The Industrial LASER USER

association of industrial AILU laser users

Issue 11 May 1998

New initiatives in AILU

Making his President's report at the AILU AGM at Coventry University on 27 April, Bill Steen pointed out the many national and international laser meetings that AILU has supported, including the Laser Institute of America ICALEO conference series, the new ICALEO Europe Applications Overview, the recent Institute of Materials meeting in laser cutting and welding *(see meeting report, page 17)* and the recent Engineering Lasers Exhibition at the NEC.

A number of new initiatives for 1998 were announced at the AGM, including the AILU Web site, the ELAN network of European laser associations on the internet, the launch of a new series of one day meetings and the new directory of AILU providers of equipment and services

AILU Web site

Thanks to a grant from the Department of Trade and Industry, the AILU Web site has been completely revamped and is now to be found at **http://www.ailu.org.uk.**

The design of the site, by C3 Solutions of Sawbridgeworth, offers a straightforward, open presentation of information to members and non-members alike. Key features of the site include a 'members only' area and the new ELAN network access to sites around Europe.

Steve Corbett of SMC Design in Abingdon is completing the site construction. The site has full functionality and at the time of going to press the Directory of Suppliers of Equipment and Services will have been uploaded and all members advertising in the directory will have been given their own page on the AILU site. All such members will then have their own Web address; those who do not have a separate Web address will be able to use their page on the AILU site, others can have a link to their Web site but may wish to use their AILU page to advertise products and services targeted at the industrial laser community.

Members will shortly be receiving their unique password for accessing the members only section. This section will include the full AILU members' directory and, increasingly, useful technical information on laser processing.

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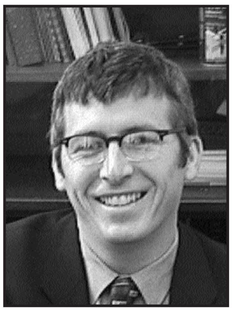
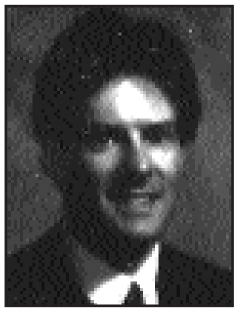
'Home page' of the new AILU Web site at ***http://www.ailu.org.uk***
Key features of the site include access to the European Network ELAN (bottom right), a 'members-only' section containing full contact details for members and useful technical and market information on laser materials processing, and a 'page per member' for those members who provide equipment and services to the laser community.
The site aims to become an essential technical and commercial resource for the UK laser community. Watch this space!

The new committee

At the AGM at Coventry University on 27 April, three founding committee members, John Bishop, Len Cooke and Maurice Gates, had each completed a 3 year term and were required by the constitution to stand down. Two nominations had been received, from Bill O'Neill and Cal Bailey. Both were duly elected together with Peter Hancocks, who until now had been co-opted onto the committee.

New committee members Bill O'Neill (left) and Cal Bailey.
Bill is a lecturer at the University of Liverpool in the field of laser materials processing and manufacturing technologies. His research topics include rapid prototyping and manufacture.
Cal was for many years a successful business consultant before he joined the Precision Laser Profiling Division of NG Bailey Manufacturing in 1996 as its General Manager.

Calling all members

NOMINATIONS FOR THE AILU AWARD 1998

The Association would like to make the award to 'an individual who has made an outstanding contribution to the industrial use of lasers in the UK.'

Promoters of the technology, business people, inventors and academics, young and old, are all eligible. The previous AILU award was made to Peter Houldcroft in recognition of his invention of oxygen assisted laser cutting.

The award will be made at the Association General Meeting on 20 October 1998.

Please send your nominations (one per member) with a few lines to explain your choice, to 'Award', AILU (usual address, see back page).

Closing date **31 July 1998**.

Letters to the editor

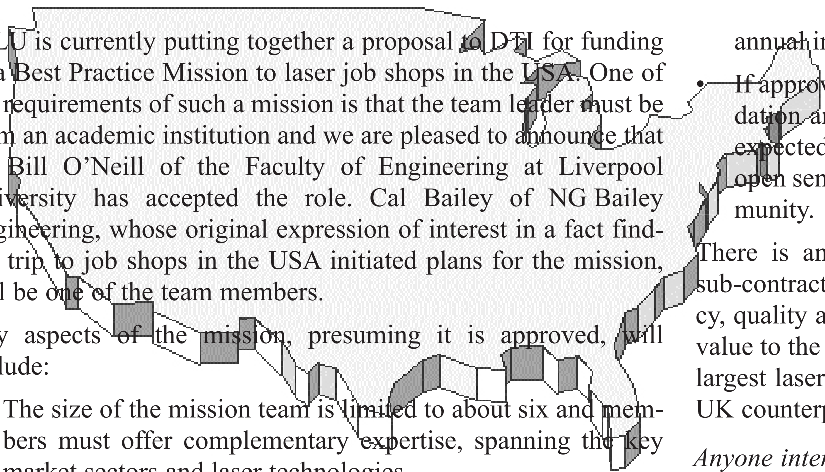
Why Hull?

By 2010 or thereabouts the laser industry will be celebrating its 50th anniversary. Maybe this milestone will be the occasion for a 'History of the Laser Industry', covering all the important developments from the initial work at Hughes, Raytheon, AVCO, RCA, Spectra-Physics and Coherent (to name just a few) through to the establishment of a worldwide industry. Maybe different volumes will deal with the various geographical locations in which the industry has operated. Obviously considerable space would have to be devoted to the USA, but within a European chapter surely the town of Hull would figure prominently. From the early beginnings of Laser Applications Ltd., through Coherent (Hull) Ltd and then to Lumonics Ltd - Hull Operations, along with the parallel development of Palomar Ltd and now Rofin-Sinar UK Ltd, Hull could be called 'The CO_2 laser capital of Britain'.With 12 years to go before 2010 who knows what more CO_2 history will be written about Hull? Certainly, given past performance another few changes of laser company name or ownership seems very possible.

History is often shaped by locations and people. A major part of the development of the laser industry has taken place in the San Francisco Bay area. Fuelled by the growing computer and electronic instrumentation industries, coupled with the enthusiasm of the West Coast entrepreneurial spirit (not to mention plenty of warm, pleasant sunshine for an enjoyable lifestyle) it would seem a very likely place for a whole new technological industry to develop. Which leaves one important question for the historians of 2010. Why did a laser industry ever develop in Hull?

Roger Beaman Coherent (UK) Ltd

AILU plans mission to USA job shops in 1998



AILU is currently putting together a proposal to DTI for funding of a Best Practice Mission to laser job shops in the USA. One of the requirements of such a mission is that the team leader must be from an academic institution and we are pleased to announce that Dr Bill O'Neill of the Faculty of Engineering at Liverpool University has accepted the role. Cal Bailey of NG Bailey Engineering, whose original expression of interest in a fact finding trip to job shops in the USA initiated plans for the mission, will be one of the team members.

Key aspects of the mission, presuming it is approved, will include:

- The size of the mission team is limited to about six and members must offer complementary expertise, spanning the key market sectors and laser technologies.
- The visits will take place over a week to ten days and end in Florida at the start of ICALEO (16 - 19 November 1998), the annual international conference on laser materials processing.
- If approved, the DTI will cover travel costs but not accommodation and other expenses. Moreover, team members will be expected to contribute to the mission report and take part in an open seminar to disseminate the findings to the UK laser community.

There is an expanding and lucrative market for laser cutting sub-contractors but the way forward involves improved efficiency, quality and service, and working with customers to add more value to the product. There is no doubt that sub-contractors in the largest laser services market in the world have lots to offer their UK counterparts, in both a technical and a business sense.

Anyone interested in participating, requiring further information or wishing to make suggestions on the scope or itinerary should contact Dr Bill O'Neill; tel: 0151 7944903, fax: 0151 7944693, e-mail: w.oneill@liverpool.ac.uk.

A note from the editor

Firstly, an apology for the late publication of this May issue. Blame it all on Engineering Lasers and the first of our open AILU workshops which we were keen to cover in this issue. In addition to these meetings I was fortunate, thanks to the generosity of the Make It With Lasers sponsors, to have the opportunity to take part in their 'Lasers in Manufacturing' meetings in Belfast and Dublin on 19 and 21 May.

All in all, this has been an excellent time to reflect on the UK laser community and I would like to share some thoughts on the job shop scene. Laser job shops make up the largest single sector of the UK laser user community and there is no doubt that the volume of business is excellent at the present time. A concern, however, is that competition between UK laser job shops is severe and is driving prices for basic laser cutting down to a seriously low level. Given the high capital investment that a laser cutting machine represents, a mad scramble to offer the lowest price for laser cutting will do the community no good in the long term.

In Ireland there are an estimated eight laser job shops (North and South) and competition is much less severe, but this is balanced by the absence of some of the manufacturing industries that provide much of the work to laser job shops in the UK. It was therefore particularly refreshing to hear Sean Mac Entee, during his presentation '*Sub-contract Laser Profiling in Ireland*' at the Dublin MIWL meeting, stressing that it is not enough just to cut metal; laser job shops must strive to work with the customer to add value to the product.

Readers of David Belforte's Industrial Laser Review will be aware that there are lots of innovative activities taking place in US laser job shops. I am sure that members will be delighted to learn that we are planning an AILU mission to the USA this year to see their job shops industry at first hand.

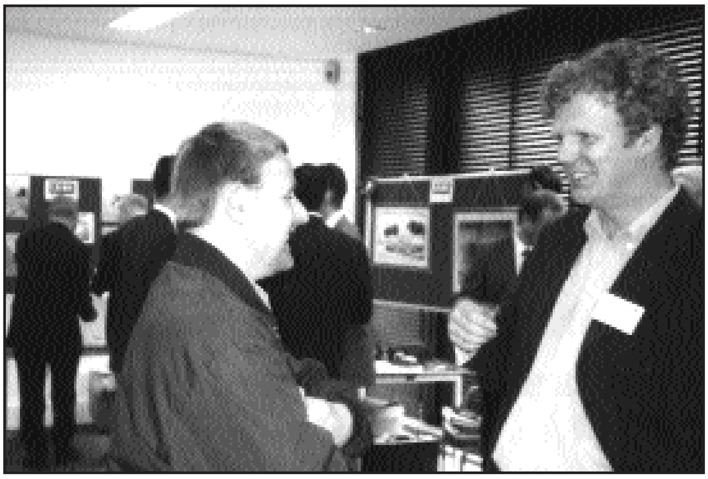
Successful first open AILU meeting

Tony Hoult and his colleagues at the International Manufacturing Centre at Warwick University opened up their excellent facilities for the first of the new series of AILU meetings, which produced an excellent turn-out of 70 delegates.

The workshop on CO_2 laser cutting began with an extended review of laser cutting basics and the effect of process parameters on cut quality and speed, for metals and non-metals, by John Powell of Laser Expertise. Tim Holt of Rofin Sinar then reviewed the various designs of CO_2 laser, from DC slow flow to RF fast flow, beam quality and the costs associated with the laser source. Moving the audience on from the laser source to the optics and nozzle design, Bill O'Neill of Liverpool University described the role of beam polarisation and assist gas shock waves. Peter Hancocks of Quantum Laser Engineering and Peter Harrison of Prima Industries reviewed the features of flatbed and multi-axis cutting machines, respectively, before the lunch break.

Seventeen organisations provided a lively table top exhibition during the buffet lunch. This was followed by a presentation on high speed laser cutting of flexible materials by David Bell of Lectra systems. Hannu Indrén of Rautaruukki Steel in Finland reviewed the requirements for laser quality steels and Jack Gabzdyl of BOC Gases completed the day's formal presentations with a summary of assist gas use.

The closing feature of the day was an open discussion which covered such topics as the design of gas nozzles and how to check them, how to find the position of beam focus and how to check for damaged optics, why does cut acrylic sometimes crack, hazards of cutting titanium and aluminium, pitfalls in gas line design.



The meeting Chair, John Powell (right) with delegates during the lunch-time exhibition

A questionnaire handed out during the meeting showed that 90% of delegates were well satisfied with the meeting and several useful suggestions were made as to how we can improve future events. The greatest challenge, however, is how we can attract better representation from laser job shops, which accounted for less than 20% of the delegates. Within the laser job shop community there remains a high level of ignorance about the laser cutting process and how to optimise it, but it is understandable that many feel they are just too busy to take a day out to learn and review.

Plans are already being drawn up for a CO_2 laser cutting meeting in 1999, this time addressing both technical and commercial concerns of the laser job shop community. Topics such as sourcing materials and measuring job profitability were suggested.

New initiatives in AILU

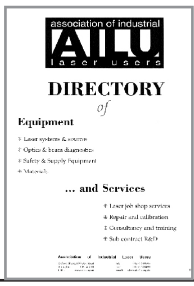
(continued from page 1)

The ELAN (European Laser Applications Network) page on the AILU site has received strong support from European laser centres. To date, over 30 centres around Europe have agreed to add the AILU-designed ELAN pages to their Web sites. In each country there is one National Contact Point and their ELAN pages should contain information about their national laser community with links to key resources. Other contact points will provide specialist or regional information. In this way, we hope to facilitate co-operation in research, exploitation and more generally in the exchange of information.

Full details including passwords and how to get your home page up on the AILU site will be circulated to members shortly

Products and Services Directory

The first edition at the AILU Products and Services Directory was ready in time for the recent Engineering Laser exhibition at the NEC and proved a great success.



The directory is a free issue item for distribution at exhibitions and AILU events during the year and is sent to anyone contacting the AILU office with a commercial query. The current issue, copies of which are circulated with this issue of the magazine, will shortly be expanded to include fuller details of laser job shop services and a moderate amount advertising to help cover the costs of printing and distribution.

AILU Meetings 1998

The laser cutting workshop on 13 May marked the start of a new series of one day specialist meetings for the Association. Their purpose is to give members the opportunity to attend user-orientated events. These cover topics of specific interest to them, something that can not properly be provided by the members-only General Technical Meetings. The large members' discount makes these meetings particularly attractive and will hopefully encourage new companies to join the association.

The programme of specialist meetings for the remainder of 1998 includes the following:

Industrial Laser Safety for Suppliers and Users
24 June, Liverpool University

Laser Beam Basics for Users
8 October, National Physical Laboratory, Teddington

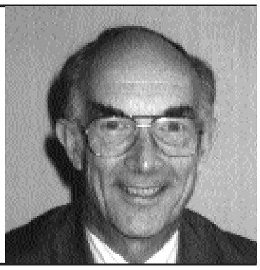
Laser Welding for Users
11 November, TWI, Cambridge

UK training of engineers with a knowledge of lasers

Opinion

Prof. Bill Steen

AILU President



The need

The laser has moved beyond being a fashion toy or an emblem for a pressure group. It is a real alternative industrial energy source. It is as basic and generic now as the dynamo was in the 1880s. The choice before us is not whether it is going to be used but whether it will be used by self taught amateurs or engineers with some knowledge of how to innovate with optical energy.

The growth of industrial spend on laser materials processing is well documented and has been 8-20% per year for some 15 years. This growth shows no sign of slacking nor should there be any wonder that it will continue at this high rate. The harnessing of one of the most flexible forms of energy ever known must have far reaching developments. But who will make these developments? Amateurs who may slow down the process through making well publicised mistakes, or trained engineers?

The current stock of self taught laser engineers have made spectacular developments in laser cutting, welding, surface heating, melting, ablation, cleaning, bending, cladding, texturing and many other processes known to the readers of *The Industrial Laser User*. So we have managed without formal training but it is irresponsible to continue that way.

The response

Laser courses are springing up all over the world in response to this need. UK courses are listed in the annual AILU Educational Supplement. Students are keen to learn and perceive the potential of a useful career with some knowledge of lasers; but the numbers are totally inadequate. The annual investment in lasers for material processing was approximately one billion US dollars in 1997/98. The annual production of graduate engineers in Europe was around 1000 per year (including approximately 600 from Germany; 100 UK; 60 France; 50 Portugal; 30 Italy; 30 Sweden; 30 Spain; 20 Greece; 10 Denmark). This is an alarming mismatch of investment to available manpower.

The solution

A step change in teaching is required to match the step change in industrial requirements. Universities should start including laser material processing in all engineering courses as a matter of necessity to reflect the change in engineering culture arising from the availability of this new form of industrial energy.
The imminent introduction of cheap diode lasers or diode pumped solid state lasers will make high powered lasers available at affordable prices within some five years. At that time the use of lasers will become almost commonplace in industry. If the University system is still not training engineers in this subject at that time they will appear professionally incompetent.

The problem for the Universities is that they need to support staff to undertake the new teaching duty. They do not have any extra money for this and hence to get the staff requires the loss of staff from other subjects. Basically the management vision and determination is not sufficient to solve that simple problem. For lack of such leadership the UK is likely to be a slow starter compared to Germany in this next industrial revolution, unless those with influence can persuade our University leaders otherwise.

COMMENTS

Where have all the graduates gone?

In response to the article by Bill Steen, I can give a very good example of the type of problem UK industry is facing now which passed across my desk at TWI only a few weeks ago. The UK manufacturing plant of a large multinational organisation recently received drawings for a new generation of machine from their offices in Japan. For several parts Nd:YAG laser welding had been specified on the drawings. No one at the company concerned in the UK had even heard of a Nd:YAG laser, let alone knew how to put one into production. When the UK company contacted the Japanese company to request clarification, the reply was - ‘go and see TWI’. While this response was good for TWI, this situation cannot be good for our UK manufacturing base. It is clear that in the UK we have a lack of both production and design engineers with a sound basis in the capabilities of the laser as a manufacturing tool.

The universities will contribute most significantly to the production of new graduate engineers in the laser field. The ‘Make It With Lasers’ programme, which has been operating successfully in the UK for nearly 10 years, continues to educate the sector of our engineering community to whom university based laser courses were not available. Approximately 2,500 persons have attended MIWL events since its inception. Additionally, TWI and Loughborough University have launched a series of three day courses on Laser Materials Processing aimed specifically at technician and operator levels. As a final comment on Bill’s article, the ratio of laser based graduates last year from Germany and the UK, 6:1, I found a little surprising. I think if it were possible, it would be useful to produce some data on what was happening to the 100 UK graduates when they leave university. As a potential employer of such graduates, TWI would certainly like to hear from them.

Paul Hilton TWI

NOTE: Next TWI/ L.U. 3 day course on Laser Processing 9-11 June, see Forthcoming Meetings

Comments continued over ...

COMMENTS (cont)

Loughborough's new training project

We read with interest the article by Bill Steen on UK Training of Engineers.

The purpose built Laser Centre at Loughborough College was opened in spring 1997 and offers a range of full time HNDs, part time HNCs and short course programmes in laser technology, laser applications and fibre optics.

In summer 1997 we applied for and received a grant for £0.5m from the European Social Fund towards the development of new vocational training in laser applications *(see news item on page 7)*.

We feel there is a need for vocational training at all levels within the industry and would like to enlist the widest possible participation. The project is funded for two years and started in January of this year. Part of the project will be specifically aimed at training and qualifications for users of material processing lasers.

There are five principal aims of the project: (i) to develop new, nationally recognised qualifications, (ii) to develop professional standards for the sector, (iii) to design and deliver flexible short courses, (iv) to initiate distance learning, and (v) to work with European partners to promote acceptance across the EU.

Our speciality at Loughborough College is in training, so we have adopted a 'for the industry, by the industry' approach to the project. In practice, this means that all aspects of the training and qualifications will be decided upon by a Steering Committee of manufacturers, users, academics, advisors and professional bodies directly involved in the industry. Currently represented on the Steering Committee alongside AILU are: TWI, Loughborough University, Lumonics, Carlton Laser Services, Trumpf, NRPB, Laser Expertise, Rolls Royce, Spectron Lasers and British Aerospace.

One of the first objectives of the project is to carry out an extensive survey to determine the training needs of personnel in the materials processing industry. From this and the advise of the steering committee the content of the course will be derived. This is where Loughborough College is welcoming the comments of the industrial laser community. From the development of competence based qualifications it would be a very small step to produce a Code of Practice and Professional standards. Again, this would be done under the guidance of the Steering Committee.

We acknowledge the difficulties in taking staff away from their jobs for training and for this reason an element of the project will be to produce Industrial Trainers and Mentors. This will allow workplace training and assessment schemes to run. Furthermore, one of the final goals of the project is to develop training programmes that allow trainees to use distance learning packages, such as the Internet, video-conferencing, on-line tutoring and on-line assessment.

The project runs until the end of 1999 and its success depends upon the active support of the *entire* industrial laser community.

Sharron Waring Laser Centre Loughborough College
Tel: 01509 215831 x249, e-mail: warings@loucoll.ac.uk.

