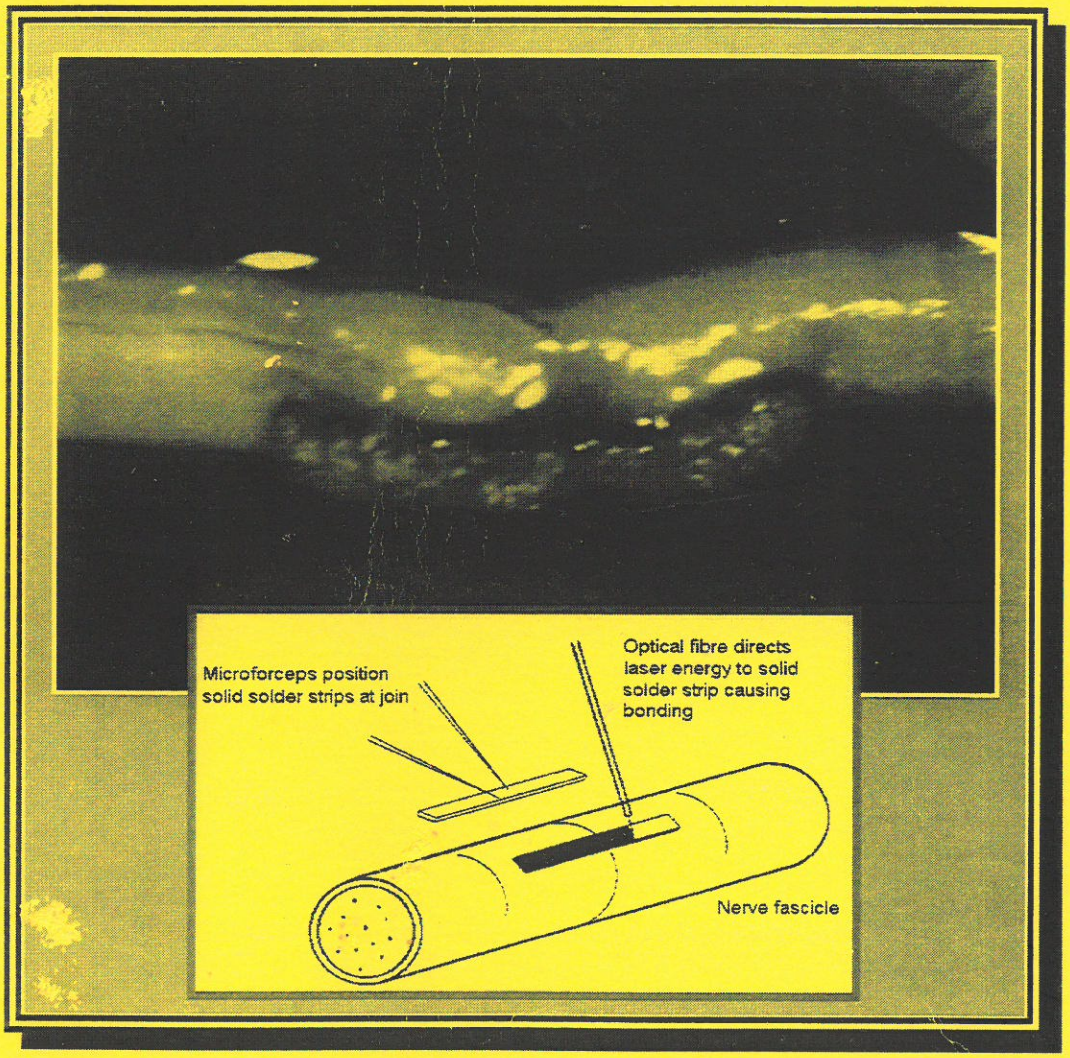
Australian Optical Society

NEWS



Volume 10 Issue 2

June 1996

Registered by Australia Post
Publication No: 233066 / 00021

JUNE 1996 VOLUME 10 NUMBER 2

AOS NEWS

COVER:
Microsurgical repair of a nerve using laser tissue welding. The photograph shows a nerve immediately after a protein strip has been applied and laser-heated. The inset is a schematic showing the process of laser welding. Using the solder simplifies and improves upon the process of nerve repair, an important achievement in the light of the number of nerves involved in a typical operation (see article p21).

SUBMISSION OF COPY:
Contributions on any topic of interest to the Australian optics community are solicited, and should be sent to the Editor or one of the Associate Editors. Use of electronic mail is encouraged, or else submission of hard copy together with an ASCII text file on floppy disk.

Accepted word processor formats include Microsoft Word (for Windows and Mac), WordPerfect and Latex. Where possible, diagrams should be contained within the document or sent as separate encapsulated postscript files. Figures on A4 paper will also be accepted.

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EDITOR
Duncan Butler
CSIRO Applied Physics
PO Box 218
Lindfield NSW 2070
Tel: (02) 413 7302
Fax: (02) 413 7200
Email :
duncanb@swifty.dap.csiro.au

DEADLINE FOR NEXT ISSUE :
7th August, 1996

ARTICLES

DEPARTMENTS

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

EDITOR - *Duncan Butler*
CSIRO Division of Applied Physics
PO Box 218, Lindfield NSW 2070
Tel: (02) 413 7302
Fax: (02) 413 7200
Email : duncanb@swifty.dap.csiro.au

ASSOCIATE EDITORS:
QUANTUM OPTICS - *Barry Sanders*
School of MPCE
Macquarie University
Tel: (02) 850 8935
Fax: (02) 850 8983
Email: barry@sanders.mpce.mq.edu.au

CSIRO - Bob Oreb
CSIRO Division of Applied Physics
PO Box 218, Lindfield NSW 2070
Tel: (02) 413 7303
Fax: (02) 413 7631

QLD - Halina Rubinsztein-Dunlop
Department of Physics
University of Queensland 4069
Fax: (07) 365 1242
Email : halina@kelvin.physics.uq.oz.au

SA - Anne-Marie Grisogono
Dept Physics & Math. Physics
University of Adelaide
Adelaide SA 5005
Tel: (08) 303 3039
Fax: (08) 232 6541
Email : amg@physics.adelaide.edu.au

VIC - Chris Chantler
School of Physics
University of Melbourne
Parkville VIC 3052
Tel: (03) 9344 5437
Fax: (03) 9347 4783
Email: chantler@physics.unimelb.edu.au

ACT - Ken Baldwin
Laser Physics Centre
Research School of Phys. Sci. and Eng.
ANU, Canberra ACT 0200
Tel: (06) 249 4702
Fax: (06) 249 0029
Email: kgb111@rsphy1.anu.edu.au

NSW - Martijn de Sterke
Department of Theoretical Physics
University of Sydney NSW 2006
Tel: (02) 351 2906
Fax: (02) 660 2903
Email: desterke@physics.su.oz.au

NSW - Judith Dawes
School of MPCE
Macquarie University
North Ryde NSW 2109
Tel: (02) 850 8903
Fax: (02) 850 8983
Email: judith@mpce1.mpce.mq.edu.au

AOS COUNCIL (1996)
PRESIDENT- *Chris Walsh*
CSIRO Division of Applied Physics
PO Box 218, Lindfield NSW 2070
Tel: (02) 413 7156
Fax: (02) 413 7200
Email : cjw@dap.csiro.au

VICE-PRESIDENT - *Brian Orr*
School of Chemistry
Macquarie University
Sydney NSW 2109
Tel: (02) 850 8289
Fax: (02) 850 8313
Email : brian.orr@mq.edu.au

SECRETARY - *Clyde Mitchell*
CSIRO Division of Materials Science and Technology
Private Bag 33,
Clayton South MDC, Vic. 3169
Tel: (03) 9542 2942
Fax: (03) 9544 1128
Email: mitchell@mst.csiro.au

TREASURER - *Esa Jaatinen*
CSIRO Division of Applied Physics
PO Box 218, Lindfield NSW 2070
Tel: (61 2) 413 7269
Fax: (61 2) 413 7200
Email : esaj@dap.csiro.au

PAST PRESIDENT - *Ken Baldwin*
Laser Physics Centre
Research School of Physical Sciences and Engineering,
Australian National University
Canberra ACT 0200
Tel: (06) 249 4702
Fax: (06) 249 0029
Email: kgb111@rsphy1.anu.edu.au

COUNCILLORS
Jesper Munch
Dept Physics and Maths
University of Adelaide
GPO Box 498
Adelaide SA 5001
Tel: (08) 303 4749
Fax: (08) 232 6541

Kieran Larkin
Department of Physical Optics
School of Physics
University of Sydney
NSW 2006
Tel: (02) 351 3941
Fax: (02) 351 0923
Email: larkin@physics.usyd.edu.au

Keith Nugent
School of Physics
University of Melbourne
Parkville VIC 3052
Tel: (03) 9344 5457
Fax: (03) 9347 4783
Email: kan@muon.ph.unimelb.edu.au

Ann Roberts
School of Physics
University of Melbourne
Parkville VIC 3052
Tel: (03) 9344 5038
Fax: (03) 9347 4783
Email: annr@muon.ph.unimelb.edu.au

Halina Rubinsztein-Dunlop
Department of Physics
University of Queensland
QLD 4069
Fax: (07) 365 1242
Email : halina@kelvin.physics.uq.oz.au

Peter Farrell
Optical Technology ResearchLaboratory
Department of Applied Physics
Victoria University
PO Box 14428, MCMC Melbourne
Tel: (03) 9688 4282
Fax: (03) 9688 4698
Email: peterf@dingo.vut.edu.au

Lew Whitbourn
CSIRO DMST Optical
Systems Engineering
Private Bag 33, Rosebank MDC,
Clayton VIC 3169
Tel: (03) 9542 2948
Fax: (02) 9544 1128
Email: lbw@dap.csiro.au

CORPORATE MEMBERS

AVIMO Electro-Optics Pty Ltd
AWA Defense Industries Pty
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AFFILIATES

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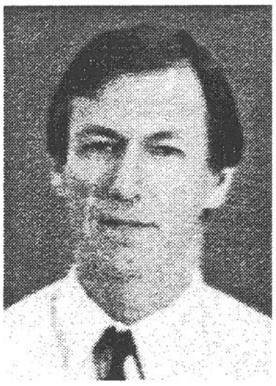
SPIE - The International Society for Optical Engineering

President's Report

by Chris Walsh



The AOS Council will be meeting immediately before the IQEC meeting in July. We have a relatively full agenda and I thought it would be worth advising members of some of the issues we plan to discuss to allow you an opportunity to comment.

First, we are planning to review the conditions of the Society's awards. In the case of the Young Optical Worker, we are considering broadening the scope of this award to be a little more like the OSA's Richardson medal, which rewards technical excellence in optics achieved in a manner not necessarily likely to result in an academic reputation or extensive publication list. The youth criteria will almost certainly remain. The conditions governing the Postgraduate award will be reviewed and although no major changes in the criteria are likely, there appears to be room to clarify them. We also plan to review the nomination and selection procedures for the AOS Medal. If you have an opinion on any of these issues please convey it to one of the Councillors.

I have had the opportunity to talk to some (but not all) of the AOS Corporate members. The general feedback about the benefits of being a Corporate Member of the Society was positive. One point made by several people was the relative lack of coverage the Society has in the field of medical optics. I would appreciate any advice from members about how we might raise our profile in this area.

This will be my last column before I hand over to the incoming President at the AGM in July. I would like to thanks the Councillors, Editors and Associate Editors past and present and the Organisers of last year's Conference for their efforts during my term. I look forward to remaining on the Council for the next two years in the position of Past President.

IQEC '96

in Sydney, 14-19 July

The 20th International Quantum Electronics Conference (IQEC '96) will be held at the Sydney Convention and Exhibition Centre, Darling Harbour, Sydney, Australia from 14-19 July 1996.

IQEC is the premier international forum for discussion of all aspects of quantum electronics, and this is represents an outstanding opportunity for interested professionals and students in Australia, New Zealand and the region to participate in a conference at the highest international level. A number of symposia highlighting areas of special current interest are integral to the conference. Among these will be a symposium honouring Professor A.M.Prokhorov, Nobel Laureate, on the occasion of his 80th birthday. IQEC '96 also incorporates a Technical Exhibition encompassing the latest products in lasers, photonics and electro-optics. The exhibition will be housed within the conference centre and will share the exhibit hall with the poster sessions and refreshment breaks.

The IQEC '96 Technical Program comprises some 600 papers to be presented in oral and poster sessions. These include 3 Plenary and 5 Tutorial Lectures, 90 Invited Papers, 477 regular contibuted papers and 24 postdeadline papers. The IQEC '96 Plenary Sessions, to be held on Monday, 15 July, feature outstanding contributors to the international field of quantum electronics: Professor **Eric Cornell** (JILA-NIST) will speak on latest experimental results in Bose-Einstein condensation; Nobel Laureate, Professor **John Polanyi** (University of Toronto) will discuss the photochemistry of adsorbates and clusters; and Dr **David Miller** (Bell Laboratories) will review physics and applications of quantum well optoelectronics. Five tutorials covering rapidly developing areas of quantum electronics are to be delivered by world leaders in their fields: Professor **David Hanna** (ORC Southampton) will lecture on developments of waveguide lasers, Dr **Ursula Keller** (ETH Switzerland) on ultrashort optic pulse sources, Dr **Artur Ekert** (Oxford) on quantum computation, Professor **Claude Weisbuch** (Ecole Polytechnique Palaiseau) on semiconductor light emitters and microcavity effects, and Professor **Luigi Lugiato** (Milano) on optical pattern formation. All plenary and tutorial lectures are freely accessible to all conference registrants.

Three satellite meetings are to be held in conjunction with IQEC '96. "Guided-wave Propagation and Devices" will be held at ANU, 10-12 July while details of the other meetings can be found on p44.

A detailed summary of the IQEC advance program can be found on p41.

- Jim Piper

OPTICS GRAPEVINE

News from the World of Optics

AOS Medal to Dr Hariharan

Dr Parameswaran Hariharan, formerly a Chief Research Scientist at CSIRO Division of Applied Physics and now holding joint Honorary positions as a Visiting Professor at the University of Sydney and Fellow at CSIRO Applied Physics, has been awarded the AOS Medal for 1996.

Dr Hariharan has an extensive publication record and record of research achievement in interferometry, holography, photography and optical instrumentation and more recently quantum optics. Among many honours he has been awarded the Fraunhofer Medal of the Optical Society of America, the Walter Boas Medal of the Australian Institute of Physics and the Thomas Young Medal of the Institute of Physics, London. Dr Hariharan is a fellow of the Institute of Physics, London, SPIE, the Royal Photographic Society and the Indian National Academy of Science.

Dr Hariharan will accept the Medal during the IQEC '96 meeting at Darling Harbour, Sydney on Thursday July 18 in a ceremony starting at 12:45 in Meeting Room 3 of the Convention Centre. All members of the AOS, as well as delegates attending the conference, are invited to attend. Dr Hariharan has agreed to give a seminar on aspects of his work and this presentation will take place immediately after the ceremony.

Kidger Optics Home Page

Corporate members Kidger Optics are now on the WWW. Their pages may be found at

http://www.demon.co.uk/kidger/

Quantum Cryptography

There has been much heated debate on the use of encryption software on the Internet over the past year. Security officials in the US, in particular, are concerned about the consequences of unbreakable codes and have successfully made illegal all encryption software which creates messages they cannot decode.

While this fact sits uneasily with most Internet users, a solution which may please both parties has appeared on the horizon. By making use of the nature of quantum measurements, researchers can send a message in such a way that they can tell if the message is monitored in transit. They can also create a secure channel by transmitting the key with the code provided that the key is the same length as the encrypted data.
[Source: *OE Reports No. 147*]

New optics newsgroup

sci.optics.fiber

This group is a splinter from the sci.optics newsgroup and has been created specifically for the discussion of optical fibres. (PS: note the US spelling of 'fibre').

