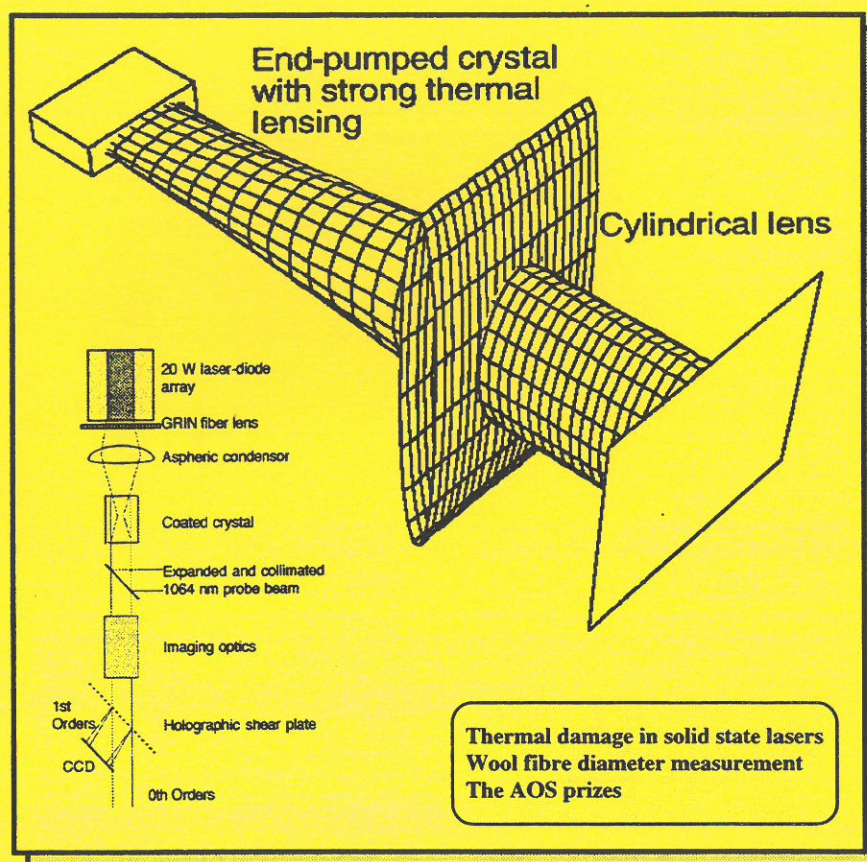


Australian Optical Society

NEWS



Volume 12 Issue 3

September 1998

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**COVER :**

This issue's cover is constructed from two figures from the article on p13, concerning the effects of heat on solid-state lasers.

With diode-pumped laser crystals, the efficiency of the nonlinear conversion process is higher for high pump powers. However, these higher powers also have the effect of heating the crystal. Such heating can adversely affect the conversion efficiency.

The authors measure the thermal lensing effects and incorporate them into a design which is suited to high-power pump sources

SUBMISSION OF COPY:

Contributions on any topic of interest to the Australian optics community are solicited, and should be sent to the editor, or a member of the editorial board. Use of electronic mail is encouraged, or else submission of hard copy together with an ASCII text file on floppy disk.



Where possible, diagrams should be contained within the document or sent as separate encapsulated postscript files. Figures on A4 paper will also be accepted.

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DEADLINE FOR NEXT ISSUE :

14th November, 1998

AOS NEWS

ARTICLES

13 Lasers produce heat as well as light!

We discuss the causes and effects of heat generation in diode-pumped laser crystals. The heat deposited in the crystal leads to adverse thermal effects, which critically influence laser design. We have measured the thermal lensing using holographic lateral shearing interferometry. With this technique, the thermal lensing power is shown to be linear with pump power and is less severe with laser action, than when lasing is suppressed. Using these results, we have developed a novel laser geometry which incorporates the thermal lens into a simple, practical cavity, and which is suited to power scaling using diode-array pump sources.

- Justin Blows and Judith Dawes

29 Wool Diameter Measurement by Laser Beam Occlusion

One of the principal factors which influence the price of wool is the thickness of the wool fibres. In general, finer wool demands a higher price. 'Laserscan' is an instrument for measuring the distribution of fibre diameters in a sample of wool. The optics of this instrument are described and the application to wool fibre sizing is discussed.

- Monty Glass

DEPARTMENTS

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AOS News is the official news magazine of the Australian Optical Society. The views expressed in **AOS News** do not necessarily represent the policies of the Australian Optical Society.

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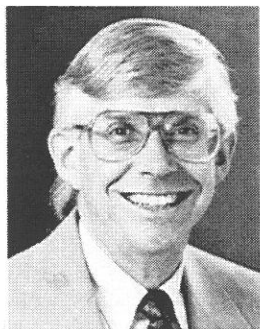
(The International Society for Optical
Engineering)



Retiring AOS President's Report

Presented to the Annual General Meeting of the Australian Optical Society, 24 July 1998

The previous issue of *AOS News* (June 1998, page 43) contained an interesting chart prepared by our trusty Secretary, Clyde Mitchell, that listed all of the AOS Councils since the inception of the Society. From this we can see that we have recently passed the fifteenth anniversary of the Society's first scientific meeting (in May 1983) and the confirmation of its foundation committee under the Presidency of Dr W.H. (Beattie) Steel. It is sobering to read the names of all those who have contributed as Councillors to the development of the AOS since those early days.



Those lists emphasise the principal resource on which the Society is always dependent: people from diverse scientific backgrounds, united by a fascination with optics both as a research frontier and as a vital form of modern technology.

The principal goal of this report is to pay tribute to today's AOS people: the many, both on AOS Council and elsewhere, whose enthusiasm and conscientiousness have maintained the Society's momentum during my term as President. Particular mention should be made of those who, for one reason or another, are stepping down from AOS Council: we know who you are and we thank you for your various efforts. To substantiate our gratitude, let me review some of the highlights (and maybe some of the lowlights, too!) of the last twelve months of AOS activity.

One constant thread binding all AOS operations is our quarterly journal, *AOS News*, edited with tremendous dedication by Duncan Butler. This publication not only maintains a regular flow of information between Society members and a succession of good scientific articles, but it also imposes a helpful form of discipline on incurable procrastinators such as myself: as the publication deadline comes around every three months, one needs to take stock of Society affairs and simply get things done! It should be noted that we are currently seeking a successor to Duncan, who aims to take a well-deserved rest from *AOS News* editorial duties. He will be a hard act to follow!

A further enterprise for which we have Duncan to thank is the AOS Web site. I (and many others, I imagine)

have found this an invaluable source of readily available information and links to other sites. The Web site has been out of action for a while, because of the demise of its file server, but we expect to be back on the air very soon. Another recent venture, thanks to our Treasurer Barry Sanders and Levente Horvath, is an email distribution list for instant communication with (almost) all current AOS members: we are still ironing out forty or so false addresses on this list, alas!

A particularly satisfying form of communication within the Society is our regular major conference series. Our recent national conference, AOS XI, was held in Adelaide last December and was a remarkable success by numerous measures - notably its high-quality scientific programme, its lively atmosphere and its record attendance of more than 270. I am sure that all who attended the AOS XI conference will want to join me in repeating the thanks and congratulations that Jesper Munch and his fellow AOS XI organisers deserve for staging the conference so capably.

Our next major conference will be the forthcoming ACOLS'98 meeting in Christchurch, New Zealand (14 - 17 December 1998) - our first "off-shore" meeting, organised by committees led by Wes Sandle and Peter Hannaford. The Web site is

<http://www.physics.otago.ac.nz/~acols98/>

where you will find much information about the exciting scientific programme and other arrangements. Next year, we expect to stage another national conference, AOS XII. This is likely to be collocated and overlapped in July 1999 with the annual ACOFT conference on photonics, probably at a venue in Sydney. Then in the year 2000, we propose to have the ACOLS conference staged in Adelaide as part of the National Congress of the Australian Institute of Physics.

The AOS maintains a wide international outreach. Ken Baldwin deserves special thanks for coordinating our international portfolio. Ken's activities include membership of OSA's International Advisory Committee and the International Council on Quantum Electronics (ICQE). Although Ken will step down from the AOS Council today after nine years invaluable service, he will remain our International Liaison Officer with a standing invitation to AOS Council meetings in a non-voting role.

Many AOS members belong to affiliated international scientific societies, notably the Optical Society of America (36% of all AOS members) and SPIE (11%) with both of which we have special joint membership fee discount agreements. Office bearers of both of these societies (Gary Bjorklund and Henri Arsenaault, respectively) participated actively in our AOS XI conference last December. Our principal contact with kindred societies in the Asia/Pacific region is through

organizing committees for the CLEO (Pacific Rim) conference series.

I take full responsibility for a lapse of corporate memory within the AOS, which caused temporary discontinuation of our affiliation with the International Commission for Optics (ICO). I am grateful to those who pointed out the undesirability of this action and rediscovered that payment of the annual ICO subscription is the responsibility of the Australian Academy of Science, not the AOS.

Closer to home, the AOS continues to interact regularly with the Australian Institute of Physics, to which one-third of our members also belong (assisted by joint membership discounts). We also have regular communications with the Federation of Australian Scientific & Technological Societies (FASTS), a lobby group for Australia's science and technology in local political, social and economic circles. An important initiative encouraged by my predecessor, Chris Walsh, has been to work towards closer ties with Australia's fibre technology and photonics communities; the outcome of this is evident in the above proposals to collocate and overlap AOS XII with ACOFT '99.

Following Chris Walsh's lead as he retired from the Presidency two years ago, AOS Council has been vigilant for opportunities to expand the Society's fields of interest. Apart from photonics and fibre technology, areas that have been flagged include medical optics and optics as a medium for education and teacher training. I know that our next President, Halina Rubinsztein-Dunlop, shares our enthusiasm for new perspectives such as these.

At the same time, we are aware of a strong viewpoint (expressed most recently in the aftermath to AOS XI) that we need to place more emphasis on traditional

optical areas, coupled with a warning that we are in danger of alienating non-academic technical workers. It is clear that we in the AOS must seek opportunities to promote optical technology as a vital element in Australia's future. If we hope to maintain a strong scientific and technological capability in optics here in Australia, then we should be doing more to encourage a viable local optics industry, supported by strong R&D. Can we regain lost ground in this age of globalisation? And should we try to do so? (I make no attempt to answer such thorny questions!)

A related problem to which the AOS is not immune arises from the relentless march of economic rationalism. With vital decisions guided only by parameters that are spreadsheet-compatible, we find that expert technical advice tends to be marginalised and innovation on the local scene bypassed because genuine productivity and national self-sufficiency do not seem to count. In this climate, many of our members are finding it increasingly difficult to be active in AOS affairs, given heavy workloads and uncertain job security. There are no signs that this will improve ...

Meanwhile, the AOS has to make the most of what it can realistically achieve and how it can best apply its very considerable talents. In that context, it is satisfying to recall the AOS's most recent awards: the AOS Medal to Jim Piper (Macquarie University), the 1997 AOS Technical Optics Award to Chris Freund (CSIRO, West Lindfield) and the double-headed award of the 1998 AOS Postgraduate Student Prize to Marlies Frieze (University of Queensland) and Justin Blows (Macquarie University). This again emphasises that the AOS is all about people and their passion for optics.

Brian Orr
Retiring AOS President

From the incoming president

It is with pleasure that I accept the role of president of the Australian Optics Society at the time when optics is becoming of ever increasing importance to our community. There are challenges ahead for the Society to maintain relevance and embrace new technologies as they develop while at the same time maintaining the strength of our foundations.

The outgoing President, Brian Orr, did an excellent job for the Society, which has prospered under his leadership for past two years. Brian undertook his duties with enthusiasm and dedication and I hope that I will serve the Society equally well.

I am looking forward to meeting and getting to know as many members of the Society as possible and enjoying the stimulation of your company as we discuss matters of mutual importance. Our Society has a vital role to play in promoting research and education in optics and it is important that we all participate in developing directions for the future. I want to work closely with the membership of the Society in charting our path for the future. Please feel free to contact me with your thoughts and ideas on how the Society might better serve the needs of our optics community.

Halina Rubinsztein-Dunlop

AOS MEDAL



AUSTRALIAN OPTICAL SOCIETY

The Australian Optical Society is seeking nominations for the fourth award of this medal, which is for an outstanding contribution or contributions to the field of optics in Australia by a member of the Australian Optical Society.

Previous winners of the medal have been:

- 1995: Mr Bill James
James Optics, Melbourne;
- 1996: Dr Parameswaran Hariharan
University of Sydney and CSIRO;
- 1997: Professor Jim Piper
Macquarie University.

This Medal is the most prestigious award of the Australian Optical Society. It would normally be presented only to a nominee at an advanced stage of his or her professional career and with a strong and sustained record of authority, enterprise and innovation in the field of optics in Australia.