Rugby centre for laser engineering training

I refer here to Bill Steen's article "UK Training of Engineers with Knowledge of Lasers". He highlights the need for increased training at Higher Education level and that it should be integrated into the studies of all engineering courses. Of course, we agree with this statement and think that the introduction of the technology at Further Education level will contribute to the pool of 'potential' engineers who recognise the advantage of laser technology and who will wish to progress through to HE for further study.

The Laser Engineering Centre was opened in May *(see news item on page 8)*. The Centre has arisen after recognition of the 'gap' in the market place for accredited training at Technician and Operator level. Consequently, Rugby College is currently working with accreditation bodies to formulate a Level 3 training programme in Laser Engineering. The programme is designed in a modular 'structure' to take into account the levels of prior knowledge and skill that clients may have. It is envisaged that students will come to us from a variety of backgrounds - some from general engineering but with no laser background, some with relevant skills who wish to take a recognised qualification, as well as our 'mainstream' engineering students, where Laser Engineering will become part of their training at BTEC/ONC and HND/C levels.

Each module will have a variety of assessment methods, where the participant will be able to demonstrate competence in:

a) Laser Health and Safety

b) CNC Systems

c) Laser Principles

d) Applications of Laser Processing.

Assessment will include practical assessments, written assignments and an end of module examination.

Rugby College is also leading on a LEONARDO funded project with the Laser Zentrum in Hannover and Friesland College in The Netherlands. The aim of the project is to develop qualifications at Level 3/4 that can be used on a European basis and to develop supporting materials, particularly multi-media, for teaching and learning. The project will run between February 1998 to December 1999 and has already resulted in the forging of new working relationships and exchange of good practice and ideas.

Viv Cooper Rugby College
Tel: 01788 338504, Fax: 01788 338575

Member's news

Coventry University links with major US research institute

Coventry University has signed a research agreement with the Oak Ridge National Laboratory (ORNL), Tennessee, one of the US Government's most advanced research institutions.

The University's Centre for Advanced Joining will be developing Plasma Augmented Laser Welding (PALW) projects with the Metals and Ceramics Division of ORNL. Coventry University, a leader in the field of PALW research, has recently licensed its patented process to Rofin-Sinar.

'This new initiative between ourselves and ORNL began in October of last year when Dr Stan David, Corporate Fellow of Lockheed Martin Energy Research and Leader of the Materials Joining and Non-destructive Testing Group at ORNL, visited Coventry University', explained Trevor Johnson of the Centre.

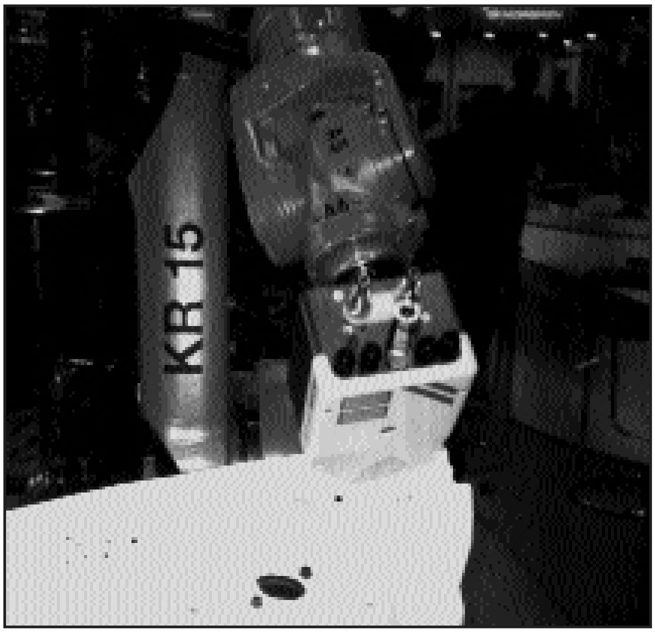
It is expected that the agreement will result in major advances in the field of welding science and technology. An exchange programme for researchers between Coventry University and ORNL is also planned.

At the signing, the Oak Ridge team flanked by Professor Ted Smith (left), Dean of Coventry University's School of Engineering, and Trevor Johnson

Rofin-Sinar project for diode laser development

Rofin-Sinar Technologies announced that an independent jury has chosen the 'Modular Diode Laser-Tools' project presented by Rofin-Sinar Laser as one of the five new projects to be supported by the German Federal Ministry of Education, Science, Research and Technology BMBF. The competition, organised by the BMBF, aims to further promote the development and application of advanced technologies.

The objective of the project is to identify the requirements and develop laser diodes suitable for material processing tools for manufacturing industries. The project includes more than 20 companies and institutes and is anticipated to last 5 years, with a total budget of more than DM 70 million (approx $40 M).



Rofin kW diode laser source mounted directly on the head of a Kuka robot at the recent NEC Exhibition

Diode lasers are extremely compact, maintenance-free and feature an efficiency of approximately 40%, significantly higher than the efficiency of conventional CO_2 or Nd:YAG lasers. However, the beam quality and related focusability with current diode technology are low, restricting industrial applications to surface treatment and soldering and welding of plastics and thin metal sheets. Therefore, improvements in beam quality, laser output power and the development of new application areas are key objectives of the research project.

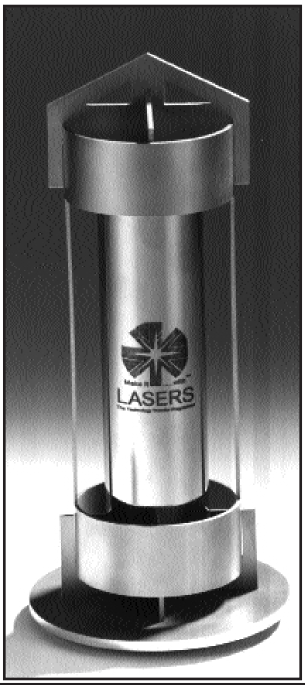
MIWL innovation award

Make It With Lasers launched its new Innovation Award at Engineering Lasers 98. The award will be made to a company which, in the judges opinion, has applied technology to achieve outstanding benefits in productivity, quality and profitability.

The closing date for nominations is 31 July 1998.

Further information from Carol Hedge at TWI (tel: 01223 891162).

The MIWL trophy was designed and manufactured at Micrometric's factory in Lincoln. It is made in stainless steel, entirely by lasers.



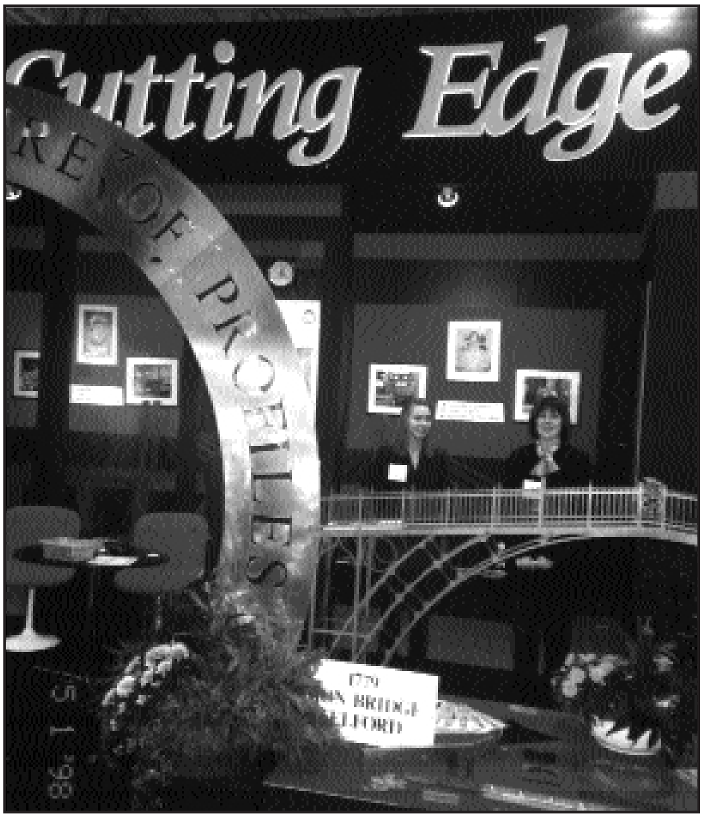
27 April - 1 May: MACH 98 - Subcon 98 - Engineering Lasers 98

Members make the most of it at the NEC

MACH and Subcon are annual events at the NEC but this was the second time for Engineering Lasers; the last was a 4 day event held in late 1996.

Some AILU exhibitors must have found it hard to know which of the shows to opt for. Laser job shop Micrometric Techniques, for example, exhibited at Engineering Lasers rather than with other laser job shops at Subcon. Similarly, the launch of Profile 600's new CO_2 cutting machine, the Laserblade, was on show at MACH; Convergent Energy, Electrox and Laser Lab also chose MACH. Gas suppliers Air Products chose the Welding and Metal Fabrication show and newcomer to the laser scene, Armstrong Steel, were in Metalworking '98 and commented 'there was lots of interest in our laser grade steel.' The net effect was to leave Engineering Lasers with a show of about the same size as before.

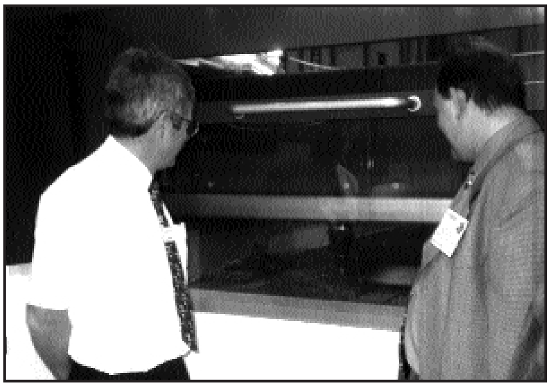
An AILU questionnaire conducted at the end of the show revealed that almost all of the 14 AILU members who exhibited at Engineering Lasers thought that the time and money spend on a stand was a good investment and planned to attend Engineering Lasers next time. Nevertheless, there was an almost unanimous feeling that 3 days would have been enough. The first and last days (Monday and Friday) were <u>very</u> quiet for most.



Part of the magnificent Lasercut Products (The Cutting Edge) stand at the entrance to Subcon 98. What better way to introduce people to emerging cutting technology!
'We have had a stand at Subcon ever since it began (1986?) but this is the first time we have taken a prime site,' said John Bishop, Managing Director at Lasercut. 'We have a stand as much to welcome our existing customers as to give us an opportunity to meet new ones,' he added.

What's a nice guy like him doing in a place like this? Joe Leece, Convergent's European sales Manager, shares the Trans Tec stand with Laser Lab at MACH. Laser Lab (Australia) is a sister company of Convergent (USA) and both belonging to Birmingham based Trans Tec. Confused?

Prima's Peter Harrison (second right) showing the Platino's automatic sequential cutting of plates of different materials and thicknesses using CNC focus control, on show in Engineering Lasers for the first time in the UK. Prima have signed a distribution agreement with Rhodes for flatbed laser systems in the UK and Ireland.



John Tricket (ex Laser Lab) shows off the new Laserblade from Profile 600 (see New Products)

On display at Engineering Lasers, Rofin's new range of sealed CO_2 lasers from 25 to 600 Watts, built at their new UK plant (see New Products)

The future of UK opto-electronics

The Rank Prize funds have generously donated £10.000 to CLAORD (Consortium for LAser and Opto–electronic R&D) in order to set up a residential seminar on the future of opto–electronics in the UK. The seminar, to be held in the Abington Hall Conference Centre at TWI from 3 to 5 June, will bring together a small group of key individuals from industry, academia and government bodies (including EPSRC and DTI) to discuss the priorities, the grand challenges and the way forward for opto–electronics in the UK.

There will be keynote talks by David Smith (British Telecom) on 'Challenges for Optoelectronics in Telecommunications' and from Randall Heyler (President of the newly formed Coalition of Photonics and Optics) on the recent US National Research Council report on the grand challenges facing optics technology.

Micrometric invests £350,000 in Trumpf Laser Processing System

Micrometric Techniques Ltd has invested £350,000 in a new Trumpf high peak power CO_2 laser process system. The 3 kW Trumpf L2530 laser will provide Micrometric with an enhanced capability to process technically demanding work and also to be competitive on sheet metal profiling applications.

The new laser takes Micrometric Techniques' manufacturing strength to 11 laser stations. Its unique combination of multi-axis Nd:YAG and high power CO_2 machines make it one of the largest and most versatile laser facilities in Europe, supplying anything from watch to tractor parts and from prototype to full production.

Dr Maurice Gates (right), managing director of Micrometric, and Brian Lewis, managing director of Trumpf, with the new high peak power CO_2 laser processing system.

New project in laser training

Loughborough College has recently received an European Social Fund Award to develop training and qualifications in Industrial Laser Applications including cutting, welding and marking.

This project has 5 principal aims: Qualifications, Professional Standards, Training Programmes, Distance Learning and Transnationality

The College realises that the project will only be successful if it gains the active support of the Industrial Laser Community. The Steering Committee comprises representatives from the Laser Industry, including AILU, BT Technical College, Lumonics, Loughborough University, TWI, Carlton Laser Services, Rolls Royce, NRPB and Laser Expertise.

Activities include the development of nationally recognised, competence-based qualifications, a Training Needs and a Vocational Task Analysis of the industry and a Code of Practice and Professional Standards. It will be the responsibility of the Steering Committee to get these accepted by the industry and AILU would hope to adopt them as its own.

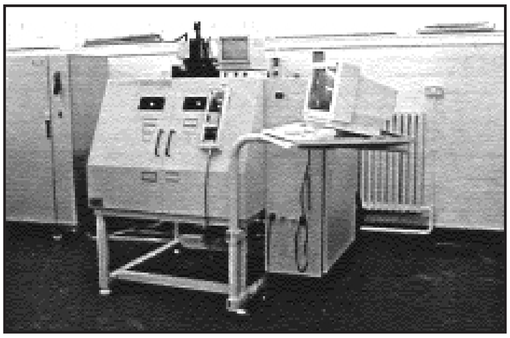
No more problems with 'humping' - thanks to Coventry University!

Your humble tin of beans could soon be sealed shut using laser power – if researchers at Coventry University's Centre for Advanced Joining get their way. The Centre has devised a new welding technique that could extend the use of laser welding into the canning industry, revolutionising production in this multi-million pound business – the biggest user of steel in the world. "The present technique for the welding of steel cans is known as mash seam welding, which can weld at 100 metres per minute", explains Trevor Johnson of the Centre. "Until now laser welding has been unable to compete due to a problem known as 'humping'. But one of our researchers, Nick Blundell, has now developed a technique that has not only overcome this problem, but also welds faster than conventional welding. With increased welding speeds, this new technique has the potential to revolutionise production techniques in the canning industry".

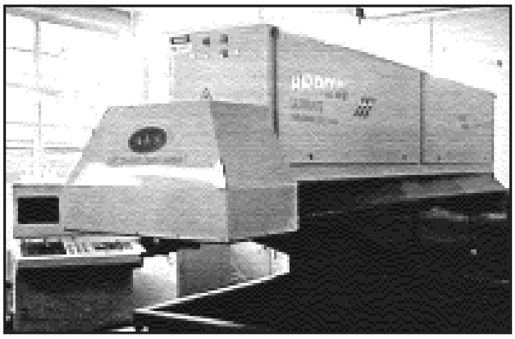
Another area in which the new technique can be used is in the manufacture of space bars in sealed unit double glazing which separate the glass panes. At the moment these are made of aluminium, which is four times more expensive than steel. The new technique allows thin sheet steel to be used for the space bars, meaning a significant reduction in price for the manufacture compared to the cost of using aluminium. "And what's more, the welds produced in steel using enhanced laser welding demonstrate improved crack resistance when compared to conventional welding, which could benefit both can and space bar manufacturers", concludes Trevor Johnson.

Open for business: Rugby College's Laser Engineering Centre

The Laser Engineering Centre at Rugby College was opened in May by Nick Stephenson, Rover Group. The facility, a result of a £364,000 investment by the UK Government Competitiveness Fund, has been planned and implemented by a team from the College, industry and AILU. It is equipped with 2 lasers; a 500 W Nd:YAG from Lumonics and a 1.7KW CO_2 laser from Convergent Energy/AES Limited.



(left) The Laserdyne 140 CNC machine with a 550 W Lumonics' Nd:YAG



(right) AES machine with a Convergent Energy 1.7 kW CO_2 laser.

'Rugby is well positioned to become a Centre for Laser Engineering Training,' said Viv Cooper, Head of Marketing and Commercial Projects at the College. 'We are situated in an area with a strong cluster of laser manufacturers, part suppliers and job shops. It is also within reach of a large number of manufacturing companies, many of whom use lasers in their processes, particularly the automotive, aerospace, textiles, ceramics and general engineering sectors,' she added.

'The Centre has arisen to fill the 'gap' in the market place for accredited training at Technician and Operator level. Consequently, Rugby College is currently working with accreditation bodies to formulate a Level 3 training programme in Laser Engineering. The programme is designed in a modular 'structure' to take into account the levels of prior knowledge and skill that clients may have. It is envisaged that students will come to us from a variety of backgrounds; some from general engineering but with no laser background, some with relevant skills who wish to take a recognised qualification, as well as our 'mainstream' engineering students, where Laser Engineering will become part of their training at BTEC/ONC and HND/C levels.'

Member's new products

New UK Laser Profiler

New 600 Group member Profile 600 launched its new flatbed CO_2 cutting laser at the NEC during MACH 98. The full flying optic profiler incorporates a 1500 W fast flow laser made by Electrox, another 600 Group member, and provides a cutting area of 3m x 1m and X and Y axis speeds up to 60 m/min.

The Laserblade has been designed to be 'affordable', offering low capital cost, running costs and maintenance.

Further info: Tim Norton at Profile 600
Tel: 01509 602600, fax: 01509 602660

The new Laserblade from Profile 600.

Rofin-Sinar expands into lower power carbon-dioxide lasers

Rofin-Sinar UK Ltd has announced the formation of a new UK based company to develop and manufacture a new range of low-power lasers to complement its existing portfolio of products. As part of its investment in the UK company, Rofin-Sinar Technologies Inc. has entered into a definitive agreement to acquire the business assets of Palomar Technologies Ltd, Kingston upon Hull, UK, a wholly owned subsidiary of Palomar Medical Technologies, Inc.

The new range of products is based on sealed gas laser expertise and proprietary diffusion cooled slab laser technology to produce CO_2 lasers in the range of 25 to 600 Watts. As the current Rofin-Sinar slab-technology starts at 1000 Watts output power, these new lasers will complete the product offering and allow the company access to new market opportunities in lower power laser processing. Experienced personnel from Palomar Technologies Ltd have transferred to the The new UK company.

According to Laser Report (January 1998) the market for sealed low-power CO_2 lasers for material processing was approximately 60 million US$ in 1997 and is expected to increase by 20% in 1998. Low power CO_2 lasers are typically used for cutting (paper, glass, plastics) and for marking, but the increasing demand for rapid prototyping is expected to create new market opportunities.

Further info: Tim Holt at Rofin Sinar
tel: 01455 250570, fax: 01455 250599

OEM Pulsed Flashlamp Drivers

Optilas announce the new 880 Series of pulsed flashlamp drivers for solid-state laser systems from Analog Modules, Inc. These OEM units are tailored to meet requirements and typically include a capacitor charging power module, simmer supply, pulse forming network, and user interface. Units can be configured for fixed or variable pulsewidth operation, 115VAC or 230VAC input, and up to 3500 W of average power. All units are power factor corrected and designed to meet IEC601-1.

Further info: Mike Hyliands, Optilas.
Tel: 01908 326326, Fax: 01908 221110

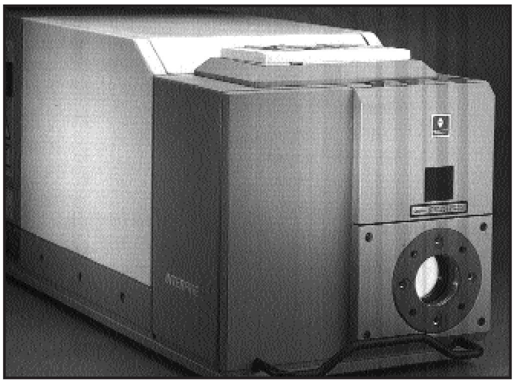
New laser gas equipment range

BOC Gases has launched a new range of gas control equipment that has been developed specifically to meet the needs of laser users. The range has been designed and engineered to meet and exceed the standards of laser manufacturers. BOC's new lasing gas regulators are of a two stage design for improved pressure and flow performance and have stainless steel diaphragms on both stages to prevent contamination of the lasing gas stream, maximising laser performance.The range also includes regulators for assist gases which are engineered to match both pressure and flow requirements, tailored to the supply mode being used.

