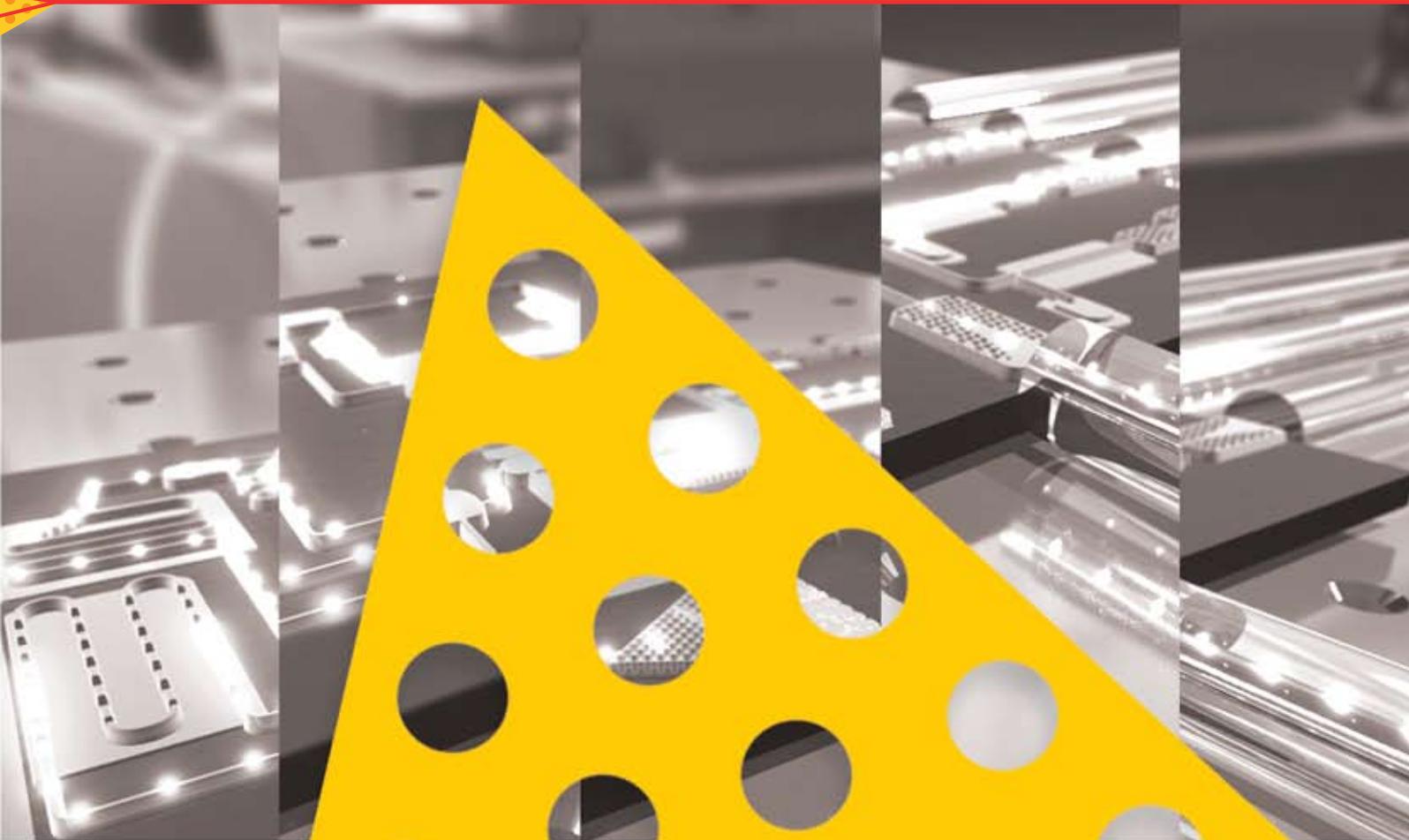




CUDOS

The Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)
An Australian Research Council Centre of Excellence



