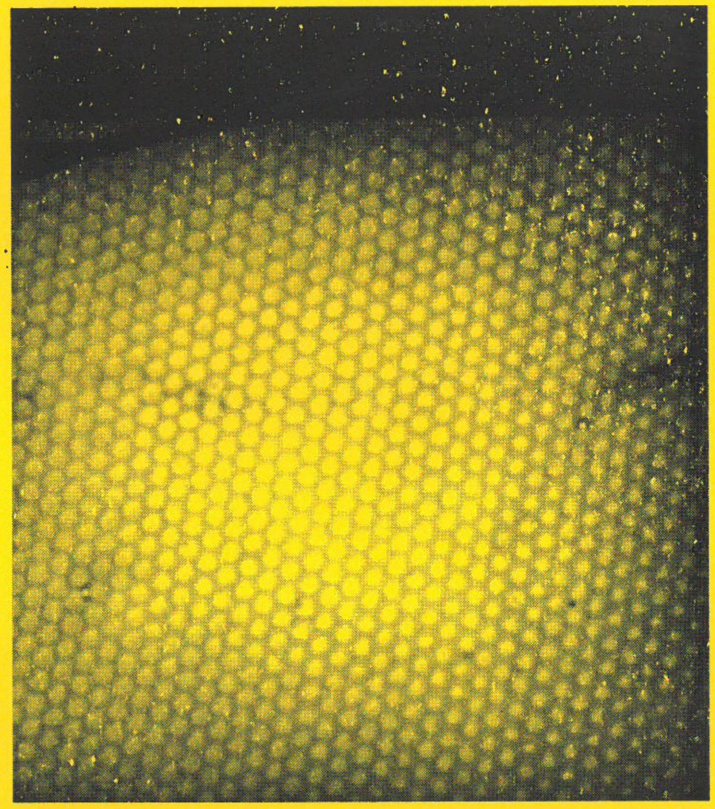
Australian Optical Society

NEWS



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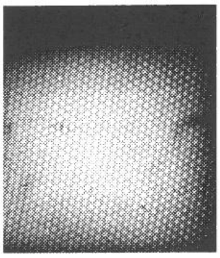
AOS NEWS



COVER:
The cover image shows a precision optical structure that occurs naturally in the animal world. The regular array of holes in this sea mouse bristle produces what is essentially a photonic band gap material. This intriguing structure, and other examples of optics and nature, are explored in this issue, in the article on page 7.

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Where possible, diagrams should be contained within the document or sent as separate encapsulated post-script files. Figures on A4 paper will also be accepted. Note: all figures should be black & white or greyscale.

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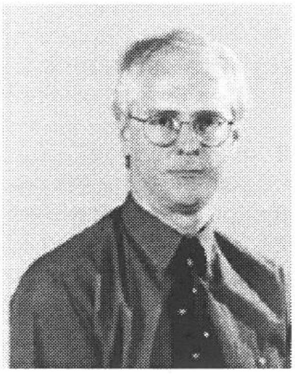
DEADLINE FOR NEXT ISSUE
20th November. 2001

ARTICLES

DEPARTMENTS

President's Report



Your president is showing gift for some prescience. In the column before last I anticipated the increase in funding for the Australian Research Council, which came to pass, and in my last column I considered the likely development of an Australian synchrotron. Well that too has come to pass with the announcement that the Victorian government will fund the construction of a synchrotron on the campus of Monash University. This was an interesting piece of hairy chested political gazumping and did leave a bitter taste in the mouths of some Queenslanders. While I think there are some issues about whether the process adopted by Victoria was optimal for the national interest (the assumption being that a Federal selection process would be more rational), the general environment is good for science. The effect of the GST is to progressively shift the centre of gravity for such decision making towards the state governments and those of us who have some interest in supporting the science area should ensure that our contacts with our respective state governments are as strong as possible. They will hold much of the discretionary income into the future.

Having said this, I would note that the new national synchrotron will offer a considerable suite of opportunities for AOS members. Although one colleague of mine did say (rather cynically) that a synchrotron is "just a collection of pipes and pumps", the construction of a synchrotron involves a huge range of modern technologies including a wide range of precision optical components, such as ultra-high smoothness mirrors. I certainly hope that the synchrotron project managers use this as an opportunity to ensure many contracts are let to Australian companies. As we all know, in the modern economy, efficiency is all and, if the aim is to build the facility as quickly and cheaply as possible, bringing local companies (and people) up to speed is not a priority. While I think this is a shame, our companies and researchers can compete with anyone in the world and we just have to ensure that our AOS corporate members are properly positioned to benefit from this major national initiative.

Other projects of interest to AOS members were released in the results of the MNRF scheme announced on August 21 included the major astronomical projects to develop the Gemini telescope and Square Kilometre Array, as well as the NANO project which will establish a national network of analytical instrumentation. The support for science in this country is certainly picking up, which is gratifying, but the Federal government is still trying to convince itself that the state of education in this country is adequate. It's not!

The AOS recently held its Annual General Meeting at the Victoria University. There was an excellent turn-out for a symposium on the role of Optics in Industry and the effort resulted in some profile for our corporate members. The presentations were excellent and it was great to see the level of interest in what is going on with the development of optics-based industry in Victoria. This meeting was particularly fitting as the arrangements for the AGM were temporarily complicated by the departure of Peter Farrell, the AOS secretary, from Victoria University to a private company in suburban Melbourne (which will be named when it becomes a corporate member!). This move reflects both the parlous state of education in Australia and the rapid development of Australia's high-technology sector.

In the Presidents report at the AGM I drew particular attention to one of our most distinguished members, Parameswaran Hariharan (Hari). Hari is a life member of the AOS and has just been awarded the 2001 SPIE Gold Medal. An article on Hari in the context of this award is given in this issue, but briefly the Gold Medal is "presented annually in recognition of outstanding engineering, scientific accomplishments in optics, electro-optics, or photographic technologies or applications, without which the technology would not have progressed to its present state". This is thoroughly well deserved honour and I am sure you will all join me in congratulating Hari on this wonderful recognition of his contributions to optics internationally.

Finally, I would like to thank my fellow counsellors for their support this (financial) year, with particular mention to Stephen Collins, Duncan Butler, Peter Farrell and Barry Sanders. However I would particularly like to thank Wayne Rowlands for bringing the *AOS News* back to life with such energy and enthusiasm. The *AOS News* is an important component of our activities and running it is a very big job. I am sure you will join me in thanking Wayne for a fantastic effort.

Keith Nugent
President of the Australian Optical Society

August 2001

Top Optical Science Award for Dr Hariharan

Dr P Hariharan has been named as the recipient of the Gold Medal of SPIE, the International Society for Optical Engineering for 2001. The Gold Medal is the highest honour of the Society and is presented annually in recognition of exceptional scientific or engineering contributions to the advancement of optics. The SPIE Awards Committee has made this recommendation in recognition of Dr Hariharan's "pioneering engineering and scientific accomplishments in optics, electro-optics and photographic science as well as outstanding contributions to optics at an international level".

Dr Haraiharan has achieved international recognition as a leading researcher in optics and photographic science. His original scientific contributions include new techniques for processing holograms, holographic interferometry, speckle interferometry, optical testing, polarisation optics, and quantum optics. He has published more than 200 papers in international journals as well as four major reviews, three in *Progress in Optics*, and one in *Reports on Progress in Physics*, and several book chapters. He is the author of three books, *Optical Holography* (Cambridge University Press, 1984, 2nd ed. 1996), *Optical Interferometry* (Academic Press, 1985) and *Basics of Interferometry* (Academic Press, 1991), and the Editor of two volumes, *Selected Papers in Interferometry* and *Selected Papers on Interference, Interferometry and Interferometric Metrology*, in SPIE's Milestone Series.

Dr Hariharan is a Fellow of the Optical Society of America, SPIE, the Institute of Physics, London, the Royal Photographic Society, the Indian Academy of Science, and the Indian National Science Academy. Honours received by him include the Joseph Fraunhofer Medal of the Optical Society of America, the Henderson Medal of the Royal Photographic Society, the Thomas Young Medal of the Institute of Physics, London, the Walter Boas Medal of the Australian Institute of Physics, the Dennis Gabor Award of SPIE, and the Gold Medal of the Australian Optical Society. In March 2001 he was awarded the degree of Doctor of Science (*honoris causa*) by the University of Sydney.

Dr Hariharan has also made outstanding contributions to optics at an international level. He was the President of the Optical Society of India (1973) and the Australian Optical Society (1988). He served on the Board of the International Commission for Optics for 9 years, initially as a Vice President (1984-87) and then as its Treasurer (1987-93). He was the Founder President of the Asia-Pacific Optics Federation and the Australian Chapter of SPIE (1987-96) and a Director of SPIE (1991-94), as well as a member of SPIE's International Activities Committee (1995).

Dr Hariharan was born in India in 1926. After completinghis Masters degree in Physics, he worked at the National Physical Laboratory, New Delhi (1949-51 and 1954-61) and at the National Research Council, Ottawa (1951-54). He received his Ph.D. from the University of Kerala in 1958 for his work on photographic resolving power. Subsequently, he became the Director of the laboratories at Hindustan Photo Films, Ootacamund (1962-71) and Senior Professor at the Indian Institute of Science, Bangalore (1971-73). He joined the CSIRO Division of Applied Physics in Sydney in 1973 and retired as a Chief Research Scientist in December 1991. After retiring, he has continued his research as an Honorary Research Fellow at CSIRO and an Honorary Visiting Professor at Sydney University. He has also held visiting positions as the Jawaharlal Nehru Professor at the University of Hyderabad, India (Jan-March 1993) and as a Visiting Scholar sponsored by the International Centre for Theoretical Physics, Trieste at the Raman Research Institute, Bangalore, India (Jan-March 1996, 1997, 1998).

A P P L I C A T I O N S

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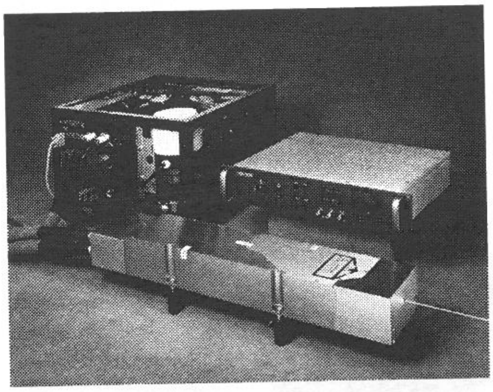

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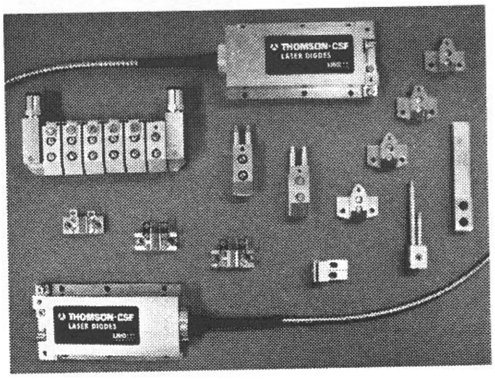

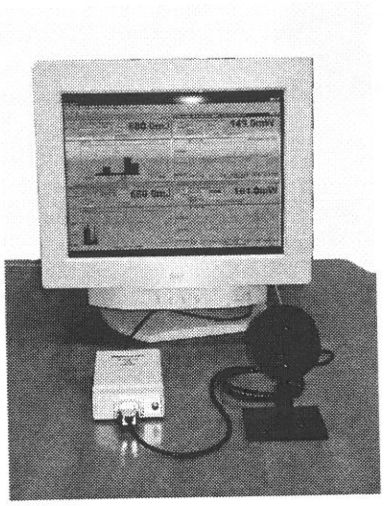

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Learning Optics in Nature's School

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[2] Department of Mathematical Sciences, University of Technology, Sydney, NSW 2007

1. Introduction

For as long as there has been science, inspiration has been drawn from natural phenomena and structures. However, as branches of science mature, they develop an increasingly rich store of ideas, techniques and technology, and the tendency to search the realm of nature for inspiration diminishes. Optics is certainly one of the oldest branches of science, and many of its practitioners perhaps imagine that most of what could be learnt from nature was learned in the epochs of Newton, Grimaldi, Young and Fresnel.

However, with increasing maturity come new tools with which we may look more closely at some of nature's more subtle structures, and discover new things hidden from previous explorers. The emerging field of *optical biomimetics* seeks to examine structures in living systems, to understand how they deliver optical effects, and perhaps, to discover new designs arrived at by evolution which may be applied in technology.

This article aims to present some examples of optical systems in nature from which we may learn new tricks, or present, as interesting examples of old tricks, to students. We believe all practitioners of optics should be interested in optical biomimetics as an emerging subfield which builds bridges to the world of living systems and which illustrates that you don't have to craft in glass.

2.Mirror, Mirror, Not On The Wall

We all should know the story of Archimedes of Syracuse, called in to use his science to help his city fend off the invasion of a fleet from Rome. He had artisans manufacture great mirrors of metal, with which he set fire to the sails and rigging of the Roman ships, foiling for a time their inevitable conquest.

Much less well known is the South American mirror fish. This ingenious fish is a rather thin, flat sided animal, which engages in optical warfare *a la* Archimedes during its territorial battles. It curves its flank in an attempt to focus ambient light in the eyes of rival fish. The more successful design will deliver a flux capable of stunning the nervous system, and the defeated fish will fall limply out of the lists, leaving Mr. Parabolic in possession of the terrain.

Our collaborator, David McKenzie of the University of Sydney, was one day lunching with colleagues at the Sydney Fish Markets when they noticed, in the display, a local fish with a shiny underbelly and a dull back. From this, there started a discussion of why the fish sought its high reflectance on one side, and also how it achieved it. The why is easily answered: the fish lives at mid-depths, and seeks to be mistaken by predators below it as being part of the reflecting surface of the water which terminates their world above. The predators above it see, with difficulty, only the dull back of the fish.

To answer the how, our colleagues bought a fish, and conducted an electron microscopic examination of the skin on its shiny belly. They discovered that the skin contained a structure consisting of layers of flat guanine crystals with random spacing (McKenzie *et al*, 1995). The guanine provides a higher refractive index than surrounding material, and the layers of crystal each operate like partially reflecting mirrors. If there is a sufficient number of such layers, they will generate a high reflectance. The random spacing means that the high reflectance will not be delivered in a narrow wavelength band, but will be wideband. Further, as the fish grows and the spacing alters, the high reflectance will be preserved.

David McKenzie and colleagues have also taken up a subject initiated by Robert Hooke, who in his book *Micrographia* reported on the lustre of the common silverfish. He observed "the appearance of so many several shells or shields that cover the whole body, every one of these shells are covered or tiled over with a multitude of transparent scales, which, from the multiplicity of their reflecting surfaces, make the whole animal a perfect pearl colour". An electron microscopic examination of silverfish samples (Large *et al*, 2001) in fact showed the scales had a ribbed structure with spacings in the range 1–3 μm, while below the scales there was a complicated multilayer structure, composed of high index layers of chitin (with index around 1.53–1.56) interspersed with low index (around 1.4) layers. The reflectance of the silverfish rises from around 15 percent near 0.4 μm, to just over 20 percent at the end of the visible, reaching a peak over 60 percent at around 1.3 μm. Most of this reflectance is due to the multilayer stack that Hooke didn't see, rather than the scales that he thought were the reason for it. Other multilayer stacks are found in some beetles having a metallic reflectance, but the beetle multilayers have a less complicated chirping than the silverfish layers.