For further information call free on 0800 02 0800

New POE Tuneable Interferometer

Precision Optical Engineering have successfully designed and built a new tuneable unequal path interferometer. Based on the Twyman Green interferometer, the Interfire 10.6 has a waveguide CO_2 laser source tuneable from 9.26 - 10.74 μm. A collinear HeNe laser facilitates alignment of external optics under test.



As a portable, easy to use, compact system, the Interfire 10.6 can be used for measuring the wavefront aberration of thermal imaging lens and mirror systems, optical homogeneity of IR materials and the flatness of optical surfaces. The tuneable Interfire 10.6 interferometer also allows wavelength changes and chromatic aberrations to be observed.

Further info: Precision–Optical Engineering
Tel: 01462 440328, fax: 01462 440329

New high power diode laser sources

Rofin Sinar had their new DL range of diode laser arrays on display at Engineering Lasers 98. The top of the range model, the DL020, offers up to 2 kW of power.

The diode source offers 30% efficiency and its rugged and compact design allows easy integration into existing production systems. *(See p6 for pic of the laser source, robot mounted)*.

Further info: Tim Holt at Rofin Sinar
tel: 01455 250570, fax: 01455 250599

New laser tube cutting system

Recent AILU members BLM-ADIGE displayed their new LASERTUBE 651 at MACH 98 recently. The laser cutting machine deals with a wide range of tube shapes and materials. A big advantage is its flexibility to carry out operations at both tube ends and along the tube as well. In addition, cut to length, any combination of holes, slots or contoured cuts can be performed. The machine is capable of accepting bundles of up to 4000 kg of tube which are then processed automatically.

Further info: Paul Lake, BLM-ADIGE Tel: 01525 402555, Fax: 01525 402312

Excimer laser beam attenuators

AG electro–Optics are introducing Acton Research Corporation multi–layered dielectric coated fused silica attenuators for 193 nm ArF and 248 nm KrF excimer lasers. Transmitted laser energy is varied by controlling angle of incidence on the attenuator. The 193 nm attenuator can change the output power of a KrF laser from approximately 20% transmission at normal incidence to approximately 85% at 45° angle of incidence. The 248 nm attenuator can vary the output power of a KrF laser from approximately 10% of its energy output to 90% output by changing the angle of incidence from normal incidence to 45°.

Further info: Dylan Abbott at AG Electro–Optics
Tel: 01829 733305, fax: 01829 733679

Situations Wanted

Matthew Henry BSc (Hons) EBOR. Requires full time employment within the laser industry as soon as possible. Currently reading for an MSc (Eng) in Advanced Manufacturing with Lasers at Liverpool University. Graduates in September.

Fabrice Leblond. Requires a temporary position within the laser industry between 1 July and 30 August. Currently a second year student in engineering at Ecole Nationale Superieure Des Arts et Metiers, a leading French National Graduate School of Engineering and manufacturing.

For full CV's contact Liz at the AILU office on 01235 539595

A Day in the Life of

Mike Osborne

The primary customer contact for laser activities at AEA Technology plc gives us a taste of the changing R&D business

If variety keeps you young, I must be in danger of regressing back to my childhood. My days are a mixture of customer visits, meetings and phone calls. These days I spend as much time in our customer's production facilities as I do in our own.

Tuesday: Another phone call, this time from one of our regular customers .... 'Hello John.....Yes, fine, and you? ... Right... yes... You want how many?....and by the end of the week!? OK,OK...I'll see what I can do.....Call you back in 20 minutes'. I know John is in the sort of business where demand is hard to predict so we like to be as flexible as we can, but he's just asked for 80 hours of laser time in 3 days. After conversation with production staff, I get back to John. 'How about 50% couriered to you late Friday and the rest hand delivered Sunday?....Fine, that's another drink you owe me.'

The telephone yet again, from someone for whom we drill small (100 µm diameter), precision holes in steel for a fluid flow application. As well as drilling, we also flow check every component ... "Hi Chris....right.... you want us is increase the flow by 0.5%.. OK, will do". A quick phone call to the chap running this production (plus the necessary QA form of course!) deals with that one. I wish all calls could be dealt with so quickly.

The next phone call is from someone completely new to us. He has an idea for replacing an existing chemical etching process with laser machining. Can it be done? I don't know, but it doesn't sound out of the question. The best I can do at this stage is to discuss the idea with others within AEA, possibly make a quick trial, and get back with a suggestion for the way forward. About two thirds of these 'new' ideas come to nought, but the other third has resulted in some of our most routine and profitable business both in carrying out laser service work and in supplying laser systems.

We are known for taking on work which lies at the 'difficult' end of laser machining, either because of the precision required, the materials to be processed or the process itself. This makes for lots of variety and interesting 'challenges'. However, it also means that we attract a number of enquiries which are not difficult, they are impossible, or at least do not stand financial scrutiny. I expect that everyone in the laser business gets a fair number of these. I shall not mention any of the many examples for fear of causing offense to the good people who were kind enough to consider the laser route - the very fact that they now think of laser machining as one of the battery of industrial processes is clearly a step forward even if, on occasion, they have little grasp of what lasers can and cannot do. I guess part of our mission is to educate them.

We also get a steady flow of what I would class as 'routine' or off-the-shelf enquiries - such as laser cutting of mild-steel blanks. These we pass on to others in the laser industry who are in the business of providing these services. At least we can help by suggesting who might be the better people to approach. Occasionally the favour is reciprocated, and we get enquiries referred to us which are beyond the capabilities of standard job-shops or standard laser systems.

The business we do under sub-contract to other parts of AEA Technology is not great, but it is diverse, mirroring the activities of the company as a whole and ranging from micromachining silicon for sensors, cutting CVD diamond, welding experimental artificial hip joints, cutting and welding of experimental battery packages. Again, boring it is not.

One of our major activities is in selective laser transformation hardening to improve the wear and erosion resistance of dies, gears, turbine blades and the like. However, the laser route is not always the best technical solution to these sorts of problems and we work closely with the other surface engineering groups within AEA who supply ion implantation, thermal and plasma spraying, diamond-like-carbon coatings and solid lubrication to provide the customer with the best treatment for the particular application.

The afternoon is given over to a meeting with one of our systems customers to update them on progress. As with many such customers, the system we are building is to put into production a process which we originally developed for them. It is particularly rewarding for them and us to see the job progress all the way from the initial, tentative feasibility study, through the hard-nosed technical, quality and financial process assessment and into production on their premises. The particular system requires sophisticated parts handling and so we have brought in our colleagues from the Automation Group at AEA. The environments where our systems operate are as diverse as the systems themselves, and range from high-class clean rooms to the back of a barge in the North Sea. Also, the level of after sales support varies according to the customer requirements from 24 hour call-out down to essentially none in some cases. We make a point of tailoring what we're offering to the customers needs.

In my ten years at AEA Technology the business has changed beyond recognition. From our background of medium-term R&D, our activities are now all focused on meeting the existing and near-term requirements of our customer base. The rather relaxed R&D ethos has gone, and has been replaced by the buzz of providing real solutions to real customer problems and seeing them in use - either on the racetrack, in the innards of your PC or in generating the electricity which keeps it going. As I said at the start, there's no shortage of variety in a 'typical' day.

Fibre optic delivery of high power laser light

Duncan Hand

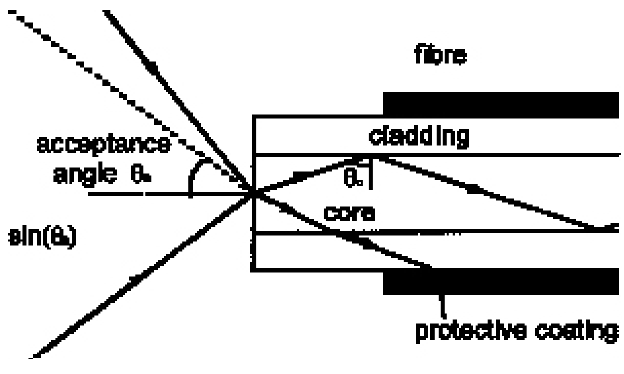
Heriot–Watt University, Edinburgh

In any industrial laser processing system the delivery of light from the laser to the workpiece is of vital importance. The ideal delivery system would be perfectly transparent, cause no degradation of beam quality and yet allow the beam to be positioned with agility and without precise realignment of optics. Fibre optics offer the highest possible flexibility, allowing full directional control of the light with transmission over 100 metres. They provide for 3-D processing and remote working capabilities, and allow one laser to be time-shared between many different workstations.

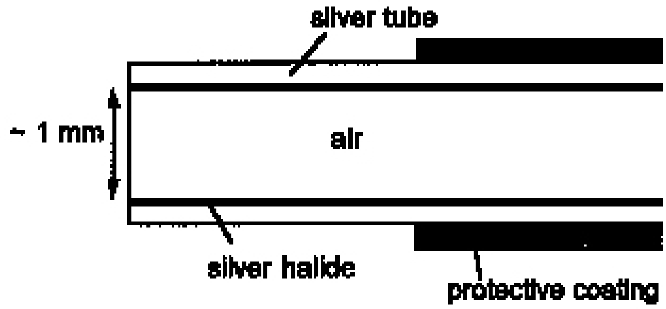
The telecommunications industry pioneered the development of fused silica optical fibres, that have since been adapted for use in laser material processing systems. Such fibres can offer outstanding transparency at the 1.06 μm wavelength of Nd:YAG lasers, in the 1 to 2 dB/km range. Typically, such fibres are used with high average power, long pulse or CW lasers. The fibres used have large cores with diameters of hundreds of μm (in comparison with the 8 μm diameter typical of telecommunications fibres), so the quality of the delivered beam is relatively low. Because of this, fibre delivery is often used for applications such as welding which do not require a particularly small spot on the work-piece.

Fibre operation

An optical fibre is a waveguide for light, and operates by providing multiple reflections at the interface between its 'core' and 'cladding', to convey light along its length. The reflection can be produced by total internal reflection (TIR) at an interface between dielectrics, where the core has a higher index, or by Fresnel reflection when the core index is lower - or even by reflection at a metallic cladding. The majority of optical fibres , including the silica fibres used with Nd:YAG lasers and for telecommunications, use TIR to provide guidance. These fibres can transmit light with very little loss, as low as 0.2 dB/km at a wavelength (λ) of 1.55 μm, caused by the fundamental process of Rayleigh scattering; the scattering loss increases as $1/\lambda^4$. For some wavelengths, for example 10.6 μm from a CO_2 laser, there is a lack of suitable materials from which to form TIR structures, and so hollow waveguides which use Fresnel reflections to guide the light are more suitable. These have very much larger intrinsic losses than their TIR counterparts, however, due to substantial attenuation at each successive reflection.



A waveguide for light: total internal reflections in an optical fibre



A hollow-core fibre provides flexible delivery for CO_2 laser light

Total internal reflectance fibres

A fibre based on TIR has the structure shown opposite. The core has a refractive index which is greater than the cladding, which means that light which is incident on the core/cladding interface at an angle θ greater than the critical angle θ_c will be 100% reflected. The angle θ_c is dependent on the refractive index difference between the core and the cladding. It is more useful to express this angle in terms of the fibre's numerical aperture (NA). Light which is incident on the front face of the fibre at an angle less than that defined by the NA will satisfy $\theta > \theta_c$, and so will be guided by the fibre. A typical silica fibre used for high power Nd:YAG beam delivery has a core diameter of between 600 and 1000 μm, and an NA = 0.22, with an attenuation at 1.06 μm of less than 0.01 $dB.m^{-1}$.

Both the core and the cladding of fused silica are made from fused silica. The difference in their refractive indices is produced by doping the core or cladding. A common strategy is to dope the core with a few percent of GeO_2 to increase its refractive index. Power handling capacity is improved by using a pure silica core, and to dope the cladding to reduce its refractive index.

In some fibres with a doped core, the doping concentration varies radially with a maximum on the axis of the fibre, thus forming a graded refractive index fibre. In such a fibre the local numerical aperture is largest on axis, and declines with radial distance to zero at the core-cladding interface.

All-silica fibres can be used with a very wide wavelength range, from 240 to 2200 nm, with reasonably low loss. At shorter wavelengths, absorption is caused by electronic transitions in the silica and at longer wavelength by vibrational transitions. For operation at longer wavelengths up to a few μm, lower phonon energy glasses, such as those based on fluorides, are suitable.

Silica fibres can be used with for a number of different materials processing lasers, including Nd:YAG (fundamental and frequency-doubled), diode lasers, copper vapour, and even the excimer 240 nm band. However, the short pulse lengths of some of these lasers can result in optical damage problems as discussed below.

The CO_2 laser currently has the highest volume sales for materials processing applications [1] but its infra-red output at 10.6 µm is unsuitable for all-silica fibres. Instead, one of the few TIR fibre structures which can transmit the 10.6 µm light from a CO_2 laser is a hollow sapphire tube. Sapphire has a refractive index of less than 1 at this wavelength, so air is suitable for the core material. However, these fibres still have high attenuation (0.5 - 2 dB.m^{-1}, increasing when the fibre is bent) and are only suitable for low power operation. In addition, they are not very flexible, which combined with the short lengths available (~ 1 m), only allows quite limited movement, and they are quite fragile and easily damaged. Some halide glasses have been developed as solid-core TIR waveguides for CO_2 lasers, but suffer from problems such as long-term deterioration and handling difficulties, whilst still having high attenuation.

Hollow waveguide fibres

A more promising fibre type for CO_2 wavelengths is the hollow waveguide. A typical example is shown above. This consists of a silver tube (glass or polymer tubes are also used), with a thin silver halide layer on the inside. The silver tube design can transmit the highest powers without active cooling, but such fibres are still limited to ~ 150 W. For this reason fibres have not been applied to CO_2 processes, apart from a few specialised low-power applications, which are primarily medical rather than industrial.

Implementation

Focusing optics are necessary to couple the light from the laser into the fibre. The optics are chosen to give a focussed spot diameter only slightly smaller than that of the fibre core. Allowance must be made for any increases in beam quality, and hence focussed spot diameter, that can occur with changes in operating parameters of some lasers. One way to avoid this is to use an imaging system where the cone angle rather than spot-size changes with beam quality. The fibre end-faces must be very flat and clean to avoid damage on coupling the light in, and are usually prepared by careful polishing to give a scratch-free surface. With small diameter fibres (outer diameter < 220 µm), however, high quality end-faces can be produced simply by cleaving with a special diamond tool - this is the standard technique used on telecommunications fibres and is much quicker and easier.

At the output end of the fibre, the light is imaged onto the workpiece with typical magnification ratios between 1:1 and 1:2. The main problem which can arise here is back-reflection of laser light from the workpiece. Such light will be refocused onto the fibre end by the optics and can cause the fibre and mounting to heat up and even damage when using high average powers. To avoid this, the fibre output housing which contains these optics is often placed at an angle of perhaps 10° to the workpiece.

Limitations

There are two factors which limit the implementation of fibre optics for delivery: optical damage and beam quality/profile degradation.

For long pulses (milliseconds up to cw), the main damage problems are thermal, associated with the high average laser power. Most high power Nd:YAG lasers for applications such as welding, cutting and drilling operate in this range. High average power levels are routinely achieved, with >3 kW feasible in fibres of 600 µm core diameter. However, with short pulses (nanoseconds), damage occurs at much lower average powers due to non-linear processes in the fibre such as self-focusing. Q-switched Nd:YAG lasers (used for marking), copper vapour, and excimer lasers all produce such short pulses.

Thermal damage

The high attenuation of hollow-core fibres means that thermal damage can occur simply due to the light that is converted to heat as it passes down the fibre. This form of thermal damage is not a problem in silica fibres because attenuation is so low. Problems for silica fibres can arise, however, on coupling the light into the fibre, since the laser must be accurately focused onto the fibre core. It is important not to overfill either the core diameter or the NA of the fibre. If this happens a proportion of the light is coupled into the cladding, and damage can then occur by absorption in the material in optical contact with the cladding, for example the glue used to mount the fibre.

Provided the laser light can be properly launched, there is potential for significantly increasing power transmission over that achieved in current applications. Experiments with an 8 µm core diameter fibre [2] have shown that the maximum long-pulse power which can be transmitted is 300 W. If this is scaled up to a more typical 600 µm fibre, and assuming that the power handling capacity scales with area, it implies that a maximum transmitted power of 0.5 GW! It may however be necessary to take into account the optical damage $1/d$ scaling law described by Brooke Ward in the February edition of this magazine [3], but even so a transmitted power of at least 23 kW should be possible.

Short pulse damage

Optical damage in silica fibres becomes a limiting factor in short pulse (tens of ns) transmission. In this case the damage threshold is orders of magnitude lower than expected from measurements made in blocks of nominally the same silica! This discrepancy is thought to arise from a combination of re-imaging of a small focussed spot in front of the fibre and self-focusing, so that even when the light is distributed over the core at the input to the fibre, it is concentrated into a small area once inside the fibre, thus exceeding the damage threshold. This situation can be significantly improved by using a diffractive optical element to produce a beam which equally excites a larger number of fibre modes, thus reducing the possibility of self-focusing [4]. By doing this, the damage threshold may be increased to ~ 25 mJ in a 400 µm fibre.

Beam quality and profile

Last (but certainly not least!), we must consider how the properties of the beam are preserved through the fibre. As indicated in the introduction, there is really no problem with silica fibres for low beam quality applications such as welding, where the loss of beam quality on transmission through the fibre is very small. Unfortunately, for higher beam quality applications, such as cutting, drilling and marking, degradation of both beam quality and profile can be a severe problem. Beam quality degradation arises simply because such beams do not match well to the mode structure of a step-index fibre (whereas the 'top-hat' profile typical of low beam quality is quite suitable).

A rough measure of beam quality is the product of the beam diameter and its numerical aperture. Irrespective of the spot size at the input of the fibre, it will ‘grow’ to fill the fibre core. Similarly, even if a low NA beam is launched into the fibre, the process of mode coupling will cause the NA of the guided beam to increase. Thus the quality of the output beam is always less than that of the input. Consequently, high quality beams must be guided by small core fibres.

Light propagates through a fibre in a number of discrete modes, and laser light output from these modes will interfere at the output of the fibre, causing a 'speckle pattern'. With a low beam quality, large core fibre, there are so many modes excited (> 75000), that these speckles are too small to be resolved whereas the smaller fibres required by higher beam quality lasers have significantly fewer modes, and so the speckle interference can become quite severe (and random!), to the extent of affecting the process. Such problems have been observed both with silica fibres for Nd:YAG precision machining [5], and hollow fibres for CO_2 marking [6]. One way of reducing this effect is to excite equally all the modes within a particular numerical aperture, by increasing the fibre length or introducing controlled bends. A better solution is to restrict the fibre core size sufficiently so that only one mode will propagate; such fibres are described as 'single-mode', and are commonly used in telecommunications applications. However, to obtain efficient coupling from the laser into the fibre, the laser must have M^2 of order unity. As a demonstration, light delivered through a 200 m length of single-mode fibre has been used to cut 0.2 mm thick stainless steel sheet at 4 mm s^{-1} [2].

Summary

Fibre optics are extremely useful components for laser materials processing, although at present they are only available for a small subset of lasers and applications. All-silica fibres have become standard components for certain laser systems, but their full potential remains to be realised. The increasing demand for lasers for precision processing has stimulated the development of Nd:YAG lasers of progressively higher beam quality. Fine processing of 3D parts is a natural application for optical fibre beam delivery. However, conventional designs of large core fibre, although entirely suitable for lower quality beams, are not appropriate for precision applications. Consequently, the active development of higher beam quality lasers is being paralleled by new approaches in the design of fibre beam delivery systems.

Whilst the enabling technologies for fibre beam delivery are all traceable to the communications industry, we are beginning to see the development of new materials and components being driven entirely by new potential applications in materials processing. Indeed, if the advantages of fibre optic delivery are to be applied to the full range of materials processing applications, new types of fibre and fibre systems must be developed.

