation, www.freedomofcreation.com

We may see mass produced injection mouldings replaced by RM offerings that offer faster and cheaper production routes. We may even see local 24-7 lights-out operation of RM technologies eliminating the advantage of outsourcing components from low wage economies. But what of fabrication in metal?

Fabrication in metal

Metal build technologies have yet to make a significant impact on the marketplace. SLS, LOM and Laser Forming through laser cladding (LF) have all been hailed as solutions for metal, but the reality is that there have been no commercial applications identified for part manufacture with the exception of short-run injection mould tooling, mould tool repair or special one-off component fabrication (usually applied by the US defence companies).

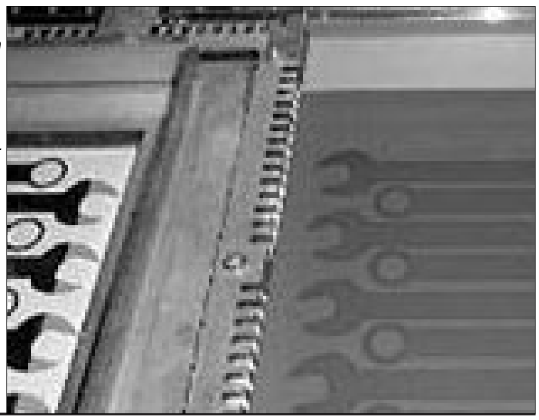


Figure 2. Speed-Part, from Speed-Part AB, Sweden. A lamp based metal production technology that offers high speed and high accuracy polymer and metal components.

EOS Gmbh, 3D Systems Inc, MCP Ltd and Trumpf Gmbh, all offer commercial laser-based metal build technologies (SLS) that can produce functional metal parts, some better than others. The routes are often slow, build rates of several cm^3 per hour, with accuracies around several hundred microns over maximum build volumes of $250mm^3$. These are impressive techniques, but they will struggle to find large volume applications.

Fast on their heels are the non-laser large-area exposure systems. The first type is the Speed-Part, of Speed-Part AB, Sweden. This uses an iconographical mask production step that controls the spatial exposure of metal or polymer powder from a powerful infrared lamp. The system is fast, cheap and can produce parts comparable with the more expensive metal SLS technology. Figure 2 shows the system and a metal component. It takes only about 10 seconds to fuse each layer (0.1mm) of a part using this method, and this time is not dependent on part geometry. Several materials are being developed for use with the system, including metals and polymers. The first machine has a build envelope of (200 x 300 x 500 mm).

The other laser approach to metal production is laser forming, a concept first proposed by Bill Steen, then of Imperial College London, in the late seventies. It has several names (e.g. laser casting, laser forming, laser cladding) but is in essence it is the deposition of a melt bead by combined laser melting and powder delivery. It is amazing that this technique has taken so long to reach the market.

One of the notable commercial offerings is from the partnership of POM Inc and Trumpf. A part manufactured by this system is shown in figure 3. Its real-world applications include mould-tool repair and modification, turbine blade repair and graded metal fabrications to name but a few. Parts require post machining to achieve net shape and can often have selected microstructures achieved through on-line control of bead cooling rates. This machine and those provided by their competitors, Optomec Inc, are sold for around $0.75M.

Non-laser metal deposition

As a researcher of RM techniques, my team at the IfM Cambridge have been developing Cold Gas Dynamic Manufacturing, a non-laser based deposition process. To understand the potential of the CGDM process first imagine the powder stream from laser cladding hopper, usually delivered at rates of a few m/s. Now imagine the same hopper capable of delivering powder at rates of around 1200 m/s. In this situation the metal particles will have sufficient kinetic energy to consolidate and produce metallurgical bonding on impact. The result of this research is a metal build system capable of delivering builds rates of many kg/hour, using any metal or combination of metals without the deleterious effects of passing metals through their molten phases.

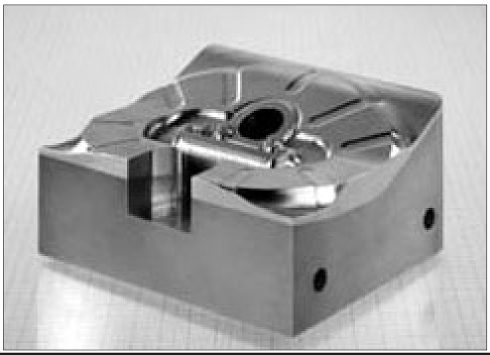


Figure 3. Product of Trumpf direct metal deposition technology.