Solid State Optical Refrigerator

Cooling of solids using laser-induced fluorescence has been demonstrated at Los Alamos. A 1W infrared beam is directed into ytterbium ion doped glass which fluoresces at a shorter wavelength, absorbing heat under the right conditions. The first generation of instrument are expected to operate at 77K. The principle advantages of such a cooling method are the low vibration and long lifetime.
[Source: *Optics&Photonics News*, Feb. 96]

Kidger Optics Optical Design Course

Advance course in computer-aided optical design
21st-25th October, 1996
Schwaing, Munich, Germany.
For more information contact :
Kider Optics Ltd. 9a High Street, Crowborough
East Sussex. TN6 2QA UK
Fax : +44 1892 664483

Other corporate members now have web sites which we are aware of:
Coherent Scientific:
http://www.adam.com.au/~coherent/
Lastek:
http://www.saschools.edu.au/lastek/lastek.html
Please email the editor to add your company's home page to this list.

Corrections :

Out of date SPIE and Kidger Optics contact numbers were printed in the previous issue of *AOS News*. The correct numbers should be:

SPIE
Phone: +1 360 676 3290
Fax: +1 360 647 1445

Kidger Optics
Phone: +44 1892 663555
Fax: +44 1892 664483

Please update your records.

The advance program for **SPIE's Annual Meeting**, the International Symposium on Optical Science,

Engineering, and Instrumentation, is now available on the WWW at http://www.spie.org/web/meetings/Denver_home.html. Also, SPIE has an e-mail list for occasional updates leading up to the symposium. To subscribe, send a message to info-spie-request@spie.org with the following in the message body: subscribe info-colo96

1996 OSA Fellows :

Several AOS members have become OSA fellows in 1996 : **Nail Akhmediev** for contributions to the understanding of nonlinear wave-guides; **Gregory Forbes** for his contributions to geometrical optics and optical design; and **Brian Orr** for laser spectroscopy and nonlinear optics and tunable laser device technology.

AUSTRALIAN OPTICAL SOCIETY

Notice of Annual General Meeting

The 1996 Annual General Meeting of the Australian Optical Society will be held in conjunction with IQEC '96, at 3:30 pm on Friday 19 July 1996 in Meeting Room 5 at the Darling Harbour Convention Centre, Sydney, NSW.

AGENDA

1. **Apologies**
2. **Agenda**
3. **Minutes of previous meeting**
4. **Business arising**
5. **President's report**
6. **Treasurer's report**
7. **Election of councillors and office bearers**
8. **Any other business**

Members unable to attend this meeting are strongly urged to complete the proxy nomination form below and submit it to the President or Secretary well before the meeting. This will ensure that (1) your vote on important matters is counted, and (2) the meeting does not fail through lack of a quorum.

Australian Optical Society Annual General Meeting 1996

PROXY NOMINATION FORM

I, ______________________________ [print name], as a member of the Australian Optical Society entitled under the Constitution of the Association to vote at the Annual General Meeting on July 18 1996, hereby appoint ______________________________ [print name] to act as my proxy at the abovementioned meeting. He/she has my authority to vote on my behalf in the election of councillors and office bearers, and in any other matters arising at the meeting on which a vote is called for.

Signed______________________________

Date______________________________

LIGO Flats and Mirrors at CSIRO Applied Physics' Optical Workshop

Applied Physics' Optical Fabrication Project has produced state of the art optical flats and slightly curved mirrors for the eminent LIGO gravity wave telescope project in the USA. Gravity wave telescopes look for ripples in the space-time fabric to give astronomers new insight into the Universe's violent origins, and the nature of gravity.

Three other optics groups are involved in producing these prototype discs, but CSIRO and Hughes-Danbury, makers of the Hubble Space telescope, have been asked to manufacture optical surfaces and certify them through the use of optical metrology of unprecedented accuracy.

Designed and constructed by a team of scientists from the California Institute of Technology and the Massachusetts Institute of Technology, LIGO is scheduled for completion in 1998, and has the potential to verify directly the existence of gravitational waves predicted by Einstein's General Relativity, as well as to prove the existence of Black Holes.

Applied Physics' Optical Workshop is involved in the LIGO's Pathfinder project, which aims to determine achievable standards of optical flatness and smoothness which will be theoretically required by the LIGO telescope.

Its work involves the super polishing of two 25 cm diameter fused silica discs 100 mm thick, whose raw material value alone exceeds $30,000.

The surface quality required demands surface smoothness on the micro and macro scale to be better than 1/800 of the wavelength of light, and the workshop has undergone equipment upgrades and developed new measurement techniques to enable the metrology demanded by these tolerances.

Fabrication and testing, under the leadership of workshop head, Achim Leistner, has produced impressive results with delivery expected in mid-March.

Optics produced will be tested by NIST, the national standards laboratory of the USA, and may lead to further involvement in LIGO in the future.

Mark Suchting
CSIRO Applied Physics
PO Box 218, Lindfield NSW 2070

ACOFT'96
CALL FOR PAPERS
21st Australian Conference on Optical Fibre Technology
Conrad Jupiters, Gold Coast, Queensland
December 1 - December 4, 1996
Deadline for Submission August 31, 1996

CALL FOR SUBMISSIONS : Original contributions are solicited for ACOFT'96. Prospective authors should fax or mail the Conference Secretariat for more information as soon as possible. Detailed instructions for the preparation of a four page paper will be sent out. Accepted papers will be chosen for oral or poster presentation at the discretion of the Technical Program Committee and will be reproduced in the Conference Proceedings.

SCOPE: The Australian Conference on Optical Fibre Technology is the major Australian meeting on optical communications, optoelectronics and related optical fibre technologies. The scope of the Conference includes research, development, production, applications and business strategies of optical fibres and components, waveguides and optoelectronic devices, sensors, networks, systems and services for the communications industry. The conference will include TUTORIALS & WORKSHOP and a TRADE DISPLAY.

INVITED SPEAKERS : **Tingye Li**, AT&T Bell Laboratories, USA; **Ken Hill**, Communications Research Centre, Canada, **David Cotter**; BT Laboratories, UK; **Yasuji Ohmore**, NTT Research and Development, Japan; **Manfred Huber**, Siemens Advanced Technology Group, Germany; **Jean-Marie Beaufils**, Alcatel Submarine Systems, France.

CONFERENCE SECRETARIAT
Conference Secretary, ACOFT'96, The IREE Society, Level 1, 118 Alfred Street, Milsons Pt. NSW 2061.
Tel: +61 2 9929 0099, Fa:. +61 2 9929 0587, Email: iree_office@eol.ieaust.org.au

FASTS Circular for March

(FASTS can be found on the WWW at http://bimbo.pharmacol.su.oz.au/fasts/fastshome.html)

1. The election and its aftermath. Three days after the election, FASTS organised a phone hook-up with the Presidents of the Academy of Science and the Academy of Technological Science and Engineering. The purpose was to discuss post-election strategy, and we very quickly found a common position on PMSEC (Prime Minister's Science and Engineering Council), ASTEC (the Australian Science, Engineering and Technology Council), the ARC (Australian Research Council) and the position of Chief Scientist.

This was conveyed to the new Minister for Science and Technology (the Honourable Peter McGauran) as soon as the Ministry was announced. At a subsequent meeting, he said that he appreciated the prompt collective advice of the Three Presidents. It certainly underlines the need for collective action by groups involved in science policy in Australia.

2. Meeting with the Minister, the Honourable Peter McGauran. I raised a number of issues with the Minister. FASTS wanted to clarify who was responsible for what, and how science and technology is to be divided between Mr McGauran and the Honourable John Moore, Minister for Industry Science and Tourism. Also on FASTS agenda were changes to PMSEC, ASTEC, the position of the Chief Scientist and the ARC; and how the Government intended to develop their promised "clear, long-term strategic approach to maximise the contribution of science, engineering and technology to the economic prosperity of the nation".

FASTS also wanted a Ministerial response to two other proposals. The first was FASTS' offer to organise a comprehensive calendar of scientific events, and the second a suggestion that scientists and technologists should be involved in the 42 Regional Development Organisations established by the previous Government.

Minister McGauran said he would be responsible for ANSTO, CSIRO, the CRC program, PMSEC and ASTEC, the Chief Scientist and science policy generally. Mr Moore would be responsible for the Syndicate Research and R&D tax schemes as part of his Industry portfolio. These arrangements are to be formally announced in a paper soon.

He welcomed a FASTS' proposal to begin the process of investigating steps towards a national science and technology strategy by making it a major theme at ANZAAS in Canberra this October. ANZAAS has agreed to this idea, and it was endorsed by the Presidents of the two Academies. Minister McGauran was less enthusiastic about the idea of a comprehensive science calendar, but said he was willing to be convinced. The calendar proposes a web address which would set out all planned events for the next decade, with the contact details of organisers, an outline of the scope of the event, and information on registration. The executive Director of FASTS is working on the detail.

In general it was a lively and positive 90 minute meeting, and clearly FASTS will continue to bring issues to the Minister at the highest policy making levels.

3. Other Ministers. FASTS has a broad range of interests which spread across a number of portfolios, and so we have also contacted the Hon. John Moore as Minister for Industry Science and Tourism as cabinet spokesperson for science; and are seeking meetings with Senator Amanda Vanstone (Minister for Employment Education Training and Youth Affairs), Senator Robert Hill (Environment) and John Sharp (Regional Development).

4. FASTS - the second decade. The FASTS Board will consider a 19 point plan at its April meeting. The plan addresses the twin problems of communication and finance, familiar issues to many in science and technology! The plan recommends a revamping of the structure established ten years ago and procedures to provide better service to Member Societies. Ultimately a finished plan will be submitted to FASTS Council meeting on November 21. Minister McGauran has accepted our invitation to speak at Council.

5. The Policy Document. The FASTS Policy Document helped shape science policy debate when it was launched at Parliament House in June last year. It was in such demand it had to go to a second printing, and now is being revised. Look for the launch of the new Policy before mid-year, with revisions shaped by the deliberations of the FASTS' Council last November.

6. Meeting with Member Societies. Last week I met with representatives of the Australian Society of Plant Physiologists. They had voted to disaffiliate at their last

AGM, and I wanted to bring them up to date with FASTS activities and to hear of matters of concern to their Society. The ASPP raised infrastructure and career paths for post-docs as key issues, and we also discussed membership of ARC panels, FASTS' meeting with the Minister, and possible nominations for the proposed Council for Vegetation Management.

Like the meetings with the Australian Geosciences Council and Derek Robinson of the Australian Mathematical Society, it proved a useful exchange of ideas and information, and I would invite other Members to contact the FASTS' office to organise similar discussions.

7. New Board Member. Professor David Curtis has resigned from the Board of FASTS because of pressure of work. In his letter of resignation he said: "I do so with great regret as I have been very impressed with the recent activities of FASTS and have great hopes for its future." I would like to thank David for his contributions, and also to welcome Dr David Tracey of the School of Anatomy at UNSW as the new representative of the Medical Sciences group.

8. Media coverage. FASTS has gained increased coverage by the media in recent months, reflecting the energy it has put into raising awareness of science in political circles. Print articles include Campus Review, the Canberra Times, the Sydney Morning Herald, SciTech, Lab News and Search; and Ockham's Razor on radio.

9. Shorts.

a. ARC is working on funding strategies for basic research, and details of progress are contained in ARC News Special Edition Feb 1996. Contact foliver@nbeet.deet.gov.au or by fax on (06) 240 9869 with a copy or with comments.

b. WISENET is considering forming a women scientists' umbrella group. Contact Diana Temple on ph. (02) 817 4941 or email dianat@pharmacol.su.oz.au

c. ASTEC study on Young Australians' Views of the Future is available from Eric James on (06) 271 5080 and John Vines (03) 695 8800.

d. FASTS will be putting a submission in to EPAC (Economic Planning Advisory Commission) on science and technology in the budget. Member Societies may like to do the same, or feed ideas through to FASTS office.

Joe Baker
President, FASTS

FASTS Circular for April

1. News from the new Government. The impact that the $8 billion cuts will have on science and technology are not yet known, but there are some ominous signs. The Universities are clearly going to be in for a difficult time, and the Government is looking hard at all areas of expenditure. The rhetoric in Canberra is that since the $8 billion hole was discovered, all pre-election commitments are back on the table. Big programs are prime targets!

That means that the CRC program and the 150 per cent deductibility for industrial R&D are being closely examined. The danger is that in its attempts to cut expenditure, the new Government will axe programs or promises which require long-term commitments to make them viable.

The Space Program is one such program in doubt, in contrast to the Coalition S&T Policy for "a viable space research program". In their policy, the Coalition criticised the previous Government for "funding doubts, disrupted programs and continual reviews." The interests of the science and technology community need to be represented in a vigorous manner, which is a job for FASTS. We also need to remind the new Government that pre-election promises are taken seriously

2. The new Ministers. This is a most important time to meet with Ministers. It is now that they are working out how to put policies into action, and when they are most receptive to advice. We are committed to ensuring that Ministers in different portfolios (eg Education, Environment and Primary Industries and Regional Development) are aware of their access to scientific and technological abilities throughout Australia.

FASTS has put several matters to Minister Peter McGauran, including a completely new approach to the funding of R&D by industry, and FASTS' views on how responsibilities between ASTEC (now ASETEC), PMSEC and the Chief Scientist should be divided.

We have opened discussion on how scientists and technologists could play a part in the development of Australia, through involvement in the 42 Regional Development Organisations. These matters will be picked up in talks with Senator Grant Tambling, Parliamentary Secretary for Regional Development, and Minister McGauran, together.

3. Careers for scientists. The limited career path for younger and middle-ranking Australian scientists existing on "soft" funding is a matter of continuing concern. We have discussed this with Minister McGauran, and recommended that ASETEC undertake a proper examination of the causes and solutions.

One change which would help younger scientists would be to increase the size and duration of grants, and couple this with review process earlier in the term of the grant so that they would have more notice of the extension or termination of programs. The combined expertise of FASTS' Member Societies would make FASTS a valuable member of the working party looking at this problem.

4. FASTS annual Council in November. The FASTS Council will meet on November 21 in Canberra. Each Member Society is entitled to send one voting representative. The Minister for Science and Technology, the Hon Peter McGauran, has accepted our invitation to address Council.

It is a valuable opportunity for Member Societies to have input in the formulation of FASTS' policy, and to make sure the concerns of ordinary members are understood. It is also a valuable opportunity to network. Last year we held a very successful dinner for all delegates at a cheap and cheerful Italian restaurant, and our guests included the science advisers to both the Minister and Shadow Minister for Science, and science journalists.

5. Minister McGauran's staff. Newly appointed Chief of Staff is Dr Michael Selley, who worked with Senator Robert Hill when he was shadow spokesperson for Industry, Science and Education. Dr Selley, a chemist formerly at the John Curtin School and in industry, played a key role in formulating the Coalition S&T policy. We congratulate him on his appointment.

6. Submission to EPAC. FASTS is making a series of submissions to the Economic Planning Advisory Commission (EPAC) for input into the budget. These submissions will be distributed to relevant Ministers and departments for consideration in framing the budget.

7. New policy document. The original FASTS Policy Document was launched in June last year. It became a hit overnight, being highly influential in science policy circles and a recognisable force in the emerging political policies. Almost 1000 copies were distributed. Now the policy is being revised. Some changes were made by FASTS' Council last year, some policies have been

adopted or become redundant, and some are necessary with the event of a new national Government.

The FASTS Board endorsed the revised version at its last meeting, and this near-final draft will be circulated by email to all Member Societies asking for comment before it goes to press. There are plans to launch the new Policy in mid-year in Canberra.

8. FASTS: the second decade. FASTS has established three new sub-committees under a 19 point plan adopted by the Board. Graham Johnston (Professor of Pharmacology at Sydney University, and immediate Past-President of FASTS) will head the Constitution Committee, which has the task of preparing a revised Constitution for consideration at FASTS Council in November.

Ken Baldwin (Senior Fellow Laser Physics, ANU) will head the Policy Committee, which is responsible for drafting a revised Policy Document and guiding it through the review process. Jan Thomas and I will lead a Membership and Resources Committee, to analyse ways to ensure FASTS has a strong membership and adequate funds to support its activities. Member Societies will have the opportunity to comment on the outcomes.

