CUDOS

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

ANNUAL REPORT

2006

Dr Mick Withford

Dr. Withford was awarded a PhD from Macquarie University in 1995 for his investigations of the effects of gas additives on copper vapour laser performance. His continuing work in this field led to the development of a new sub-class of metal vapour, termed kinetically enhanced copper laser, in 1998. His current research interests include laser micromachining and fabrication a range of photonic devices such as fibre Bragg gratings, periodically poled ferroelectric materials and photonic crystals. Dr. Withford leads both the Macquarie University node of CUDOS and commercial venture Laser Micromachining Solutions. He is a currently a holder of an ARC Australian Research Fellowship.

CUDOS Research Contribution

Flagship Project: Waveguide amplifier and oscillators

Other projects: Quasi phase matched devices, Radiation Dynamics, MOF studies, Laser micromachining of planar photonic crystal structures, Optic fibre instrumentation for astronomy

Roles and Responsibilities

Macquarie Node Director and member of the CUDOS Executive

Science Leader: Waveguide amplifier and oscillator Flagship Project

Awards, honours, visits

Invited visit to Heriot Watt and Strathcyde Universities, September, 2006.

Description of Research Activities

Withford is Science Leader for the Flagship project: Waveguide Amplifiers and Oscillators. In this role he is responsible for determining the broad research directions, building links with end-users such as DSTO and NICTA, identifying commercial opportunities and keeping this program aligned with industry needs, and providing the fabrication and diagnostic resources required to reach project milestones. Withford also leads a project developing quasi-phased devices for non-linear optical processing. He also collaborates with CI Judith Dawes on self assembly of 3-D photonic platforms for studies into radiation dynamics.

Withford also contributes to Microstructured Optical Fibre (MOF) investigations that spans several nodes within the Centre. With Dr Graham Marshall he collaborates with members of the Sydney team in developing novel femtosecond grating writing techniques for inscribing gratings in MOFs. He also collaborates with UTS to investigate the influence of rotation and wavelength on side coupling into the core of MOFs. This body of work has recently led to a new collaboration with the OFTC inscribing gratings in air clad fibre lasers. Withford also contributes to a research project investigating optic fibre instrumentation for astronomy with partner investigators at the Astrophotonics group at the Anglo-Australian Observatory.

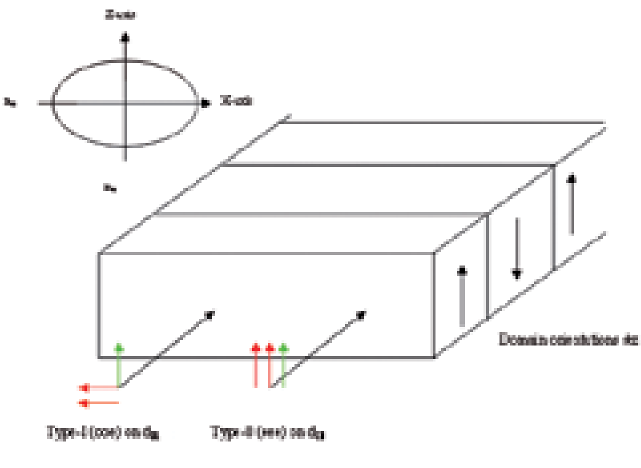
Achievements 2006

Flagship Project: Waveguide Amplifiers and Oscillators

Our key achievements within the Flagship Project were demonstrations of new benchmarks for low transmission loss in femtosecond laser direct-written waveguides [1] and a world's first report of a waveguide Bragg grating device [2] where a waveguide incorporating a point-by-point Bragg grating [3,4] was manufactured using a single fabrication platform. The inclusion of gratings into passive and active waveguide devices paves the way for a wide range of devices such as WDM channel selectors and monolithic waveguide lasers.

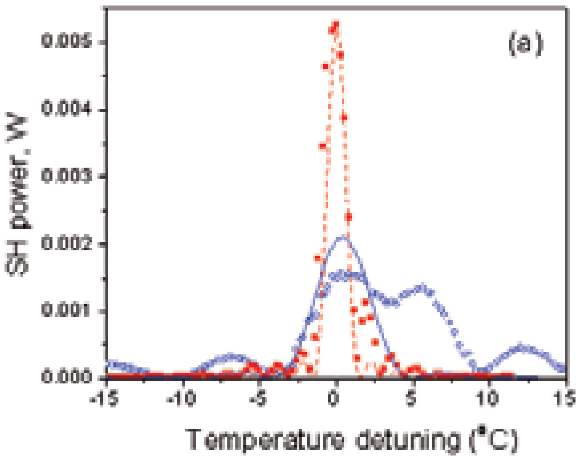
Quasi-phase matched devices

A collaboration with Prof. Yuri Kivshar (ANU) and visitor Prof. Solomon Saltiel (University of Sofia, Bulgaria) led to a new initiative examining cascaded non-linear processes in quasi phase matched lithium niobate. In particular we identified conditions permitting simultaneous phase matching of both type-0 second harmonic generation (SHG) using the d_{33} nonlinear coefficient (eee) and type-I SHG using the d_{31} nonlinear coefficient (ooe). This is shown schematically in Figure 1, where the inset at top left shows the crystal axis and refractive index that input polarisations see for z-cut lithium niobate, while the main diagram shows the polarisations for the fundamental (red) and second-harmonic (green) for the type-0 and type-I mixings.