References

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[2] D. P. Hand, J. D. C. Jones: 'Single-mode fibre delivery of Nd:YAG light for precision machining applications', Applied Optics, to be published, March 1998

[3] B Ward: 'Intensely damaging', The Industrial Laser User, 10 (1998) 24

[4] W C Sweatt, M W Farn: 'Kinoform/lens system for injecting a high power laser beam into an optical fiber', Proc. SPIE 2114 (1993) 82-86

[5] D. P. Hand, D. Su, M. Naeem, J. D. C. Jones: 'Fibre optic high quality Nd:YAG beam delivery for materials processing', Optical Engineering, 35 (1996) 502-506

[6] D Su, S Somkuarnpanit, D R Hall, J D C Jones: 'Hollow core waveguide for high quality CO2 laser beam delivery: exploitation of bend-induced mode coupling', Optics Comm. 114 (1995) 255-261

Comment

Duncan's article is an excellent introduction to the subject of fibre optic beam delivery. Fibre optics form a vital part of modern laser materials processing systems, being fitted to over 90% of the Nd:YAG processing lasers which we make at Lumonics. However the topic has not been well covered in the press from the viewpoint of the typical user, with most articles either too technical, or very superficial. This article provides an excellent reference for those who wish to have a practical understanding of the operation, capabilities and limitations of fibre optic beam delivery.

It may be that people have differing interpretations of what may be meant by 'large core fibres' and 'lower quality beams' in Duncan's closing summary. Our experience shows that fibres down to 300 or 400 microns in diameter can readily transmit beams of around 15 mm.mrad (half angle × radius) with <20% loss in beam quality. This is adequate for cutting applications with kerf widths down to 150 - 200 µm, which will comfortably meet the needs of most current volume production applications.

As an aside, regarding beam quality measurement - there has been a trend in recent years to quote mm.mrad in (half angle × radius) rather than (full angle × diameter), largely driven by our laser community colleagues in Germany. This makes the figures look better (lower), but can anyone explain to me how you can process parts using the radius of the beam and only half of the cone angle!

Keith Withnall Lumonics

Personally I do not think CO_2 lasers can be transmitted by fibre at all satisfactorily. Even the one or two 'CO_2 fibres' available today ruin the laser mode at certain bend angles and attenuate the power too much. I would stick to mirrors! For the YAG, however, the situation is different. Rofin use step index fibres for our high power lasers, these are designed to be very low loss. For marking lasers we offer step index or graded index, depending on application.

People always say that the YAG laser produces finer cutting kerfs. However, this is only true if the YAG laser uses fixed optics, it is not true if it is fibre delivered. When the beam exits the fibre, it is collimated and then focused. So, if you have a 600 µm fibre and 1:1 imaging, the spot size at focus is 600 µm, with 2:1 imaging you can you get a 300 µm spot. Typically, a 2:1 imaging system places the focusing lens too close (e.g. 60mm) to the work and the lens or the protection slide, will get damaged very quickly. To get the laser beam into a smaller diameter fibre requires a correspondingly better laser beam quality which usually means using a lower power laser. So, it is not easy to get a high power, small spot from a fibre delivered YAG laser.

If we compare this with the Rofin slab CO_2 laser, as a rule of thumb, the spot size in µm is equal to the focal length in mm. i.e. a 150 µm spot can be obtained with a 150 mm focal length optic. This is far better than a conventional lamp pumped YAG laser can achieve down a fibre. Diode pumped YAG is another story!!

Flexible beams

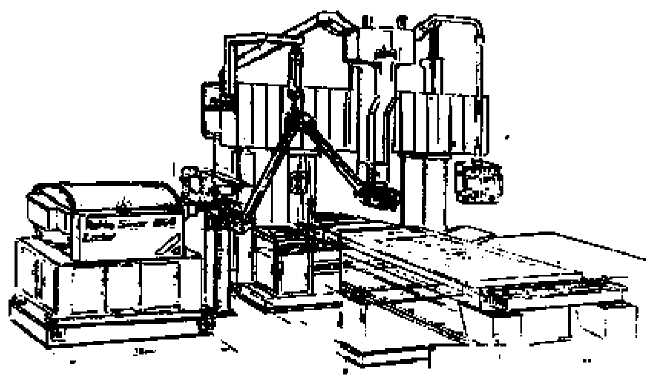
Sending CO_2 beams around the bend

Brooke Ward

Europtics

I don't like fibres. Let me be thoroughly contentious. Let those YAG people put me in the stocks! Why do we go to all that trouble to minimise thermal distortion in the rods? We carefully select a resonator to give the best mode and power. Then ruin it all by squeezing high-power beams into multimode waveguides.

A few months ago, Mike Green showed me some leaflets describing the new Rofin-Sinar FLEXARM® system for CO_2 lasers and the arnold flex arm technology from the laser system integrator, Arnold of Ravensburg in Germany. When I looked at the pictures, a great flood of nostalgia overwhelmed me again - so Mike asked



An illustration of the FLEXARM® taken from the product brochure

me to record some of the history from my point of view.

The flexible beam guide is an attractive technology for delivering a high quality laser beam to a moveable focus head. It can preserve mode quality in a controlled atmosphere so there will be no thermal blooming from noxious vapours such as water, oil or solvents. There is a fixed optical path length between the laser and focus head so there will be no variation in the focused spot size or

. . . . . . delivering a high quality laser beam to a moveable focus head

. . . . . no thermal blooming from noxious vapours

. . . a fixed optical path length between the laser and focus head

position as the head moves over large workpieces.

The idea of the beam guide is very simple. A number of tubes linked with plane mirrors at the joints direct a beam along the tube axes. The first example I came across was in a Patent taken out by Alan Beech in 1968 (I think). He was at UKAEA Aldermaston at the time and thought it a good idea for safely manipulating beams inside nuclear caves. The mechanism was a clever use of a single mirror at each tube elbow. The mirror had to move only half the angle the tubes moved - so he linked the mirror drive to the cage of the ball race that formed the elbow pivot. The cage moves at half the speed of a shaft so it all worked perfectly - for a while, until a bit of slip took place.

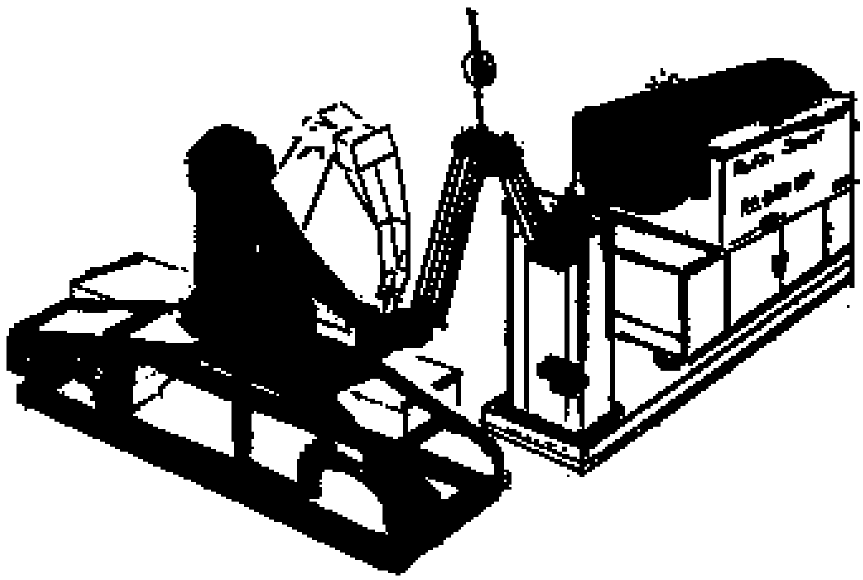
I thought of using linkages or sun/planet gear systems to overcome the problems but that whole concept was rather limited. Alan Travis and Arthur Taylor at Culham decided to use a two-mirror elbow. Alan went the manual manipulator route while Arthur fastened his guide to an anthropomorphic robot.

We were all quite proud of our achievements. Then we went to Laser '75 in Munich - and saw the Sharplan (Israel) exhibit. It was an almost identical manual guide equipped with a 50 W laser for medical purposes. We subsequently went to a lecture given by the Israelis at the Nuffield Orthopedic Hospital in Oxford. What we had been describing for material processing as the heat affected zone, those MD's called the necrotic area! We didn't like the smell of it so we left the medical area to others.

Meanwhile, Westland Helicopter's saw the manual guide and

Alan Travis demonstrates Culham's flexible CO_2 beam delivery thought it might help with some of their cutting tasks. The system was taken to Yeovil and put in the hands of an Asea robot. It worked so well that one Westland employee, helping with the tests, left and set up his own company. He took a license to the Culham robotised technology, got married and moved up to the North East all within a few weeks, I seem to remember. The company was Flexible Laser Systems Ltd, the machine was called Cobra and the man pushing it all was our own Trevor Johnson, now with the Coventry Centre for Advanced Joining.

By 1983, more financial muscle was needed so Trevor sold his setup to Ferranti. They modified the designs a bit, gave Trevor a job, improved the bearing and mirror mounting precision and put some systems in the automobile industry and some went to Japan. Nevertheless, those multi-jointed beam guides took an expert to align them and keep them running. Nick Rutter from Culham spent a few weeks in the fleshpots of Japan, re-aligning the systems.



Fed by a Rofin-Sinar 6kW CO_2 laser, the FLEXARM® is now performing production welds along the roofs of Audi's .

Back at the ranch (Culham), the demands were rising for a cutting system to cut the wrappers from Fast Reactor fuel elements. This was all part of the European Fast Reactor programme. The beam guide is pre-eminent for operation in such a hostile environment. There are no linear slides or seals to give contamination problems. The beam environment can be rigorously controlled. The whole unit can be folded and withdrawn from the cave for replacement. It is the ideal system for precision cutting. We were well on the way to a 10 kW, 100 mm bore system with remote maintenance capability. Another more compact system was supplied to BNFL for cutting the lids from rusty oil drums of low-activity waste. Again, the ideal solution. We patented the system for welding oil and gas pipelines in situ. Then came

No worries . . . . about grease and oils from lead-screws . . . . . over scattered beams hitting plastic bellows.

. . . just a straightforward, quality preserving, beam guiding environment.

. . . . . . no linear slides or seals to give contamination problems

. . . . . the ideal system for precision cutting

Three Mile Island, - then Chernobyl! Programmes closed down and the technology shelved.

While this was going on, Ferranti decided to improve the precision of the system. The next that I saw of the technology was during a BRITE meeting in Stuttgart. Joe Leece, now the European Sales Manager for Convergent Energy but at the time the Ferranti Sales Manager, took us to see some developments. Ferranti had commissioned the Fraunhofer Institute for Production Engineering in Stuttgart to advance the design. I saw some carbon fibre tubes being installed to reduce bending errors in a much enlarged system.

Gunter Hartock was the man in Stuttgart. He is now building tower cranes in Pamplona, Spain. I spoke to him the other day. It appears that when Ferranti ran into their problems in the US in 1990, they had to drop the work. At that time, there was very little incentive to put robotic laser cutting systems into industry so the technology was shelved.

Gunter and Karl Cloos Gmbh. took up the baton in Stuttgart for a while. Then that all-important enthusiast in the funding company left and Gunter went to build tower cranes. Again, the technology was shelved.

Of course there were others who continued. Sharplan, as part of Laser Industries Ltd. are probably still supplying the beam guide system as part of their package of surgical laser accessories. Laser Mechanisms of the US make a smart, compact manual system for the lower power range. These are all good products, rugged and reproducible. But where have those high power beam guides of Rofin and Arnold come from?

It appears that Arnold decided that the flexible beam guide had some serious potential. A laser beam delivery system that is a separate entity to the workpiece and tool manipulating system is very attractive. A conventional machine tool can be coupled with a laser machining head. The beam-line atmosphere can be kept free of pollution. No worries about grease and oils from lead-screws. No worries over scattered beams hitting plastic bellows. Just a straightforward, quality preserving, beam guiding environment.

Arnold looked at what had gone before. They adopted the concepts of carbon fibre technology from the Fraunhofer work, the spherical mirror seat from Arthur Taylor's BNFL can-opener and put together a large high-power system. Fed by a Rofin-Sinar 6kW CO_2 laser it is now performing production welds along the roofs of Audi's. I knew it was a good idea!

As I said at the beginning, most of this is personal faltering recollection - so any resemblance to the truth might be regarded as coincidental.

Comments

Sending CO_2 beams round the bend

Memories! It is nice to think about the old days when we were all young and innocent (well apart from Trevor Johnson, who was never innocent!). Brooke Ward's article has taken me back, in the nicest possible way.

I was at Westlands with Trevor, albeit in another department, when news came of his disappearance. I left Westlands shortly after (long story) and joined Ferranti. Who should I meet there but Trevor with his Cobra? I remember sharing an office with him and listening in awe at his side of the wheeler-dealer discussions with DTI and Rover in order to get the Cobra installed at Rover. It all went well in Rover's development facility, but it went "pear shaped" when it moved over to their production site. Another long story, and one I was intimately involved with, as by this time Trevor had left to look after Ferranti's interests in the USA and I got stuck with the project. The Cobra subsequently moved to Liverpool University where, I think, it still resides.

When Rofin passed me the first news about the FLEXARM, I thought "not again"! However, after going over to Germany and seeing the FLEXARM designed by Arnold in use with both our slab laser and our 6kW cross flow laser, I was very impressed. All the difficulties of alignment which I had been used to with the Cobra had disappeared. the spherical mirror mounts make setting up the FLEXARM really easy and it stays in alignment! We now sell it as one of our standard beam delivery systems, which just goes to show how far these things have come. We offer a galvo scanning head option which can be fitted at the "sharp end" that can produce all types of weld shapes.

Tim Holt **Rofin Sinar**

I wouldn't go so far as to put Brooke 'in the stocks', as I found his article a very enjoyable read. I also think it admirably demonstrates how desperately people have struggled over the last 25 years or so to create flexible beam delivery systems.

A well designed fibre beam delivery for YAG should not lose more than 10 - 20% of the hard won beam quality. If there were such a fibre optic system for high power CO_2 lasers would people really still pursue flexible arm designs in order to win back this 10 - 20%? I think not!

Keith Withnall **Lumonics**

MEETING REVIEW

Exploitation opportunities for laser cutting and welding of steel

reviewed by

Alan Thompson British Steel

The conference incorporated the presentation and discussion of a wide range of processes, whilst taking time to explore particular aspects in more detail. Overviews were provided of the practice of laser processing, automotive welding fabrication both in components and final assembly, steel development and testing and cutting. In addition a good appreciation of the pros and cons of different laser sources, particularly Nd:YAG and CO_2 was also provided. Lastly, two case studies provided insight into the real challenges and potential advantages of adapting a process route to include laser processing.

The primary driver for laser technology is cost reduction of the overall fabrication. However, this is rarely identified at the point of laser application, but is more commonly immediately identified as a benefit to quality or to tolerance, which, if the process route as a whole is correctly designed, translates to cost reduction at a later stage. Use of lasers has already been established in the automotive and aerospace industries and is now growing beyond simply profiling in the off-road vehicle, shipbuilding and pipeline transportation industries. Accompanying the growth of lasers in the automotive industry has been the growth of automation, especially that required to hold components in place.

An excellent example of the need to design around the laser was provided, using the explanation of how subsequent pressing and laser weld orientation should be considered together at the design stage. Testing was covered and although the general news in terms of toughness and fatigue was good, several challenges relating to the high hardness of the laser welded region were highlighted. Several attempts to compare Nd:YAG with CO_2 lasers were made, but the complexities of capital and running costs, safety and slight performance differences made this inconclusive. For example, the Nd:YAG may appear more portable due to being generally smaller and capable of doing more work in steel for a given output power; but the beam is more dangerous to the eye necessitating more complete screening and the efficiency of power conversion to the beam may not be as good. A Nd:YAG laser scored highly for the flexible beam delivery whilst CO_2 laser are still available in higher powers and power for pound cost less. It was agreed that comparison was only useful for specific applications.

An excellent insight into the advantages of precisely cut and marked components in a Shipyard was given. Huge savings in rectification costs and ease of assembly had not only paid for the laser quickly, but had also raised the overall quality of finished vessels. The distortion in panels had been virtually eliminated, thus not only improving aesthetics but also reducing resistance to movement through the water. At another location laser cutting marking and welding was being trailed. These various processes used different focus heads on the laser, but the same source. In many instances the ability to share the laser source had been stated as a benefit. Laser welding was quoted as being the most difficult process, but with great potential benefits.

I believe that the conference was a great success and could only have been improved by the attendance of representatives of more companies, which I am sure could increase their profitability by exploiting of laser processing.

Laser Fabrication of tailored blanks

Craig Bratt

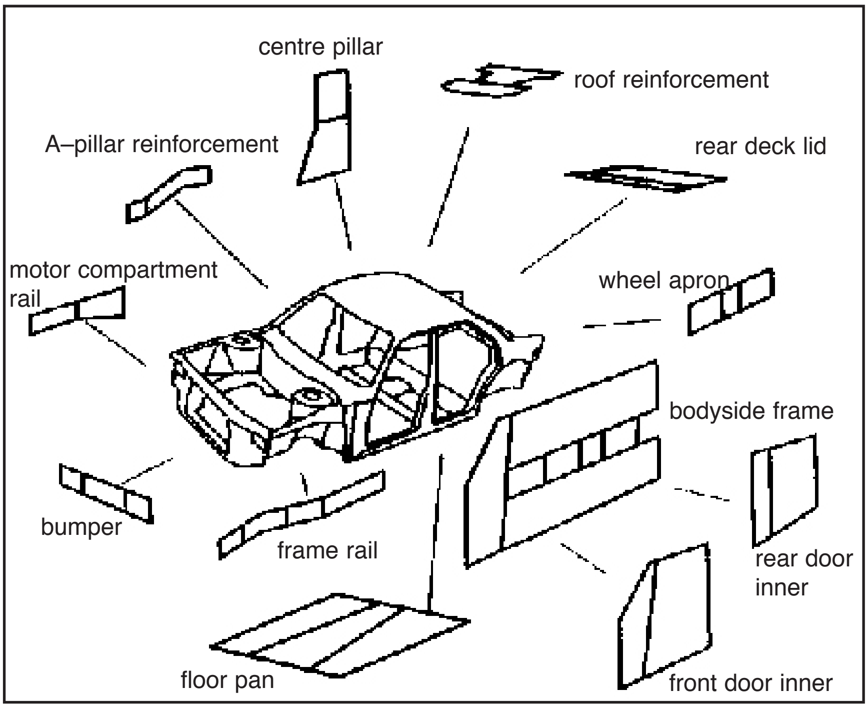
British Steel Strip Products

Tailor Welded Blanks

In the early 1980's Thyssen used the laser welding process for joining two steel sheets in order to produce a one piece floor pan stamping for the Audi 80/90 and 100/200 series (coils of the required width were not available). The process was then developed for joining different sheet materials in order to produce Tailor Welded Blanks.

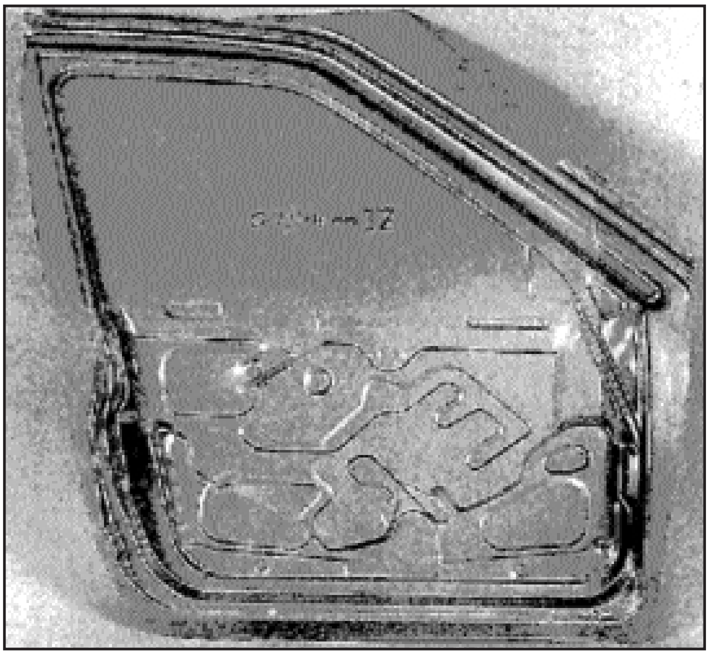
Tailor Welded Blanks consist of steels of different gauges, strengths, and coating types, welded together to produce a single blank prior to press forming.

Mash seam, high frequency butt, and laser processes can all be used for welding TWB's, but the laser process can produce better corrosion resistance, good aesthetic appearance, high tolerance to coating type and material thickness differences, and long welds. The advantages of this have been well documented and include weight reduction, part consolidation, improved crash management, and increased material utilisation.



Possible TWB applications in car bodies.

British Steel's Customer Technical Centre has been developing this technology for over 4 years, and many prototype blanks have been produced for its automotive customers on its research and development facility at Port Talbot. This facility comprises a 5 kW CO_2 Howden (formerly Laser Ecosse) AF5 laser and a HELD flying optics system allowing 2D beam manipulation. The machine is capable of welds up to 2.25 metres long and can produce prototype TWB's for most automotive components.