9. Chief Scientist. A proposal to extend the term of the current Chief Scientist, Professor Michael Pitman, has gone forward from the Minister for Science and Technology to the Prime Minister. This would be a stop-gap appointment, effective until the Government approves and funds Minister McGauran's plans to give the position new status as a statutory body.

Such a move would require legislation, but the appointment process for Professor Pitman's successor could begin as soon as approval came through. Professor Pitman leaves for overseas early in May, and is expected to be absent until August.

10. New Secretary. I am delighted to welcome Dr Chris Easton of the Research School of Chemistry at the ANU to this important role. Chris takes over from Graham Heath, also of the RSC at ANU. I would like to thank Graham for his contribution to FASTS, particularly in helping make the first Policy Document a reality.

11. Media coverage. FASTS is increasingly being mentioned in articles on science policy and related matters. In April, FASTS featured in the Sydney Morning Herald, the Campus Review and the Canberra Times; with articles on the Australian Mathematical Sciences Council appearing in the Age and the Australian. It is a sign of the increasing acceptance of FASTS as a major player in science policy matters.

Joe Baker, President

Quantum Optical Computing

Gerard J. Milburn
Department of Physics, The University of Queensland
QLD 4072, Australia

The fundamental quantum nature of optical interactions may be harnessed to build powerful computers. In theory these machines have the ability to be far superior to anything we can expect from classical devices.

Introduction

What kind of computation can be done in a quantum world? The answer to this question is only beginning to emerge and it is overturning our long accepted paradigm of computation, a paradigm based squarely on classical physics. The result is likely to be computational power which makes today's most advanced super-computer look like an abacus. The first person to suggest that quantum computers might be vastly more powerful than classical computers was the famous Caltech physicist, Richard Feynman [1].

A computer is no less a physical device than a car engine or electrical motor, and as such is subject to physical limitations. However there is a deep and fundamental difference between an engine and a computer. Where an engine processes energy, a computer processes information. The physics of the nineteenth century was largely driven by the need to understand what restrictions physics placed on the ability of an engine to process energy. A century of thinking about this question produced thermodynamics, one of the cornerstones of physics. Thinking about the real limits to information processing is now yielding new physical insight [2].

The Physics of Information

Information can be measured and has a real cost in terms of the computer memory needed to store data [3,4]. However the crucial step in recognising information as a true physical concept came when Rolf Landauer of IBM, while thinking about the ultimate physical limits to computation, realised that to erase information costs energy. The result, now known as Landauer's principle, provides the link between the nineteenth century concepts of energy and thermodynamics and the twentieth century concepts of information. It is the crucial step which leads us to a physics of information.

The transistors that switch on and off in computer circuits are very inefficient and a great deal of power is lost as heat. Modern processors give off about as much heat as a cooking surface of comparable size. Heat is also generated even if the device is not actively switching. In the 1960's Rolf Landauer asked if the heat associated with logical processing was required by the laws of physics or simply an historical accident - we just happened to have built computers out of inefficient transistors. Landauer's principle [5] states that whenever a bit of information is erased, k_BT energy must be given up as heat (roughly equivalent to the kinetic energy of an air molecule at room temperature). How do we erase information? Consider a coin toss. If the two sides of the coin are distinguishable we gain one bit of information when we learn the result of a single toss. If both sides of the coin were the same we would gain no information upon tossing the coin. Thus to erase information we must arrange for two previously distinguishable alternatives to become indistinguishable.

Suppose we have a small box containing a single air molecule. On what side of the box is this molecule located - is it on the left or the right? The molecule is zipping around inside the box so fast that the result of successive observations should be a random sequence of results, left or right. Clearly this is a molecular coin toss. To destroy information we have to arrange for the molecule to be found only on one side of the box. We can do this by pushing a piston in from one side until it has halved the volume of the box. If we push the piston in from the left the air molecule is now necessarily located on the right. We gain no information when we observe which side the molecule is on as we already know it must be on the right. We can now consult a text on thermodynamics to see what is the minimum amount of heat we need to dissipate to halve the volume of a box containing one air molecule. The result, $k_BT\ln 2$ is exactly the amount required by Landauer's principle for the erasure cost of one bit of information.

Every existing computer necessarily wastes energy. This is not because engineers are careless, but is determined by the fundamental logical processing elements in the machine. Take for instance the AND gate. This is a device with two inputs and one output. If both input

voltages correspond to the binary symbol '1' , the voltage at the output corresponds to the symbol '1' also. For every other input, that is for all the other pairs of ones and zeros present at the input, the output voltage codes for a '0'. Such a device is destroying information. This compression of distinguishable possibilities must destroy information and, by Landauer's principle, must be accompanied by a small amount of energy as heat. The kind of logic embodied in the AND gate is called irreversible logic as we cannot reverse the output and obtain the input precisely because different inputs are mapped onto the same outputs. Landauer's principle shows that the device is irreversible in the thermodynamics sense as well, as potentially useable energy is lost as heat.

But must we use irreversible logic gates to build computers? The answer given by a number of physicists in the late seventies and early eighties is no. It should be easy to see that a reversible gate must have the same number of inputs as outputs, so the question becomes, what is the minimum number of inputs a gate must posses in order to be sufficiently powerful to build all possible logical operations from it? The answer is, three. One such gate was invented by Ed Fredkin and Thomas Toffoli[6].

A computer built from reversible gates is itself reversible and so in principle need dissipate no energy whatsoever. However as the computation proceeds the device becomes cluttered with bits left over from intermediate steps, bits that must be present if each operation is to be reversible. Somehow we must get rid of these bits if we are to reuse the computer. We cannot simply erase the trash bits, as that will immediately invoke an energy retribution via Landauer's principle. The answer was provided by Charles Bennett of IBM [7]. We first make sure we c+opy the answer we want when the computer produces it (which can be done reversibly), then we just run the entire computation backwards, thus resetting all the internal logic states to their initial configuration. As each step in the machine is reversible there is no problem in reversing the computer.

Does quantum mechanics permit reversible computation? Early investigations concentrated in showing how Turing machines and reversible gates, such as the Fredkin gate, could indeed be implemented in quantum mechanics. In 1988 I proposed a simple optical device, based on the Mach-Zhender interferometer that would implement a Fredkin gate at the level of single photons [8]. (A similar idea was proposed, independently, and at about the same time, by Yoshi Yamamoto then at NTT in Japan). The lesson was clear; as reversible logic was necessarily carried out by physically reversible devices they would work just as well quantum mechanically as classically.

Reversible Quantum Logic Gates

The whole discussion entered an entirely new domain when David Deutsch showed in 1985 that by directly manipulating probability amplitudes quantum reversible logic gates can do much more than their classical counterparts, thus fully justifying Feynman's extraordinary insight [9]. It is now clear that a universal quantum computer can be built out of a gate with only two quantum inputs.

The idea of directly manipulating probability amplitudes to do computation has since been elaborated by a number of people culminating in an astonishing result obtained in 1994 by Peter Shor of AT&T, New Jersey; quantum computers can factor large numbers very much faster than any classical computer [10]. This result is of considerable commercial and military interest as one of the most common data encryption systems is based on the supposed computational difficulty of factoring large numbers.

Why should quantum computers be so much more powerful than classical computers? The answer lies in the notion of a qubit introduced by Ben Shumacher [11]. A qubit is an elementary quantum process with only two, mutually exclusive, outcomes. The outcomes can be coded by the binary digits 1 or 0, or simply as heads or

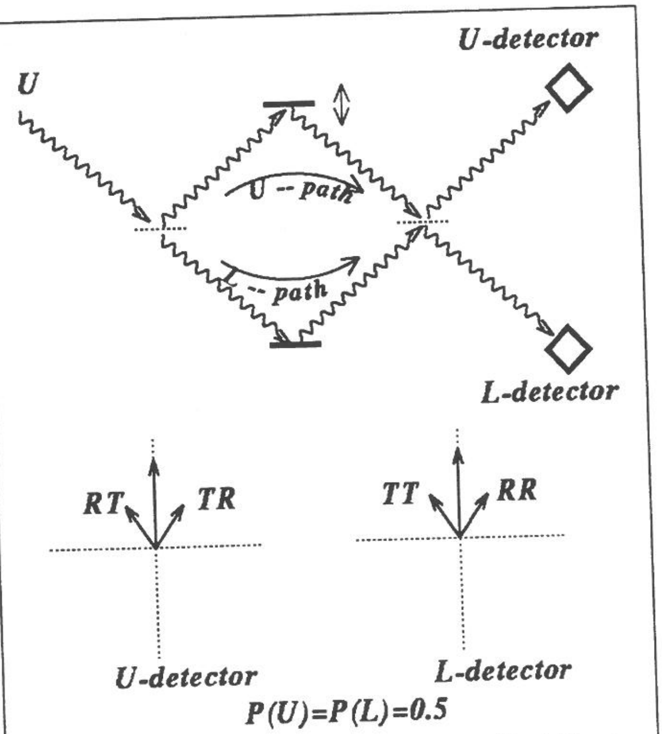


Figure 1: *A square-root-of-NOT gate (SRN) is a Mach-Zhender interferometer operating on a single photon at a time. The path lengths are adjusted so that the probability amplitudes to emerge in the U or the L channel have the same size. Then there is a an equal chance to detect the photon at either channel.*

tails. However, unlike a coin toss, the probability of a particular outcome for a qubit is determined at a deeper level by a probability amplitude. Quantum theory shows us how to manipulate these amplitudes directly (a unitary transformation), and it is this fact that enables quantum computers to do much more than a classical computer.

To see how a quantum computer can do better than a classical computer we need to build one - at least on paper. I will begin with a simple example, first devised by David Deutsch and Richard Jozsa [12], called `the square-root-of-NOT'. A NOT gate is simply a device for turning a head into a tail, or a 1 into a 0. That is, a NOT gate is a single input device which reverses the logical status of a single bit. The square-root-of-NOT gate is itself a single input gate. Two such gates run into each other give a NOT gate overall.

It is possible to realise a square-root-of-NOT (SRN) gate using a simple optical device, a Mach-Zhender interferometer, but operated at the level of a single photon (figure 1). The device has two inputs and two outputs, which I distinguish by the labels U for upper and L for lower. Light enters either the upper input (U) or the lower input (L) on the left. I will assume throughout that we are using light of such a low intensity that, in any run of the experiment, no more than one photon is injected into the device. Of course that photon can go into either the U or the L input. Likewise we can only detect a single photon at either the U output or the L output. Whether we detect a photon at the U or the L output depends on the relative lengths between the two paths through the interferometer. I will label these paths also by the symbols U (for the upper path) and L (for the lower path).

There are two histories leading to a photon being detected in the U output - the photon can either be reflected (RR) at both half-silvered mirrors or transmitted (TT) at both half-silvered mirrors. As the detection does not distinguish these two histories, the probability amplitude to detect a photon at the U-output is the sum of the probability for each history separately. Likewise for the L output, with the two histories symbolised by RT or TR (see figure 1). It is possible to vary the angle between the probability amplitudes for various histories simply by changing the relative path length. For example, if the path lengths are the same, the amplitudes for RR and TT may be identical, while those for RT and TR point in opposite directions and thus cancel exactly. In this case the photon is detected with certainty in the U output.

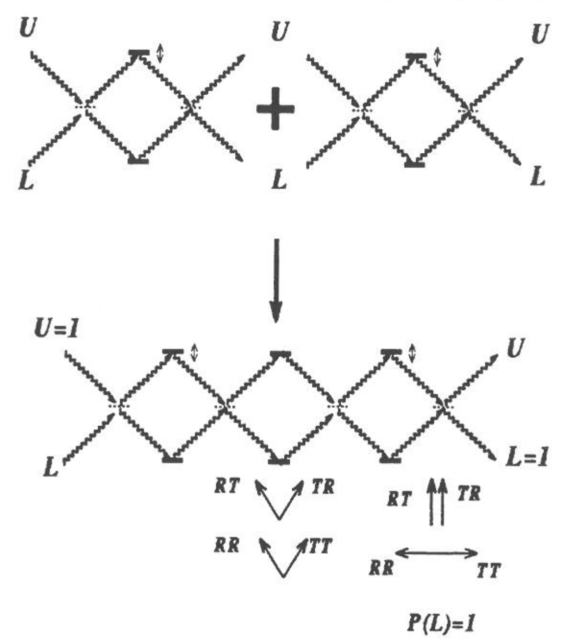


Figure 2: Two Mach-Zhender interferometers, with unequal arm lengths, run back to back form a NOT gate. Each Mach-Zhender interferometer is then a square-root-of-NOT gate.

It might look like the device in figure 1 is simply an elaborate coin toss, a simple one-bit game. In fact the device produces a qubit which behaves very differently to a coin-toss. To see this suppose we now take the output of this device and run it straight into another identical Mach-Zhender interferometer, without looking to see which output the photon emerged in (see figure 2). This causes the probability amplitudes to continue to rotate. The result is that at the final output, the amplitudes for the RR and TT histories cancel exactly while those of the RT and TR reinforce each other. The result is that the photon emerges with certainty in the L-output. Thus a photon at the U-input has been sent to the L-output. This is very different to what we would get if we simply injected photons at random into the two inputs of a single interferometer. In that case they would simply emerge at random from the final outputs. Because we have not determined which histories were actually realised at the first device we must keep working with probability amplitudes which simply continue to rotate in the second interferometer. Overall this device inverts the input. A U-input goes to an L-output and an L-input goes to a U-output. To make this a NOT gate we change our symbols to the conventional binary symbols 1 and 0. If we map U to 1 and L to 0, we see that the total device takes a 1 to a 0 and a 0 to a 1 (see figure 2).

In contrast, if the first Mach-Zhender device were simply using a coin toss to assign photons to the outputs, the same would hold for the second device and the photon could emerge in either output direction with equal probability. The whole device would not be a NOT gate but rather an elaborate coin toss game.

Towards a Quantum Computer

To make a quantum computer we need to manipulate many qubits. Fortunately a discovery Adriano Barenco and co-workers in the Oxford quantum computing group in collaboration with Richard Jozsa at the

University of Plymouth [13], and independently demonstrated by T. Sleator and H. Weinfurter [14] in Innsbruck, shows that any computation on a register of qubits can be broken up into a series of operations on pairs of qubits. One way to do this is with a **controlled NOT** (CN) gate.

To do this we will need four SRN gates. We run two SRNs into each other to make two single bit gates. This would produce two independent NOT gates. We could go on with this, but it is simpler to readjust the path lengths in each SRN so that instead of two NOT gates we get two IDENTITY gates. (A NOT-NOT gate in fact!) The trick to making a CN gate is, not surprisingly, to get one gate to control the other.

Two independent IDENTITY gates have two inputs and two outputs. Let us call the input to one of the gates a **control** qubit, and the other qubit the **target** qubit. Now we need to connect the two gates to realise the following rule: If the bit on the control qubit is a '1', invert the output of the target leaving the control unchanged, otherwise do nothing (see figure 3).

Input		*Output*	
Target	*Control*	*Target*	*Control*
1	*0*	*1*	*0*
0	*0*	*0*	*0*
1	*1*	*0*	*1*
0	*1*	*1*	*1*

Figure 3: *A table summarising the principle of a controlled NOT (CN) gate. The device has two inputs and two outputs.*

The key to realising how to do this is to see that a controlled NOT gate is nothing more than a quantum nondemolition measurement of the state of the control qubit. If we see the target qubit become inverted we are sure that the bit on the control qubit was a '1'. It is a quantum nondemolition measurement because, whatever happens, the control qubit does not change.

Overcoming Practical Difficulties

A CN gate constructed from four Mach-Zhender interferometers is show in figure 4. Two pairs of Mach-Zhender interferometers are coupled in series to produce two parallel IDENTITY gates. We will now couple these two gates together in such a way that target gate performs a QND measurement of which path, upper (U) or lower (L) that the photon took in passing between the two component interferometers of the control gate. We will choose the coupling so that if we send a photon into the U-input of the target gate and it comes out in the L-input, we are sure that the photon in the control gate passed along the upper path in the middle.