3. Colour by Chemistry or Physics

Many animals rely on colour to attract mates, to attract lunch, or to signify that they are not a particularly desirable item for a predator's menu. There are two main methods for achieving colour: by chemistry, through the use of pigments, or by physics, through the use of interference or diffractive structures. Animals tend to use pigments where there is plenty of light and energy: pigments tend to photobleach, and so will have to be replaced, which burns up energy. The pigments deliver colour by selective absorptance rather than selective reflectance, and so are not as good in low light environments, where photons have to be handled with somewhat greater care.

The colours arising through interference and diffraction are called structural colours, and are coded into a physical structure within the living system. They have been detected in a range of animals, fish and insects, and those occurring in butterflies have received much recent attention in Exeter (Vukusic et al, 1999) and Sydney (Quantum, April, 2001).

Butterflies use both pigments and structural mechanisms to obtain colour effects. One interesting way to distinguish one from the other is to look at old specimens, such as those in the collection of the Australian Museum. The pigment colours bleach and fade with time, leading to dull

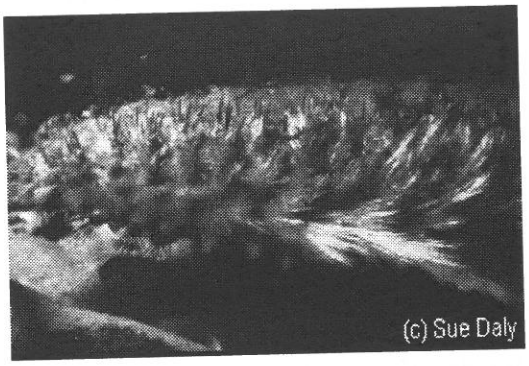

Fig. 1: A sea mouse or *Aphrodita* (note the iridescent felt on the edge of its body). From Sue Daly, *Marine Life of the Channel Islands*, 1998 (with permission).

specimens, while those relying on structure are not subject to colour loss, and are as bright today as when they were collected. This is an interesting advantage, which may be sufficient to ensure commercial success for those who find a way to generate at low cost patterns of structural, rather than pigmental, colour.

One remarkable fact is that we can look at the fossil record, and in exceptionally well-preserved specimens, such as those from the Burgess Shale in British Columbia, we can see examples of structural colours arising even in long extinct animals. We can also follow, if we are lucky, the evolution of an optical design towards increasing complexity and better functionality in a sequence of fossils. Those who wish to read more of this should consult Andrew Parker's beautiful review article (Parker, 2000), 515 Million Years of Structural Colour.

4. Aphrodite's Allure

We turn now to a humble sea creature with a splendid name, the sea mouse or *Aphrodita sp*. This lives on the sea bed, from depths of a few metres to a few thousand metres, and is a *Polychaeta* or bristle worm. It is seen in Fig. 1 to be generally dune coloured, to merge in with sandy or muddy bottoms. However, the lower edge of its body carries longer felt or hair, with a beautiful iridescence. *(for colour images, see the website indicated at the end of this article -ed.)*

This iridescence was known to fishermen, and was commented on by Linnaeus, who classified the species in 1758. It intrigued us as to how this animal was able to achieve such brilliant colouration with the limited index contrast of the materials available to it (about 1.54 for the chitin to 1.33, given it lives in water). We were given a spine or thicker bristle from a specimen collected by Andrew Parker at Palm Beach, which had a strong reddish colouration in white light, and subjected it to an electron microscopic examination.

The results in Fig. 2 show that the spine is annular, with a hollow core and a wall punctuated by an amazingly regular array of holes (white) in the biological material chitin (dark). One can view the spine structure as a sequence of interference layers, taking the hole region to have an effective index between that of chitin and sea water, with these equivalent low index layers being separated by chitin. In order to achieve strong colouration (with spectrophotometry revealing spine reflectance close to 100 percent in the red), the relatively weak reflectance resulting from low index differences must be compensated by a large number of layers adding their reflectance coherently. This is the case only if the spacing of the layers of holes is as regular as that shown in Fig. 2, much as X-ray multilayer stacks must be of very high regularity.

We view the structure of Fig. 2 as being composed of a stack of diffraction gratings, and we use tools that we have developed (McPhedran *et al*, 1999; 2001, Botten *et al* 2000) to model the reflectance and transmittance of stacks of cylinder gratings of one index embedded in a matrix of another index. In this way we calculate the reflectance of the spine structure for a range of wavelengths, for a given incidence angle of plane waves. The result is shown in Fig. 3, for one of the two principal polarizations (denoted E and H depending on whether the incident wave has its electric or its magnetic field oriented along the holes). Note that, "normal" light is not polarized, so we always have a mixture of the two polarizations.

The optical properties of the sea mouse hairs are then in good accord with the results of rigorous calculations, using as data their measured geometry. Another way of looking at the sea mouse structure, developed to yield high

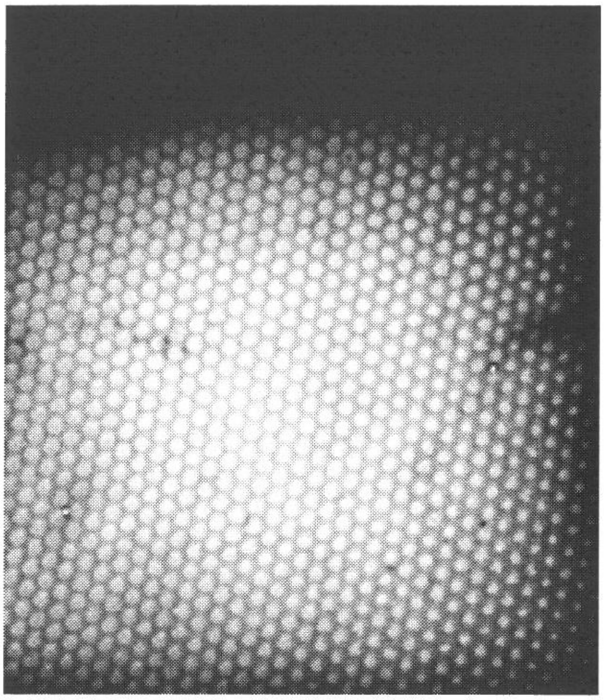

Fig. 2 An electron microscopic image of a spine of a sea mouse. The wall of the spine contains 88 layers of holes, whose spacing is 0.51 micron.

reflectance in a narrow wavelength band, is to regard it as having exploited a photonic band gap.

In this way, it is connected with a currently "hot" area in electromagnetic optics, in which groups all over the world are attempting to create and exploit structures in which light is unable to propagate in certain wavelength ranges, for all angles of incidence and polarizations. These structures would then be the optical analogues of semiconductors, and could be doped by the introduction of appropriate irregularities in their optical properties.

Normally, to achieve a bandgap in which propagation is impossible for all directions, the structure has to incorporate high index contrast (around 3 to 1). Nature does not have at its disposal such high index materials for living creatures, and so the sea mouse structure achieves only a partial band gap (shown in Fig. 3), inhibiting propagation for a range of wavelengths in the red, but only for a restricted range of directions and polarizations. Nevertheless, the result is adequate for its purposes: strong reflectance in a narrow band which shifts with angle of incidence, giving the creature its characteristic iridescence, which presumably warns predators it is not particularly good eating.

5.Conclusions

We have argued that Nature provides a good book for the education of opticists, and that many good design ideas have been arrived at by evolution rather than analysis and computer power. The main example we have cited, the sea mouse, is a spectacular example of nature's micro-

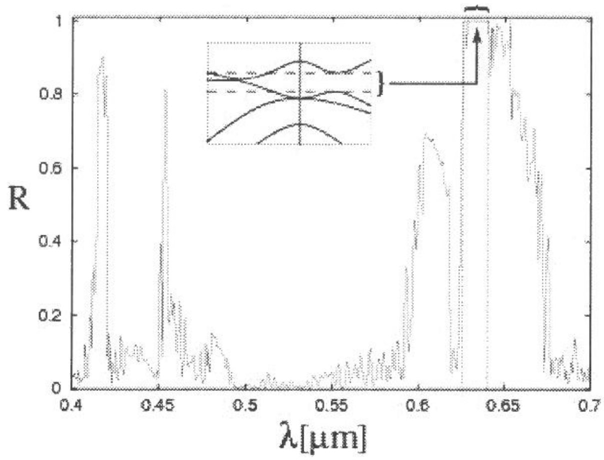

Fig.3 Reflectance of the 88 layer stack of gratings constituting the spine structure of Fig.2, for normally incident radiation, and E polarization. The vertical dashed lines correspond to the band gap in a segment of the photonic band diagram shown in the inset.

engineering, and may well give rise to technological off-shoots, if we can find a way to mimic its tricks in molecular assembly that give rise to the regular structure of Fig. 2. If we could make such layer structures at reasonable cost over large flat areas, the result would be a new technology delivering brilliant, pure and unfading colours.

For those who wish to learn more about the sea mouse, references and colour images may be found at

http://www.physics.usyd.edu.au/~nicolae/seamouse.html

References

Botten, L.C., Nicorovici, N.A., Asatryan, A.A., McPhedran, R.C., de Sterke, C.M., and Robinson, P.A.
J. Opt. Soc. Am. A **17**, 2165-2176, (2000)

Large, M.C.J., McKenzie, D.R., Parker, A.R., Steel, B.C., Ho, K., Bosi, S.G., Nicorovici, N.A. and McPhedran, R.C.
Proc. R. Soc. Lond. A **457**, 511-518, (2001)

McKenzie, D.R., Yin, Y. and McFall, W.D.
Proc. R. Soc. Lond. A, **451**, 579-584, (1995)

McPhedran, R. C. Botten, L.C., Asatryan, A.A, Nicorovici, N.A.,de Sterke, C.M. and Robinson, P.A.
Aust. J. Phys. **52**, 791-809, (1999)

McPhedran, R. C., Nicorovici, N.A., McKenzie, D.R., Botten, L.C., Parker, A.R., Rouse, G.
Aust. J. Phys. **54**, in press. (2001)

Parker, A.R.
J. Opt. A: Pure Appl. Opt. **2**, R16-28, (2000)

Vukusic, P., Sambles, J.R., Lawrence, C.R., and Wootton, R.J.
Proc. R. Soc. Lond. B **266**, 1403-1411, (1999)

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Complex-shaped 3-D microstructures fabricated by two-photon photopolymerization

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The ability to fabricate complex-shaped three-dimensional (3-D) microstructures with a resolution on the order of one micrometer is an essential requirement for the production of micromachines or optoelectronic microdevices. By a new laser scanning two-photon excitation photopolymerization technique such structures can be generated efficiently. As examples a 3-D pacman-like cone structure and a 3-D kangaroo are presented.

1. Introduction

Complex three-dimensional structures with dimensions of the order of a few microns have an enormous potential for scientific and commercial applications as mechanical or optical microdevices. Microstructures may act as sensors or actuators such as force sensors, micro-pumps or micromovers in microscopic systems, which may be used for example for diagnosis or surgery inside the human body. Recent developments include the construction of micro-machinery parts like micro-gears or axles, based on the LIGA (lithography, galvo or electro plating and abformung or injection molding) technology[1].

While many techniques, such as multi-run sputtering and etching have proved to be quite complicated, photopolymerisation of a resin by radical formation involving a two-photon excited photoinitiator, is a simple process with the potential for many microstructure applications [2-6]. The versatility of structures that can be fabricated and the cheapness of the materials used make it a very promising approach. The photopolymerisation process involves the simultaneous absorption of two photons of a specific infrared or visible wavelength by special photoinitiator molecules in a liquid resin. The excited photoinitiator then starts a chemical reaction, which solidifies the resin locally by polymerisation of formed radical monomers and oligomers. As simultaneous absorption of two photons requires very high laser intensities, two-photon photopolymerisation can only be achieved in the centre of the focus of a high-numerical aperture objective. Therefore, the polymerised region can be limited to a very small volume in all three dimensions, which is effectively the two-photon point spread function [7]. By moving the focus along a predetermined trajectory, objects of arbitrary shape are generated.

2. Efficient microstructure fabrication by two-photon photo-polymerization

Fabrication of complex-shaped three-dimensional microstructures with high spatial resolution on a time scale on the order of ten minutes requires suitable photopolymers as well as a fast and efficient scanning procedure. While optimized photopolymers may increase the scan speed by about a factor of five [4,8], scan algorithms that are well-adapted to structure detail may enhance the production efficiency by one to two orders of magnitude.

Structures were fabricated using a Spectra-Physics Tsunami Ti:sapphire mode-locked laser tuned to a wavelength of 800 nm. 110 mW ultrashort (80 fs) pulsed laser light were focussed onto the sample using an Olympus ULWD MS Plan 100x IR NA 0.8 objective. Fabrication was achieved by mounting the sample onto a 200x200 μm piezoelectric stage (Physik Instrumente, Waldbronn, Germany) and moving it relative to the focus of the laser while selectively opening a shutter. The scanning stage, the shutter and the objective position were controlled by a standard desktop PC fitted with a National Instruments 4-channel analog output card. The fabrication process was monitored in situ using a CCD camera. Details of the experimental setup can be found in Ref. 8.

A commercially available resin, consisting of a photoinitiator, urethane acrylate monomer, and urethane acrylate oligomers, was used due to its peak absorption at 380 nm and negligible absorption at 800 nm. Sample preparation occurred in the dark as the polymer is photopolymerisable in the UV. A thin layer of the resin, typically a one millimeter square of up to 60 μm in depth, was held between a slide and a 100 μm thick glass cover-slip. The structures were fabricated on the under-side of the coverslip.

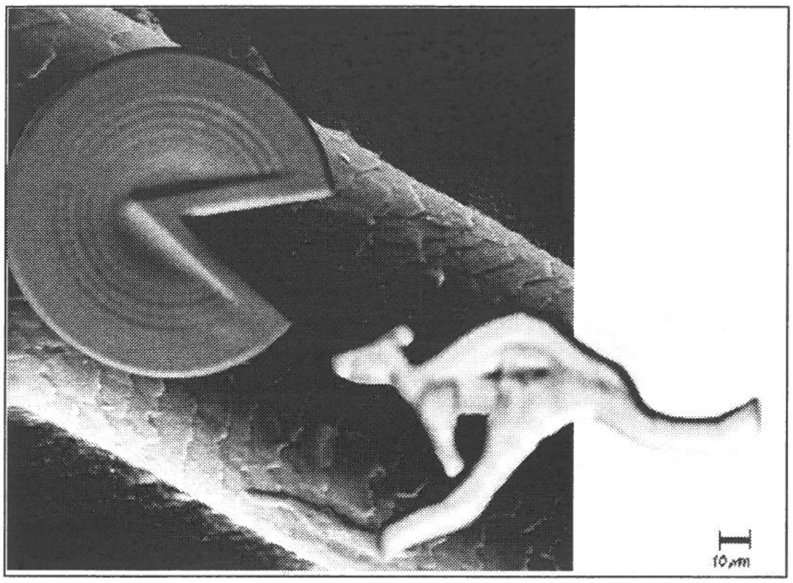

Fig. 1. Differential interference contrast images of a three-dimensional pacman-like cone structure and a kangaroo, as fabricated by laser scanning two-photon excitation photo-polymerization. For comparison, a 100 μm thick human hair is shown. A kangaroo design, based on a familiar 2-D logo but given some additional definition, was also chosen, because it is a complex, non-mathematical structure. From head to tail it is 140 μm. The outline was scanned four times with a line separation of 1 μm. Each cross section was repeated three times with a 1.5 μm increment between subsequent layers. The writing speed was 20 μm/sec again.

