OPTICS:

HIGHLIGHT OF

THE FUTURE

a report by

the Australian Optical Society

on

the current status
and future directions
of optics in
Australian
industry, research and society

March, 1994

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1. EXECUTIVE SUMMARY

The Australian Optical Society (AOS) has prepared this report to demonstrate the key role that optics plays in modern Australian society. To underpin this document, the AOS has undertaken a National Optics Survey of organisations in the following sectors:

- government laboratory research
- university research
- the optics industry

The AOS has used this information to compile a database which reveals the importance of optics to the culture, wealth generation and employment capacity of this country. The conclusions arising from this document can be summarised as follows:

o Optics is an enabling science and is an important component of modern, high technology societies and economies

o Both in research and industry, optics is a major growth area of modern science and technology that shows no signs of abating in the foreseeable future.

o Australia has considerable quality, breadth and depth in optics research, which contributes to its high standing in the international optics community, and to its capability for underpinning industrial applications of research in optics.

o Optics is a growing contributor to employment and wealth generation in Australia

o Optics is an appropriate industry for Australia in terms of its scale, relation to the strong optics research base, and its low environmental impact

This report contains the following major recommendation

RECOMMENDATION: THAT OPTICS BE MADE A PRIORITY AREA FOR NATIONAL INVESTMENT IN SCIENCE AND INDUSTRY

On behalf of the Australian Optical Society, I commend this report to you.

(Signature)

Dr. Ken Baldwin,
President,
Australian Optical Society

2. INTRODUCTION

Optics as a Field of National Economic Importance

Optics is one of the growth areas of modern physics and engineering. As a result, optics finds applications in almost every walk of life in our society, and optical devices are crucial components in many sectors of industry. The development of our modern technological lifestyle is becoming increasingly linked to developments in the field of optics. This encompasses areas that are well known in *traditional* optics:

- optical materials (glasses, crystals, thin film technology)
- optical components (lenses, mirrors, gratings),
- photometry (light measurement, colour definition)
- vision

Conventional optical components are already present in many devices and instruments which are in everyday use in our society:

- solar collectors and concentrators
- optical systems (cameras, telescopes, microscopes, photocopiers etc.)
- lighting and display systems
- eyewear

Furthermore, the new fields of *modern* optics encompass growing areas which are at the forefront of current scientific research, such as

- lasers
- fibre optics
- photonics
- optical computing
- atom optics

More importantly, the applications of modern optics increasingly underpin our social and economic well being, and are an important component of modern, high technology industry. Examples include:

- lasers in medicine (cancer surgery, laser angioplasty, eye surgery)
- optical communications (mass information transfer, optical switching)
- imaging and sensing (bar code readers, laser alignment tools)
- optical data storage (compact discs, digital cameras)
- precision measurement (laser rangers and gyroscopes, interferometers)
- holography (data storage, structural testing, security devices)
- materials processing (laser annealing, drilling and cutting)

In 1993, the sale of lasers alone had a world wide market of $A1,270 million and a projected growth rate of over 9% p.a. (*Laser Focus World, January 1994*). The market for products incorporating lasers is likely to be of the order of tens, if not hundreds, of billions of dollars.

A recent report by a panel of the U.S. National Research Council on the Future of Atomic, Molecular and Optical Science (the FAMOS report) showed that AMO science was an important enabling factor in industries accounting for around 9% of the U.S. GNP, and overall the products of AMO science influenced over 20% of U.S. GNP. The general atomic and molecular science classification incorporated many sectors heavily involved with or reliant on optics (laser spectroscopy for example) as well as some non-optics related work, but on the other hand excluded non-laser based optics from the optics component. On balance, the results of this study are therefore most likely to be generally indicative of the importance of optics to the U.S. economy.

o Optics is an enabling science and is an important component of modern, high technology societies and economies

Perhaps the single most significant example with the greatest potential to change our lives is the proposed information superhighways, which hold enormous promise for enabling the access to a world wide knowledge base in every household. These will be based entirely upon optical communications, and the information displayed, stored and processed on optical devices.