Nominations for the 1999 AOS Medal Winner should include brief personal details and a curriculum vitae emphasising the main contributions made by the nominee

to Australian optics.

Two letters of recommendation should also be provided. Nominations may be made either by or on behalf of any eligible candidate. The selection panel reserves the option to seek additional information about candidates for the award.

It is hoped that the person selected to receive the medal will be able to do so at the next AOS Conference, which is planned for mid-1999.

The closing date for nominations is 15 February 1999. Nominations should be sent to the AOS Secretary:

Dr Clyde J. Mitchell
Optical Systems Engineering
CSIRO MST
Private Bag 33
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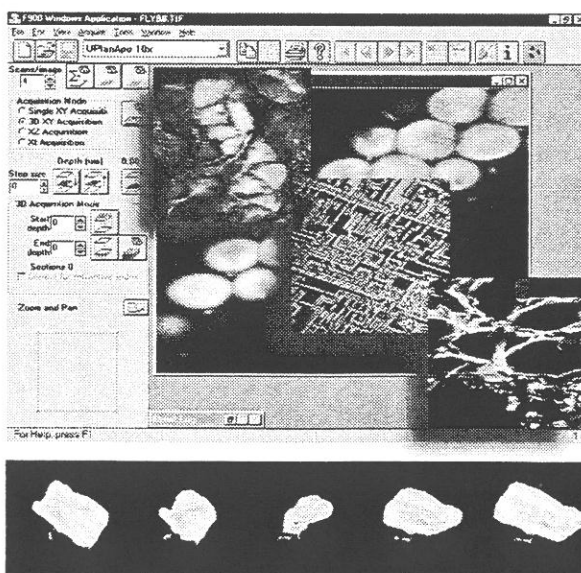
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POSTGRADUATE STUDENT PRIZE

A. Preamble

The Australian Optical Society wishes to encourage participation in national and international conferences by high-quality postgraduate students. To this end, the Society has instituted an award, the Australian Optical Society Postgraduate Student Prize. This will take the form of a grant to assist the grantee to attend a conference in optics or a related field. For 1999, the award will be valued at up to \$1500. The Society now invites applications from suitably qualified people for this prize for 1999.

B. Prerequisites

An applicant must be: (1) a citizen or permanent resident of Australia, (2) a member of the Australian Optical Society, (3) enrolled in a postgraduate research degree in Australia at 31 October 1998, with a project in an optically related area. Non-members of the AOS may join the Society concurrently with their application for the prize. (Application forms are available in *AOS News*, or may be obtained from the Treasurer or Secretary). The prize cannot be awarded more than once to any individual.

C. Selection criteria

An applicant must be sufficiently advanced in the research project to have obtained significant results in optics or a related area, such that those results are suitable for presentation at a proposed conference that falls in the twelve month period commencing 1 December 1998. It is expected that the presentation at the proposed conference would take the form of a research paper, invited or contributed, oral or poster. The successful applicant will be expected to write a summary of the conference for *AOS News*.

Preference will be given in the selection procedures to applicants who intend to use the prize to attend and present their research results at a major conference outside Australia or New Zealand.

It is not essential that the results to be presented should already have been accepted for presentation at the proposed conference at the time of application, but no payment of the prize will be made until evidence of such acceptance is provided to the Society. Applicants are encouraged to provide tangible evidence of the results likely to be presented at the proposed conference (for example, in the form of an outline of a paper that has been accepted or submitted or is being prepared for that conference) and to make clear the benefits that would arise from their attendance at that conference.

The AOS award is not intended to cover the full cost of the applicant's attendance at the proposed conference. Wherever possible, applicants should identify means by which their research group and/or institution is likely to make a substantial contribution to their travel costs. Evidence of any such supplementary support should be provided (for example, by an undertaking in the supervisor's letter of recommendation). However, students with no identifiable supplementary travel support will not be disadvantaged in the selection process.

Since the research supervisor's report is a major factor in the assessment process, supervisors should be prepared to rank their students against the selection criteria if contacted by the selection committee.

D. Application Details

1. Curriculum vitae;
2. List of publications, conference papers, theses, reports, etc.;
3. Details of postgraduate research project;
4. Details of proposed conference (including its status and relevance to optics);
5. Details of participation in the conference (nature of contribution as specified above);
6. Details of predicted expenses, as well as other (probable or confirmed) sources of funding for attendance at the conference;
7. Reports from the candidate's research supervisor and one other referee;
8. Statement that the candidate is a citizen or permanent resident of Australia;
9. Statement of agreement to write a summary of the conference for *AOS News*.

Applications should be sent to the Secretary:

Dr Clyde J. Mitchell
Optical Systems Engineering
CSIRO MST
Private Bag 33
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Fax: (03) 9544 1128

and **must be received by 31 October 1998**. The winner will be announced early in 1999.



OPTICS GRAPEVINE



News from the World of Optics



Australian Conference on Optics, Lasers and Spectroscopy

University of Canterbury
Christchurch, New Zealand

14-17 December, 1998

(details p38)

**'Early Bird' registration due
Friday October 16**

The AOS is currently seeking nominations for the **AOS Medal** (see p5). Also currently open for applications are the **AOS Postgraduate Student Prize** (p6), and the **AOS Technical Optics Award** (p11).

New President and Council

The AOS council was re-elected at the Annual General Meeting in July. Halina Rubinsztein-Dunlop takes over as president from Brian Orr, who now becomes the past-president. Keith Nugent joins the council as vice-president. As well as Keith, new to the council are John Love, Gerard Milbourn, and Murray Hamilton. Barry Sanders and Clyde Mitchell are continuing as treasurer and secretary, respectively.

APOLOGY!

I wish to apologise for the sudden disappearance of the AOS web pages in July. This was caused by the loss of a fileserver, amongst other things, and it was impossible for me to even leave a message explaining what had happened.

Here is the new address:

<http://www.physics.mq.edu.au/~aos/>

My thanks to Barry Sanders for agreeing to host the site.
-Duncan Butler

Polymer Gels as Optical Sensors

Polymer Gels consist of 96% water and 5% polymer network. In many regards they look and behave like ordinary jelly. However, with the right polymer network they can be made sensitive to such things as temperature, light, or electric fields. By writing lattice arrays on the surface of such gel, a sensor is constructed that can be read by optical means. For example, if the lattice spacing changes the effect on the diffraction pattern is obvious.

The ultimate applications of such gels probably lie in visual displays (because they have wider viewing angles than conventional liquid-crystal displays) and as biological sensors (since they are readily compatible with chemical and biological systems). (See *O&PN* July 98, p8).

OSA/SPIE To Pursue Closer Ties

The OSA and the SPIE have set up a task force to look at the potential benefits of bringing the two organisations closer together. From the OSA web site:

"The OSA and SPIE are exploring new structural relationships to better serve the global optics community, and to preserve and expand the opportunity for professional growth in the field of optics in the face of a changing world."

"The 'mission' of the Joint Task Force is to examine structural relationships that would unify and combine the strengths of SPIE and OSA to serve the worldwide optics and photonics community most effectively, in more ways, and with greater responsiveness and higher value than either current society can achieve alone."

For recent information visit the joint task force web site:

<http://www.spie.org/info/jtff/>

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Conference Review : CLEO/IQEC 1998

Marlies E.J. Friese

*Centre for laser Science, Department of Physics, The University of Queensland,
Queensland 4072 Australia.*

The 1998 Conference on Lasers and Electro-Optics (CLEO '98) and International Quantum Electronics Conference (IQEC '98) were held in at Moscone Convention Center, San Francisco in May 1998. Over 7000 delegates attended, and a total of 1117 papers were presented during the five-day meeting. The emphasis of CLEO was applied physics, engineering, and uses of lasers and electro-optics, while basic science and uses of lasers and electro-optics in scientific research was the focus of IQEC. As well as invited and contributed papers, plenary talks, tutorials, and a special Nobel Prize Winners symposium were included in the schedule. The CLEO trade exhibit is also an important aspect of the conference, presenting a unique opportunity to speak to overseas suppliers and gather information on new products. The exhibit is the largest of its kind in North America.

Papers presented at CLEO '98 fell into fourteen categories. Sessions were devoted to specific types of lasers and optical materials, as well as a range of different types of applications and processes. 719 papers were presented, 194 of these were poster presentations. A total of 374 papers (49 invited and 325 contributed) were presented at IQEC. 275 of these were oral presentations and 99 were presented in the poster sessions. The conference covered 5 major areas: Ultrafast Dynamics and Optical Interaction with condensed matter, Photophysics, Photochemistry and Photobiology, Nonlinear Optical Phenomena and High Field Physics, Quantum Optics, and Linear and Nonlinear Optics of Surfaces, Waveguides and Nanostructures. It was good to see that despite the high costs associated with attending such a conference, Australian and New Zealand physics was well represented at IQEC '98. Approximately 7% of oral presentations and 8% of poster presentations had Australian or New Zealand authors, including some fresh results on the helium ground state Lamb shift that were presented in the post deadline session. This work was the result of collaboration between Kenneth Baldwin at the Australia National University and coworkers at NIST, the University of Connecticut, and the American Physical Society.

One rather interesting paper, titled "Laser cooling of a solid by 21 K starting from room temperature" by Timothy Gosnell and co-workers, was presented in the

Optical Lattices and Laser Cooling session. The cooling of a piece of Yt doped fluoride fiber takes advantage of the anti-Stokes photoluminescence of laser-excited Yt3+ impurities. Optical pumping at 1015 nm leads to the anti-Stokes' fluorescence of the sample that cools the host lattice. Two methods, photothermal deflection spectroscopy and laser induced fluorescence spectroscopy, were used to determine that the solid was being cooled. A two-level model for the system was presented, which showed that the theoretical limit of cooling by this method might be as low as tens of Kelvin. This is the first demonstrated laser cooling of a solid, and the theory indicates that the cooling method could have future applications as cryo-cooling device.

Aside from the many interesting presentations of new results in physics, the tutorials were a great opportunity to acquire a little more in-depth knowledge on a variety of subjects. One example was "Terahertz waves, T-rays, and T-birds", on terahertz waves generated by triggering a little charged antenna system by a pulse from a picosecond laser and detected by delayed triggering of a second antenna. Martin Nuss, of Bell Labs, Lucent Technologies, discussed how the broadband pulses could be used for imaging applications like safe luggage inspection.

One very special event of the conference was the Nobel Prize Winners symposium, held on the Tuesday evening in honour of the three winners of the 1997 Nobel prize in physics (atom cooling and trapping). Prize winners Bill Phillips (NIST) and Steven Chu (Stanford University) gave interesting talks detailing the history of laser cooling and trapping, and how laser cooling and trapping techniques are currently being applied in numerous areas of science and engineering. Applications discussed included atomic clocks, atom interferometers for inertial sensors and for the measurement of the fine structure constant, as well as studies in polymer dynamics and protein motion. Their tales of the Nobel Prize award ceremony and banquet presided over by the Swedish Royal Family were also quite fascinating.

I would like to thank the Australian Optical Society for the award of the 1997 Student Prize, which I used to attend CLEO/IQEC '98. I presented a paper titled "Optical torques align and rotate microscopic

waveplates". My co-authors were Timo Nieminen, Halina Rubinsztein-Dunlop and Norman Heckenberg. Our paper describes experiments and theory that show how microscopic birefringent particles, when trapped using optical tweezers, become aligned to the plane of polarization of the trapping laser beam or are set into

rotation, depending on the ellipticity of polarization of the trapping beam. Calcite fragments of around a micron in diameter can be set into rotation at hundreds of hertz, and have since been used to drive the secondary rotation of another optically trapped particle.

GST and Scientific Research

The scientific community welcomes the Government's commitment to reviewing the tax system.

It seems that the way we treat capital gains is a positive disincentive to high technology start up firms growing in Australia. The fact that one such company, Memtech, was recently sold to American interests make it clear that we do not have a level playing field, and that the Government's present capital gains taxes are an impediment to growing such firms in Australia.

The Federation of Australian Scientific & Technological Societies is of the view that a high technology, knowledge based society is the only attractive future for Australia. We seek policy settings that will help bring it about rather than provide barriers.

We are concerned about the recent sharp drop in Business Expenditure in R&D, the first such drop since the ABS commenced collecting the statistics in the mid seventies. It seems clear that industry in Australia does not have the confidence or conviction to invest in R&D under the present financial settings and economic climate.

The removal of tax incentives seems to have reduced "research" in the finance sector more than in industry R&D. We are concerned however about the slow start to the START scheme which was supposed to provide more targeted industry support to R&D and was underspent by \$50 million last year.

The science and technology community does not oppose a GST in principle, but it does have concerns about how such a tax might be developed and what impact it might have on universities, CSIRO and other research organisations.