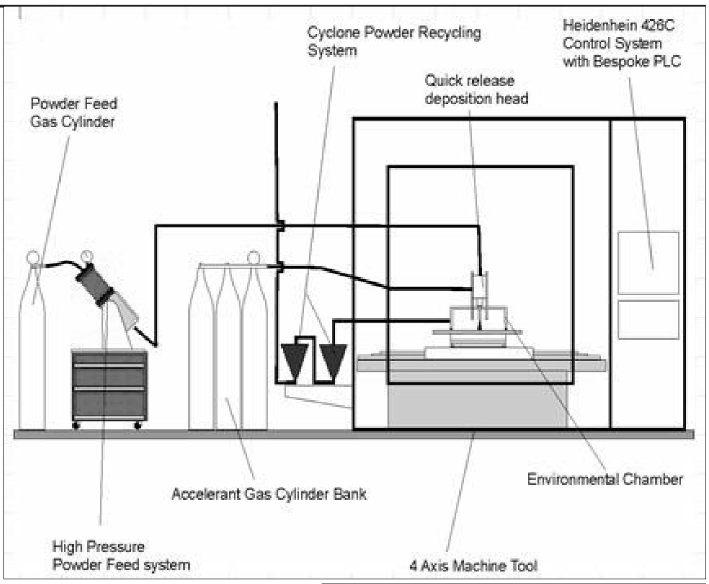


Figure 4. Cold Gas Dynamic Manufacturing technology (CGDM), Institute for Manufacturing, University of Cambridge

Figure.4 shows the first generation CGDM system. Like laser cladding it requires post machining for net shape production, but unlike laser cladding it requires only a simple control system as there are no problematic thermal events to manage during fabrication. One of the many exciting opportunities offered by CGDM is to bury electronic, optical, thermal, and mechanical sensor elements deep within a component, since these are not damaged when they are covered by the cold metal spray.

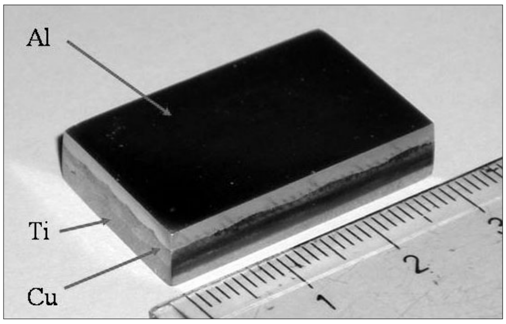


Figure 5. Tri-metal deposit by CGDM, showing Al, Cu and Ti stratified layers.

Fig.5 shows a tri-metal stratified layer deposit comprising 2mm thick layers of Aluminium, Copper and Titanium. The benefits of this approach are obvious to those who have tried to do this with laser cladding! It is perhaps ironic and a sign of the times that we chose to dismantle a 4-axis laser forming build station only to reconfigure it for a non-laser approach.

In summary, Rapid Manufacturing is set to expand its role within manufacturing operations of the future. The trend from laser to non-laser based technologies will increase as fabrication systems offer improvements in speed, capabilities and cost. There will of course be a position for RM-based laser technologies, although their use will not be widespread unless the laser industry is capable of reducing system costs by an order or magnitude.

Listing of current laser processing standards (1/6/2004)

Please note that the listing includes draft (pn) standards and that only the EN reference numbers are given.
Underlines highlight changes over the last year

Safety of Laser Products

Safety of laser products series:
-Part 1: Equipment classification, requirements and user's guide
incorporating amendments 1, 2 and 3 and Corrigendum No 1
EN 60825-1 1994
Product standard plus user guide. Harmonised to the Low Voltage Directive.

-Part 4: Laser guards
incorporating amendment 1 and 2
EN 60825-4 1998
Product standard plus user guide. An applications guideline will be included in the next revision.

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

-Part 14: A user's guide
PD IEC TR 60825-14 2004
Technical report. New risk-assessment based user guide, extending and updating the guidance in 60825-1.

Safety of machinery - Laser processing machines - Part 1 General safety requirements
EN ISO 11553 1996
Harmonised to the Machinery (Safety) Directive Currently under revision to extend the application to laser processing machines which do not have Class 1 enclosures. Revision will also give fuller cross references to related standards.