3. Results

A three-dimensional pacman-like cone structure and a 3-D kangaroo were constructed using an outline scan algorithm, which traces only the border of the structure leaving its unsolidified interior to be UV-cured afterwards. Fig. 1 shows both the cone and the kangaroo as compared to a human hair. A hollow 3-D cone, with a slice cut out of it (a "pacman", becoming slightly smaller in each subsequent cross section) was chosen because it contains both sharp and curved surfaces, has a width that changes with height and does not have a solid interior supporting it. The structure was anchored to the cover-slip and fabricated from the base up at a scanning speed of 20μm/s in 70 min. The maximum diameter was 90 μm with its total height 45 μm. Cross sections were fabricated using 5 outline scans separated by 1.2 μm, providing a total shell width of 6 μm. Each cross section was repeated twice with a z-stage increment of 1.5 μm, and the radius of each successive cross section was reduced by three microns.

4. Conclusion

Two-photon photopolymerization enables comparatively cheap fabrication of complex-shaped three-dimensional microstructures with one micron resolution. Using improved photoinitiators and efficient scan algorithms fabrication times on the order of ten minutes can be achieved, as demonstrated by the examples of a 3-D pacman-like cone structure and a kangaroo. This technology promises to open up many fields of applications, for instance in micromechanics, microoptics, or medicine.

References

[1] E.W. Becker, W. Ehrfeld, P. Hagmann, A. Maner, D. Muenchmeyer, *Micro Electronic Engineering* **4**, 35 (1986).

[2] Shoji Maruo, Osamu Nakamura, and Satoshi Kawata, *Opt. Lett.* **22**, 132 (1997).

[3] Mukesh P. Joshi, Haridas E. Pudavar, J. Swiatkiewicz, and P. N. Prasad, *Appl. Phys. Lett.* **74**, 170 (1999).

[4] Brian H. Cumpston et al., *Nature* **398**, 51 (1999).

[5] Hong-Bo Sun et al., *Opt. Lett.* **25**, 1110 (2000).

[6] Peter Galajda and Pal Ormos, *Appl. Phys. Lett.* **78**, 249 (2001).

[7] Min Gu, *Principles of three-dimensional imaging in confocal microscopes*, World Scientific Publishing, Singapore, 1996, p. 155.

[8] Nina Rimac and Min Gu, *Australian Optical Society News* **15** (1), 24 (2001).

AUSTRALIAN OPTICAL SOCIETY

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 2002, the award will be valued at up to $1500. The Society now invites applications from suitably qualified people for this prize for 2002.

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 2001, 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 2001. 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 Peter Farrell
Altamar Networks
PO Box 644
Doncaster VIC 3108
Fax. (03) 9848 0650

and **must be received by 31 October 2001**
The winner will be announced early in 2002.

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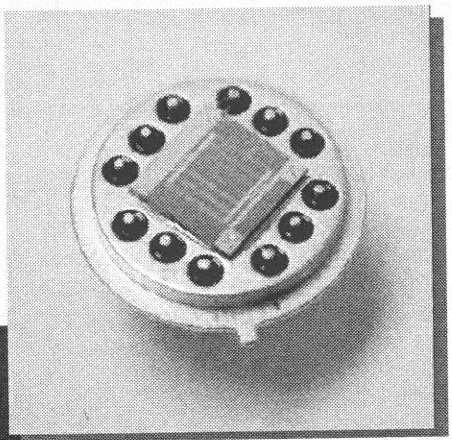

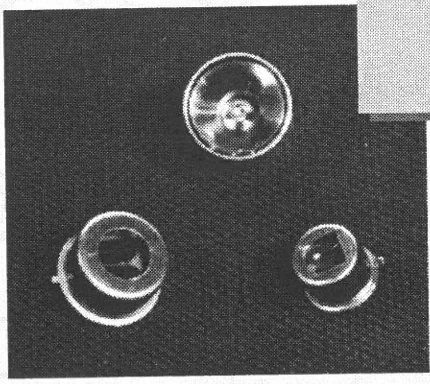

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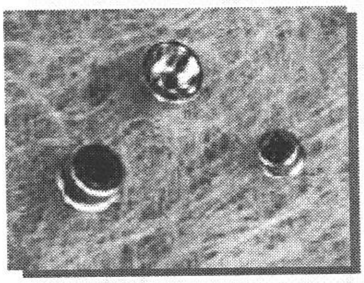

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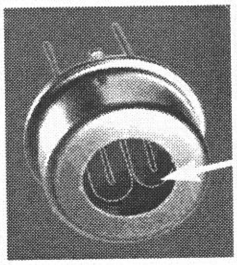

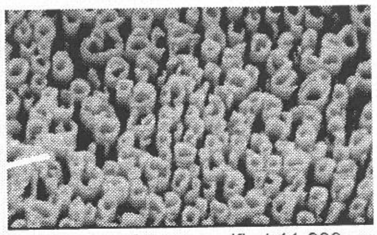

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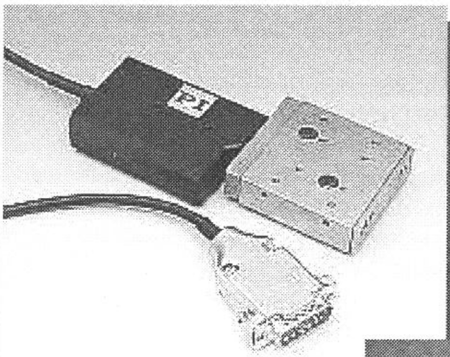

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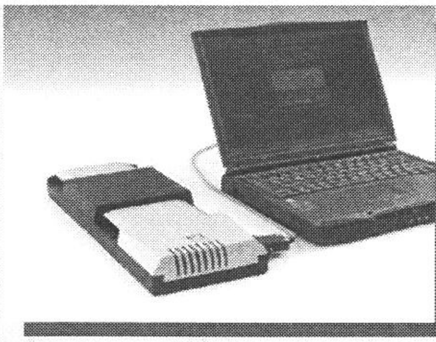

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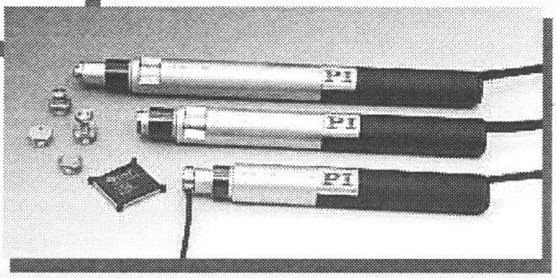

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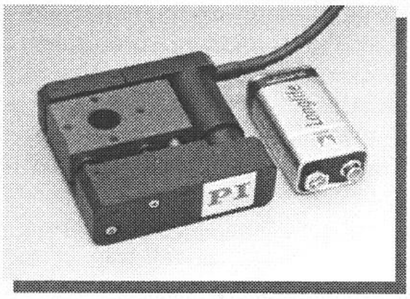

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Recent Conference Reports

Quantum Electronics and Laser Science Conference (CLEO/QUELS 2001)
Baltimore, USA (May 6-11, 2001)

Report from W. Hensinger (Winner of the 2001 AOS Postgraduate Student Prize)

The Quantum Electronics and Laser Science Conference (QELS) is the largest North American conference concerning research in lasers, nonlinear optics, and the fundamental laser spectroscopy of atoms and condensed matter. I am very thankful to the Australian Optical Society to award me the Postgraduate Student prize, which enabled me to attend this conference. It was an excellent conference as a lot of new very exciting results were presented in my field.

I gave two contributions at this conference. I presented one talk about the observation of dynamical tunnelling and a second one about the occurrence of multiple bifurcations in the dynamics of cold atoms in an amplitude modulated standing wave. The first talk was entitled "Bifurcations in the non-dissipative dynamics of cold atoms" where I reported the experimental observation of several bifurcations in a non-linear Hamiltonian system. The dynamics of ultra-cold atoms in modulated potential exhibit multiple bifurcations, which can be identified when measuring atomic momentum distributions. These results provided an introduction into the dynamics of cold atoms in a far detuned optical lattice. The second talk reported the observation of dynamical tunneling. Quantum mechanics allows the existence of rather strange effects, one of them being quantum tunneling. So far quantum tunneling was known to result in the rather surprising observation that an object, which has not enough energy to surmount a potential barrier, is able to tunnel through that barrier. This process is forbidden by classical physics. We have now observed a new kind of quantum tunneling, namely coherent dynamical tunneling. Dynamical tunneling does not involve a potential energy barrier, however a constant of motion (other than energy) forbids this motion classically. In fact atoms coherently tunnel back and forth between their initial state of oscillatory motion and the state oscillating 180° out of phase with the initial state. The experiments were undertaken as part of a collaboration of Nobel Laureate William Phillips at the National Institute of Standards and Technology in Gaithersburg, USA and Halina Rubinsztein-Dunlop / Gerard Milburn at the University of Queensland.

There was a wide range of interesting contributions at this conference and it was difficult to attend all the interesting ones as there were a lot of parallel sessions. I can only describe a few which stuck most in my memory of the conference. It is surely impossible to give a representative overview due to the multiplicity of great talks and posters. Although not exactly in my field I attended a short course on biomedical optical diagnostics. It described how the physics of light propagation in tissue can be used to design new tumor diagnosis methods. It was quite impressive to see, that the work that physicists do today is already at the stage of applications where it can save lives. Joseph Izatt the presenter of this course gave an overview of optical coherence tomography and showed its advantage relative to conventional diagnostic methods. There was a large variety of atom optics talks at the conference. New results from Mara Prentiss's group and Juergen Mlynek's group about atomic wave guides were shown. This area seems to advance very quickly as only a few weeks after this conference, two groups (Haensch and Zimmermann) announced simultaneously the achievement of a Micro-BEC on these kind of wave guides. Talks on quantum chaos were presented by Nir Fridman and Mark Raizen. Nir Fridman discussed atom optics billiards. Two acousto-optic modulators are used to scan a laser beam in x and y direction, producing a dark optical trap. The dynamics of the atoms, enclosed in that trap, depend on the shape of the billiard (trap) and the wall softness (meaning the intensity profile of the laser). A very interesting variety of dynamics arises. Mark Raizen also discussed optical billiards, and also gave his latest results in which he claimed to observe chaos assisted tunneling. His results are related to the experiments I presented at this conference, but he reported tunneling of a different motional state. A quite interesting concept was explored in experiments by Gerd Raithel's group where he used feedback control of atomic motion to achieve stochastic cooling. The scheme measures the coherent redistribution of photons in the optical lattice, which gives some information about the position of the atoms relative to their ideal well position. This reading is then used to feedback to the lattice position to minimize the atomic energy. Ted Haensch gave a talk on the history and physics of frequency combs. Using a single femtosecond laser one can produce a grid of reference frequencies spanning over the visible and infrared spectrum. He gave a history of this method starting from the earlier days where complicated experiments occupying many labs were needed to produce frequency chains. Jordan Gerton from Randy Hulet's group reported on their experiments of growth and collapses in a Bose-Einstein condensate with attractive interactions. The experiments start initially with around 100 atoms. The number of atoms increases until it reaches a critical number at which the condensate collapses (remember that a BEC, confined in a trap and consisting of atoms with attractive interaction, is only stable if the number of atoms does not exceed a limiting value). This process occurs periodically allowing a good measurement of the critical number of atoms. Eric Cornell gave a talk about the occurrence of vortices when the condensate is rotated sufficiently fast. Finally quite impressive was the direct observation of Fermi pressure presented by Andrew Truscott, who did his PhD at the University of Queensland and is now at Rice University, which he illustrated by comparing the width of the atomic distribution of Li fermions and bosons, which were in thermal equilibrium. He achieved these results using sympathetic cooling. In fact there was a whole lot more of interesting talks and posters. However due to the large number of parallel sessions it was impossible to go to all the ones which sounded interesting. The conference was huge, the number of participants amazing. There were accompanying events like an Institute of Physics party where I met an editor of a journal, which had published one of my papers. The trade exhibition was huge and apart of providing me with some new contacts to some product suppliers I also got a lot of little (more or less) useful freebies. Baltimore is quite an interesting city, however quite different to a typical Australian city. The murder rate is quite high with an incident every morning on the news. In fact on my last day in Baltimore I had a quite interesting experience. When I was returning to my hotel I saw a bus with a bus sign, which rather than stating its destination, said "Emergency, please call the police". Nobody seemed to be bothered by this. I decided to call the police from the reception desk from my hotel, which was close by. The receptionist dialed the emergency number. Nobody actually picked up the phone on the emergency line for quite some time and when somebody picked it up finally, the person on the other line took another 5 minutes asking for directions for the hotel from which I called, although it was located right in the center of the city. This incident really made me hope that I would never be in need of any emergency assistance during my stay in Baltimore.

In summary the conference was very useful for me and gave me a lot of new ideas and insights for my own research, and also provided me with more contacts to other researchers in my field. All of this was made possible by the Australian Optical Society Postgraduate Student prize for which I am very thankful.

Winfried Hensinger
University of Queensland

ICOLS-XV

Fifteenth International Conference on Laser Spectroscopy
Snowbird, Utah, USA (11-15 July 2001)

Report from P. Hannaford

The International Conferences on Laser Spectroscopy (ICOLS) began unofficially in 1971 when Ali Javan (MIT), co-inventor of the helium-neon laser, organised a small meeting in a luxurious hotel in Esfahan in Iran, about 400 km south of Teheran, as part of the Shah's celebrations of the 2000th anniversary of the Persian Empire. The theme of the meeting was to discuss the enormous potentialities of lasers, and especially the newly developed tunable dye lasers, in the field of spectroscopy. The meeting included an excursion by chartered flight to Persepolis, an ancient ruin of the Persian empire destroyed by Alexander the Great. The series of ICOLS conferences that subsequently evolved have become the main forum for the announcement and presentation of the most exciting new developments in laser spectroscopy, such as high-resolution Doppler-free laser spectroscopy; coherent transient spectroscopy; nonlinear spectroscopy; quantum optics; spectroscopy of ions stored in traps; laser cooling and trapping of atoms; atomic fountain clocks; atom interferometry; Bose-Einstein condensation; atom lasers; and precision spectroscopic measurements of fundamental constants and optical frequencies.

The ICOLS conferences have a tradition of being held in a scenic and remote (usually mountainous) location in order to provide an informal atmosphere for the presentation and exchange of ideas on latest developments and applications in the field. The venues to date have been Vail (Colorado Rockies); Megève (French Alps); Jackson Lake (Wyoming Rockies); Rottach-Egern (Bavarian Alps); Jasper Park (Alberta Rockies); Interlaken (Swiss Alps); Maui (near Haleakala Crater); Åre (Åreskutan mountain, Sweden); Bretton Woods (Mount Washington); Font Romeu (French Pyrenees); Hot Springs (Appalachian Mountains); Capri (near Mount Vesuvius); Hangzhou (Zhejiang Province); and Innsbruck (Austrian Alps).

