RESEARCH SCHOOL OF PHYSICAL SCIENCES & ENGINEERING

Department of Applied Mathematics

The Department of Applied Mathematics performs research on fundamental and applied topics in colloid, surface and polymer science, largely in measurement of surface forces; on self-assembly of organic and inorganic structures at mesoscopic scales; and on disordered materials, mostly on micron-scale morphology, granular materials and transport in porous structures and on complex systems.

The research activities of the Department remain very diverse, encompassing researchers with very different backgrounds and often very different approaches to research. It is fitting then that this year our founder, Professor Barry Ninham, be awarded the David Craig medal for his lasting contributions to the broad science he has made over the past 50 years. As reflected in Barry's contributions this also remains the Department's great strength. In reality it is much like a physics, chemistry, biology, mathematics, materials and chemical engineering department all rolled into one. Work in the Department continues to include experimental work as well as theory and simulation.

The research interests in condensed matter can be broadly classified into three main areas:

(a) soft matter systems (polymers, liquid crystals, surfactants);

(b) surface science – particularly systems involving colloidal and soft materials; and

(c) porous and disordered materials.

Although condensed matter and materials research dominates the Department's efforts, individual programs are diverse; for example, studies of wettability in plant capillaries, modelling of multiphase flow properties of oil-bearing rocks, tomographic imaging of fossils and studies of networks and analysis of economic data are part of the Groups' ongoing research programs.

A large part of the Department's effort has been funded by the ARC Cooperative Research Centre, SmartPrint, which focuses mainly on fundamental research on surface physics and material structure with applications to the paper industry (Knackstedt, Fogden, Senden and Craig). A joint research project with companies in the oil and gas industry is now being undertaken. In both cases the Department has been able to forge solid research consortia, where industry is being driven by the application of pure research. So successful have these relationships been that the partners are in fact championing the development of ANU technology in the global setting. Largely, progress continues to be open science, although a number of commercial opportunities have presented themselves. In supporting open research the collaborating industry partners are recognising the role universities play in providing the broad and basic training that their industry draws upon.

The Department has grown to its largest now comprising over 50 people, and in terms of academic staff is the largest in the Research School. It continues to grow, thanks mainly to the support of the Australian Research Council (ARC) in terms of fellowships, the Co-operative Research Centre (CRC) and industry-related grants.

During 2005 the research of the Department continued much as in recent years. Of particular note was the commencement of the Federation Fellowship awarded to Professor Stephen Hyde. His research program underlines the breadth of the Department; his interest include self-assembly of molecular and macromolecular amphiphiles and lipids in solution into liquid crystals, formation of inorganic materials in biological and abiotic conditions. His work also includes characterisation and enumeration of geometric networks in various spaces, including two-dimensional hyperbolic networks and higher- dimensional euclidean networks. To great

fanfare, Stephen, Vanessa Robins and Stuart Ramsden initiated the 'Euclidean Patterns in Non-Euclidean Tilings' (EPINET) project, which explores 2D hyperbolic (H^2) tilings as a source of crystalline frameworks (or networks) in 3D euclidean (E^3) space.

Just as the Atomic Force Microscope (AFM) facility has been extended to ANU researchers as an open access facility, the X-ray Micro-tomography facility has also provided support to researchers outside the Department. Some of these innovative projects include quantifying the neural capacity of bees, exploring the sensory systems of 270 Million year old fossil fish and the arrangement of wood fibre composites.

Staff List

Professor and Head of Department

Mark Knackstedt BSc Columbia, PhD Rice (ARC QEII Fellowship)

Professors

Stephen Hyde BSc PhD Monash (ARC Federation Fellowship)
David Williams BSc Sydney, PhD Cambridge (ARC Fellowship)

Senior Fellows

Tomaso Aste DipHons Genova, PhD Milan (EU, Marie Curie Fellowship)
Vince Craig BSc PhD ANU (ARC Fellowship)
Tiziana Di Matteo BSc PhD Salerno (ARC QEII Fellowship)
Tim Senden BSc PhD ANU (ARC Fellowship)
Adrian Sheppard BSc Adelaide, PhD ANU

Research Fellows

Christoph Arns DipPhys Aachen, PhD UNSW (ARC Postdoctoral Fellowship)
Andrew Fogden BSc PhD ANU, Docent Lund
Mika Kohonen BAppSc BSc PhD ANU
Ankie Larsson MSc Lic PhD Lund, Doc Stockholm
Nobuo Maeda BSc PhD ANU
Chiara Neto BSc PhD Florence (ARC Fellowship) (until December)
Shannon Notley BSc PhD ANU
Drew Parsons BSc PhD Karpov, DipEd UNSW
Vanessa Robins BSc ANU, PhD Colorado
Arthur Sakellariou BSc PhD Melbourne
Rob Sok BSc PhD Groningen

Postdoctoral Fellows

Liliana De Campo BSc PhD (Graz)
Gary Delaney PhD Trinity, Ireland (from October)
Francois Ghoulmie
Mayhar Madadi BSc Tehran, MSc IASBS, PhD IASBS (from November)
Ruipeng Liu PhD Kiel (from November)
Ray Roberts BSc PhD ANU
Mohammad Saadatfar BSc Mazandaran MSc IASBS, PhD ANU (until November)
Pär Wedin MSc KTH Stockholm, PhD Karlstad

Visiting Fellows

Ji Youn Arns PhD UNSW
Tom Beck PhD Cincinatti
Fabio Clementi PhD Italy
Corrado Di Guilmie PhD Italy
Stjepan Marcelja Dip Ing Zagrep, PhD Roch, FAA
Barry Ninham MSc WA, PhD Maryland, DTech (hon causa) KTH Stockholm, DPhil (hon causa) Lund, FAA (Emeritus Professor)
Chiara Testa Universiti Genova, Italy (October-December)
Denis Weaire Trinity College, Ireland (November-February)
Pierandrea Lo Nostro University of Florence, Italy (December)

Senior Technical Officers

Anthony Hyde Assoc IE Aust
Tim Sawkins

Departmental Administrator

Margo Davies

Other Staff

Holger Averdunk BSc Biochemistry, BSc Computer Science
David King (Browitt Nanopartical Laboratory Innovations Building)
Stuart Ramsden GradDip Film & Television Swinburne
Callum Robertson
Erica Seccombe (Artist in Residence, September-November) (ACT grant)
Ross Stephens PhD Sydney (Browitt Nanopartical Laboratory Innovations Building)
Jan-Paul Veldkamp BSc BEc ANU

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

Book Chapters

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Langmuir 22 (2006) 9238-9243

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Langmuir 22 (2006) 5025-5035

Refereed Conference Proceedings

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Microelectronics, MEMS and Nanotechnology, SPIE International Society for Optical Engineering (2006) 60390G-1-14

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Olafuyi, A.O.*, Sheppard, A.P., Arns, C.H., Sok, R., Cinar, Y.*, Knackstedt, M. and Pinczewski, W.V.*
Experimental Investigation of Drainage Capillary Pressure Computed from Digitized Tomographic Images
SPE/DOE Symposium on Improved Oil Recovery, Society of Petroleum Engineers (2006) 7 pages

Atomic and Molecular Physics Laboratories

As recognised by the Division of Atomic, Molecular, and Optical (AMO) Physics of the American Physical Society, "AMO physics is an enabling science that supports many other important areas of science and technology." Indeed, students graduating in AMO Physics acquire a breadth of knowledge and skills, enabling them to contribute to many areas of science, technology, and society. AMO physicists have also appeared prominently among Nobel laureates in recent times. The Atomic and Molecular Physics Laboratories are engaged in a broad range of experimental and theoretical studies of the interaction of electrons, positrons, and photons with atoms, molecules, and solids, in order both to further our knowledge of fundamental physical and chemical processes, and to provide essential information that is critical to applications in other scientific disciplines, technology, and the environment.