Thirty years ago, the enormous impact of lasers on modern optics and technology could not have been predicted. Even now, the full range of possible applications afforded by lasers has yet to be realised. There are also signs that other fields in modern optics, for example atom optics - where atoms are controlled with light in the same way as "conventional" optics controls light with matter - offer similar potential for new technological applications, such as gyroscopes for navigation and gravitometers for mineral exploration.

o Both in research and industry, optics is a major growth area of modern science and technology that shows no signs of abating in the foreseeable future.

3. THE AOS AND THE NATIONAL OPTICS SURVEY

The Australian Optical Society was formed in 1984 to represent the optics community and to facilitate the advancement of optics in this country. The AOS has some 300 members and corporate members representing workers in all fields of optics and drawn from many major organisations in the government, higher education and industry sectors. To facilitate the flow of information on optics in Australia, the AOS publishes a quarterly journal - AOS NEWS - which provides a conduit through which researchers, teachers and practitioners of optics can keep up to date on advances and issues in this field.

The AOS also conducts a series of national conferences which were initially held as a series of biennial stand-alone meetings. During the late 80's the AOS joined with the spectroscopy and later the laser communities to establish the ACOLS series of conferences - the Australian Conference on Optics, Lasers and Spectroscopy - which most recently had its 3rd biennial meeting in Melbourne in December 1993. Typically the participation is in excess of 300 with a number of international attendees. Optics also forms a major part of the Australian Institute of Physics Congresses, and at the 1994 Congress (to be held jointly with the Asia Pacific Physics Congress), optics will feature in at least three parallel sessions.

Such has been the expansion of activity and interest in optics in recent years, the AOS has again reverted to a series of biennial stand-alone meetings in the alternate years to ACOLS. The next such conference will be AOS X to be held in Brisbane in mid-1995. As an indication of the high prestige of Australian optics internationally, Australia will host *the* major world laser conference - the International Quantum Electronics Conference - in Sydney in 1996. The 1996 ACOLS conference will be subsumed into IQEC '96, and Australian optics researchers will play a key role in organising the conference which will further establish Australia on the international optics map.

Australia already has strong international links through with a number of learned optical societies. The AOS is recognised as the national committee for optics by the International Commission on Optics. In recent times, the AOS has established a formal joint membership arrangement with the Optical Society of America (OSA) and SPIE (the international society of optical engineers). These arrangements allow members to receive the benefits of both societies at reduced rates, enabling the dissemination of information between journals, and facilitating the attendance of international conferences organised by the societies.

The National Optics Survey

The National Optics Survey was undertaken in mid - 1993 to determine the current status of optics in Australia, and to examine the growth in research and application of optics during the period 1987 - 1992. Organisations which were involved in optics research, development, innovation or manufacturing were surveyed, but many more organisations which simply used optical components in a routine fashion as a small part of a wider process were not included. Hundreds of individuals and organisations were contacted, and the responses collated to build an integrated picture of organisations involved with optics in Australia.

While most organisations involved in optics teaching, research or industry responded to the document, there were a few exceptions which declined, primarily due to company confidentiality. All the information displayed in this survey has been checked with the originating organisation for verification and is, to the best of our knowledge, correct at the end of 1993 for the periods indicated.

The results are categorised and summarised in the following sections: university research, government research and the optics industry. The descriptive information returned in the survey is presented in Appendix A, while the statistical information is tabulated by state and sector in Appendix B. The questionnaire itself precedes the two appendices.

For a more comprehensive survey of the role in Australia of lasers alone, the references listed under Wood '91 and '92 are included as an adjunct to this survey on optics generally.

4. OPTICS IN GOVERNMENT RESEARCH

Optics R&D in Australian government organisations are most strongly represented in the three southeastern mainland states and the ACT. The organisations involved are: DSTO (SA, Vic.), CSIRO (NSW, Vic., ACT), and the Australian Defence Force Academy (ACT).

DSTO employs 43 staff in optics-related areas (32 in SA and 11 in Vic.) The main effort is concentrated in SA, where three divisions have optics research programs. In Victoria, optical R&D is carried out at the Aeronautical Research Laboratory.

* The Optoelectronics Division is engaged in research and development of epitaxial growth technology and its optical applications (Photonics Devices Discipline), as well as research into a wide range of laser devices with potential military applications e.g. optical power limiters (Active Sensing Discipline).