Laser safety equipment

Personal eye-protection series:
Filters and equipment used for personal eye-protection against laser radiation (laser eye-protectors)
EN207 1999
Product standard and user guide.

Eye-protectors for adjustment work on lasers and laser systems (laser adjustment eye-protectors)
EN208 1999
Product standard and user guide (visible radiation only).

Screens for laser working places - Safety requirements and testing
incorporating amendment 1
EN 12254 2002
UK edition contains a foreword cautioning users on limitations of test requirements.

Laser Product Standards (other)

Lasers and laser related equipment - Lifetime of lasers
EN ISO 17526 2003

Lasers and laser related equipment - Laser devices series:
-Minimum reqts. for documentation
EN ISO 11252 1994
The list of laser parameters will be extended in the next revision.

N.B. EN ISO11253 'Mechanical interfaces' has been withdrawn

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

Optics and optical instruments - Laser and laser-related equipment - Vocabulary and symbols
EN ISO 11145 2001
N.B. Some definitions differ from 60825-1.

Laser beam measurements

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

Lasers and Laser Related Equipment - Test Methods for laser beam parameters series:
Beam width, divergence angle and beam propagation ratios
prEN ISO 11146 2004
To be in 2 parts: Part 1 ' Stigmatic and simple astigmatic beams'; Part 2 'General astigmatic beams'

Laser beam power, energy and temporal characteristics
EN ISO 11554 2003
Amendments to the ISO Standard are about to be issued

Laser beam positional stability
EN ISO 11670 2003
Amendments to the ISO Standard are about to be issued

Laser beam parameters: Polarization
EN ISO 12005 2003
Amendments to the ISO Standard are about to be issued

Laser beam power (energy) density distribution
EN ISO 13694 2001

Test methods for spectral characteristics of lasers
prEN ISO 13695 2004
Submitted to formal vote.

Laser and laser related equipment - Test methods for determination of the shape of a laser beam wavefront series:
-Part 1: Terminology and fundamental aspects
ISO 15367-1 2003
-Part 2: Hartmann-Shack sensors
prISO 15367-2 2004
A Part 3 'Interferometric measurements' is currently under development.

Optics and optical instruments, lasers and laser-related equipment. Test method for absorptance of optical laser components
EN ISO 11551 2003

Laser processing performance

The EN ISO 15616 series 'Acceptance tests for CO_2-laser beam machines for welding and cutting, Parts 1, 2 and 3' remains under critical review, with many national standards bodies unhappy with these documents. Others are listed below.

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

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

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

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

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

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

Welding - Recommendations for welding of metallic materials - Part 6 - laser beam welding
prEN ISO 1011-6 2004

End

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

Trends in the development of femtosecond lasers Alexander Fuerbach and Christian Spielmann

Just from the authors I could tell it was going to be a good, accurate paper. And it is – a good summary of the technology and applications.

My thoughts about fs lasers are summarised in their conclusions. These lasers won't really take off (like CO2 or YAG lasers have) unless and until a (relatively) simple and more robust source (and appropriate beam delivery) is available. Devices like these are looking promising now but there is still room for improvement. Having said that, fs lasers are probably far more developed than the early CO_2 and YAG were, it is just that our expectations have been raised. We now expect a quick turn on with minimal set up, simple & reliable operation, giving consistent results.

The current state of the art with fs lasers reminds me of my youth when I had to repair my own car. I wanted to replace the clutch on my old Allegro (don't laugh). This looked like a fairly simple thing to do and indeed the chapter in the Haynes manual was very short – however, the first paragraph of the chapter said "Refer to Chapter one and remove the engine" at that point I closed the book and resolved to sell the car. The situation with fs lasers is similar: it starts "use a Ti-sapphire laser to pump…." There must be an easier way….

Tim Holt Institute of Photonics

Femtolasers Productions GmbH produce an excellent sub 20 fs pulse-duration oscillator which is the start-point of the femtosecond system at the heart of TOPS. I have no expertise in the clinical field but would like to comment on the commercial viability of femtosecond lasers for industrial applications.

In my experience the useful pulse-energy, for femtosecond laser micro-structuring, extends over two octaves from ~ 100 nJ to 10 mJ. Here, typical 1-10 kHz regen. femtosecond systems are highly wasteful, while above this pulse-energy range picosecond lasers are generally perfectly adequate.