Staff List

Professor and Head of Laboratories

Brenton Lewis BSc PhD DSc Adelaide, C Phys, FInstP, FAPS, FOSA, FAIP

Professors

Stephen Buckman BSc PhD Flinders, FAPS, FAIP, FInstP
Anatoli Kheifets BSc PhD St Petersburg, FAPS

Adjunct Professors

Lewis Chadderton BSc DSc Durnham, MA PhD Cambridge, C Phys, FInstP, FAIP
Robert McEachran MSc PhD UWO, C Phys, FInstP
Robert Robson BSc Queensland, DipMet, PhD, FRMS, FAPS, FAIP (until November)

Senior Fellows

Kenneth Baldwin MSc ANU, DIC PhD London, FAIP, FOSA
Stephen Gibson BSc PhD Adelaide
Maarten Vos MSc PhD Gröningen

Fellows

Julian Lower BSc Adelaide PhD Flinders
Andrew Truscott BSc PhD Queensland (ARC Fellowship)

Research Fellows

Steven Cavanagh BSc PhD Griffith
Robert Dall BSc CQueensland
Igor Ivanov BSc PhD Moscow
Mitsuhiko Kono MSc KyotoIT, PhD GUAS Tokyo
Franklin Mills BSE Princeton, MS PhD Caltech (joint with CRES)
Stan Newman BSc PhD Manchester
James Sullivan BSc PhD ANU (ARC Fellowship)

Postdoctoral Fellows

Susan Bellm BSc PhD Flinders (ARC Fellowship)

Subhendu Mondal MSc PhD Banaras (from August)
Michael Went BSc Newcastle, PhD Griffith

Research Assistants

Alan Heays MSc Auckland
Linda Uhlmann B App Sci CQueensland

Visiting Fellows

Robert Crompton AM, BSc PhD Adelaide, FAA, FInstP, FAPS, HonFAIP (Emeritus Professor)
Erich Weigold BSc Adelaide, PhD ANU, FAA, FTSE, FAPS, FAIP

Head Technical Officer

Graeme Cornish AssocDip MechEng CIT

Technical Staff

Stephen Battisson AssocDip MechEng CIT
Colin Dedman AssocDip SciInst Bdgo CAE
Gary Picker AssocDip MechEng CIT
Kevin Roberts MechTech Cert SAIT

Departmental Administrator

Deborah Bordeau (from March)

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

Book Chapters

Kheifets, A., Vos, M. and Weigold, E.
Electron Momentum Spectroscopy
in **Analytical Characterization of Aluminium Steel and Superalloys**, Taylor & Francis (2006) 641-659

Mills, F., Sundaram, M., Slanger T.G.*, Allen, M.* and Yung, Y.L.*
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in **Advances in Geosciences Volume 3: Planetary Science (PS)**, World Scientific Publishing Company (2006) 109-117

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Brunger, M.J.*, Cho, H.*, Tanaka, H.* and Buckman, S.J.
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Buckman, S.J. and Sullivan, J.
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Department of Electronic Materials Engineering

The Electronic Materials Engineering (EME) Department undertakes world-class interdisciplinary research into the growth, structure, properties, processing and applications of electronic materials and related structures and devices. It also plays an important role in the training of undergraduates, postgraduates and other early career researchers. The Department's diverse research program is underpinned by core expertise, a strong network of national and international collaborators, and a comprehensive suite of state-of-the-art equipment and facilities.

Staff List

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Jim Williams BSc PhD NSW, FAA, FAIP, FIEAust, FTSE, FAPS

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Mark Ridgway BSc McM, MSc PhD Queens

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Yong Kim PhD KAIST (until July)
Hoe Tan BE Melb PhD ANU (until May) (ARC QEII Fellow)
Jenny Wong-Leung BSc Bristol PhD ANU (ARC QEII Fellow)

Research Fellows

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Qing Li BSc BNU, MSc ISCAS, PhD HKU
Rui Rao MSc WUST, PhD HUST, China
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Andrew Wilkinson PhD ANU (from February)
Hongzhou Zhang PhD Rice

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Martin Conway (until March)

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Departmental Administrator

Renee Vercoe

Publications

Legend: * *External to the University*
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Laser Physics Centre

The Laser Physics Centre is engaged in laser-based research on topics spanning fundamental and applied physics and engineering. Research in the Centre covers many of the most exciting aspects of contemporary laser physics. The activities can be broadly divided into the following areas: laser matter interaction physics; nonlinear optical phenomena; nonlinear and nanostructured materials; quantum information processing; laser spectroscopy; and photonics. Research in photonics is partly supported by the Australian Research Council Centre of Excellence for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS).

Research highlights for 2006 include:

In collaboration with colleagues in the Sydney node of CUDOS, we have produced nonlinear waveguides in chalcogenide glass and demonstrated all-optical regeneration and wavelength conversion – key elements for all-optical signal processing. (Choi, Madden, Luther-Davies, Pelusi, Baker, Ta'eed and Lamont)

As part of the CUDOS program on nonlinear photonic crystals, we have re-engineered the ANU focused ion beam system to achieve highly accurate (few nm) milling over several hours, allowing us to make chalcogenide glass photonic crystals of unsurpassed quality which have been used to demonstrate fibre coupling to waveguides and moderate-Q resonators. (Freeman, Luther-Davies, Madden, Grillet, Eggleton and Smith)

The relationships between composition, structure and properties of Ge-As-Se glasses have been established, and a method for theoretical prediction of the optical properties of these glasses has been developed. The properties of a range of chalcogenide glasses have been measured against model predictions. (Zha, Prasad, Wang and Luther-Davies)

The Solid State Spectroscopy group has demonstrated a quantum memory for light using a rare-earth doped crystal with an efficiency of 13% which is the highest efficiency yet demonstrated. Theory predicts that using a longer crystal, efficiencies approaching 100% will be possible. The aim of this work is to enable long distance quantum communication. (Sellars, Manson and Harrison)

We have demonstrated a simple scheme for generating sodium "laser" light at 589 nm to generate a guide star for adaptive optics based on optical parametric amplification. (Kolev, Duering and Luther-Davies)

We have demonstrated that huge pressures (multi-Mbar) and temperatures (0.5 Million Kelvin) with extreme heating and cooling rates can been achieved by focusing a single laser pulse (100 nJ, 800 nm, 200 fs) inside a sapphire crystal. A new super-dense form of sapphire has been created. (Gamaly, Rode, Luther-Davies, Juodkazis and Mizawa)

By studying the size distributions for nanoclusters of carbon produced by laser ablation in an argon atmosphere for pressures from vacuum to 1500 Torr we showed that above a particular pressure a transition occurs from *expansion-limited* to *diffusion-limited* aggregation of clusters in the plume, which leads to a degree of control over cluster growth. (Rode, Gamaly, Luther-Davies and Madsen)

We have demonstrated the basis of a 3-D optical memory in iron-doped lithium niobate using single 150 fs, 800 nm laser pulses. Rewritable bits 2×2×8 μm3 was obtained with a refraction index modulation of $\sim 10^{-3}$. (Gamaly, Krolikowski, Rode and Juodkazis)

We have determined the linear and complex nonlinear refractive index of deoxyribonucleic acid (DNA) as a function of wavelength (in the range 530 - 1300 nm) to characterize it as a

material for potential use in nonlinear waveguiding devices. Refractive index anisotropy indicated that the DNA molecules were aligned in the direction parallel to the surface plane of the films. (Samoc, Samoc, Miniewicz and Grote)

We have found very efficient three-photon absorption can be achieved for femtosecond laser pulses in the 1000-1500 nm wavelength range in an organometallic dendrimer. (Samoc, Morrall, Dalton Cifuentes and Humphrey)

Organometallic complex containing Ru and Fe atoms have been used to demonstrate electrochromic switching of the nonlinear absorption and refraction between three distinct states differing in oxidation states of the two metal atoms. (Samoc, Gauthier, Cifuentes, Paul, Lapinte and Humphrey)

Second-harmonic generation was observed for the first time in films of an oriented liquid crystalline derivative of closo-decaborane. (Miniewicz, A. Samoc and M. Samoc)

Experimental demonstration of attractive forces between dark solitons in nonlocal media. (Krolikowski and Neshev; Dreischuh [University of Sofia, Bulgaria]; Petersen and Bang [DTU, Denmark])