At present these organisations are largely exempt from sales tax. If a broadly based GST was introduced they might be taxed not only on their scientific equipment and supplies, but on any services they purchase.

This could introduce a serious impost on research. Industry investment is already catastrophically low in

R&D investment, and a GST tax impost hardly seems a sensible way to improve the situation. If a GST increases the cost of doing research what does the Government intend to do to prevent a further decline in Business investment in R&D in science and technology?

The GST is likely to have major impacts on universities if the New Zealand experience is anything to go by. Students paying transport and accommodation costs for excursions and field work find they have a GST imposed, books and scientific serials are taxed, departments that buy in services (the current outsourcing fashion) find they are taxed on the services.

The universities are also finding a major clerical load in being expected to keep track of the tax on myriads of small purchases and transactions? Will university operating grants be increased to pay for the tax and the administrative burden, or is this just another way that operating costs can be removed from the education process itself?

FASTS could not support any measures that increased costs to the university sector or other research groups by adding to their direct costs or administrative load. The universities have enough on their plate as it is. Education needs to be "zero rated" as at present, or compensatory funding needs to be provided as part of the University operating grants.

FASTS believes that research and development should be encouraged as an activity vital to Australia's future. There is a strong argument for scientific research activity (as well as the provision of educational services) to be zero rated in any GST. This is a simple and explicit means of encouraging R&D. We appreciate that many groups are seeking exemption from a GST, and the problems this gives to Government. If the tax is indeed to be broadly based, then other compensation mechanisms for research providers and those that commission the research should be developed.

We look forward to a better tax system that will encourage industry and research groups to create wealth, employment and solutions to our environmental problems.

Peter Cullen

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Lasers produce heat as well as light!

Justin Blows and Judith Dawes

*Centre for Lasers and Applications, School of Mathematics, Physics, Computing and Electronics,
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We discuss the causes and effects of heat generation in diode-pumped laser crystals. The heat deposited in the crystal leads to adverse thermal effects, which critically influence laser design. We have measured the thermal lensing using holographic lateral shearing interferometry. With this technique, the thermal lensing power is shown to be linear with pump power and is less severe with laser action, than when lasing is suppressed. Using these results, we have developed a novel laser geometry which incorporates the thermal lens into a simple, practical cavity, and which is suited to power scaling using diode-array pump sources.

1. Introduction to diode-pumped solid-state lasers

Solid-state lasers (eg. Nd:YAG) are now the most desirable laser technology for many applications. While semiconductor laser-diodes are simpler, cheaper, more compact and efficient than solid-state lasers, high output powers can only be obtained with laser-diode arrays, which have very poor beam quality.

Diode-pumped solid-state lasers are particularly attractive. They retain in part the efficiency and compact nature of diode lasers, while possessing the beam quality, output power and high peak-power capability of solid-state lasers. The high efficiency is due to the excellent overlap of the diode spectral emission and the absorption peak of the Nd laser material. This leads to better efficiency, and a reduction in the overall waste heat produced in the laser (and power supply), which simplifies the laser engineering design. It can also lead to better laser stability, more compact lasers and lower maintenance downtime, as additional benefits. Nonetheless, as discussed below, heat deposition cannot be totally eliminated. A key issue in the design of diode-pumped solid lasers is how the output power can be increased, without sacrificing beam quality. Indeed there is strong commercial interest in laser designs which can be "power scaled" in this way. An early review of diode-pumped solid-state lasers may be found in [1].

As an extreme example of the effects of heat in laser materials, consider the Omega laser at the University of Rochester, NY, built for laser fusion studies. This terawatt power laser, based on a flashlamp-pumped Nd oscillator and multiple Nd amplifiers, is restricted to two shots per hour because of the poor heat conduction in the Nd:glass amplifier rods. The thermal lensing in such

systems is so severe that several spatial filters are used in the beam path to improve the beam quality between amplifier stages.

Here, we consider more modest end-pumped solid-state lasers, in which the diode light is focussed into one end of the laser crystal. Such a scheme offers a more efficient transfer of pump energy to the fundamental lasing mode than does a side-pumped laser. However, it is generally not used for high-power systems, because of the risk of material damage from high-power focussed pump beams incident on the end-face(s) of the laser crystal.

For our end-pumped lasers, both high-brightness laser emitters (1-3 W from an emitting area of $\sim 1 \times 100 \mu\text{m}$) and diode laser arrays (20 W cw in an emitting area of $1 \times 10,000 \mu\text{m}$) have been used as pump sources. For simplicity, as well as for improved thermal management, we have used simple pump-beam optics, so that the focussed pump-beam profiles are not round, but elliptical or rectangular.

2. The effects of heat generation in laser crystals

Since 20-40 % of the diode pump energy is converted to heat in Nd:YAG laser crystals, (see Figure 1) it is important to consider its effects on the laser performance. The heat deposited in the crystal leads to a temperature gradient in the crystal, with the highest temperature on the central axis. This is because the pump light (and heat) is focussed near the centre of the end-face of the crystal whereas the edges are usually cooled either by conduction to the surrounding mount or a Peltier-cooled block. This leads to a thermal lens being induced in the material because of the temperature dependence of the refractive index. In Nd:YAG, dn/dT is positive, leading to a positive lens being formed. There are secondary effects due to the thermal stress induced in the crystal, which changes the refractive index, and the curvature of the end faces, which also contribute to the thermal lensing. At higher pump densities, there is a risk of thermal stress in the crystal causing damage or fracture of the crystal.

The thermal lens in the crystal may have a pronounced effect on the laser cavity stability and also influences the laser output beam quality. The thermal lens affects the laser mode size, as do other lenses in the cavity, and so the thermal lens needs to be considered when the laser resonator is designed. Note also that the thermal lensing

depends on the pump power, so that a given laser needs to be developed for a specific pump power. Alternatively, it needs to include a device such as an adjustable intracavity telescope, to allow for changes to the thermal lensing with pump power.

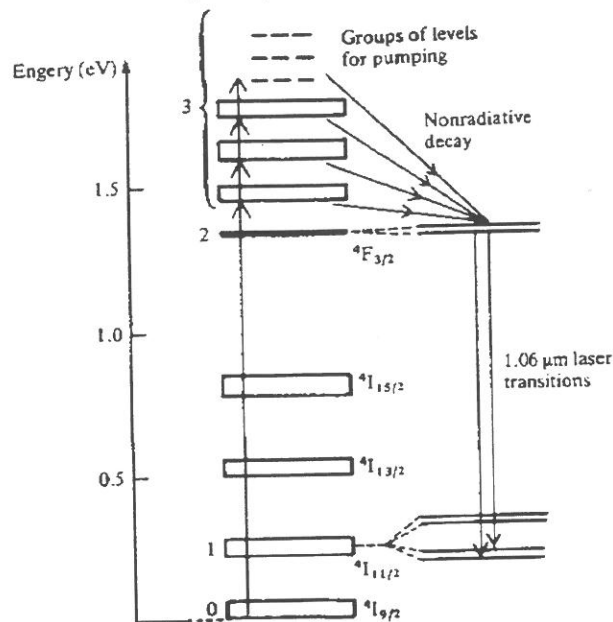


Figure 1: The energy level diagram for Nd:YAG, showing the energy difference between the pump and laser photons. This is deposited in the crystal as heat.

The laser output beam quality is influenced by the degree of aberration on the thermal lens. An ideal lens corresponds to a parabolic temperature profile in the crystal. In theory, a parabolic temperature profile arises when heat is deposited uniformly in the crystal, and the heat is conducted to the edges. However, this situation is rarely the case in practice. With Gaussian pump beams focussed in the centre of the end face of the laser crystal, a uniform heat deposition may be assumed over some central pumped region, but the unpumped edges of the crystal show a linear or other temperature profile. Thus a typical end-pumped laser crystal thermal lens is near-ideal in the centre, and aberrated towards the edge. These aberrations may affect the laser efficiency by introducing diffraction losses, and also reduce the output beam quality.

The thermal-lens focal length depends on the pump power, and is typically in the range 10-300 mm for the diode-pumped Nd:YAG laser crystals which we have been studying. The focal lengths are considerably shorter for Nd:YVO₄ crystals because of their poorer thermal conductivity.

3. Measuring thermal lensing

Since the thermal lens is so important to cavity design, it is important to be able to quantify it. In simple cases, one can solve the heat diffusion equation, to determine the

steady-state crystal temperature profile. This has been done analytically for end-pumped geometries with circular, uniform pump beams [2]. For less symmetric examples, the heat diffusion equation can be solved numerically [3]. However, experimental measurements remain necessary to determine the fraction of absorbed power deposited as heat and the resulting thermal effects on the laser output.

One method of measuring thermal lensing uses a probe beam to propagate through the pumped laser crystal, and measures the deflection of the probe beam as a function of position (and possibly time) in the laser crystal.[4]. However, the geometry of this arrangement is not suited to end-pumped systems, and it is unlikely to offer the spatial resolution that is needed for diode-end-pumped lasers.

A second method, which we have explored in diode- and flashlamp-pumped systems, is to measure the laser cavity stability as a function of its length. Using resonator stability theory, the thermal lens focal length can be inferred. The output power vs input power curves for a range of cavity lengths may be plotted. As the cavity stability limit is exceeded, the output power decreases and the slope efficiency "rolls over". This gives an approximate value of thermal lensing focal length, although it takes account of the spatial variation in the lens in an empirical way. It does not give information about astigmatic lenses for example, and is limited to lensing which can be accommodated with convenient cavity lengths. An example of such measurements is provided in Figure 2. A variation on this technique is to measure the beam profile in the near- and far-field and to infer the beam quality factor M^2 and the thermal lens from these measurements. [5].

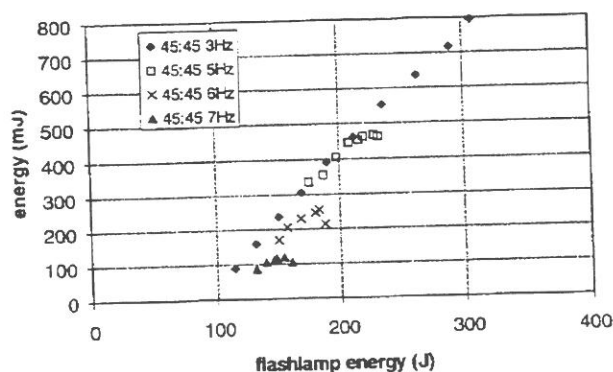


Figure 2: Laser output power vs input powers for a range of cavity lengths, showing the slope efficiency roll over [6].

Here, however, we describe a technique developed by our collaborator A/Prof. Takashige Omatsu of Chiba University, Japan for spatially-resolved thermal-lensing measurements of our diode-pumped lasers. In this holographic lateral shearing interferometry technique, [7, 11] shown schematically in Figure 3, a probe beam is double-passed through the pumped laser crystal and the

wavefront aberrations induced by the thermal lens are measured using lateral shearing interferometry. The lateral shear is provided by a double holographic grating which diffracts the perturbed probe beam into two identical beams in slightly different directions. The degree of lateral shear is determined by the angle of the two beams and the distance that they propagate. These two beams interfere, and the resulting fringes can be detected with a CCD array. Examples of fringes are shown in Figure 4 for the unpumped and lasing cases. The fringes are analysed by Fourier methods, to yield a spatial profile of the optical phase difference in the laser crystal [8].

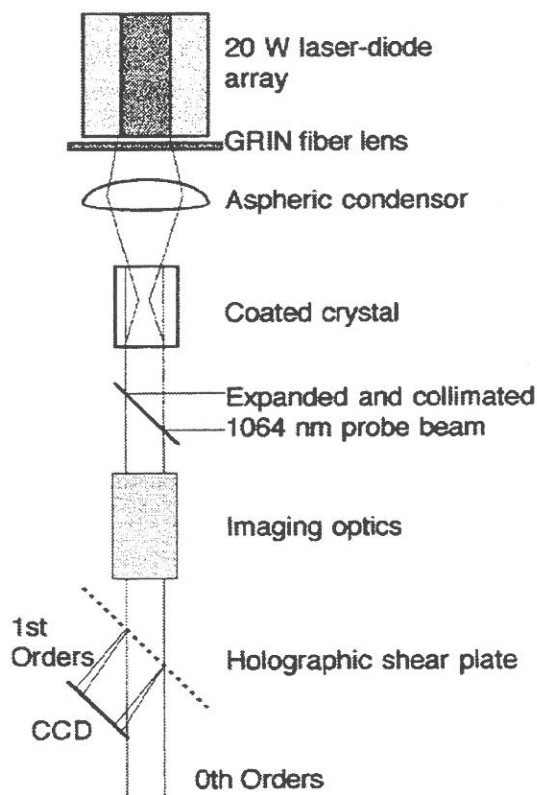


Figure 3: Schematic of the holographic lateral shearing interferometry technique. The probe beam passes through the laser crystal twice, and the resulting wavefront distortions are measured using the lateral shear plate. Reprinted from [9].

