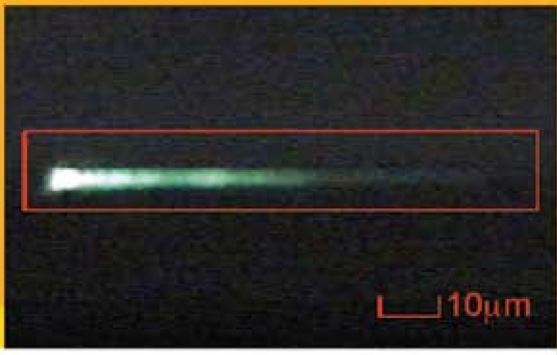
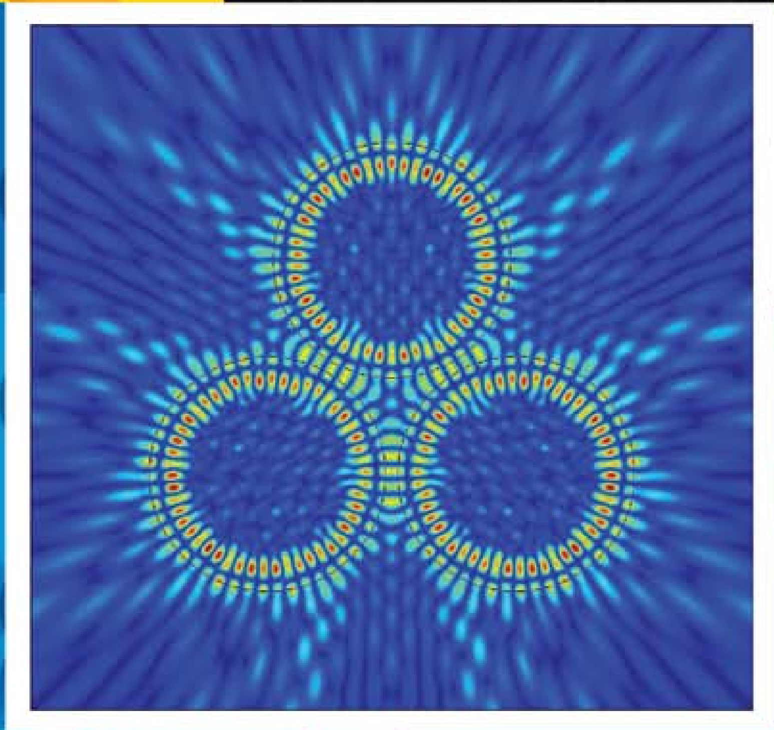
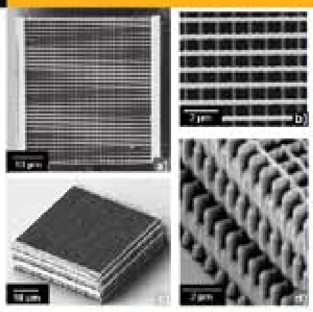
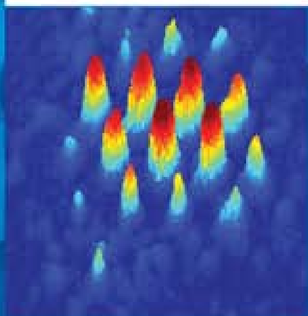
# CUDOS

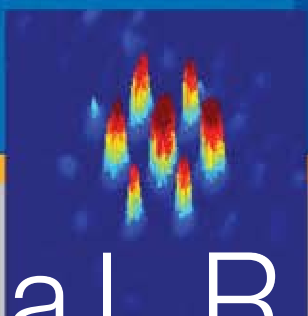
## The Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)