Theoretical demonstration of formation of rotating soliton complexes in nonlocal nonlinear media. (Krolikowski, Edmundson, Lopez-Aguyao, Desyatnikov and Kivshar; Skupin [Paris, France]; and Bang [DTU, Denmark])

Experimental demonstration of Zener tunelling in two-dimensional photonic lattices. (Krolikowski, Neshev, Sukhorukov and Kivshar; Trompeter, Poeschel, Pertsch and Lederer [Jena, Germany])

Experimental demonstration of formation of gap solitons in optical lattices with defocusing nonlinearity. (Krolikowski, Rosberg, Neshev, Sukhorukov and Kivshar; Matuszewski and Trippenbach [Warsaw, Poland]; Mitchell and Austin [RMIT, Melbourne])

Experimental demonstration of surface waves in optical lattices. (Krolikowski, Rosberg, and Neshev; Mitchell [RMIT, Melbourne]; Vicencio and Molina [Chile])

During 2006 the Centre benefited from strong levels of funding from the Australian Research Council (ARC) with major grants supporting CUDOS; Professor Luther-Davies's Federation Fellowship; six Discovery grants and two Linkage grants as well as significant funding from DARPA (USA), AOARD (USA), DOD (Australia) and DSTO. Three new ARC Discovery grants were awarded for commencement in 2007 and one new ARC Linkage grant commenced in 2006. The Centre congratulates Yinlan Ruan, Lily Luo, Joanne Harrison and Joseph Morrall on the award of their PhDs and welcomes Morgan Hedges and Daniel Buccoliero as new PhD students.

Staff List

Professor and Head of Department

Barry Luther-Davies BSc PhD S'ton, SIEE, FAIP (ARC Federation Fellowship)

Professors

Wieslaw Krolikowski MSc PhD Warsaw
Neil Manson MSc PhD Aberdeen

Senior Fellows

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Andrei Rode MSc PhD Moscow

Marek Samoc PhD DSc Wroc

Research Fellows

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Steve Madden PhD Imperial College
Anna Samoc MSc PhD Wroc
Matthew Sellars BSc PhD ANU
Rong Ping Wang PhD CAS

Postdoctoral Fellows

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Vesselin Kolev PhD ANU
Jevon Longdell PhD ANU
Congji Zha BE Jingdezheng, ME WUT, PhD Sydney

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Robbie Charters BSc Nott, PhD Cranfield
Ben Cornish BSc ANU
Graham Gordon BSc PhD ANU
Mark Humphrey Bsc PhD ANU
Dax Kukulj BSc PhD UNSW
David Pulford BSc PhD ANU

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Craig Macleod AssocDipMechEng CIT
Anita Smith BSc Flinders

Technical Officers

John Bottega
Maryla Krolikowska
Martin Wulf

Departmental Administrator

Belinda Barbour

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

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Non-linear Physics Centre

The Nonlinear Physics Centre is a relatively new research team in the School engaged into interdisciplinary, both theoretical and experimental, research that covers a number of diverse topics unified by the general concepts of nonlinear physics and nonlinear optics.

The Centre's structure is defined by five major research directions and activities.

Experimental nonlinear photonics (Group leader: Dr. Dragomir Neshev).

The research topics of this group focus on the experimental study of linear and nonlinear light propagation in fabricated and optically-induced periodic photonic structures including waveguide arrays, photonic lattices, microstructures optical fibers, and photonic crystals. The research concentrates on nonlinear light localisation of monochromatic and supercontinuum light, formation of nonlinear patterns and solitons, nonlinear dynamics of vortices, and broadband second harmonic generation.

Theoretical nonlinear photonics (Group leader: Dr. Andrey Sukhorukov).

The activity of this group involves the research of light propagation in nonlinear micro-structured materials, including the investigation of approaches for all-optical control of laser beams and pulses. Most recent results reveal new possibilities for dispersion management, switching of slow-light pulses, and shaping of supercontinuum radiation through the effect of nonlinear localization in spatial and spectral domains. These studies are performed in close collaboration with the experimental groups, enabling the efficient development from the level of theoretical concepts and ideas towards the practical demonstrations.

Singular photonics and optical vortices (Group leader: Dr. Anton Desyatnikov).

This is the newest group driven by a recently awarded Discovery Project. The major research topics include the theoretical and experimental studies of the complex light with angular momentum, phase dislocations and optical vortices; topological transformations of mono- and polychromatic light in chiral, periodic, and nonlinear photonic structures; optical spin-orbit coupling and polarization singularities.

Nonlinear matter waves and quantum-atom optics (Group leader: Dr. Elena Ostrovskaya). This group is closely associated with the ARC Centre of Excellence on Quantum-Atom Optics, and specialises in the fields of nonlinear atom optics and quantum many-body physics. In particular, it is engaged in the theoretical studies of ultracold atomic gases (Bose-Einstein condensates) in optical lattices, magnetic waveguides, and reconfigurable atomic traps suitable for atomic interferometry and sensing.

Composite structures and left-handed metamaterials (Group leader: Dr. Ilya Shadrivov). This is a new and very successful direction that involves the study of composite metamaterials with the property of negative refraction, with the emphasis on our pioneering results on nonlinear metamaterials and left-handed superlattices. One of the targets of this group is the experimental verification for the first time in Australia of the basic phenomena of left-handed propagation and negative refraction for microwaves.

Research highlights for 2006 include a number of important theoretical and experimental results, presented in many research publications including papers in Physical Review Letters, the top-ranked journal in physics.

Some of the signature results include the prediction of slow-light optical bullets in nonlinear Bragg-grating waveguide arrays (A. Sukhorukov), the extensive analysis of all-optical switching, bistability, and slow-light transmission in photonic crystal waveguide-resonator

structures (A. Miroshnichenko), the theoretical prediction and experimental demonstrations of polychromatic gap solitons in nonlinear photonic lattices (A. Sukhorukov, D. Neshev), the development of an analytical model for describing Zener tunneling in two-dimensional photonic lattices (A. Desyatnikov), the prediction of quantum vortices in the Bose-Hubbard systems (C. Lee, T. Alexander), the development of the concept of spinor gap solutions in Bose-Einstein condensates (T. Alexander, E. Ostrovskaya), and the first experimental studies of microwave metamaterials (D. Powell, I. Shadrivov).

In addition, a number of the world-first experimental observations have been made by the members of the Department in 2006; the experimental works have been performed in collaboration with Professor W. Krolikowski from the Laser Physics Centre. This includes eexperimental studies of photonic Bloch oscillations and observation of Zener tunnelling of light in two-dimensional photonic lattices [H. Trompeter et al. Phys. Rev. Lett. 96, 053903 (2006)], prediction and observation of reduced-symmetry two-dimensional spatial gap solitons and their enhanced mobility of these self-trapped nonlinear modes [R. Fischer et al. Phys. Rev. Lett. 96, 023905 (2006)], experimental demonstration of nonlinear surface waves localized at the edge of an array of nonlinear waveguide, the modes are identified nonlinear optical Tamm states [C.R. Rosberg et al. Phys. Rev. Lett. 97, 083901 (2006)], and observation of linear propagation and nonlinear localization of polychromatic light generated by a supercontinuum source [A. Sukhorukov et al. Opt. Express 14, 11265 (2006)].

In 2006, the students of the Centre, together with a few students of the Laser Physics Center, initiated a new Student Chapter of the Optical Society of America, the second chapter in Australia (President: Christian Rosberg). This chapter will bring concrete benefits to students at ANU through provision of funds for visiting lecturers and special events, and will benefit students involved in the chapters through assistance in attending OSA meetings and networking opportunities at those meetings.

This year, the members of the Center was extremely successful in the competitive grant scheme of the Australian Research Council with 7 grants awarded, including 5 personal fellowships: QEII: Dr. A. Sukhorukov, ARF: Dr. E. Ostrovskaya, and APD: Dr. C. Lee, Dr. A. Mirochnichenko, and Dr. I. Shadrivov.

The Centre continues to play an important role in the two Centre's of Excellence funded by the Australian Research Council announced at the end of 2002, namely the ARC Centre of Excellence for Ultra-high Bandwidth Devices for Optical Systems (CUDOS) and the ARC Centre of Excellence for Quantum-Atom Optics (ACQAO).