* The Communications Division is researching into a wide range of optical technology for signal processing.

* The Electronic Warfare Division applies a variety of optical techniques to the solution of wide bandwidth signal processing and infrared signature processing.

* The Aeronautical Research Laboratory has optics-related areas of work which include flow visualisation, laser doppler velocimetry, deformation and defect measurement, visual displays, guidance, night imaging and microscopy.

CSIRO employs 86 staff in optical research and development, of whom almost half are in the Division of Applied Physics (NSW). Four other divisions in NSW, plus three in Victoria and one in the ACT, account for the remainder.

* The Division of Applied Physics devotes about half of its optics R&D effort towards the maintenance of national standards. Activities include thin films, optical fabrication and testing, profiling, holography, image processing, diffraction gratings, length measurement, fibre sensors, and radiometric, photometric and frequency standards.

* The Division of Exploration and Mining is doing research on the use of optics and lasers for mineral and mineface mapping and remote sensing.

* The Division of Manufacturing Technology is engaged in research on the use of high power lasers for heat processing and machining. Optical fibres are used for some applications.

* The Division of Mineral and Process Engineering uses lasers and optical techniques for in-line analysis of minerals and coal, and for processing and production control.

* The Division of Wool Technology is developing optical instruments for measuring fibre, web and yarn properties such as fibre diameter and diameter distribution.

* The Division of Materials Science and Technology carries out optical design and analysis, high precision laser spectroscopy and atom cooling and trapping, thin film design and fabrication, optomechanical design, and manufacture of optical components and complete instruments, many of which are for remote sensing applications.

* The Division of Environmental Mechanics uses optics for research in flow measurement and visualisation, and for soil structure analysis.

* The Division of Building Construction, and Engineering utilises optics and lasers in flow visualisation and combustion laser diagnostics. (The Division of Atmospheric Research at Aspendale also uses LIDAR and flow visualisation.)

Optical research has expanded considerably in the government sector during the surveyed period

(1987 - 1992) reflecting the increasingly important role of optics as an enabling technology. This expansion is evidenced by the increase in optics personnel and research budgets, but more importantly by the generation of significant export earnings. As shown in the Highlights section, the role of government research in generating new products of major commercial significance is a well documented contribution to the national economy.

5. OPTICS IN UNIVERSITY RESEARCH

1. Introduction

The summary numbers tell the story of the rapidly increasing importance of optics in Australian universities. Research using optics and developing optics has taken on a high profile in the country's science and engineering. This activity is not surprising when considered in terms of the suitability of such a field to a nation with an economy the size of Australia's. The establishment of a world class optics laboratory is in the low to medium cost scale, typically of the order of M$1 or less. With this capital investment, Australian university scientists are repeatedly producing results that are at the forefront of discoveries in the international context. The added importance as far as optics is concerned, is that much of this research can be realised commercially.

An indication of the importance of the optical community to Australia research in terms of applications is the awarding of CRC status to the Australian Photonics Cooperative Research Centre - the only CRC in physics. This is the largest of the CRC's with participation not only from the Universities of Sydney and Melbourne and the Australian National University, but also from an impressive array of national and international companies.

Also recognising the strength of optics research in Australia was the awarding of Special Research Centre status to the Centre for Lasers and Applications at Macquarie University.

2. Data Summary

The data which is collated by state or territory in the Appendix, shows a dramatic increase in commitment to, and investment in, optics research in the five years 1987 to 1992. The number of research scientists and engineers involved in optics or related research has increased from fewer than 100 to greater than 200. In 1992, there were nearly 200 research students compared with approximately 72 in 1987. It was estimated that the capital invested in optics and related research in Australian universities was almost M$30 in 1992, with grants to these groups from all sources (including the ARC) approaching M$12 annually and total budgets well above this amount.

3. Research Areas

University research in optics is spread across applied and fundamental areas. These activities have been coarsely classified into areas and are briefly described below.

(a) Optical Fibres and Photonics

One of the major advances in this technology in Australian universities is the development of facilities for the design, fabrication and testing of specific optical fibres. This activity includes the research and development of next generation components and devices including optical switches, fibre lasers and fibre amplifiers. These devices are of importance to the advancement of photonics. Photonic devices and circuits are being developed for application to very high bit rate optical communication systems and networks including local and metropolitan area networks for delivery of pay television etc. Other research is being undertaken into nonlinear optical materials and devices with applications to all optical switching. This work is at the leading edge of technology for the future and has enormous potential to deliver significant export earnings.