For the femtosecond laser to have any future as a more mainstream commercially viable micro-structuring device pulse repetition rates of 1 - 10 MHz and average output powers consequently approaching 10 W are required. Otherwise the high capital cost combined with the low through-put will invariably out weigh any value added. My guess is that this will never be achieved with the current technology and probably never will. A rather negative view I know - but it is my carefully considered opinion and I will be more than happy to be proved wrong!

David Jones TOPS, Strathclyde University

With the advent of reliable high power femtosecond lasers has come an explosion in the application of non-linear optical phenomena in applied research and industry. Of particular note has been the generation of coherent ultrashort pulsed laser radiation over wide spectral regions from THz to X-ray, which were previously difficult or impossible to access. These processes include parametric generation, harmonic and high-harmonic generation, sum-frequency generation, white-light continuum generation, difference frequency generation and rectification. Access to THz radiation has opened up novel 3D imaging techniques with potential for tomographic imaging of materials. Attosecond light pulses have also been generated using high-harmonic generation fast enough to take snapshots of an electron as it moves around atom core.

The access to the new spectral ranges has also revolutionised 'pump and probe' time-resolved spectroscopy: techniques that are helping to unveil the secrets of life, where many fundamental processes occur on femtosecond timescales. Phenomena studied include the charge and energy transfer processes within biomolecular systems, changes in molecular structure that are at the core of the process of vision, the dynamics of hydrogen bonds within DNA and other biologically relevant systems.

Another example of a nonlinear process that makes a profound impact on our understanding of the world we live in is multiphoton fluorescence microscopy. Multiphoton excitation by femtosecond near IR lasers can be used to excite visible fluorescence without the collateral damage associated with conventional single photon excitation. This property has been used to study the functionality of cells, drug delivery into cells and their efficacy in target bio-systems.

It is difficult to cover the vast range of applications that have emerged and are constantly emerging as a result of the advent of femtosecond lasers. At this point in time it can be safely concluded that femtosecond laser technology has not yet uttered its last word and that many more scientific discoveries are awaiting us on this exciting path of natural sciences.

Pavel Matousek and **Mike Towrie**
Central Laser Facility, CCLRC Rutherford Appleton Laboratory

Low levels of output energy are essential for some thin film related applications when submicron accuracy is required. However, femtosecond brings other benefits to material processing, including excellent edge condition (due to the quasi athermal process) and wavelength independent process (due to multiphoton absorption).

Therefore, micro processing with femtosecond pulses is not limited to thin films and can be used on significantly thicker materials. In such cases, kilohertz repetition rates and higher pulse energies are needed. Cutting 200µm thick glass is a typical example: existing processes stress glass and can generate micro cracks, which can have very bad effects on the yield. Pulse energies of a few hundreds of micro Joules at several kilohertz (Thales' BRIGHT industrial femtosecond laser) are absorbed and allow to cut glass without those side effects and very clean edge condition. Even though the processing speed is relatively slow compared to other processes, it remains acceptable as the yield per wafer is improved. Another example is micro machining with frequency doubled or tripled fs pulses in order to gain accuracy: harmonic generation crystals have low conversion efficiency and require high input energy in order to have a few micro Joules at the output.

Antoine Duret Thales Laser

High Power CO_2 Laser Cutting
Frits de Lange et al.

This is an interesting paper on the subject of high power cutting. however I would have found it even more interesting if the authors had given us some information about cut quality as well as the cut speed. As the final sentence of the article reveals, this project was primarily an exercise in making a high power welding laser into a cutting machine.

Schneider and Petring's "autonomous nozzle" (see issue 25, Dec 2001 of The Industrial Laser User) achieved this aim using nitrogen as the cutting gas. The cut edges produced were of high quality and ready for subsequent welding. It would be very interesting to know what quality of edge was achieved in the case of the work reported here.

John Powell Laser Expertise

The new high power laser cutting head is of an ingenious design and clearly allows high power laser delivery to the plate surface without compromising optimum gas delivery for multi-directional cutting. I would be interested to see more results, especially on thicker material. There are a couple of areas of concern however; the solutions to which, I did not detect.

I note that with the rather poor beam quality and with a tolerance for beam misalignment, the restricted 'window' between the oxygen nozzle and the main beam path must be of considerable size. The dimension of this hole is not specified, but would I be correct in assuming that it may be even larger than the cutting nozzle aperture? If so we are wasting considerable gas and also supplying highly flammable gas into the atmosphere? Also, whereas some high power lasers offer good beam quality, others do not. Hence, an interesting statistic would be the proportion of high power lasers that could benefit from this technology.

