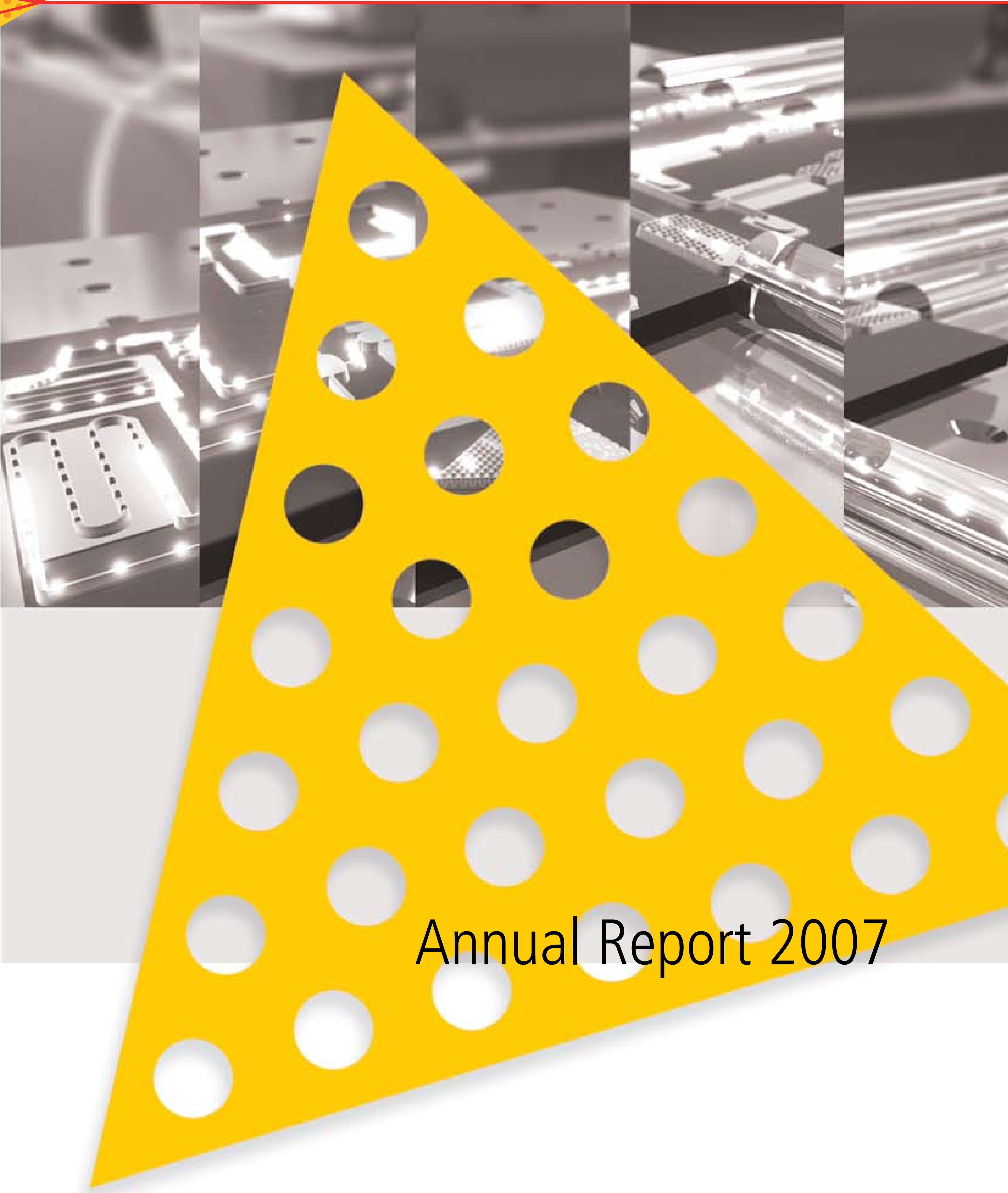
CUDOS The Centre for Ultrahigh bandwidth Devices for Optical Systems (CUDOS)

An Australian Research Council Centre of Excellence



Annual Report 2007

A/Professor Judith Dawes

Judith Dawes is Associate Professor in Physics at Macquarie University, working on the radiation dynamics of photonic crystal structures and active plasmonic devices, and novel diode-pumped crystalline lasers and their applications in communications, medicine and dentistry. She teaches Physics and Optoelectronics, and is a member of Macquarie's MQPhotonics Research Centre. She is currently the Postgraduate Director for Physics, and the Director of the B Technology (Optoelectronics) and B Optical Technology degrees. She is a member of OSA, SPIE and APS, and is a Councillor of the Australian Optical Society. She received her BSc (Hons) and PhD from the University of Sydney, after a 1-year Rotary fellowship at the University of Rochester, and pursued Postdoctoral research at the University of Toronto. She joined Macquarie University in 1991.

Key areas of research contribution within the Centre

Judith's research program includes characterisation of the radiation dynamics of emitters within opals (3D photonic crystals), linked to the 3D Bandgap Confinement flagship program, the fabrication and characterisation of waveguides or optical fibres within opals and inverse opals, and plasmonics with active laser materials. The opals research program is focussed on understanding the behaviour of optical emitters in photonic crystals and on harnessing the emitted light in waveguide devices incorporated into photonic crystals, with the goal of creating more efficient optical amplifiers for light propagating in photonic chips.

Surface plasmons are optical-electronic excitations that propagate on the interface between a thin metallic film and a dielectric substrate. Plasmonics offers the potential for compact, efficient devices combining optics with electronics for signal processing, although the propagation losses of plasmons are relatively high due to absorption in the metallic layers. In this research, the goal is to create plasmonic devices that amplify plasmons as they propagate.

Researchers and students

Research students within Macquarie working on 3D bandgap effects in photonic crystals are Luke Stewart, Sara Ek, and on Active Plasmonics, Jacek Gosciniak. Research staff at Macquarie contributing to these activities are Dr Peter Dekker, Dr Graham Marshall, Dr Adel Rahmani (now at UTS), Assoc Prof Mike Steel (formerly at RSoft and University of Sydney), and Assoc Prof Michael Withford. Collaborating researchers are Dr Frank Dillon and Prof Martyn Pemble, Tyndall Institute in Ireland.

Research achievements during 2007

There are two potential approaches to the fabrication of waveguides in opals. The waveguide may be fabricated in situ within the opal, or the opal may be assembled around an existing waveguide (or optical fibre). In the latter case, opals have been successfully grown on tapered optical fibres and capillary tubes of varying diameters. Fig. 1 shows evidence of photonic bandgap guiding in an opal-clad optical fibre transmission spectrum. These results were presented at the AIP conference in Brisbane (December 2006) and at ECLEO in Munich, Germany (June 2007).

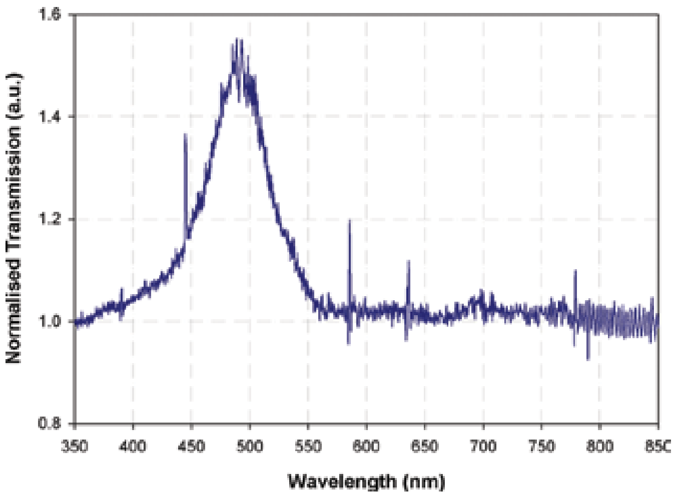


Fig 1: Wavelength specific increase in opal clad fibre transmission. The position of the increase corresponds to the position of the photonic bandgap.

Experiments to examine the effect of substrate curvature on the quality of the opal photonic crystals were presented at SPIE in Canberra (December 2007), and demonstrated that opal growth was less successful for highly curved substrates (diameter < 50 μm). See Fig. 2.

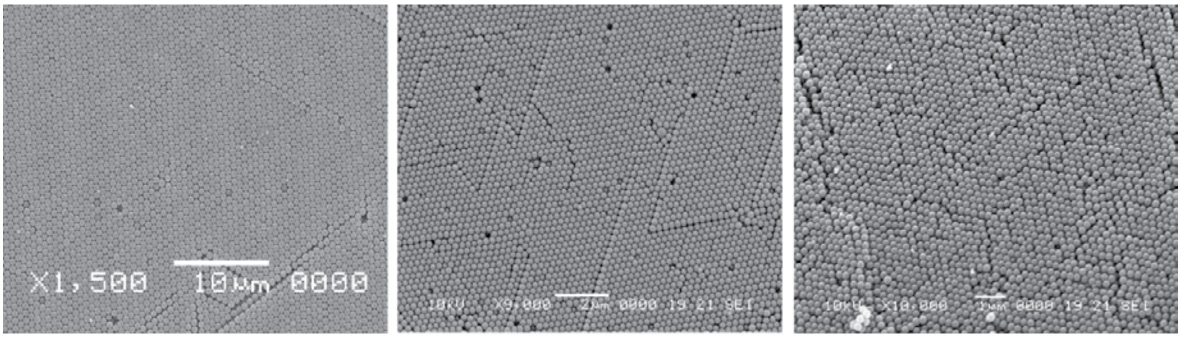


Fig 2: SEM images of opals grown on various surfaces: (a) flat surface, (b) capillary and (c) optical fibre. It is obvious that as the substrate curvature increases, the periodicity of the top layer of spheres gets worse.

Fabrication of opals was improved, with better temperature control of the process leading to faster growth and improved photonic crystal periodicity. With funding from DEST-ISL, Luke Stewart spent 2 weeks at the Tyndall Institute in Ireland learning to fabricate mono-disperse silica microspheres. He also doped these microspheres with ytterbium and europium rare earth ions and nano diamonds to investigate the effect of the 3D photonic crystal on the emission. Sara Ek demonstrated that spin-coating of microspheres produced high quality single layer photonic crystal deposition.

Another approach to introducing waveguides into photonic crystal structures is by lithography in inverse opal structures. Self-assembled photonic crystals (opals) such as that in Fig. 3 may be fabricated from polystyrene spheres. From a well-ordered 3D opal template, high quality inverse opals have been fabricated, such as that shown in Fig. 4. This was done by infiltrating the structure with sol-gel glass or with photoresist followed by removal of the sphere matrix. The next step in the process is to lithographically introduce waveguides inside the 3D photonic crystal.

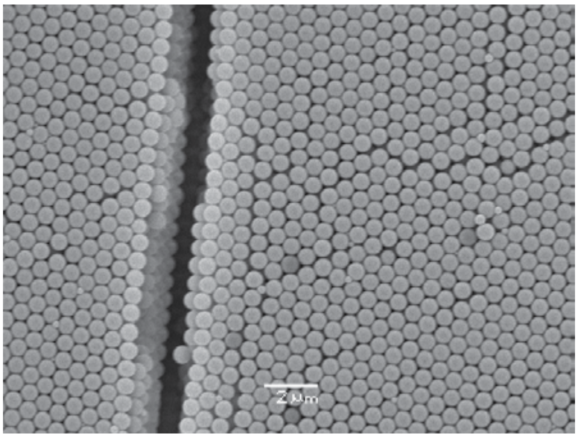


Fig 3: A 3D photonic crystal made of polymer micro spheres arranged in a face centred cubic symmetry.

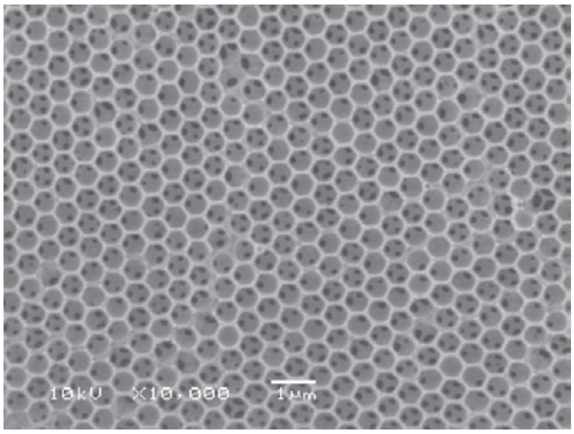


Fig 4: An inverse opal structure showing periodicity over large areas.

Surface plasmons are optical-electrical excitations, which may be guided by nano-scale metal wires, and promise very compact and powerful devices for information processing. However the severe absorption losses experienced by surface plasmons limits the size to impractical dimensions, and this research program aims to amplify the plasmons using laser gain materials as the substrate for the metallic wires. Gold films have been deposited and laser-micro-processed to create fine wires (see Fig. 5) and plasmon propagation experiments are the next step in the development of this approach.

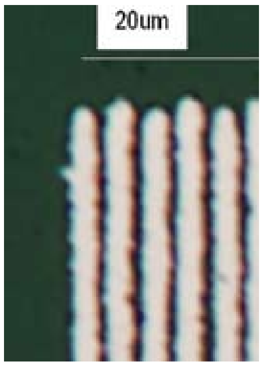


Fig 5: Gold film on glass substrate with laser-micro-machined lines etched to create nano-wires for plasmonic waveguides.