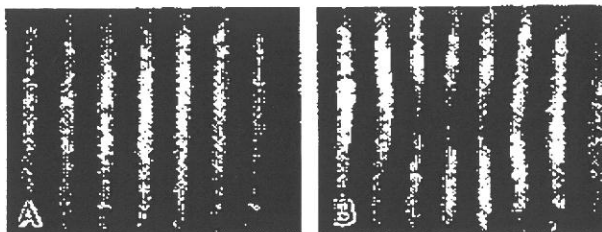


Figure 4: Examples of the fringe patterns obtained using holographic shearing interferometry when the laser crystal is unpumped and pumped [9].

The resulting optical path difference can be plotted as a function of displacement, as, for example, shown in Figure 5. For this result, the diode array pump beam was elliptical (with a spotsize of $30 \times 800 \mu\text{m}$ at focus) and the laser crystal was a thin slab ($1 \times 3 \text{ mm}$ cross-section) which was 3 mm long. By fitting a parabola to the central pumped region, an estimate of the thermal lensing focal length can be made for each pump power. For our planar geometry and elliptical diode pump beam, the resulting thermal lens is almost cylindrical.

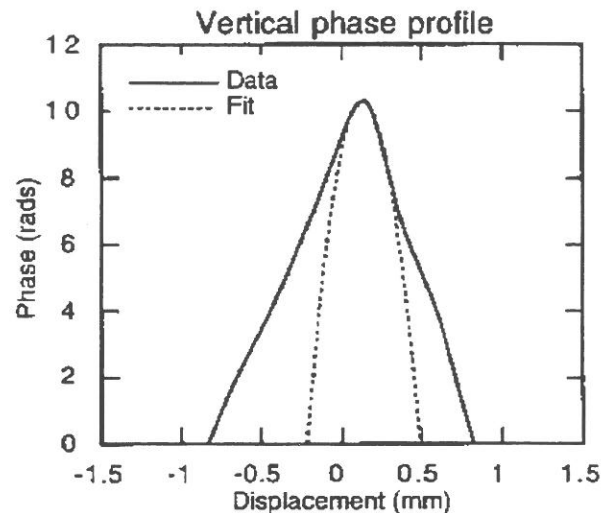


Figure 5: Optical path difference measured for diode-pumped Nd:YAG in a planar geometry, showing the vertical lens profile.

4. The effect of lasing on thermal lensing

The probe beam used in the initial experiments was resonant with the Nd:YAG crystal, but an insignificant amount of energy was extracted from the pumped laser crystal. However, this raises the question of the effect of stimulated emission on the heat deposited in the crystal and the resulting thermal lens. In fact the stimulated emission (or laser oscillation) reduces the heat deposition and the strength of the thermal lens. This was measured using a modified experimental set-up similar to that of Figure 3. A bent-cavity laser was set up with a polarising beam splitter to allow the probe beam to be introduced into the laser crystal. This cavity was somewhat lossy compared with a standard linear cavity, but was sufficient to demonstrate the importance of measuring the thermal lens under the appropriate laser conditions.

The results of these measurements are shown in Figure 6 for Nd:YAG, for the vertical dimension in a planar geometry. While the linear dependence of thermal lens strength on absorbed power is maintained for the non-lasing case, the lasing case shows weaker lenses. When these experiments are repeated for Nd:YVO₄ laser crystals, the difference in results are even more striking, with the non-lasing and lasing cases differing by a factor of two.

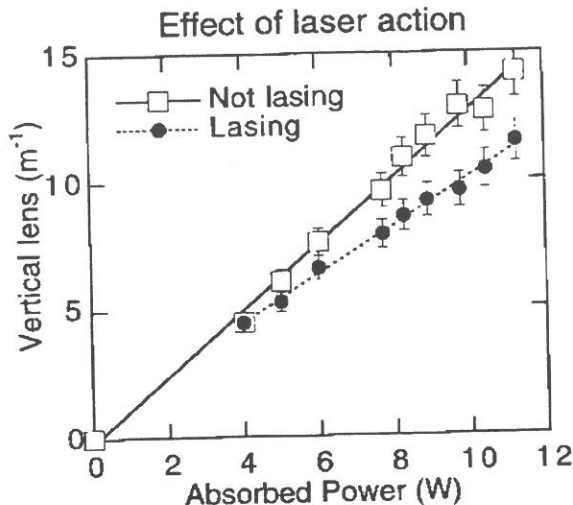


Figure 6: Thermal lens strengths in the vertical dimension for the lasing and non-lasing cases of a diode-array pumped planar Nd:YAG laser crystal [9].

Nd Energy levels: decay processes

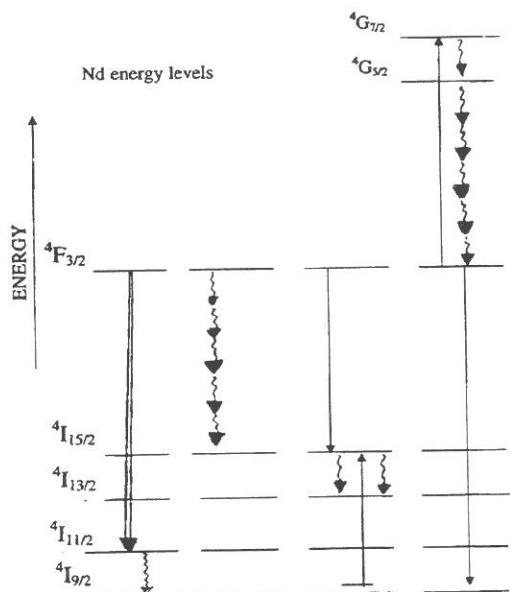


Figure 7: Schematic showing upper laser-level decay mechanisms. Non-radiative transitions leading to heat deposition are shown with wiggly arrows.

The effect of stimulated emission may be understood by considering all the possible mechanisms for the upper-laser level population to be reduced. These mechanisms include stimulated laser emission, non-radiative decay by multi-phonon emission, cross-relaxation to the $^4I_{15/2}$ state, or transfer to a non-radiative defect site. As shown schematically in Figure 7, these mechanisms all depend on the concentration of excited Nd ions [10]. An additional mechanism at high pump powers, and high Nd concentrations is due to 2 excited ions interacting to give an Auger-style relaxation. The relative contribution of this mechanism depends on the Nd concentration and the host crystal.

5. An end-pumped planar Nd:YAG laser

Building on the measurements above, we have developed a novel planar Nd:YAG laser, (shown in Figure 8) which efficiently uses the elliptical pump beam available from diode arrays. The cylindrical thermal lens induced in such a pumped laser crystal has been incorporated into the simple linear resonator, and an additional intracavity cylindrical lens is aligned orthogonally to it. This yields a mode with an elliptical profile, but which is of good beam quality in each direction.

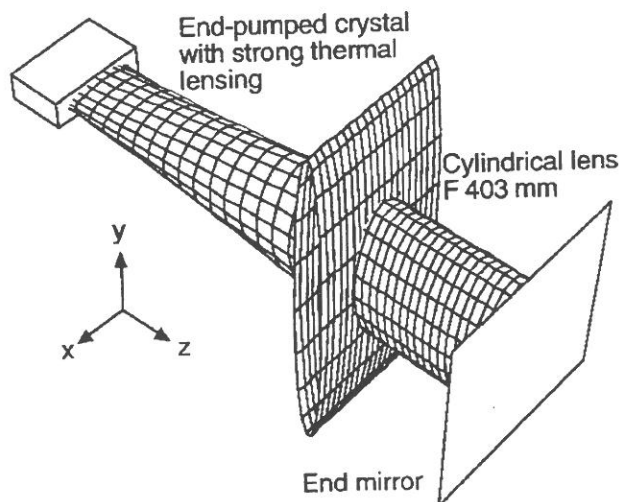


Figure 8: A diode-array end-pumped planar laser design. The (approximately) cylindrical thermal lens in the crystal and the additional intracavity lens control the cavity stability and the laser mode [11].

The laser shown above has been demonstrated to give over 3 W of TEM₀₀ output at 1.064 μm , with an incident pump power of 11.2 W [9]. Because of the effectively one-dimensional heat flow in the planar geometry, thermal-lens aberrations are less severe than those expected in axially-symmetric geometries [12]. In fact the laser operates with a cavity mode substantially larger (2x) than the pump beam with very little loss or deterioration in beam quality.

The prospects for increasing the power of the new laser are very promising. Modelling of the expected temperature profile in the crystal indicates that if the pump beam is extended in the horizontal direction, to increase the power, the central crystal temperature is expected to reach a constant value [13, 9].

6. Conclusion

Even though heat is a necessary by-product of laser operation, the resulting thermal lens in laser crystals can be measured, and efficiently incorporated into the laser resonator design. Using a planar laser crystal and an elliptical pump beam, we have designed a novel laser cavity suited to diode array pumping.

Acknowledgments

We would like to acknowledge valuable discussions and experimental assistance from our colleagues at Macquarie, in particular, Peter Dekker, Helen Pask, Greg Forbes, and Jim Piper, as well as our collaborator Takashige Omatsu of Chiba University who introduced us to the technique of holographic shearing interferometry.

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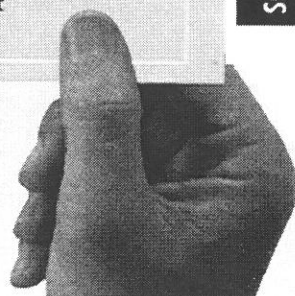
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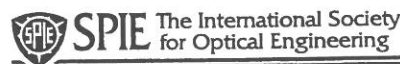
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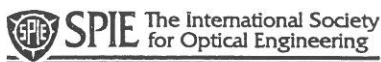
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- aes02 Infrared/Electrooptic Systems
- aes03 Millimeter-Microwave
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- aes07 Automatic Target Recognition
- aes08 Airborne Reconnaissance/Photogrammetry
- aes09 Atmospheric Propagation Engineering
- aes10 Atmospheric Sciences
- aes11 Atmospheric and Earth Sensing
- aes12 Ocean Optics
- aes13 Astrophysical Sensing
- aes14 Space Ground and Deployed Materials
- aes15 Adaptive & Active Optics
- aes16 Smart Structures

AUTOMATION & PRODUCT ENGINEERING

- aup01 Robotic Systems and Hardware
- aup02 Mobile & Space Robots
- aup03 Sensors & Controls for Automation
- aup04 Machine Vision

- aup05 Metrology, Interferometry, NDT
- aup06 Thermal Sensing
- aup07 Flow & Particle Diagnostics
- aup08 Chemical Process Control
- aup09 Environmental Sensing
- aup10 Laser Materials Processing
- aup11 Optical Security and Anticounterfeiting
- aup12 Forensic Science
- aup13 Bararea/Character Recognition
- aup14 Agriculture & Forestry
- aup15 Energy Efficiency & Solar Conversion
- aup16 Commercial Product Development

BIOMEDICAL OPTICS

- bio01 Physicians
- bio02 Scientists/Engineers
- bio03 Biostereometrics
- bio04 Health Care

ELECTRONIC IMAGING

- eli01 Scanning & Capture
- eli02 Storage
- eli03 Displays
- eli04 Printing/Hardcopy
- eli05 Holographic Imaging
- eli06 Image Analysis
- eli07 Digital Process. Algorithms/Architecture
- eli08 Graphics/Workstation Systems
- eli09 Human Vision & Color Perception

- eli10 Medical Imaging Systems
- eli11 Biomed. Electronic Imaging & Processing
- eli12 High Speed Photography & Videography

FIBER OPTICS

- fio01 Components
- fio02 Materials & Fabrication
- fio03 Local Access Networks & Services
- fio04 High Speed Networks & Channels
- fio05 User Interface Technologies
- fio06 Sensors & Applications
- fio07 Instrument Engineering

LASER/SOURCE TECHNOLOGIES

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- lst02 Solid-State Lasers
- lst03 Semiconductor Lasers
- lst04 Dye Lasers
- lst05 Gas Lasers
- lst06 FEL, Synchrotron, X-Ray/UV Sources
- lst07 Other Coherent Sources
- lst08 Power Supplies
- lst09 Resonators
- lst10 Nonlinear Optics
- lst11 Laser Damage
- lst12 Laser Beam Optics & Diagnostics
- lst13 Directed Energy & High Power Radar
- lst14 Laser Communications

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- mod01 Microelectronic Manufacturing
- mod02 Microlithography
- mod03 Photochemical Coatings & Applications
- mod04 Optoelectronic Devices
- mod05 Interconnects/Packaging/Hybrid Circuits
- mod06 Integrated Optics
- mod07 Micro-Machined Sensors & Actuators
- mod08 Optically-Activated Switching
- mod09 Photovoltaic Cells
- mod10 Photomask
- mod11 Micro-Mechanics Engineering (MEMS)