(b) Lasers and Applications

The manufacture of new laser systems has already proven an export earner for Australia and it is the research and expertise contained in universities that has underpinned this development. Lasers ranging from semiconductor, solid state and CO_2 systems operating in the infrared, to metal vapour and rare gas lasers operating in the visible and ultra violet, are being researched and developed. The application of laser technology is prevalent, particularly in non-destructive testing and diagnostics. High precision machining of polymers using ultraviolet lasers, the study of man - made plasmas and hypersonic gas flows using laser diagnostics, medical diagnostics employing lasers, and holography are just some of the research topics undertaken in universities in which laser technology is directly applied.

A major recommendation of the FAMOS report was to make a priority for "research that promises new and improved lasers and other advanced sources of light for a broad range of applications and for furthering studies of the properties of light and its interaction with atoms and molecules".

(c) Conventional Optics

The field of conventional optics plays a role of ever increasing importance. Diverse activities such as microscopy, imaging, optometry, solar collectors and astronomy are ongoing activities in Australian universities.

A wide variety of specialist microscopes are currently under development in a number of active research groups which are as likely to be in departments of physiology and anatomy as in departments of physics. Many hospitals are also very active as there is promise, using advanced imaging techniques, for developing methods for the early detection of diseases such as glaucoma. Optometry both as a public service and as a research field is the topic of activity at several universities.

Astronomy is also dependent on high quality optics as highlighted by the custom precision optics, lasers and quantum imaging devices used by the Sydney University Stellar Interferometer. The development of suitable optical components is essential to the advancement of solar energy technology which has the potential to both deliver cheap and efficient electricity to Australians and to become an export earner.

(d) Vision

The study of vision spans scientific disciplines from mathematics to physiology. Understanding the processes of pattern recognition and visual processing will have implications in problems associated with machine vision such as range sensing and measurement of optic flow. There is growing interest and activity in Australian universities in research in this area which is evolving as an important component in high technology industry.

(e) Atomic and Molecular Physics and Quantum Optics

This predominately fundamental area of research is important to optics in two ways. Firstly, most modern methods of investigating processes in atomic and molecular physics involve the use of state of the art lasers together with high quality optics. Secondly, major advances in modern optics have emanated from this area. For example, the discovery of optical bistability in atomic sodium was the precursor to the field of photonics. Atomic physics gave the world the laser and, more recently, squeezed states. The list can be continued. Research in atomic and molecular physics and quantum optics is an area of strength in Australian universities which has international reknown.

(f) Particle and Atom Optics.

Over the last ten years there has been explosive growth of worldwide interest in the optics of massive particles such as atoms and neutrons. Although predominantly concerned with exploring the foundations of physics, as evidenced by the significant involvement of Australia's strong quantum optics community, practical applications are increasingly being recognized. These applications are primarily concerned with realising the analogues of conventional optics for light, and extending this to further applications which arise from the wavelike nature of matter, such as atom interferometers. Australia has an admirable international reputation in this area and so is well positioned to benefit from any commercial spin-offs that result. The very widespread use of electron and proton imaging by both research establishments and industry should also be included under this heading.

The highest research priority in the recommendations made by the FAMOS committee was "to promote research that promises new technologies through the invention and development of

techniques and instrumentation to better control and manipulate atoms, molecules, charged particles, and light for a broad range of applications".

(f) X-ray Optics.

This area is of considerable importance as it not only services fundamental studies in materials science and astronomy but also underpins the areas of medical imaging, industrial inspection and advanced materials development. Many of the experimental techniques in x-ray optics, although common in principle with other areas of optics, present a unique set of challenges. The widespread importance of x-ray optics to Australian Science and Technology has been recognized with the recent establishment of the Australian National Beamline Facility at a synchrotron in Japan.

The presence of major international strengths in Australian optical research in a number of areas with significant technological applications again emphasises the important contribution of optics as a truly enabling science for the advancement of the national economy.