How do we couple the two gates together? It must be done in such a way that a photon passing through the upper part of the control gate can change the probability amplitudes in the target gate. In other words, we must ensure that if a photon passes along the upper path in the control gate it changes the path length in the target gate to such an extent that the amplitudes for the target photon to emerge in the U-output cancel exactly. There are suggested schemes to do this none of which are very practical at this stage. However in principle it can be arranged.

You may think that this could be overcome with a suitable arrangement of amplifiers but there is a problem. The connection between the target gate and the control gate must be entirely reversible. If not, then the whole device is no longer reversible and it cannot operate at the level of probability amplitudes. Classical devices such as linear amplifiers are necessarily irreversible. The connection between the control and the target gate must remain at the quantum level and the result of the QND measurement must remain suspended between potentiality and actuality.

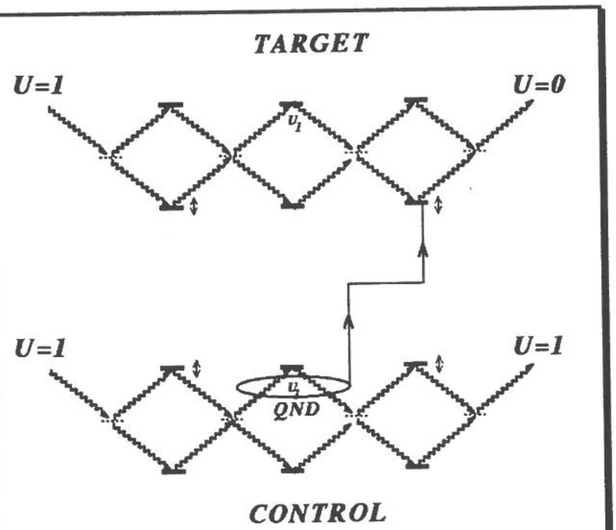


Figure 4: *An illustration of how to build a CN gate from four Mach-Zhender interferometers.*

The key to making a quantum computer is to be able to adjust all the probability amplitudes in just the right way, so that the probability amplitudes for a right answer all add up to give a large overall probability for being right. In addition to being able to exploit the unusual way probability amplitudes add, a quantum computer has another interesting feature - it can simultaneously do many calculations at once, simply by preparing the input as a superposition of all possible input states. *(continued p.19)*

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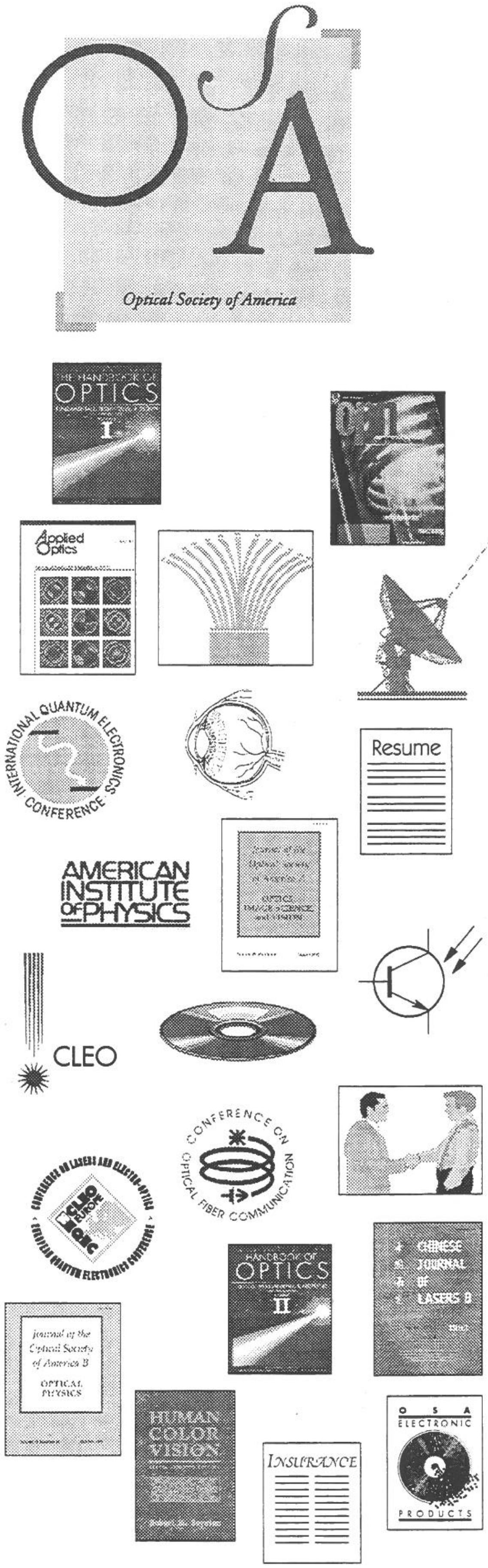

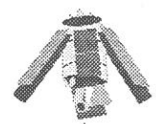

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Suppose we have a difficult decision to make that depends on one or the other of two mutually exclusive conditions having occurred. We can represent the decision process as a function of the binary inputs 0 or 1, which code for the two mutually exclusive input conditions to the decision. We could try and get a rational basis for our decision by first assuming the input is 1 and working the calculation through to a result. We then repeat the calculation again for an input of 0.

But suppose this is a very difficult decision with weighty consequences for error. For example the decision may require making a crucial investment exactly 24 hours after the input conditions become available. If the fastest computer we have takes more than 24 hours just to run the calculation through for a 1 input alone, then we are sunk, and can do nothing. However if we have a quantum computer we can prepare the input in a coherent superposition of the two inputs and do both calculations simultaneously in 24 hours.

Since Deutsch's paper a number of people have used the idea to devise many interesting problems that can be solved more efficiently on a quantum computer than on a classical computer, culminating in 1994 with Peter Shor's factoring result. This has resulted in the new field of quantum computational complexity. It is now clear that a quantum computer would not just be a bizarre, but useless device for astonishing classically minded physicists.

A number of groups have suggested physical systems that could be used to build a quantum computer. The discovery that we only need to manipulate two qubits at a time, rather than the three required for classical reversible computation, has made the search a lot easier. The optical gate proposed by my group at The University of Queensland and Yoshi Yamamoto is certainly a candidate as it can easily be run as a two bit quantum gate. The crucial problem will be to get it to work with single photons. This requires large optical nonlinearities. Unfortunately optical nonlinearities tend not to be unitary state transformers due to their tendency to absorb light. However recent work by Jeff Kimble and his group at the California Institute of Technology, using very small cavities and single atoms, may overcome this problem.

Another very promising suggestion was made in 1994 by J. I. Cirac of Universidad de Castilla-La Mancha in Spain and Peter Zoller at The University of Innsbruck in Austria [15]. Zoller and Cirac suggested using the quantised collective motion of a large number of ions in a trap to enable qubits to be exchanged, by a sequence of unitary transformations, between ions. In mid 1995 Dave Wineland's group at NIST (National Institute of Standards Technology) in Boulder, Colorado used the idea of Cirac and Zoller to build the world's first quantum CN gate [16]. Of course this is not a quantum computer but it is the essential building block from which a quantum computer can be constructed. Wineland and coworkers are confident that their scheme can be extended to work on many qubits not just two as in the CN gate.

Conclusion

Despite the huge surge of interest in the possibility of quantum computation, it is unlikely that any serious device will be available for many years. The basic problem is the need to ensure that all the quantum probability amplitudes are transformed in a completely reversible way (that is unitarily). This requires that the computer be completely isolated from the outside world while the calculation takes place. However we are decades (at least) from realising a quantum computer. If you are one of those people that simply must have the latest in computer technology, I am quite sure your decision will not be made any more difficult by the need to consider a quantum computer.

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(Editor's note : Quantum computing will be one of the feature topics at IQEC'96 in July. Gerard is currently a professor in theoretical physics at the University of Queensland, his interests include quantum and atom optics, quantum measurement and control, quantum noise in mesoscopic electronics and quantum computers and cryptography. His latest book, "Quantum Technology", is about to be published by Allen & Unwin).

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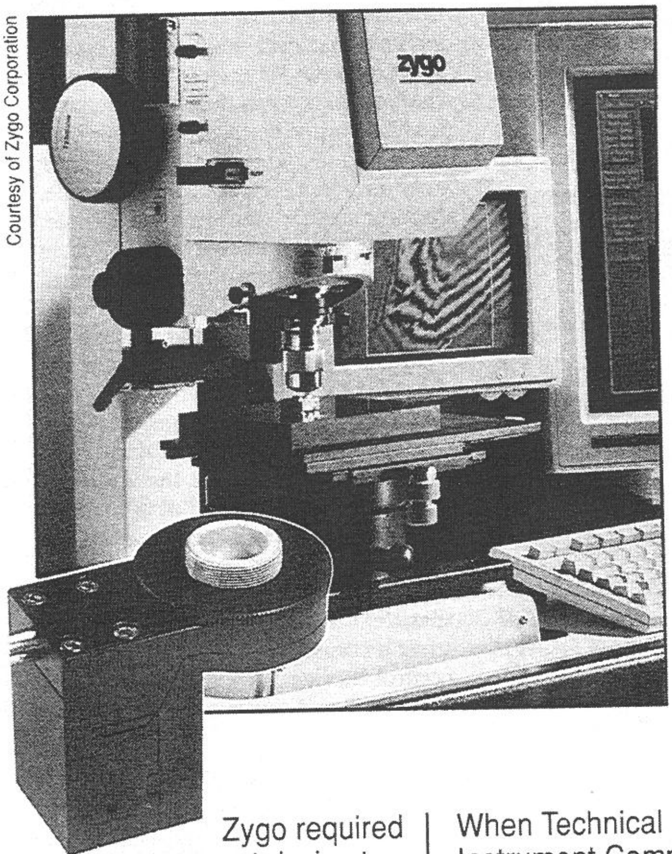

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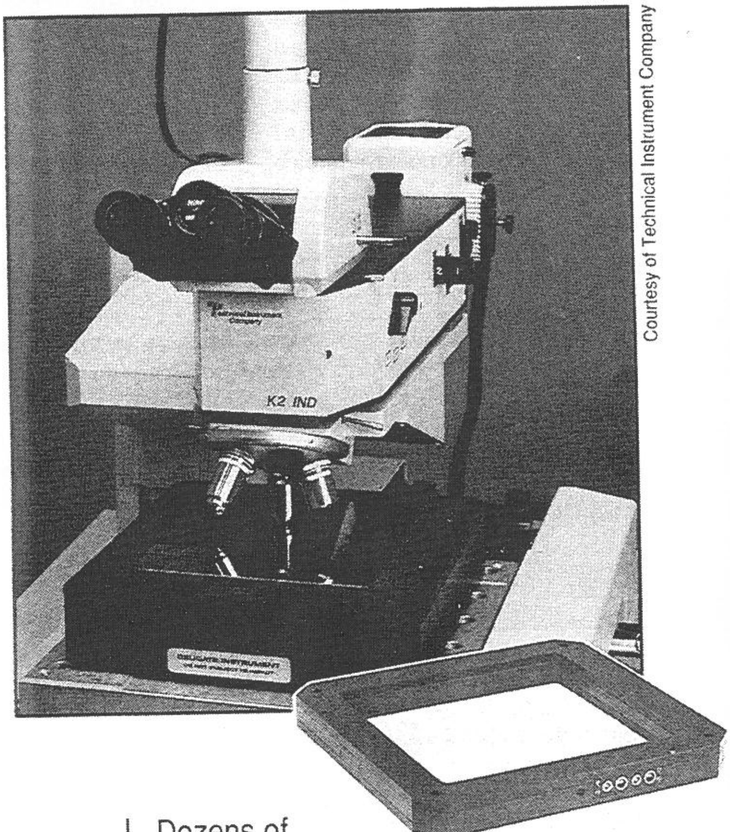

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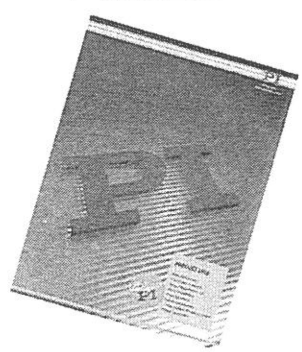

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Laser Tissue Welding for Microsurgical Repair of Nerves

J.M. Dawes*, A. Lauto*, R.I. Trickett# and E.R. Owen#
*Centre for Lasers and Applications, School of Mathematics, Physics, Computing and Electronics, Macquarie University, Sydney, 2109.
#Microsearch Foundation of Australia, 1 Esther St, Surry Hills, 2010.

Abstract: An 800 nm semiconductor diode laser has been used to heat a protein solder containing a strongly absorbing dye to aid in welding severed nerves together. The protein solder has been formed into strips, which are placed across the nerve join. The protein strips are then irradiated by the laser to form a strong bond. This technique has several advantages: the laser light is poorly absorbed by the nerve tissue, thus avoiding thermal damage to the nerve itself, and the protein strips are easy to handle (with micro-forceps) making the whole microsurgical procedure easier and thus quicker. The diode light is delivered by standard multi-mode optical fibre, enhancing flexibility of use in an operating theatre.

In vivo comparisons of the nerve repairs using the laser solder strips with conventional micro-suturing show that these techniques are equivalent in enabling functional recovery of the tibial nerve in rats over a 3 month period, while the laser solder repaired nerves show no scarring or foreign body reaction.

Introduction

Lasers are increasingly being used in medicine and surgery, both for diagnostic and therapeutic purposes. The key advantage of a laser is that it is a directed non-contact source of energy, while its wavelength specificity is important in allowing certain tissues or cells to be targeted. Because the power may be varied over a wide range, laser light may be used to heat and fuse (weld) tissue or to ablate (vaporise) it.

We have sought to develop a laser-based tissue-welding technique for microsurgical repair of severed nerves, which is easier and simpler to perform than currently accepted methods. To date we have performed *in vitro* and *in vivo* experiments in rats using the technique.

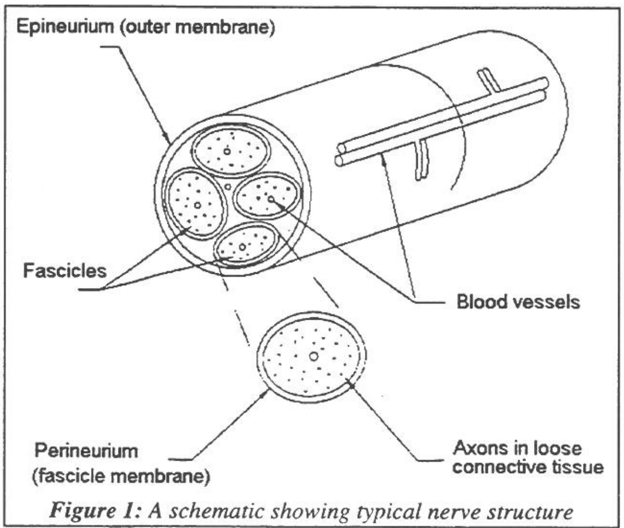

Figure 1: *A schematic showing typical nerve structure*

In order to understand techniques of nerve repair, a brief description of nerve structure is useful. A nerve fibre (fascicle) consists of a central core of tissue, containing many axons, each wrapped in an insulating cell (a Schwann cell) with myelin sheath. These axons carry the electrical signals in the nerve fibre. The axonal tissue is surrounded by a thin membrane of connective protein, the perineurium. A typical nerve structure is shown schematically in Figure 1. Several nerve fibres may be coupled together before branching off the main nerve.

When a limb or digit is severed accidentally, detailed and precise surgery is required to rejoin each of the damaged tissues, including tendons, nerves, blood vessels and muscle. The surgeon relies on a microscope to operate, and uses fine sutures (approximately 20 μm diameter, with 60 μm needles) to stitch the severed tissues together. Since 3-4 stitches are required to join a single nerve fibre, or fascicle, and up to 40 fibres (containing many nerve axons) are present in the main nerve to the hand, rejoining the tissues correctly is a slow and difficult process.