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- opc01 Laser-Matter Interaction Physics
- opc02 Nonlinear Optical Materials
- opc03 Compound Semiconductor Physics
- opc04 Silicon Semiconductor Physics
- opc05 Superconductor Physics
- opc06 X-Ray/EUV Physics
- opc07 Photoelectrochemistry
- opc08 Chemical Physics
- opc09 Molecular Biology & Genetics
- opc10 Optical Microscopy
- opc11 Non-Optical Microscopies
- opc12 Spectroscopy

OPTICAL SCIENCE & ENGINEERING

- ose01 Traditional Optical Sciences
- ose02 Lens & Optical System Design
- ose03 Passive Materials
- ose04 Fabrication & Testing
- ose05 Thin Films & Coatings
- ose06 X-Ray/EUV Components
- ose07 Polarization
- ose08 Scattering & Contamination
- ose09 Optical System Testing
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- ose12 Micro-Optics
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SIGNAL & IMAGE PROCESSING

- sip01 Signal Processing
- sip02 Sensor Fusion
- sip03 Neurobiology & Computational Vision
- sip04 Neural Networks
- sip05 Artificial Intelligence
- sip06 Fuzzy Logic
- sip07 Image Restoration/Recovery/Enhancements
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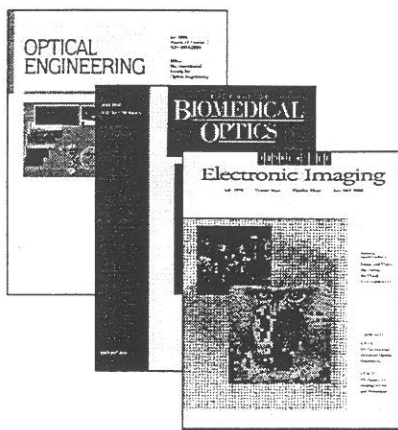
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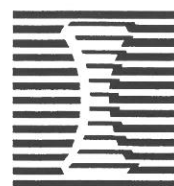


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Meetings Calendar at a Glance



Date	Meeting	1998	Contact	Location
Oct 2-4	Annual Meeting Inter-Society Color Council		OSA	Baltimore, MD
Oct 4-9	Interdisciplinary Laser Science Conference		OSA	Baltimore, Maryland
Oct 4-9	OSA'98 Annual Meeting		OSA	Baltimore, Maryland
Oct 5-9	International Conference on Universal Personal Communications		OSA	Florence, Italy
Oct 5-10	IEEE International Semiconductor Laser Conference		OSA	Nara, Japan
Oct 6-9	Optical Fiber Communications: Techniques and Applications		OSA	Los Angeles, CA
Oct 12-16	Charge-Coupled Devices, Cameras, and Applications		OSA	Los Angeles, CA
Oct 19-21	MEMS for Optical and RF Applications		OSA	Los Angeles, CA
Oct 21-23	International Symposium on Multispectral Image Processing		SPIE	Wuhan, China
Oct 26-28	Digital Video Technology		OSA	Los Angeles, CA
Oct 27-31	PT/Expo Comm China'98		OSA	Beijing, China
Nov 1-6	Photonics East (Intelligent Systems and Advanced Manufacturing; Voice, Video, and Data Communications; Industrial and Environmental Monitors and Biosensors; Enabling Technologies for Law Enforcement and Security)		SPIE	Boston, MA
Nov 2-4	Video Compression		OSA	Los Angeles, CA
Nov 8-12	Communication Theory Mini-Conference		OSA	Sydney
Nov 8-12	Conference on Global Communications		OSA	Sydney
Nov 10-13	Ocean Optics		SPIE	Kailua-Kona, Hawaii
Nov 17-19	Conference and Workshops on Applied Geological Remote Sensing		OSA	Denver, Colorado
Dec 7-9	Optical Technology and Image Processing in Fluid, Thermal, and Comb.		SPIE	Yokohama, Japan
Dec 9-12	International Conference on Optics and Optoelectronics		OSA	Dehra Dun, India
Dec 14-18	International Conference on Fiber Optics and Photonics		OSA	New Delhi, India
Dec 14-17	Australasian Conference on Optics, Lasers and Spectroscopy		AOS	Christchurch, NZ
Dec 15-18	International Photonics Conference		OSA	Taipei, Taiwan.
Date	Meeting	1999	Contact	Location
Jan 31-3	ASSL '99 - Advanced Solid State Lasers.		OSA	Boston, MA
Jan 19-22	VSIA '99 - Vision Science and its Applications		OSA	Santa Fe
Jan 21-26	Integrated Optics and Optical Fiber Communication		OSA	San Diego, CA
Jan 21-26	OFC '99 - Optical Fiber Communications		OSA	San Diego, CA
Jan 23-29	Photonics West (High-Power Lasers and Applications; Integrated Devices and Applications; International Biomedical Optics Symposium; Electronic Imaging: Science and Technology)		SPIE	San Jose, CA
Jan 26-28	Precision Engineering for Optical Fabrication		SPIE	Delft, The Netherlands
Feb 21-26	Medical Imaging		SPIE	San Diego, CA
Mar 1-5	Smart Structures and Materials		SPIE	Newport Beach, CA
Mar 3-5	Nondestructive Evaluation for Aging Infrastructure and Manufacturing		SPIE	Newport Beach, CA
Mar 14-19	Microolithography		SPIE	Santa Clara, CA
Mar 22-26	Principles and Applications of Time-Resolved Fluorescence Spec.		OSA	Baltimore, MD
Mar 30-1	Symposium on Design, Test, and Microfabrication of MEMS/MOEMS		SPIE	Paris, France
Apr 5-9	AeroSense		OSA	Orlando, Florida
Apr 12-16	OIC '99 - Optics in Computing		OSA	Aspen, CO
Apr 12-16	QOE '99 - Quantum Optoelectronics		OSA	Aspen, CO
Apr 12-16	SLM '99 - Spatial Light Modulators		OSA	Aspen, CO
Apr 12-16	UEO '99 - Ultrafast Electronics and Optoelectronics		OSA	Aspen, CO
Apr 13-16	International Conference on Optical Fiber Sensors		OSA	Kyongju, Korea
May 19-21	Symposium on Microelectronic Manufacturing Technologies		SPIE	Edinburgh, Scotland
May 20-22	Optoelectronic Distance: Displacement Measurements and Applications		OSA	Pavia, Italy
May 23-28	CLEO'99 - Conference On Lasers and Electro-Optics		OSA	Baltimore, Maryland
May 23-28	QELS - Quantum Electronics and Laser Science Conference		OSA	Baltimore, Maryland
May 24-28	Symposium on Optical Systems Design		SPIE	Berlin, Germany

Date	Meeting	1999 (cont')	Contact	Location
Jun 7-10	Fourier Transform Spectroscopy: New Methods & Applications		OSA	Monterey, CA
Jun 7-10	Optical Remote Sensing of the Atmosphere		OSA	Monterey, CA
Jun 8-11	6th International Symposium on Metallomesogens		OSA	Germany
Jun 9-11	Optical Amplifiers and their Applications		OSA	Nara, Japan
Jul 12-16	Workshop on Adaptive Optics for Industry and Medicine		OSA	Durham, England
Jul 14-16	7th Microoptics Conference		OSA	Chiba, Japan
Jun 16-18	Optical Engineering for Sensing and Nanotechnology		SPIE	Yokohama, Japan
Jul 18-23	SPIE Annual Meeting		SPIE	Denver, Colorado
Jul 19-21	Integrated Photonics Research		OSA	Santa Barbara, CA
Jul 21-23	Photonics and Switching		OSA	Santa Barbara, CA
Aug 29-3	Conference on Ferroelectric Liquid Crystals		OSA	Darmstadt, Germany
Sep 1-3	Nonlinear Guided Waves and Their Applications		OSA	Dijon, France
Sep 17-22	Photonics East		SPIE	Boston, MA
Sep 24-26	Bragg Gratings, Photosensitivity and Poling in Glass Waveguides		OSA	Santa Clara, CA
Sep 24-26	Organic Thin Films for Photonics Applications		OSA	Santa Clara, CA
Sep 25-1	Interdisciplinary Laser Science Conference		OSA	Santa Clara, CA
Sep 26-1	OSA'99 Annual Meeting		OSA	Santa Clara, CA
Date	Meeting	2000	Contact	Location
Jan 21-27	Photonics West		SPIE	San Jose, CA
Mar 5-10	Optical Fiber Communication Conference		OSA	Baltimore, Maryland
Mar 7-12	CLEO Conference on Lasers and Electro-Optics		OSA	San Francisco, CA
Mar 7-12	QELS - Quantum Electronics and Laser Science		OSA	San Francisco, CA
Jul 30-4	SPIE Annual Meeting		SPIE	San Diego, CA
Sep 10-15	CLEO/Europe2000 - Conference on Lasers and Electro-Optics		OSA	Nice, France
Sep 10-15	IQEC - International Quantum Electronics Conference		OSA	Nice, France
Nov 3-8	Photonics East		SPIE	Boston, MA
Date	Meeting	2001	Contact	Location
Feb 12-14	Photonics West		SPIE	San Jose, CA
Feb 18-23	Optical Fiber Communication Conference		OSA	San Francisco, CA
May 6-11	CLEO - Conference on Lasers and Electro-Optics		OSA	Baltimore, Maryland
May 6-11	QELS - Quantum Electronics and Laser Science Conference		OSA	Baltimore, Maryland

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- BiOS '99—International Biomedical Optics Symposium
- SPIE/IS&T's EI '99—Electronic Imaging: Science and Technology

Technical Exhibit 26-28 January

Education Program and Short Courses

Medical Imaging 1999

20-26 February

San Diego, CA USA

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Instrument exhibition

SPIE Short courses

1999 Symposium on

Smart Structures and Materials

1-5 March

Marriott Hotel and Tennis Club
Newport Beach, CA USA

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SPIE Short Courses

1999 Symposium on

Nondestructive Evaluation Techniques for Aging Infrastructure and Manufacturing

3-5 March

Marriott Hotel and Tennis Club
Newport Beach, CA USA

Technical Exhibit

1999 International Symposium on

Microlithography

14-19 March

Santa Clara Convention Ctr.
and Westin Hotel
Santa Clara, CA USA

Technical Exhibit

SPIE Short Courses

Design, Test, and Microfabrication of MEMS/MOEMS

30 March-1 April

Le MERIDIEN Montparnasse Hotel
Paris, France

Technical exhibit

AeroSense '99

Aerospace/Defense Sensing and Controls

5-9 April

Marriott's Orlando World Center
Resort and Convention Center
Orlando, FL USA

Exhibit 6-8 April

SPIE Short Courses

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Symposium on Photomask and X-Ray Mask Technology

13-14 April

Kawasaki City, Kanagawa Japan

Abstract Due Date: 13 November 1998

Technical Exhibit

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SERIES

Microelectronic Manufacturing Technologies

19-21 May

Edinburgh, Scotland

Abstract Due Date: 19 October 1998

Technical Exhibit

EUROPTO[®]
SERIES

Optical Systems Design

24-28 May

Berlin, Germany

Abstract Due Date: 26 October 1998

Technical exhibit

EUROPTO[®]
SERIES

Industrial Lasers and Inspection

14-18 June

Munich, Germany

Abstract Due Date: 16 November 1998

Technical Exhibit

International Conference on

Optical Engineering for Sensing and Nanotechnology (ICOSN '99)

16-18 June

Yokohama, Japan

Abstract Due Date: 30 September 1998

Technical Exhibit

Cosponsored by Optical Society of Japan (OSJ)
and SPIE

Optical Data Storage

11-15 July

Kauai, HI USA

International Symposium on Optical Science, Engineering, and Instrumentation

SPIE's 44th Annual Meeting

18-23 July

Denver, CO USA

Abstract Due Date: 21 December 1998

Technical Exhibit

18th Annual BACUS Symposium on

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20-21 September

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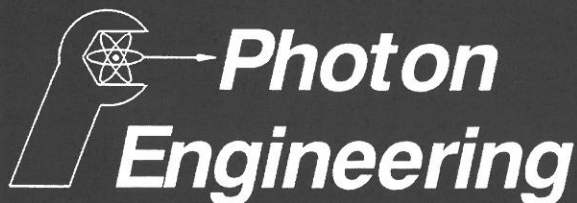
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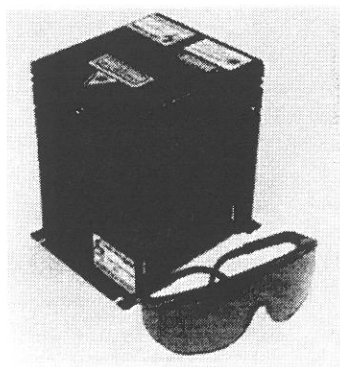
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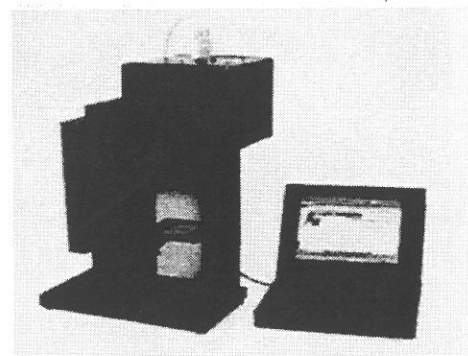


The Orion



5W TEMoo Orion

The miniature air-cooled Orion is compact enough to "fit in the palm of your hand" and can produce in excess of 5 Watts at 1064nm in either CW or Q-switched format. This powerful little laser has a wide range of industrial marking, military and medical applications. The rugged, reliable portability of this system has meant that it has already been used on airplanes and helicopters, robotic arms and all terrain vehicles - anywhere where size and portability is critical.