Staff List

Professor and Head of Department

Yuri Kivshar BSc PhD Kharkov UKR, FAIP, FOSA, FAA (ARC Federation Fellow)

Professors

Alexander Dreischuh PhD Bulgaria (June–October)
Solomon Saltiel PhD Russia (March–May, August–October)

Senior Fellows

Miklos Gulacsi BSc MSc Cluj, PhM PhD Trieste (December-August)

Research Fellows

Anton Desyatnikov PhD Moscow
Magnus Johansson PhD Sweden (April–July)
Dragomir Neshev MSc PhD Sofia, BG (ARC Fellow)
Elena Ostrovskaya MSc Moscow, PhD ANU
Andrey Sukhorukov PhD ANU

Postdoctoral Fellows

Tristram Alexander PhD ANU (ARC APD)
Chaohong Li PhD China
Andrey Miroshnichenko PhD Dresden
Ilya Shadrivov PhD ANU
Kristian Motzek PhD Germany (March–July)
David Powell PhD Monash

Visiting Fellows

Sergey Gredeskul PhD DSc Kharkov
Sergei Kun MSc PhD Kiev
Anatoly Sukhorukov MSc PhD DSc Moscow
Dmitry Chigrin
Abdolrahman Namdar Azarbaijan
Ole Bang
Savin Semevov

Research Assistants

Steven Morrison BEng Griffith (to June)
Alex Minovich (April–July)

Departmental Administrator

Wendy Quinn BA ANU

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

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Nuclear Physics

This year was productive in terms of both the research carried out by staff and other users and in the operation of the Heavy Ion Accelerator Facility which provides a broad range of energetic ion beams for research, ranging from applications in materials science to basic studies of nuclear structure and nuclear reactions. It is the main laboratory in Australia for accelerator-based research and training in Nuclear Physics.

Over 50 papers were published in major peer-reviewed journals by Department staff, many in conjunction with international collaborators. About 20 invited papers were delivered at International meetings and there were numerous contributions to international and national conferences and workshops.

Several projects were successful in obtaining funding through the Australian Research Council including a new program aimed at exposure dating using Accelerator Mass Spectrometry (AMS) intended to study long-term landscape evolution. The project is based on the group's earlier measurements on haematite material from Brazil with a known erosion history that showed that the production rate of Mn-53 by cosmic rays on Fe was relatively high. AMS exploits a broad range of beams from the accelerator facility and highlights of other research carried out this year included measurements of the heavy isotopes Pu-239 and U-236 in a wide range of uranium ores and the development of a model to describe the processes by which they are produced. Studies also continued of sediment transport in the Herbert River catchment using bomb-produced plutonium as a tracer, a technique being evaluated as an alternative to the use of Cs-137. The initial aim is to understand water-borne sediment transportation into the Great Barrier Reef Lagoon, to differentiate between natural processes and those caused by human land-use practices.

The ARC LIEF – funded project initiated by the AMS group to develop an ultra-sensitive radio-carbon system for collaborative research on climate, natural resources and ecosystems progressed with preparations for its installation in a new laboratory in RSES and final testing in the manufacturer's workshops. Delivery of the system is now scheduled for January 2007.

On the basic research side, the Fission-Fusion group has continued the development of a broad range of instrumentation for fusion, fission and heavy-ion break-up studies, above and below the Coulomb barrier. With the full implementation of the superconducting solenoid – SOLITAIRE - a program of high precision fusion excitation function measurements was undertaken to understand the role of multi-phonon excitations in nuclear fusion. These measurements provide new information on the interactions at the touching configuration between heavy nuclei, just prior to fusion.

Other measurements of fission mass and angular distributions were undertaken to investigate the quasi-fission mechanism that hinders fusion of very heavy nuclei, results which have implications for the study of super-heavy elements. Measurements of elastic and inelastic scattering at sub-barrier energies have given unambiguous information on the shape of the inter-nuclear potential and they also promise to shed new light on the energy dissipation processes that causes nuclei to be captured after passing inside the fusion barrier. Studies of incomplete fusion have also continued with measurements and a new theoretical model of breakup and fusion of weakly bound nuclei developed in collaboration with Jeff Tostevin of the University of Surrey.

The spectroscopy group, whose main focus is the study of unusual nuclear states pursued detailed design work and modeling of reactions that it hopes to use, exploiting SOLITAIRE as a transport device, with gamma-ray and electron instrumentation at the focal plane. As well as

this initiative, which will focus on neutron-deficient heavy nuclei, significant progress continues to be made on the discovery and characterization of isomeric states in well-deformed nuclei near to, and to the neutron-rich side of stability, drawing on the extensive data sets obtained with Gammasphere at Argonne National Laboratory in recent years. Another Gammasphere proposal extending this work was approved in 2006 and an experiment was carried out in December.

The main spectroscopic studies carried out locally have been measurements on a range of nuclei in the trans-lead region, including identification and characterization of metastable states in Bi, Po, Rn and Fr isotopes, as well as studies using incomplete fusion reactions to complement the results on neutron-rich nuclei obtained from the deep-inelastic studies.

Other experiments which involve complementary studies on the local facilities and exploit the capabilities of overseas accelerators include a new generation of magnetic moment measurements on exotic radioactive ions, led by Andrew Stuchbery. The group was successful this year in obtaining funding through the ARC to develop the area of moment measurements under the demanding conditions that pertain in exotic beam measurements, including very low intensity beams and often relativistic energies. In association with this research area, regular use is now being made of the low temperature Hyperfine Spectrometer that was recently commissioned. One application has been investigation of terbium as a ferromagnetic host to probe the mechanisms by which polarization is transferred to ions moving swiftly within a magnetized medium.

In a more general area the Department now has formal involvement with the IAEA with Tibor Kibedi as the Australian representative in the Nuclear Data project. Through an international collaboration, Kibedi has taken a major role in evaluating existing and new theories of internal conversion, and a critical evaluation of all available experimental data. The result has been the development of new codes for the generation of conversion coefficients and their acceptance by the international community, including the provision of a web-based calculation tool for researchers, hosted by the Department.

Progress has also continued in developing the Superconducting LINAC to extend the Facility capabilities. New RF control electronics has provided a major improvement in the reliability of the system and considerable progress being made in developing high intensity beams from a new gas-cathode ion source. Several beam-proving runs with acceleration through the LINAC for delivery to experimental stations were carried out, leading to the resolution of a number of outstanding beam transport issues. In parallel, technological developments aimed at a new generation of accelerating structures have progressed, with success in the design of a two-stub resonator and a novel rotary tuner, which it is hoped, will find application on the local system and on new accelerators overseas.

The Department had a significant presence at the Annual General Meeting of the Australian Academy of Science held in May 2006 with the presentation of the 2006 Pawsey Medal to Nanda Dasgupta , and the induction of David Hinde as a Fellow of the Academy. Also in the public arena, George Dracoulis was appointed to the Prime Minister's select Taskforce reviewing Uranium Mining, Processing and Nuclear Energy (UMPNER) which delivered its final report at the end of 2006. This has resulted in numerous media reports and public presentations and both he and Aidan Byrne continue to be regularly involved in public outreach associated with energy issues and the Nuclear debate.