The latest conference in this series, organised by Nobel Laureate Steve Chu and colleagues from Stanford University, was held in Snowbird, Utah, a beautiful alpine resort in the majestic Wasatch Mountain Range, about 25 miles south of Salt Lake City, Utah. The conference was attended by 136 participants from

around the world, including three from Australia (about par for our R&D effort!). Participants were reminded that much of quantum mechanics was developed and discussed in mountain settings and that the thin mountain air at the Snowbird altitude of 8,200 ft may provide us with comparable inspiration. The atmosphere was further enhanced by a Melbournesque temperature swing, from near-century heat to subzero with the arrival of a foot of snow during one of the talks. The conference schedule included an afternoon excursion to Temple Square in Salt Lake City, home of the Tabernacle Choir, where we were introduced to some Mormon culture.

After nearly 30 years of ICOLS conferences one might naturally expect the field to have matured or even stagnated. However, major new developments keep bobbing up, and indeed Snowbird was no exception. In the following report I attempt to capture some of the many highlights of Snowbird.

The most recent major development was reported in two postdeadline poster presentations, by Claus Zimmermann (Tübingen) and by Jakob Reichel (Munich), who independently succeeded on the eve of the conference in realising a Bose Einstein condensate (BEC) in magnetic surface microtraps fabricated lithographically on a substrate ('atom chip'). In Zimmermann's experiment, ^{87}Rb atoms were transferred from a single-MOT set-up to the surface microtrap by adiabatic transport of the trapping potential and after only 7 s of evaporative cooling a Bose condensate of about 4×10^5 atoms was achieved in the microtrap and then outcoupled into a magnetic waveguide. In Reichel's experiment a condensate was achieved with just 2.5 s of evaporative cooling. These experiments open the way for greatly simplifying the production of BECs, as well as for producing 'fast' BECs and for investigating coherence phenomena in surface-based waveguides and atom optical devices. In another poster, Wolfgang Ketterle's group (MIT) reported the construction of a BEC chamber in which a ^{23}Na Bose condensate is transported downstream by optical tweezers to a 'science chamber', where the vacuum can be readily broken and experiments performed on the condensate. Preliminary experiments have so far succeeded in transporting a condensate about 12 cm downstream.

In a session on quantum degeneracy in lithium, Christophe Salomon (Paris) and Randy Hulet (Rice) reported using sympathetic cooling in an isotopically mixed lithium gas to reach quantum degeneracy in samples of both bosonic ^{7}Li and fermionic ^{6}Li atoms in a single magnetic trap. The Rice group achieved a ^{7}Li temperature of about 240 nK, or about 0.25 times the Fermi temperature. The experiments were used to illustrate dramatically the effects of Fermi statistics in a degenerate ^{6}Li Fermi gas. Prospects for observing a BCS-type phase transition with ultracold fermionic ^{6}Li atoms in an optical trap were discussed. The Rice team includes Andrew Truscott, formerly of the University of Queensland. In a related paper, John Thomas (Duke) reported progress towards achieving quantum degeneracy in a two-component (2 spin-state) Fermi gas of ^{6}Li atoms confined and evaporatively cooled in an all-optical trap based on an ultrastable CO_2 laser.

Dan Heinzen (Texas) described the production of translationally-ultracold Rb_2 molecules by stimulated Raman photoassociation of ^{87}Rb atoms in a Bose condensate at temperatures of around 300 nK. Due to the extremely small spread of kinetic energies of the atoms, the Raman transition linewidth was only about 1 kHz and was determined by interactions between the molecules and the atomic BEC. As a result the group was able to measure the molecule-BEC interaction for the first time. The theory was performed in collaboration with Peter Drummond of the University of Queensland.

Mark Kasevich (Yale) described how, by analogy with quantum optics, it is possible to generate squeezed states of the many-body field of a BEC. He reported the first results of some recent experiments in which a chain of optical traps was created in a harmonic lattice potential, allowing atoms to resonantly tunnel between adjacent wells. An array of squeezed states was then prepared by adiabatically raising the strength of the tunnel barrier and monitored through interferometric readout of the relative phases of adjacent potential wells. This work could have important technological applications in atom interferometers operating below the shot-noise limit to dramatically improve the sensitivity of the measurements.

Winnie Helsinger (Brisbane) reported some recent work, carried out in collaboration with Bill Phillips' group at NIST, on the observation of dynamical tunnelling of ultracold ^{23}Na atoms from a BEC in a periodically-driven, amplitude-modulated optical standing wave. In this 'quantum driven pendulum' atoms coherently tunnel back and forth between their initial state of oscillatory motion and the state oscillating out of phase with the initial state. The quantum-driven pendulum may have application as an efficient coherent beam splitter.

Chris Westbrook (Orsay) described a recent experiment in which Bose Einstein condensation was realised for the first time in metastable ^{4}He* atoms. Penning ionisation due to collisions between metastable helium atoms was suppressed by utilizing spin-polarised ^{4}He* atoms and the metastable helium atoms were detected by a multi-channel plate placed beneath the magnetic trap. Bose condensation was observed with about 10^5 metastable ^{4}He* atoms at temperatures of about 1 μK. The scattering length (and hence elastic collision rates) for cold ^{4}He* atoms is found to be unexpectedly large ($a\approx+20$ nm). Future experiments will include sympathetic cooling of fermionic ^{3}He atoms.

Dave Weiss (Berkeley) reported a series of experiments on 3D Raman sideband cooling of ^{133}Cs atoms in a far-off resonance optical lattice trap. Atoms isolated on separate lattice sites do not experience collisions and a large fraction can be shelved in dark states or cooled to dark states, so that laser cooling is not limited by spontaneously emitted photons. By combining increased spatial density of the atomic samples with decreased temperature, laser cooling in optical lattices has reached a phase space density as high as 1/30 (with no evaporative cooling), compared with about 10^{-6} in a MOT. These results offer the prospect of a fast approach to BEC (in about 1 s) and of achieving a BEC in ^{133}Cs atoms in a far-off resonance optical lattice trap.

Vladan Vuletic (Stanford) reported a new generic laser cooling method based on coherent scattering of atoms excited by a far-detuned laser beam inside an optical resonator. This technique should allow laser cooling of atoms with arbitrary internal structure, and possibly also molecules and other particles, to the single-photon recoil limit. It is based on the idea that scattering events in which the scattered photon carries away a larger energy than the incident photon energy can be enhanced in an optical resonator that is tuned to resonance with a frequency higher than that of the incident light. An experimental set-up to implement 'cavity Doppler cooling' of ^{133}Cs atoms was described. This new method could open the door for important developments in chemistry and possibly even in biology.

Joel Hensley (Stanford) described a high precision measurement of the fine structure constant α based on measurements of the recoil shift of laser-cooled ^{133}Cs atoms. The measurements were made using a light-pulse atom interferometer based on stimulated two-photon Raman transitions between hyperfine states in ^{133}Cs. A definitive value of α with an uncertainty of 3 parts in 10^9 was reported.

Kurt Gibble (Yale) presented recent results on an atomic clock based on a fountain of laser-cooled ^{87}Rb atoms. The cold-collision frequency shift for Rb is about 30 times smaller than for Cs, allowing the clock to run at higher density and to achieve greater short-term stability and accuracy. The results of a 'juggling fountain' experiment were described in which several atom clouds are sequentially launched and optically 'depumped' so that the clouds of atoms can pass through each other without experiencing cold collisions. In this way it should be possible to reduce integration times and achieve a precision of about $4\times10^{-15}\tau^{-1/2}$.

Fujio Shimizu (Tokyo) reported giant quantum reflection (up to about 90% reflectivity) of thermal metastable neon atoms incident on a silicon surface that was etched in the form of a ridged grating structure. The ridged structure reduces the density of the solid near the surface, which in turn increases the strength of the van der Waals interaction and results in up to 100-fold gain in reflectivity. It should be possible to apply the ridge structure to various reflection-type optical elements including coherent mirrors, beamsplitters and gratings.

In a session devoted to absolute optical frequency measurements, Ted Hänsch (Munich) gave an overview on how an optical frequency comb synthesizer, based on a single mode-locked femtosecond laser plus a holey 'rainbow' fibre, is sufficient to synthesize millions of evenly spaced spectral lines spanning much of the visible and infrared region over more than an optical octave. The mode frequencies are known absolutely in terms of the pulse repetition rate and the carrier-envelope phase slippage rate, which are both accessible to simple radiofrequency counters. Such optical frequency synthesizers will provide the clockwork for future atomic clocks based on atoms, ions or molecules oscillating at optical frequencies. In initial experiments, femtosecond laser frequency combs have been applied to the measurement of absolute frequencies of the Cs D_1 line, the narrow hydrogen 1S-2S two-photon resonance (to 1.8 parts in 10^{14}, thus realising the most accurate measurement of an optical frequency to date), as well as narrow transitions in In^+, Hg^+, Yb^+ and CH_4. In the second paper Jun Ye (JILA) described a 'shoe-box' femtosecond laser frequency comb synthesizer which provides phase-coherent references throughout the optical spectrum and down to the microwave/radiofrequency domain, with the stability of the transfer process reaching the 10^{-15} level. The optical frequency comb has allowed measurement of the frequency of an iodine stabilised Nd: YAG laser for over a year, with a recorded frequency measurement uncertainty of below 5×10^{-13} over this period. Using frequency domain control techniques the JILA group has also synchronised the pulse timing between two independent femtosecond lasers, allowing them to phase-lock the carrier frequencies of two femtosecond lasers for the first time. In the third paper Jim Bergquist (NIST, Boulder) reported on progress toward the realization of a highly stable and accurate atomic clock. The clock comprises a femtosecond laser frequency comb to phase-coherently divide down the frequency of a stabilised laser locked to a narrow transition of a single (nearly motionless) laser-cooled $^{199}Hg^+$ ion confined (for up to 3 months) in a cryogenic Paul trap. The fractional frequency instability of the single ion mercury standard is $\leq1\times10^{-15}$ $\tau^{-\ -15}$ with a fractional frequency uncertainty approaching 10^{-18}. A mile-long fibre link has been established between JILA and NIST in Boulder.

Isaac Chuang (MIT) described the recent implementation of a five-qubit NMR quantum computer, based on a molecule involving five ^{19}F spins, capable of executing a quantum algorithm for order-finding. This represents the first demonstration of a Shor-type quantum algorithm for efficient prime factorization and represents a key step in the experimental realization of a quantum computer. The work is currently being extended to a seven-spin system.

Judging by the number of major new developments in the field and the large proportion of young scientists present at this conference, the field of laser spectroscopy is in a very healthy state, and we can look forward to many exciting and stimulating conferences in the years ahead. Chairman Chu and his team are to be congratulated on an excellent conference, in my opinion the most exciting yet in this series.

During the conference, it was announced that the next (Sixteenth) conference in this prestigious series will be held in Australia from 13-16 July 2003. The venue will be Palm Cove (at the foot of the Atherton Tableland and next to the Barrier Reef).

For further details, see the conference website:

http://www.swin.edu.au/lasers/icols03

or e-mail the committee at:

icols03@swin.edu.au.

I thank Fujio Shimizu for the background material on the ICOLS conferences.

Peter Hannaford
Centre for Atom Optics and Ultrafast Spectroscopy
Swinburne University of Technology

CONFERENCE ANNOUNCEMENT

Multi-dimensional Microscopy 2001 – MDM2001

The 3rd Asia-Pacific International Symposium on Confocal Microscopy and Related Technologies

November 25-28, 2001, Melbourne, Australia

Multi-dimensional Microscopy (MDM) is a new international conference series with a focus in the Asia-Pacific region. The aim of the MDM conference series is to provide a principal forum for scientists, engineers and research students to exchange topical research and development information and to stimulate discussion on novel applications and concepts. The first meeting of MDM was held in the National University of Singapore in 1999. After the second successful meeting of MDM in Kaohsiung in 2000, MDM2001 (the 3rd Asia-Pacific Symposium on Confocal Microscopy and Related Technologies) will be organised by Swinburne University of Technology at Melbourne, Australia, from November 25 – 28, 2001.

Location

MDM2001 will be held in Eden on the Park (http://www.edenonthepark.com.au/), Melbourne, Australia. This stylish hotel is located at a picturesque site near Melbourne's Albert Park Lake and is close to the Hawthorn campus of Swinburne University of Technology. The Hawthorn campus is located seven kilometres east of the city of Melbourne.

Deadlines

Submission of abstracts:	August 31, 2001
Registration:	November 2, 2001

Topics

- Confocal microscopy (fluorescence and non-fluorescence)
- Two-photon fluorescence microscopy
- Multi-photon (SHG, THG, CARS) microscopy
- IR and UV microscopy
- Spectroscopy microscopy
- Novel light sources for microscopy
- Instrumentation and theory
- Novel approaches for biological applications (green fluorescent protein)
- Living cell imaging
- Laser tweezers and trapping
- Three-dimensional optical data storage and micro-fabrication
- Optical coherence microscopy
- Laser gene scanners
- Near-field scanning microscopy
- Multiple scattering and imaging through turbid media
- Fluorescence resonance energy transfer microscopy
- Digital signal processing and image reconstruction
- Fluorescence lifetime imaging

Further announcements for MDM2001 (submission, registration, and accommodation) will be available at the following web site:

http//:www.swin.edu.au/optics/cmp/aps2001

Acols 2001

ACOLS 2001: Australasian Conference on Optics and Laser Spectroscopy

ACOLS 2001

ABOUT THE CONFERENCE

ACOLS 2001 is the fifth in the ACOLS series. It incorporates:

- the 14th Australian Optical Society Conference
- the 10th Australian Laser Conference
- the 20th Australian Spectroscopy Conference

ACOLS 2001 is the region's showcase of research and development in all aspects of optics, lasers and spectroscopy, and provides a broad forum for discussion of these important areas at the modern facilities of the University of Queensland.

Each Day will feature general interest plenary talks from speakers of high international standing followed by parallel oral sessions with both invited and contributed papers. Two poster sessions will also be held in the same venue.

TECHNICAL EXHIBITION

A technical exhibition is being planned in conjunction with the conference. Our aim is to feature leading Australasian suppliers of equipment in the field of optics, lasers and spectroscopy. The exhibition will be held in the Heith Room at the University of Queensland, close to the conference lecture theatres.

THE VENUE

ACOLS 2001 will be held on the campus of the University of Queensland (www.uq.edu.au), featuring 20 hectares of parklands and lakes. The University is situated within the city of Brisbane, the capitol of Queensland with convenient access to international and domestic airports, and the beaches and rainforests of the Gold Coast and hinterland. Brisbane also serves as the jumping off point for the Great Barrier Reef.