The successful repair of blood vessels, tendons and muscle can be confirmed soon after surgery, as these require essentially mechanical joins. But the repair of damaged nerves is much more subtle as the nerve axons (the cells which actually transmit electrical signals) die back to the site of damage and each individual axon must thus regrow (regenerate) along the old path. Microsurgeons suture the nerve fibres end-to-end to encourage the axons to regenerate along the appropriate paths, but since the sutures typically penetrate the axonal tissue, some dislocation is inevitable. Depending on the length of the damaged nerve, the

axons take a period of weeks or months to regenerate. In general, functional recovery is delayed until the restoration of a significant fraction of axons. Hence "successful" repair of the nerve is difficult to ascertain. In addition, problems in the recovery of the damaged limb or digit can occur because of scarring, which typically occurs around the sutures. Such scarring hinders the regrowth of the nerve axons and sometimes also causes painful growths (neuromas) of nerve tissue in the region of the damage.

Thus a technique such as laser-tissue welding, which can eliminate the use of sutures, offers the promise of reduced scarring, with consequent improvements in nerve recovery rates. Lasers such as CO_2 lasers have typically been used for tissue welding, since their mid-infrared output light is well absorbed by the water-containing tissues. However, such light is not transmitted by standard optical fibre, and must be delivered using an articulated arm. This has reduced the usefulness of such lasers in microsurgery, where the surgeon requires fine control and manoeuvrability of all the tools used. For this reason, near-infrared diode lasers are increasingly being used, in combination with optical fibre, providing a suitable chromophore (indocyanine green dye for example) is added to the tissue to increase its absorption.

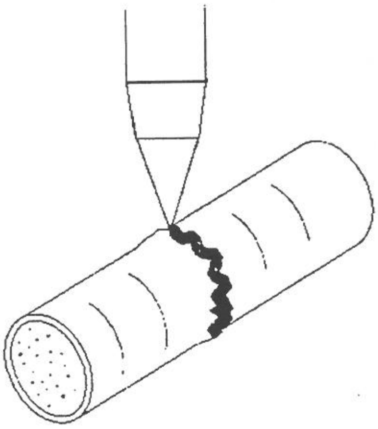

Figure 2: A schematic showing a typical method of laser-welding to join peripheral nerve stumps

The surgical technique, shown in Figure 2, to achieve a "direct" laser weld consists of holding the two nerve ends together, (sometimes with a single suture). The outer nerve membranes are then overlapped together and irradiated with the laser light until they turn white or slightly brown (caramel) [1,2]. This "end point" signifies that the protein in the membrane is denatured, although denaturation may occur before the "end point" is observed. This is an irreversible change in the protein structure, and in this case the protein is firmer, and less elastic. The actual mechanism of laser tissue welding seems to rely on the formation of crosslinks in the form of covalent bonds between protein molecules [3]. (An analogy is the cooking of egg white or albumin).

Many studies have shown that the laser welds of nerves obtained by the "direct" laser method are unsatisfactory as they tend to break more easily than the sutured controls, thus preventing the axons from regrowing in the correct direction. (Failure rates of approximately 20% are reported in animal studies [1,2]) These failure rates appear to be due to the fact that there is insufficient protein in the outer membrane of the nerve to form a strong bond. Thus some workers have added a "protein solder" as a fluid solution of protein [2] (albumin or fibrinogen) or protein and dye [4,5] to the weld site. When this is heated by the laser energy, the weld is thereby strengthened considerably. Some drawbacks of the protein solder are that it must be mixed within a few hours of the operation and that it tends to run everywhere because it is quite fluid. We have found that the nerve welds formed with this material are stronger than those due to direct laser irradiation, but not as strong as those due to sutures[6].

Our technique:

We have developed a new form of the solder which is solid, and slightly malleable [7,8]. It can be cut into strips of any shape and size desired. It contains a natural connective tissue protein, albumin, and an absorbing dye, indocyanine green. Using these solder strips we have simplified the surgical method required to join a nerve, so that a comparatively less-skilled operator (even a laser physicist!) can still achieve good results. In our method, the severed nerve fibre ends are placed close together, using micro-forceps, and thin strips (0.15 x 0.5 x 3 mm dimensions) of the protein solder are placed longitudinally across the join, as shown in Figure 3.

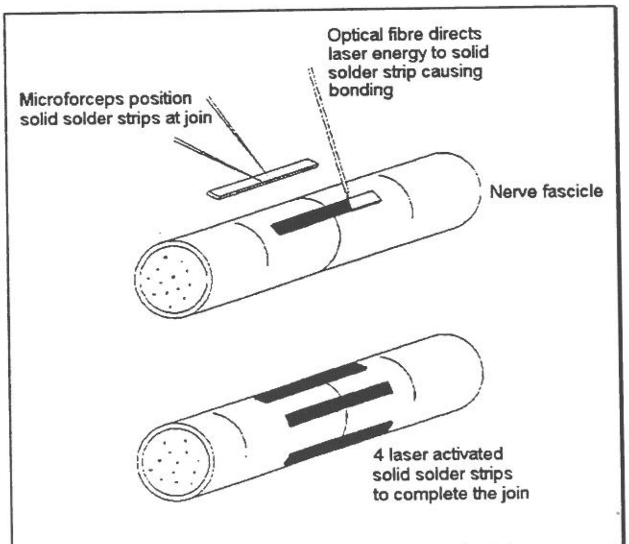

Figure 3: A schematic showing the method of laser-cured protein solder strips applied to the nerve longitudinally. Typically 4 strips are applied to hold the nerve firmly together.

This alignment prevents all the laser heat being concentrated at the ends of the nerves, which are the

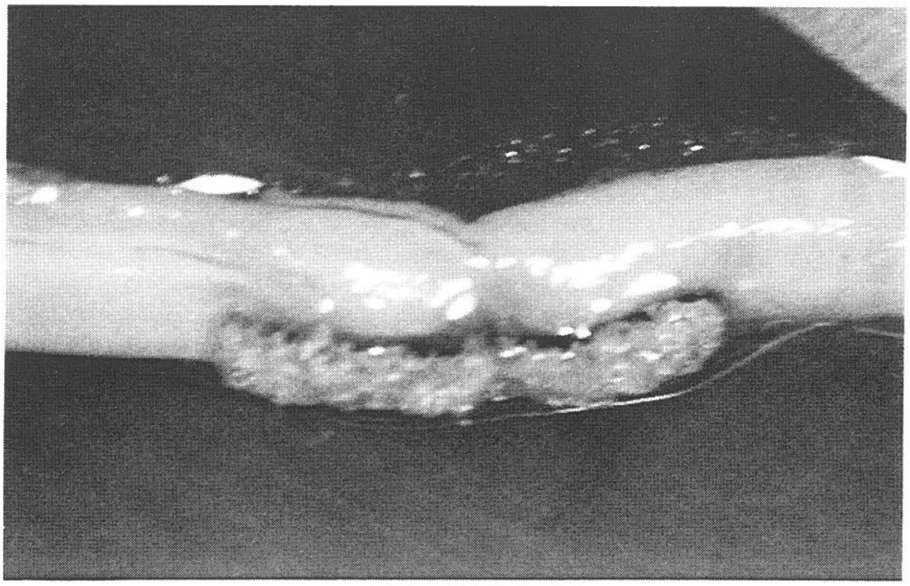

Figure 4: A light micrograph of a nerve immediately after a protein strip has been applied and heated by the laser light.

most vulnerable points to damage, since the axons must regrow from this point. A suture to fix the nerves is not necessary as the protein strips stick to the moist nerve. The diode laser light, (up to 90 mW delivered by a 100 μm core multi-mode optical fibre) is used to irradiate each strip uniformly until a suitable denaturation point is reached (the surface turns brown). Typically 4 strips are applied for each nerve fibre, to ensure a robust nerve join. A photograph of the resulting nerve is shown in Figure 4. One advantage of this approach is that the near-infrared diode laser light is poorly absorbed by the nerve tissue so there is less risk of thermal damage to the surrounding tissue.

We have tested our technique on the tibial nerve in rats (one of the nerves controlling movement and sensation in the hind foot). We have performed laser-solder nerve repairs and microsuture repairs on opposite legs of a group of animals, and allowed them to recover over 3 months. We have then tested the functional recovery of the tibial nerve using electrical stimulation of the nerve

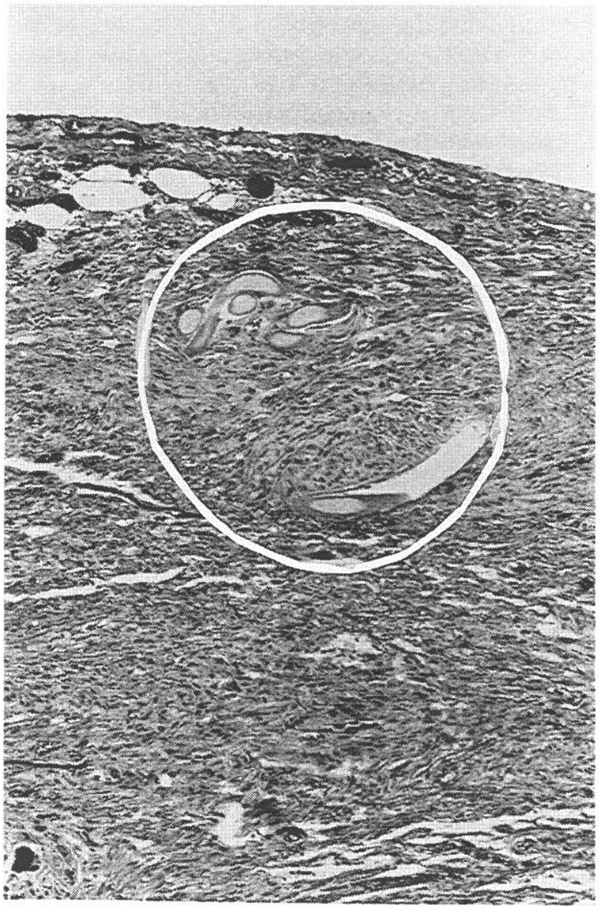

Figure 5: A light micrograph of a longitudinal section of a micro-suture repaired nerve fascicle, 3 months after surgery. The suture is shown in the ring. (Magnification 100X, stain Giemsa).

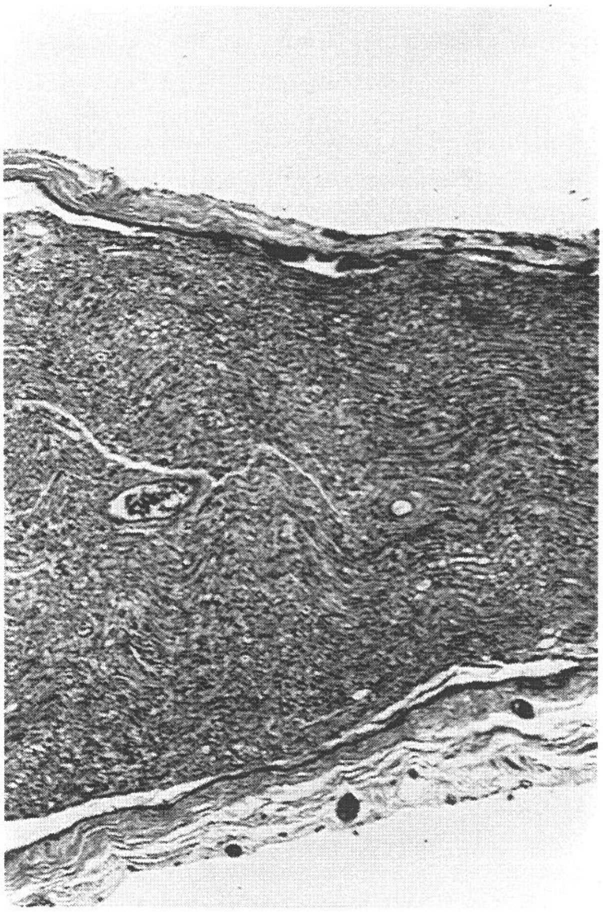

Figure 6: A light micrograph of a longitudinal section of a laser-solder repaired nerve fascicle, 3 months after surgery. Magnification is 100 X, and the stain is Giemsa.

above the operated site, to determine the compound muscle action potential (the electrical signal which is received from the excited nerve by the foot muscle). This is performed on anaesthetised animals. The two techniques give equivalent performance indicating that the laser-solder welds are at least as good as those which are microsutured. The signal from each type of nerve repair is significantly less (50 %) than that of a normal healthy rat. Thus 100 % recovery is not obtained after 3 months. (This is common in neurosurgery, but sometimes some nerves take over the function of others, improving the overall performance of the muscles.)

As well as testing for functional recovery we have investigated the repaired nerves histologically, for evidence that the nerve axons are regrowing correctly. There is evidence of scarring on the microsutured nerves, but none on the laser-soldered nerves. In fact the site of the repair is not obvious after 3 months in the laser-soldered case. The protein solder has been absorbed or dissolved by the body, and the nerve is smooth and continuous. Light micrographs of sections of the nerves 3 months after surgery are shown in Figures 5 and 6. The suture is visible in Figure 5, and in both figures, the normal nerve axons have a continuous wavy character. The outer membrane is continuos and smooth. (The cracks in the section occurred during histological preparation of the 5 μm thick tissue sections.) The stain is Giemsa and the magnification is 100 X.

Conclusions

Thus our laser-solder strip technique works as well as microsuturing, and since it is much easier to perform, it takes only one quarter of the time. This is an important consideration in a long microsurgery operation in which many separate tissues must be reconnected. The technique is relatively simple to implement, as the protein strips can be made up to a few weeks in advance if they are correctly stored. They are easy to handle with micro-forceps, and stick to the moist tissue even before they are denatured, making positioning easy. They are also bright green, so not liable to get lost in the body! The diode laser used in the experiments, has a wavelength of 810 nm and power level of less than 100 mW from a multi-mode optical fibre coupled to it. Thus it is relatively inexpensive. The dye which is used in the strips has US Food and Drug Administration approval for diagnostic use in humans, but laser scientists may also recognise it as IR -125, a laser dye from Kodak.

At this stage of the research, we have demonstrated that the laser solder protein strip technique is effective in repairing severed rat nerves. There are many possible extensions of the technique to other tissues and using other dyes, lasers and proteins. There is also scope to investigate what determines the "end point" of the denatured protein strips more precisely. While we are excited at the potential it offers, there are further tests of sterilisation and antibody reactions to make before it can be used in clinical trials for human surgery.

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Miscellaneous snipets...

"Perhaps the most dramatic moment in the development of physics during the 19th century occurred to J.C. Maxwell, when he combined the laws of electricity and magnetism with the laws of the behaviour of light. As a result, the properties of light were partially unravelled - that old and subtle stuff that is so important and mysterious that it was felt necessary to arrange a special creation for it when writing Genesis. Maxwell could say, when he was finished with his discovery, "Let there be electricity and magnetism, and there is light!" - *R.P.Feynman, The Feynman Lectures on Physics Vol I*

Caption for Figure 3.29 in Hecht and Zajac (an infrared image of Hecht) contains one of the few instances of humour ever to be found in an optics text. It reads "Thermograph of one of the authors (E.H.). Note the cool beard."

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Development of New-Technology Coronagraphs

Ray Smartt
National Solar Observatory/Sacramento Peak
Sunspot, New Mexico 88349, USA

Many of the critical problems in contemporary solar physics demand higher quality data than are available from conventional singlet-lens-objective Lyot coronagraphs. Super-polished mirror objectives offer the prospect of designing new-technology coronagraphs that have far superior performance characteristics. Prototype reflecting coronagraphs using such mirrors have been constructed and this work has led to a plan for an innovative large-aperture, low scattered-light coronagraphic telescope for both solar and nighttime use.

1. Introduction

At a total solar eclipse the solar corona appears as a halo of light with complex structures as illustrated in Fig.1. The maximum spectral brightness of this "white-light", or K, corona is only a few millionths that of the solar surface (photosphere), and arises from Thompson scattering of photospheric light by free electrons in the million-plus degree coronal atmosphere. The structures in the corona trace the magnetic field distribution. The "emission" corona is produced by (mostly forbidden) transitions of coronal ions. The spectral brightness of the strongest visible coronal lines close to the solar limb, around the period of solar maximum, can be two orders of magnitude greater than that of the white-light corona, but mostly this emission is also just a few millionths of the spectral brightness of the solar disk. Although the electron density in the low corona is far less than at the photospheric surface below (at least three orders of magnitude), coronal observations provide critically important information about solar surface magnetic field distributions, surface events, and especially the relationship between such events and interplanetary disturbances.

