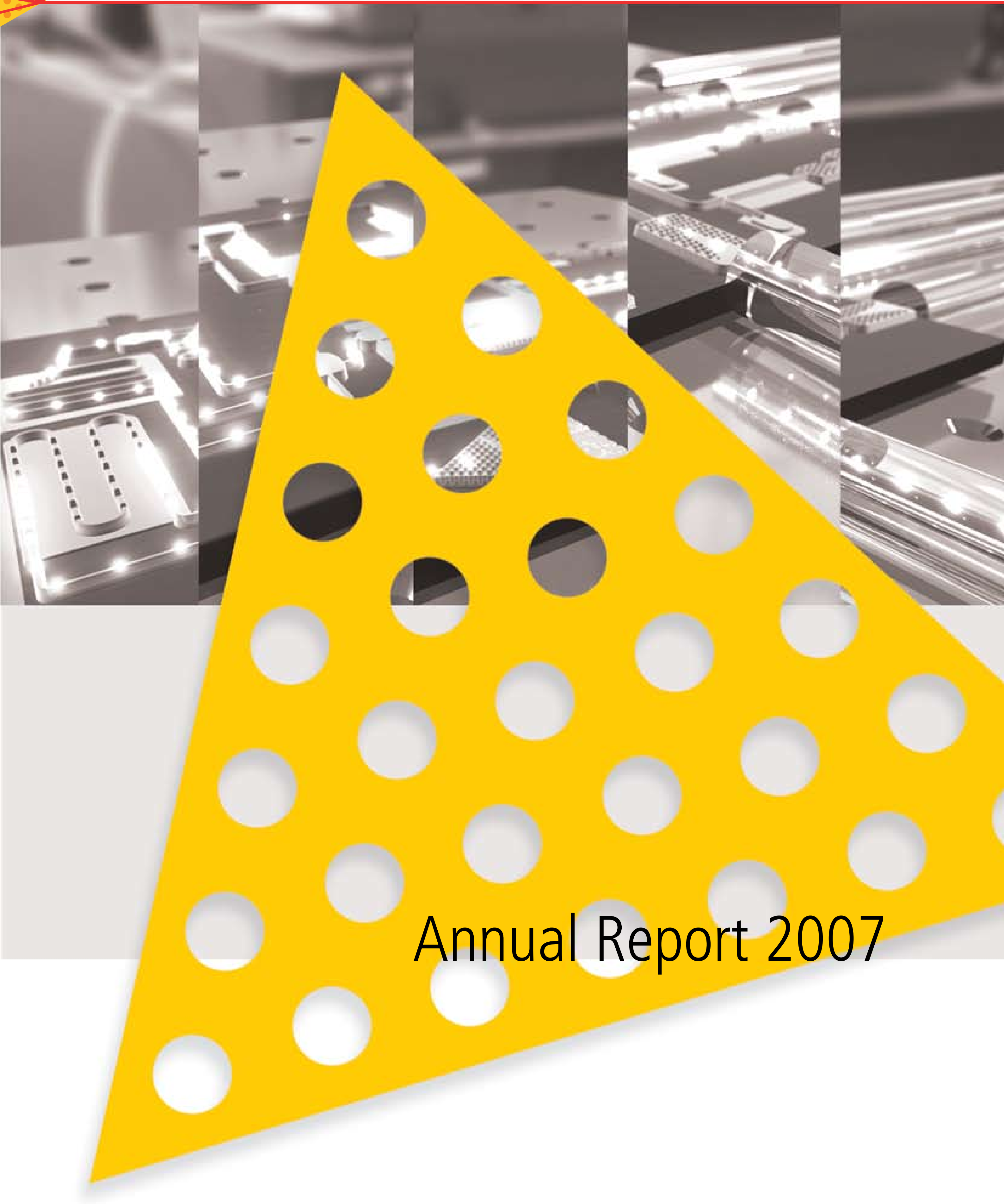
CUDOS The Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)

An Australian Research Council Centre of Excellence



Annual Report 2007

INTEGRATED WAVEGUIDE OSCILLATOR

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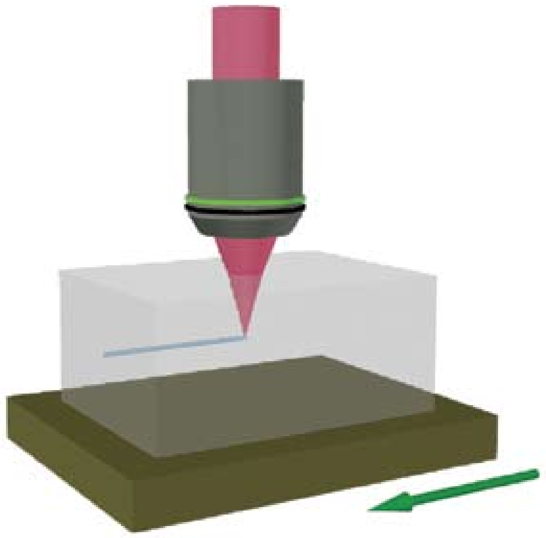
Students: Nemanja Jovanovic, Robert Williams, (Macquarie University)

Four year vision/long term goal and motivation

The femtosecond laser direct write technique is a unique tool for the creation of integrated optical waveguide systems. Using this technique it is possible to fabricate arbitrary networks of waveguides in a wide range of optical media including passive, active and highly-nonlinear glasses. The ability to combine different waveguide functional forms such as splitters, amplifiers, gratings and lasers in three-dimensional 'circuits' is enabling novel research in fields such as telecommunications, bio-photonics and micro-sensing. Our work leads the international field in the development of active integrated optical systems. Examples of devices developed at Macquarie include waveguide amplifiers and monolithic lasers.

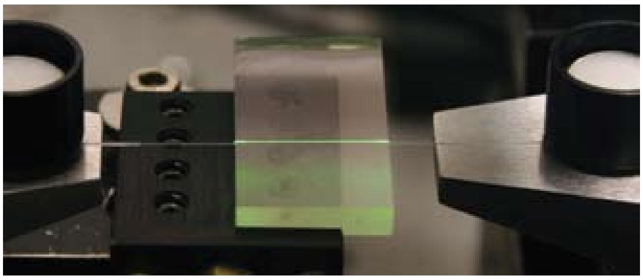


Representation of the direct write method. A femtosecond laser beam is focused inside a moving dielectric material sample to create a permanent optical waveguide.

The miniaturisation and integration of components for optical communication and sensing networks is recognised as an essential step in the development of these technologies. These goals lie at the core of the CUDOS research program. This Flagship program encompasses these goals in its aims to develop integrated optical systems for amplifier and laser applications while enabling the experimental realisation of coupled non-linear waveguide devices designed by our colleagues at ANU. In collaboration with external research partners such as DSTO we will continue to conduct internationally leading research towards:

1. the development of miniature arrays of laser sources for environmental health sensing and civil defence applications
2. the application of three-dimensional 'circuitry' to the miniaturisation of optical devices enabling higher bandwidth fibre communications links
3. the study of fundamental optical physics through unique waveguide manufacturing capabilities developed at Macquarie University.

Cudos strategy/competitive advantage



A waveguide laser device being tested at CUDOS Macquarie University. The active waveguide region glows green under optical pumping.

Macquarie University is an international leader of the field of laser materials processing. Our expertise has enabled the development of world-class facilities dedicated to the field of direct-write photonics. Through several ARC and internal university funding programs we have strategically invested in ultrafast laser, nanopositioning and optical diagnostics systems to enable us to create nanofabrication facilities that are uniquely flexible and almost without equal in our field. Our combined approach of fundamental light/materials interaction research and practical device development has enabled us to conduct insightful research and demonstrate world leading photonic device results.

Collaborative links

Within CUDOS, Macquarie collaborates closely with the University of Sydney and Australian National University. Sydney offer technical advice and support on waveguide amplifier testing while ANU has expertise in the design of non-linearly coupled waveguide devices. DSTO (through Partner Investigator Dr John Haub) will formally join the CUDOS collaboration from 2008 and provide a user-driven perspective on applications for compact waveguide oscillators. External to CUDOS we have established collaborative research links with Aston University in the UK. In 2007 Dr Graham Marshall took part in an Australian Academy of Science funded collaborative research project with Professor Ian Bennion at Aston University on the applications of high-repetition rate laser materials processing.

Goals for 2007

The project goals for 2007 included the demonstration of a monolithic waveguide oscillator and its subsequent power scaling, the measurement of bit error rates in pigtailed waveguide amplifiers, the development of coupled waveguide devices, and the creation of 'lossless' optical signal splitters.

Achievements and highlights for 2007

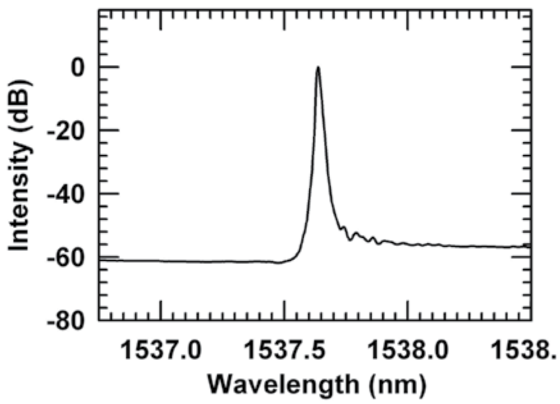


Fig 1: Output spectrum from a WGL. The width of the laser line is limited by the 10 pm OSA slit width.

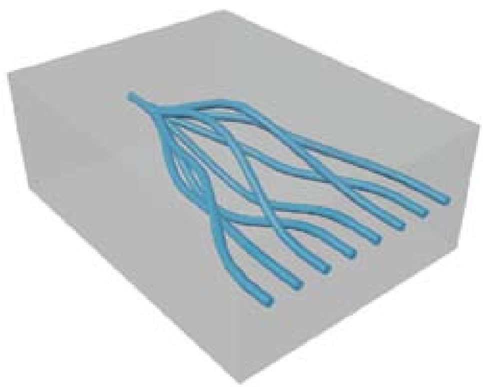


Fig 2: The rendered drawing of a 1-to-8 three-dimensional waveguide splitter. The design pictured above was directly used to fabricate the splitter and is not an artistic impression.

In August 2007 we were the first in the world to demonstrate the creation and successful operation of a monolithic waveguide laser. This was a directly-written DFB laser structure that was written in one laser processing step applied to an Er and Yb doped phosphate glass. When optically pumped the device lased in the C-band (see Figure 1). This work was presented as a post-deadline paper at BGPP 2007 and is to be submitted to Optics Letters in February 2008. In further developments of the 3-dimensional capabilities of the direct-write technique Martin Ams designed and fabricated a 1-to-8 signal splitting waveguide based on equal radius of curvature arms (see Figure 2). This work was included in Martin Ams' doctoral thesis which he completed in 2007. As part of the collaboration with ANU, waveguide samples were produced for further collaborative research into coupled waveguide systems.

Targets for 2008

In light of the successes of 2007 we will predominantly focus on further developing active waveguide devices in 2008. In parallel with the device research the project team will be augmenting the manufacturing and diagnostics facilities at Macquarie University. These project goals can be broadly categorised as device or infrastructure targets and are:

- The power scaling of waveguide laser systems to 1 mW.
- Development of waveguide laser arrays (4 laser devices).
- Creation of 'lossless' splitter devices (1-to-8 designs).
- Continuing investigation of coupled non-linear waveguide systems in coordination with ANU.
- Commissioning of a high power oscillator laser system for rapid and more flexible waveguide fabrication.
- Diagnostic facilities commissioning namely the application of a micro-refractive index profilometer and QPm software. These systems provide sub-micron resolution measurements of waveguide refractive index profiles.
- Improvements to device substrate preparation with the commissioning of new optical sample preparation and polishing facilities in our glass-processing workshop.

Published papers

G. D. Marshall et al. "A Directly-Written Monolithic Waveguide-Laser Incorporating a DFB Waveguide-Bragg Grating," manuscript in preparation for submission to OL Feb' 2008.

M. Ams et al. "Investigation of ultrafast laser–photonic material interactions: challenges for directly written glass photonics," Invited paper JSTQE Organic and Inorganic Photonic Materials, manuscript in preparation for submission Feb '2008 and publication Q3 2008.

G. D. Marshall, P. Dekker, M. Ams, J. A. Piper, M. J. Withford, "Monolithic Waveguide-Lasers Created in Bulk Glass Using the Direct Write Technique," Proceedings Advanced Solid State Photonics, Optical Society of America, Paper MD5, 2008.

M. J. Withford, G. D. Marshall, M. Ams, N. Jovanovic, P. Dekker, A. Fuerbach, and J. A. Piper, "Ultrafast laser direct writing of resonant photonic devices," Proceedings Photonics West, SPIE, Invited paper 6879A-19, 2008.

G. D. Marshall, P. Dekker, M. Ams, J. A. Piper and, M. J. Withford, "Monolithic Waveguide-Laser Created Using the Direct Write Technique," Proceedings Bragg Gratings, Photosensitivity and Poling in Glass Waveguides, Optical Society of America, Post Deadline Paper JWBPDP2, 2007.