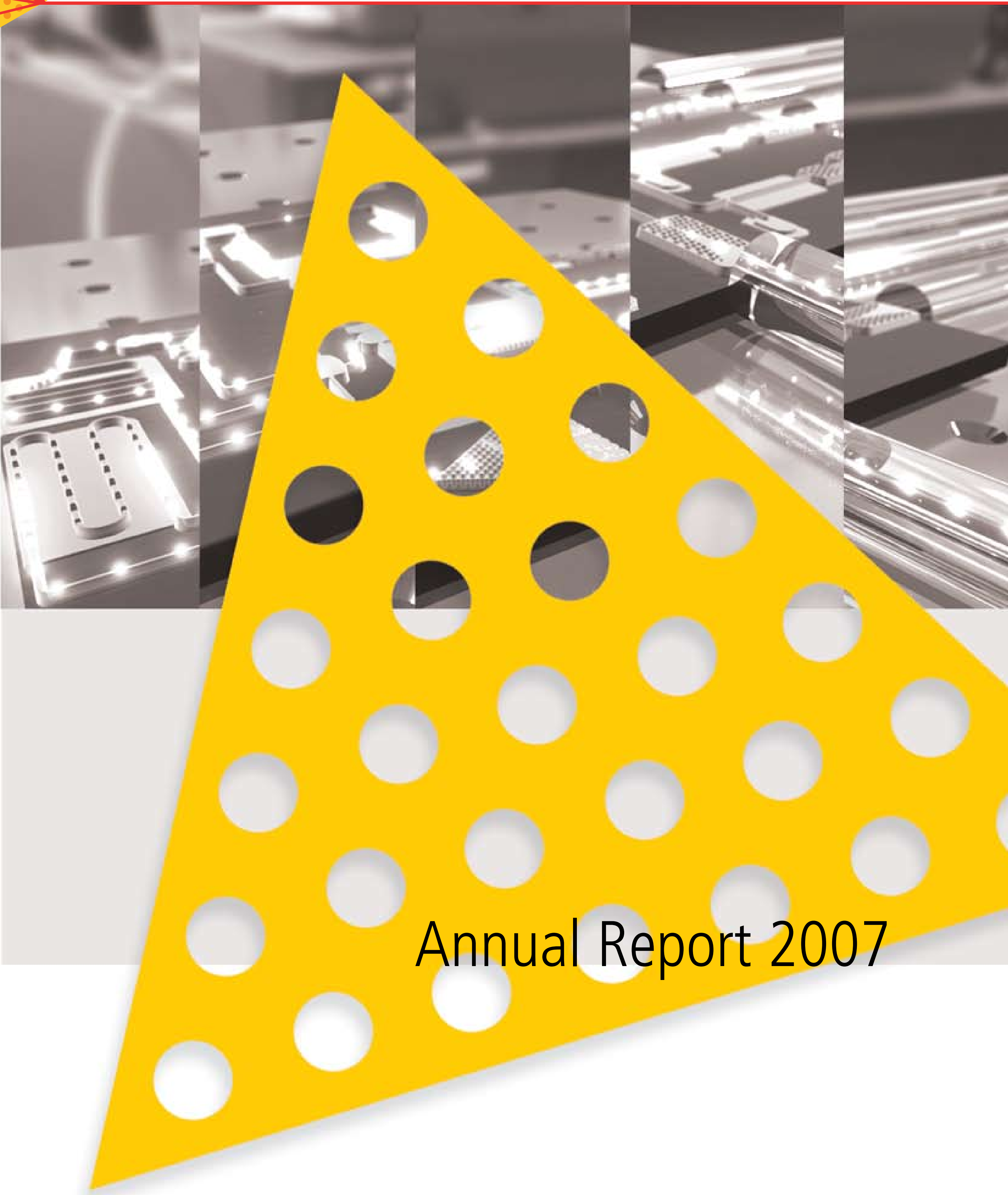
CUDOS The Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)

An Australian Research Council Centre of Excellence



Annual Report 2007

A/Prof. Michael Withford

Fig 1: Macquarie University group photo (without A/Prof Judith Dawes). Withford is front row, extreme left.

A/Prof. 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 of a range of photonic devices such as fibre Bragg gratings, periodically poled ferroelectric materials, guided wave devices and self assembled photonic crystals. Dr. Withford leads both the Macquarie University node of Australian Research Council (ARC) Centre of Excellence: Ultrahigh-bandwidth Devices for Optical Systems (CUDOS) and NCRIS Node OptiFab incorporating the Bandwidth Foundry, Optical Fibre Technology Centre and Laser Micromachining Solutions.