Lyot (1) devised the **coronagraph** in the 1930's to observe the corona outside of an eclipse. Such coronagraphs work remarkably well, given the faintness of the corona adjacent to the overwhelmingly brighter solar disk, and the scattered-light contributions from the sky and instrument. Observations are obtained routinely under clear-sky conditions at high-altitude sites.

Examples of advanced Lyot coronagraphs are the Sacramento Peak general purpose 40-cm-aperture emission-line coronagraph and the 20-cm-aperture patrol emission-line coronagraph [2], the white-light Mk III K-Coronameter operated by the High Altitude Observatory in Hawaii [3], and the 52-cm-aperture coronagraphs of the FSU. The basic design uses a singlet objective lens specifically fabricated to minimise scattered light. An occulting disk at the primary focus blocks the image of the Sun itself. Beyond the primary focal plane, a field lens forms an image of the primary objective. A circular aperture (Lyot stop) is located at this image with a slightly smaller opening such that the bright rim of diffracted light from the objective is blocked. A further lens system forms the final image.

For imaging the emission corona, the sky background contribution is minimised by using narrow-band filters with bandwidths that closely match the line width. The white-light corona is detected by using polarisation subtraction techniques. A primary limitation of Lyot coronagraphs arises from the colour curves of a singlet-objective lens. The secondary optical system can correct this colour over a wide range of wavelengths and over a relatively large field. By use of a Mangin mirror, the total system can be made achromatic over the

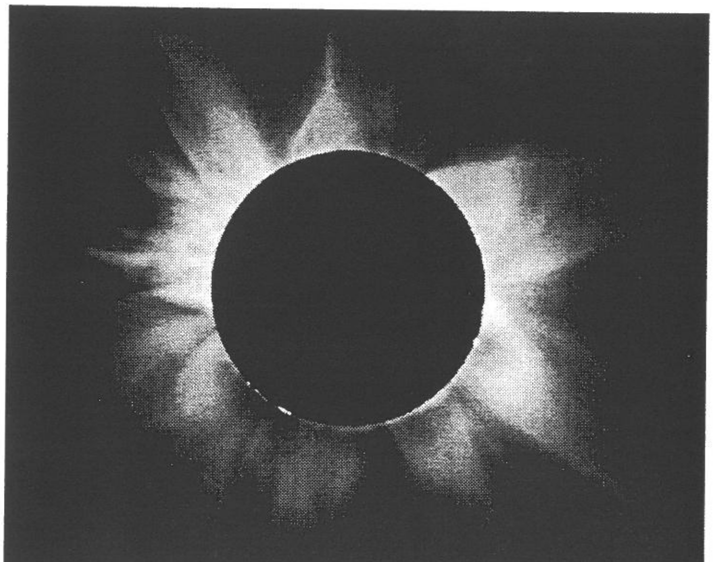

Figure 1: *Eclipse image showing detailed structures in the white-light corona. Its presence around most of the limb is typical of the period around solar maximum (S. Koutchmy)*

wavelength range transmitted by the glass. However, while the solar image is colour-free, the image of the occulting disk has an enormous amount of colour, with magnification a function of wavelength. This property precludes simultaneous observations at widely differing wavelengths, while observations close to the limb require a variable diameter occulting disk whose position along the optical axis is a function of wavelength. Overall, Lyot-type coronagraphs suffer from: a) the chromatic properties of the primary objective; b) aperture limitations of a singlet lens, with a realistic limit probably < 1 m, limiting resolution and light flux; c) long- and short-wavelength limits as determined by the glass spectral transmittance; d) internal seeing due to heat flux from the solar image.

Despite such limitations, ground-based emission-line and white-light coronagraphs have provided a wealth of data about the morphological and dynamical characteristics of the corona, although numerous studies would benefit from improved instrumental capabilities. For example, many observed transient phenomena are not yet well understood [eg. 4,5], higher sensitivity observations are needed for progress in magnetic field studies [eg. 6], and higher angular-resolution data are required for definitive tests [eg. 7,8]. Nevertheless, the long-term characteristics of the distribution of the corona around the solar limb as a function of the eleven-year solar cycle can be well-studied with existing instruments [9] by recording the brightness of spectra at a fixed height above the limb or by using extremely sensitive coronal photometers [10]. In addition, the use of high-resolution image intensifiers and special CCD recording techniques has further enhanced instrumental observing capabilities [11]. But the key to improved understanding of the coronal plasma and its dynamical manifestations is measurement of velocities and magnetic fields in small-scale structures, which is, in general, not possible with current instrumentation.

Spaced-based, white-light coronagraphs [12,13] have provided a large database of coronal transients, especially coronal mass ejections (CMEs). The important inner corona is not accessible due to the vignetting characteristics of externally-occulted coronagraphs and to the overall design constraints that must allow for the imprecision of the pointing system. Recent soft x-ray coronal observations from Yohkoh [14] constitute a rich source of data that display the extreme dynamical behaviour of the corona as observed in this wavelength regime, and data from SOHO is similarly revealing new information about coronal instabilities. The angular resolution is necessarily limited (at least several arcsecs) in these space-based instruments by the effective resolution imposed by current array detectors and also by practical limits on aperture size. In principal, much larger systems could be deployed in space, a lunar base offering the prospect of extremely precise tracking [15,16] that is essential for coronal observations in the critical regime just a few arcsec above the solar limb.

Despite the sophistication represented in the above instrumentation, many of the fundamentally important questions of coronal physics such as heating mechanisms to account for the high coronal temperature, mechanisms for accelerating the fast component of the solar wind, the sequence of events leading to CMEs and even basic plasma parameters in coronal holes, etc., remain unanswered, or postulates unconfirmed, due primarily to inadequate angular resolution and photon flux of conventional coronagraphs. We describe here a program to develop new-technology coronagraphs that is regarded as crucial for further progress in the field, especially since advances in theoretical and analytical techniques in coronal physics, and in solar physics in general, have now far outpaced the observing capabilities.

2. New-technology Coronagraphs

The key requirements are: a) White-light (achromatic) high-resolution capability. Over a large field-of-view of order of 10 $arcmin^2$, the spatial resolution should be at least 1 arcsec, with the capability of a much higher resolution over a substantially smaller field. b) Transmission extending from the near UV to the IR, with achromatic properties. c) Very low net instrumental polarisation to allow precise magnetic field measurements.

It is noted that for coronagraphs in general, the level of scattered light should be $\leq 10^{-6}$ at a radial distance of 30 arcsec above the limb. We now discuss the ongoing program at NSO/SP to develop both ground-based and space-based reflecting coronagraphs.

2.1. Low-scatter mirror technology

A mirror objective avoids the problems inherent in a singlet-lens objective coronagraphic design and large apertures are feasible. The primary image is achromatic, and with an all-mirror design, high-angular-resolution infrared and ultraviolet observations can be achieved. Mirror objectives for coronagraphs have been successfully applied to small, externally-occulted, rocket and balloon-borne coronagraphs [17,18], and the C1 coronagraph of the LASCO instrument of SOHO also has a mirror objective [19].

Super-polished surfaces, with micro-roughness values in the range of a few Angstroms rms, can now be achieved routinely. Moreover, techniques have been developed for producing reflective films, such as overcoated aluminium, that have virtually no intrinsic micro-roughness. The amount of scattered light produced by a high-quality optical mirror depends primarily on the residual microroughness of the substrate and on the reflective coating, apart from that due to surface contaminants. The term 'microroughness' generally refers to roughness over surface scales in the micron

range. Surface ripple where the scale is in the millimetre range (roughly from a fraction of a millimetre to a few millimetres) commonly occurs on polished optical surfaces. Such roughness contributes also to stray light, but mainly in the form of extremely low-angle scatter (at visible wavelengths), since in broad terms light is scattered/diffracted through an angle λ/b, where b is the period of some characteristic scale of roughness across the surface. For example, for $\lambda = 0.5$ µm, and b = 0.1 mm, a first order maximum occurs at an angle from the specular direction ~ 17 arcmin.

While both surface characteristics should be minimised for a solar coronagraph, micro-roughness is of primary concern. Larger-scale roughness is of critical importance for typical nighttime studies where a bright source is angularly close (a few arcsec or less) to some faint emission under study. The Zernike phase-contrast test is suitable for measuring surface ripple in the sub-millimetre, millimetre or larger-scale ranges of large optics, but this test is rarely used, even though easily carried out. Its principle is conceptually simple. In an image plane where the specular and scattered components of the light are spatially separated, a filter is introduced that attenuates the direct light to balance the amplitudes of the two components. Since the two components are in phase quadrature, the filter also introduces a $\pi/2$ phase shift to maximise the contrast of the surface features [18].

The relationship between the roughness of an optical surface and the resultant scattered radiation has been treated extensively in the literature [20]. In the case of an rms roughness, σ, where $\sigma << \lambda$, for radiation of wavelength, λ, and with a Gaussian distribution of roughness, the scattered component of reflectance at normal incidence, R_s, can be characterised by $R_s = R_o(2k\sigma)^2$, where R_o is the reflectance of a completely smooth surface, and $k = 2\pi/\lambda$. The corresponding scattered component of transmittance is:

$$T_s = T_o\left(\left|n_p - n_q\right|k\sigma\right)^2$$

where T_o is the transmittance of a specular beam through a smooth surface that bounds media of refractive index, n_p and n_q. For a glass surface in air, $T_s \sim T_o(0.5k\sigma)^2$. It is noted that under these conditions the scattered components are proportional to σ^2 and λ^{-2}. Hence, for reflecting and transmitting surfaces with the same characteristic roughness, the reflected scattered component is roughly 16x that of the transmitted scattered component. But two surfaces of a singlet lens contribute to the scattering. Hence, neglecting bulk scattering in a lens, a super-polished mirror would have a similar performance to a super-polished singlet lens when the rms roughness of the mirror, $\sigma_m \sim \sigma_l/3$. where σ_l is the roughness of the surfaces of the lens.

2.2 Infrared advantage

As outlined in this section, infrared coronal observations offer many advantages, now feasible with new technology arrays. Strong coronal emission lines are available in the near-IR (eg., Fe XIII at 1074.7 nm and 1079.8 nm) that have greater Zeeman and linear-polarisation sensitivity than visible lines, allowing more accurate magnetic field studies. The above two lines also provide a useful coronal density diagnostic. It should be pointed out that the spectrum of coronal lines in the near-IR is still not well established. With the availability of large-format, high-quantum-efficiency near-IR arrays, high-resolution imaging can be expected, especially since the seeing characteristics of the atmosphere improve with wavelength - Fried's seeing parameter, r_o, varies as $\lambda^{1.2}$ (measurements at SP at 1600 nm gave an exponent of 1.5).

In general, the performance of ground-based coronagraphs improves with increasing wavelength, especially due to the reduction in sky brightness, as well as the reduction in fractional instrumental scatter. From the previous section, it can be seen that mirror scattering is $\propto \lambda^{-2}$ (measurements in the near IR give values of the exponent in the range -1.5 to -3). The sky brightness decreases as a function of wavelength. Rayleigh scattering is approximately $\propto \lambda^{-4}$, which means that the spectral brightness due to molecular scattering quickly becomes negligible into the infrared. The angular and spectral scattering characteristics of aerosols depend on the size, shape, internal structure and complex refractive indices of the individual particles, and on their large-scale spatial distribution. Measurements of particles in the upper atmosphere (upper troposphere and stratosphere) indicate diameters typically < 0.2 µm [21]. Such particles would likely have irregular shapes, but if hygroscopic, would tend to be spherical. In the limit of $p \equiv 2\pi a/\lambda << 1$, where a is the particle radius and λ is the incident wavelength, the scattering of a spherical particle with a real refractive index has the same spectral dependence as that of Rayleigh scattering. For $p >> 1$, the aerosol scattering coefficient can be assumed to be roughly constant with wavelength, and for p in the intermediate range, the scattering coefficient can be assumed to be proportional to λ^{-n}, with n usually in the range 0.8 to 1.6 for a high-altitude site such as Sac Peak.

3. Mirror-Objective Coronagraph Designs

3.1 MACS

The first prototype reflecting coronagraph, Mirror Advanced Coronagraph (MAC I), constructed in this program is based on a 5-cm-aperture, spherical, superpolished silicon objective mirror, with a focal length of 1-m, and a micro-roughness ~ 0.3 nm rms. The optical system is simply off-axis reflection from the primary mirror to a secondary optical system that is a conventional Lyot coronagraph configuration, namely an occulting disk, field lens, Lyot stop, narrow-band filter and camera system. Both a photographic camera, as well as a video CCD camera together with an image tube have been used to record images of the green-line

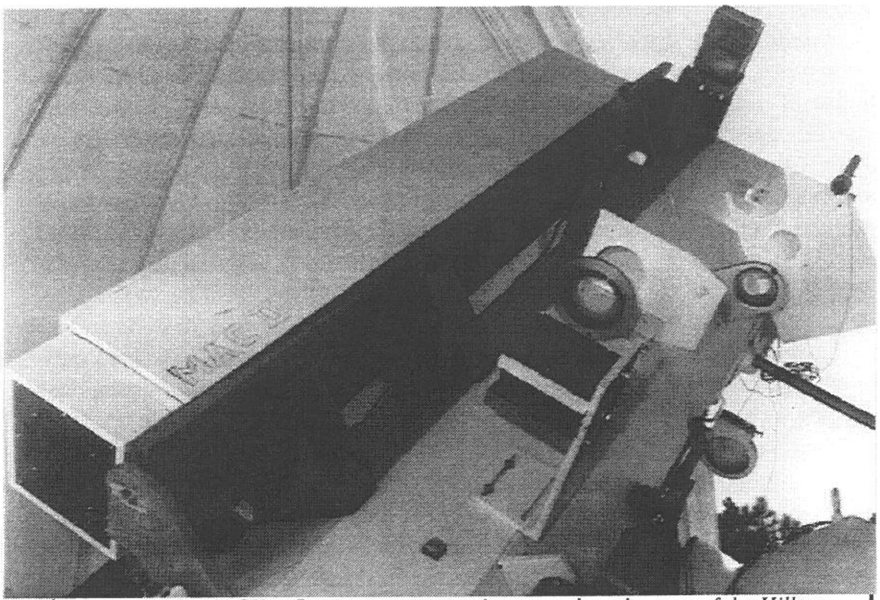

***Figure 2:** MACII reflecting coronagraph mounted on the spar of the Hilltop Facility of the National Solar Facility/Sacramento Peak.*

corona, the first coronal images obtained with a ground-based reflecting coronagraph. Much of the background in coronal images is due to the contribution of "flying dust" particles. The trace of these particles in the video image can be removed post facto by applying an algorithm to the digitised data that discriminates between stationary and moving components.

A second, more advanced, prototype instrument (MACII) has been constructed that has a zerodur 15-cm aperture, superpolished mirror objective with a 2.25-m focal length and an rms microroughness ~0.4 nm. In a joint agreement with Institut d'Astrophysique (IAP), part of the construction has been carried out by IAP. The objective mount, designed and constructed at IAP, allows extremely accurate tilting of the mirror under remote control, required to centre the solar image accurately relative to the secondary optical system. A concave annular field mirror, located near the primary focal plane, forms an image of the objective at the position of the Lyot stop. This field mirror functions as an inverse occulting disk (the coronal field is reflected, while the solar image is transmitted through the central hole to a light trap). The remainder of the secondary optical system consists of a Lyot stop, collimating lens, filter and camera system. The successful performance of this mirror-objective coronagraph points to a new era of astronomical observational techniques, namely the development of very low-scattered-light level achromatic telescopes of large aperture with important applications in the near UV and IR.