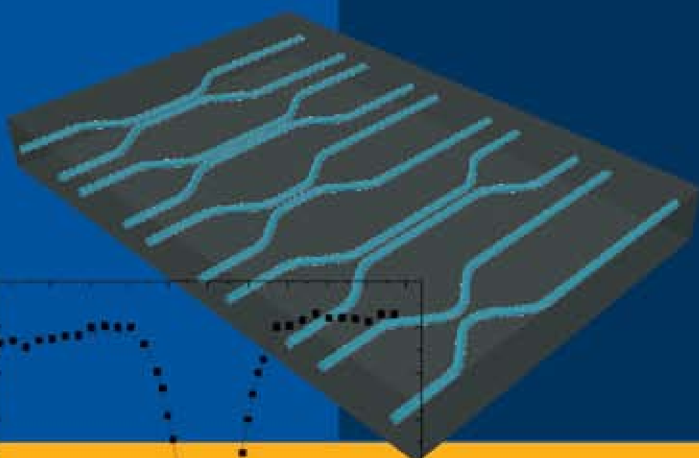


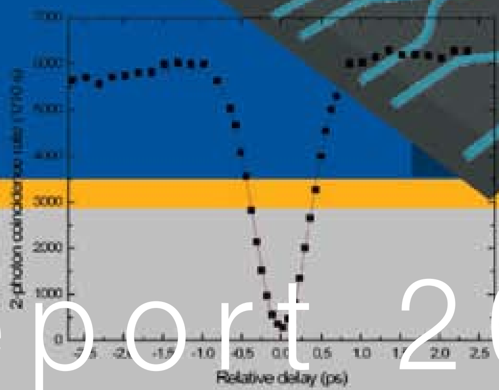














# Annual Report 2008

12. G. D. Marshall, M. Ams, J. C. F. Matthews, A. Politi, P. Dekker, J. L. O'Brien and M. J. Withford, *"Optical Quantum Circuits Created Using the Femtosecond Laser Direct Write Technique"*, Paper 646 in the 18th National Congress of the Australian Institute of Physics (AIP), Adelaide, Australia, 2008

13. J. C. F. Matthews, A. Politi, A. Laing, A. Stefanov, M. J. Cryan, J. G. Rarity, S. Yu, G. D. Marshall, M. Ams, M. J. Withford and J. L. O'Brien, *"Multi-Photon Quantum Optics on a Chip"*, Paper P1-8 in Quantum Communication, Measurement & Computing (QCMC), Calgary, Canada, 2008

14. M. Ams, G. D. Marshall, P. Dekker and M. J. Withford, *"A compact, monolithic, 36mW Yb-doped DFB waveguide laser fabricated using femtosecond laser direct-write techniques"*, Post-deadline Paper 1677 in the European Optical Society Annual Meeting 2008, Paris, France, 2008

15. G. D. Marshall, P. Dekker, M. Ams, J. A. Piper and M. J. Withford, *"Monolithic Waveguide-Lasers Created in Bulk Glass Using the Direct Write Technique"*, Paper MD5 in Advanced Solid State Photonics (ASSP), Nara, Japan, 2008

# Flagship Project

## TUNABLE MICROPHOTONICS

**Project Manager:** Arnan Mitchell

**Science Leader:** Yuri Kivshar

**Contributing staff:** Ben Eggleton, Ross McPhedran, Boris Kuhlmey, Mark Pelusi, Feng (Sydney), Yuri Kivshar, Wieslaw Krolikowski, Dragomir Neshev (ANU). Arnan Mitchell (RMIT), Mick Withford, Graham Marchall (Macquarie)

**Students:** Bill Corcoran

### Science Vision

Tunability is a core issue for the operation of all-optical photonic devices and circuits. Highly resolved wavelength selectivity and precisely defined dispersion must be actively tuned and stabilized to be practically useful. Further, if the nonlinear response itself can be tuned then a new range of all optical switching device may be realized.

The general goals of this project can be summarized as follows:

- To suggest, design, and study theoretically novel types of nonlinear periodic structures with active control of their dispersion and diffraction properties and tunable characteristics
- To demonstrate experimentally the control of light in microphotonic periodic structures, mainly on the two-dimensional platform

### Project Goals

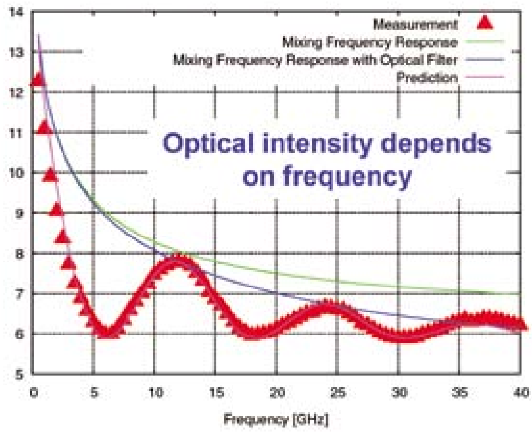
This Flagship program encompasses these general goals in its aims to explore the fundamental science of nonlinear optics while also connecting these breakthrough discoveries to practical applications, particularly in defence. In collaboration with external research partners such as DSTO we will continue to conduct internationally leading research towards:

1. Spatio-Temporal Tunable Nonlinear Effects: We explore the behaviour of light in coupled waveguide structures which exhibit unusual non-local nonlinear coupling and ultimately aim to experimentally investigate spatially and temporally confined optical pulses (often termed 'optical bullets').
2. Tunable Complex Nonlinear Heterostructures: We utilise new platforms such as fluid infiltrated photonic crystal fibres and microfluidic planar structures as flexible and reconfigurable platforms. We aim to explore nonlinear optical behaviour in strongly nonlinear platforms with potential applications in photonic signal processing and optical sensing
3. Microwave Photonics on a Chip: We will harness the demonstrated breakthrough technology created within CUDOS and apply it to a specific set of photonic signal processing problems faced by radar warning systems for defence platforms. Technologies of interest include compact wavelength filtering and tunable delays integrated with fast nonlinearities for signal mixing.

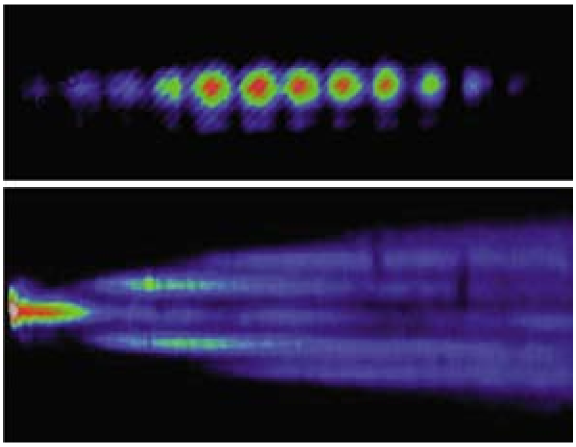
### CUDOS strategy/competitive advantage

CUDOS is a proven world leader in nonlinear photonic technology, both in terms of physical concepts (lead by the Nonlinear Physics Centre at ANU) and practical ultra-broadband systems (The University of Sydney). By combining these capabilities with the platform capabilities of RMIT University applied to the Australian electronic warfare research environment, CUDOS will bridge the gap between fundamental science and practical application. This unique combination of expertise will provide a wealth of new photonic technology to advance the Australian defence capability and industry, but will also identify new insights and challenges faced by industry which will stimulate innovation at the most fundamental level.

**Tunable Microphotonics team.**




**Instantaneous Frequency Measurement from 0-40GHz using all optical mixing highly nonlinear fibre (Bui et. Al Optics Express 2009 – submitted)**



**Measurements from planar polymer fluid infiltration platform: a) mode profile at output, b) plan view with fluorescent trace provided through rhodamine doping of the polymer – discrete diffraction evident. Zeller et. Al CLEO Europe 2008 (submitted)**

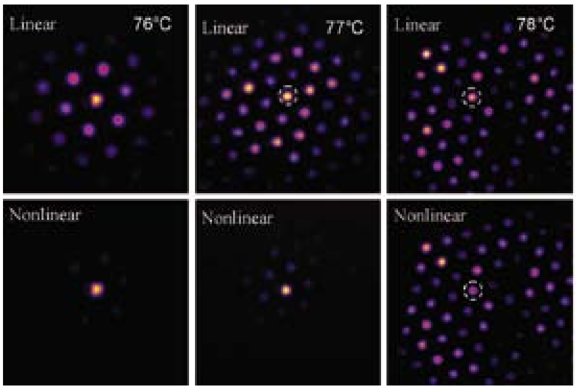
## Collaborative links

This project spans three major CUDOS nodes. The Nonlinear Physics Centre at ANU providing nonlinear concepts in tuneable microphotonics and experimental verification of these concepts; RMIT University providing fluid infiltrated polymer platforms and microwave photonic applications and context; and The University of Sydney providing nonlinear photonic systems expertise. This project has a strong collaboration with Defence partners, particularly DSTO and has pursued interactions with DMO and BAE Systems with the aim of providing microwave photonics on a chip as a solution to challenges in modern electronic warfare self defence systems.

## Goals for 2008

A number of specific goals were identified for 2008. These included

1. Demonstrate tuneable all-optical switching using liquid crystals
3. Demonstrate Spatio-Temporal Behaviour in PCF
4. Demonstrate selectively infiltrated planar structure
5. Demonstrate nonlinear optics as a platform for microwave photonics.