LTWB Door inner pressing (0.7/1.4mm thickness Zinc coated steel).

TWB's have been widely adopted by most of the large car manufacturers world–wide and the major applications either under development or in production include:

Door inners (BMW, GM, Ford, Chrysler, VW, Honda, Toyota)

Bodysides - inners and outers (GM, Nissan, Toyota, Renault)

Rails (Audi, Ford, GM, Renault, SEAT, Volvo, VW)

Pillars: (GM, Fiat, Mercedes, Volvo,Renault, VW)

Virtually all car manufacturers have TWB's either in production or in development for their next models. In the recent ULSAB (Ultra Light Steel Auto Body) vehicle designed by Porsche Engineering Services for a world–wide consortium of 35 steel companies, more than half the body-in-white weight is made up of TWB's.

TWB applications in the UK automotive market are now beginning to take off, with several major car manufacturers implementing this technology in their new vehicle build programmes.

BSD (British Steel Distribution) has installed and commissioned the first UK production facility for volume TWB manufacture at its specialist automotive centre in Wednesfield. The facility features a 6 kW CO_2 Rofin Sinar laser and is fully automated. Further machine purchases are envisaged in order to cope with increased demand.

Another recent development is the advent of British Steel's Automotive Engineering Group (AEG) based in Coventry. A primary function of the AEG is to develop closer EVI (Early Vendor Involvement) links with British Steel's automotive customers. AEG's design experts help customers to optimise TWB design

BSD's TWB facility at Wednesbury.

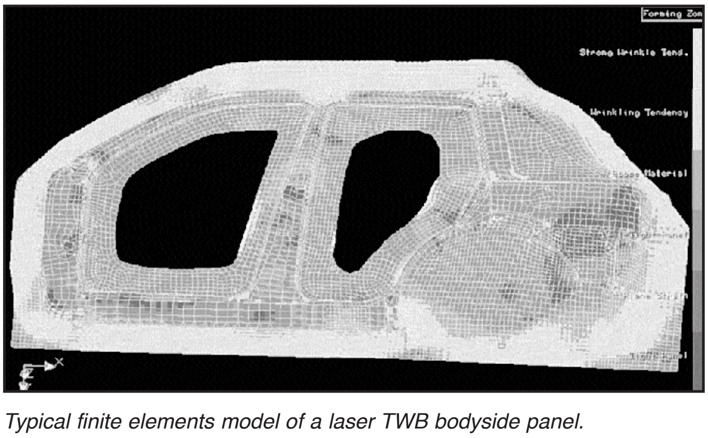
and ensure that all TWB options are evaluated and supported from the design concept stage.

Computer modelling of TWB formability performance is an important factor and this is assessed by finite element analysis packages such as PAMSTAMP and OPTRIS at the Welsh Technology Centre. British Steel therefore has the facilities and expertise to help its automotive customers throughout the entire process from concept design to volume manufacture.

Lasers in 'Body-In-White' Construction

Now that lasers have been widely accepted by the automotive industry for welding of both TWB's and drivetrain components (gears etc.), the next step is for the application of lasers in B–I–W construction to become widespread. Volvo were the first large company to use lasers in this way – they came up with the concept of laser welding the roof to the side-frame over 10 years ago, using a CO_2 laser in conjunction with a roller device for maintaining good joint fit-up. Since then both BMW and Audi have undertaken major developments in this area, and both companies now boast over 8 metres of laser welding in their latest models. The ULSAB vehicle has more than double this length of laser welding with 18 metres. The benefits of this approach are increased torsional rigidity, continuous leak tight joints, and improved quality and performance. This approach also facilitates the wider use of of thinner gauge high strength steels for weight reduction.

The above developments all use CO_2 laser technology with relatively inflexible and cumbersome beam delivery systems, and expensive mirrors. Recent developments in the field of Nd:YAG lasers has lead to the viability of supplying 4 kW of laser power to the workpiece via a fibre optic cable, providing more flexibility and reduced total system cost. In addition, the new demands of the latest vehicle build technologies, incorporating hydroformed tube structures and space frames, will doubtless necessitate the further development of this technology for high volume automotive construction. Conventional fusion welding processes are seen as detrimental because of their high heat input, distortion, coating removal necessity and poor aesthetic appearance. Laser welding, therefore, is expected to increase in future automotive body–in–white construction.



Typical finite elements model of a laser TWB bodyside panel.

Craig Bratt BEng MSc European Laser Engineer is currently employed as a Research Officer at British Steel's Welsh Technology Centre, and has over 10 years experience in welding related technology. He has been heavily involved in the development of Laser Welding technology for British Steel's Automotive customers for the last 3 years, especially in the field of Tailor Welded Blanks.

Laser welding in car body production

An extract from 'New advances in laser welding for car body production'
by Dr Ing C Emmelmann, Rofin Sinar

More than 10 years ago the laser established its industrial production credentials in two different welding applications in the automotive industry. The first laser welded tailored blank for the underbody of the AUDI 100 was qualified by companies Thyssen and Rofin-Sinar. The first on-line production laser welded roof was produced by BMW with a cross-flow CO_2 laser.

Since that time, more automobile manufacturers have been engaged in qualifying laser cutting and welding applications in car body production, particularly in the last 3 years many lasers have been installed on automotive production lines. Figure 1 shows an overview of typical laser processed car body parts, which are either cut or welded by CO_2 or Nd:YAG lasers in various car manufacturer's plants. The wide range of laser processed parts include underbody, roof, and various structures at the front and rear of the car. Several installations have already combined different cutting and welding applications with the same laser beam source, for example the Volvo V70 sports car or the Mercedes S class.

In collaboration with the international steel industry, Porsche is developing the steel car body of the future (ULSAB: ultra light steel autobody). The ULSAB car combines typical welding applications with laser welding of hydroformed parts. At present, the ULSAB car body includes more than 50 laser welded joints (see Figure 1)

The reasons why so many automotive manufacturers are investigating the use of more laser welding production are the high static and dynamic strength of the joints, only one sided access is required for laser welding, the low thermal stress of the final part and the high visual quality of the laser welded joint. In addition to the many laser applications planned for the future, the laser will increase its 'flexibility' appeal by using one beam source for different tasks, cutting and welding for example, on the car body. Consequently the high investment and running costs can be shared over more processes.

Laser welding and cutting tools for car body production

The way the laser beam is guided to the component geometry is one of the factors that are essential for reliable integration of the laser beam into an industrial machine tool. However, many others must also be considered. These are process gas supply, protection cross-jet, additional moving axes, contact or capacitive sensors, wire feeding devices, clamping tools and process sensors, which all have to be integrated in or around the cutting or welding head.

An important component for reliable and consistent car body

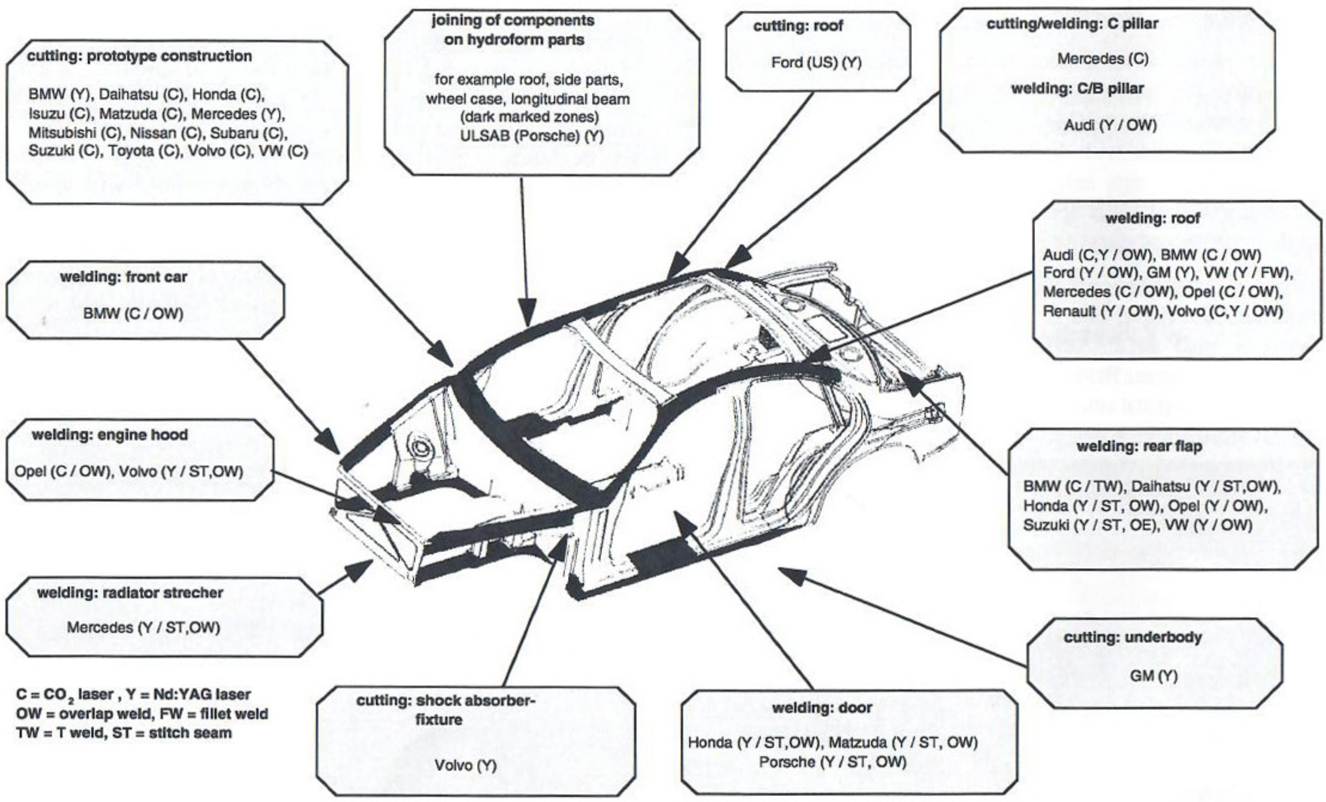


Figure 1. Laser processed car body components

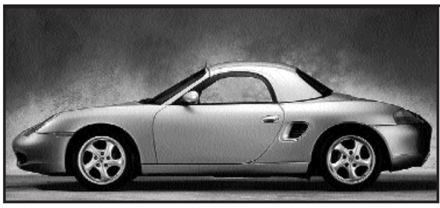


Photo: Porsche

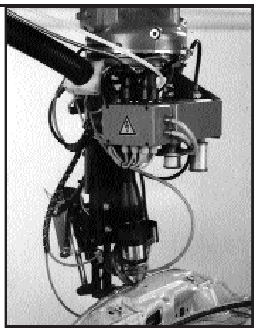


Photo: Kuk Roboter GmbH

Figure 2. Laser stitch welding with a robot guided clamping roller

welding is a flexible clamping tool, which is integrated into the welding head. Several solutions for different car part requirements for fixed, flexible, one- and two-sided clamping had been qualified already in production. For example, production of the Porsche Boxter proves that an overlap stitch seam on the door can be laser welded by a robot guided clamping roller in multiple shift-operation (see Figure 2)

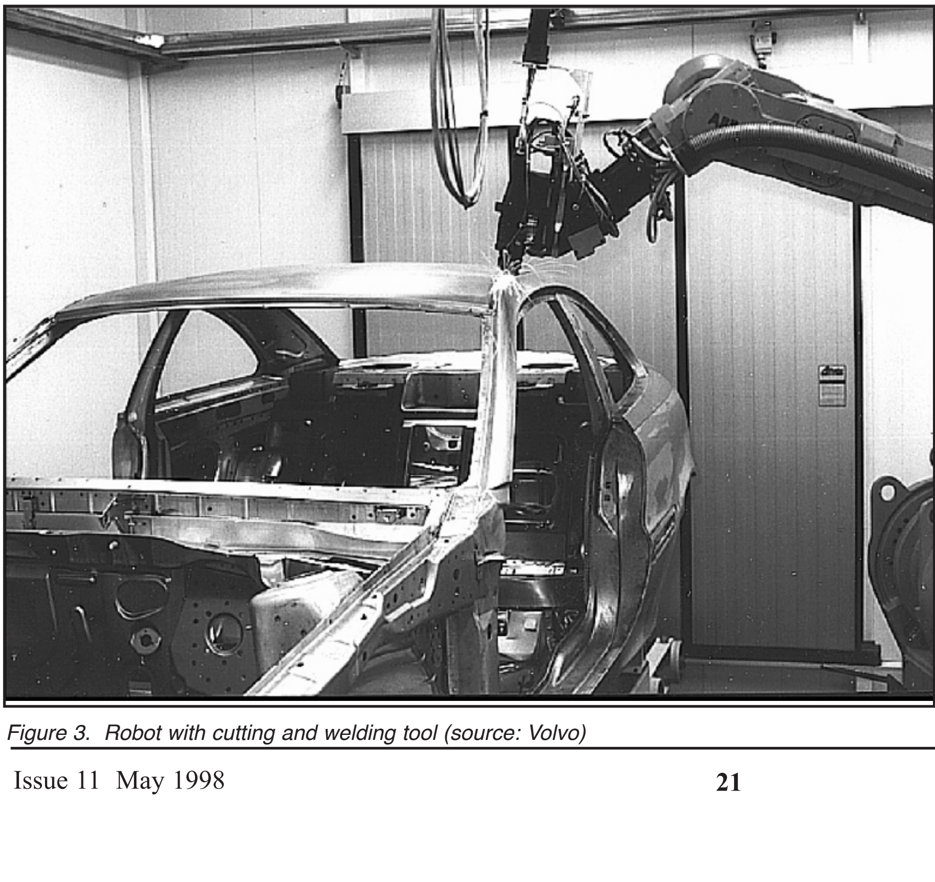
An alternative to the clamping roller is a clamping liner (patented by AUDI) which has been designed for one-sided overlap clamping near the laser's focal spot. With this tool, different types of contours can be welded flexibly in car body production.

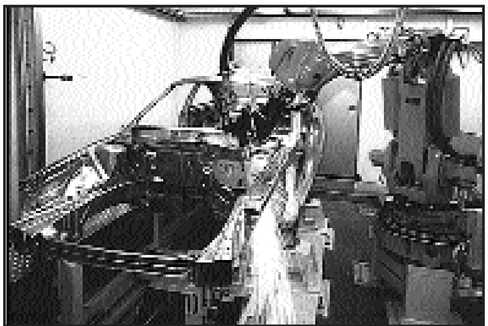
Volvo in Sweden uses one laser beam source for welding of the roof and for cutting of the shock absorber-fixture in the production of the C70 sports car. The robot process head is exchanged depending upon the application, welding or cutting, the heads being located in an exchange system. Both tools are supplied with laser light via an optical fibre and a beam switch module. A special feature of the cutting tool is that the capacitive focusing head can be guided within an extra X–Y system with high resolution and speed. The macro positioning of the X–Y moving system is done by the robot and the precise positioning performed by the X–Y stage at the cutting head. The welding head is combined with a clamping finger, which includes the process gas supply. In addition, an off-axis cross-jet is fixed to the welding head, which diverts back–spatter from the zinc coating away from the 120 mm focusing lens, ensuring long term reliability of the optics (Fig 3).

Figure 4 shows a welding head for fillet joints, which includes different functional components for focusing, clamping, seam control, wire-feed device and process control. This concept has been developed by Kuka, based on experience in several different applications and it is suitable for both CO_2 and Nd:YAG laser systems. Also compact capacitive cutting heads have been successfully tested for high beam quality (<15 mm•mrad*) Nd:YAG lasers in on-line production situations.

A further interesting welding tool for the future can be seen in the different mirror configurations for 'remote' laser welding. In this scheme, a laser beam with high beam quality is deflected with high accuracy and speed with scanning galvanometer mirrors and optics with a focal length of up to 1000 mm. With a suitable beam guidance system, parts with dimensions of approximately 1 x 1 x 0.5 m can be welded with one laser beam in any fixed plane. The inclination of the welding surface can reach a maximum value of 45°. As an alternative to rigid installations of beam guidance systems it is also possible to use adaptive components for CO_2 lasers with articulated arms. This also increases the flexibility of the lasers as a welding tool in automotive car body production. However, for this application, the CO_2 laser must have a high beam quality, of the order of 5 mm•mrad, otherwise the long focal lengths required cannot be achieved.

Figure 5 shows a scanner system which is already qualified by the IWS institute in Dresden, for the first welding applications it used a focal length of 300 mm. In addition to the possibility of welding over large areas with long focal length optics, these systems can also be used to widen the weld seam by oscillating or wobbling the beam. Other ways to achieve wider laser weld seams, which may be required for fillet joints, include using lasers with worse beam quality or combinations of the laser with conventional welding techniques (hybrid welding) as well as the use of multiple beam sharing modules in the focusing head. However, the scanner system offers, at the moment, the most flexible method of matching the focal spot of the laser to the required seam width. In addition, the scanner offers the possibility of adjusting the macro position of the beam using data from a seam finding tracking system.





cutting ↑

↓ welding

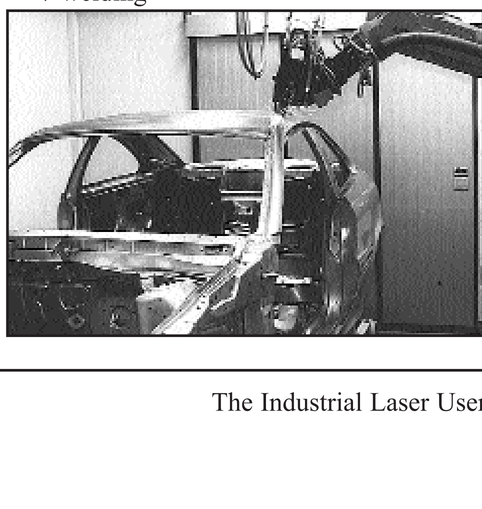
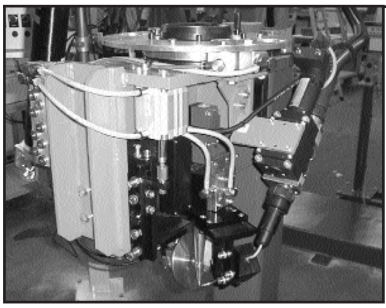
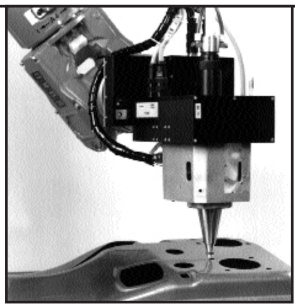


Figure 3. Robot with cutting and welding tool (source: Volvo)

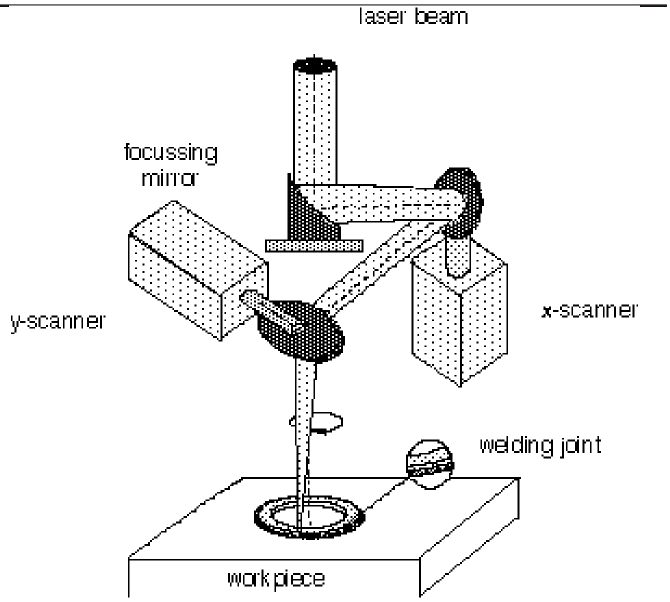


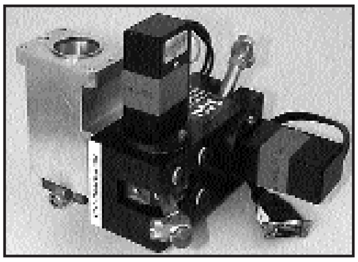
Modular welding head for fillet joints with focusing optic, damping roller, additional axis, seam sensor system and wire device



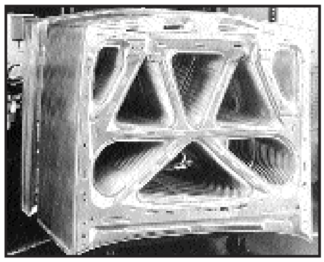
Capacitive cutting head with X–Y moving system

Figure 4. Laser welding and cutting tools for car body production (sources: Kuka Roboter GmbH, Precitec)





Scanner optic



Nd:YAG laser welded aluminium hood with 32 stitch seams

Figure 5. Remote welding (source: IWS Dresden)

Editors Note
In the next issue we will examine laser spot welding application in the auto industry.