Cut quality is often the reason for choosing laser, does the Powercut head offer benefits relative to existing conical/vortex designs, such as that by Precitec?

However, I would not want to sound critical. I think this is an interesting idea and look forward to trials on thicker plate.

Alan Thompson and **Stewart Pigg** Corus Group

Authors' response:
The worry regarding the gas loss is understandable. Some gas loss occurs through the intermediate nozzle, but the intermediate focus is only 1/3 the diameter at the final focus, and in addition, the final nozzle size increases as it is located outside the focus position, whereas the intermediate nozzle is exactly at the focus position. This implies that the cross sectional area of the intermediate nozzle is normally less than 10% of that of the final nozzle.

Note that any safety margin added for angular errors (±0.5 mrad) that is added to the intermediate nozzle diameter also has to be added to the final nozzle diameter, so it does not change the ratio of the nozzle dimensions. The angular errors are errors during operation. Misalignment errors are compensated by aligning the complete head.

The resulting 10% of gas loss can still be reduced by use of an aerodynamic window. For us, the gas loss was acceptable at the present stage of development. Naturally, good ventilation of the beamline must be taken care of, to avoid high concentration levels potentially dangerous gasses in the beamline system.

Frits de Lange University of Twente

High power remote welding
Frank Vollertsen et. al.

As pointed out in the interesting article on "high power remote welding" potential for its use is considerable. However, the market is seen to be slow in reaping this potential. Why is this?

As far as we can tell, few parts, if any, are being specifically designed for remote welding. As a consequence, what suppliers willing to look into remote welding as an alternative way of manufacturing normally find is that there is (i) the additional task of convincing the customer through certified welding results, and (ii) a need for certain design changes and a lack of time to implement these changes due to the advanced stage the project has already reached.

Nevertheless, through this mechanism, First Tier manufacturers as well as their OEM customers are become increasingly aware of the potential of remote welding, and results of timely Simultaneous Engineering in this field are bound to show up in vehicles sold to the public, sooner rather than later.

The challenge, when designing machines for remote welding applications, is not limited to welding and fixturing. Since the processing (i.e. welding) time as a portion of total cycle time is reduced dramatically, fast materials handling becomes a key success factor. Consequently, the contribution of an integrator to the Simultaneous Engineering phase can considerably sharpen the competitive edge of the approach.

Theo Slangen Serra Soldarura

The article gives an excellent analysis of Laser Remote Welding, and includes a full account of both the advantages of the process, and the challenges associated with it.

It was especially interesting to see the results of the analysis of beam approach angle on the quality of the weld.

There are, however, those who would challenge the absolute need for using filler wire when welding aluminium alloys, as there is evidence that relatively high silicon content alloys (such as the 6xxx series) are less prone to either hot or micro cracking within the weld without filler wire, provided the key parameters are optimised; and I know of papers presented at a number of different conferences which provide evidence to support this.

The issue of presenting shield gas to the point of weld when remote welding is also well discussed, and is of interest because all the production applications using remote welding that I have seen were accomplished without any shield gas.

The use of compressed air blown over the weld area would raise the issue of noise, as well as the risks of water vapour and oil contaminating the work area, and it is certainly true that to use Helium or Argon at the volumes mentioned would not be economic in most processes. However, I have worked with a potential solution that does dispense Argon from nozzles mounted in the clamping using both solenoid and anti surge valves to ensure that gas is only used in the immediate weld area.

One key aspect of remote welding that is not mentioned is the fact that the location and clamping strategy used with the process can be a lot more flexible, with a significantly reduced clamp density, and the base fixture structure can be significantly less rigid than conventionally designed, as neither have to counteract the forces associated with resistance spot welding; this can allow a significant cost saving to be realised and also allow a higher level of reuse of facilities for model changes.

In addition, the ability of remote welding to produce stitch welds that are able to provide better joining within a smaller area (by using S-shaped welds for example) can also help ensure a simple fit up of the parts to be assembled (by using castellated flanges, for example), reducing their cost, complexity and weight.

The conclusions drawn in the article are correct: remote welding has a bright future in a wide variety of industries, once product designs exploit its advantages to the full.