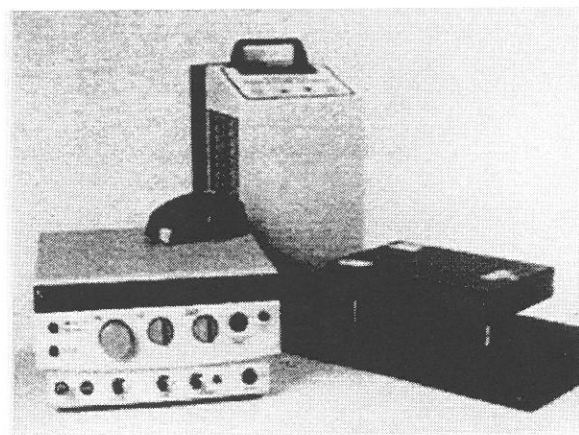
An air-cooled OEM Orion laser as part of a laser marking system

The Lightbook System

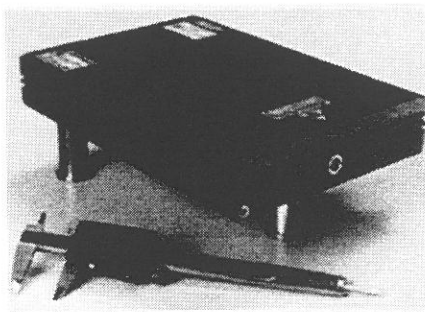
The basic 10W *Lightbook* System produces > 10W of TEMoo output ($M^2 = 1.1$) at 1064nm in either CW or Q-switched format. Pulse energies up to 1.5mJ and repetition rates from 1kHz to 100kHz enable many applications requiring high power and excellent beam quality. However the Lightbook is more than just a 10W IR laser - it is a truly modular system that can be upgraded at anytime to a variety of formats, that simply mount on top of the basic head without increasing the footprint of the laser head.

The new *Spectrum* add-on allows the user to switch between 10W @ 1064nm, to 5W @ 532nm to 1W @ 355nm. Other add-ons available include monolithic OPO's for multiwatt output at 1.57, 2.1 or 3.4 μ m, and the upcoming PPLN OPO for output anywhere in the 1.5-5 μ m range.

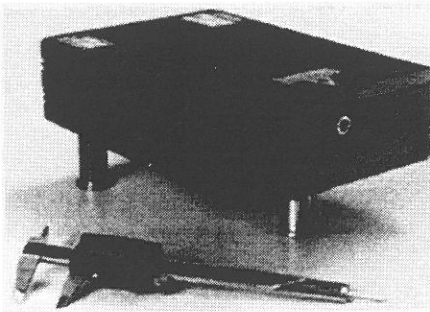
The new *LightAMP* amplifier module added to the Lightbook produces in excess of 20W of TEMoo output power. The cw-pumped LightAMP can also come stand-alone to double the power of most 1064nm lasers including cw, pulsed, Q-switched and mode-locked.



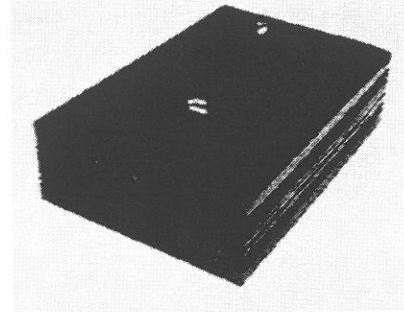
Complete Lightbook System with
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10W TEMoo Lightbook



20W TEMoo LightAMP



Lightbook Spectrum with
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Editorial

The sudden disappearance of the AOS web site was an unfortunate occurrence, caused by the disappearance of two file servers (one of which was unexpected). My thanks to Barry Sanders for resurrecting the site at

<http://www.physics.mq.edu.au/~aos/>

Barry plans to incorporate on-line membership forms, amongst other things.

The AOS is currently seeking nominations and applications for the three prizes: the AOS Medal, the Postgraduate Student Prize, and the Technical Optics Award. Details can be found in this issue of *AOS News*.

A further reminder that ACOLS is nearly upon us. The conference organisers have done a great job, making registration and abstract submission an easy task through the web. Some facts about the conference can be found on p38.

Duncan Butler

Wool Diameter Measurement by Laser Beam Occlusion

Monty Glass

CSIRO Telecommunications and Industrial Physics
PO Box 218, Lindfield NSW 2070

One of the principal factors which influence the price of wool is the thickness of the wool fibres. In general, finer wool demands a higher price. 'Laserscan' is an instrument for measuring the distribution of fibre diameters in a sample of wool. The optics of this instrument are described and the application to wool fibre sizing is discussed.

1. Introduction

The Laserscan [1] is a laser-based instrument used to measure the distribution of wool fibre diameters within a distribution of fibre snippets. This information is used by laboratories, test-houses, and combing and spinning mills both as a measure of wool quality and also to predict processing performance. The price attached to a bale of wool is highly dependant upon fibre diameter. Figure 1 shows the market price of wool as a function of mean diameter for the years 1995 and 1996. Despite marked differences in the price from year to year, the trend is the same, with fine wool being more expensive. This is particularly so for the finest wools, where a difference of only 0.1 μm in the average fibre diameter can significantly affect the price.

The Laserscan is capable of accurately measuring fibre diameters in the range 5-150 μm and is now in widespread use in the wool industry. The instrument was developed and commercialised by the CSIRO Division of Wool Technology, Ryde, during the period 1991-1995. Other instruments have been developed for the same purpose [2]. These include an air flow technique, which measures the air flow resistance of a sample of wool, and several image analysis techniques which work out the diameter distribution from microscope images of the wool fibres. All of the techniques have advantages and disadvantages, and all are in relatively good agreement for most types of wool. There are small differences ($\sim 1\mu\text{m}$), however, for a few particular wools.

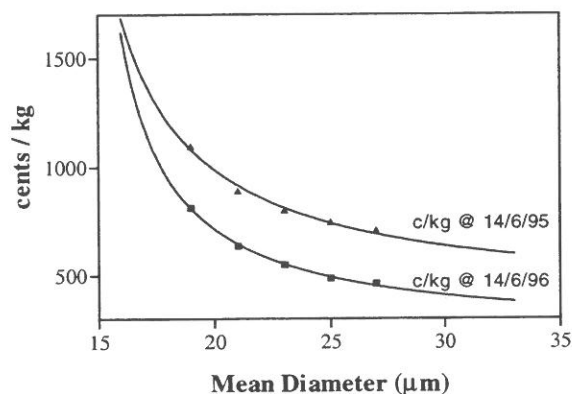


Figure 1: The price of wool as a function of mean diameter

2. Principle of Operation

The Laserscan measures fibre diameter via a diffraction based shadowing technique. A simplified schematic diagram is shown in Figure 2. A Helium Neon laser illuminates a round pinhole which effectively sizes the beam at the measurement cell. Light emerges from the pinhole in a characteristic (Airy) diffraction ring pattern and passes through a glass walled measurement flow cell, through which flows a dilute slurry of fibre snippets (2 mm long) in isopropanol and 8% water by volume. Since the diameter of wool swells by up to 17% from bone dry to saturated, water is added to the isopropanol to simulate an approximate standard condition of 65% RH in air. Some of the light is split off from the laser beam before the cell and monitored at the reference detector for changes in laser power.

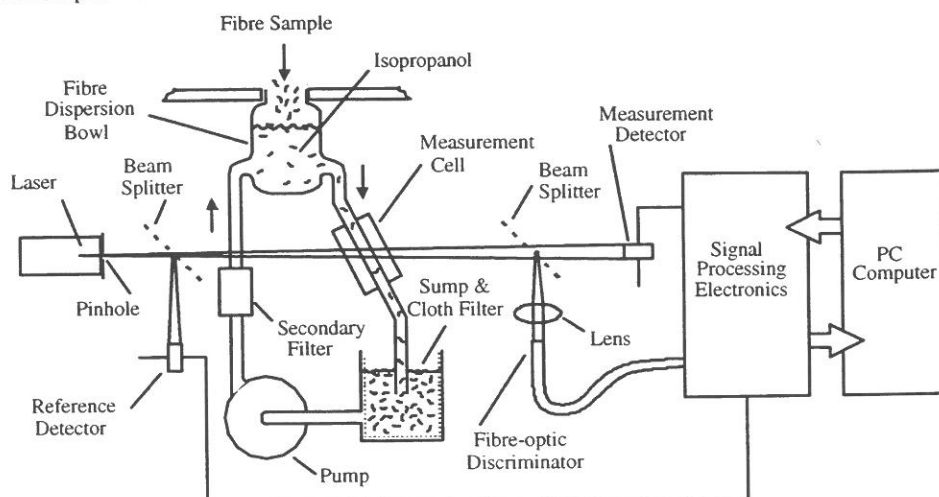


Figure 2: Schematic diagram of the Laserscan.

The cell incorporates a 2 mm wide expanding flow channel, which results in turbulent fluid flow and helps the snippets align perpendicular to the flow direction, so that they tend to go through the beam transversely. A fibre in the cell on passing through the beam scatters the laser light. The scattered light in the immediate vicinity of the optical axis is dominated by diffraction. The measurement detector catches some of the diffracted light from the wool fibre and the drop in power seen by the detector gives a direct measure of fibre diameter.

Some of the light emerging from the cell is split off and focused onto the face of an optical fibre discriminator. The discriminator is used to discriminate against invalid measurements such as dirt, wool fragments, snippets not fully intersecting the beam ("ends") and double or multiple fibres. Of all the snippets traversing the laser beam typically only 55% - 65% are accepted as being valid measurements.

Figure 3 shows a computer generated impression of the light intensity on the measurement or main detector for a 50 μm diameter snippet (vertically) spanning the centre of the measurement beam. The bright circle near the periphery of this figure indicates the edge of the measurement photo-detector.

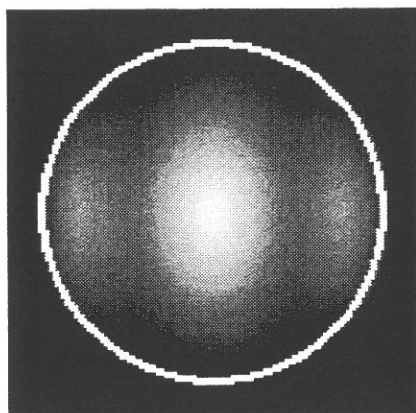


Figure 3: Calculated intensity distribution on the detector when the beam is occluded by a 50 μm diameter fibre. The detector is indicated with a circle.

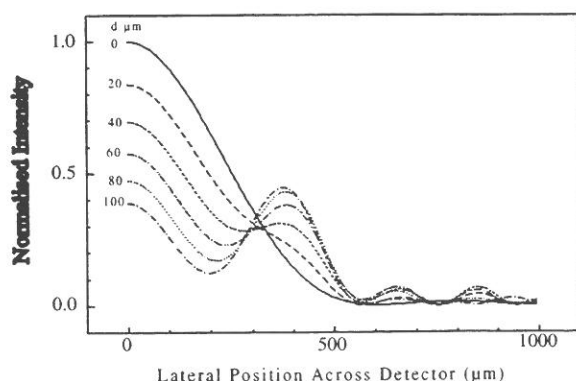


Figure 4: Calculated intensity distribution on the detector for different fibre diameters.

Figure 4 shows profiles of intensity on the measurement detector centreline for various diameter snippets up to 100 μm . Details of the theoretical model used to generate these figures may be found in [1].