6. OPTICS IN INDUSTRY

The information presented in the summary statistics for industry are perhaps the least complete of the three categories, with almost 100% returns being received from the University and Government research sectors. The figure was much less for the private sector, due perhaps to a combination of commercial confidentiality, time constraints and the attachment of less significance to a survey by a non-government organisation.

By contrast, a very complete survey of laser based industries was performed by DITAC in recent times (see Wood '91 and '92). Given the greater resources and the response commanded by DITAC, we have concentrated mainly on ensuring that canvassing of the non-laser sector was complete in our survey. Subsequently, the AOS believes it would be appropriate for the Department of Industry, Science and Technology to build on this work and perform its own comprehensive survey of optics in Australia at some future stage. Nevertheless, we have attempted here to ensure as much as possible that we have covered the full range of laser and non-laser based companies, and have accumulated what can be considered to be a large, representative sample of optics enterprises.

In the present survey, the total figures obtained from the industry sector represent a significant *underestimate* for the contribution of the optics industry to employment and wealth generation in this country. However, within this large sample base, the trends which we have derived *are* expected to be statistically valid.

The Australian optics industry is diverse and sophisticated for a country of this size. Australia has a long history of optics instrumentation manufacturing going back to the Second World War and to the development of defence and space industries which immediately followed. This trend continues with a number of companies performing defence related optics work, some of which is linked to Government research laboratories (e.g. AWA Defence Industries).

Australia has also had historical commercial success in the manufacture of conventional optics. The IMAX lens used in IMAX theatres for wide angle film projection was designed in Australia. Perhaps the greatest single example is the development of the Atomic Absorption Spectrophotometer, which has generated more in export earnings (and employment) than the entire amount invested in optics research in Australia to date (see Highlights section). Of similar scale is the manufacture of a range of eyewear products by the Sola International Holdings Research Company, which had earnt more than $200 million in exports by 1992. Added to this are a range of smaller companies manufacturing conventional precision and ophthalmic optics, indicating the strong contribution from traditional optics industries to wealth generation in Australia.

However, the major growth area in the Australian optics industry has been in modern optics, and in fibre optics communications in particular. In this context, the capability for replacement of foreign imports by home grown optical technology is as important a contribution to Australia's economic well being as export earnings. A number of companies, especially Telecom and Optus, have made enormous investments in Australian developed optical communications technology, and are supplemented by a number of smaller companies, such as Australian Optical Fibre Research which contribute to niche markets in this field. With the replacement of electrical communications technology by fibre optics, this is expected to remain a growth area as is indicated by the statistics for these companies over the five year period surveyed.

Australia also has a young and growing industry based on the development of laser technology. In addition to the plethora of laser importers and distributors, companies such as Visiray, Laserex and Laserdyne are all examples of home grown laser manufacturers. Even more importantly, there are a number of companies incorporating lasers into various optical systems which yield significant added value, such as Electro Optic Systems (see Highlights). The growth of these companies is even more spectacular than the '87 - '92 statistics suggest. In 1994, EOS now employs almost 50 personnel and has revenues of $10 million annually, mostly from exports (up from $5 million in '92). Laserex now has a total complement of 150 people with an annual turnover of $16 million (up from $4.6 million).

These strong growth trends are reflected in the statistics collected from the entire sample of the optics industry surveyed. The employment of optics scientists and engineers almost trebled in the period 1987 to 1992, while the total personnel involved in optics more than doubled. The optics budget/turnover of the companies surveyed increased by a massive 320% during this period.

However, the most encouraging aspect of the survey was that of the manufacturing companies, all but a few small operations were involved with exporting optical technology. Indeed, the total export earnings of the surveyed companies that responded alone was in the $100's of millions, and the growth rate of exports in the '87 - '92 period was 150% - an extremely encouraging performance in the national context.

7. HIGHLIGHTS OF OPTICS IN AUSTRALIA

The breadth and depth of optics in Australian industry and research represented in the preceding summaries is augmented by a number of additional indicators which point to the standard, quality and economic contribution of optics in Australia.