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Research Fellows

Timothy Barrows BSc, PhD ANU (ARC Fellowship)
Clyde Morton BSc Sydney, PhD ANU
Stephen Tims BSc PhD Melbourne

Postdoctoral Fellows

Alexis Diaz-Torres BSc MSc Havana, PhD Giessen
Leandro Gasques BSc PhD São Paulo (from July)
Paivi Nieminen Msc PhD Jyväskylä
Renju Thomas BSc Kerala, MSc Cochin, PhD Mumbai
Hiroshi Watanabe BSc PhD Kyushu

Visiting Fellows

Karl-Hugo Maier PhD Berlin (November–May)
John Newton MA PhD Cambridge, DSc Manchester, FAA (Emeritus Professor)
Heiko Timmers ADFA, UNSW (jointly with EME, until Oct)
Leandro Gasques PhD Sao Paulo (February–June)
Anjali Mukherjee PhD Calcutta (February–June)
Jeff Tostevin PhD Surrey, CPhys, FInstP (April–August)
Qiuju Guo PhD Nagoya (from September)

Accelerator Research and Operations Manager

David Weisser, MSc, PhD Minn, FAIP

Engineer

Nikolai Lobanov, BSc Moscow, PhD St Peter

Research Officers

Paul Davidson, BSc, MSc Auckland, PhD ANU
Gordon Foote, BSc London, PhD ANU (retired June)

Technical Officers

John Bockwinkel, AssocDipMechEng

Alan Cooper, AssocDipMechEng
Alan Harding
Justin Heighway, AssocDipAppSci
John Kennedy
Tom Kitchen (from June)
Lorenzo Lariosa
Matthew Lenahan (until September)
Alistair Muirhead
Bob Turkentine
Howard Wallace

Departmental Administrator

Marjorie O'Neill (until March)
Petra Rickman (from April)

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

Book Chapters

Wilson, A., Dracoulis, G., Davidson, P.M., Hubel, H.*, Korichi, A.*, Astier, A.*, Azaiez, A.*, Bazzacco, D.*, Bourgeois, C.*, Byrne, A., Clark, R.G.*, Fallon, P.*, Gorgen, A.*, Hannachi, F.* and Lane, G.
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Bastin, J.E.*, Herzberg, R.*, Butler, P.A.*, Jones, G.D.*, Page, R.D.*, Jenkins, D.G.*, Amzal, N.*, Brew, P.M.T.*, Hammond, N.J.*, Humphreys, R.*, Ikin, P.J.C.*, Page, T.*, Greenlees, P.*, Jones, P.*, Julin, R.J.*, Juutinen, S.*, Kankaanpaa, H.*, Keenan, A.*, Kettunen, H.*, Kuusiniemi, P.*, Leino, M.*, Leppanen, A.P.*, Muikku, M.*, Nieminen, P., Rahkila, P.*, Scholey, C.*, Uusitalo, J.*, Bouchez, E.*, Chatillon, A.*, Hurstel, A.*, Korten, W.*, Le Coz, Y.*, Theisen, Ch.*, Ackermann, D.*, Gerl, J.*, Helariutta, K.*, Hessberger, F.P.*, Schlegel, Ch.*, Wollerscheim, H.J.*, Lach, M.*, Maj, A.*, Meczynski, W.*, Styczen, J.*, Khoo, T.*, Lister, C.J.*, Afanasjev, A.V.*, Maier, H.J.*, Reiter, P.*, Bednarczyc, P.*, Eskola, K.* and Hauschild, K.*
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Bostock, H., Opdyke, B., Gagan, M., Kiss, A.E.* and Fifield, L.
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Hinde, D.J.
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Jones, G.A.*, Walker, P.M.*, Podolyak, Z.*, Regan, P.*, Williams, S.J.*, Carpenter, M.P.*, Carroll, J.*, Chakrawarthy, R.S.*, Chowdhury, P.*, Cullen, I.J.*, Dracoulis, G., Garnsworthy, A.*, Hackman, G.*, Janssens, R.V.F.*, Khoo, T.*, Kondev, F.G.*, Lane, G., Liu, Z.*, Seweryniak, D.*, Thompson, N.* and Zhu, S.*
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International Conference on Reaction Mechanisms and Nuclear Structure at the Coulomb Barrier American Institute of Physics Conference Proceedings Series (2006) 198-201

Optical Sciences Group

The Optical Sciences Group is successfully continuing the study of localized structures in dissipative systems as well as increasing the physical understanding of the basis of loss mechanisms in bent fibres and microstructured fibres. It is also making major contributions to the teaching of photonics at undergraduate and graduate levels in both the Department of Physics and the Department of Engineering in the College of Engineering & Computer Science, as well as supervising Honours students in both departments and having contributed to the graduation of the first ever ANU students in the Bachelor of Photonics degree and the Master of Photonics degree.

The subject of dissipative solitons has emerged recently, driving an impressive number of studies in many areas of nonlinear science. The previous studies of the group, which related to temporal and spatial solitons, have been highly useful, for both fundamental science and for the development of high bit-rate optical telecommunications and passively mode-locked lasers. The notion of a dissipative soliton allows us to extend this knowledge to an amazingly wide range of phenomena in nature and technology.

The international workshop "Dissipative solitons", organised by Professor Nail Akhmediev in the Max Planck Institute for Complex Systems, Dresden, Germany, in January 2006, attracted more than 40 world-class experts from various fields of science where they established firm grounds for this new scientific direction of research. The consideration of common features in phenomena related to propagation of nerve pulses, brain waves, the formation of patterns in dry land fields, laser physics and optical transmission lines allowed the scientists to exchange and 'enrich' knowledge accumulated in each particular field.

The new book "Dissipative solitons: from Optics to biology and medicine" is being prepared for publication by Springer-Verlag by Professor Akhmediev and Dr. A. Ankiewicz. This book will reflect the most recent trends and ideas in this new area of research. These ideas represent a significant development since the first book "Dissipative solitons" was published in 2005 and has now been translated into Russian. The second book covers a much wider range of phenomena than in the previous highly popular publication. In addition Prof. J.D. Love contributed the basic theory chapter to the comprehensive "Handbook of Optoelectronics" published by Taylor & Francis in June 2006 and is working with Prof A.W. Snyder on a second edition of "Optical Waveguide Theory" first published in 1984.

The work of the group led by Prof. N. Akhmediev is funded by the ARC Discovery Grant "Bifurcations of dissipative solitons". Among the many achievements of the group is a new understanding of localized structures in dissipative systems and their interactions. Single solitons for a given set of parameters can be perfectly stable. However, this does not necessarily mean that a bound state formed by two of them is either stationary or stable. Moreover, their relations can be highly complicated and even chaotic. These observations can have far-reaching consequences in many areas of natural and social sciences. Our studies present these complicated phenomena for both one-dimensional and three-dimensional structures, known as double soliton complexes. We provide novel insight regarding the possible dynamics of these soliton complexes, consider collision cases between two solitons, and discuss the ways non-stationary evolution can lead to pattern- formation in various branches of science.

This year, graduate students Mr. W. Chang and Mrs. N. Devine joined the team, starting their work towards PhD degrees. Their main goal is to reveal the highly complicated behaviour of localized structures with multiple bifurcations occurring at various values of the external parameters of the dissipative system.

Staff List

Professors

John Love MA Cambridge, MA DPhil DSc Oxford
Nail Akhmediev MS PhD DSc Moscow, FOSA

Fellow

Adrian Ankiewicz BSc BE UNSW, PhD ANU

Research Fellow

Douglas Bulla PhD Sao Paulo (until May)

Postdoctoral Fellow

Céline Durniak PhD Lille

Research Assistant

Natasha Devine DSc Moscow (from March)

Visiting Fellows

Yuhong Bai Changchun Institute of Optics, Mechanics & Physics, China
Vika Steblina VA FutureTech Consulting, Sydney

Departmental Administrator

Trina Merrell

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

Refereed Journal

Kanna, T.*, Lakshmanan, M.*, Tchofo, D.P.* and Akhmediev, N.
Soliton Collisions with Shape Change by Intensity Redistribution in Mixed Coupled Nonlinear Schrödinger Equations
Physical Review E (Statistical Nonlinear and Soft Matter Physics) 73 (2006) 026604-1-15

Soto-Crespo, J.M.*, Akhmediev, N. and Grelu, P.*
Optical Bullets and Double Bullet Complexes in Dissipative Systems
Physical Review E (Statistical Nonlinear and Soft Matter Physics) 74 (2006) 046612-1-11

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Derivation of the Paraxial Form of the Angular Momentum of the Electromagnetic Field from the General Form
Journal of Modern Optics 53 (2006) 1947-1952

Tsoy, E.N.* and Akhmediev, N.
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Yu, X.*, Shum, P.*, Tang, M.*, Yan, M.* and Love, J.
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Two Types of Stationary Solitons in Dissipative Systems
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Bulla, D.A.P. and Love, J.
Bend Loss in Silica Optical Fibre with Low Refractive Index Coating
ACOFT & AOS Conference (ACOFT 2006) Unknown (2006) 78-80

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ACOFT & AOS Conference (ACOFT 2006) Unknown (2006) 7-Sep

Durniak, C. and Love, J.
Suppression of Cladding-mode Coupling in Single-mode Slab Waveguides of Varying Curvature
ACOFT & AOS Conference (ACOFT 2006) Unknown (2006) 90-92

Love, J. and Durniak, C.
Bound Modes of Holey Optical Fibres
ACOFT & AOS Conference (ACOFT 2006) Unknown (2006) 1-Mar

Plasma Research Laboratory

Toroidal Plasma Group

The Toroidal Plasma Group studies an increasingly diverse range of pursuits associated with and including a common theme of the physics of magnetised plasma; the physics of complex media, electromagnetics remote sensing and inverse methods and non-equilibrium systems. Plasma physics presents several "grand challenges" of physics:

exploring solutions of equilibrium, stability and wave propagation problems in a highly complex medium,

understanding transport in this complex medium in terms of turbulence theory or more generally, the theory of non-equilibrium systems,

remote measurement of three dimensional plasma properties in an extremely hostile and complex environment, and ultimately,

the generation of clean sustainable energy from the fusion of hydrogen isotopes.