Annual Report 2007

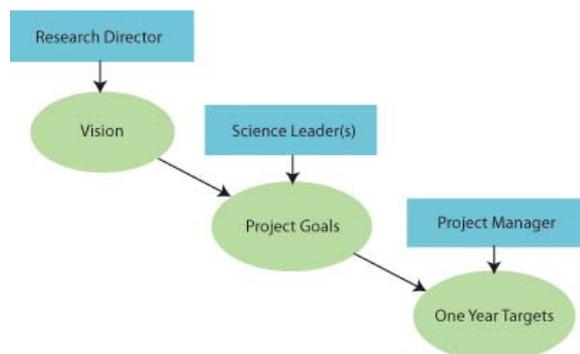
Ben Eggleton, Research Director

2007 completes the fifth year for CUDOS, and by the time this report is completed we will have commenced our three years of extension funding. During 2007 we bedded down our five Flagship projects and introduced a new one on Tunable Microphotonics, led by Arnan Mitchell of RMIT. Although A/Prof Mitchell will not formally join CUDOS as a Chief Investigator until 2008, he is actively working with us to develop a Flagship that not only capitalises on his group's skills in lithium niobate waveguide fabrication but which links into the theory and experimental programs at ANU, Sydney and Macquarie.

The rationale for Flagship projects, their management structure and role in the CUDOS program were comprehensively overviewed in the last CUDOS Annual report and only a brief introduction is given here. Flagships are strategic projects that both develop and build on fundamental research through long-term collaboration and international links. At the same time they demonstrate to the broader community the path toward delivery of social and economic benefit arising from the research outcomes. For example the slow-light project is exploring new and innovative ways in which light might be slowed in one and two dimensional media without the bandwidth restrictions of other approaches. The outcomes of this work will be directed towards "enhancing" the devices being developed in the nonlinear signal processing project. Similar comments can be made regarding the optical switch project.

Flagship projects pose significant management challenges, as their activities link many nodes of the Centre. Our project managers are drawn mainly from outside the ranks of our most senior researchers. Project Managers take the lead role in planning the outcomes projects on a year by year basis, negotiating resources with Chief Investigators, linking with our Partner Investigators, communicating within the project team, reporting to the Research Director and ultimately, reporting the outcomes of the project at meetings and in journals. To assist our project managers, the Centre is providing training in the principles of research project management as well as on-going mentoring.

The role of the Chief Investigators as Science Leaders is to address the longer term scientific directions of the Centre. This is shown schematically in the figure below, in which the responsibility for developing the Vision for the Centre is shown to rest with the Research Director, the long term aims of each science program with the Science Leaders (in consultation with the Research Director) while the yearly goals are the responsibility of the Project Manager, negotiated and discussed with the Research Director and Science Leaders.



As in 2006, our 2007 Annual Report will contain overview reports of the achievements of each Flagship project, as well as a science report from each Chief Investigator. Our aim is that the reader will obtain a 'big picture' understanding of the directions of our science program as well as a more in-depth picture of the outstanding science achievements by our researchers during the year.

Another perspective on our research achievements can be gained from an examination of our publications output for 2007. During the year, CUDOS researchers published over 80 papers in refereed journals with an average impact factor greater than 3.8 for the 55 top-ranked publications, and gave more than 30 invited papers at international conferences. Over 25% of our publications were collaborations between two or more nodes. These numbers are well ahead of our targets and provide a quantitative estimate of the quality and volume of our research productivity. In addition, our researchers were invited to provide two commentaries to the prestigious journal *Nature Photonics*.

Flagship research highlights

Nonlinear Optical Signal Processing

This project is managed by Dr Mark Pelusi, who has both industry and academic research experience in high bit rate optical networks. Professor Ben Eggleton is the Science Leader. The long term aim is to develop all-optical signal processing devices and technologies based on nonlinear optical phenomena with femtosecond response times, with a view for implementation in next generation ultrahigh bandwidth optical networks.

The project achieved some major successes during the year both in the development of a technology platform and in the demonstration of prototype devices. On the materials side, the key achievement was the production of a long 22.5 cm length As_2S_3 planar waveguide 4 μm in width with record low propagation losses of 0.05 dB/cm. The nonlinearity achievable in such waveguides is proportional to the length and the nonlinear coefficient of the material and inversely proportional to the cross sectional area. With the high inherent nonlinearity of chalcogenide, we were able to achieve, at modest power levels, broadband wavelength conversion of 40 and 80 Gb/s signals by cross phase modulation with a co-propagating continuous wave laser at a bit-error rate power penalty of just 1 dB. In another experiment we time-division demultiplexed a 160 Gb/s signal to extract tributary 10 Gb/s channels through the four wave mixing of the signal with a propagating pump pulse at a repetition rate of 10 GHz.

Demultiplexing and wavelength switching are two of the key functions that a future all-optical processor might manage. During 2008 we plan to extend this ground-breaking work to signals with more exotic modulation formats.