The signal current resulting from the power incident on the measurement photo-detector is essentially a measure of the average intensity in the diffraction pattern falling within the area of the circular photodiode. It is usual to think in terms of the fraction or percentage of beam occlusion seen by the detector for a given snippet partially blocking the measurement beam. As a single snippet moves transversely across the measurement laser beam, the power on the detector reduces monotonically up to the point where the snippet is on the beam centreline (see Figure 5) and then from this point on increases monotonically as the snippet leaves the beam. The point where the snippet is right on the beam centreline is the moment of minimum detector signal (or maximum occlusion) and provides the direct measure of snippet diameter used in the Laserscan. Mathematically, we define the occlusion to be

$$c = 100(1 - P/P_0), \quad (1)$$

where P is the minimum signal measured when the fibre is crossing the beam, and P_0 is the unobscured signal.

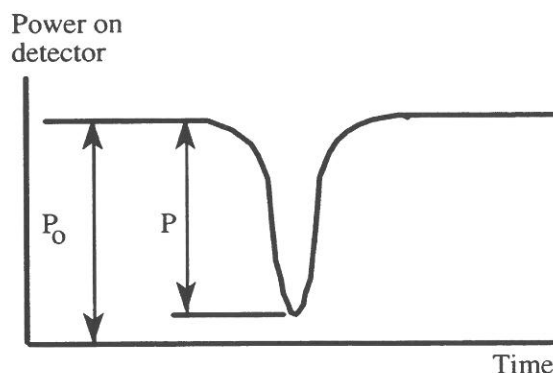


Figure 5: The occlusion as a function time as the fibre moves through the beam.

Figure 6, where the percentage beam occlusion has been graphed against fibre diameter, is the theoretical response curve for the Laserscan. Once this curve is known the fibre diameter can be determined from occlusion measurements. However, in practice it is more reliable to calibrate the Laserscan by using wool of "known" mean diameter. Calibration avoids two problems, the first being that a theoretical calibration depends critically on idealised assumptions about the optics (the lenses are perfect, the beam is paraxial and dimensions are known precisely), and the second being that users prefer a calibration which causes Laserscan to give the same mean diameter for the calibration samples as were assigned to them initially, regardless of whether these assigned values are correct.

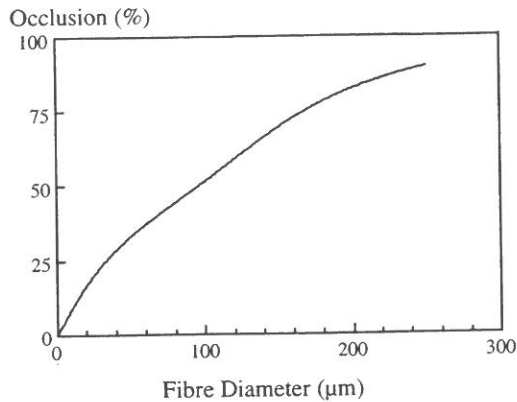


Figure 6: Theoretical occlusion as a function of fibre diameter.

3. Calibration and Measurement

Laserscan is calibrated [3] using "standard" woollen (IH) tops issued by the Interwoollabs group based in Belgium. A new set of eight calibration tops, usually in the range of 17 - 38 µm mean diameter, is issued for sale every three years. These tops have been specially prepared by repeated blending to achieve uniformity along their length. Assigned diameter values for each top are determined from the result of projection microscope round-trials in a number of laboratories around the world. Although this system of ascribing assigned diameters to a natural material with inherent variability is fraught with many problems, the level of precision and harmonisation achieved between laboratories using these IH tops for calibration is very good. The absolute accuracy of the measurements is more problematic, however. Current research into the Laserscan is directed towards basing the calibration on a traceable length standard.

To perform a measurement, a sample of wool is first cleaned, and a batch of 2 mm snippets is obtained using a guillotine with 2 mm wide blade. The snippets are added to the Laserscan isopropanol bath where they are dispersed, and pass through the measurement optics while their diameters are recorded. The snippets are removed from the solution by filters.

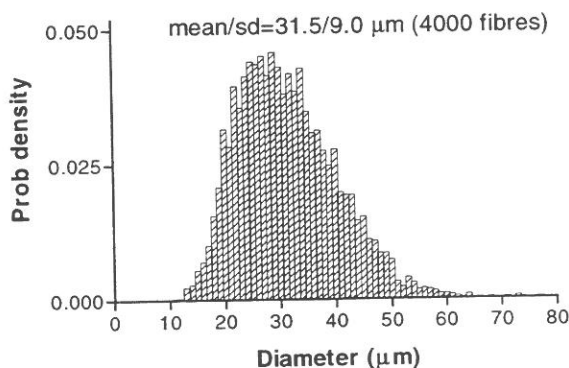


Figure 7: Typical Laserscan output showing the distribution of wool fibre diameters in the sample.

The results from a typical Laserscan measurement are shown in Figure 7. The probability of finding a diameter d is extracted from measurements (in this case) on 4000 individual fibres. The instrument calculates both mean diameter and the standard deviation, as well as providing the full distribution in this form. Laserscan can typically analyse more than 4000 fibres per minute.

4. The 'Diameter' of Wool

The importance of being able to measure a distribution of wool fibres is made clear in Figure 8, which shows a magnified image of a wool fibre. The fibre cannot be considered uniform in any sense. In general single wool fibres when viewed under the microscope are extraordinarily non-uniform in surface morphology and diameter along a single fibre length. In cases where there is very little symmetry (i.e. non-parallel sides) at sections along a fibre the concept of *diameter* itself breaks down as there is no clear generating axis to take a normal with respect to. This nevertheless is not the subject of this paper and is only mentioned in passing. The 'diameter' changes along the length and the wool has scales which may be a few microns in height. Further examination of wool reveals that it is often elliptical in cross-section, and that the axes of the ellipse rotate in a helical fashion along the length of the fibre.

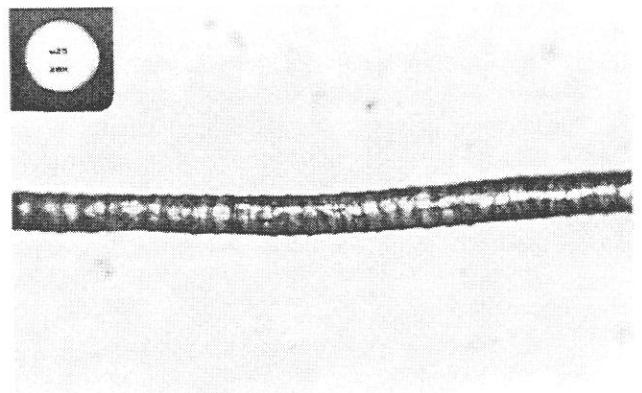


Figure 8: Optical micrograph of a nominally 25 µm diameter fibre.

Given this complicated structure, we cannot talk meaningfully of the 'diameter' of a single wool fibre. No method of diameter measurement will give repeatable results on a single fibre unless that fibre is presented to the instrument in exactly the same position and orientation. Nevertheless, the *mean* diameter of a distribution of fibres can be measured in a repeatable fashion. In Laserscan, for example, mean diameter measurements of more than 2000 snippets on the same sample usually agree to within 0.1 µm.

Acknowledgments

Support for this work was provided by Australian Woolgrowers and the Australian government through the International Wool Secretariat and the Commonwealth Scientific and Industrial Research Organisation.

References

- [1]. Glass, M., Fresnel diffraction from curved fiber snippets with application to fiber diameter measurement, *Applied Optics*, 35, No. 10, pp.1605-1616, 1996.
- [2]. Baird, K., Barry, R.G. and Marler, J.W., Mean fibre diameter differences using airflow, projection microscope and Sirolan-Laserscan, IWTO technical report 8, Nice, November 1993.
- [3]. Irvine, P.A. and Barry, R.G., An improved calibration model for the Sirolan Laserscan, IWTO technical report 1, Nice, December 1997.

FASTS ON THE CURRENT STATE OF SCIENCE TEACHING

Australia's peak council for scientists and technologists today urged parents of students at secondary schools and colleges to talk to teachers about the crisis in the supply of qualified science and mathematics teachers.

Ms Jan Thomas, Vice-president of the Federation of Australian Scientific and Technological Societies (FASTS), said that urgent Government action was needed.

"The Government should offer incentives to make teaching an more attractive career for science and mathematics graduates. HECS exemptions and scholarships will encourage good graduates into teaching, and current teachers helped to upgrade their qualifications," she said.

"This is an issue FASTS is adding to the election agenda."

She listed three major problems:

- * an imminent shortage of qualified science and mathematics teachers in Australia
- * low job satisfaction
- * existing teachers lacking appropriate qualifications to teach science and mathematics

Ms Thomas said that teaching science and mathematics was not regarded as an attractive career option. The Preston Report (1997) showed many universities are having difficulty filling their quotas for students training to be science or mathematics teachers.

"The TIMSS Report (1997) showed that 52 per cent of Australian teachers in science and mathematics would prefer to change to another job. That's twice

the rate of comparable countries in Europe, North America and Asia," she said.

"We'd suggest this is because too many teachers lack the right qualifications, and they don't feel comfortable with what they are being asked to do.

"Teachers should have at least two years of university study in science and mathematics to take classes at secondary schools and colleges," she said.

"These are specialist subjects and require specialist skills. Good teachers enthuse students, but we need more of them."

Ms Thomas was releasing the first in a series of questions FASTS will put to politicians of all parties in the election lead-up, for FASTS' President Professor Peter Cullen who is overseas:

She said that scientists and technologists wanted to cast their vote on the basis of being part of a smart Australia in the 21st century, and were seeking unambiguous answers to their questions.

Australia will suffer a serious shortage of qualified science and mathematics teachers in secondary schools and colleges by the year 2000.

How will you and your Party overcome this shortage?

Professor Cullen has written to the Minister for Education Dr David Kemp, to offer FASTS' help in reviewing the training of prospective teachers of science and mathematics.

Mr Toss Gascoigne
Executive Director
Federation of Australian Scientific and Technological
Societies

Submission Guidelines

The *AOS News* is always looking for contributions from its members. Here's a short summary of the how to make a submission.

What can you submit?

* *Scientific Article*

A scientific paper in any area of optics.

* *Review Article*

Simply give a run down of the work conducted at your laboratory, or some aspect of this work. Authors of scientific or review articles will receive proofs by fax.

* *Conference Report*

If you have been to conference recently, writing a short report would be greatly appreciated.

* *News Item*

Any newsworthy stories in optics from Australia or abroad.

* *Book Review*

If you have read an interesting (and relatively new) book in some field of optics please consider a review for the *AOS News*.

* *Cartoon or drawing*

If you have some artistic bent why not consider submitting a cartoon!

How can you submit?



The easiest way is by email. Either send the document text in your mail, or attach a word processor file using Eudora or your favorite mail program. We accept nearly all file formats. (Famous last words!).



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FASTS - THE TEN QUESTIONS

Q1. Australia will suffer a serious shortage of qualified science and mathematics teachers in secondary schools and colleges by the year 2000. How will you and your Party overcome this shortage?

Q2. Bill Clinton, President of the world's most successful economy, said earlier this year: "We must seize this moment to strengthen our nation for the new century by expanding our commitment to discovery, increasing our support for science." Then he announced the largest funding increase in American history for science and medical research. What policies have you and your Party to encourage Australian scientists to develop their best ideas, and what funding will you apply to enable them to do so?

Q3. Australian science and technology supports industries in the bush such as wine, mining and agriculture. They build better communication and transport systems, and help protect our environment. CSIRO, the universities and other research institutions contribute to community life in rural areas. How will you and your party support research and technology to strengthen Australian industries in the bush?

Q4. When Australia looks to the next century, biotechnology and information technology are among the areas which offer huge potential growth and employment. What vision do you and your Party have for Australia in the 21st century?

Q5. The capacity of Australian universities to provide world-class education and research training is being threatened by: budget cuts to operating costs: the decline of laboratory and library facilities, outdated equipment, increased teaching loads, the failure of Government to meet properly negotiated salary increases. How do you and your Party plan to put our universities back on an internationally competitive footing?

Q6. In 2004 Australian territory will more than double in size under the United Nations Law of the Sea. Twelve million square km of under-sea territory will be added to the nation's land area of nearly 8 million square km. How will you and your Party ensure that Australia has the scientific and technological expertise to manage this potentially rich resource responsibly?

Q7. The Australian Research Council funds a large part Australia's basic research. But the last Budget wrote in future cuts of \$33 million (7.5%) in 1999-2000 and a further \$28 million in 2000-2001. This will make it even harder for scientists to gain funding for their research. Do you and your Party believe that funds for research should be increased? If so, how and when will you increase them?

Q8. Job insecurity, lack of career paths and low salaries are driving good young scientists away from jobs in research. Australia is in danger of losing a generation of scientists and technologists. How will you and your Party work with industry, providers of venture capital and research organisations to encourage research and the commercialisation of research?