The Group operates the National Plasma Fusion Research Facility based on the H-1 heliac, an innovative plasma confinement device with flexible geometry that allows exploration of basic plasma physics, and advanced concepts ultimately for improved design of fusion power stations. This was the first year of operation under the re-negotiated contract for operation of this Facility, and marked the completion of the transition from parallel efforts of construction, commissioning and operation to a more efficient, largely automated mode of operation in support of research. The broad scope of these fundamental and technological challenges equips the group to engage in a diverse range of related and complementary pursuits, which are becoming increasingly important and are summarised below.

The Advanced Imaging and Inverse Methods Group led by Prof. John Howard undertakes research into passive (optical) and active (laser-based) techniques for plasma diagnostics, and their associated inverse methods, with applications in industry and medicine. This year saw a number of invited international talks on our patented optical coherence imaging (CI) technologies. Under contract to the Japanese Atomic Energy Agency, we have developed and successfully operated a compact CI system for Thomson scattering, and in addition have deployed a system for imaging of high temperature molten iron flows at Bluescope Steel. Supported by an Australian Research Council (ARC) Discovery Grant and in collaboration with researchers at Chalmers University in Sweden, the group has commenced research into suitable inverse techniques for microwave imaging of human tissue. Mr Scott Collis (PhD, Helium beam diagnostic) and Mr Ben Powell (MPhil, supersonic gas injector for plasma fuelling) completed their studies and submitted their theses this year.

In 2006 the Turbulence and Transport Studies Group led by Dr Michael Shats expanded the scope of their research; studies into the interaction between large coherent structures and turbulence in plasma were complemented with experiments in quasi-two-dimensional fluid turbulence. Among new important results was the discovery of the role of mean zonal flows in the formation of transport barriers in the improved confinement mode. The formation of zonal flow coincides with suppression of turbulence near the transport barrier. This confirms that spectral condensation previously suggested by the group as the universal mechanism of plasma self-organization, is indeed an important ingredient in the physics of improved plasma confinement. These results were published in Physical Review Letters. Hua Xia was awarded a PhD degree in 2006 and was appointed as a Postdoctoral Fellow with the group. The group had a central role in organizing 19th Canberra International Physics Summer School held at the Australian National University in January 2006 (convenor Dr. M.G. Shats) and the Workshop on

Turbulence and Coherent Structures in Fluids, Plasma and Granular Flows. Drs. M. Shats and H. Punzmann have compiled and edited a book of Lecture Notes published by World Scientific as part of the Lecture Notes in Complex Systems series. The book includes a chapter "Experimental studies of plasma turbulence" by M.G. Shats and H. Xia.

Research on BushLAN is driven by the goal of using a wireless system to overcome the last mile Internet connectivity problem in regional and remote areas, and was a spin-off of research into using plasma antennas for radio frequency communications. This year saw the development of several important technologies for the new television band (VHF/UHF) BushLAN broadband system. Developments included digital signal processing software for the physical layer processing and the Intermediate Frequency (IF) amplifier, developed by students in the College of Engineering and Computer Science (CECS). Students in the ENGN4521 RF engineering class in the Department of Engineering developed the VHF section which is to be completed by the following year's class. The BushLAN project is an excellent example of research-led teaching. BushLAN is topical again this year now that the Australian Government has rekindled the regional Internet debate with a 2 billion dollar investment on regional services. It is not clear that such services could be provided within the limitations of ADSL and WiMAX, and many now consider optical fiber to the home as the only way to achieve adequate broadband data rates.

The Plasma Configurations Group is applying an innovative data mining technique to the investigation of Alfvén-range instabilities in the H-1 plasma. The wide range of magnetic configurations and the precise computer control of H-1 make it uniquely suitable for fundamental studies of these instabilities, the understanding of which is crucial to the success of future large experiments, such as international fusion experiment (ITER). The cross-campus collaboration with Dr. M. Hegland of the Mathematical Sciences Institute has been extended internationally to include the Heliotron-J experiment in Japan, and a theoretical and computational collaboration with Dr. C. Nührenberg of the Max Planck Institute, Greifswald. In related work on plasma configurations, preliminary studies of the effect of magnetic islands on H-1 plasma have shown a possible link between island formation and the "Core Electron Root Confinement" phenomenon, which improves plasma confinement.

Many improvements were made to the Facility, including a substantial upgrade of the data system to a linux/MDSplus open source system, increasing speed by more than ten times, the construction of a new interchangeable foil soft X-ray detector, and the commissioning of a fast electronically scanning interferometer for measuring electron density profiles and their time evolution. The recently installed supersonic helium beam diagnostic for measurement of temporally and spatially resolved electron temperature and density came into full operation, in collaboration with the University of Sydney, and the fast electron beam mapping system successfully mapped magnetic fields at ½ Tesla.

Looking to the future, outreach and development activities included the international summer school and workshop on turbulence on coherent structure described above, which attracted a large attendance from both novices and experts in the field. Members of the Toroidal Plasma Group played a central role in the Australian ITER forum activities to promote an Australian involvement in the international fusion experiment (ITER)

Finally, continuing the restructure begun in 2005, we welcome four new staff – Dr. Frank Detering, Research Fellow (Data Mining project jointly with COSNet), Dr Hua Xia, Postdoctoral Fellow, Ms Bronwyn Stuart, Administrator and Ananda Galagali, Technician.

Staff List

Head of Group

Boyd Blackwell BSc PhD Sydney

Senior Fellows

John Howard BSc PhD Sydney, FInstP
Michael Shats MSc KPI, PhD GPI Moscow

Fellow

Gerard Borg BSc PhD Sydney

Research Engineer/H-1NF Facility Manager

Horst Punzmann BSc Regensburg, PhD ANU

Research Fellow

George Warr

Postdoctoral Fellows

Frank Detering BSc Oldenburg, PhD Saskatchewan
Hua Xia, Msc Chongquing (from November)

Adjunct Fellows

Scott Collis BSc Sydney
Benjamin Powell BSc BLM CQU
Hua Xia Msc Chongquing

Visiting Fellows

Joe Baker MSc PhD Qld, OBE, FTSE
Marcela Bilek BSc Syd, PhD Cambridge
Andrew Cheetham BSc PhD Flinders
Roger Gammon BTech PhD Brunel, FInstP, CPhys, MIE Aust, CP Eng, FAIE, FAIM
Sydney Hamberger PhD DSc London, FAIP (Emeritus Professor)
Dennis Mather BSc PhD UNSW, DipEd STC
John O'Connor BSc PhD DSc
Anthony Sproule ME UT Sydney, GradDipOR NSWIT
Robin G. Storer Bsc PhD Flinders
Masayuki Yokoyama

Senior Technical Officer

John Wach BAppSci CAE Ball, GradDipEl CCAE

Technical Officers

Costanzo Costa (until May)
Ananda Galagali (from August)
Mark Gwynneth

Departmental Administrator

Helen Hawes BA ANU (until July)
Bronwyn Stuart (from August)