Stephen Ainsworth SJ Ainsworth Consultancy

In my own mind I am still undecided as to whether 'remote' welding is a prime example of 'technology push' or has arrived on the scene due to real requirements and 'industry pull'. The technology developed relies on advances in CO_2 laser beam quality, high speed, low inertia, scanning systems, and the associated control software. The latter developments are of course closely related to laser marking, whereas the advances in CO_2 laser technology have been driven by the requirements of high speed laser cutting. Put all this together with high power, and we have a marker that can weld!

The article describes the advantages and disadvantages of remote welding. It may be a surprise to some to realise that weld penetrations as deep as 6mm are being spoken of. Questions are raised about the use/need of shielding gases in remote welding. It is clear that for some applications, welds fit for purpose can be made without shielding gas. However, at higher powers where the wavelength of the CO_2 laser creates difficulties due to plasma formation, helium shielding gas is needed; and delivery of this in an economic and practical way becomes a problem. At the wavelength of the Nd:YAG and other solid state lasers (10 times lower), these effects are not as problematical. However, beam quality issues with CW solid state lasers have, until very recently, precluded this type of laser from 'remote' applications. A look at the IPG Photonics web site indicates that things in this area might soon change. IPG claim to have developed a 5.5kW Ytterbium fibre laser with a beam quality such that it can be delivered through a 100 µm fibre. This laser has been demonstrated in a remote welding mode, using a 1400mm lens to focus the beam. At the approximately 1 µm wavelength of this laser, it will be interesting to see if deep penetration welds can be made without the use of shielding gas.

Paul Hilton TWI

After several years on the sidelines, the automotive world is starting to move to Remote Welding as a solution for large areas with many individual welds. In the beginning we were faced with the age old problem of trying to laser weld components designed to be resistance welded. Only recently have the designers realised the potential of RWS and taken it into consideration when developing new structures.

Large area “Remote Welding Systems” have been available for several years. The very high beam quality of the Rofin slab provided a suitable laser source as early as 1998. The first production unit was installed in 2001.

With a K factor of 0.9 (M2 = 1.1) the Slab operates at a focal length of up to 1.6m. By combining a linear drive focus optic and a single moving mirror a working area of 2400mm x 1500mm x 650mm has been achieved, and is in production both in Europe and North America. With power levels of up to 6 kW, components such as doors and pillars with maximum dimensions of over 1 meter can now be handled without moving fixtures. This goes a long way towards simplifying clamping fixtures and shielding gas nozzles.

There are several key factors that have to be looked at when considering a RWS:

- Overall part size. The larger the part, the more time that can saved by the high positioning speed of a RWS compared to a robot.
- Number of welds. As with part size, the more welds you have the greater the time saving during positioning. (>50 is a good guideline)
- Welding is non-contact. Fixtures can be relatively lightweight.
- Clamping. Well designed clamping is essential to achieve high quality remote welds. Clamps must not shadow the area to be welded.
- Plasma suppression. When this is required, shielding gas can be fed sequentially through a series of solenoids to the areas being welded. This will reduce cost of gas on large area applications where flooding the area is impractical.
- Long focal length systems have excellent depth of field. This allows a relatively wide tolerance on focus position.
- Exhaust. Keeping the area clear of smoke is key to a good process.
- Footprint. With the laser mounted on top of the unit, the overall footprint can be considerably less than that of the equivalent number of robotic systems.
- Maintenance. There are no electrodes, robots or other mechanisms to replace or maintain. All of the moving parts are contained within a box that is constantly purged with clean air.

By introducing RWS as early as possible in the design process we can open up hundreds of new applications. It isn’t always the right process, but when it is we can offer our customers a solution that provides a considerable advantage over current robotic resistance welders.

David Tinker Rofin-Baasel Laser

Laser Trimming
Bo Gu

Bo describes the techniques of laser trimming of resistors, and rightly comments that this will play an important role in the future manufacture of PCBs. Although resistors represent the most common use of this technology, there are other closely related areas of growing interest.

The increasing use of wireless communications, and the inevitable pressure this brings on accurate frequency control, is resulting in laser trimming of inductive and capacitive (or waveguide) components.

The question of whether and how to employ laser trimming can be a complex one. Can the part be manufactured within specification without trimming? If so, at what cost and at what yield? Is laser trimming simply recovering out-of-specification components or is it an integral part of the manufacturing process? I suspect that the quest for ever-tighter tolerances will mean that it is increasingly the latter.

