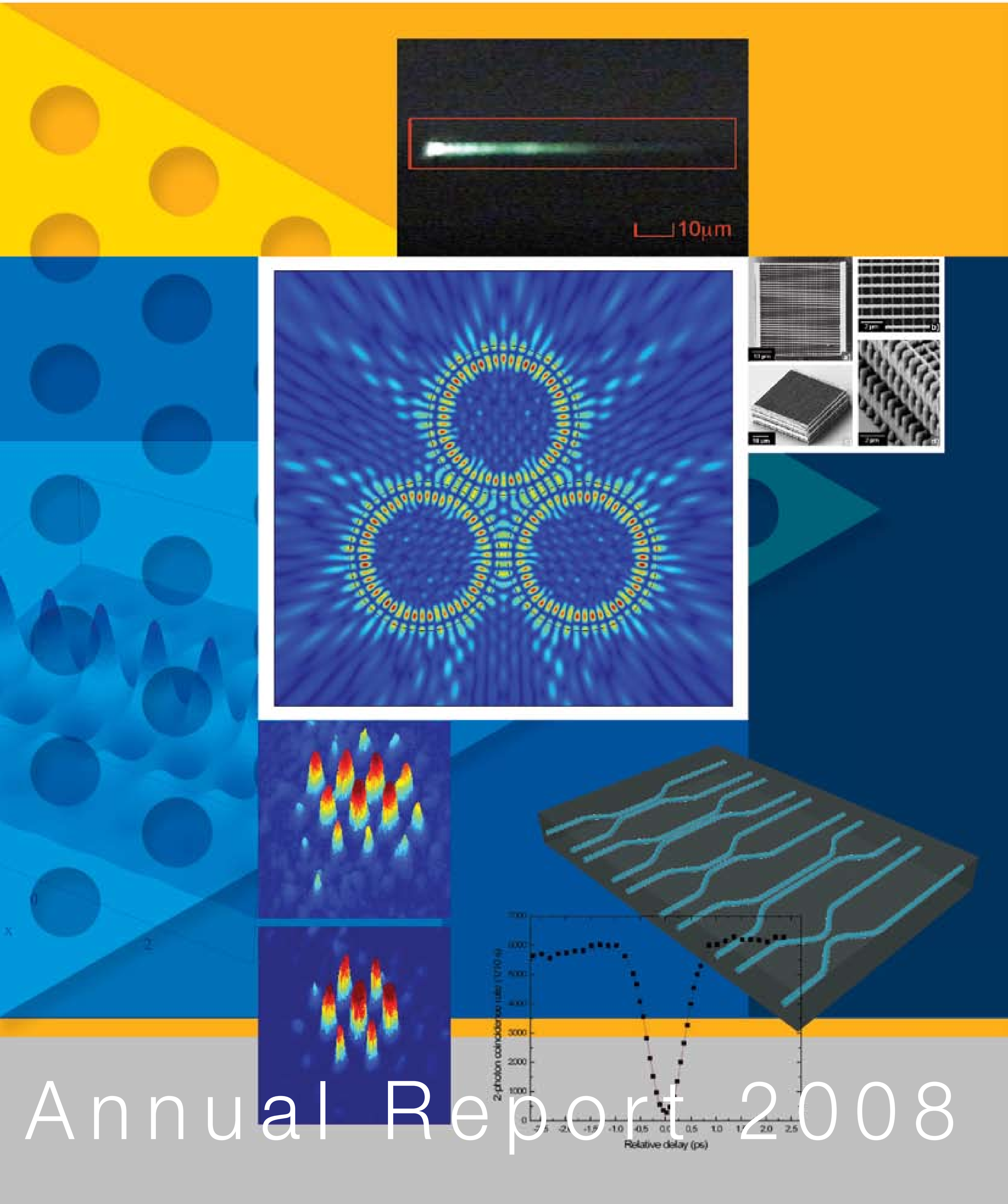
CUDOS

The Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)