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

Book Chapters

Shats, M. and Xia, H.
Experimental Studies of Plasma Turbulence
In **Turbulence and Coherent Structures in Fluids, Plasmas and Nonlinear Media**, World Scientific Publishing Company (2006) 233-280

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Collis, S., Howard, J., Blackwell, B., Carlsson, P.*, Abelsson, M.* and Powell, B.
A Supersonic Gas Injection System for Fuelling and Probing Fusion Plasmas
Plasma Sources Science and Technology 15 (2006) 797-804

Dewar, R., Nührenberg, C.* and Tatsuno, T.*
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Gesto, F., Blackwell, B., Charles, C. and Boswell, R.
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Howard, J.
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Plasma Physics and Controlled Fusion 48 (2006) 777-787

Howard, J.
High-speed High-resolution Plasma Spectroscopy using Spatial-multiplex Coherence Imaging Techniques
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Howard, J. and Oliver, D.
Electronically Swept Millimeter-wave Interferometer for Spatially Resolved Measurement of Plasma Electron Density
Applied Optics 45 (2006) 8613-8620

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Plasma-based Lens for Microwave Beam Steering
Electronics Letters 42 (2006) 444-446

Oliver, D., Howard, J., Tekke, A.S., Pretty, D. and Blackwell, B.
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Czechoslovak Journal of Physics 56 (2006) 1353-1359

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Xia, H., Shats, M. and Punzmann, H.
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4th International Symposium on Turbo Codes and Related Topics, IEEE Inc (2006)

Anderson, M., Reed, M. and Borg, G.
MMSE Equalization for Serially Concatenated CPM over ISI Channels
40th Annual Conference on Information Sciences and Systems (CISS), IEEE Inc (2006) 438-1439

SP3 Group

The SP3 Group is led by Professor Rod Boswell and Dr Christine Charles and conducts work on both basic and applied plasma physics. The recent discovery of current free double layers has led to an invitation from the European Space Agency and a DEST contract with the CRC for Satellite Systems and AUSPACE Pty Ltd to construct a space thruster prototype which was tested in the European Space Agency Technology Division (ESTEC) in April 2005. Late in 2006 we were contacted by ASTRIUM, the largest Space company in Europe, and a large contract for further development of the HDLT has been signed with the Canberra company AUSPACE who are representing ASTRIUM in Australia.

During the wrap up of the test program in ESTEC, a new gridded ion thruster was discussed, and in June negotiations commenced on the design and fabrication of the dual stage thruster using an rf plasma source, similar to our focussed ion beam source. The contract was awarded and the ion thruster was designed and built from scratch by a small team in the short time of 3 months. The test campaigns in ESTEC in late 2005 and mid 2006 were extraordinarily successful with the thruster being run up to 30kV with an ion current of 10 mA.

We have a major program to simulate and model the double layer phenomena observed in the laboratory. Computer simulation using millions of particles shows the dynamics of the plasma and allows us to determine fundamental processes associated with the thruster. Analytical modeling allows more dimensions to be considered and is useful for discovering the basic physics underlying the plasma phenomena. Applied space plasma thruster work includes plasma detachment from spacecraft which allows us to find the best conditions to prevent the plasma ion beam from returning and consequently not generating any thrust.

The contract for optimisation of our bright plasma source for FEI Company in the USA, and an associated ARC Linkage grant have now been successfully completed Previous focussed ion beams use metal ions which can change the properties of the nano-structures being machined whereas our source uses inert gas ions. Present measurements show that it is many times brighter than presently available sources and FEI Company have decided to move the source into commercialisation.

After a number of years of fruitful collaboration with the University of Orleans, France, we were successful in obtaining funding until 2009 from the Australian Research Council to pursue our own fuel cell development program. There are two post doctoral fellows and two students working on the sputter deposition of platinum onto carbon electrodes, testing of membrane electrode assemblies (MEAs) using Nafion membranes and the development of a completely new plasma deposition system for methyl insensitive membranes which will allow methanol to be used as a fuel instead of hydrogen. The work on the electrodes is progressing along with diagnostics such as Rutherford Backscattering Spectrometry (RBS) for depth analysis and the testing station is complete. We also have a hot press so we can fabricate MEAs. A new deposition system for growing nanotubes and co-sputtering catalyst is nearing completion. This will allow a greater flow of gas through the gas diffusion layer/electrode while have an adequate supply of catalyst distributed through the film.

We are developing outreach programs with a school in Southern Queensland for showcasing hydrogen economy systems to schools and colleges in Queensland, NSW and the ACT. As part of increasing the public profile of fuel cells and non-pollute commute we intend to actively push for permission to run Neighbourhood Electric Vehicles on roads or perhaps cycle tracks as is done in the European Union. We wish to add fuel cells to these cars and bikes (trikes) in a push to really demonstrate that there is an alternative to hydrocarbon fuelled vehicles.

The work on non-linear properties of optical thin films we deposit is continuing and has given birth to a discovery that the deposition system is also very good for the growth of nanotubes

and fibres. These have many application and we are actively pursuing this new avenue of research. A new model of deposition and stress growth has been developed for very thin films as they move from 2D to 3D growth. This has led to the development of an *in situ* method of measuring stress which can be applied to most thin films being grown.

Our expertise in plasma modification of surfaces is being used to functionalise both hard and soft (polymer) surfaces. Primarily this devolves about changing the hydrophobicity (wetting property) of the surface as antibodies and protein attachment to these substrates and be controlled. In protein mobility studies we are developing a very small sample plate for large population sampling in collaboration with the University of Sydney.

In order to be able to modify the properties of surfaces in the most effective way possible for industrial applications, an atmospheric pressure plasma system has been developed and is yielding very good results: filamentary discharges can be eliminated and replaced by uniform glow discharges, which, when pulsed have been successfully used to reduce the hydrophobicity of plastic surfaces for some days.

Application of our results to solar and space physics is very successful with a new mechanism for the genesis and ion heating of the solar wind being proposed.

Staff List

Professor and Head of Group

Roderick Boswell BSc Adelaide, PhD Flinders, FAPS, FATS

Senior Fellow

Christine Charles INSA Rennes, PhD Orléans
Ane Aanesland MSc PhD, Tromso
Douglas Bulla MSc PhD USP Brazil (jointly with OSG)
Cormac Corr PhD Belfast
Orson Sutherland BE, PhD ANU
WeiTang Li MSc China, PhD Sydney

Visiting Fellows

Mike Lieberman PhD Elect Eng, Berkeley (from December)
Kazanori Takahashi

Senior Technical Officer

Peter Alexander

Departmental Administrator

Helen Hawes BA ANU (until July)
Bronwyn Stuart (from August)

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

Refereed Journal

Aanesland, A. and Charles, C.
Plasma Expansion from a Dielectric Electron Cyclotron Resonance Source
Physica Scripta T122 (2006) 19-24

Aanesland, A., Boswell, R. and Smith, N.S.*
High voltage Breakdown in an Inductively Coupled Ion Source
Journal of Physics D: Applied Physics 39 (2006) 3588-3595

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Upstream Ionization Instability Associated with a Current-free Double Layer
Physical Review Letters 97 (2006) 075003-1-4

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Experiments and Theory of an Upstream Ionization Instability Excited by an Accelerated Electron Beam through a Current-free Double lacyer
Physics of Plasmas 13 (2006) 122101-1-10

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Comparison of Stress in Single and Multiple Layer Depositions of Plasma-deposited Amorphous Silicon Dioxide
Journal of Physics D: Applied Physics 39 (2006) 164-171

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The Astrophysical Journal 640 (2006) L199-L202

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Rare Metals 25 (2006) 150-152

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Theory for Formation of a Low-pressure, Current-Free Double Layer
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A Theory for Formation of a Low Pressure, Current-free Double Layer
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Meige, A. and Boswell, R.
Electron Energy Distribution Functions in Low-pressure Inductively Coupled Bounded Plasmas
Physics of Plasmas 13 (2006) 5

Smith, N.S.*, Skoczylas, W.P.*, Kellogg, S.M.*, Kinion, D.E.*, Tesch, P.P.*, Sutherland, O., Aanesland, A. and Boswell, R.
High Brightness Inductively Coupled Plasma Source for High Current Focused Ion Beam Applications
Journal of Vacuum Science and Technology B 24 (2006) 2902-2906

Department of Theoretical Physics

The Department of Theoretical Physics is one of the University's founding departments. The core research areas involve theoretical aspects of plasmas and fluids, mathematical physics and condensed matter physics. The Department also undertakes research in atomic and molecular physics through joint appointments with the Atomic and Molecular Physics Laboratories.