Mike Osborne OpTek Systems

Success for first PICALO Conference

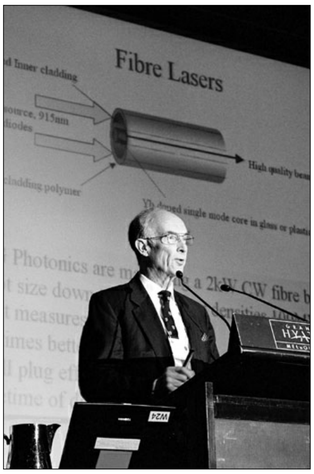
The 1st Pacific International Conference on Applications of Lasers and Optics (PICALO) organized by the Laser Institute of America in Melbourne, Australia from 19 – 21 April, 2004 proved by all accounts to be a great success. The conference general chairs Milan Brandt and Erol Harvey of the Industrial Research Institute Swinburne (IRIS), Swinburne University of Technology, Melbourne, Australia attracted many international, regional and local researchers, industry users and suppliers to hear and share the latest developments in macro and micro machining with lasers.

Some key people at PICALO. (l to r) Plenary speakers Akira Endo and Dirk Petring, Prof Tom Spurling (Director of IRIS), Bill Steen (leading Plenary speaker), and General Chairs Erol Harvey and Milan Brandt

PICALO was a three day international conference covering all aspects of laser technology and application focusing in particular on the growth and application of lasers in the Pacific region. The conference attracted some 100 technical papers and over 160 delegates from China, Japan, Korea, Singapore, Hong Kong, Taiwan, Germany, UK, USA, Austria, Sweden and Australia.

In his welcoming remarks Milan Brandt said that “one of the aims of PICALO is to provide a regional forum for researchers who normally do not attend ICALEO to present their ideas and discuss their results and this goal was achieved”. The conference was attended by a large number of postgraduate students who had a unique opportunity to discuss their projects with the many prominent research leaders present such as Bill Steen, Akira Matsunawa, Friedrich Dausinger, Dirk Petring, John Powell, Fleming Olsen, HC Man, GC Lim and Minlin Zhong.

The conference opened with an excellent review by Bill Steen of the developments and milestones in the growth of lasers and laser applications. He concluded that lasers and their applications is a successful and growing industrial subject that will shape a whole range of industries in the future. Other plenary speakers were Dirk Petring from the Fraunhofer Institute for Laser Technology, Aachen, Germany, who presented the latest developments in the laser-arc hybrid welding, the technology which is revolutionizing the shipbuilding industry in Europe. He was followed by Akira Endo from EUVA, Hiratsuka, Japan with a talk on “Laser-produced-plasma Light Source for EUV Lithography” and Martin Straub from the Centre for Microphotonics, Swinburne University of Technology, Australia, with a talk on “Femtosecond Fabrication of Three-dimensional Photonic Crystals in Polymers”.



Bill Steen delivering the opening the PICALO presentations with a review of laser milestones

The macro and micro sessions that followed covered all aspects of laser cutting, welding, control and monitoring, laser technology, photonic devices, femtosecond and biomedical applications and laser materials interactions. It is interesting to note that compared to similar European conferences as well as ICALEO what stood out as the dominant research area of interest in the region is laser surfacing. Three sessions with some 22 paper covered a whole range of laser surfacing applications involving steels to light and super alloys. This reflects the size and importance of industries such as mining and oil and gas to the regional economies.

The conference proceedings, containing all the papers including the plenary session, are available on a CD and can be ordered online at http://www.laserinstitute.org.

Events

MACH and SUBCON feedback

This was the first year for AILU to have a stand in both MACH (19-23 April) and SUBCON (19 - 22 April) at the NEC. Broadly speaking, the MACH stand concentrated on member services whilst the Subcon stand concentrated on AILU's 'Design for Laser Manufacture' initiative and the services offered by AILU job shop members.

The number of visitors followed the familiar pattern over the four days of the show: exhibitors talking to each other, good, good, fairly good; and (for MACH on Friday) back to exhibitors talking to each other. An unscientific poll of AILU members with stands in the Engineering Lasers area of MACH gave an average of 3.5 on a scale of 1 (dreadful) to 5 (spectacular). The best marks given by the laser marker exhibitors. After a very poor Engineering Lasers show in 2002, its better location and signing well have kept the initiative alive.