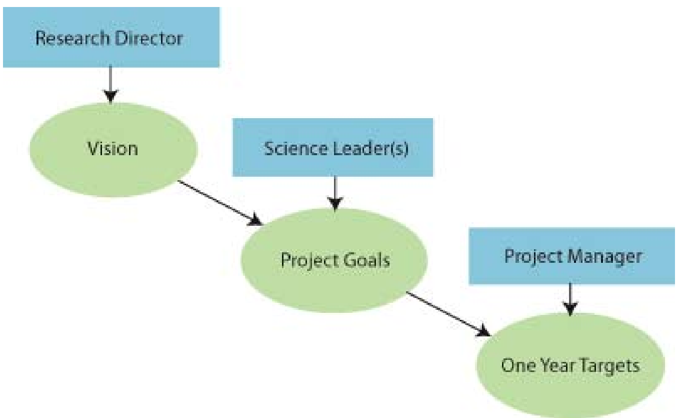
Annual Report 2008

Our research report is presented in two sections. We first provide overviews of each of our Flagship projects: their long term goals, objectives for 2008, achievements against those objectives, and plans for the coming year. Each of our Chief Investigators then provide a short report of their activities and principal achievements for the year.

Flagships are strategic projects that both develop and build on fundamental research through long-term collaboration and international links. Their outcomes should demonstrate to the broader community the potential for social and economic benefits arising from the research.

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, presenting the outcomes of the project at meetings and in journals. Science Leaders, in consultation with the Research Director, are responsible for articulating the longer term scientific directions of each project and leading that longer term research. The two roles are complementary and both are vital to the success of a Flagship project.

The relationship between the Research Director, Science Leaders and Project Managers is shown schematically in Figure 1, 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 lie 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.



We can also measure our research output bibliometrically. During the year, CUDOS researchers published over 80 papers in refereed journals with an average impact factor greater than 4.3 for the 40 top-ranked publications, and gave more than 30 invited papers at international conferences. These numbers are well ahead of our targets and provide a quantitative estimate of the quality and volume of our research productivity.

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 team has developed two platforms for driving nonlinear effects in chalcogenide glass, a high index material with high nonlinearity. Both rely on tight mode confinement to produce very high intensity and hence a strong nonlinear optical response even for modest power inputs.

The tight mode confinement is achieved either by tapering a chalcogenide fibre through which the light propagates, or by lithographically producing rib waveguides of small cross sectional area in a thin film of chalcogenide glass. The Flagship team has pursued both approaches, and achieved spectacular results with each.

Using an extreme tapered fiber of 5 cm length whose nonlinearity coefficient is more than 5000 times that of standard single mode fibre, the team succeeded in demultiplexing a 160 Gb/s signal by four-wave mixing with a relatively low launch power of 25 mW.

We also fabricated photonic chips with ultra high nonlinearity that, in collaboration with DTU (Denmark), have demonstrated record-breaking demultiplexing of a 640 Gb/s signal.

Each of these results is discussed in more detail in the Flagship report. These landmark results demonstrate that exotic approaches like cross phase modulation and four wave mixing can in fact be harnessed for all optical signal processing. There was international media interest in the 640 Gb/s demultiplexing result; please see the Outreach section to find out more.

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 Science Leader is Professor Barry Luther-Davies. The aim is to develop a highly compact ultrafast optical switch for optical signals where the switching is driven either by the light itself or by an optical control pulse.

Optical switching directs light from one output port to another. For practical implementations, the operation must be performed rapidly and with small energy of the control pulse. Many approaches to this problem are based on resonant cavities that, in simple terms, "multiply" the impact of the control pulse by the quality factor Q of the cavity.

During the year we demonstrated several novel approaches for low-loss confinement of light that lead to high Q cavities. In the first approach, light is confined inside a length of photonic crystal waveguide by filling the holes in the crystal at either end of the waveguide to change the dispersion characteristics and so confine the light to the central region. This simple approach gave Q values of 60,000 and is far more straightforward to implement than, for example, lithographically changing the periodicity of holes at either end to achieve the same effect.