DEADLINES

Submission of Abstracts: CLOSED

Post-Deadline Papers: see website

Registration: 2 November 2001

Notification to Authors: 15 October 2001

ORGANISING COMMITTEE

Chair: Prof. H. Rubinsztein-Dunlop (Queensland)
Treasurer: Dr. M. Friese (Queensland)
Secretary: Dr. H. Wiseman (Griffith)
Technical Exhibition: Dr. R. Sang (Griffith)
Program Chair: Prof. W. MacGillivray (Griffith)

PROGRAM COMMITTEE

Prof. G. Milburn (Queensland)
Prof. A Knight (Griffith)
Prof. K. Nugent (Melbourne)
Prof. J. Harvey (Auckland)

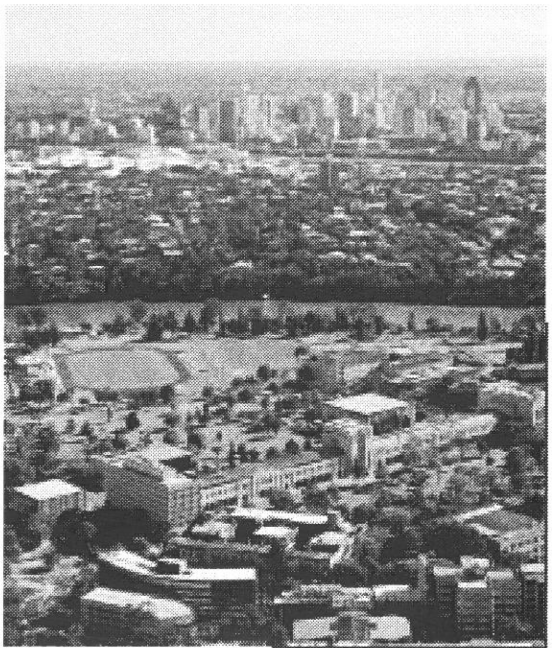
3 – 6 December, 2001

University of Queensland
Brisbane, Queensland, Australia

SPONSORS AND STUDENT PRIZES

The Optical Society of America (OSA) and the International Society for Optical Engineering (SPIE) have provided sponsorship assistance to ACOLS 2001. This is in the form of running short courses at the conference (see following page) and offering a student prize.

The SPIE and the OSA will combine to provide a prize for the best presentation by a student at ACOLS 2001. The prize is US$2500 in travel support to one Societies' managed meeting or conference in 2002. The student prize will be presented at the ACOLS 2001 dinner by the president of the Australian Optical Society.



INVITED PLENARY SPEAKERS

- **Mark Kasevich** *(Frew Lecturer)*
  Yale, USA
  Atom Interferometry
- **Anthony Johnson** *(OSA Lecturer)*
  New Jersey Institute of Technology
  Ultrafast Optical Phenomena
- **Eleanor Campbell**
  University of Göteborg
  Collision of Fullerenes
- **Hideo Mabuchi** *(Coherent Scientific Lecturer)*
  California Institute of Technology
  Ultra-sensitive Real-time Optical Measurement: From Quantum Feedback to Biochemistry
- **James A. Harrington** *(SPIE Lecturer)*
  Rutgers University
  Infrared Optical Fibres
- **Deborah M. Kane**
  Macquarie University
  Integrated Semiconductor Lasers
- **Anthony Legon FRS**
  University of Exeter
  Rotational and Vibrational Spectroscopy
- **Motoichi Ohtsu**
  Tokyo Institute of Technology
  Microscopy

REGISTRATION

Registration Fees (Australian Dollars):

Delegate Early *(before 02 Nov 2001)*	$360
Delegate Late	$450
Student Early *(before 02 Nov 2001)*	$150
Student Late	$200

Registration details available on the web

ACCOMMODATION

Accommodation is available on campus in comfortable budget rate university student colleges, or in nearby hotels.

Grace College	$33 per night *single room*
Cromwell College	$33 per night *single room*

ACOLS2001

For more details and registration

www.physics.uq.edu.au/acols2001/

ACOLS 2001: Australasian Conference on Optics and Laser Spectroscopy

SHORT COURSES

The Optical Society of America (OSA), the International Society for Optical Engineering (SPIE), and the Australian Optical Society (AOS) have combined to sponsor two exciting short courses at ACOLS 2001. Each course is conducted by a leader in the relevant field and provides the opportunity to gain insights only an expert can impart. Numbers are strictly limited, so early registration is advisable. These courses are each anticipated to run for half a day and to be presented consecutively on Friday 7 December 2001.

COURSE 1

The Musical Score, the Fundamental Theorem of Algebra, and the Shortest Events Ever Created.
Rick Trebino, Georgia Inst. of Tech., USA

This course is intended for anyone with an ultrashort laser pulse who would like to measure it. Anyone who would like to perform measurements of solids, liquids, gases, or plasmas would also find these techniques useful. This course is also intended for anyone who would like to see how to measure the shortest events ever created without using a shorter one.

SHORT COURSE FEES

Pre-registration Fees: (Australian Dollars)

Member *(AOS, OSA or SPIE)*	$150
Non-Member	$300
Student Member *(AOS, OSA or SPIE)*	$100
Non-Member Student	$150

A surchage of $50 will be levied for late registration.

COURSE 2

Infrared Fiber Optics.
James A. Harrington; Fiber Optic Materials Research Program, Rutgers University

The intended audience is anyone interested in learning about this emerging specialty fiber field. This includes engineers, scientists, optical designers, and those interested in adapting IR fiber optics in their systems. Learn the differences between these unique fibers and the traditional silica fibers so that you will know what to realistically expect from current IR fiber technology.

ACOLS 2001 CONTACTS

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Brisbane, Queensland, 4072
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WWW: http://www.physics.uq.edu.au/acols2001/

Fax: +61 + 7 + 3365-1242

Report from FASTS

Peter Cullen

President, Federation of Australian Scientific and Technological Societies

1. "SCIENCE MEETS PARLIAMENT" DAY

One hundred Parliamentarians have already responded to our invitation to meet with scientists on Wednesday August 22 in Canberra, and we expect that three quarters of all Federal MPs will put aside 45 minutes or so to discuss Australia's national investment in S&T.

We've asked Parliamentarians to nominate what issues they would like to discuss; and water and salinity come out top with 24 mentions so far, aheadof education and training (14) and climate change and greenhouse (13).

Some discipline areas have been active in nominating scientists and technologists to come to Canberra for the two day event, but others havebeen slow to take advantage of this wonderful opportunity to make the case for science in an election year.

Clearly we cannot take this event for granted. It requires the active support of all Members.

The easiest way to register is on our web site:
www.fasts.org

2. THE ELECTION

We are running into election mode. The Government has introduced its policies in "Backing Australia's Ability", which includes many of the ideas FASTS has been proposing. We must commend Minister Minchin for being able to carry these ideas into cabinet. On the downside, many of these proposals do not kick in as early as we would have liked, and there are
still serious gaps relating to university base funding and to CSIRO.

The ALP has released its Knowledge Nation Report. The report is a smorgasbord of spending opportunities and includes much that has come out of "Backing Australia's Ability", the Chief Scientist's Review and the FASTS' policy document. The challenge for the ALP is to choose a set of policies that they are prepared to back with funding, and the challenge for the science community is to encourage them to choose wisely. It is clear we will not hear these until the election campaign is formally declared.

It is exciting that Science and Technology issues are high in the thinking of both major parties for the first time for some years, and this provides important opportunities.

3. NATIONAL INNOVATION AWARENESS COUNCIL

The Government has established this new Council, to be chaired by David Miles, to advise on raising community awareness of innovation, science and technology, and on the implementation of the $35 million National Innovation Awareness Strategy.

The first $1.2 million funding round has been announced, with grants of up to $100,000 being awarded to projects that promote enhanced awareness of innovation and entrepreneurship in addition to projects in science, engineering and technology awareness.

The closing date for applications is Thursday 30 August. Further information is available from ISR on 02 6213 6455.

4. WORKSHOP FOR MEMBER SOCIETIES

The Board meeting endorsed a proposal that FASTS should investigate the possibility of running workshops for our Members, concentrating on helping them deliver benefits in the most efficient way.

The general squeeze on the science sector has placed some professional and learned societies under pressure, and the Presidents of our Members identified the following five issues as their main concerns:

a) Delivering benefits to members
b) Finding, motivating and coordinating a volunteer workforce
c) Finding and working with professional help - executive and communication officers

d) Communicating with members, including finding what members want
e) Influencing policy and raising the profile (including use of media)

The Executive is presently considering the best way to get these workshops underway.

5. PARLIAMENTARY SCIENTIFIC FELLOWS

The US has a program of placing scientists in Congress to work for individual members of the House or the Senate or on Congressional Committees. The appointments last for a year, and help make science a natural part of the Congressional climate.

The Board invited Dr Lesley Russell to talk about her experiences as the first Australian national to be appointed to one of these positions; and we are now considering how this program might be introduced into Australia.

6. NEXT COUNCIL MEETING

The Annual Council of FASTS enables the Presidents of all Member Societies to meet with the Board and Executive to discuss policy issues, and to put concerted advice to the Board both on its performance and for future actions.

Council this year will be held in Canberra at 9.30 am on Monday November 19. All Members are entitled to send one representative to Council.

A brief AGM will precede Council. There will be at least one vacancy on the Executive, and anyone interested in these positions should contact Toss Gascoigne in the FASTS' office.

Professor Chris Fell will take over as President of FASTS in November. He led an excellent discussion on "FASTS - the next ten years" at the Board meeting, and is gearing himself up for the Presidency.

7. THE PRIME MINISTER'S SCIENCE COUNCIL

As President of FASTS, I am a member of the PM's Science, Innovation and Engineering Council. This is a wonderful opportunity to discuss policy issues with the PM, leading members of his Cabinet, and other heads of national science groups.

Ken Baldwin stood in for me at the last PMSEIC meeting as I was overseas. He reported an intensive day, beginning with a dinner hosted by the PM, followed by a morning meeting with the PM and half his Cabinet; and an afternoon meeting for the scientist and engineer members of the Council.

Details of discussions are confidential. The main items were on commercialisation of public sector research, minerals exploration process, developmental health and wellbeing, and biodiversity.

8. THE FOURTH FASTS' "OCCASIONAL PAPER"

The paper by the Australian Society for Parasitology has been finalised and is ready for publication. This 20 page document outlines the possibilities Australia ignores and the threats we face if we continue to neglect investment in science.

FASTS is assisting with editing, printing and launching this paper. Other Members interested in a paper from their perspective should discuss it with our Executive Director, Toss Gascoigne.

A copy of the paper will be sent to all Member Societies in September.

9. MEMBERSHIP FEES AND FASTS' FINANCES

FASTS' finances have been well managed over the past few years, and I am happy to report that we have now achieved our goal of having a year's operating funds in reserve. Whilst this demonstrates responsible financial management, it also provides FASTS with the opportunity to extend our range of services to our member societies. The above mentioned workshop is one example - several others were discussed at the most recent Board meeting.

I would like to thank all our member societies for your support over the previous year, and we look forward to continuing to raise the profile of science and technology on the political front in the coming year. Invoices for the annual subscriptions to FASTS will shortly be sent to all Members. We will soon be contacting you to find out the number of full members of your society as of 30 June 2001.

10. THE INNOVATION ACCESS PROGRAM

In launching this new program, Minister Nick Minchin said that the new IAP drew on the successful aspects of the Technology Diffusion Program and aimed to increase access to the 97 per cent of scientific papers that Australia did not produce.

IAP offers support for a broad range of activities to build Australia's connectivity with the needs of both the business and research community and innovation in the rest of the world.

This could include funds for visits, conferences, fellowships and targeted missions to key economies. The emphasis is on building linkages and accessing global research and development.

More details on www.innovation.gov.au,

or the AusIndustry Hotline 13 28 46.

Peter Cullen
President of FASTS

"The Storage of Light" and Very Large Variations of the Group Velocity of Light in Coherently Prepared Atomic Media

Alexander Akulshin and Geoffrey Opat

School of Physics, The University of Melbourne
Victoria 3100, Australia

The coherent superposition of atomic states induced by resonant radiation can be responsible for a dramatic modification of the dispersive properties of an atomic medium. In such a modified medium light can propagate with ultra-slow or infinitely large positive or negative group velocity. This subject is currently attracting considerable attention because of its fundamental importance and promising applications, which include quantum information processing. This article will review some recent experiments on light-pulse propagation through coherently prepared media that exhibit an extraordinarily steep normal or anomalous dispersion, and some of the consequences will be discussed.

1. Introduction

As the new century began, the news that *'light had been stopped'* caught the attention of a wide public and surprised and excited more than a few physicists. *The New York Times* [1] reported that two independent teams of researchers had brought light to a complete stop, held it still for a while, and then released it. They had been able to manipulate light as if it were an ordinary material particle; strange indeed. This newspaper report was based on the findings of two original experiments published in the well-respected journals: *Nature* [2] and *Physical Review Letters* [3].

The constancy of the speed of light in vacuum is one of the best-known fundamental facts of Nature. (Of course we exclude from our discussion the modification of the velocity of light in non-inertial frames [3].) In fact, in recent years a wide variety of speeds of light in matter have reported [4-6]. If a person were only to read magazine headlines, some of them really exciting: *Laser smashes light-speed record; Ultraslow light pulse propagation; Storage of light makes possible time stopping*, they might believe that the construction of a time machine was only a few years away, or at least that scientists might now have some idea how to stop time.

Let us consider what actually happened. Firstly we address the question: *How do we get 'slow light'?*, because it is so-called slow light that is involved in 'light storage'.

2. Slow Light

2.1 Phase, group velocities and dispersion

In recent years the process of light propagation through a highly dispersive medium has received much attention because of its fundamental interest as well as its promising applications.

How can we characterise the propagation of light in a dispersive medium? nodes of an electromagnetic wave move with *phase velocity*: $\boldsymbol{V_P=c/n}$, where $\boldsymbol{c}$ is the speed of light in vacuum and $\boldsymbol{n}$ is the refractive index. If the index of refraction depends on the optical frequency, the various frequency components of multi-chromatic light will travel through the medium with different phase velocities. On the other hand, a light pulse or a wave packet will travel through a medium with the *group velocity*. By definition, the group velocity of light, $\boldsymbol{V_g= d\omega/dk = c/(n+\nu \times dn/d\nu)}$ also depends on the frequency dependence of the refractive index through the dispersion, $D \equiv dn/d\nu$. Thus the pulse envelope moves at the group velocity, while the individual cycles move at the phase velocity. The group velocity is a more informative characteristic of the medium than the dispersion D, because in the former case we have a very good reference speed $\boldsymbol{c}$, the speed of light in vacuum.

It is well known that the refractive index changes rapidly when the optical frequency is tuned close to an absorption line of the medium. According to the classical theory of dispersion, which works reasonably well in the case of a low-pressure gas, the real and imaginary parts of the complex refractive index may be written in the form:

$$\boldsymbol{n}^2= (n - i\kappa)^2 = 1+ 2Ne^2/m(\nu_0^2-\nu^2 + i\gamma\nu)^{-1}, \qquad (1)$$

where N is the atomic density, and e is the charge and m the mass of an electron. ν, ν_0 and γ are the frequencies of the optical field, the resonant frequency of an optical transition and the width of the line, respectively. At resonance ($\nu = \nu_0$), the dispersion $dn/d\nu$ and the linear absorption coefficient $\alpha = 2\kappa k_0$ (where k_0 is the vacuum wave number and $I(z)=I_0 \exp(-\alpha z)$) depend on the linewidth γ and the atomic density N, specifically: $dn/d\nu = 2Ne^2/m\nu_0\gamma^2$ and $\alpha(\nu_0) = 2k_0Ne^2/m\nu_0\gamma$. So, the dispersion may be expressed as a function of the linear absorption:

$$dn/d\nu = \alpha(\nu_0)/k_0\gamma. \qquad (2)$$

On the slope of an absorption line, the dispersion is positive or *normal* $D>0$. Thus, if the dispersion is high and positive in some spectral region, the absolute value of the group velocity will be essentially smaller than ***c***. At resonance the dispersion is negative or *anomalous* $D<0$. Note that in the case of negative dispersion, $D<0$, the group velocity can exceed ***c***. This interesting case will be considered later.