1. High International Standing in Research

Australia is a major contributor to international research in optics. It also has a number of areas within optics that are widely regarded internationally as major strengths, which are detailed in the summary of research activities. The FAMOS report shows that in 1989 Australia contributed around 2% of papers that cite publications in AMO journals, an overwhelming number of these journals being in optics or optics related areas. This is a contribution to international research out of all proportion to the number of optics researchers working in Australia (the AOS membership is around 2% of the OSA membership alone).

A major indicator of Australia's international research standing is the holding of major international conferences in optics and related areas in this country. Two such conferences which represent *the* major world biennial meeting in their respective fields are the International Conference on the Physics of Electron and Atomic Collisions (ICPEAC '91) which was held in Brisbane, and the International Quantum Electronics Conference (IQEC '96) to be held in Sydney.

Another indicator is the major role which Australia plays in international optics bodies. The AOS has joint membership agreements with the Optical Society of America and SPIE and is a foundation member of the Asia Pacific Optics Federation. Australia (together with New Zealand) is a joint voting member of the International Council on Quantum Electronics (the ICQE).

An Australian, Dr. W. H. Steel, was President of the International Commission for Optics (ICO) from 1972-75. Another Australian, Dr. P. Hariharan, was a Vice-President of the ICO from 1984-87 and Treasurer from 1987-93. He is also currently a Director of SPIE - the international society for optical engineering, and is founding President of the Asia-Pacific Optics Federation.

The international recognition of Australians in optics is also indicated by the award of international honours. Dr. W. H. Steel was awarded the Mees Medal of the Optical Society of America in 1985, and the same award was made to Professor H.A. Buchdahl in 1993. Dr. P. Hariharan is holder of the Fraunhofer Award of the OSA (1989), the Henderson Medal of the Royal Photographic Society London, (1990), the Thomas Young Medal of the Institute of Physics, London (1991) and the Dennis Gabor Award of the SPIE (1992). Dr. K. Nugent received an RD 100 for the joint invention of the penumbral imaging camera with workers at the Lawrence Livermore Laboratory in 1988, and Professor A. Snyder was made a Fellow of the Royal Society in 1990, to name but a few recent holders of international awards.

2. Prominence in Australian Research

Within the Australian research sector, optics has a similar high profile. This is evidenced by the awarding of the only CRC in the physical sciences to the Australian Photonics Cooperative Research Centre - the largest of the CRCs. Also recognising the strength of optics research in Australia was the awarding of Special Research Centre status to the Centre for Lasers and Applications at Macquarie University. Optical processes and laser engineering also feature strongly in another Special Research Centre in Photovoltaic Devices and Systems at UNSW, and through optical technology involved in the Astrophysics SRC at the University of Sydney.

The large proportion of ARC funding in optics is also a significant indicator of the strength of optics based research. In 1992 in the Physical Sciences Group alone, over one million dollars (11% of the total) was allocated in large grants to areas directly concerned with optics, and this excludes the contribution of optics to areas such as astronomy which are heavily dependent on

optical technology (ARC Report on Research Funding Programmes, 1992). Optics also featured in grants awarded in a number of other Groups including Chemical Sciences, Engineering and Applied Sciences (I and II), and Materials Sciences.

Optics completely dominated the 1992 Scientific Instrumentation priority group with optics based projects comprising 17 of the 33 funded proposals in *all* categories (including biology), representing $906,100 of the $1,689,000 total allocation (54%). More than a third of the items requested under the large equipment grant category in 1992 included optics based components - lasers, spectrometers, x-ray diffraction devices etc. Furthermore, 4 of the 41 collaborative grants (10%) comprised projects involving optics.

Out of the 109 ARC Fellowships awarded in 1992 in all categories of research in higher education, 8 were in optics - an outstanding number given the diversity of fields pursued, from the humanities to molecular engineering.

Despite its contribution out of all proportion to the number of researchers involved, and despite the enabling technology provided to many research categories both within and outside the physical sciences, it is interesting to note that optics features only once in a specific ARC category classification: that being Optical Electronics and Communications (16% of funded projects in Engineering and Applied Sciences II), and as a sub-category of Condensed Matter: Electronic, Magnetic and Optical (in Physical Sciences, and Materials Science and Mineral Processing). Given the importance of research in optics, and the recommendation for national priority contained in this report, it may be appropriate to specifically identify research in optics under the ARC classification scheme.