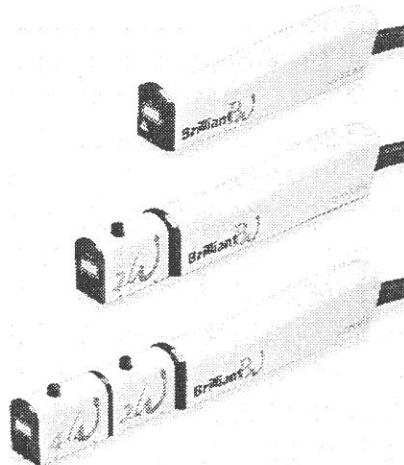
Q9. This year, business expenditure on R&D dropped for the first time in 20 years. Australia's ranking is way behind comparable countries - 19th out of 24 OECD and Asian nations. What will you and your Party do to encourage industry to invest in the new ideas and new technologies to generate wealth and jobs in Australia?

Q10. The Boston Report said Commonwealth funding should increase by \$125 million per annum to restore university infrastructure to satisfactory levels, but many university laboratories no longer even meet basic health and safety requirements. Do you and your Party support increased spending to restore the laboratories and libraries of our research organisations?

Mr Toss Gascoigne
Executive Director, FASTS

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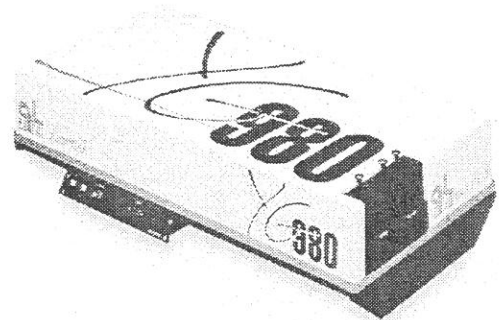
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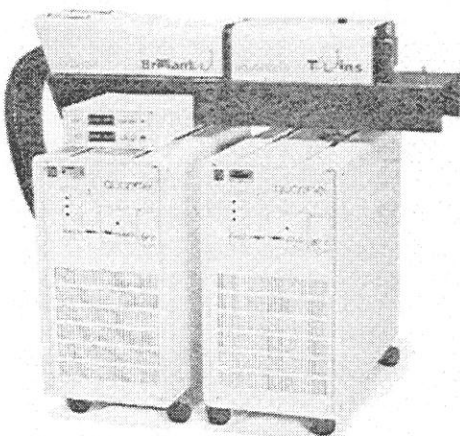
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WARSASH Scientific

Photonics Spectra Circle of Excellence Awards for 1998

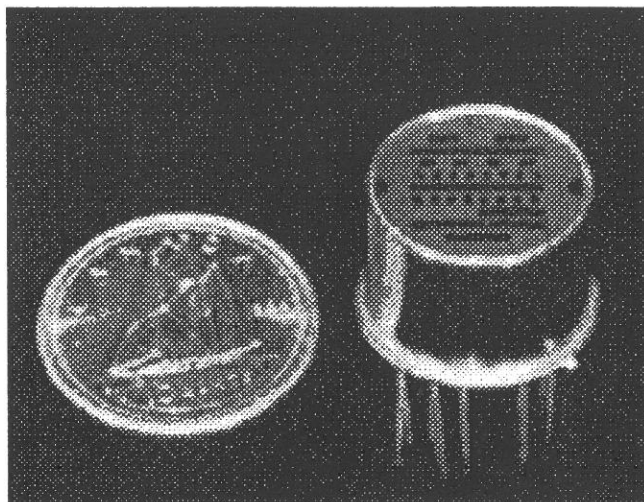
WARSASH Scientific is proud to announce that three companies we represent have won the prestigious Photonics Circle of Excellence Award for 1998. EG&G Canada Ltd Optoelectronics Division for their two band HARLID (high angular resolution laser irradiance detector), Labsphere, Inc. for their revolutionary BFC-450 bispectral fluorescent colorimeter, and Polytec PI for its six-axis nanoautomation stage with adaptive trajectory control.

We congratulate these three world leaders for their achievements in scientific development.

EG&G Canada's two band HARLID (*high angular resolution laser irradiance detector*) module has been designed to detect and provide angle of arrival information for incident laser pulses from rangefinders, target designators and other active electro optical systems. The assembly has a combined spectral sensitivity range of between 400 and 1700 nm.

The module field of view is $\pm 45^\circ$ in both azimuth and elevation, and the angular resolution is approximately $\pm 1^\circ$ in one plane either azimuth or elevation, depending on the module orientation.

The device is an ideal primary sensor for warning or taking counter measures against laser guided weapons and/or laser based surveillance systems.



Polytec PI, recognizing that the trend in microelectronics to smaller structures and a higher level of integration demanded that positioning errors be held to subnanometer and sub-arc-second levels, developed its *six-axis nanoautomation stage*.

With its digital controllers, it provides automatic real time correction of motion errors including flatness, straightness, pitch, yaw and roll. The result is better than 0.5-nm planarity of travel through any arbitrary plane that can be defined throughout a $\pm 500\text{-}\mu\text{rad}$ rotational range. The Z-positioning range is 6 μm , with an in-position stability better than 0.033 nm rms. Step response is better than 8 ms.

Applications include near-field optical probing, waveguide metrology and fabrication, scanned-probe metrology, pole-tip recession measurement, white-light interferometry and nanomachining.

Labsphere's award was for their revolutionary BFC-450, the world's first *bispectral fluorescence colorimeter* designed for absolute measurement and quantification of the colour appearance of fluorescent materials.

The entire measurement routine is completed in less than 10 minutes with a full colour rating report generated instantaneously. The report displays complete sample data, time, names etc. as well as the values for luminescence reflectance, total tristimulus, chromaticity, brightness and many more, all independent of illumination method.



WARSASH Scientific

Website Launched

Like so many Sydney streets, our website has been "under construction" for some time, but now we can confidently point to an interesting and updated review of our suppliers' developments.

Check it out, and contact us to get more detailed technical data and see the many - unexpected - application possibilities.

You can find it all at:

<http://www.ozemail.com.au/~warsash/>



Super Luminescent Diodes

EG&G Optoelectronics Canada have developed a line of super luminescent diodes CW operated types.

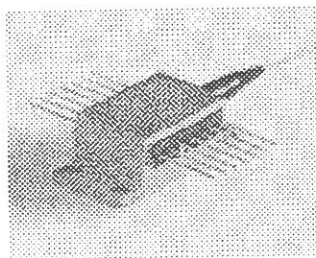
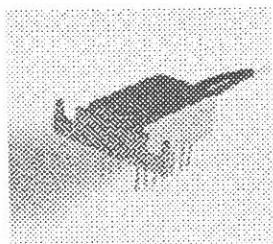
Operating at 850 nm, 960 nm (InGaAs) and 1300 nm (InGaAsP), they are produced using the latest MOCVD and MBE growth techniques.

Devices are offered in TO-style packages and 14 DIL and Butterfly outlines coupled to polarisation maintaining fibre (except C86115E-13, where 50/125 μ m fibre is standard).

Optional single mode and multimode optical fibre are also available on a custom basis. DIL (M) and Butterfly (V) packages are equipped with an integral TE cooler, thermistor, reverse protection diode and monitor photodiode.

Pigtailed units benefit from a unique highly stable fibre alignment process which maintains precise fibre to emitter position over significant case temperature excursion.

Typical applications include fibre optic gyroscopes, fibre optic sensors (nonFOG), and optical tomography.



WARSASH Scientific

tel: (02) 9319 0122 - fax: + 61 2 9318 2192

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Precision Optics

WARSASH Scientific can supply all the necessary support required for virtually any optical system or individualised components in all aspects of optical manufacturing.

We assure our customers total quality, while maintaining time delivery, at the best possible prices.

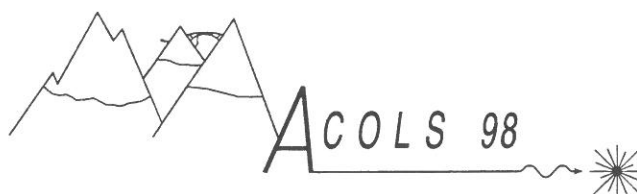
Using Takos, our customers can be sure in the knowledge that time and money will be saved and the highest standards will be met.

Takos can align an optical system or supply a customer with a system made for individual requirements.

Total integration of all aspects of the product is part of the service provided.

Takos works to quality level of ISO 9000 and guarantees all products adhere to the most critical quality standards.

Verification of all products and their requirements is achieved through a variety of exact testing, including laser damage testing, spectrophotometric response, interferometric analysis, as well as all physical and environmental testing.



Australasian Conference on Optics, Lasers & Spectroscopy

14th–17th December, 1998

University of Canterbury,
Christchurch, New Zealand

Conference Chair: Professor Wes Sandle, Department of Physics,
University of Otago, Dunedin, New Zealand.

Notification to authors byMonday 28th September

"Early bird" registration byFriday 16th October

For current information:

Web: <http://www.physics.otago.ac.nz/~acols98>

Email: acols98@physics.otago.ac.nz

The **Frew Lecture** will be given by Professor Carl Wieman of JILA.

Confirmed Plenary Speakers:

Janet Fender, past president of the OSA
Allister Ferguson, University of Strathclyde
Peter Hannaford, CSIRO
Stephen Leone, JILA
Keith Nugent, University of Melbourne
Wilson Sibbett, University of St Andrews
Dan Walls, University of Auckland

Confirmed Invited Speakers:

Ken Baldwin, Australian National University
Tom Barnes, Auckland University
Chris Foot, Oxford University
Crispin Gardiner, Victoria University
of Wellington
Murray Hamilton, Adelaide University
Dwayne Heard, University of Leeds

Richard Hughes, Los Alamos National Lab
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Queensland
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Alan Shore, University of Wales
Wim Ubachs, Vrije University, Amsterdam
Sylvia Volker, Leiden University
Chris Walsh, CSIRO;
Andrew Wilson, University of Otago
Michael Withford, Macquarie University

Preliminary Programme

The programme will be headlined by two plenary lectures each day, followed by two parallel sessions including invited and contributed oral presentations. Two poster sessions will be held. Contributed papers covering recent original work in the conference programme areas will be considered for 20 minute oral presentations, or for poster presentations.

Programme Areas

The six programme areas for ACOLS 98 are:

1. Atomic and Molecular Spectroscopy (including ultrafast phenomena)
2. Quantum and Atom Optics (including BEC and Quantum Computing)
3. Chemical and Biomedical Applications of Spectroscopy
4. Nonlinear Optics and Laser Development
5. Generalised Optics, Applications of Optics and Lasers
6. New Faces (by invitation)

Invitation to Exhibitors

A technical exhibition to coincide with the ACOLS 98 conference is being planned. We aim to feature leading Australasian suppliers of equipment in the fields of optics, lasers and spectroscopy. Companies operating in areas relevant to the conference are invited to participate in the technical exhibition. All sessions, catering and technical displays will be held in the one complex.

If you would like more information, please contact
 Dr Roger Reeves, Exhibition Co-ordinator,
 Department of Physics and Astronomy,
 University of Canterbury,
 Private Bag 4800, Christchurch, New Zealand.
 Phone +64 3 364 2572
 Fax +64 3 364 2469
 Email: r.reeves@phys.canterbury.ac.nz

If you intend exhibiting, please contact:
 The Conference Organiser, ACOLS Conference,
 C/- Centre for Continuing Education,
 University of Canterbury,
 Private Bag 4800, Christchurch, New Zealand.
 Phone: +64 3 364 2162
 Fax: +64 3 364 2915
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The Venue

The conference will be held at the attractive, modern campus of the University of Canterbury in Christchurch. Christchurch Airport, with both international and domestic services, is only five kilometres from the University. December is early summer in Christchurch with pleasant daytime temperatures around 20 degrees Celsius.

Daniel F. Walls Symposium

A Symposium to honour the achievements of Professor Dan Walls is to be held as part of ACOLS 98, on Wednesday 16th December. The Symposium, which will begin following the ACOLS plenary talks, will be held in three sessions and is focused on Quantum and Atom Optics. The ten talks in the symposium are by invitation, but contributed talks in the Quantum and Atom Optics programme area will also be scheduled for other conference sessions.

A keynote address for the Symposium will be given by Professor Jeff Kimble, Caltech.

The speakers are :

Hans Bachor, Australian National University
 Peter Drummond, Queensland University
 Roy Glauber, Harvard University (to be confirmed)
 Ed Hinds, Sussex University
 Richard Hughes, Los Alamos National Laboratory
 Gerard Milburn, Queensland University
 Geoff Opat, Melbourne University
 Robert Scholten, Melbourne University
 Sze Tan, Auckland University

In conjunction with ACOLS 98, a special issue of *The Journal of Quantum and Semiclassical Optics* associated with the Quantum and Atom Optics programme area and the Walls Symposium has been organised. Details of the special issue, including the submission process, are available on the conference web site.

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Main Activities (number up to three in order of importance)

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