Let us estimate, for example, the value of the group velocity of light in a cloud of motionless (eg. laser-cooled) rubidium (Rb) atoms, for the strong D_2 line. In this case the width of the absorption line is close to the natural width ($\gamma \approx 10$ MHz). If $\alpha = 5$ cm^{-1} (a reasonable value for laser trapped and cooled Rb), $D \approx -1 \cdot 10^{-12}$ Hz^{-1} or $V_g \approx -c/400$. Thus, the reduction of the group velocity of light is high, but not as large as reductions observed in the experiments mentioned above. (Note that the dispersion in optical glass is much less, being about $5 \cdot 10^{-17}$ Hz^{-1}). On the slope of the resonance the dispersion is normal, but the absolute value is even less. In an atomic vapor cell the dispersion (for a similar absorption level) is about 50 times smaller, because of Doppler broadening. (At room temperature for Rb, $\Delta_D/\gamma \approx 50$).

2.2 Coherent Population Trapping & Electromagnetically Induced Transparency.

The effect called *coherent population trapping* is responsible for so-called *"slow light"* as well as for *"light storage"*. The coherent superposition of atomic states induced by resonant radiation is associated with a number of interesting phenomena, such as coherent population trapping (CPT) [8], amplification and lasing without population inversion [9], the nonlinear resonant Faraday effect [10] and so on.

We now briefly consider the most striking manifestation of quantum interference in an atomic gas. In a suitable three-level energy configuration, the absorption of a weak resonant light probe may be eliminated if a strong drive field is applied to the linked transition. This level configuration, similar to the Greek letter ***Λ***, may be realized for example in the alkali atoms, where states |1> and |2> are the hyperfine sublevels of the ground state and |3> is an excited state, (See fig.1). Using a two-photon Raman transition $\nu_P - \nu_D = \Delta$, where Δ is the splitting of the ground states, the atomic population is trapped in a coherent superposition of the ground states. In this superposition the atoms can no longer absorb resonant light as a consequence of destructive interferences in the excitation channels. Media with optical depths exceeding 100 can be made transparent because of CPT. The phenomenon of absorption cancellation due to CPT is called *Electromagnetically Induced Transparency* (EIT).

This effect is very sensitive to frequency detuning. The ultimate width of the absorption dip is determined by the relaxation rate of the ground states, which can be very long, up to 1 second. Thus, the typical width of the EIT window is much less than the natural width of an optical transition, *Γ*.

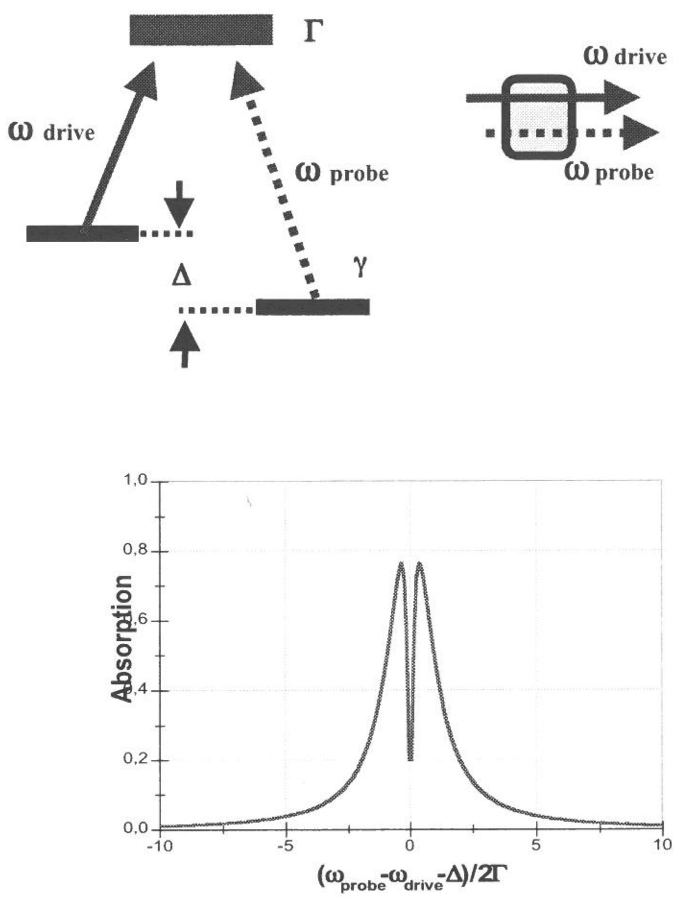


Fig.1. Coherent population trapping in the three-level Λ system. Γ is the natural width of the optical transition, while γ is the ground state width (Γ>>γ).

2.3 "Slow" light

According to the Kramers-Kronig relation, extremely strong dispersion occurs under the condition of almost 100% absorption variation within a sub-MHz spectral range, fig.2. This dispersion curve is steep and normal, and results in a very slow group velocity for the resonant probe light. In the last two years several papers related to so-called "slow" light have been published [5,6].

The first direct measurement of the extremely low group velocity of light in a coherently prepared atomic medium was demonstrated by Lene Hau's team at Harvard University [5]. In this work, the dispersive properties of Na atoms were investigated in a laser trap over a large range of atom cloud temperatures, from 2.2 μK to 50 nK, significantly below the critical temperature (435 nK) for Bose-Einstein condensation (BEC). First, sodium atoms were cooled and pumped to the lower ground state sublevel. The almost pure BEC Na cloud, with correspondingly high atomic densities, completely absorbed a weak resonant probe. To observe EIT in the atomic medium, a drive field tuned to the other ground state sublevel was applied. A probe pulse was then applied to the 230-μm-long cloud orthogonally to the drive beam. In the vapour cell experiment (i.e. using room-temperature atoms) the co-propagating probe-drive geometry is required to prepare EIT, but for the motionless atoms in a laser trap it is not important. Absorption was strongly suppressed and dispersion was very steep but normal. A coherent atomic sample in a non-absorbing state acts as a time-delay line for the probe light. The pulse delay

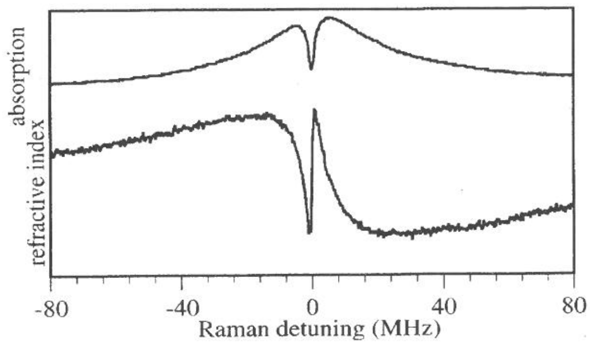


Fig.2. Absorption and dispersion spectra in the vicinity of the two-photon resonance as a function of Raman detuning [11].

measurement is shown in fig.3. The probe pulse is delayed by 7 μs in a 230 μm-long atomic cloud and the corresponding group velocity of light is only 32 m/s.

It is important to note that the probe pulse was long enough (about 2.5 μs) to be within the EIT window. In addition to that, the dispersion of the group velocity on resonance was almost zero. This allowed pulse propagation without strong

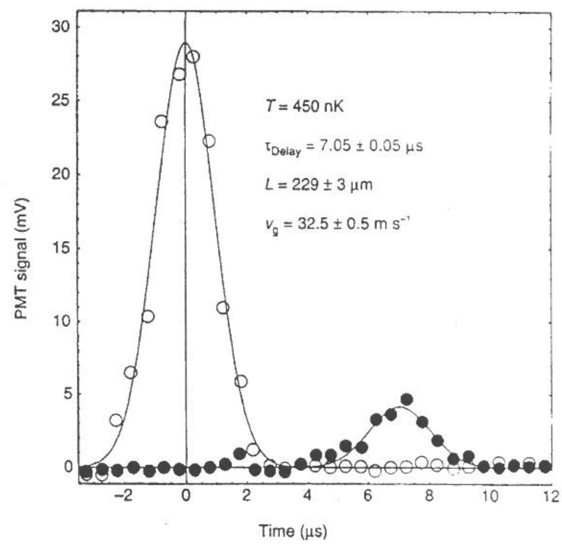


Fig.3. Pulse delay measurement. Open circles fitted with Gaussian line represent the probe intensity with no atoms in the trap (reference pulse). Filled circles indicate probe intensity transmitted through a 230 μm-long atomic cloud. The pulse is delayed by 7μs. It corresponds to the group velocity of light about 32 m/s [5].

distortion. It is interesting to note that the 0.7-km-long probe pulse was spatially compressed in the Na cloud to 70 μm!

A few months after the BEC experiments, researchers in Texas showed that using hot Rb vapour it is also possible to get almost the same low values of light group velocity (about 90 m/s) [6]. In a vapour cell it is impossible to get EIT with very high atomic density as with BEC (8×10^{13} cm^{-3}), so they managed to reduce the width of the Raman resonance for matching the results obtained in the trap. This experiment was also performed when both ground state hyperfine levels were coupled to a common excited state to prepare a coherent "dark" state. This showed that BEC and very deep laser cooling are not necessarily required for such a dramatic reduction in group velocity.

3. Stopping light

3.1 Theory

In May 2000, M.Fleischhauer and M.D.Lukin, published a theoretical paper about a "dark-state polariton" [12]. This was the beginning of the story about *"light storage"*. By studying the quantum physics of light propagation through a dissipation-free coherently prepared medium, they found that the equation has a simple solution if a new quantum field was introduced. This field is a coupled mixture of a light field and an atomic coherence. It was shown that if the number of photons is much less than number of atoms, the new field could be considered as a bosonic quasi-particle or polariton. The group velocity V_g of the polariton depends on the ratio between the light and matter components of the new quantum field, and may be manipulated by varying the coupling field intensity.

An exchange between the light and matter components of the field when the intensity of the drive field was changed was demonstrated. When the coupling field is off, the polariton is stopped and the light component of the probe pulse disappears. However, the matter component is a maximum under these conditions. This is more or less the expected behaviour, because without the coupling field EIT does not exist. After turning the coupling beam on, the light component is revived. Thus, the signal pulse *disappears* in the EIT medium when the coupling field is off. The matter-like polariton can then be *converted back* into a photon pulse. This is the main result of the theoretical paper.

3.2 Experimental realisation

A short time later two very similar experiments were performed by another two independent teams. One of them was done with hot Rb gas using the D_1 absorption line [3]. At 80° C a 4 cm long cell containing Rb vapour was totally opaque for a weak circularly polarized resonant probe. A more intense component with an opposite circular polarization was used as a coupling field. The two components were separated after interaction with the atoms. The circularly polarized coupling as well as the

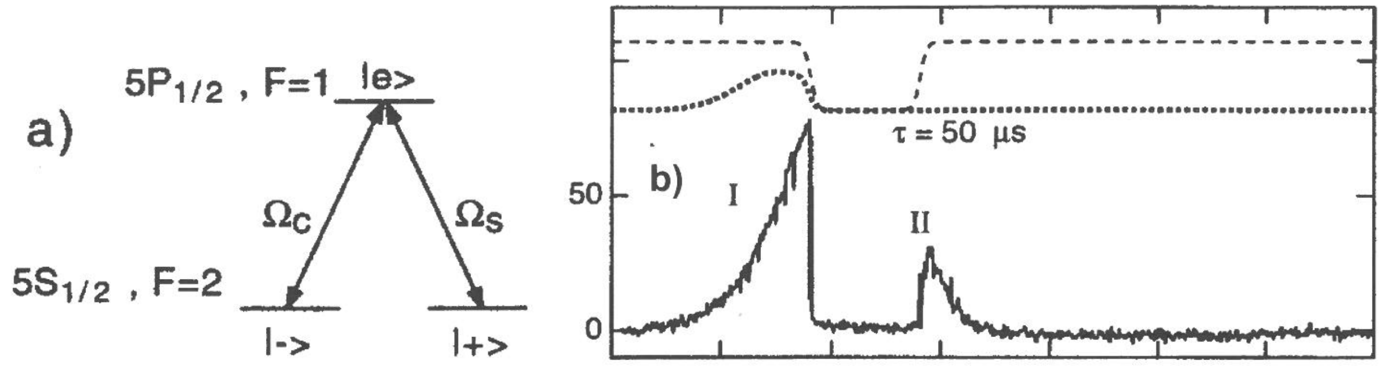


Fig.4. (a) Schematic diagram of the two-photon transition between ground state Zeeman sublevels on the ^{87}Rb D_1 line. (b) Probe pulse regeneration (pulse II) after turning the drive field (dashed line) on. (Adopted from [3])

probe light alone is unable to create Zeeman coherence in the ground state. EIT was realized at zero magnetic fields when magnetic sublevels in the ground state were coupled by the two-photon Raman transition using two components with same optical frequency, fig. 4. It resulted in a large enhancement of the probe transmission.

To demonstrate the *"storage"* of light, the magnetic field was fixed near zero and a pulse of the probe component was applied instead of the CW probe. A typical pulse duration was 10-30 ms. It should be emphasised that the probe pulse was able to propagate through the Rb vapour because of the dissipation-free coherent state. As was shown, the light group velocity for the probe in this case is very low, $V_g << c$. A fraction of the signal pulse left the cell with 30 μs delay with respect to input pulse. This delay corresponds to a group velocity of light of about 900 m/s. The front edge is slowed first, so the spatial length of the probe pulse was compressed from several kilometres outside the Rb cell to a few centimetres inside the coherently prepared medium. The compressed probe light and the Rb atoms in coherent state form the so-called dark state polariton. While the main part of the probe pulse was in the cell, the coupling field was shut down. The transmission of the probe drops sharply to zero without the coupling field. The probe pulse came into but did not leave the cell. It looks as if it was stored inside the Rb vapour. Revival of the probe pulse occurred, just after turning on the coupling field. The regenerated pulse leaves the cell at the normal speed of light.

A more detailed experiment was performed by Lene Hau and co-workers [2] employing the apparatus that had been previously been used for slowing the light group velocity. Na atoms were initially laser cooled and magnetically trapped. In this case, both ground state hyperfine levels were coupled to a common excited state to prepare a coherent "dark" state.

The probe pulse was sent through the sodium cloud. The presence of the co-propagating coupling field, tuned to the linked transition, ensured the high transparency of the very dense Na cloud as well as the steep dispersion for the probe light. As a result, the probe pulse was delayed by 12 μs due to the interaction with Na atoms, fig.5a. Taking into account the dimension of the Na cloud (340μm) the delay corresponds to light group velocity about 30 m/s. When the probe pulse was compressed to the cloud size, the coupling field was shut down. There was no transmitted probe pulse if the coupling field was turned off. All the probe energy had been transformed through stimulated scattering into the coupling field and the matter coherence. During the "dark" interval, information about both fields is contained in the population amplitudes and in the relative phases between the different atoms.

The probe pulse was regenerated through stimulated process. Thus, the information was read out and transferred back into a light form by turning on coupling field back. Revival of a probe pulse after the coupling beam was turned off and turned back on is shown on the fig.5b,c. Of course, the storage and regeneration of light are not perfect. The amplitude of regenerated pulse is smaller for a longer storage time.

Multiple read-out of stored coherent information using a series of short coupling laser pulses was also demonstrated. Each of the regenerated probe pulses contains a part of total energy. It was found that total the energy of 2 or 3 pulses is the same as the energy of a single revived probe pulse.

3.2 Discussion

It is clear that it does not make sense to talk about photons at rest, as is implied by the phrases "stopped light" or "stored light". The regenerated probe pulse contains absolutely fresh photons produced by stimulated scattering.