All Optical Switch

This project is managed by Dr Christian Grillet (an Australian Postdoctoral Fellow), who has a strong research background in photonic crystals. The aim is to develop a highly compact ultrafast optical switch for optical signals. In other words, the switching is driven either by the light itself or by an optical control pulse.

Our approach has been to investigate the use of resonant cavities in a nonlinear optical material – the use of a cavity reduces the input power requirements and the nonlinearity leads to a power-dependent change in refractive index whose effects can be engineered into an optical switch.

One of the project's breakthroughs this year was the development of a novel approach based on the photosensitivity of the refractive index of chalcogenide glass that has allowed us to tune the coupling conditions of cavities in photonic crystals to enable efficient coupling into high Q cavities.

Both this project and the Slow Light Flagship stand to benefit over the coming years from a collaboration with a European research consortium SPLASH.

3D Photonic Crystals

This project is managed by Dr Baohua Jia, a researcher at Swinburne University with expertise in microfabrication and microscopy. Professor Min Gu is the Science Leader. Our interest in three dimensional photonic crystals is driven by fundamental science opportunities and long term applications.

The project had some remarkable successes during the year, with the first reported observations of the effect of a 3D photonic crystal on the emission properties of quantum dot optical sources inside the crystal lattice. This work is appearing as two publications in *Advanced Materials*, a prestigious journal with an impact factor of 8.

In a strong collaboration across CUDOS nodes, the chalcogenide team at ANU produced substrates with thick layers of chalcogenide which were then processed at Swinburne using the two photon micromachining and etching process to produce 3-dimensional photonic crystals with high refractive index contrast. The work opens the way for the production of 3D photonic crystals with complete band gaps.

Slow light

The project is managed by Dr Christelle Monat (an Australian Postdoctoral Fellow) with Professor de Sterke the Science Leader.

Light can be slowed down to an arbitrarily low group velocity when travelling through an optical medium with high dispersion. Unfortunately, the range of wavelengths over which this behaviour can be observed is commensurately small, meaning that short pulses of light (with a broad spectrum of constituent wavelengths) will be significantly distorted when travelling as 'slow light'. Our goal is to develop innovative solutions to this problem, and to exploit slow light to lower the threshold for nonlinear devices under development in CUDOS.

One way to avoid this problem is by conversion of the light pulse into a soliton, whose propagation is by definition dispersionless. We first accomplished this in a 10 cm long Bragg grating in 2006 and observed delays equivalent to two pulse widths. We extended this work in 2007 in collaboration with Southampton University by using 30 cm long gratings to measure delays of nearly five pulse widths.

This work was done in silica fibre, and during 2007 we succeeded in fabricating gratings in a chalcogenide rib waveguide and exciting the formation of a train of solitons. With careful control of parameters, we expect that we will achieve slow light pulse formation during 2008 at considerably lower power levels than was required for the silica fibre.

We are also active in investigating opportunities to apply slow light, and theoretically demonstrated switching of slow-light pulses in nonlinear couplers with phase-shifted Bragg gratings, and in

further work demonstrated a directional photonic crystal coupler where dispersionless routing of slow light pulses was realized.

Compact Waveguide Amplifier

The project is managed at Macquarie by Dr Graham Marshall, a researcher with a strong background in laser systems and micromachining. Associate Professor Michael Withford is the Science Leader. During 2007 the team became the first in the world to develop a fully integrated laser waveguide oscillator with Bragg reflectors in a waveguide written into active material using femtosecond laser micromachining. This experimental *tour de force* opens the way for the Centre to integrate active (gain) modules with its nonlinear optical processors, switches and other components developed as part of the overall program.

Tunable microphotonics

The project is managed by A/Prof Arnan Mitchell at RMIT with Professor Kivshar the Science Leader. Dr Mitchell, presently an Associate Member of CUDOS, will be a Chief Investigator from 2008 onwards.

This Flagship commenced in 2007 and is presently building capacity and developing innovative technologies for producing and controlling highly variable refractive indices in planar, fibre and 3D photonic crystal resonant structures. In pioneering work with photonic crystal fibres filled with high index nonlinear liquids, the project team has demonstrated a range of controllable nonlinear phenomena at significantly reduced threshold intensity, paving the way for an exciting research program over the coming years.

Fundamental research

The CUDOS program is one of strategic fundamental research in a range of theory and experimental programs covering nonlinear photonics and microphotonics. Not all this work is explicitly mentioned in the Flagship reports, but is covered in more depth in the reports by the Chief Investigators, who are the science drivers of the Centre. Their reports provide a compelling picture of the vibrance and innovation in our research program.