In October 2006 the Department moved back into office space in the refurbished Le Couteur Building after spending a year in temporary accommodation in the Oliphant Building. Professor Kenneth Le Couteur and his family toured the refurbished building and were greatly impressed by the opening up of space and the benefit the building will provide for future generations of physicists.

Research highlights for 2006 include the calculation of exact low-energy properties of a one-dimensional interacting gas of anyons, the discovery of hidden structure in quantum groups, the integrability of a q-deformed Bose gas, novel quantum transport in mesoscopic systems, application of quantum chaos concepts to plasma instabilities in stellarators, a model of coupled edge-core dynamics of magnetic fusion plasmas, a study of experimental grassland fires and further development of generalized geometries in the context of string dualities, mathematical foundations of C*-algebras in tensor categories and their applications in physics.

Staff highlights for 2006 include the promotion of Dr Matthew Hole. Members of the Department continued their active involvement in undergraduate teaching in both the Physics and Mathematics Departments in the Faculties. They also continued their significant role in the PhB program through providing research projects and student mentoring. Honours students supervised by members of the Department who graduated in 2006 were Man Chung (Simon) Fung and Jolyon Bloomfield (University Medal). Graduating PhD students in 2006 were Dr Philip Brydon and Dr Norman Oelkers who took up postdocs at MPI, Stuttgart and the University of Queensland, respectively.

Members of the Department also continued their strong involvement on national and international committees and editorial boards. One of the conference highlights for 2006 was the AMSI/CMA/RSPhysSE/IGA workshop, "The Mathematics of String Theory" (MOST06), organized by Professor Bouwknegt with colleagues from Melbourne and Adelaide. Dr Matthew Hole co-organized the international workshop, "Towards Australian involvement in ITER", which attracted delegates from five of the seven ITER partners, as well as Australian scientists, industry and media. Professor Batchelor served on the Lars Onsager Prize Selection Committee of the American Physical Society.

The Department continued its strong success in competitive funding, with over $1M held in external grants and fellowships for 2006. As in past years, this external income exceeds the Department's recurrent budget. Professor Peter Bouwknegt was awarded a new Australian Research Council Discovery grant in 2006 for work on "Generalized Geometries and their Applications".

The Department is host to the ARC Research Network on Complex Open Systems (COSNet) and the Centre for Complex Systems (CCS). The Centre's activities are highlighted elsewhere.

Staff List

Professor and Head of Department

Murray Batchelor BSc (Hons) UNSW, PhD ANU, FAIP, FAustMS, FInstP (ARC Fellowship) (jointly with MSI)

Professors

Vladimir Bazhanov PhD Serpukhov
Peter Bouwknegt BSc MSc Utrecht, PhD Amsterdam, FAIP, FAustMs (jointly with MSI)
Mukunda Das MSc Utkal, PhD Roorkee, FAIP, CPhys, FInstP
Robert Dewar MSc Melb, PhD Princ, FAIP, FAPS, FAA
Anatoli Kheifets Msc PhD St Petersburg (jointly with AMPL)

Senior Fellow

Shin-Ho Chung BSc Stanford, PhD Harv (until April)

Fellows

Vladimir Mangazeev MSc Moscow, PhD Serpukhov
Sergei Sergeev MSc Moscow, PhD Serpukhov, PhD St Peter
Wen Xu BSc MSc PhD Antwerp

Research Fellows

Rowena Ball BSc PhD Macquarie
Xi-Wen Guan BSc Qufu, MSc Sichuan, PhD Jilin (jointly with Mathematical Science Iinstitute)
Linda Stals BSc PhD ANU (jointly with Mathematical Sciences Institute) (from June)

Postdoctoral Fellows

Alex Flournoy PhD Boulder (until August)
Matthew Hole BSc BE PhD Sydney
Matthew Hoyles BSc PhD ANU (until April)
Igor Ivanov BSc Moscow IPT, PhD RAS
Ryusuke Numata BSc MSc PhD Tokyo

Visiting Fellows

Fred Barker MSc Mel, PhD Birm (Emeritus Professor)
Michael Bortz DipPhys PhD Dortmund
Jorgen Frederiksen BSc DSc Adel, PhD ANU
Michael Hall, MSc PhD ANU
Brian Kenny BA MSc Melb, PhD Chicago, FAIP
Sang-Hoon Kim MSc Korea, PhD UMC (until June)
Kailash Kumar BSc Agra, MSc Alld, PhD McM, FAIP
Sergei Kun MS PhD Kiev (until July)
J. Walter Larson BA BSc Drake, Msc, PhD W&M
Brian Robson MSc PhD DSc Melb, FAIP
Robert Robson BSc Qld, DipMet, PhD, FRMS, FAPS, FAIP (jointly with AMPL)
Hisham Sati BSc Beirut, MSc Louisiana, PhD Michigan
Emilia Solano CIEMAT, Spain
Andrew Stewart FAIP, FInstP ANU
Lindsay Tassie MSc PhD Melb, FAIP ANU

Claudio Tebaldi PhD Bologna
Zengo Tsuboi BSc Kyoto, MSc Tokyo, PhD Tokyo
William Woolcock BSc Qld, PhD Cambridge, FAIP ANU

Departmental Administrator

Mrs Trina Merrell

Publications

Legend: * *External to the University*
Member of another area of this University other than this School

Refereed Journal

Barker, F.C.
Energy Dependence of the ^{7}Be(p, γ)^{8}B S Factor, and Charge Symmetry in the ^{7}Li + n and ^{7}Be + p Systems
Nuclear Physics A 768 (2006) 241-252

Barker, F.C. and Fynbo, H.O.U.*
Beta Decay of ^{9}Li to ^{9}Be(1/2^{+})
Nuclear Physics A 776 (2006) 52-54

Batchelor, M. T. and Guan, X.-W.
Generalized Exclusion Statistics and Degenerate Signature of Strongly Interacting Anyons
Physical Review B - Condensed Matter and Materials 74 (2006) 195121-1-7

Batchelor, M.T., Bortz, M., Guan, X.-W. and Oelkers, N.
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Exact Results for the 1D Interacting Fermi Gas with Arbitrary Polarization
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One-dimensional Interacting Anyon Gas: Low-energy Properties and Haldane Exclusion Statistics
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Baxter, R.J.
Hyperelliptic Parametrisation of the Generalised Order Parameter of the N=3 Chiral Potts Model
ANZIAM Journal 47 (2006) 289- 307

Bazhanov, V. and Sergeev, S.
Zamolodchikov's Tetrahedron Equation and Hidden Structure of Quantum Groups
Journal of Physics A: Mathematical and General 39 (2006) 3295-3310

Benet, L.*, Kun, S. and Qi, W.*
Effect of Phase Relaxation on Quantum Superpositions in Complex Collisions
Physical Review C: Nuclear Physics 73 (2006) 064602-1-8

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Bortz, M. and Sirker, J.*
The One-dimensional Hubbard Model with Open Ends: Universal Divergent Contributions to the Magnetic Susceptibility
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Bouwknegt, P. and Ridout, D.*
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Bouwknegt, P., Evslin, J.*, Jurco, B.*, Mathai, V.* and Sati, H.*
Flux Compactifications on Projective Spaces and the S-duality Puzzle
Advances in Theoretical and Mathematical Physics 10 (2006) 345-394

Bouwknegt, P., Hannabuss, K.* and Mathai, V.*
Nonassociative Tori and Applications to T-duality
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Brosche, P.* and Tassie, L.
The Value of the Superstring Tension and Dark Matter
Astronomische Nachrichten 327 (2006) 379-382

Brydon, P. and Gulacsi, M.
Bosonization Solution of the Falicov-Kimball Model
Physical Review Letters 96 (2006) 036407-1-4

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