A final indication of the quality of optics research is the award of national honours. In the last 12 years, one third of the Pawsey medals awarded by the Australian Academy of Science have gone to workers in the field of optics (Prof. J. Piper, 1982, Prof. B. Luther-Davies, 1986, Prof. K. Nugent, 1989 and Dr. P.Fisk, 1994). The Walter Boas medal of the Australian Institute of Physics has also been dominated by optics researchers in recent years (Prof. A. Klein and Prof. G. Opat, 1990, Dr. P. Hariharan, 1991). Optics is also well represented in the Australian Academy of Science.

o Australia has considerable quality, breadth and depth in optics research, which contributes to its high standing in the international optics community, and to its capability for underpinning industrial applications of research in optics.

3. Success in Australian Industry

The contribution that optics plays in the wealth generating capacity of our nation has already been demonstrated in the summary section on the optics industry. The following section highlights a number of highly successful Australian commercial enterprises in optics which serve to underline the contribution of optical technology to the Australian economy. Just one example - the Atomic Absorption Spectrophotometer - has generated more export income than the total sum invested in optics research in Australia to date.

The AAS was originally developed by CSIRO scientist Sir Alan Walsh in the 1950's. We highlight here the present manufacture of this analytical instrument by one Australian company, GBC Scientific Equipment of Melbourne. Over 90% of the company's production is exported, with the instrument being sold to over 70 countries, making it the third largest manufacturer of such instruments in the world. The annual turnover of the company exceeds $30 million, with a forecast growth rate of around 45%. The royalties alone to the Australian Government from the licensing of patents up until their expiry in the 1970's was $1.5 million. The export earnings to the country now exceed $100 million, and the company employs hundreds of people in its manufacturing plants. Just one single success such as this pays off the entire historical national investment in optical technology research in a very short time.

The CSIRO has also been involved in another commercial success story - the development of optical technology for the security of banknotes and credit cards. Several generations of these optical security devices have been developed by Dr. Robert Lee from the CSIRO Division of Material Science and Technology, starting with the optically variable device on the Captain Cook $10 dollar note, and continuing with the development of more sophisticated catastrophe pixel technology. The potential market for these devices is enormous: Mastercard saved $150 million in fraud charges each year following the introduction of hologram technology, which is now itself threatened with forgery. The exporting of the pixelgram technology developed by the CSIRO could fill this niche in the counterfeit prevention market world-wide in the same way as its application to banknote security has in Australia.

Another highlight of Australian optics technology is the success of the laser instrumentation company Electro Optic Systems based in Queanbeyan, NSW near Canberra. This firm was started by Dr. Ben Greene in 1986 to develop laser ranging and tracking systems, and is now the world's leading supplier of non-military laser tracking systems, having never lost a tender. Significantly, it attributes much of its leading edge to its investment in in-house research, innovation and development. EOS designs, develops and manufactures specialised lasers, and incorporates a significant proportion of Australian optical components to which it adds value many times over through electronic systems and software control. EOS has a staff of almost 50 and produces annual revenues of $10 million, mostly from exports, representing a 100% growth rate in the past two years. It is a prime example of a successful small-to-medium size, export oriented business which is at the forefront of optics industry enterprise in this country.

o Optics is a growing contributor to employment and wealth generation in Australia

4. Building on natural advantages

It is clear from the highlights of the Australian optics industry outlined here that rapid exploitation of optical technologies involving growth from a small but viable base can yield enormous returns from a limited initial investment. Quite often these opportunities have arisen through advances in publicly funded research which have then been transferred into the commercial sector. It is characteristic of many of these optical technologies that the market is dominated by the international rather than the domestic sector.

Modern optics is very appropriate to this scale of small to medium enterprise, and can demonstrably contribute to Australia's economic development without enormous infrastructure costs. As pointed out previously, the same is true for university and government optics research laboratories. The FAMOS report, for example, emphasizes that optics research is generally small science pursued by groups of significantly less than 10 people and with USNSF research grants of the order of US$100,000 per principal investigator. A similar pattern of productive work is being accomplished by small groups in Australia that do not generally require large facility funding.