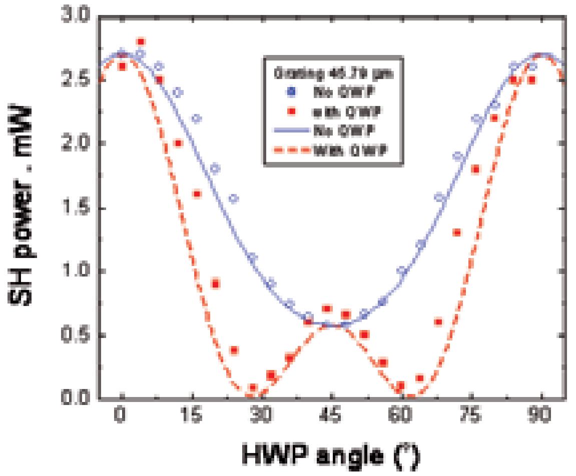


▲ **Figure 1. Schematic illustrating simultaneous, co-linear Type 1 and Type 0 nonlinear processes in periodically poled lithium niobate.**

A 45.75 µm period PPLN crystal meeting these conditions was fabricated using the rapid prototyping techniques developed at Macquarie [5]. Figure 2 shows the temperature tuning curves for the Type 0 and Type 1 SHG processes. The two processes produced SHG at a tuning temperature of ~160 °C. To the best of our knowledge this was the first experimental verification of this effect [6]. Of greater interest were the observations of phase dependent destructive and constructive interference of the two SHG waves within the crystal (see Figure 3). When these were injected into the crystal with zero phase shift then the Type 0 and Type 1 SHG waves would interfere constructively. However, a $\pi/2$ phase shift between the fundamental waves resulted in destructive interference.



▲ **Figure 2. Experimental (dots) and theoretical (lines) temperature phase-matching curves for SHG Type I (red) and SHG Type 0 (blue) in a 45.75 µm period gratings.**



▲ **Figure 3. Theoretical (lines) and experimental (dots) relationship between the SH power and the half-wave plate (HWP) angle which is controlling the input polarization. Blue traces indicate linear polarizations where only the HWP is in use. Red traces indicate elliptical/circular polarizations where a quarter wave plate is used in tandem with the HWP.**

In a related body of work visiting student Steffen Hahne (University of Applied Sciences, Fachhochschule Jena, Germany) undertook a 6 month project with the group developing an advanced laser micromachining method that will enhance our ability to pole lithium niobate. He developed a novel method for switching, on a pulse by pulse basis, between the s- and p-linear polarizations of our kHz pulse rate laser system [7]. This technique can facilitate the laser micromachining of high aspect ratio surface grooves in lithium niobate.

Self-Assembly of 3-D photonic crystals

In 2006 we fabricated our first inverse opal structures by in-diffusing sol-gel into templates consisting of our 3-D self assembly opals fabricated from polystyrene micro-spheres. Experiments are underway to dope the sol-gel with rare earth ions for future radiation dynamic studies of light emitting ions constrained by a neighbouring 3-D photonic bandgap. In a parallel study we demonstrated, for the first time, photonic bandgap guiding in a SMF fibre encapsulated by an opal.

Laser micromachining of planar photonic crystal structures

We undertook comparative investigations of the optical properties of grating structures consisting of lines and holes inscribed in the surface of the rib waveguide structure. PhD student Andrew Lee demonstrated narrow line width Bragg reflections from these 1-D photonic crystal devices. An analysis of the spatial position of these surface features implies that the mode overlap with different order modes can be engineered to target specific modes. Andrew Lee submitted in 2006 and is expected to graduate early in 2007.

Optic fibre instrumentation for astronomy

This is a new collaboration with partner investigator the Anglo Australian Observatory to develop astronomical instrumentation using fibre imaging bundles and tapers. One theme under investigation seeks to compensate for the numerical aperture mismatch between the focal plane of the telescope and the detectors. Our involvement commenced in 2006 as part of a research contract with CUDOS student Nem Jovanovic [8], and has since evolved into a joint Macquarie / AAO Masters project undertaken by new student Dionne Haynes.

References

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