Awards, honours, major international visits

Withford's team received a Highly Commended Award in the 2007 Engineers Excellence Awards organised by Engineers Australia. In 2007 he was an invited speaker for the Asian Optoelectronic Expo (Shanghai) and ACOFT (Melbourne). He was also a Program Committee member of the SPIE Conference on Photonics: Design, Technology and Packaging (Canberra).

Fig 2: A/Prof Withford and Martin Ams accepting the Engineering Excellence Award, in the category of Innovation and Invention, from sponsor Tony Smeeton from Davies Collision Cave.

Key areas of research contribution within the Centre

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 identifying commercial opportunities. Withford also leads a project developing quasi-phased devices for non-linear optical processing. He collaborates with CI Assoc/ Prof. Judith Dawes on self assembly of 3-D photonic platforms for studies into radiation dynamics. He also collaborates with Dr Alex Fuerbach investigating ultrafast laser interactions with photonic materials and developing novel fibre lasers with Dr Stuart Jackson of the OFTC. Withford and Dawes also collaborate in a research project with partner investigators at the Astrophotonics group at the Anglo-Australian Observatory investigating optic fibre instrumentation for astronomy.

Achievements 2007

Flagship Project: Waveguide Amplifiers and Oscillators

This was a landmark year for this project due to our world's first demonstration of a monolithic waveguide laser fabricated using ultrafast laser direct-write techniques. This result was presented as a post-deadline paper at the Conference on Bragg Gratings, Photosensitivity and Poling (Quebec) [1]. This fabrication platform has important implications for the implementation of 3D integrated photonic chips, details of which are given in the associated Flagship Project report. Other outcomes underpinning this Flagship Project include the development of Near-field Scanning Optical Microscopy (NSOM) methods for characterising the internal nano-structure of waveguides written using ultrafast laser direct-write techniques. By polishing back a waveguide sample at an angle to the waveguide axis, we were able to detect perturbations in the transverse field of the waveguide using a laboratory built NSOM. This fine structure, which we attribute to ultrafast laser beam filamentation, has not been reported previously. This work was presented by PhD student Doug Little at the SPIE Microelectrics, MEMS and Nanotechnology conference at the ANU in December 2007.

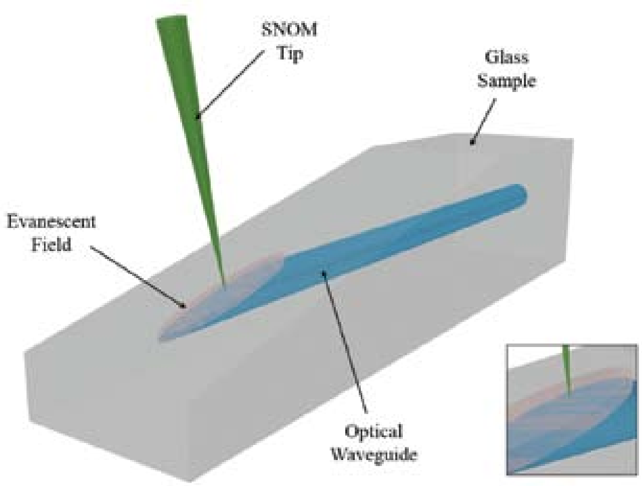


Fig 3: Schematic illustrating probing of ultrafast laser written embedded waveguides using Near-field Scanning Optical Microscopy.

Quasi phase matched devices

In this project we continued to build on our pre-existing collaboration with CUDOS@ANU (Non-linear) and Prof. Solomon Saltiel from the University of Sofia (Bulgaria). In a previous study we identified a set of conditions quasi-phase-matching (QPM) conditions in z-cut congruent lithium niobate whereby simultaneous QPM of type-I (ooe) and higher order type-0 (eee) second-harmonic-generation can occur. These non-linear interactions share a common second harmonic wave. In 2007 we demonstrated that energy exchange between the two fundamental waves, via the shared harmonic wave, can be observed when the two harmonic processes are simultaneously phase matched and the input fundamental waves have enough intensity to ensure ~10% SHG efficiency with respect to the total input energy [2]. A key feature of this energy exchange is its instantaneous nature due to the nonlinearities involved being of the second order.