Our second approach was to fabricate, and optically characterize, microspheres in chalcogenide (As_2Se_3). The microspheres are produced by laser heating of a tapered fibre leading melting and subsequent cooling into spherical droplets with exceptionally smooth sidewalls, allowing "whispering gallery" modes to be excited with very little loss. We excited high Q modes of a 9.2 µm diameter chalcogenide glass by evanescent coupling with a silica tapered fiber and measured loaded Q factors of more than 20,000. We expect this architecture to be an ideal environment for versatile applications at both the telecommunication and mid infrared wavelengths.

3D Photonic Crystals

This project is managed by Dr Baohua Jia, a researcher at Swinburne University with expertise in micro-fabrication and microscopy and an Australian Postdoctoral Fellow. Professor Min Gu is the Science Leader. The research spans teams at Swinburne, Macquarie, Sydney, ANU, and UTS. Our interest in three dimensional photonic crystals is driven by fundamental science opportunities and long term applications.

Our research of 3D photonic crystals has focused first on producing crystals of high refractive index contrast to enable a 3D bandgap, and second, producing crystals with such band gaps in the visible, and third, studying the inhibition in spontaneous emission that occurs when optical sources are placed inside the crystal structure.

We made strong progress in each of these areas during 2008, and in fact our work on demonstrating the role played by photonic crystals in modifying the spontaneous emission of light from quantum dots inside the crystal that was published in Advanced Materials attracted sufficient attention to be highlighted on the web site of Nature Publishing Group Asia Materials in May.

During 2008 we achieved the *first* demonstration of 3D high-index photonic crystals with higher-order stop gaps in the NIR wavelength range. This important work was published in Optics Letters and highlighted by the MRS Bulletin.

Slow light

The project is managed by Dr Christelle Monat (an Australian Postdoctoral Fellow) with Professor de Sterke the Science Leader. The project team achieved major success during the year with experimental demonstrations of the influence of slow light on thresholds for nonlinear optical behaviour.

In collaboration with Prof. Krauss' group at St Andrews, the Sydney University team investigated the enhancement of nonlinear Kerr effects in the slow light regime. These experiments were carried out onto a series of silicon photonic crystal waveguides with a controlled group velocity (between c/10 and c/50) and a reduced group velocity dispersion to avoid the distortion of the slow light pulse. The team saw third harmonic generation – i.e. the emission of visible green light from near-infrared pulses – from these tightly confined waveguides with a strong enhancement due to slow light. This was presented as a postdeadline paper at the European Conference on Optical Communications (ECOC) in September 2008 and has recently been accepted for publication in Nature Photonics.

We also investigated slow light couplers that may find applications for the simultaneous tuning of the pulse delay combined with spatial switching. We conducted experimental proof-of-principle studies at microwave frequencies, following which we extended our study of these couplers to show that slow gap solitons could be all-optically switched between two phase shifted gratings. These results were selected as one of the monthly Research Highlight of the *Nature Photonics* journal in September 2008.

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.

The project achieved spectacular success during 2008. After considerable effort to systematically control all the parameters of the complex procedure required to write an optical waveguide and distributed Bragg reflectors in bulk material, the team at Macquarie were able to demonstrate a diode pumped laser in a single monolithic piece of optically active glass with output power of 50 mW in a single line. This result placed CUDOS as international leaders in this field, and provoked interest from groups interested defence applications, and also from leading international research groups involved in photonic approaches for quantum computation.

Tunable microphotonics

The project is managed by A/Prof Arnan Mitchell at RMIT with Professor Kivshar the Science Leader.

At one of our regular research strategy meetings, we identified tunability as a key capability in microphotonics. By tuning the refractive index of a photonic structure like a photonic crystal using infiltration of materials like liquid crystals, we can modify not only the linear but nonlinear dispersion of the structure, opening up a range of exciting opportunities in fundamental research.

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 excitement in our research program.