In some sense, the storage of light is similar to atomic teleportation as mentioned by M. Scully [14]. In teleportation, all of the quantum information needed to reproduce the original atomic state is imprinted on the light field, and then this field is transmitted in space. Afterwards, this information can be used to prepare an atom in the original state. In the case of atomic tele-

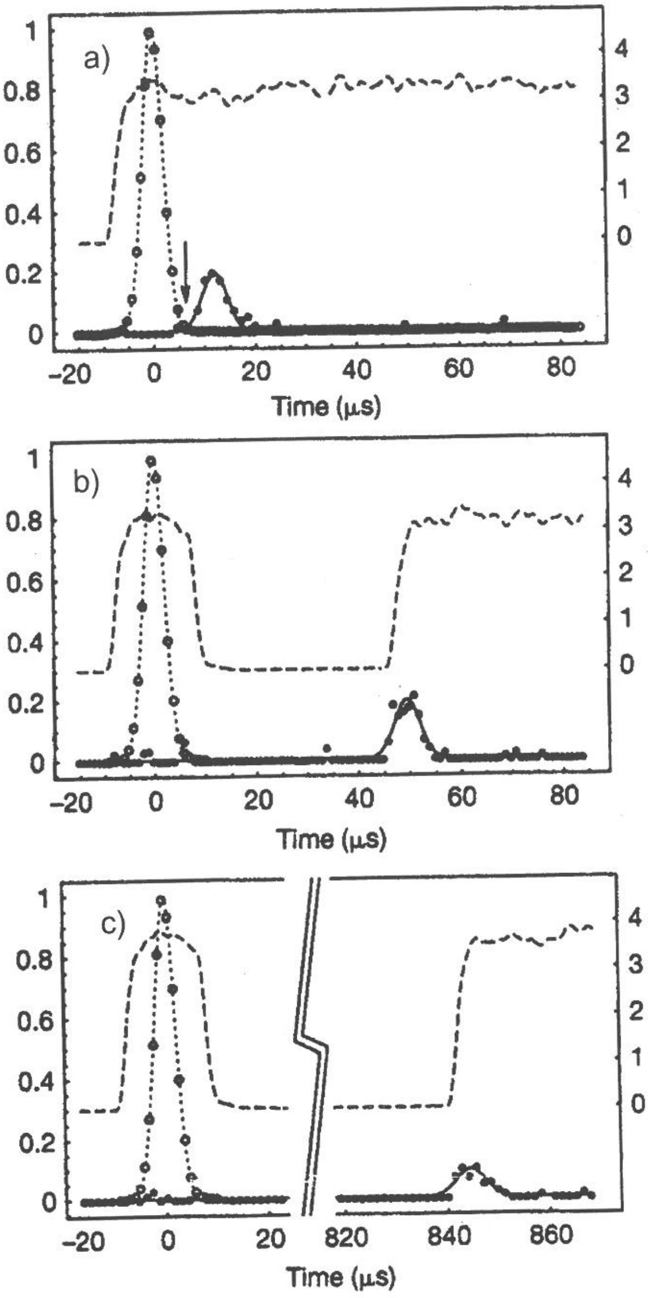


Fig.5. Observation of delayed and revived probe pulses [2]. Open circles fitted to the dotted Gaussian curves show reference pulse in the absence of atoms. Dashed curve and solid circles show intensities of coupling and probe pulses transmitted through the sodium cloud respectively **(a)** Delayed probe pulse. **(b,c)** Revival of a probe pulse after coupling field is turned back on at 44 μs and 840 μs, respectively.

portation, light is the carrier of the information. In the case of "stopped light", the situation is reversed. The information about the light may be saved in the form of collective atomic excitations and transported in space and time.

'The storage of light in an atomic vapour' is an attractive but physically incorrect title. The resonant medium does not contain photons during the dark interval (i.e. when the coupling laser is switched off). It may be considered as if an image or "photo" of the pulse (but not the probe pulse itself) was stored in a coherent atomic ensemble. For example compare this to how real light may be stored in a high finesse optical cavity. So, in addition to some very interesting and elegant experiments, we have a smart example of very efficient publicity and promotion.

It is of considerable interest, however that this reversible process is, in principle, non-destructive. This is because the information is contained in the atomic ground state only. This unique property makes it an attractive candidate for potential applications involving coherent communication between distant quantum-mechanical systems. It could also be used to help increase the security of communications.

4. Anomalous dispersion

Let us now consider a light-pulse propagating through media with anomalous dispersion ***(dn/dν)<0***. The group velocity of the light is now greater then ***c*** (see section 2 above), and there appears to be a serious conflict with a fundamental axiom of relativity that no signal can ever be transmitted faster than light in vacuum. Such contradictions were extensively discussed at the beginning of the last century. Brillouin pointed out that the principle of causality requires the speed of a light signal to be limited by ***c***, rather than light pulse itself, which travels at the group velocity [15].

In the pre-laser era it was widely believed that the concept of the group velocity was meaningless in the case of steep anomalous dispersion because of the very strong absorption. However, it was later shown that a smooth light pulse sent into such a medium will travel with some distortion of its shape, or envelope. Different spectral components of the pulse are attenuated and phase-shifted by different amounts, in such a way that the peak of the wave envelope moves faster than **c**. This redistribution gives a group velocity that is greater than **c**, while the rate of energy transmission and the signal speed remain less than **c**, the universal speed limit.

Thus, a pulse of resonant radiation can, in principle, travel faster than **c**. Moreover, the group velocity may be negative. This means that the peak of the pulse exits the medium before it goes in. This counterintuitive situation has been observed experimentally [7]. A negative group velocity of **-c/310** was reported by Wang and his colleagues. Anomalous dispersion was created between two closely spaced lossless EIT-lines in a caesium vapour contained in a cell with and paraffin coated walls containing a buffer gas.

However, there is simpler way to make even higher values of anomalous dispersion. Recently it was found that a medium with ground state coherences prepared within a degenerate two-level transition might have directly opposite dissipative and dispersive properties [16,17]. In addition to the common destructive interference of excitation paths (the effect of EIT), evidence of *constructive* interference was found in an *N-type* level configuration within the D_2 lines of alkali atoms. When both drive and probe waves were tuned to the optical transitions starting from the upper ground state hyperfine sublevel, an absorption enhancement instead of reduction was observed at zero frequency offset. This effect, termed electromagnetically induced absorption (EIA), is also the result of a two-photon Raman transitions. Consequently, the ultimate width of the absorption resonance is also determined by the ground state lifetime.

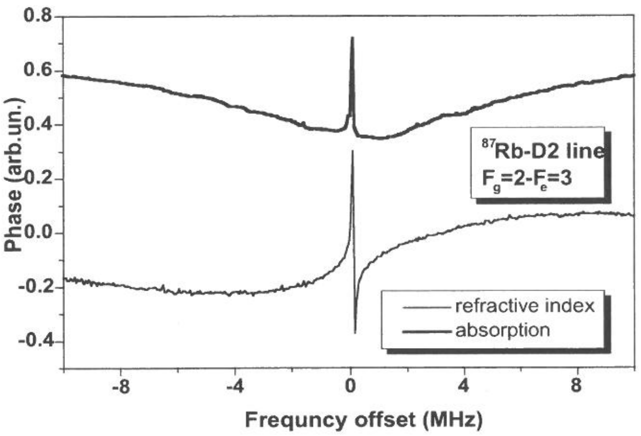


Fig.6. Electromagnetically induced absorption and steep anomalous dispersion of a warm Rb vapour on the D_2 line.

It was shown experimentally that the dispersion of an atomic gas is steep and anomalous (fig.6) under the conditions required for EIA [18]. The maximum observed negative dispersion is $D \approx 6 \times 10^{-11}$ Hz $^{-1}$. This value of anomalous dispersion corresponds to the light group velocity of $-$ ***c*/23000**. It is interesting to note that for the EIA-medium, incredibly large variations of the light group velocity V_g (from infinitively large positive to negative) can be achieved simply by varying the drive field intensity.

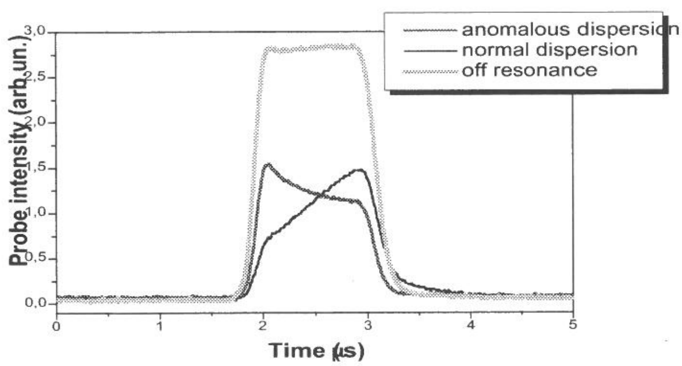


Fig.7. Propagation of sharp-edge probe pulses through highly dispersive medium with anomalous and normal dispersion.

Propagation of a probe pulse and an amplitude modulated (AM) probe wave through a medium with anomalous dispersion was investigated. It was demonstrated that the AM probe wave reaches the detector in advance with respect to the non-resonant light. However, for a pulse with a sharp leading edge, it was found that no output light ever emerges at times earlier than the transit time, fig.7. These observations are in an agreement with the principle that nothing can travel faster than light.

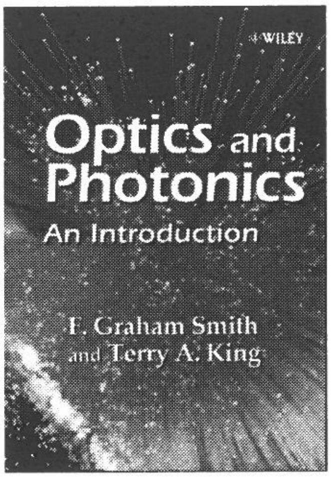
5. Conclusion

Further investigation of light propagation through media with steep dispersion looks very promising for quantum information processing amongst other things. New concepts of few-photon non-linear optics based on slow light in coherently prepared media [19] can be applied to EIT, as well as bright coherent states. Under the conditions of EIA, a resonant gas also possesses a high non-linear susceptibility at low light intensity [20]. It provides, among other things, interesting techniques for atomic coherence transportation between two spatially separated points and the generation of non-classical states of light and atomic ensembles.

References

1. J.Granz, *The New York Times*, Jan 18, 2001.
2. C. Liu, Z.Dutton, C.H.Behroozi & L.V.Hau, *Nature*, **409**, 490-493, (2001).
3. D.F.Phillips, M.Fleischhauer, A.Mair, R.L.Walsworth, M.D.Lukin, *Phys. Rev. Lett.* **86**, 783-786, (2001).
4. *Nature*, **412**, 158 (2001).
5. L.V.Hau, S.E.Harris, Z.Dutton, C.H.Behroozi, *Nature* **397**, 594, (1999).
6. M.M.Kash *et al., Phys.Rev.Lett.* **82**, 5229-5232, (1999).
7. L.J.Wang, A.Kuzmich & A.Dogariu, *Nature*, **409**, 277-279, (2000).
8. E.Arimondo, *Progress in Optics*, XXXV, pp.257-354 (1996).
9. A.,S.Zibrov *et al., Phys.Rev.Lett.* **75**, 1499 (1995).
10. D.Budker et al. *Phys.Rev.Lett.* **83**, 1767-1770 (1999).
11. R,Wynands, A.Nagel, *Appl.Phys.* **B68**, 1-25 (1999).
12. M.Fleischhauer, M.D.Lukin, *Phys.Rev.Lett.* **84**, 5094-5097, (2000).
13. O.Kocharovskaya, Y.Rostovtsev, M.Scully, *Phys.Rev.Lett.* **84**, 628 (2001).
14. M.Scully and G.Welch, *APS News*, April 2001.
15. L.Brillouin, *Wave propagation and Group velocity* (Academic, New York, 1960).
16. A.M.Akulshin, S.Barreiro, A.Lezama, *Phys.Rev.A* **57**, 2996 (1998). A.Lezama, S.Barreiro, A.M.Akulshin, *Phys.Rev.A* **59**, p.4996 (1999).
17. A.V.Taichenachev, A.M.Tumaikin, and V.I.Yudin, *Phys.Rev.A* **61**, 011802(R) (2000).
18. A.M.Akulshin, S.Barreiro, A.Lezama, *Phys.Rev.Lett.* 83, 4277-4280 (1999).

Book Review



Optics and Photonics: An Introduction.

by F. Graham Smith and Terry A. King
Wiley. Chichester. 2000
Paperback, 434 pages, $76.50
ISBN 0-471-48925-5

Optics, the study of light, is a subject with a very long history, while Photonics as a word was coined within the past two decades to describe the generation, manipulation and detection of photons. The Authors' intention in this book has been to provide an introduction to Optics and Photonics suited to a senior undergraduate lecture course.

The contents of the book are weighted towards Optics, with the first 14 chapters and the last chapter covering standard topics in optics, such as geometric optics, waves and Fourier theory, diffraction, interference, coherence, optics in nature, and a series of optical instruments. There are also 7 chapters on Photonics topics including lasers, optical fibres, holography, light detection and scattering. For self-study, there are numerical examples and conceptual problems at the end of each chapter. Brief solutions are provided at the end of the book. Each chapter is introduced by an apt quotation, giving some historical and cultural flavour. A short list of references (books) for further reading is provided at the end of each chapter, and these are well-chosen classics.

Several aspects of the general approach and ordering of the topics in Optics are appealing in this book. After an introduction and discussion of ray optics, with details on various aberrations and adaptive optics, there is a chapter on a series of optical instruments including the human eye, telescopes, binoculars, cameras, and standard and confocal microscopes. This is somewhat unconventional, but I think the examples of practical applications of optics help to motivate students for the following somewhat abstract theory. I also like the early introduction of Fourier theory, building on the wave properties of light. This theory is then naturally integrated into subsequent chapters. There is a detailed treatment of interferometry including principles of Fabry-Perots and other interferometers for length and angle measurements. Diffraction (Fresnel and Fraunhofer) diffraction gratings (in the visible, radio and X ray regions) and spectrometers are also treated in detail. Maxwell's equations and the polarization properties of light are treated more briefly. The chapter on coherence and correlation succeeds in demonstrating the application of this theory for radio astronomy and phase contrast microscopy.

The topics related to Photonics are effectively introduced by a chapter on spectroscopy, detailing optical transitions and linewidths, and leading to a chapter on lasers. Semiconductor lasers are treated separately, and a general chapter on laser light explains some properties of gaussian beams as well as mode locking and Q-switching and a very brief (inadequate) description of nonlinear optics. Key features of optical fibres such as guided waves, modes, dispersion and fabrication are presented, and the book is right up to date with its mention of photonic crystal fibres. Holography is briefly covered but scattering (in its various forms) could have been given in more detail. The Photonics section concludes with a comprehensive survey of detectors and discussion of noise sources. The book ends with an appealing chapter on optical effects in nature, which can be appreciated for their beauty as well as their relation to earlier topics.

The writing style is generally clear and succinct. There are very few typos - I found one on page 297 - and there are some attractive colour plates illustrating particular topics. The figures throughout are clear and chosen appropriately to illustrate the material.

