Departments of the Research School

Optical Sciences Centre

The Optical Sciences Centre was born in 1988, although it had existed as an independent entity within the Department of Applied Mathematics from 1983. Led by Professor Allan Snyder (who had also been Head of Applied Mathematics from 1980 to 1983), ably supported by Professor John Mitchell, Dr John Love, Dr Nail Akhmediev and a team of international researchers, the Centre has been substantially supported, significantly honoured and widely reported for its achievements. It has worked actively and fruitfully with a very varied range of collaborators, including the School's own Laser Physics Centre.

From a base of research in vision and visual perception, the Centre has expanded its activities into a wide range of optical projects, from sophisticated mathematical analyses to very practical optical tech-

Members of the Optical Sciences Centre celebrating the award of a CRC in optical fibre and photonic technology to the ANU in December 1991.

Back row (L to R): Dr John Love (Senior Fellow), Dr Wanda Henry (Visiting Fellow and former PhD student), Dr Leon Poladian (PD Fellow), Dr Adrian Ankiewicz (Senior ARC Fellow), Xioping Yang (PhD student), Dr Nail Akhmediev (Senior Fellow), Professor Allan Snyder (Head of Centre), Professor John Mitchell, Dr Trevor Hine (Research Fellow), Tony Joblin (Vacation Scholar).

Front row (L to R): David Atai (PhD student), David Ronland (PhD student), Mrs Andrea Robins (Centre Admin), Fracoise Ladouceur (PhD student), Mrs Diana Wallace (Applied Maths admin), Chris Wallace (Vacation Scholar), Dr Graeme Cole (Research Fellow), Dr Yijiang Chen (Senior ARC Fellow).

nologies. Some examples follow.

Global strategies for brain and machine vision

The focus here is the manner in which the brain incorporates prior knowledge of the visual environment to accelerate visual information processing in general and object recognition in particular. This research is performed in collaboration with visual biologists and computational scientists. The most recent approach to these questions probes the extraordinary capabilities of autistic child artists.

Light guiding light

Guiding and manipulating light by light itself, without any intervening fabricated structures, is the central aim of this exciting research; a topic revolving around the physics of dynamic spatial solitons* and one relevant to futuristic all-optical devices (eg without optical fibres). This research has been a passion at the Optical Sciences Centre since 1990 and was featured in *New Scientist*, (Vol. 12 January 1991, p. 14.) Various theoretical predictions have now been realised collaboratively with the experimental program of the Laser Physics Centre.

**a soliton is a solitary wave that travels long distances without substantial dissipation (e.g. a tidal wave at sea). A light soliton is then an appealing potential carrier of information in optical circuits.*

Unification of linear and nonlinear waves optics

A new conceptual approach, whereby nonlinear optics is viewed from the perspective of linear physics, is the basis of this project. This philosophy not only unifies nonlinear waves but it has also been the crucial inspiration for several discoveries of major significance, including dynamic solitons and the universal stability criterion of nonlinear guided waves.

Nonlinear dynamics of multi component solitons

Research in this area covers several modern problems in optics: short pulse propagation in birefringent optical fibres, solitary waves in non-linear couplers, and spatial and temporal vector solitons in nonlinear media. The theory of Hamiltonian dynamical systems with an infinite number of degrees of freedom is developed to describe these type of phenomena and to predict novel effects.

Nonlinear waves and solitons in higher dimensions

The aim here is to observe and identify spatial and temporal solitons in experiments, with the higher dimensions effects being analysed in detail. This includes two and three-dimensional spatial (dark, grey and bright) solitons as well as soliton-like objects ("light bullets") in waveguide structures. One of the purposes is to establish a link between realistic physical models and exact integrable equations.

Optically written photonic circuitry

This project involves the collaborative development of the direct uniting of light-processing elements onto a sandwich of transparent material, thus making three-layer optical fibres obsolete. The technique depends on the "light guiding light" principle outline above, and involves the use of a highly-focussed and controlled laser beam modifying the central, doped layer of the transparent sandwich.

Planar waveguides and devices

Novel planar optical devices, such as mode combiners, separators and transformers, multiport couplers, multilayered guides, grating assisted devices and integrated-optics interfaces, are being devised for a broad range of applications, including optoelectronic circuitry, telecommunications networks, optical sensing and confocal microscopy.

Major developments

The discovery of an optical fibre that transmits over an extended distance only light of a fixed polarisation led, in 1983, to the formation of the Australian Optical Fibre Research Co., recently sold by BHP to a large American company.

In 1991, the Centre was a key player in the award to the ANU of a Cooperative Research Centre (CRC) for Optical Fibre and Photonic Technology (photonics being the control and storage of information using the elementary units of light called photons). The CRC is expected to have $100 million at its disposal over seven years and to focus on developing new optical devices and technologies for communications, information processing, sensing and industrial applications.

In addition to the award of advanced degrees to members of the Centre, Professor Snyder was made a Fellow of the Australian Academy of Science in 1985, of the Australian Academy of Technological Sciences in 1987, and of the Royal Society of London in 1990; he was awarded the Lyle Medal of the Academy of Science in 1986, the Sutherland of the Academy of Technological Sciences in 1991, the A.E. Mills Oration of the Royal Australian College of Physicians in 1996, and the Harrie Massey Prize of the British and Australian Institutes of Physics in 1996. In 1995, the CSIRO External Medal for Research was awarded to Professors Snyder and Mitchell.

Milestone discoveries

The first prediction of optical vortex solitons and proof that they are stable.

Demonstration of light guiding light, as well as self-induced optical components using dark spatial solitons, in collaboration with the Laser Physics Centre.

The discovery of ‘dynamic solitons’ - an important and ubiquitous new class of solitons whose intensity is uniform but whose electric field changes with propogation.

A universal criterion for the stability of fundamental nonlinear waves, including solitons, modes of nonlinear waveguides, and waves at nonlinear interfaces.

The first analytical method for describing interacting (bright and dark) solitons of planar and circular cross-sections propagating in an arbitrary medium. The development of a new conceptual framework whereby nonlinear waves are approached from the perspective of elementary linear physics (the philosophy of this approach underpins the above theoretical discoveries).

The discovery of temporal soliton states that are the key objects governing a variety of switching phenomena in dual-core and multi-core optical fibre arrays.

Passive optical devices that multiplex between the modes of a few-moded waveguide and an equivalent number of single-mode waveguides, thereby enabling superposition between information channels.

It has been shown that any multiport coupler comprising an arbitrary number of fibre cores in an array has an equivalent planar coupler comprising a planar array of buried channel cores.

The discovery of a new class of motion illusions that could influence theories of human motion perception.

Allan Snyder