A third, research quality, instrument has been designed based on a 60-cm diameter Si-SiC objective. A small field mirror covers only the part of the corona under study. Different regions of the corona are then observed by rotation of this mirror around an axis passing through the centre of the solar disk. The optical system, as indicated in Fig. 3, has four mirrors with an overall length ~ 7m, and an effective focal length of 17m in a f/34 beam.

In this design, mirrors 1 and 3 are off-axis aspheres, 2 is spherical and 4 is plane. Spectral analysing instruments, including a grating spectrograph, an LC Fabry-Perot etalon and a polarimeter, incorporating fast spectral chopping techniques, are planned for this instrument. It will have more advanced technologies than those of MAC I and II. For example, the high-thermal-conductivity objective mirror will be actively cooled to minimise mirror seeing. Electrostatic dust control will be used, both for the air flow system within the tube and for the objective itself. An addressable LC pupil mask will be actively controlled to suppress light scattered at the objective surface. MAC III should be especially useful for IR studies. The design of this instrument represents overall the preferred optical system for a reflecting coronagraph, with full achromaticity and allowing UV and IR observations to the full extent of atmospheric transmittance, mirror reflectance and available detectors.

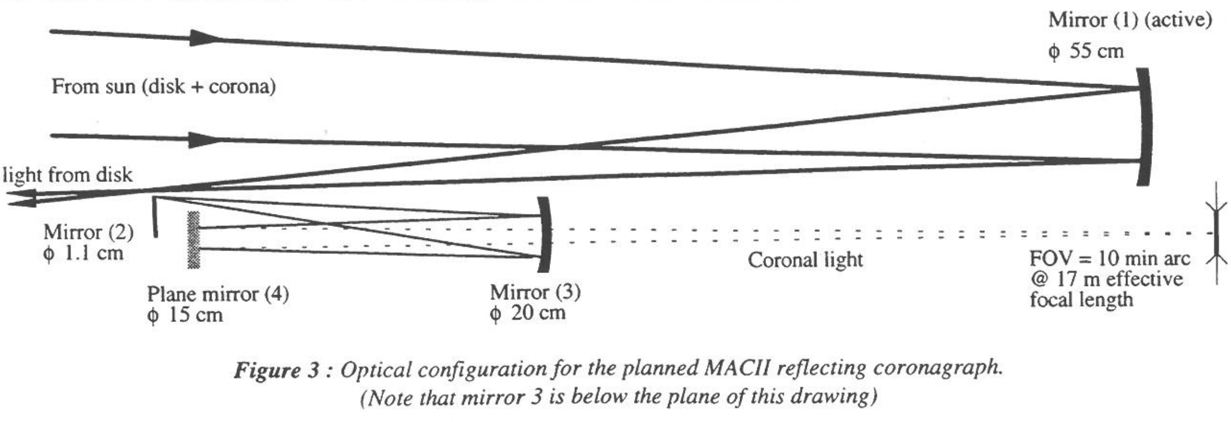

***Figure 3 :** Optical configuration for the planned MACII reflecting coronagraph.*
(Note that mirror 3 is below the plane of this drawing)

3.2 SWATH Coronagraph

For the proposed SWATH (Space Weather and Terrestrial Hazards) mission, a novel white-light coronagraph has been constructed at NSO/SP [24]. Mission objectives for the coronagraph are to study transient coronal disturbances and to explore the feasibility of detecting space debris in the sub-cm range of particle sizes.

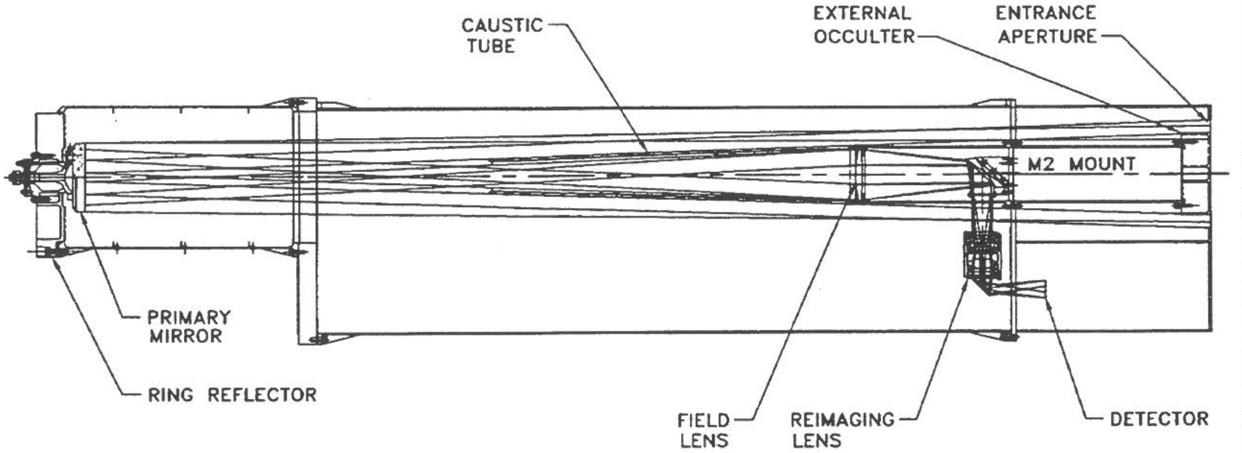

***Figure 4**: SWATH Coronagraph optical system in which light enters from the right through the annular entrance aperture. The external occulter shadows the primary mirror at the far left, which focuses coronal light through the field lens and secondary optical system. The ring reflector focuses the direct solar light back through the entrance aperture.*

The design, indicated in Fig. 4, uses a spherical superpolished primary mirror (100-mm diameter; 1035-mm focal length; 0.055 nm rms microroughness achieved after coating), singlet field lens, a 6-element relay lens that provides excellent correction (over a wavelength band of approximately 200 nm), and a 2048 x 3072 CCD detector.

The annular entrance aperture is formed by the centred external occulter and a surrounding serrated aperture of 160-mm diameter, giving a field-of-view of 1.5 - 6.0 R_o, with 100% obscuration at 1.5 R_o, and 30% at 6 R_o. The effective focal length of the entire system is 354 mm with an overall focal ratio of 3.5 and a depth of field of ~ 25 μm. The inner field limit of 1.5 R_o provides a safe margin in the case of unexpected spacecraft pointing errors, while also minimising scattered light problems.

The primary mirror is surrounded by an annular toroidal mirror that rejects the direct solar light by focusing it to a narrow ring at the plane of the entrance aperture. This special mirror, and also the external occulter, are diamond-turned and polished to produce low-scatter reflecting surfaces, critical for efficient coronagraph performance.

4. CLEAR

The above discussion of the MAC program highlights the need for larger aperture coronagraphs to produce higher angular-resolution and higher photon-flux imaging. Further, there is considerable interest in obtaining observations of faint emission associated with different types of nighttime objects. Examples are the study of reflectance spectra of solar system objects such as planetary rings and outer satellites, white dwarf companions of binary systems, searches for protoplanetary disks around stars, and the study of other faint emissions associated with some stellar, galactic and extragalactic objects. A low-scattered light telescope (without occulting) would also be very useful for near-IR molecular line studies on the solar disk. A dual-purpose (solar and nighttime applications) coronagraphic telescope with an aperture of two or more meters has therefore been proposed as the final stage in this program [22,23]. A phase-A engineering study for such a new-generation solar telescope called CLEAR (Coronagraphic and Low Emissivity Astronomical Reflector) is currently under way under the direction of J. M. Beckers, NSO Director. We will discuss briefly the key design parameters being considered for this proposed new telescope[25].

An overall optical configuration similar to MACIII is envisaged, with a single imaging element before the prime focus, a broad wavelength coverage, ideally from 380 nm to 3500 nm, high angular resolution (<0.1 arcsec in visible over small fields), low emissivity (<3% at 1000 nm), and low scattered light (< 3 x 10^{-6} at 1 R_o, or 1.6 arcmin, above the solar limb). A superpolished (< 0.5 nm), off-axis paraboloidal primary objective mirror of 2-4 m diameter and 15-m focal length is proposed, with an f/63 Gregorian f/ratio and an f/65 Coude f/ratio. Material for the primary objective is likely to be zerodur or ULE. It will be thermally controlled to avoid mirror seeing. Superpolishing of large aspheres to the quality required is extraordinarily difficult, but has already been achieved for some space optics (for example, the AXAF mirror). The actual wavelength coverage achieved will be determined principally by the properties of the coating applied to the objective, with primary requirements of low scattered light, and low emissivity at IR wavelengths (if a compromise is required, the specification for UV coverage would be dropped). Instrumental polarisation should be small (P < 1%; $\Delta\varphi$ <

0.25°). Image quality will be maintained via a tip-tilt mirror (to correct image motion), and an adaptive optics system (for instantaneous wavefront correction). Finally, as a practical method to minimise the problem of dust accumulation on the primary objective, the telescope will be enclosed in a tube with properties similar to that of a clean room, including air filtration, thermal control to minimise internal seeing, and operating with a slight overpressure to prevent external dust from entering the CLEAR system.

Finally, the above discussion outlines the path for major advances in ground-based solar astronomy through new-technology telescope designs as embodied, for example, in the CLEAR concept.

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Corporate Membership Address List

Australian Holographics Studios Pty Ltd
PO Box 160
Kangarilla
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AVIMO Electro-Optics Pty Ltd
14 Fifth Lok Yang Road
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Tel: 65 265 5122
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9a High Street
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TN6 2QA, UK
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Fax: +44 1892 664483
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PO Box 359
Southport, QLD, 4215
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Fax: 03 761 5600

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Fax: 02 318 2192

Atom Optics with Laser Light

V.I Balykin and V.S. Letokhov
Laser Science and Technology Vol. 18
Harwood Academic Publishers GmbH,
Chur Switzerland, 1995
x + 111, r.r.p. $72 (paperback)
ISBN 3 - 7186 - 5697 - 3

Atom optics is an expanding field whose rapid development over the last decade or so has outstripped those who may have been motivated to produce an introductory (let alone definitive) work on the field. Two previous Russian books (one involving the second author in the present volume) have laid some of the groundwork through the development of the concepts and applications of laser light forces, but these have fallen short of a general introduction to atom optics. It was with some anticipation, therefore, that I approached this particular volume authored by two major contributors to the field.

Atom optics is a dramatic realisation of the complementarity principle whereby the wavelike nature of atoms enables the development of the exact analogues of optical elements for light. Mirrors, gratings, beamsplitters and collimators have been generated, which have been used to assemble practical devices such as atom interferometers that have already been employed to measure acceleration, field gradients and collisional phase shifts with great accuracy. The existence of internal atomic structure has enabled the use of laser light forces to create many of these atom optical components. More importantly, these special atomic properties (such as spontaneous emission which yields dissipative processes), has enabled atom optics to go beyond conventional light optics to generate completely new applications such as laser cooling and trapping. This has led to the production of the coldest known temperatures (several nanoKelvin), and the recent realisation of one of the "holy grails" of modern physics: Bose-Einstein condensation (BEC).

The present book contains some, but by no means all of these developments. It commences with a general introduction to the concepts of atom optics and the use of laser radiation forces to manipulate atoms. Applications of these principles are then treated under the following chapter headings: collimation, focusing, channeling, reflection and atom cavities. The general emphasis is on alteration of the atomic centre of mass motion rather than the de Broglie wavepacket, and consequently the book does not deal with devices such as atomic beamsplitters and interferometers. It also appeared too early for BEC.

Although the narrowness of the subject matter belies the title, it is clear that the book fulfills the aim of the publication series outlined in the preface: "When a sufficient number of tracts devoted to a specific field have been published, authors will update and cross-reference their pages for publication as a volume of the handbook". Consequently, the book appears as a compendium of the collected works of the authors, both of whom have contributed significantly to these sub-areas. Indeed, many of these developments were pioneered or suggested by Balykin and/or Letokhov. Historical introductions have been included where appropriate, and while it is pleasing to see mention of Australian contributions to this field, the referencing is not exhaustive.

While therefore falling short of initial expectations, this slim volume nevertheless is a useful introduction to the topics presented. From an editorial viewpoint it is a little rough around the edges, and the diagrams are tersely captioned and relatively low-tech in this age of desktop publishing. But if you are a new worker in the field, or an interested observor after a flavour for some of the potential of atom optic devices, then this book would be a useful starting point.

K. Baldwin
Laser Physics Centre
Research School of Physical Sciences and Engineering
Australian National University

1996-1997 Meetings Calendar at a Glance

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NW Washington DC 20036,USA
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WA 98227-0010, USA

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Email : spie@mom.spie.org
SPIE *(http://www.spie.org/)*

Date	Meeting	Contact	Location
July 1	**12th Australian Institute of Physics Congress**	AIP	Hobart, Australia
July 7	**Summer Topical Meetings**	OSA	Maui, Hawaii.
July 10	**Optical Amplifiers and their Applications.**	OSA	Monterey, California
July 14	**International Quantum Electronics Conference (IQEC '96)**	OSA	Darling Harbour, Sydney
July 29	**Applications of Photonic Technology (ICAPT'96)**	OSA	Montreal, Canada
Aug 4	**Symposium on Optical Science, Engineering, and Instrum.**	SPIE	Denver, Colorado
Aug 19	**International Commission for Optics (ICO XVII)**	ICO	Taejon, Korea.
Aug 22	**Photon Correlation and Scattering**	OSA	Capri, Italy
Aug 25	**Organic Thin Films for Photonic Applications**	OSA	Orlando, Florida
Aug 26	**ICHOIP '96, Holography and Optical Inf. Proc.**	OSA	Nanjing, China
Aug 27	**IWI '96, Internat. Workshop on Interferometry**	ICO	Wako, Japan
Sept ?	**Nonlinear Guided Waves and Their Applications**	OSA	United Kingdom
Sept 9	**CLEO/EUROPE**	OSA	Hamburg, Germany
Sept 7	**Biomedical Optics IV**	SPIE	Vienna, Austria
Sept 15	**Optical Communication**	OSA	Oslo, Norway
Oct 7	**Imaging Sciences and information Services**	OSA	Berlin, Germany.
Oct 15	**Optoroute'96-Photon'96 (Information highways)**	OSA	Grenoble, France
Oct 20	**OSA `96 Annual Meeting**	OSA	Rochester, N.Y.
Oct 20	**Optical Fiber Communication (OFC '97)**	OSA	Dallas, Texas
Oct 20	**Interdisciplinary Laser Science (ILS-XII)**	OSA	Rochester, N.Y.
Oct 22	**Ocean Optics XIII**	SPIE	Nova Scotia, Canada
Oct 27	**High Speed Photography, Videography, and Photonics**	SPIE	Sanat Fe, New Mexico
Nov 4	**Photonics China '96**	SPIE	Beijing, China
Nov 18	**Photonics East**	SPIE	Boston, Massachusetts
Dec 1	**ACOFT'96 Australian Conference on Optical Fibre Technology**	-	Gold Coast, Queensland
Dec 10	**Photonics and Fibre Optics (Photonics India 96)**	SPIE	Madras, India
	1997		
Feb 8	**Photonics West '97 (Inc. Optoelectronics,LASE '97,BiOS'97,EI'97)**	SPIE	San Jose, California
Feb 16	**Optical Fiber Communication (OFC '97)**	OSA	Dallas, Texas
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Mar 2	**Smart Structures and Materials**	SPIE	San Diego, California
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April 20	**AeroSense : Aerospace/defence sensing and controls**	SPIE	Orlando, Florida
April	**Photomask Japan**	SPIE	Kawasaki City, Japan
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June 16	**EUROPTO Series : Environmental sensing III**	SPIE	Munich, Germany
June 20	**Lasers and Optics for Research and Manufacturing III**	SPIE	Munich, Germany
July 27	**SPIE Annual Symposium**	SPIE	San Diego, California
Sept 9	**EUROPTO Series: BiOS Europe V (Biomedical optics)**	SPIE	Italy
Sept 17	**Photomask Technology and Management**	SPIE	Santa Clara, California
Sept 22	**EUROPTO Series: Satellite remote sensing IV**	SPIE	France
Spet 28	**Photonics East**	SPIE	Philadelphia, Pennsylvania
Oct	**Micromachining and microfabrication**	SPIE	Austin, Texas
Oct	**Microelectronic Manufacturing**	SPIE	Austin, Texas
Oct	**Applied Imagery Pattern Recognition Workshop**	SPIE	Washington, DC
Oct 11	**OSA'97 Annual Meeting**	OSA	Long Beach, California.
Oct 11	**Interdisciplinary Laser Science (ILSC-XIII)**	OSA	Long Beach, California

Highlights of the IQEC '96 Technical Program

PHYSICS OF COHERENT LIGHT SOURCES

More than 80 papers represent some of the latest advances in laser physics with emphasis on semiconductor, crystalline solid state and fibre lasers, and UV and XUV lasers. K.Eberling (Ulm) will report recent demonstrations of highly efficient vertical cavity diode lasers, and B.Chai (CREOL), G.Huber (Hamburg) and A.Kaminski (Inst of Crystallography, RAS) will discuss recent developments in solid state laser materials. K.Weingarten et al (ETH, Switzerland) will report novel pumping geometries yielding 1 Watt cw power from a diode-pumped Cr: LiSAF laser, and P.Toschek and colleagues (Hamburg) will present new results for diode-pumped visible Pr^{3+} fibre lasers in a session highlighting continuous improvements in the performance of all-solid-state lasers. Progress in development of UV Ce^{3+} flouride lasers will be described by D.Coutts (Oxford), and of the "Titania" 10 TW KrF laser system by J.Lister et al (Rutherford Appleton Lab). New results on XUV generation in gases based on femtosecond optical pulsing techniques will be presented by S.Hooker et al (Stanford).