Optics based companies tend to be clean, high technology activities with relatively low environmental impact. These enterprises are often based around the assembly of existing components into highly value added systems. In addition, as shown by the laser based applications in BHP, and by the application of optical communications technology by Telecom and Optus, there is also significant potential for wealth creation by optics in larger industries.

o Optics is an appropriate industry for Australian in terms of its scale, relation to the strong optics research base, and its low environmental impact

8. RECOMMENDATIONS AND CONCLUSION

The body of evidence assembled in this report all points to optics being a major contributor to the modern economies, cultures and societies - both internationally and in Australia. There is considerable potential for optics to increase this contribution given the enormous expansion in modern optical technology, provided that the appropriate conditions can be created for this development.

A stimulus for the development of these conditions can come from national research priority setting. Research in optics is central to the success of the modern optics industry. The companies surveyed in this document are unusual in Australian industry for the significant contribution by commercial R&D, which complements the undoubted high quality of public sector optics research in this country.

Both these sectors attest to the fact that optics research in Australia has traditionally been a major national strength, on the same international level as, for example, medical research and astronomy to which optics also makes significant contributions. It is further apparent that optics - both in industry and research - is appropriate to a country of this size.

However, despite the growth of activity in optics indicated by the AOS survey, Australia has not kept up with the growth in the field internationally. The statistics from the FAMOS report show that between 1981 and 1989 the percentage contribution of Australia to international publications in AMO science (expected to be indicative of performance in optics) actually declined, despite growing in absolute terms.

The benefits of expanding Australia's national research effort in optics to the point where the marginal return is equal to the return from investment in other sectors goes without saying - it is merely a question of judgement when this point is reached. The AOS believes that at this stage of development, the Australian optics sector has not yet reached this limit. Therefore, expansion of research in optics will still yield proportionally higher returns for this investment.

In line with the recommendation of the Australian Institute of Physics strategic plan (Physics: A Vision for the Future, 1993) the Australian Optical Society therefore makes the following recommendation:

RECOMMENDATION: THAT OPTICS BE MADE A PRIORITY AREA FOR NATIONAL INVESTMENT IN SCIENCE AND INDUSTRY

There are many mechanisms by which this prioritisation may be implemented. Funds may be earmarked for specific allocation to optics in industry/public sector research programs, or under

the ARC grants system which, as has been shown, already has a substantial optics component distributed over a number of categories.

However, more importantly, the AOS believes that special consideration should be given to the encouragement of young people into optics research and industry in this country. This may be achieved through the allocation of specific scholarships and fellowships to students and researchers in optics, perhaps supplemented by the incentive of higher salaries and stipends for these people. By this means, excellent research applications and projects will flow naturally from the inclusion of high calibre workers in this discipline.

There is also a need to train and retain the skilled optical workers and technicians who have historically contributed to optics in industry and research in this country. There are indications that these human resources, and the accompanying infrastructure (such as thin film coating and optical polishing facilities), require further support. For example, the AOS has received no nominations for its Young Optical Worker of the Year award in recent years, and the turnaround for optical fabrication in Australia is often long because of the high demand for such services.

It is apparent, therefore, that the implementation of a national priority in optics will need to be addressed at a number of levels. Whatever mechanisms are instituted, the Australian Optical Society will remain committed to promoting excellence in the field of optics with its important ramifications for Australia's future.

9 APPENDIX A:

ORGANISATIONS INVOLVED IN OPTICS RESEARCH AND INDUSTRY

The information presented in this section was taken from the National Optics Survey undertaken by the Australian Optical Society. A copy of the survey is presented below. The details of each organisation and its activities in the field of optics are presented in this appendix, while a summary of the numerical information is presented in Appendix B.

NATIONAL OPTICS SURVEY

Organisation name:

Chief contact person:

Postal address:

Phone: **FAX:** **e-mail:**

One paragraph summary of activities involving optics and lasers (+ keywords):

Total personnel in optics areas: **1987:** **1992:**

Optics related scientists/engineers: **1987** **1992:**

Student numbers (Hons/PG): **1987: /** **1992: /**

Total capital investment in optics/laser equipment: **$**

Approx. optics budget/turnover: **1987: $** **1992: $**

Approx. annual export sales: **1987: $** **1992: $**

Approximate total export earnings to date: **$**

Collaborations/grants in optics: **1987: $** **1992: $**

Additional information: