

## Newsletter January 2004

### **Ben Eggleton introduces the Newsletter:**

2003 was an exciting year for CUDOS and represented the beginning of a long and fruitful collaboration. In 2003 we established the research programs, developed the collaborations and announced ourselves to the world. We are off to a great start as was evident by the strong presence at the ACOLS meeting in Melbourne. It was great to receive such positive feedback to the CUDOS technical presentations. As we move in to 2004 the research goals are being refined and the collaborations are developing. The two CUDOS workshops have been very effective in bringing the CUDOS team together and provided an ideal forum for establishing the research interactions and the sharing of information. This newsletter serves several purposes, primarily it will keep all CUDOS members informed of general developments, both the research highlights and more general issues. The newsletters will be distributed every second month, the content and format will evolve so please provide constructive feedback.

### **Chris Walsh reports:**

The final draft of the intellectual property agreement was completed before Christmas and is being circulated to all collaborating organisation for signature. Once this is signed off, we will convene the Commercialisation Committee (by phone) for an initial discussion. Several patent disclosures have been made from the different nodes – these are being handled using the local procedures at present although Ben and I should be kept in the loop as a matter of course.

We are in the process of obtaining quotes from commercial vendors to completely overhaul the external and internal web sites. I have prepared a scope of work document that I am happy to send anyone if they request it.

Preparations for the Annual Report are underway. This needs to be completed by March 31. I have already been in contact with chief investigators for information – this is a gentle reminder!

### Reports from the Research Nodes

#### **Ben Eggleton reports from Sydney:**

The experimental program is making strong progress in several areas. 2003 focussed on building the laboratory,

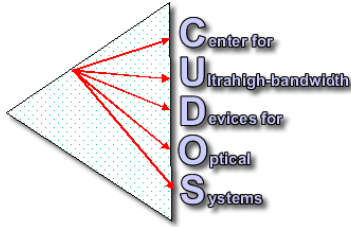
training students and hiring. As the group grows we are organizing into several research themes: (a) Nonlinear optics and ultra-fast optical systems; (b) microstructured optical fiber devices; (c) planar photonic devices; and (d) optical grating devices.

A recent research highlight, in collaboration with the Swinburne CUDOS node, was the demonstration of a novel photonic crystal device geometry using microstructured optical fibers transversely. This device architecture has led to numerous microphotonic device demonstrations including a microfluidic tunable photonic bandgap device, tapered photonic crystal devices and novel tunable filters. Several papers have been submitted and a postdeadline paper was presented at the LEOS annual meeting.

The nonlinear linear optics activity is making important progress in the characterization and optimization of optical parametric amplifier devices. We are currently installing a number of high-power pulsed lasers for future nonlinear optics experiments and are beginning to order equipment for the ARC LIEF funded Raman facility (Usyd, Macq, ANU).

### **PUBLICATIONS**

1. T. T. Ng, J. L. Blows, J. T. Mok, P. Hu, J. A. Bolger, P. Hambley, and B. J. Eggleton, "Simultaneous residual chromatic dispersion monitoring and frequency conversion with gain using a parametric amplifier," *Optics Express* Vol. 11, Page 3122 (2003).
2. H. Nguyen, P. Domachuk, B. J. Eggleton, M. Straub, M. Gu, "Microfluidic tunable photonic bandgap device," in press *Applied Physics Letters* (2004).
3. J. T. Mok and B. J. Eggleton, "Impact of group delay ripple on repetition-rate multiplication through Talbot self-imaging effect, In Press *Optics Communications* (2004).
4. H. Nguyen, P. Domachuk, B. J. Eggleton, M. J. Steel, M. Straub, M. Gu, M Sumetski, "A new slant on photonic crystal fibers," submitted to *Optics Express*.
5. E. Magi, P. Steinvurzel and B. J. Eggleton, "Tapered photonic crystal fibers," submitted to *Optics Express*.
6. E. Magi, P. Steinvurzel and B. J. Eggleton, "Transverse probing of tapered photonic crystal fiber," submitted to *Applied Physics Letters*.



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7. H. Nguyen, P. Domachuk, M. J. Steel, B. J. Eggleton, "Experimental and FTDT characterization of photonic crystal fibers," submitted to Optics Letters.

Ross McPhedran was on sabbatical leave during December and January.

### *Martijn de Sterke reports from Sydney:*

We have worked out the symmetry of the modes of coupled photonic crystal waveguides - they behave differently than conventional coupled waveguide. In the latter the fundamental mode is always even, whereas in the photonic crystals the fundamental mode can be either even or odd.

### **Publications / Conferences**

A. Lobo, C. Martijn de Sterke, and J.A. Besley, "Reflection spectra of rotationally symmetric blazed gratings," submitted to J. Lightwave Technol.

C. Martijn de Sterke, L.C. Botten, A.A. Asatryan, T.P. White and R.C. McPhedran, "Modes of coupled photonic crystal waveguides," submitted to Opt. Lett.

Andrew H. Norton and C. Martijn de Sterke, "Aperiodic 1-dimensional structures for quasi-phase matching," submitted to Optics Express.

### **People**

We have appointed the following research staff:

- Dr Christian Grillet brings experimental expertise in 2D photonic crystal devices, lithography and planar photonic integration. Christian will interact closely with the CSIRO CUDOS group researching photonic crystal devices. Christian is initially focusing on tunable photonic crystal delay lines.
- Dr David Moss brings strong expertise and a wealth of knowledge in planar technology, semiconductor devices and nonlinear optics. Dave spent the last few years in industry leading the development of micro-optical devices. Dave will play a lead role in CUDOS efforts in planar photonic devices, underpinning our efforts towards the photonic chip. Dave will work closely with the

CSIRO CUDOS group and international facilities, including the CPFC in Ottawa which has world class microfabrication.

- Dr Libin Fu has accepted a position with CUDOS and is currently waiting for a VISA. Libin completed a 3 year postdoctoral position working with Dr Morten Ibsen at the ORC in Southampton University. Libin has expertise in fiber lasers, fiber gratings, photonic devices and nonlinear optics and he will play a lead role in the nonlinear photonic devices area.

Visitors to the Sydney node since mid-November include Professor Sajeed John (University of Toronto), Dr Dick Slusher (Lucent) and Dr Neil Broderick (ORC, Southampton). A number of PhD students are presently visiting; they are

- Mr Yannick Lize (Ecole Polytechnique, Montreal), for three months working with Ben Eggleton
- Ms Rossella Zoli (University of Bologna) for three months working with Ross McPhedran and Ben

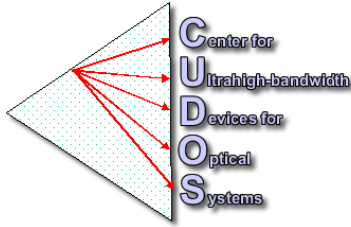
We have also had a number of vacation students: Thomas Yuan, Airlie Chapman and John Zhu.

### *Lindsay Botten reports from UTS:*

Research by the UTS group during this time has focussed on:

- The development of the Linear Photonic Crystal modelling codes designed to efficiently model linear structures based on photonic crystal segments. This development continues with generalisations of polarisation and geometry that can be handled by the suite. Two theoretical papers describing the method are in preparation for JOSA while a third has been invited for a special issue of Optics Express. The work has attracted some attention and has led to invitations to speak at the PIERS Computational Optics session (Pisa, March 2004), the SIAM Conference on Mathematical Aspects of Material Science (May 2004) and the OSA IPR Conference (June/July 2004)..

- Elucidation of mode symmetries in photonic crystal waveguides — the Bloch mode analysis has succeeded in unravelling a fundamental question of what governs the symmetry of modes in coupled photonic crystal



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waveguides, a source of some controversy in the literature. In PC guides the fundamental mode can be either odd or even, in contrast to coupled conventional guides for which the mode is always even, and we have developed an elegant analysis which characterises the behaviour in terms of Bloch modes and the sign of sign of the fundamental Bloch factors in the background (PC) structure. A paper has been submitted to Optics Letters.

- Studies of Photon Conductance in both regular and random photonic crystal structures. Originally developed to describe the transport properties of electrons in disordered wires, the concept of conductance can also be applied to photons. In investigating the conductance fluctuations of photons in 2D disordered photonic crystal (with the support of a parallel ARC Discovery Grant) we have shown substantial differences between the widely used Pichard theory of electron conductance and the behaviour exhibited by photons. Specifically, there is a very strong dependence on the role of evanescent coupling between adjacent layers and we outline the impact of this on the formulation of the theory of conductance in a paper submitted to Phys Rev Letters.

Much of this work has been undertaken in collaboration with our fellow theoreticians at Sydney University.

### Publications / Conferences

T P White, L C Botten, R C McPhedran, C M de Sterke, Ultra-compact resonant filters in photonic crystals, *Optics Letters*, 28, 2452-2454, 2003.

C M de Sterke, L C Botten, A A Asatryan, T P White, R C McPhedran, *Modes of photonic crystal waveguides*, submitted to *Optics Letters*

A A Asatryan, L C Botten, T N Langtry, C M de Sterke, R C McPhedran, P A Robinson, *Conductance of photons in disordered photonic crystals*, submitted to *Phys. Rev. Lett.*

L C Botten, T P White, A A Asatryan, T N Langtry, R C McPhedran and C M de Sterke, "Modelling of extended photonic crystal devices", ACOLS 03

A A Asatryan, L C Botten, N A Nicorovici, R C McPhedran, C M de Sterke and T N Langtry, "Conductance of photons in ordered and disordered photonic crystals", ACOLS 03.

Two abstracts have been submitted to CLEO.

### People

Three new research appointments have now been made at UTS. They are:

- Dr Ara Asatryan to a Senior Research Associate
- Dr Andrew Norton to a Senior Research Associate
- Dr Kokou Dossou to a Research Associate

Ara Asatryan commenced late in 2003, Andrew Norton takes up his post in February 2004 and Kokou Dossou, who will be joining us from the University of Laval in Canada is in the throws of acquiring an Australian permanent residency visa. Michael Byrne has also joined us as a new PhD student funded by an APA scholarship.

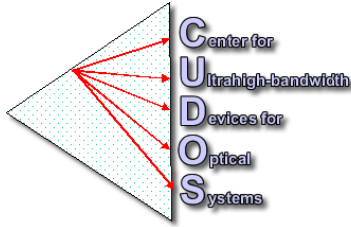
### *Wieslaw Krolikowski reports from ANU:*

The nonlinear optics experimental team headed by Wieslaw Krolikowski and Dragomir Neshev completed two new setups. Our experimental efforts concentrate on the study of optical beams and solitons in nonlinear media (photorefractive crystals) with optically-induced periodic index lattices. In particular, we have recently succeeded in the generation of spatial gap solitons and observation of their anomalous steering properties.

We are currently studying the formation of multi-gap vector solitons formed by mutual interaction of two optical components which, in the linear regime, belong to the first and second band of the periodic structure. Preliminary observations confirm the existence of interaction induced mutual focusing. In another experiments we are currently working on the Bloch oscillations of optical beams.

### *Yuri Kivshar reports from ANU:*

The theoretical team completed several research projects, and the results will be soon submitted for publications. These include the theory of asymmetric



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vortex-like structures and phase flipping effect in 2D lattices (A. Sukhorukov and Yu. Kivshar), and the theory of a giant Lamb shift in photonic crystals (X-H. Wang and Yu. Kivshar)

### Publications

(1) A paper on a combined experimental and theoretical work on the nonlinear Bloch-wave scattering, has been accepted for publication in Physical Review Letters and is scheduled for publication in February: "Nonlinear Bloch-wave interaction and Bragg scattering in optically-induced lattices", by Andrey A. Sukhorukov, Dragomir Neshev, Wieslaw Krolikowski, and Yuri S. Kivshar;

(2) The first paper on the project on the left-handed periodic bandgap structures has been completed and submitted for publication to Applied Physics Letters, entitled "Tunable transmission and bistability in left-handed bandgap structures" by Michael W. Feise, Ilya V. Shadrivov, and Yuri S. Kivshar

As announced recently, the group's work will be presented by 11 papers at the forthcoming OSA Topical meeting on Nonlinear Guided Waves - seven of which have been accepted as ORAL.

### CUDOS new students, members etc

During recent months we have been hosting a number of PhD and undergraduate students who have participated in our experimental work. They include:

- Jochen Schroeder, Diploma student, University of Muenster, Germany (2 weeks in November-December)
- Thomas Pertsch, PhD student, University of Jena, Germany (10 Days, December)
- Nick Pak, Vacational scholar, Otago University, New Zealand (December-February)
- Byron Villis, Vacational Scholar, Melbourne University (January)
- Henrike Trompeter, PhD student, University of Jena, Germany (January-February)

### CUDOS visitors

Prof. Ole Bang (COM, Denmark): January 4-23

### CUDOS events

Dr. Andrey Sukhorukov visited the Moscow Lomonosov University and participated in discussions of possible collaborative projects with the group of Prof. Alexei Zheltikov in the field of nonlinear effects and multi-frequency generation in photonic crystal fibers.

### CUDOS seminars

January 21: Prof. Ole Bang (Denmark) talked about current project on photonic crystals fibers at COM.

### *Barry Luther-Davies reports from ANU:*

The CUDOS program will benefit from the availability of a new JEOL/Orsay Instruments dual SEM/FIB that has recently been commissioned within the Electron Microscopy Unit at ANU. The FIB software will be upgraded to enable it to write patterns either into photoresist for transfer into a film via dry etching or by direct milling into the film. Both approaches will be pursued by Darren Freeman. At this stage patterns have been transferred into Al films on Si substrates as part of the learning exercise using the tool. A sample pattern is shown in the attached image.

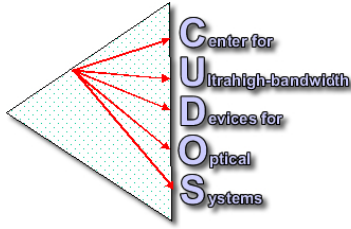
The first high power UV generation experiments from of ablation laser have been completed. We have shown that 50% conversion into 265nm is possible and have developed a new approach to overcome the problem of thermal loading in the BBO crystal at high average powers. The first experiments on ablation of materials using the UV have been performed.

A number of papers on laser ablation relevant to CUDOS have appeared in the past few months. A review chapter on ultra-fast PLD is in the editing stage.

### Publications / Conferences

Zakery, A., Ruan, Y., Rode, A.V., Samoc, M., Luther-Davies, B. "Low-loss waveguides in ultrafast laser-deposited As<sub>2</sub>S<sub>3</sub> chalcogenide films" Journal of the Optical Society of America B: Optical Physics (2003), 20(9), 1844-1852

Golberg, D., Rode, A.V., Bando, Y., Mitome, M., Gamaly, E.G. Luther-Davies, B. "Boron nitride



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nanostructures formed by ultra-high-repetition rate laser ablation” Advanced Materials and Nanomaterials Laboratory, Diamond and Related Materials (2003), 12(8), 1269-1274.

Luther-Davies, B., Kolev, V. Z., Lederer, M. J., Yinlan, R., Samoc, M., Jarvis, R. A., Rode, A. V., Gieseckus, J., Du, K.-M., Duering, M. “Ultrafast pulsed laser deposition of chalcogenide glass films for low-loss optical waveguides” Materials Research Society Symposium Proceedings (2003), 780 (Advanced Optical Processing of Materials), p131-142.

### *Mick Withford reports from Macquarie:*

Group research highlights include:

- First demonstration of nano-scale fabrication using femtosecond laser machining
- 1st demonstration of SHG from a sample of PPLN produced using the laser based fabrication method developed at Macquarie.
- Demonstration of laser written, single mode waveguides in silica
- Andrew Lee was the winner of the 2003 AIP (NSW) Postgraduate Award

### **Seminars/invited papers:**

1. Presentation (by Mick) at DSTO on CUDOS@Macq research directions
2. Invited paper at SPIE (see publications)

### **International Conferences:**

M. J. Withford, A. J. Lee, B. F. Johnston, M. Ams, J.M. Dawes and J. A. Piper, “Fabrication of photonic devices using novel laser assisted methods”, invited paper, Proc. of SPIE: Conference on Microelectronics, MEMS and Nanotechnology, Perth, Australia, 2003.

B. F. Johnston and M. J. Withford, “Rapid prototyping of periodically poled lithium niobate”, CLEO/Pac Rim '03 (ISBN 0-7803-7766-4), Tapei, Taiwan, 2003.

A. J. Lee, M. J. Withford, D. R. Baer and J. M. Dawes, “Microstructure fabrication using heat shrinkable polymer films”, CLEO/Pac Rim '03 (ISBN 0-7803-7766-4), Tapei, Taiwan, 2003.

### **National Conference Papers (extended abstracts):**

Andrew J. Lee, Michael J. Withford and Judith M. Dawes, “Fabrication of photonic crystal structures using a two-step mould process”, Australasian Conference for optics, lasers and spectroscopy (ACOLS), Melbourne, 2003.

Benjamin F. Johnston and Michael J. Withford, “Novel techniques for fabricating periodically poled lithium niobate” Australasian Conference for optics, lasers and spectroscopy (ACOLS), Melbourne, 2003.

Martin Ams, Michael J. Withford, Judith M. Dawes and James A. Piper, “Fabrication of optical waveguides in bulk materials using a femtosecond laser”, Australasian Conference for optics, lasers and spectroscopy (ACOLS), Melbourne, 2003.

### **People:**

Graham Marshall (ex Clarendon Laboratories) has joined CUDOS@Macquarie as a Research Associate.

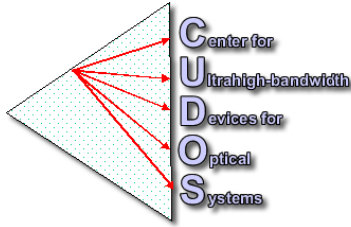
Dr Marie Wintrebert-Fouquet, presently a scientist in the semiconductor processing facility at Macquarie, will be working part time on CUDOS projects.

Mr Ben Johnston has joined the group as a PhD student.

### *Min Gu reports from Swinburne:*

Recent research highlights include:

- Fabrication of 3-D photonic crystals with higher-order stop gaps (published in Phys. Rev. Lett. and highlighted in Laser Focus World)
- Fabrication of organic/inorganic polymer resin for fabrication of high quality photonic crystals
- Development of the angle-resolved FTIR spectroscopy methods for photonic crystal characterisation
- Development of high efficiency polymer resin
- Development of a polymer-based superprism



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### Publications / Conferences

M. Straub, M. Ventura, and M. Gu,  
“Multiple Higher-Order Stop Gaps in Infrared Polymer Photonic Crystals” Phys. Rev Lett. 91 043901 (2003)

M. J. Ventura, M. Straub, and M. Gu “Void channel microstructures in resin solids as an efficient way to infrared photonic crystals” Appl. Phys. Lett. 82 1649 – 1651 (2003)

G. Zhou, M Ventura and M Gu “Two dimensional NIR photonic crystal fabrication by generation of void channels in solid resin” Chinese Opt. Lett. 1 719 – 21 (2003)

A paper on the Photonic crystal fabrication was also presented at CLEO Pac Rim (2003) and at the International Nanophotonics conference.

#### People:

Dr. Martin Straub has taken up an appointment as a Senior Research Fellow with CUDOS.

#### CUDOS in the news

- Laser Focus World in its September 2003 edition carried a review of the Swinburne research on photonic crystals
- Martin Straub contributed an article to the Australian Optical Society Newsletter in December 2003.

#### *Nick Savvides reports from CSIRO:*

The CSIRO team (Nick, Julie Glasscock, Jia Du, Jason Vanajek) has been active in the development of tools and processes for producing rib waveguides on SOI (Silicon-on-Insulator) substrates. The three main recent achievements are:

- the team has established conditions for reactive ion etching of silicon in  $CF_4$  plasmas. Waveguides 16 mm in length, 5  $\mu m$  by 5  $\mu m$  cross section have been fabricated with smooth ( $\sim 0.1 \mu m$  RMS roughness) and near-vertical walls. The next challenge is to optimise the coupling.
- The software and hardware for the Nanometre Pattern Generation System (NGPS) has arrived and is being installed on a CSIRO SEM machine for electron beam lithography.
- An ICP reactive ion etching machine has been “mocked up” and successfully operated. Nick is now building a system based on this that will be installed in

the clean room. Most of the components have arrived, with the exception of the chamber. Funding is being sought for two ion beam generators.

#### People:

Martin Soh (a student from UWA) is working with Nick on a joint project with Prof Laurie Faraone. Vahid Ta’eed and Cristian Grillet from the Sydney group are working approximately two days per week at CSIRO.

### Publications / Conferences

Three papers will be presented at the 28<sup>th</sup> Annual Condensed Matter and Materials Conference at Wagga, 3 – 6 February 2004.

Nick presented a paper on the MEMS work with Martin Soh at the SPIE Conference on Microelectronics, MEMS and Nanotechnology, Perth, Australia, 9 – 12 December 2003.