**Temperature tuning of nonlinear behaviour in fluid infiltrated fibre above 77C nonliear localisation is not possible. Bennet, et. al Optics Letters 34, 295-297 (2009)**

## Achievements and highlights for 2008

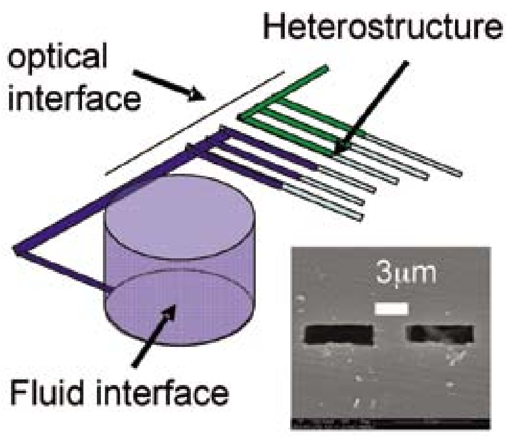
The Nonlinear Physics Centre (ANU), has focused on nonlinear beam and pulse shaping in liquid-infiltrated periodic hollow micro-channels, include the cladding of various photonic crystal fibers and planar polymer micro-periodic channels. Infiltrated liquids offer (i) highly tunable optical properties; and (ii) enhanced optical nonlinearity.

Our achievements using fluid infiltrated structures include (i) prediction of optical bullets in 2D coupled channels [1]; (ii) demonstration of novel nonlocality effects in periodic structures [2]; and developed platforms for (iii) selective infiltration of 2D optical networks; and (iv) low-cost polymer 1D periodic channels for beam control and bio-sensing [3].

To support these investigations, RMIT has developed a new air-structured integrated optic platform which is a planar analogue of photonic-crystal 'holey' fibres. High resolution lithography was employed in combination with a thin-film lamination technique to embed air filled features within planar optical waveguide structures [3]. Discrete diffraction has been observed within this platform and it is currently being investigated for nonlinear behavior.

We also continue our work on the enhancement of light in periodic structures with infiltrated liquid-crystal defects to dramatically reduce the threshold power of nonlinear effects. We have found that the very nature of the optical Fréedericksz transition can be changed from the second to the first-order leading to all-optical switching [4]. This enables a hysteresis width of the multi-stable response of almost 100%, with the minimal power required to sustain the "on" state. We have also performed the first experimental verification of these predicted effects for both, homeotropic and planar alignment [5].

RMIT and The University of Sydney have collaborated to achieve a significant advancement in the use of nonlinear optics for microwave photonic signal processing. We demonstrate the use of highly nonlinear fiber as an all optical mixing element in an instantaneous frequency measurement systems[6]. All optical mixing is used to convert high-frequency RF signals on an optical carrier to DC signals that can be measured using low-cost photo-detectors. This initial demonstration was broadband (2-40GHz), highly efficient, and exceptionally stable. This result has paved the way for a sequence of improved system demonstrations in 2009 with relevance to electronic warfare and the potential for monolithic integration in 2010.




**Fluid infiltration platform – inset: realised air structured polymer waveguide platform with 3mm cores separated by air; diagram: proposed fluid/optical interface to demonstrate in 2009**

## Targets for 2009

In 2009 we will further advance the successes of 2008 continuing to continue to pursue our science vision, but also to moving closer to technology platforms that will support our industry partners. Our 2009 targets are thus:

1. Demonstrate Tempero-Spatial behaviour in liquid crystal infiltrated photonic cavities
2. Access fast nonlinearities in fluid infiltrated photonic crystal fibre using fluid for dispersion engineering and explore applications in photonic information processing
3. Develop planar polymer fluid infiltrated platform with engineered fluid and photonic interfaces and explore applications in biosensing
4. Demonstrate a suite of microwave photonic applications of CUDOS nonlinear photonic technology of specific relevance to the Australian defence industry and pursue single chip integration of such systems.

## Published papers


[1] Opt. Express 16, 5878 (2008)

[2] Opt. Express 15, 12145 (2007) , Optics Letters 34, (2009) (in press)

[3] Bennet et al., PECS (2009) (submitted), Bennet et al., CLEO Europe (2009) (submitted)

[4] A. Miroshnichenko et al, Appl. Phys. Lett. 92, 253306 (2008), Phys. Rev. A 78, 053823 (2008)

[5] U. A. Laudyn et al., Appl. Phys. Lett. 92, 203304 (2008)

[6] Bui et al. CLEO USA (2009) (submitted), Bui et al. Opt. Express (submitted)