Comment

MMMMMMMM . . . . .$\mathcal{M}^2$ *and* MM•MRAD?

Brooke Ward
Europtics

What's all this then? Someone got another definition of beam quality?

No, not really. Rofin have been using mm•milliradians for some time. So what is 'mm•milliradians'? It is a perfectly good measure of beam quality.

To use the jargon, beam quality, whether defined by $\mathcal{M}^2$ ($\mathcal{M}$ squared) or mm•milliradians, is an invariant of propagation. That is just another way of saying that the quality of a beam is defined in such a way that it keeps the same value wherever it is measured along a beam passing through a string of perfect optics.

Both measures of beam quality involve the product of the beam's waist width and its far-field divergence. The only thing you have to watch out for is the fact that Rofin use half-the-width and half-the-angle – plus, they are measuring the angle in milliradians.

So if Rofin quote their 5 kW Nd:YAG laser as having a beam quality (BQ) of 25 mm•mrad, what's the $\mathcal{M}^2$?

Well, the half–width/half–angle product of a TEM_{oo} beam is $10^3\lambda/\pi$, and $\mathcal{M}^2$ is simply the ratio of the laser's beam width/divergence product to that of the perfect TEMoo beam. This means that the conversion factor between $\mathcal{M}^2$ and mm•milliradians depends in the wavelength only i.e.:

$$M^2 = 10^{-3}\frac{\pi}{\lambda}BQ$$

where wavelength is measured in mm.

Using this equation, for a Nd:YAG laser of 1.064 µm wavelength (= 1.064. 10^{-3} mm) the conversion factor is 2.95, so a figure of 25 mm•mrad for a Nd:YAG beam converts to an $\mathcal{M}^2$ of 74!

This brings me back to my hobby-horse. The f/4 focused spot sizes of this 1.06 mm beam will be about 400 µm. The f/4 spot size of an M^2 = 2 multi kilowatt CO_2 laser will be about 100 µm!

Mechanics for Lasers - Part III: control and laser interfacing

Peter Hancocks
Quantum Laser Engineering

This is the third and last of a series of review articles describing the essentials of getting useful work out of a laser. Part I covered mechanics, Part II axes drives. Here we review motion control and laser interfacing. An earlier article, *Control Systems for Laser Machines* by Erol Harvey (Issue 7, pp29) covered some aspects of this area and was principally concerned with the safety issues of control systems featuring a PC emulation of a Programmable Logic Controller (PLC).

Motion control

Motion control systems come in a range of complexities, the simplest being an indexer which allows the position of a single axis to be controlled. Such indexers can be built into an axis drive when they are usually controlled by RS232C commands issued by a PC or up-market PLC, allowing easy integration of equipment such as rotary or linear tables. In some cases two or more such axes can be controlled, each axis essentially independent of the others.

When axes need to operate in unison then cards are available which plug into a PC. The simpler of these operate as multi-axis indexers while the most capable plug-in cards enable a PC to operate as a full CNC system with a front panel simulation on the screen. Such cards convert a PC, that masterpiece of cost effective electronics, into a capable and low cost CNC. However this low cost is only for the axis control element and you will still need to control I/O via suitable modules and your axis drives, magnetics, housing and system wiring remain unaltered. These factors probably make these plug-in CNC systems most appropriate for relatively simple systems, although they are now available with high specifications.

Dedicated CNC systems now provide so many features that they require several manuals each with hundreds of tersely written pages to convey their full capability to a systems engineer. The lucky user usually only has one such manual (i.e. the programming manual) to deal with and if he purchases an appropriate programming system can usually avoid having to read even this one. In addition to basic axis control, modern CNC systems provide inbuilt (or closely linked) PLC functions that enable programmable control of machine and laser.

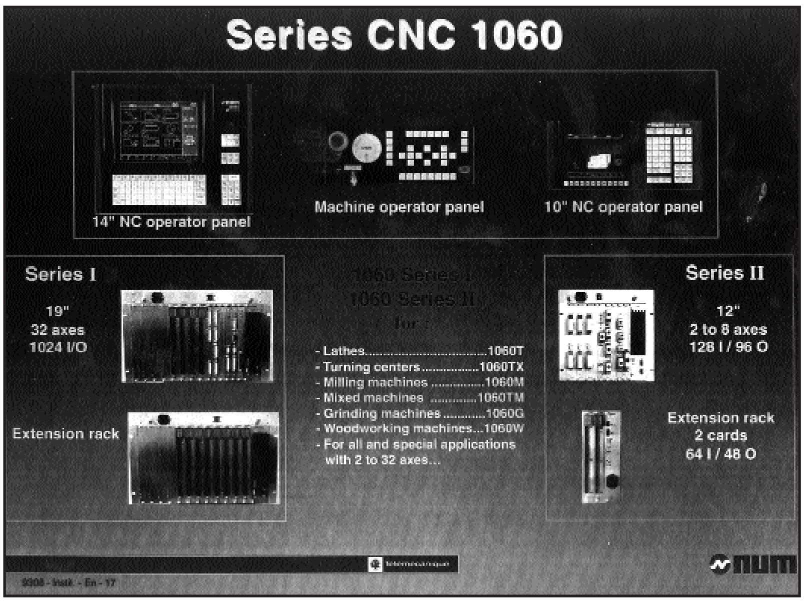
PLC Control

PLC control of a laser's power, pulsing etc. becomes relatively straightforward even through some of the arcane interfaces encountered! Systems are also capable of accepting and producing analog voltages, enabling the implementation of such features as focus height control, power ramping and laser power feedback to be implemented with minimal external hardware. However, it is disappointing that in most environments users seldom make use of the sophisticated laser control easily available them. One reason for this is that without substantial initial effort most programming systems produce fairly simple programs into which extra commands have to be grafted more or less manually to use the enhanced features.

Servo system limitations

CNC systems originally developed for metal cutting applications used relatively slow feed rates and were provided with axis control algorithms that allow axes to lag behind their theoretical positions by an amount proportional to the axis speed. Servo lag, or *following error*, can be displayed on many CNC systems. The amount of lag, as a function of the axis speed is referred to as the *servo gain*. A servo with a gain of 1 exhibits a lag of 1mm at 1000mm/min, or 2.5mm at 2500mm/min, while a higher gain (stiffer) servo having a gain of 2.5 would have a lag of 1mm at 2500mm/min.

When two axes with matched servo gains are interpolated to provide straight line movements the effect on the cut path is zero but this convenient balance breaks down when circular interpolation



CNC equipment for CO_2 laser processing.

is used. The path generated is always smaller in diameter than that desired and is oval unless the gains are exactly matched. Increasing the servo gain reduces this effect but the extent to which this can be done is limited by the match between the servo drives and axis mechanics, too high a gain resulting in jerky movements and ultimately in system instability.

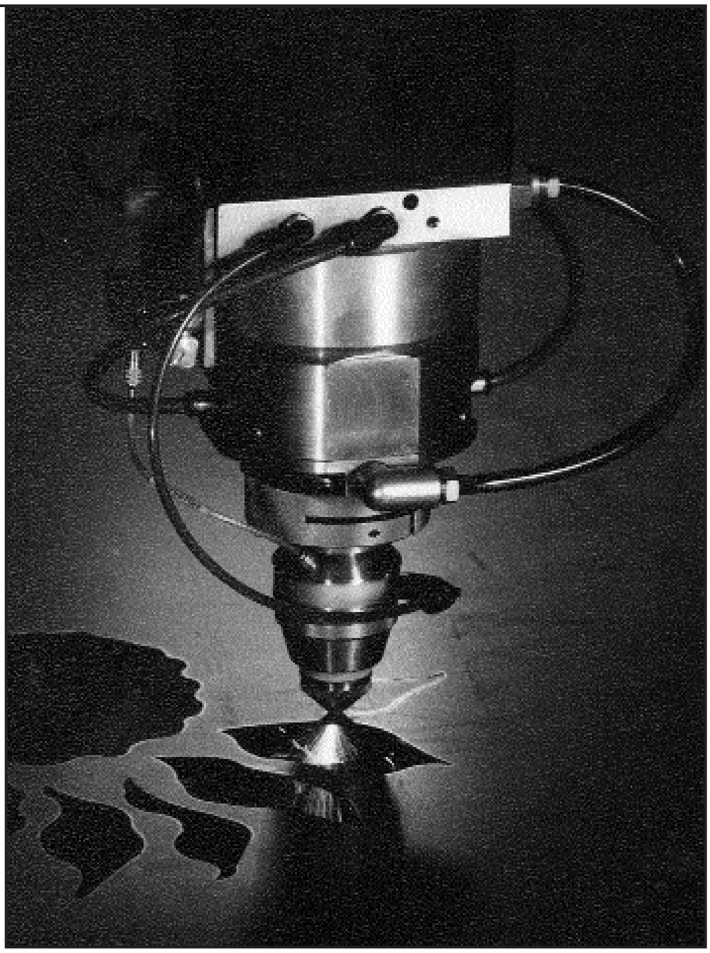
These effects were well known to the builders of early high speed machines. In the early 70s I was involved in the later stages of a project by SATRA (Shoe and Allied Trade Research Association) of Kettering who developed a high speed water jet cutting system controlled by a mini computer (PDP something). This was programmed with details of the servo drives capability and produced an axis speed command that was updated every few milliseconds. The controller enabled the machine to cut complex shapes accurately at high speeds, although it had to perform several minutes of calculation and store all the relevant data on an enormous hard disk system prior to following a profile. This system also had a shape nesting program that required an overnight run to automatically generate a nest: so please appreciate the performance of your Pentium when it takes a few seconds for the same task!

We were producing high speed routers, water jet and laser cutting systems at this time and found the difference between the cornering capability of our NC driven machines and the SATRA system, whose mechanics we were working with, quite startling. This situation persisted until quite recently when CNCs with 'High Speed Machining' - essentially zero following error servo systems - became available. This has enabled modern machines to perform at the level of the SATRA machine in the 70s, albeit in a much more flexible way. As always, such benefits have their drawbacks; machines which provided more or less acceptable results with 'sloppy' servos will shake and vibrate alarmingly if these tighter control loops are used and even well constructed systems require careful setting up before the benefits are achieved. CNCs which use integrated drives, referred to in Part II, should simplify such setting up.

Focus maintenance

Most laser systems require that the beam be brought to a focus at or at a set distance away from the material being processed. In some cases this can be done by a fixed focus system operating on a well positioned target. Often the target material varies in thickness or is not intrinsically flat in which case the focusing system has to move to suit. Early systems used a focus head that was pneumatically lowered onto the work surface and was fitted with hardened pads or rollers that allowed the head to move with relatively little friction. Such an arrangement is cheap and effective when addressing rigid materials but problematic on fragile or easily scratched surfaces.

The next stage of evolution was to use a sensing foot, mounted on the focus head, linked to a displacement sensor that formed part of a servo loop controlling the focus position. Such systems can greatly reduce the force on the surface and allow easy on-line adjustment of the focal height. Disadvantages are considerably higher cost, since they require a servo driven axis, and since they still make some contact with the surface they are easily disturbed by surface debris.



CO_2 laser cutting nozzle with capacitive focus control.

An enhancement of the sensing foot system is the sensing coil, mounted round the base of the focus head, which senses the surface position instead of the foot and sensor. This provides non-contact height sensing but is normally restricted to metallic surfaces. The present state of the art is to use the capacitance between the delivery tip and the material to sense the distance. This requires a specially constructed nozzle assembly with an insulated delivery tip and sophisticated electronics to provide an appropriate signal. Such systems are relatively costly but have sufficient advantages to ensure that they have become the norm on cutting systems. Special contacting feet allow their use with non-metallic materials when required.

Particular systems may require other sorts of focus control; such as seam tracking where the position of a join line cannot be guaranteed. These systems are beyond the scope of this review but are available in many forms - mechanical, optical, inductive and capacitive - many tailored to particular situations. Their use can require complex interactions between sensor and control system, putting a premium on control flexibility.

Finally, regular readers of this magazine will be aware that there are many other areas of development that control systems are starting to have to take account of. These include beam monitoring systems, process monitoring systems, polarisation rotation, adaptive optics and automatic beam alignment. It should remain an unusually interesting field to work in.

This article concludes Peter Hancock's excellent 3 part series on Mechanics for Lasers

Delivering the right gas to your laser

Mark Dixon
BOC Gases

Gases are a major consumable in industrial laser applications and are used in two main areas: lasing gases which generate the laser light and assist or process gases which facilitate the laser materials processing application. The purity and composition of these gases in both cases can be critical.

CO_2 lasers use a mixture of helium, nitrogen and CO_2 (with occasional additions of CO and H_2) as the lasing gas. Each of these gases has a critical role to play in the energy cycle of the laser discharge. The nitrogen is excited by the electric discharge and in turn transfers energy to the CO_2 molecules by collision. The CO_2 molecules then release this energy through stimulated emission generating the laser light and the helium is there because of its excellent thermal properties to remove all excess heat from the cycle helping to bring the CO_2 molecules back to the ground state so they are ready to repeat the cycle. The relative concentrations of these gases are optimised to maximise the efficiency of this cycle for each laser design. This is an over simplified description, but hopefully conveys the importance of the gaseous components.

Laser gases are speciality gases, supplied either as pure gases which are blended inside the laser or a premixed cylinder of gas. The gas composition requirements and purity tolerances vary between the various laser manufacturers. In recent years higher purity specifications have been placed on these laser gases to help increase the quality and reliability of the laser output as manufacturers try and squeeze more power and greater efficiency from their machines. These gases are invariably supplied in high pressure steel or aluminium cylinders. In general moisture and hydrocarbons are critical to laser operation and limits are often placed on these impurities. Typically laser gas purities of 99.995% or better are being specified by laser manufacturers. But as it is the specific impurities that are more critical and limits of < 5 vpm moisture and < 1 vpm THC are often quoted. For premixed gases, mixing tolerances of +/-5% of minor components are normally specified.

It is one thing to supply gases at these purities in cylinders but what is really required is that these purities are maintained into the laser cavity. A quality gas supply system is therefore essential to ensure that there is minimum degradation in gas quality between the gas cylinder and the laser.

Choosing the right gas control equipment is essential in maintaining gas purity. Gas regulators should have stainless steel diaphragms, common industrial gas regulators can aspirate air leading to moisture and oxygen contamination of the gas stream and in addition the use of neoprene diaphragms can be a potential source of low level hydrocarbon contamination. Supply pressures and gas flow rates are generally low and therefore do not cause any problems.

The installations should be hard piped in either copper or stainless steel. Copper piping is more than adequate providing it is correctly installed. Great care must be taken when brazing the joints in the pipeline to prevent the contamination of the inside of the pipe with flux and oxides. The pipe should be purged with nitrogen while making the joints. Plastic or rubber hoses can allow low levels of impurities to permeate into the gas stream and are therefore not recommended for laser gas installations. A full set of guidelines on gas installations for laser materials processing systems has been published by the International Institute of Welding (*Welding in the World* Vol 30 3/4)

One thing that is frequently omitted is leak testing of pipelines to ensure their integrity. Appropriate leak testing of the gas supply system should be carried out as part of the installation procedure and should be repeated on a regular basis to avoid atmospheric contamination of the laser gas stream.

Assist gases on the other hand are typically industrial gases and although the purity requirements are generally less onerous it is still an important issue. Typically oxygen or nitrogen are used for cutting while helium or argon are used for welding. The effects of gas purity on laser cutting was covered in Issue 4 of the Industrial Laser User. These gases are supplied in compressed cylinders or in liquid form depending on consumption levels of individual users. The gas installations are important to ensure trouble free operation.

For industrial grade gases industrial regulators and gas control equipment are adequate, however, when there are additional purity requirements then superior equipment should be used e.g when cutting with high purity oxygen.

The equipment should tailored to the gas service to which it will be put. This is particularly relevant to oxygen service where the materials of construction and cleanliness specifications for the assembly of the equipment are more important. At this point I would like to stress that no other gases should be used through lines used for oxygen service particularly compressed air due to the risk of oil contamination which could result in ignition.

It is important that the regulator output meets the pressure and flow requirements of the laser process. This is particularly applicable to high pressure nitrogen assisted cutting of stainless steels where the elevated process pressure and high volume flow rates require specialised gas control equipment. Using the wrong equipment can lead to equipment failure.

For laser welding applications flows are generally low and the gas purity requirement depend on the specific application and so the choice of gas control equipment should be made on an individual basis, but if in doubt one should err on the side of higher quality in order to be sure that it will not adversely contribute to the final product quality.

As for the piping of assist gases the same rational applies as for lasing gases, however, it is accepted that in some cases the use of non metallic hose is required where flexibility is a major consideration.

A little consideration to the gas supply installation for your laser, both lasing and assist gas, will be rewarded with years of trouble free service.

The application of non-contact laser measurement in automobile assemblies

Stephen Ainsworth

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Laser-based measurements may be used to assist in the control of certain key features on an assembly of components to ensure consistent quality and performance. Such features, which may be important either to the functioning of the assembly or to creating a good first impression to a prospective customer, must be controlled within strict limits.

The examples and concepts outlined here are taken from the Automotive Industry, but they may readily be applied in a large number of other industries.

Product Quality

The quality of a product can be assessed in two equally important ways:

1. by accurately measuring a statistically valid sample of components to ensure that each meets specification, and then testing a sample of finished assemblies to ensure that they meet the required performance targets.
2. by assessing the features that the Customer perceives as being a sign of quality, and closely controlling either the features themselves, or the part of the assembly which makes the main contribution to the apparent quality of the feature.

   These features include areas such as paint finish, the effort required to open or close a door or boot lid, the consistency of the gap around a door or boot lid (known as a closure shut line), the ease of using controls (brake and throttle pedal effort) etc.

The various quality characteristics which make up the features in (2) are known in the Automotive Industry as CDVR's - Customer Driven Vehicle Requirements.

The list of CDVR's covers an increasing number of features as market demands become more sophisticated and the customer demands more in terms of fit and finish, reliability and performance. For example, over recent years the best in class shut line around car doors has moved from 5mm +/- 1,5mm to a current best in class of 3,5mm +0,5mm/ -0mm (as per the VW Passat and others).

In addition, legislation has a key part to play. Recent European Directives covering both Vehicle Interior Noise and Drive By Noise Requirements have meant that many features need to be much more closely controlled than was previously necessary especially, as in the case of shut lines, where they can contribute to wind noise, or allow exterior noise to enter the vehicle interior.

For many years it has been possible to measure both very fine tolerances and very small dimensions using lasers, exploiting the advantages of non contact measurement to prevent disturbance or damage to the component or feature being measured.

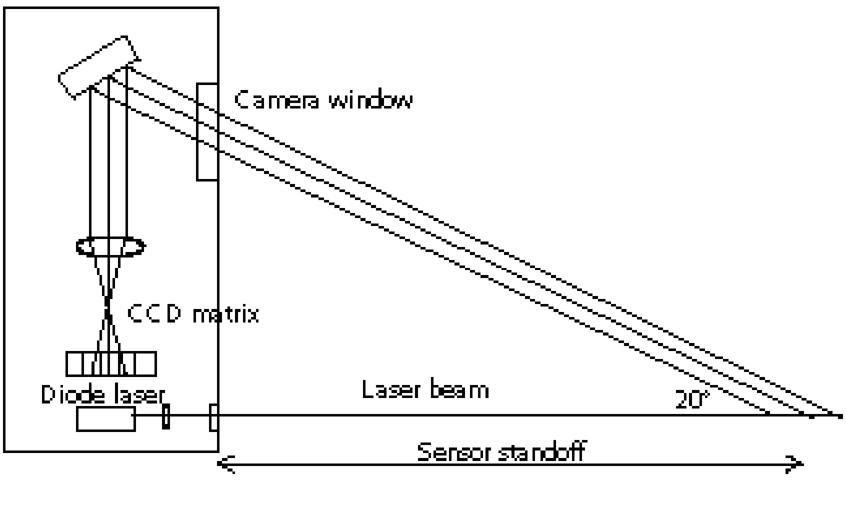
The same basic approach is now being used to measure the various key features which go to make up CDVRs. Measurements may be made either after or during assembly, i.e. as part of a feedback control mechanism to allow a robot or other device to accurately place a component relative to another (such as best fit around a door or positioning a windscreen into the body aperture) during a process cycle. For the laser measurements described here it is not necessary for the surfaces being measured to be reflective, straight or flat.