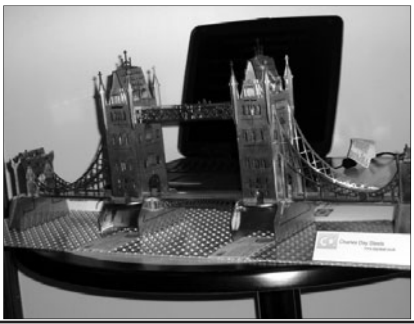
"Wednesday at SUBCON was notable for both the number and nature of the visitors; there were many job-shop customers and potential customers, including a high proportion that were not member's customers. This allowed us to further two objectives; to draw attention to the services offered by members and to raise issues of design for manufacture by laser," said Tim Weedon. "The up-dated chart of job shop flatbed cutting capability was a great asset," he added.

Surprisingly, 5750 Components was the only AILU member exhibiting in SUBCON (indeed, as far as we could tell, the only laser job shop exhibiting) yet 5750's Andy Murphy seemed well pleased with the level of interest at the show. According to Tim Weedon the range of interest in laser processing went beyond flatbed cutting, however. "We met several potential buyers of both laser welding services and laser welding equipment, many of these for the production of medical tools or devices," he said. "A surprising number of people were interested in laser joining of polymers, driven primarily by concern over the environmental impact of the solvents they use currently."

The bulk of visitors appeared to be from the Midlands and South of England, with the addition of a surprisingly high number from Ireland and the Indian sub-continent.

Twelve new companies signed up to AILU membership during the week, taking advantage of a special offer of £100 off the first year membership for enrolling during the show.

About a dozen members generously donated time to help man the two stands over the week, including the LAMP team of Coventry and Warwick University who provided 1 person per day for the whole show. In addition, Tim Weedon and Mike Green would like to thank Mike Barrett who generously stepped in to help dismantle and transport the two stands at the end of the show.



The laser cut tower bridge provided by Charles Day Steel for AILU's Subcon stand

September

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

Photon04 is the largest optics event in the UK and the second in the series that began in Cardiff with Photon02. Photon04 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*

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

October

4 **ICALEO 2004 (4 - 7)**
Laser Institute of America
San Francisco, California, USA
Info: http://www.icaleo.org (see opposite page)

20 **AILU Technology workshop**
Subcontract laser processing: the future
National Metalforming Centre, West Bromwich
Info: Contact AILU for preliminary details

November

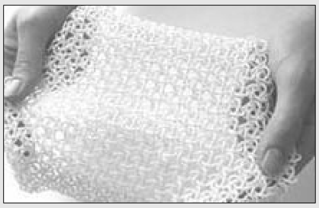
AILU Technology workshop
Laser-assisted Joining
Welding, brazing, preparation for adhesive bonding and other laser-based joining processes
TWI Sheffield
Info: Contact AILU for preliminary details

Presentations at the AGM

Presentations at the AGM at BMW Hams Hall on 31 March 2004. (left) Tim Weedon presenting the AILU Prize to Adrian Orchard and (right) Ken Lipton presenting the AILU Award to Denis Hall. Our special thanks go to Adrian Norton (thinklaser) for providing the laser marked plaque (AILU Prize), Mike Batchelor (Rofin-Baasel) for providing the laser engraved glass block (AILU Award) and Neil Main (Micrometric) for providing its laser cut and marked metal mounting.

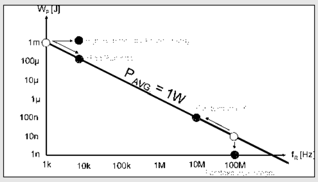
Contents

IN THIS ISSUE

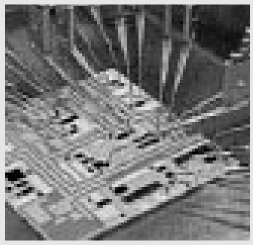


Rapid Manufacturing expansion p 36

integrated measurements p24

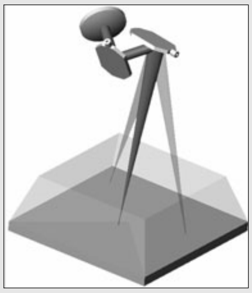


Short pulse trends p34

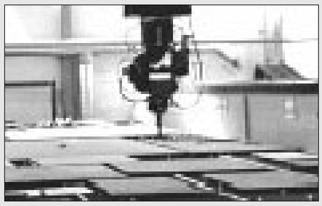


Testing PCB trimming p32

controlling back reflections p26



Remote welding p27



High power cutting optics p30

Editorial Policy

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

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

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

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