Fibre Lasers

This project leverages the direct-write techniques developed by the Flagship Project and applies them to producing novel fibre laser sources, in collaboration with staff at the Optical Fibre Technology Centre (OFTC). In 2007 we demonstrated that a fibre laser with a fibre Bragg grating inscribed into its core using an 800 nm femtosecond laser, could be scaled to a continuous-wave output power of > 100 W while offering a very narrow linewidth of 260 pm [3]. This result was presented as a postdeadline paper at ECLEO'07 (Munich). This narrow linewidth high power source was also frequency doubled efficiently into the green, generating up to 2.1 W of visible radiation [4]. In collaboration with the Defence Science and Technology Organisation (DSTO), we also developed a simple, low power oscillator format with a switchable state of linear polarisation [5].

Fibre based instrumentation for astronomy

In 2007 we investigated light loss mechanisms in optical fibres used for astronomical instrumentation. We clearly identified that the end-face surface roughness of fibres can have a significant impact on the Focal Ratio Degradation (FRD) of the fibre. FRD is a major potential source of light loss in fibre based astronomical instruments and it is therefore a significant design consideration. In order to avoid light loss instrument designers must quantify the FRD in the fibres prior to designing the instrument optical components, such as the spectrograph collimator. We have quantified the effect surface roughness has on the far field light distribution of the fibre, and in doing so have developed and alternative FRD model which includes the contributions from scattering, diffraction and modal diffusion. We found a Voigt function to better simulate the observed behaviour of the far field light distribution and it provides and improved fit over the current Gaussian model. Because our model is based on physical processes happening within the fibre it can be used to deconvolve the various components of FRD and quantify their contribution to the light loss. Therefore it is a very valuable tool for astronomical instrument scientists as it will allow them to identify, quantify and potentially minimise sources of FRD and hence improve the fibre and instrument performance.

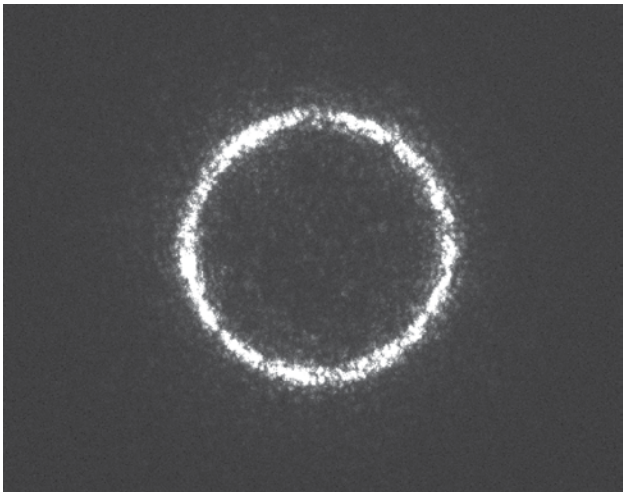


Fig 4: Image of the far field light distribution of a fibre with 8nm rms surface roughness using a HeNe laser as the input light source.

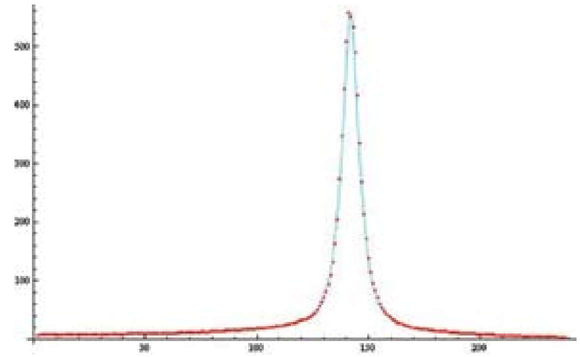


Fig 5: A plot of flux vs radius in pixels for a fibre with a surface roughness of 45nm rms. Red points are the data, blue line is a Voigt fit to the data. The Voigt fit is a significant improvement over the Gaussian fit.

Researchers and students

A/Prof Judith Dawes
Dr Graham Marshall
Dr Alex Fuerbach
Dr Peter Dekker
Martin Ams
Ben Johnston
Doug Little
Luke Stewart
Nem Jovanovic
Dionne Haynes
Sara Ek
Robert Williams

References

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5. N. Jovanovic, A. Fuerbach, G. E. Town, G D. Marshall, M. J. Withford, S. Bennetts and D. G. Lancaster, "Linearly polarised, single-mode Ytterbium doped fibre laser utilizing point-by-point inscribed intra-core fibre Bragg gratings", in Proceedings of SPIE: Conference on Microelectronics, MEMS and Nanotechnology, Canberra, Australia 2007.