The Laser Camera

The body of the camera unit is made from extruded aluminium, and access is via removable end plates to allow the internal optics and electronics to be removed as a complete assembly. The basic arrangement is shown below.

The laser camera works on simple triangulation, although the algorithms required to make a actual measurement can be complex and difficult to verify. An array of such units are used, connected to a single control PC.

To undertake measurements on an assembly it must first be accurately positioned in a fixture. This positioning relative to



Courtesy of Perception Inc TriCam Sensors

The Laser Camera. An InGaAIP 670 nm laser diode provides a visible red beam, which after passing through the optics fans out in a flat plane. Reflected laser light is analysed by the CCD camera. The image can be compared with a stored image held in aPC. The equipment is contained within a compact rectangular section unit measuring approximately 300 mm long, 100 mm wide and 100 mm high.

the cameras will vary according to the type of measurement and operation required. The laser cameras, with fixed focal lengths of 300 mm, 600 mm or 900 mm, are spaced within the measuring fixture such that ideally the feature to be measured is in the focal plane.

To helps with initially positioning the cameras and provide a quick visual check that none of the cameras have moved, each of the fixtures has a setting master supplied with it. The setting master uses the same locations on the fixture as the assembly to be measured, and has datum lines scribed onto it at each measurement point so that the point where the laser beam hits the master can be seen.

System Set Up

Setting the laser cameras is the most complex part of the process. The setting process currently requires a 4 head theodolite system, although work is currently being done to develop it so that a single laser tracker will do the job.

The laser camera reports measurements as a deviation from a preset standoff and the object of this setting procedure is to establish the true position of the camera units relative to the fixture so that readings can be translated into measurements on the assembly.

The setting involves positioning a small fixture above the laser exit window at approximately the focal length of the unit. This fixture has 4 threads strung across it (coloured fishing line is the best!) each at different heights and perpendicular to the laser beam, such that the beam intersects each of the threads. The theodolites take an accurate measurement of the position of these points, which show up as scattered red light.

The process is time consuming, about 20 minutes per camera once the 4 head theodolite system is set up. Bearing in mind the cost of hiring such a system and the fact that one of the fixtures that I have been working with recently has over 40 laser cameras on it, setting up can be a substantial investment in time and money. Consequently, the camera units must be very reliable, you don't want to have to change them too often!

Accuracy and Repeatability

The cameras themselves have a repeatability of 0.03 mm. This may not seem very good in laser terms, but is well within 10% of the full tolerance range for assemblies, the repeatability specification typically used within the automotive industry.

The overall accuracy and repeatability of the measurement system depends very much on the design of the components being measured and the fixtures that locate them. The most important factor in repeatability is whether or not the component or assembly being measured provides a positive feature which is relevant to datums of the assembly that a camera can register on. Other major considerations include the trueness of components edges and the degree of designed-in slippage of components within the assembly to provide positional correction.

Examples of installations

Closure Installation

The gap around the door of a car has long been known to be a feature which customers perceives as a good measure of vehicle quality, and one which can cause wind noise. The important characteristic is to keep the gap between the door and the frame consistent, and therefore pleasing to the eye. The current 'Best in Class' is a consistent gap of 3.5 mm + 0.5 mm / - 0 mm; most manufacturers can achieve 4 mm +/- 1 mm with their current equipment and processes.

The solution is to measure the position of certain key features around the door aperture in the body side (known as a Master Build Section - MBS) after the vehicle body, less doors, has been completed, and to make an appropriate selection from a group of door assemblies that have been pre-measured at the equivalent MBS points around the door, to give best fit within the gap specification used. After selection, the door must be positioned within the aperture so that the correct all round gap is achieved, and then fixing the hinges in place. The door positioning system uses a robot arm to hold the door in a fixture and then move it around within the aperture, using a feedback loop, until the laser cameras measure all the features as being within specification.

This approach has been made practical by the development of the process to press one-piece body sides, because the build up of tolerances within the old traditional assembly was too great to achieve the consistency required.

The measurement of the doors and the apertures can both be done using an array of laser cameras, positioned so that the true location of each MBS can be accurately established with the assemblies held in a fixture. This usually requires more than one camera unit per MBS feature. The doors are uniquely identified, often by a bar code label, and their profiles individually measured and recorded.

The assembly of the inner door to the outer door can be controlled in a similar manner. This ensures that a consistent assembly is presented prior to clinching, thereby achieving high levels of repeatability to be maintained in the door edge profile by the clinching operation.

A similar process is used to place windscreens correctly (now part of the structure of a vehicle) into the body windscreen aperture within the flash off time of the adhesive, usually less than 3 minutes from application to the glass. In this way, windows can be placed and adhesed into position in one operation, thereby minimising water leak path created by any sliding movement after contact between glass and body flange.

Positioning of Chassis Modules in the Body

The refinement required to allow modern high performance cars to achieve the levels of ride, handling and quiet running required by customers, as well as recent Internal and External Noise Regulations, has meant that the positioning of the front and rear suspension modules and the alignment of the driveline (for rear wheel drive) has to be closely controlled. This is achieved by offering the units up to the body from below, an operation known as Stuffing, and individually adjusting their X and Y-axes alignment before securing them in place.

To do this, laser cameras measure the positions of each of the machined datum features in the chassis crossmembers relative to the master datums on the vehicle body, and the cameras feed back offsets to the stuffing fixtures so that they can adjust the position of the modules to correct for any errors found.

After the Modules are secured in place, the driveline alignment can be measured, and adjustments made in the Z axis only by placing a shim under the propshaft centre bearing according to the thickness calculated by the camera control algorithms. This process allows the significantly tighter tolerances required to meet Customer and Legislative Demands.

In-process measurement

The key points in an assembly are normally measured in one of two ways:

a). Measuring them individually using a gauge or fixture.

b). Using a Co-ordinate Measuring Machine.

The disadvantage of both of these is that they usually take a long time to produce results or require the assembly to be measured to be moved off line and taken to a separate area. The delay in each of these processes can result in a number of incorrect assemblies being made before a problem is identified, leading to high rectification costs, and an increase in non-standard work.

The speed of measurement of the laser camera (less than 3 seconds from measurement to output of result) and the compact size of the camera unit means that an array of cameras can measure the key features of an assembly within the process cycle time. This makes it practical to install measuring stations immediately after a key operation, such as a framing station, or as a buy-off point before the assembly moves into the next assembly zone; for example, as part of a ‘No Faults Forward’ assembly system.

Using statistical process control techniques it is possible to control the key dimensions within the assembly, such that no reject parts are made. This can be achieved either by stopping the line until the necessary adjustments are made (No Faults Forward) or by creating a feedback loop involving the laser camera output, so that in-process corrections are carried out automatically.

Using this approach, it is possible to achieve as near real time control of the assembly process as is practical.

In-Process Location

Rather than use location pins in datum holes to accurately position components within a fixture, the laser camera unit can be used to locate the key points. This process, which can be used to eliminate or reduce tolerance stack up in assemblies, works by first placing the components into the clamping fixture (rather than onto locations pins), then activating a measuring routine whereby the cameras, linked to stepper motors acting on “Push me Pull You“ units, position the key points of each component. In critical applications it would also be possible to measure after clamping to verify that the parts have not moved.

For this approach to work the assembly must designed with slip or lap joints rather than butt joints, to allow the various joints between components to move. Also, there needs to be features on components which allow them to move on the fixture and others for the “Push me Pull you’s” to bear on. A number of tooling holes can be eliminated by this technique, thereby simplifying press tool requirements and eliminating the need plug holes later.

This process is still in the early days of development, but tests have proven that it does work successfully, and has the potential of giving both reductions in costs and improvements in quality.

Practical Experience

Having used the systems in practice, I have found that they are indeed very reliable, however, there are certain aspects that must be borne in mind when considering their use:

1. Care must be taken to protect the cameras from bright light sources including direct sunlight and welding flashes, as well as undiffused task lighting etc.
2. The laser exit and camera windows (see figure above) need to be kept clean of accumulated dirt and dust - cleaned as much as once per shift in a welding shop with a lot of airborne dust.
3. No short cuts can be taken with the set up procedure.
4. Considerable thought must be given to the design and layout of the measuring fixture, especially with respect to the design of the setting master and provision for the safe means of storage of the master when it is not in use but which still allows it to be brought into position quickly and with minimum disruption as and when required. This requirement may involve an idle station between the Assembly Station and the Measuring Station to allow the master to be shuttled in when required.
5. Care should be taken when identifying the key features to be measured to ensure that all the key points used throughout the assembly procedure covered, not just those important for the process where the measuring station is located.

   Identifying the features which control the accuracy or acceptability of the final CDVR’s is the key to this: and they are not always obvious!.
6. First principal measuring facilities (such as a co-ordinate measuring machine large enough to both accommodate, and access, all parts of the completed Assembly) are still required, even when a measuring station is installed.

Conclusion

The application of laser measurements in this way has the potential of allowing significant improvements in quality to be realised in areas where it has traditionally been difficult to get real time feedback on the dimensional and functional integrity of assemblies of components, especially in working environments that are not friendly to traditional measurement devices.

In addition, the ability of the control devices associated with the laser camera systems to provide feedback control for positioning devices such as robots or stepper motors makes it possible to achieve improved dimensional integrity in assemblies without the need to apply complex fixturing, clamping and location strategies.

NCLA's new surface inspection facility

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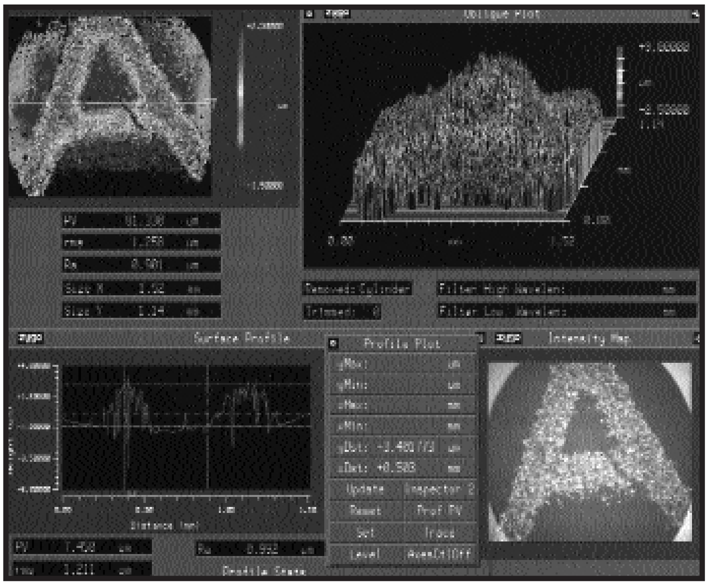
The NCLA was founded in Galway in the West of Ireland in 1989 as a centre of excellence in laser technology, to support and in particular, to encourage the use of lasers in Irish manufacturing industry. The Centre facilitates the transfer of technology to industry by providing access to comprehensive laser facilities and expertise.

The Centre conducts both fundamental and applied research to improve the understanding of existing techniques and to develop new laser processing applications. Applied research involves the development of laser based processes or product prototypes, usually on a bilateral basis with industry. This work can range from advice on appropriate laser technology to the development of production line modules allowing new technology to be transferred to industrial environments. Centre personnel act as a liaison between companies and laser manufacturers/ system integrators to ensure that the most reliable and cost effective solution is achieved. Applications include welding, drilling, cutting and marking on metals polymers and ceramics. Lasers facilities include Nd:YAG, CO_2 and diode laser systems. In addition, a wide range of training courses in laser technology are provided on a regular basis to industry, both in-house and on-site. The courses provide a significant amount of hands-on experience of a range of laser types and optical instrumentation. Courses include laser safety, laser maintenance, and laser / spectroscopic applications. Laser safety audits and safety consultancy are also carried out. These aid clients in identifying laser associated hazards and in the implementation of, and compliance with, laser safety regulations.

With the concentration in the West of Ireland of both indigenous and multinational manufacturers from the healthcare sector, a sector characterised by rapid innovation and cross-disciplinary technology development, a significant amount of the Centre's industrial interactions are with companies in this field. A widely-used maxim for manufacturing, particularly in the medical device industry is: 'If you can't measure it, you can't make it.' For this reason, the NCLA has recently commissioned a scanning white-light interferometer from Zygo Corp. to expand its measurement and characterisation facilities. The interferometer is used to measure the 3-d surface profiles of materials and devices to a very high degree of precision, giving essential information on product quality and aiding process optimisation.

The figure above shows a typical measurement and analysis for the instrument. The sample is the Laser Institute of America 30th anniversary pen with decorative marking along the barrel.

This example is perhaps trivial, but the qualification and quantification of product marks is certainly not; particularly in the context



Marker Detective at Work on the Anniversary Pen!

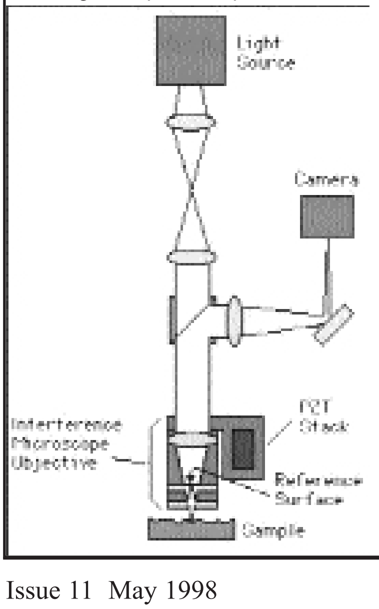
The sample is a pen, with which some readers may be familiar. It was issued to Laser Institute of America members to mark the 30th anniversary of the LIA and has some very pretty decorative lettering on the barrel. As a previous successful application developed at the NCLA had been decorative laser marking of fountain-pen barrels for A.T. Cross, our first impression was that we had in this pen a fine example of laser marking.

A 100 μm scan with the Zygo white light interferometry. was carried out on the pen, at a magnification of 50 X. A software filter was then employed to remove the gross cylindrical form of the pen, which naturally dominates, and obscures any surface features. The letter 'A' is then apparent in a colour-coded contour map (top left display on the figure). A line is then drawn across this image and a 2-d contour plot of the sample under the line is plotted in the bottom left picture. Sadly, it is evident from these images that the lettering has been inked on, as the letters have a profile raised approximately 3.5 μm above the pen surface; perhaps they'll be laser-marked for the 50th anniversary?

The images on the top and bottom right of the figure are an oblique plot of the data and a video image respectively. With a number of objectives and zoom settings, the field-of-view is variable from 6 X 4.5 mm down to 0.18 x 0.13 mm.

How does a white light interferometer work?

White light is split in a special interference microscope objective.

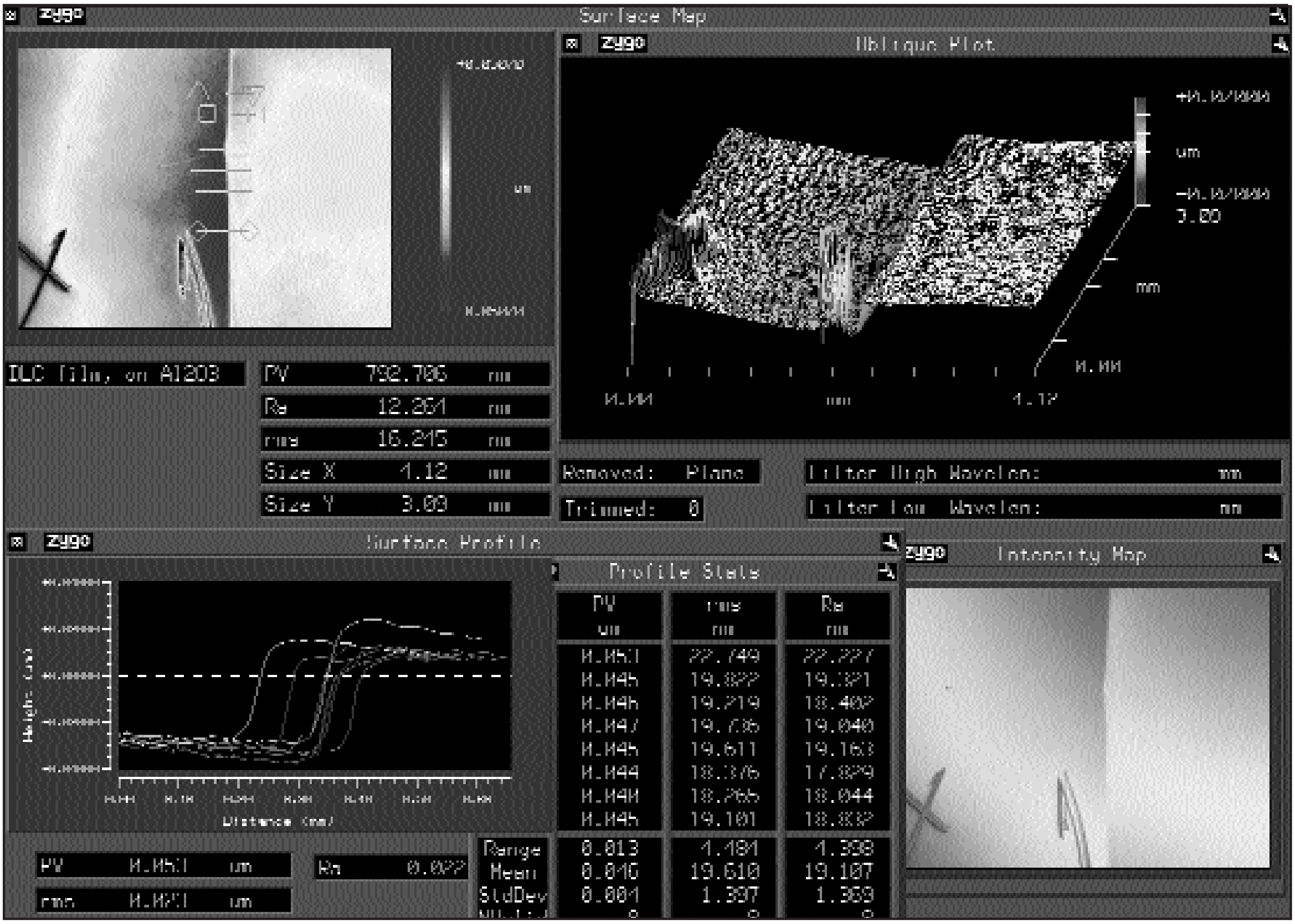


Part of the light travels to a spot on the sample of interest, and the remainder is directed to a reference mirror.

When the two parts recombine, bright and dark lines (interference fringes) appear at the point of focus; the condition for white-light interference is that the two optical path lengths are the same.

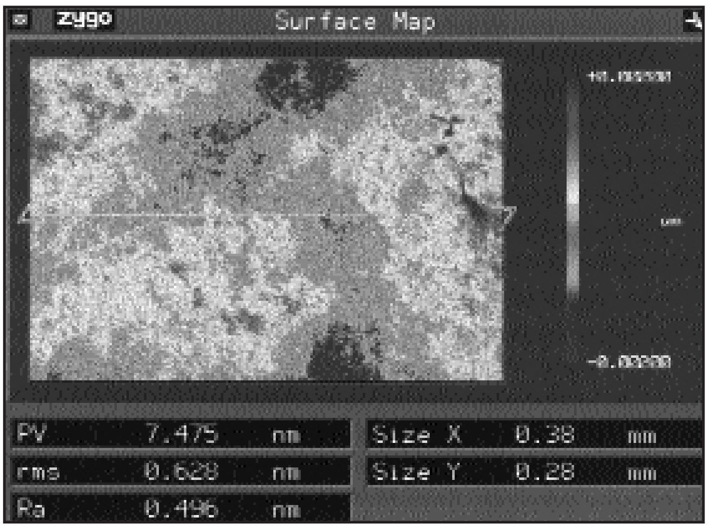
A piezoelectric stack moves the objective in the vertical direction through a scan of between 5 and 100 μm.

Fourier transform algorithms convert the recorded data into surface topography information which is then graphically displayed.



Analysis of a 37 nm diamond-like carbon film deposited on a silica wafer

of the healthcare industry. New European legislation requires medical device manufacturers to place unique identifying marks on any products which will be implanted into the human body. As laser marking represents a clean, safe and rapid method of applying this information, it is rapidly gaining acceptance amongst medical manufacturers. Since the interaction between the surface of the device and the biological medium is critical to the performance of the device, it is important to be sure that the surface modifications induced by the laser affect neither the functionality nor the bio-compatibility of the device. The interferometer can determine changes in surface form or roughness, or the size of a lip or any heat affected zone raised above the sample surface. It can also be used as a process monitor to ensure that there are minimal batch-to-batch variations in this parameter.