I would recommend the text for a course on modern optics, where the emphasis is on optics. The book suits this niche well as the standard optics topics are covered, and the additional up-to-date photonics topics enhance the students' overall appreciation of the current state of optics. The book is not suited to a stand-alone photonics course, because the treatment of this set of topics is not sufficiently detailed for senior undergraduates. I regret that there has not been a greater integration of the optics with the photonics material, even for example in the conceptual problems. However, a book combining the major topics in optics with modern concepts and examples of technology is indeed worthwhile.

Dr Judith Dawes
Department of Physics
Macquarie University. 2109.

Directors' Report and Financial Statement

Australian Optical Society
ABN 63 009 548 387

Director's Report:

The Members of Committee present their report on the company for the financial period ended 30 June 2001.
The names of the directors in office at any time during or since the end of the period are:

Dr. Kenneth G H Baldwin (appointed 28th June 2000)
Dr. Duncan Butler (appointed 28th June 2000)
Dr. Christopher T Chantler
Dr. Peter M Farrell
Dr. Murray W Hamilton
Professor John D Love
Professor Keith A Nugent
Dr. Wayne J Rowlands (appointed 24th September 2000)
Professor Halina Rubensztein-Dunlop
A/Professor Barry Sanders (appointed 28th June 200)
Dr. Christopher Walsh
Dr. Lewis B Whitbourn

Directors have been in office since the start of the financial period to the date of this report unless otherwise stated.

The profit of the company for the financial period amounted to $140.66

No significant changes in the company's state of affairs occurred during the financial period.

The principal activities of the company during the financial period were:

(1) To provide a forum for persons involved in or in any way interested in an y aspects of optics or a closely related branch of science to meet with a view to:-

(a) Spreading and sharing existing knowledge of optics and closely related branches of science; and

(b) Advancing the state of knowledge of optics and closely related branches of science.

(2) To strengthen the teaching of optics in Australian educational institutions and provide education in optics in the form of seminars, lectures, demonstrations and the like at various venues around Australia.

(3) To encourage further the interest of, and to promote research and other activities in, optics in all its diversity

(4) To foster closer international collaboration in optics through such avenues as:-

(a) Extension to cover closely neighbouring countries;

(b) Collaboration with other national optical societies;

(c) Amalgamation with other national optical societies to forma strong regional optical society.

No significant change in the nature of these activities occurred during the period.

No matters or circumstances have arisen since the end of the financial period which significantly affected or may significantly affect the operations of the company, the results of those operations, or the state of affairs of the company in future financial years.

Likely developments in the operations of the company and the expected results of those operations in future financial years have not been included in this report as the inclusion of such information is likely to result in unreasonable prejudice to the company.

The company's operations are not regulated by any significant environmental regulation under a law of the Commonwealth or of a State or Territory.

No dividends have been paid or declared since the start of the financial period.

No options over issued shares or interest in the company were granted during or since the end of the financial period and there were no options outstanding at the date of this report.

No indemnities have been given or insurance premiums paid, during or since the end of the financial period, for any person who is or has been an officer or auditor of the company.

No person has applied for leave of Court to bring proceedings on behalf of the compnay or intervene in any proceedings to which the company is a party for the purpose of taking responsibility on behalf of the company for all or any part of those proceedings.

The company was not a party to any such proceedings during the period.

Signed in accordance with a resolution of the Directors;

(SIGNED) Dr. Duncan Butler, Director
(SIGNED) Professor Keith A Nugent, Director

Dated this 24th day of August, 2001

Australian Optical Society
Statement of Financial Performance for the period ended 30th June 2001

	2001	2000
INCOME		
Subscriptions	8,851.99	13,431.00
Interest	2,786.72	381.00
	11,638.71	13,812.00
EXPENDITURE	–	
Accounting and Audit Fees (Note 2)	3,158.50	2,065.00
AOS Medal and Poster Prize	–	50.00
Bank Charges	276.66	285.00
Conference Books	–	2,228.00
Committee Travel and Food Expenses	577.73	372.00
Filing Fees	95.00	265.00
Newsletter Expenditures	2,499.52	2,553.00
Postage	130.00	130.00
Printing & Stationery	343.25	69.00
Professional Fees	–	466.00
Postgraduate Awards	1,800.00	3,012.00
Subscriptions - FAST/ANCI	1,150.00	1,035.00
Speaker Costs	1,467.39	959.00
Sponsorship Conferences	–	9,828.00
Travelling	–	18.00
	11,498.05	23,335.00
NET OPERATING PROFIT	140.66	(9,523.00)
Retained Profits - Beginning of Year	29,549.00	41,914.00
	29,689.66	32,391.00
OTHER APPROPRIATIONS		
Capital Distribution (ACOLS)	–	2,842.00
	–	2,842.00
UNAPPROPRIATED PROFIT AT 30TH JUNE 2001	$29,689.66	$29,549.00

Australian Optical Society
Statement of Financial Performance for the period ended 30th June 2001

	2001	2000
SHARE CAPITAL AND RESERVES		
Unappropriated Profit	29,689.66	29,549.00
Represented by:		
CURRENT ASSETS		
Cash at Bank	11,900.58	13,347.42
Term Deposit	16,000.00	16,000.00
Accrued Interest (ACOLS)	1,480.00	–
AOS News Account	172.76	201.58
	29,553.34	29,549.00
CURRENT LIABILITIES		
Input Tax Credits	(279.71)	–
GST Payable	143.39	–
	(136.32)	–
NET ASSETS	$29,689.66	$29,549.00

Statement of Cash Flows for the period ended 30th June 2001

	2001 ($)
CASH FLOW FROM OPERATING ACTIVITIES	
Receipts from members	8,852
Payments to suppliers and employees	-11,498
Interest received	1,306
Net cash provided by (used in) operating activities	-1340
CASH FLOW FROM FINANCING ACTIVITIES	
Movement in GST accounts	-136
Net cash provided by (used in) financing activities	-136
Net increase (decrease) in cash held	-1,476
Cash at beginning of year	13,549
Cash at end of year	12,073

Incorporation: The Society was formed on 17th September, 1984

Comparative figures: The 2001 figures in the accounts represent the period from 1st April 2000 to 30th June 2001. The 2000 comparative figures represent the period from 1st July 1999 to 31st March 2000.

Membership Subscriptions: For the 2000 calendar year the Society's membership was as follows:

Paid up memberships	243
Lif or Honorary Members	21

Liability of members: In the event of the Society being wound up and not being able to pay its debts in full, every member will become liable to contribute an amount not exceeding $100.

Audit conducted by Renshaw Dawson Lang, Chartered Accountants, Blackburn Victoria, dated 23rd August 2001.

** IMPORTANT NOTE FOR AOS MEMBERS **

There are many people reading this journal that are not currently financial members of the AOS. It is vital to the survival of our society that all active participants in optical science in Australia are paid-up members. Conference attendance and contributions to the AOS News show that there is very strong support for the continued existence of the Australian Optical Society.

It is urgent that all non-financial members of the AOS pay their 2001 membership fees as soon as possible.

Also, there appear to be a surprising number of people in the field of optical science (especially students) who are not as aware of the AOS as they should be. Encourage as many friends/colleagues/students/etc. to consider joining up (point them to the website, or make a copy of the subscription form in the back of the News.

- PLEASE PAY YOUR AOS SUBSCRIPTION NOW -

EDITORIAL

In an attempt to once again synchronise the AOS News with the calendar (ie. for the December 2001 issue to come out some time close to December this year), this edition is a "double issue". Although it is not quite twice the content of a usual edition, I think that it certainly contains an excess of interesting articles and features. Thank you to all of the contributors, especially the few that met my deadlines and then waited so long to hear from me.

Without any particular intention, there is a slight emphasis on reviews in this edition. This includes a book review, some conference reports from recent conferences, and even an article reviewing some exciting theory and experiments that manipulate the speed of light. One of the conference reports comes from the recent winner of the AOS Postgraduate Student Prize, Winfried Hensinger. Although time is running out, I would urge all completing optics-related postgraduate students (and their supervisors) to consider applying for this prize. I believe that Winfried's report indicates how valuable the award is to a student.

Still on the topic of conferences, the annual AOS conference is almost upon us again, this year as part of the ACOLS meeting in Brisbane. Have a look at the information in this edition, and go to the website for more up to date details. The list of invited speakers is impressive, and combined with contributed papers it should promise an exciting conference in sunny Queensland (as I look out of my Melbourne office window!)

As a last point, I think that we all need to give some serious thought to recruitment activities for the AOS. In my pursuit of contributors for this journal, I continually come into contact with people involved in optics that are not at all familiar with our Society. Please make an effort to promote the AOS wherever you can, even if it simply means lending your copy of the AOS news to a student or colleague (or even a supplier or commercial partner)

Wayne Rowlands

ADVERTISMENT

Lastek Press Release

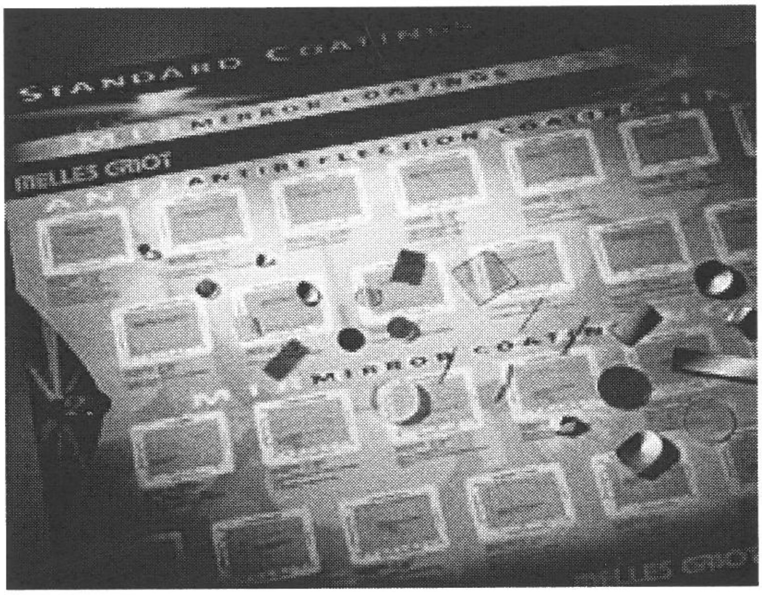
Melles Griot Coatings Poster

Irvine, California - This new instant reference tool provides at-a-glance specifications and reflectance curves for Melles Griot standard optical coatings. Mount this colourful 36" X 24" wall chart in your office or laboratory to keep this reference information readily available.

Information is divided into two sections. The first, anti-reflection (AR) coatings, includes single-layer magnesium fluoride coatings and multi-layer dielectric HEBBAR™ (high-efficiency broadband anti-reflection) coatings. The second section, reflecting coatings, includes: metallic coatings (eg, aluminium, silver, and gold; protected and bare), MAXBRIte™ (multi-layer all-dielectric xerophilous broadband reflecting interference) coatings with greater than 98% reflectivity over a 200 to 300 nm range, laser line coatings tuned for the highest reflectivity at specific laser wavelengths (typically >99.5%), and low-dispersion ultrafast coatings for femtosecond Ti:Sapphire laser applications. Each coating entry is represented by a typical reflectance curve and includes detailed information on reflectivity, wavelength range, and damage thresholds. In many instances, performance is shown for both normal and 45-degree incident light.

Many of the optics in the Melles Griot catalogue are available, off the shelf, with the most common coatings shown on this chart. And any of these coatings can be applied to any of the uncoated optics in the catalogue. Melles Griot is a leading global supplier of photonics products including optics, lasers, motion-control systems for the telecommunications industry, laser measurement instrumentation, and opto-mechanical hardware. The company has manufacturing and distribution activity in 41 countries worldwide and is a member of Barloworld Scientific Ltd.

For a copy of this attractive wall chart, or to talk to an applications engineer about a custom coating, contact Lastek,



CVI Manufactures EDFA Pump Combiners/Splitters

CVI EDFA pump combiners/splitters are un-packaged dielectric long wave pass beamsplitters that are used to direct 980nm pump energy in fiber optic amplifiers. Using a CVI proprietary process, the beamsplitters simultaneously provide 980nm pump reflectance and signal transmission, approaching 100 percent efficiency. A long wave pass configuration combines and splits the pump and signal wavelengths.

EDFA pump combiners/splitters achieve optimum pump irradiance and spot size through low surface roughness and a high-damage threshold coating greater than 30KW per squared cm CW. Produced at any incidence angle for 1mm or larger substrate dimensions, the beamsplitters can be deposited on a variety of optical surfaces. Contact CVI early in your project and our engineers will assist you with prototype and production volume optics built to your specification.

Lastek Pty Ltd, 10 Reid Street, Thebarton SA 5031
Tel: (08) 8443 8668, Fax: (08) 8443 8427
Email: sales@lastek.com.au Web: http://www.lastek.com.au

Meetings Calendar

The following list of optics-related conferences is compiled from several sources and should be used as a guide only.

Date	Meeting 2001	Contact	Location
Oct 3-5	Photomask Technology	SPIE	Monterey, USA
Oct 11-12	Photonic Nanostructures	OSA	San Diego, USA
Oct 14-18	ILS-XVII - Interdisciplinary Laser Science Conference	OSA	Long Beach, USA
Oct 16-19	ISOM 2001: International Symposium on Optical Memory	SPIE	Taipei, Taiwan
Oct 22-24	2nd International Symposium on Multispectral Image Processing and Pattern Recognition	SPIE	Wuhan, China
Oct 22-25	Micromachining and Microfabrication	SPIE	Santa Clara, USA
Oct 24-26	MOC '01 - Eighth Microoptics Conference	OSA	Osaka, Japan
Oct 28-31	Photonics Boston	SPIE	Boston, USA
Nov 2-3	9th International Symposium on Laser Spectroscopy	OSA	Taejon, Korea
Nov 5-9	LLMC 2001- Internatioanl Laser, Lightwave and Microwave Conference	OSA	Shanghai, China
Nov 7-10	International Symposium on Optoelectronics and Microelectronics	SPIE	Nanjing, China
Nov 12-16	APOC 2001-Asia-Pacific Optical Communications Conference	SPIE	Beijing, China
Nov 25-28	Multi-dimensional Microscopy		Melbourne, Australia
Nov 26-30	Photonics and Applications	SPIE	Singapore
Nov 27-30	7th Int. Conference on Education & Training in Optics & Photonics	SPIE	Singapore
Nov 26-28	ETOP 2001: The 7th International Conference on Education and Training in Optics and Photonics	SPIE	Singapore
Nov 28-Dec 1	3rd Asia-Pacific Workshop on Near Field Optics	AIP/AOS	Melbourne, Australia
Dec 3-6	ACOLS 2001: Australasian Conference on Optics & Laser Spectroscopy	AOS	Brisbane, Australia
Dec 17-19	International Symposium on Microelectronics and MEMS	SPIE	Adelaide, Australia
Date	**Meeting 2002**	**Contact**	**Location**
Jan 18-25	Photonics West	SPIE	San Jose, USA
Mar 19-21	12th International Workshop on Lidar Multiple Scattering Experiments	SPIE	Germany
Jun 2-6	Photonics North (ICAPT '02)	SPIE	Quebec City, Canada
Jul 17-19	International Conference on Smart Materials, Structures and Systems	SPIE	Bangalore, India
Sep 29-Oct 3	25th International Congress on High Speed Photography and Photonics	SPIE	Beaune, France
Oct 30-Nov 1	International Symposium on Biomedical Optics and Photomedicine	SPIE	Tokyo, Japan

Further information on the above conferences can be obtained from:

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