LASER SPECTROSCOPY & PHOTODYNAMICS

Highlights of the Laser Spectroscopy and Photodynamics Section of IQEC'96 include recent developments in high precision laser spectroscopy. T.Hansch (Munich) will report on a determination of the absolute frequency of the 1S-2S two photon transition in hydrogen using a phase-coherent optical frequency chain with an accuracy surpassing the best previous measurements by more than an order of magnitide. J.Hall (Boulder) will describe a precision determination of the natural linewidth of the sodium $3^2P_{3/2}$ level using a sample of Raman velocity-selected ultra-cold sodium atoms, thus resolving a long-standing discrepancy between experiment and theory. P.Fisk (CSIRO, Sydney) will report the performance of a 12.6 Ghz microwave frequency standard based on $^{121}Yb^+$ ions confined in a linear Paul trap which currently has a fractional frequency stability of better than 2 parts in 10^{15} and an accuracy approaching one part in 10^{13}. W.Demtroder (Kaiserslautern) will describe recent investigations of sub-Doppler spectroscopy combined wth molecular beam techniques and mass spectroscometry to obtain information about the structure and dynamics of small molecules and clusters. Other highlights include papers on laser spectroscopy of alkali atoms in superfluid helium (T.Yabusaki, Kyoto); the use of polarised laser pump-probe techniques to study the state-resolved differential cross-sections and rotational alignments for simple atom-plus-molecule reaction products (M.Brouard, Oxford); and the spectroscopy of ionisation products in pulsed laser ablation of superconductive, ferroelectric and metallic films (E.Arimondo, Pisa).

ATOM OPTICS

The possibilities to manipulate atoms with light continues to make spectacular progress. Atoms can be trapped and cooled to temperatures lower than any other matter has been: less than 1 millionth of 1 degree kelvin. Cold atoms have peculiar properties: they show the features of waves, that can be reflected and diffracted. Atom interferometers are now used as precision instruments. There are now proposals for optical components - using both light fields and magnetic fields - resulting in close to perfect mirrors and grating.

In addition atoms show quantum behaviour. The cold atoms act like one big quantum system. They form a Bose Einstein condensate, which has properties unlike all other materials. Quantum physics dominates this macroscopic systems. Many proposals are made to utilise and to understand the quantum features: Heisenberg microscopes use the uncertainty principle, and finally it might be possible to build an atomic laser.

The atom optics symposia and general sessions at IQEC '96 feature the world's leader in this exciting area.. The plenary by Eric Cornell (JILA-NIST) is followed by sessions on laser cooling with invited papers from S.Chu (Stanford), E.Piek and C.Cohen-Tannoudji (Laboratoire Kastler Brossel), and P.Hannaford et al (University of Melbourne). The symposium on Bose-Einstein Condensation has invited papers from the gourps at MIT, University of Oxford, University of Konstanz and Kurchatov Institute/University of Amsterdam. Sessions on atom optics include invited papers from D.Heinzen (University of Texas, Austin), F.Shimizu (University of Tokyo), and C.Kurtsiefer et al (Konstanz).

QUANTUM OPTICS

For two decades quantum optics has been an extraordinary source of innovation, from fundamental tests of quantum principles to proposals for ultra-high precision measurements. The continuing activity of the field is evident in this program where ground-breaking results in areas as diverse as quantum computing and crytography, quantum measurement and gravitational wave detection are presented. A symposium on gravitational wave detection features invited papers detailing progress in the world's leading groups; speakers include J.Sandeman (Australia), A.Brillet (France), S.Whitcomb (USA), H.Welling (Germany) and S.Bagayev (Russia). Progress towards experimental realisation of quantum computation will be described by S Barnett (Strathclyde) and J Cirac (Castilla). The symposoium on quantum measurement includes invited papers by S.Haroche (Paris), W.Schleich (Ulm), G Breitenbach et al (Konstanz) and P.Knight (Imperial College). Latest experimental results of lasing without inversion will be described by E.Fry of University of Texas at Austin, and H.Kimble (Caltech) will review the phenomena arising in cavity QED.

OPTICAL MATERIALS AND DEVICES

This session covers a broad range of activity in materials and devices including new semiconductor materials and devices, solid state laser materials, fibres, photorefractives and glasses. The session is headed up by some very significant developments in the infrared through invited talks by Capasso and Elliott. Capesso (Bell Labs, USA) will describe the revolutionary Quantum Cascade Laser which employs band-gap engineered semiconductors to produce infrared lasing. Elliott from DRA, (Malvern) has produced a series of new optoelectronic devices based on InSb by extracting intrinsic carriers to produce extrinsic material. Another new device to hit the headlines is the VCSEL (vertical cavity surface emitting laser). Gourley (Sandia National Laboratory) will describe the use of these lasers to study biological processes. Cascaded optical nonlinearities look promising for all optical switching and their use is organic materials will be reviewed by Torruelles from CREOL. Photonic band gaps have also shown a dramatic rise in activity: Campillo (NRL) will discuss new photonic band gaps fabricated in glasses.

Advances in both nonlinear optical materials and laser sources

in recent years A symposium on Optical parametric Sources covers advances in both optical parametric oscillators (OPO and optical parametric amplifiers (OPA). M.Dunn from St Andrews, Scotland will review OPO's with cw to fsec outputs while A.Piskarskas (Vilnius) will discuss OPA's. Periodically poled LiNbO3 providing quasi-phase matching or OPO operation has produced great excitement for cw devices in the past year and will be described in an invited talk by L.Myers and W.Bosenburg from Lightwave Electronics. Other talks will describe new tunable picosecond and femtosecond devices and applications.

NONLINEAR OPTICAL PHENOMENA

IQEC '96 has a strong program in nonlinear optics encompassing nonlinear dynamics, solitons, nonlinear optical processes, nonlinear optical materials, nonlinear optics and spectroscopy and highly nonlinear optical effects. The first three report exciting recent progress in the more traditional areas, the session on solitons including invited papers by M.Segev (Princeton), G.Stegeman et al (CREOL) and V.Tikhonenko et al (Australian National University). B.Eggleton (Sydney) will describe recent experimental observations of grating solitons in optical fibres. In the nonlinear optical materials session, several papers including an invited paper by C.Zhang et al (Hong Kong) will describe the application of optical second harmonic generation to studies of semiconductor surfaces and interfaces and metal clusters. In nonlinear optics and spectroscopy, nonlinear optics of single molecules will be discussed by M.Orritt (CNRS, Bordeaux). In highly nonlinear optical efects, invited talks by S.Watanabe (Tokyo) and R.Schoenlein (Berkeley) will cover the topics of generation of ultrashort X-ray pulses, one by Compton scattering and the other by high harmonic generation in gases. There will also be many other related sessions and symposia for example, covering lasers without population inversion, and physics at high laser intensities.

OPTICAL INTERACTIONS WITH CONDENSED MATTER

The five sessions of the scientific program cover a broad range of laser induced phenomena in condensed matter. Coherent optical interactions with atoms in solid environment will be discussed in the invited talks of S.Rand, Ann Arbor and D.Suter, Dortmund. A Kummrow, Berlin and other speakers will present new results on the ultrafast coherent dynamics and femtosecond photochemistry of large molecules in liquids. The major part of the program is devoted to semiconductor physics. The main topics are ultrafast coherent spectroscopy of elementary excitations in semiconductors, nonequilibrium dynamics of carriers, and optical studies of low-demensional semiconductors and microcavities. Both coherent oscillatory polarizations and dephasing processes are studied by a variety of experimental techniques, including four-wave-mixing, transmittive electro-optic sampling and Thz emission, as discussed - for instance - in the invited presentation of P.Leisching, Palaiseau. The session on carrier dynamics includes new experimental and theoretical results on electron dynamics in low-dimensional systems and on the terahertz response of high-T superconductors. New techniques of microscopy are applied to realize local optical probes of microstructures and devices. Polariton splitting and propagation in microcavities and quantum well waveguides are the subject of several talks, including the invited paper of M Shirai, Tokyo (Japan). These topics are complemented by a number of reports on optical processing of materials.

ULTRAFAST PHENOMENA

In the area of ultrafast phenomena, three sessions will cover advances in high-intensity physics,generation and measurement of ultrashort pulses, and applications inmaterial dynamics. Highlights of the symposium on Physics at High Intensities are reports of recent developments in generation of ultrashort (10-50 fs) pulses in the soft X-ray region, and in laser-particle Wakefeild acceleration. The general sessions will highlight new advances in ultrashort source development and measurement techniques, new nonlinear materials, and applications of ultrashort pulses to study of dynamic processes in materials. Invited speakers include W.Sibbert (St Andrews), R.Trebino (Sandia National Labs) and B.Luther-Davies (Australian National University).

ADVANCED PHOTONICS AND OPTICAL COMMUNICATIONS

This important topic area is an exciting addition to the IQEC program. Sessions will encompass latest developments in optical switching, photonics systems, lasers for optical communications and lightwave devices. Invited speakers include T.Kimura (NEC), who will discuss the shape of photonics systems in the 21st century, and J.Yoshida (NTT), describing recent progress in the application of integrated optics to devices in optical communications systems. M.Erman (Alcatel Alsthom) will describe advanced optoelectronic technologies for optical switching and signal processing, and K.Lau (UC Berkeley) will discuss the physics of multi-quantum well lasers. Advanced optical frequency converters for lightwave communications networks will be described by R.Tucker (Melbourne)

APPLICATIONS IN BIOLOGY, CHEMISTRY AND ENGINEERING

Laser technology has extensive applications and their requirements have further stimulated the development of laser technology. The application area covered by the present IQEC includes: combustion processes, material processing, biological and medical applications, environmental sensing, and high precision measurements, as well as basic research in physics and chemistry. Invited speakers include D.Rakestraw (Sandia National Labs) in the area of combustion diagnostics, H.Masuhara (Osaka) in the area of microfabrication, J.Wolfrum (Heidelburg) and A.Lauto (Macquarie University) in biological applications of lasers, and F.Tittel (Rice University) and H-L.Chen (Lawrence Livermore) in the area of industrial sensing and processing. Laser technology has also stimulated the development of advanced imaging and microscopic techniques which provide the theme of a special symposium which includes invited papers from S.Hyde et al (Imperial College), S.Weiss (UC Berkeley) and V.Letokov (Inst. of Spectroscopy, RAS)

Full details of the IQEC '96 Technical Program, and registration and accommodation booking information are contained in the IQEC '96 Advance Program, which can be obtained from :

IQEC '96 General Chair,
Prof Jim Piper,
Centre for Lasers and Applications,
Macquarie University,
NSW 2109 Australia
Tel: +612 850 8911
Fax: +612 850 8983
email: jpiper@mpce.mq.edu.au

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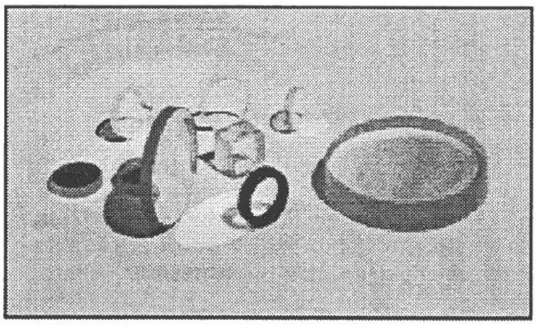

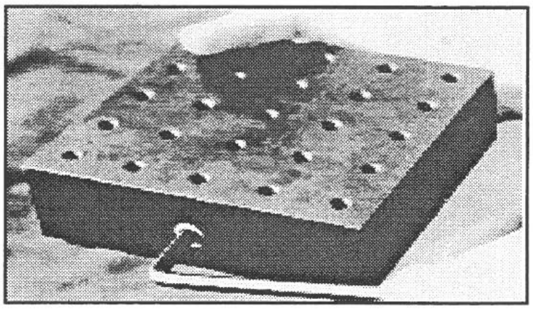

For more information please contact::

Svetlana Karaganova
A.H. Studios P/L
P.O.Box 160
Kangarilla, S.A. 5157
Australia
Tel: 08 383 7255
Fax: 08 383 7244
e-mail: austholo@camtech.com.au

or *Mikhail Grichine*
Geola UAB
P.O.Box 343
Vilnius 2006
Lithuania
Fax/Tel:+370 2 232 838
Tel: +370 2 232 737
e-mail: Mike@lmc.elnet.lt

Atom Optics Cairns96

Two overlapping satellite meetings will be held just prior to IQEC'96 in Palm Cove, Cairns, North Queensland, Australia.

Quantum Optics 8 - 9 July 1996
Atom Optics 9 - 11 July 1996

Program:
These meetings complement the IQEC program. The presentations will be more technical or speculative in nature. The schedule will allow ample time for discussions. The programs of the two meetings overlap on Tuesday, when topics such as Bose Einstein Condensation will be presented. The program contains invited and contributed talks and poster sessions. Already more than 50 contributions have been registered already. Applications for innovative and original contributions.post deadline contributions are welcome, please enquire with the organisers.

Topics:
Quantum information theory and quantum computations
Bose Einstein Condensation
Laser cooling and trapping
Quantised motion
Atom lasers
Atom interferometry
Applications of atom optics
Neutron and electron optics

Venue:
The NOVOTEL Palm Cove Resort,
Cairns, North Queensland
AUSTRALIA.

Invited speakers include:
S. Chu (Stanford)
A. Aspect (Paris)
K. Burnett (Oxford)
C. Cesar (Fortaleza)
D. Walls (Auckland)
J. Mlynek (Konstanz)
F. Shimizu (Tokyo)
W. Ertmer (Hannover)
M. Kasevich (Stanford)

Please contact: Prof.H-A.Bachor, Physics Department Faculties, The Australian National University.
Tel: + 61 6 249 2747 Fax: +61 6 249 0741
e-mail: hans.bachor@anu.edu.au

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Dr Esa Jaatinen,
Hon. Treasurer AOS,
CSIRO,
Division of Applied Physics,
PO Box 218,
Lindfield 2070, AUSTRALIA
Tel: 02 413 7269 Fax: 02 413 7200
EMAIL: esaj@swifty.dap.csiro.au

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First ______ Second ______ Third ______

1 astronomical optics
2 atmospheric optics
3 communications and fibres
4 electro-optics
5 fabrication and testing
6 information processing
7 lasers
8 optical design
9 optical physics
10 radiometry, photometry & colour
11 spectroscopy
12 thin films
13 vision
14 quantum optics
15 nonlinear optics
16 teaching
17 holography
18 (.......................................)
19 (.......................................)
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