Surface of a highly polished Silicon wafer. The scale on the contour map is ± 2 nm

Another significant application of the instrument is in thin-film thickness monitoring. The figure at the top of the page shows a film of plasma-deposited diamond-like carbon (DLC) deposited on the surface of a silicon wafer. These films are typically applied to impart high hardness and wear properties to a component. By making measurements at the step, film thicknesses can be determined extremely accurately. In this case the film was measured to be 37 nm thick, corresponding with complementary measurements made using AFM.

The incredible sensitivity of the instrument is seen in the figure opposite, which is an image of the surface of a polished silicon wafer from an IC fab. Surface roughness was measured to be 0.5 nm, again comparing very well with stylus measurements.

We have also used the instrument on a wide range of materials including metals, polymers and semiconductors looking at parameters such as kerf width, surface roughness and localised strain, with new applications developing all the time.

For further information on the white light interferometer contact the author on ++353 91 750469 or e-mail: tony.flaherty@ucg.ie

Standards for laser welding

Derek Russell

TWI

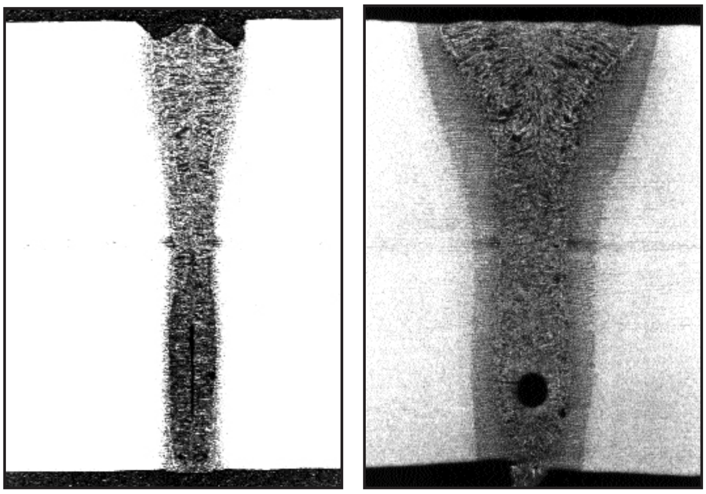
Laser welding has been widely used in industry for many years but unlike most other welding methods there have been no codes or standards that specifically refer to laser welding until recently. Most welds made by the laser process have at best been controlled in production by individual company specifications and procedures. Many laser welded products have been produced without a detailed specification other than a sample requirement for weld depth. However, with the new demands for responsibility for the quality and fitness for purpose of the welded product it has become increasingly necessary to bring laser welding into line with most other welding processes, to nationally and internationally agreed quality standards.

Up to now, when the need arose to work to a code requirement regarding weld quality and properties, it had become the practice to use existing fusion welding codes. These are written for arc welding processes but allow other welding processes to be qualified using the same criteria as are applied to arc welding with allowance for such things as power being in laser watts rather than volts and amperes, in the welding procedure documents. However, this is not an ideal situation since laser welds have very different characteristics in comparison with arc welds. This particularly applies to tests for weld properties but can also apply to tests for quality assessed by radiographs or ultrasonic inspection (NDT).

When a new series of European standards was proposed a few years ago the opportunity was taken to develop standards specifically for laser welding as well as cutting. These new standards are now reaching the final stages of development and the first four are now issued documents and copies can be obtained from BSI. These are listed in the Table below.

In qualifying a welding procedure and welded product it is necessary to consider several factors:

- What level of weld quality can be achieved in the materials of interest under industrial conditions and with commercial welding equipment?
- What types of weld imperfection can occur?
- How can they be non-destructively detected and quantified?
- What factors influence weld quality and how should they be specified and controlled in a procedure document?
- What tests should be specified to determine joint properties?



CO_2 laser weld in 12 mm thick C-Mn steel showing (left) centre line crack and undercut and (right) porosity

- What quality and properties are needed for a specific application i.e. fitness for purpose?

As can be seen from the table below, two standards have been issued specifying quality levels for laser welds in steel and aluminium. A third standard has been issued covering the means of specifying a welding procedure and the last standard in the Table has only just been issued for public comment and covers the means by which the welding procedure can be qualified.

A few words of explanation about these current standards could be appropriate.

Laser Weld Quality

The two standards relating to weld quality are almost identical (EN ISO 13919-1 parts 1 and 2) and the two separate documents refer to welds in steel and aluminium respectively from 1 – 12 mm thick. It should be noted that these standards also cover EB welding for which 50 mm is the normal upper thickness limit.

The purpose of these standards is to specify the weld quality level

Current Issued Standards for Laser Welding

BS EN ISO 9956-11:1996	Welding procedure specification for laser beam welding
Pr EN ISO 15614-11 (Issued for public comment)	Specification and approval of welding procedures for metallic materials. Welding procedure test – part 11: Electron and laser beam welding
.ISO 13919-1:1996	Guidance on quality levels for imperfections Part 1: Steel .Electron and laser beam welded joints.
ISO 13919-2:1996	Guidance on quality levels for imperfections Part 2: Aluminium. Electron and laser beam welded joints

which should be attainable using well developed and executed welding procedures by competent operators. Three levels of quality are described in the standards, B, C and D covering the best achievable (stringent) through intermediate to moderate. The purpose of having three levels is to allow the welding contractor to agree with the customer what degree of quality is needed and if only a moderate quality is needed for a particular application then there is no need to pay for a more exacting welding procedure which would produce a welded product with stringent quality level welds. The reason why the levels start at B rather than A is obscured by arc welding history. Unfortunately the laser standards have to follow the precedents laid down by previous arc welding standards and it is sometimes hard to find the logic for some aspects of terminology. However, these standards are written specifically to take into account the characteristics of EB and laser welds and the particular types of imperfection which can be encountered.

The standards cover all types of imperfection which could be encountered in a laser weld, including:

- cracks (see figure)
- crater cracks
- porosity (see figure)
- clustered and linear porosity
- inclusions
- lack of fusion
- lack of penetration
- undercut and sagging (see figure)
- excess weld beads
- misalignment
- spatter

None of the quality levels allow cracks (or linear indications from an NDT procedure which could be a crack) but for all other imperfections different sizes of imperfection are allowed according to the quality level.

This brief description of the quality standards cannot give a complete picture and it is necessary to study the standards in detail to understand many of the requirements particularly with respect to porosity and clustered porosity. The main difference between the steel and aluminium standards is that they recognise the different, practically achievable, quality in the two materials e.g. it is more difficult to achieve porosity control in Al welds than in steel.

The final point to be made concerning these standards is that they are workmanship standards and not fitness for purpose standards. The designer or purchaser must decide what quality is needed for his application.

Welding Procedures

Two standards refer to qualification of welding procedures. The first BS EN ISO 9956-11:1996 is a fairly short document which lists the parameters which need to be specified in a welding procedure and how they should be measured.

The main standard for procedure qualification is still in draft form and has just been issued for public comment, pr EN ISO 15614-11. This document covers both electron and laser beam welding and specifies all aspects of a weld which need to be assessed in order to qualify the welding procedure. This includes destructive as well as non destructive tests. Also included are recommendation for a Welding Procedure Record form (WPAR) which would be an important part of any legal document in a contract.

An important area where the working group which developed this standard succeeded in breaking away from the arc welding tradition creates the possibility for the customer and contractors to agree on the quality level which should be achieved in the manufacture of the weld submitted for approval of the procedure as opposed to the quality needed for the production stage. Thus for simple non critical applications the moderate quality could be agreed at lower cost than the stringent level. For the arc welding case, all welds for approval must be made to the stringent quality level irrespective of eventual application needs.

Further information on procedure qualification will be reported at a later date after the public examination.

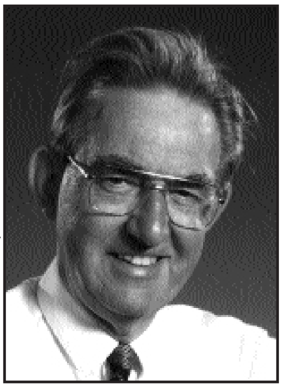
Fitness for Purpose

No standards yet exist to control those features of laser welds such as strength, toughness and fatigue (and also the means of testing these properties) which affect the ability of the weld to fulfil its service performance function. At present this type of information is agreed between contracting parties. It is hoped that standards covering these aspects will be developed in the future but unfortunately it could take some time.

Concluding Remarks

The existing standards and those which are in the pipeline should make a significant contribution to the coming of age of laser welding, enabling it to take its place alongside other welding processes as an acceptable and controllable means of fabrication. It should be noted that the adoption of these standards by the UK means that they are mandatory and cannot be ignored by anybody involved in laser welding.

Derek Russell is Manager of Power Beam Processes at TWI. At TWI he has worked on metallurgical and process developments for 30 years and pioneered early developments in both laser and electron beam equipment development and applications. He subsequently became department head of the process department concerned with new welding and cutting processes. In recent years he has concentrated in technical developments in the power beam processes and collaborations with European partners.



Derek Russell - BSc, CEng, FIM, FWeldI

Book Review

Laser Materials Processing (2nd Edition)

Professor WM Steen

Springer Verlag 1998

Bill Steen has for many years been a great ambassador for the laser materials processing industry, his youthful vigour and intense curiosity has enabled him to make significant contributions to our understanding of the applications of lasers to materials processing. Having created one of the first university based laser materials processing groups in the world at the Royal School of Mines, Imperial College, Bill moved to Liverpool in 1987 to reconfigure his research activities and expand his interests. For more than 25 years he has lectured to many different audiences on the subject of lasers and laser materials processing and retains a wealth of knowledge about the subject. It is fitting therefore that Bill should write a core text on the subject of laser materials processing.

Since the release of the 1st edition 1991, Laser Materials Processing has become a valuable text for thousands of researchers, engineers, analysts and students. Its coverage spans all areas of engineering and manufacture with detailed descriptions of all the main processes and short packets of information on the little known applications. Combined with the main text in the book is a set of references which makes this text so useful to those interested in acquiring more detailed knowledge of particular processes.

The second edition of Laser Materials Processing provides more information on those process technologies that have seen significant changes over the past 7 years. It includes new chapters on the rapidly expanding area of Rapid Prototyping and low volume manufacture. Bill has managed to retain the fresh feel of his text in this new updated version. It is a useful text for all people working in the field and it is very easy to spot well thumbed copies of the first edition on the tops of lasers, in workshops, on boardroom tables and sticking out of student backpacks.

Bill O'Neill University of Liverpool

CO_2 Laser Cutting (2nd edition)

Dr John Powell

Springer/ ISBN: 1 85233 047 3/ 270 pages/ £37.50

This much sought after book is now, at last, available in paperback at a more reasonable price

Introduction to Industrial Laser Materials Processing

Rofin Sinar

Rofin Sinar 180 pages £10

This paperback is packed with useful information, pictures and graphs. It is a comprehensive review of the subject. It is available from Tim Holt at Rofin on 01455 250570

Magazines & Journals

An update of the AILU database of papers up to May 1998

Group to clarify laser safety issues
OLE March 1998 p 5

Laser pointers do not injure eyes
M Barrett et al OLE March 1998 p 8

EU643 Safety in the industrial application of lasers: results of the UK program
JM Green JLA February 1998 p 41

European countries act to outlaw laser pointers
OLE May 1998 p 5

Other

Optics give hard drives a new lease of life
PS April 1998 p33

Eco-optics: remote sensing keeps industry clean
RW Hardin PS April 1998 p102

Lidar unravels environmental mysteries
B Grant PS April 1998 p120

Diode lasers pinpoint pollutants
RW Hardin PS April 1998 p110

Pollutants can't hide from fibre optic sensors
KG Tatterson PS April 1998 p116

Diode lasers fuel platemaking advances
Ron Gibbs LFWJanuary 1998 p 135

Lithography offers market for UV solid-state lasers
RD Mead and CI Miyaki LFWJanuary 1998 p 113

Diode lasers light up disks, communications and printers
EJ Lerner LFWJanuary 1998 p 123

Focusing on the Far-East
ELPBP March 1998 p 14

Lithography demands high-productivity lasers
Diana Zankowsky LFWFebruary 1998 p 35

Key:

ELPBP = Engineering: lasers and power beam processing
ILR = Industrial Laser Review
JLA = Journal of Laser Applications
LFW = Laser Focus World
PS = Photonics Spectra

Laser Cutting

Cutting cost/part on the graveyard shift
ILRFebruary 1998 p14

The Taguchi method for determining CO2 laser cut quality
BS Vilbas et al JLA April1998 p 71

Assist gasses assessed
J Gabzdyl ELPBP March 1998 p 9

Laser cutting gives competitive edge to Chinese industry
ILRMay 1998 p11

Laser Marking

New life for an old system: laser marking pens
J Derzy PS April 1998 p134

Laser Welding

Laser vision aids robotic welding
PS February 1998 p 47

Mastering the mixtures – shielding gases for arc welding: part 2
Welding & Metal Fabrication April 1998 p28

Using a Nd:YAG laser to seam weld in the fabrication of lithium batteries
Welding & Metal Fabrication April 1998 p8

Mastering the mixtures – shielding gases for arc welding: part 1
Welding & Metal Fabrication March 1998 p36

Manufacturing Tailored blanks
Sheet Metal Industries May 1998 p 12

Ultra light steel auto body
Sheet Metal Industries May 1998 p 37

Turnkey laser welding system
ILRApril 1998 p3

Auto workshop features European advances over US reticence
ILRMay 1998 p14

User profile: Pioneering a new technology in the tailored blank industry
Steve Prue ILRApril 1998 p15

Application experiences with laser beam welding
Donald Johnson ILRApril 1998 p20

Laser welded tailored blanks - a practical guide
Trudy Auty ELPBP May 1998 p 12

Mass-produced laser welded blanks - a UK first
ELPBP May 1998 p 8

Laser Micromachining

Micromachining cuts costs for copper vapour lasers
EK Illy and JA Piper PS March 1998 p 106

Nanopositioning accuracy: big job on a small scale
Europhotonics April/May 1998 p32

Laser micro-machining is the future of microchip production
ELPBP March 1998 p 7

Other Materials Processing

Fibre and laser unite in restoration effort
RA Mendonsa PS March 1998 p22

Industrial imaging: finding the right tool for the job
RW Hardin PS February 1998 p 96

Microlasers: short pulses increase applications
D Guillot PS February 1998 p143

Laser bursts strengthen metal parts
PS February 1998 p 40

Water aids laser material processing
PS April 1998 p35

High power laser peening strengthens metal
LFWFebruary 1998 p 40

Diode lasers solve soldering problems
ILRFebruary 1998 p16

Design characteristics and development of a nozzle for coaxial laser cladding
J Lin and WM Steen JLA April1998 p 55

Ultrashort pulsed laser beam ablation of diamond
JLA April1998 p 64

A review of ultrashort pulsed laser ablation of materials
MD Shirk and PA Molian JLA February 1998 p 18

Shaping the future with laser sintering
Dion Griffith ELPBP May 1998 p 20

Ultrafast lasers get a boost from new materials research
Europhotonics February/March1998 p41

Laser Institute of America: Materials processing conference illustrates industry trends
ILRMay 1998 p26

Stronger metals through laser peening
ILRApril 1998 p3

Excimer helps ceramics stick together
OLE May 1998 p 34

Lasers and optics

Special report: blue diode lasers. Are laser manufacturers blue with envy?
PS January 1998 p 116

Industrial imaging: finding the right tool for the job
D Guillot PS February 1998 p143

Fundamentals of semiconductor lasers
M Ettenberg PS February 1998 p 148

Aluminium-free laser diodes overcome hurdles to mass production
S Todd PS May 1998 p 152

Optoelectronics World. Detectors.
Supplement to LFWMarch 1998

Photonic metrology: Making sure 1 µm = 1000 nm
SA Weiss PS March 1998 p134

Photonics design & solutions: software eliminates guesswork
D Li and B Nathan PS May 1998 p 211

Simple scanners reveal shape, size and texture
OLE April 1998 p 29

Office software assesses illumination for linescans
M Muehlemann OLE March 1998 p 27

Measurement meets challenge of more powerful lasers
E Greenfield LFWJanuary 1998 p 191

Robot polishers grind weeks off lens making
P Hill OLE April 1998 p 21

Back to basics: High power diode lasers offer efficiency and reliability
EJ Lerner LFWMarch 1998 p93

Interferometric techniques characterise CW laser beams
GJ Dixon LFWJanuary 1998 p 147

Diode laser wavelengths shift deeper into the infrared
Eric J Lerner LFWFebruary 1998 p 95

Back to basics: laser theory
DA Belforte ILRFebruary 1998 p7

Back to basics: motion systems
DA Belforte ILRApril 1998 p27

Back to basics: beam delivery basics
GJ Hass ILRApril 1998 p11

High power diode lasers debut
ELPBP May 1998 p 6

UV meter sees the light

Eureka April 1998 p 21

Modern techniques can fabricate IR refractive optics
Charles Anderson LFWFebruary 1998 p 121

Positioning equipment: System performance can hinge on mirror mounts
Dave Arnone and Bob Shine LFWFebruary 1998 p 145

Micro-optical integration spurs mass production
A Erlich LFWMarch 1998 p77

Diffractive elements to shrink optics benches
P Hill OLE March 1998 p 23

Optics give hard drives a new lease of life
PS April 1998 p33

High power laser optics: a critical link in materials processing
PS January 1998 p 105

Aspheric lenses: high-volume applications direct development
PS January 1998 p 106

Lens design: when do you need an expert?
W Smith PS January 1998 p 161

Optical tolerance: shortcuts save time
AE Hatherway PS March 1998 p152

Optical testing eases aspheric manufacturing
HP Stahl PS March 1998 p114

Safety

Forthcoming Events

June 98

9-11 Laser Materials Processing
Loughborough University, Loughborough
For further info: Ms Ann Hammond
Tel: 01509 223222

11 Advanced Topics in Opto-Mechanics
Bromley, Kent (organised by SIRA)
For further info: Diane McGraw
Tel: 0181 467 2636

15-19 A Short Course in Lasers and Applications
Imperial College, London
For further info: Dr DM Segal
Tel: 0171 594 7779

24 <<NEW>>AILU Workshop Industrial Laser Safety for Suppliers and Users
University of Liverpool
Further info: Liz at AILU
Tel: 01235 539595

July 98

13-16 Lasers and Materials Meets Industry
Quebec City, Quebec, Canada

15 International Laser Safety Meeting
Orlando, Florida, USA
Abstracts due by above date for meeting 8-11 March 1999

August 98

24 -28 11th International Conference on Experimental Mechanics
Oxford
Further Info: Professor IM Allison, BSSM
Tel: 01483 295715

Further ahead...

31-5 Sept XII International Symposium on Gas Flow Chemical Lasers and High Power Laser Conference
Baltic State Technical University, St Petersburg, Russia
Tel/Fax: +7(812)251 51 90,

15 September
Tech Focus II Lasers in Modern Manufacturing
(part of CLEO/Europe)
AILU supported

13-18 September
CLEO/Europe-EQEC'98
Glasgow

21-23 September
Optical Engineering I (Foundation) Course
SIRA Bromley, Kent

24-25 September
Optical Engineering II (Advanced) Course
SIRA Bromley, Kent

8 October <<NEW>>
AILU Workshop
Laser Beam Basics for Users
National Physical Laboratory, Teddington
Details will be circulated in July

20 October
AILU General Technical Meeting (Members Only)
Rutherford Appleton Laboratory, Didcot
Details will be circulated in July

22 October
Lasers in the Automotive Industry
Make it with lasers
Nissan, Washington, Tyne & Wear

4-5 November

11 November <NEW>
AILU Workshop
Laser Welding for Users
TWI, Cambridge
Details will be circulated in September

Photonex '98
KLV Ketteirng, Northamptonshire

16-19 November
ICALEO '98
AILU Supported event
Orlando, Florida, USA

19 November
Pulsed Laser Micromachining
Make it with lasers
Oxford

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LASER OPTICS
Diamonds are forever
Ricardo Sussmann of De Beers describes progress on CVD diamond optics

LASER CUTTING
Laser Gas Nozzles, Part II
Bill O'Neill completes his review of nozzle design.

Laser job shops in Ireland
Sean Mc Entee reviews job shop business in Ireland and offers some good advice on prospering without the support of the traditional customer base.

LASER WELDING
Nd:YAG Multiple Spot Welding
The state of the art in this imporant manufacturing technology.

LASER MARKING
Review of Applications
We look at some important and challenging applications.

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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