School of Physics University of Wollongong

SUSANNA GUATELLI, JOSIP HORVAT, MICHAEL LERCH, ROGER LEWIS AND ALEXEY V PAN, ANATOLY ROZENFELD
SCHOOL OF PHYSICS, UNIVERSITY OF WOLLONGONG, AUSTRALIA

INTRODUCTION

The University of Wollongong (UOW), Australia, was established as an independent institution in 1975 and it has become one of the best modern universities in the world: dynamic, agile and prominent in national and international rankings for the quality of its teaching, research, student experience and outcomes. As a young and vibrant university with undiminished ambitions, UOW is an international network of campuses and regional learning centres. It is a global leader in research and learning, focused on transforming lives through a strong and connected presence in communities throughout Australian and the world. The main UOW campus is situated in the outskirts of Wollongong (Figure 1). Rich park-like environment, with buildings merging seamlessly with native flora, provides an ideal place for research and learning (Figure 2).

The School of Physics was a foundation department of the University of Wollongong in 1975 and the School of Physics today is one of six Schools within the Faculty of Engineering and Information Sciences (EIS) at UOW (http://eis.uow.edu.au/physics/index.html). The degree programs currently offered by the School include undergraduate with end-on and integrated Honours, Masters by coursework and research (Master of Research), and Doctor of Philosophy (Ph.D.). All of the undergraduate degrees are accredited by the Australian Institute of Physics. The medical physics related courses offered by the School are accredited by the Australasian College of Physical Scientists and Engineers in Medicine. There are currently 200 undergraduate and 110 postgraduate students enrolled in the School's degrees.

Fig.1: View of the City of Wollongong.

Fig.2: Students enjoying a break on the main campus.

Fig. 3: Research staff and students from the Centre for Medical Radiation Physics (CMRP).

The vision for the School of Physics is to enhance its position as an internationally recognised, research focused School with a reputation for high quality, innovative and student-centred undergraduate and postgraduate educational programs.

The School of Physics has a highly robust teaching program that adapts to both internal and external changes in the student environment and cohort. From a teaching perspective the School aims to facilitate a greater awareness and engagement of society in physical science through continued exploration, development and usage of human and technological capacity for the benefit of its region, the nation and the international community. Academics within the School have a long track record of enthusiasm and active involvement in the development and running of new teaching and course initiatives within and outside the faculty. This track record enables high quality, hands-on education and training for undergraduate and postgraduate students in the areas that extend a core program of physics, including Condensed Matter Physics, Medical Radiation Physics, Thin Film Technology, Magnetism and Superconductivity, Biomolecular Physics, Atmospheric Physics and Photonics (Figure 3). Academic staff provide significant service teaching for the Bachelor of Engineering programs in the first year and in addition, a significant cohort of students from the wider university community undertake subjects of general physics in areas of Environmental Physics, Biophysics, Energy Systems and Astronomy. This attraction of students from all university disciplines demonstrates that our tight internal integration does not preclude wide interaction.

MEDICAL RADIATION PHYSICS

The Centre for Medical Radiation Physics (CMRP - http://eis.uow.edu.au/cmrp/index.html), directed by Distinguished Professor Anatoly Rozenfeld, is within the School of Physics and is mainly dedicated towards the development of semiconductor detectors and dosimeters for clinical applications in radiation protection, radiation oncology, imaging and nuclear medicine. Other research themes include the development of Monte Carlo simulation tools for medical physics and of drug agents for targeted radiotherapy.

CMRP is internationally recognized and has attracted competitive funding from the National Health and Medical Research Council (NHMRC), the Australian Research Council (ARC), Cancer Institute NSW and NSBRI (NASA), as well as strong support from industry. The CMRP has close links with major Australian hospitals, such as St George Cancer Care Centre (Kogarah, NSW), Illawarra Cancer Care Centre (Wollongong, NSW), Liverpool (Liverpool, NSW), Prince of Wales Hospital's Radiation Oncology Department (Randwick, NSW) and Peter McCallum Cancer Center (Melbourne, Victoria). These links provide opportunities for translational research and training in medical physics. CMRP has also strong research collaborations with the Australian Nuclear Science and Technology Organisation (ANSTO, Lucas Heights), the Australian Synchrotron and Commonwealth Scientific and Industrial Research Organisation (CSIRO, Sydney).

International collaborations include MGH Francis H. Burr proton therapy centre (USA), Loma Linda University (US), Mayo clinic (Minnesota, USA), the Heavy Ion Therapy Centre at Heidelberg (Germany), HIMAC (NIRS, Chiba, Japan), INFN (Catania, Italy), IN2P3 (Bordeaux, France), CERN (Geneva, Switzerland) and the University of Surrey (UK).

Objectives:

- Research and development in the field of radiation detectors and radiation instrumentation for mini- micro- and nano- dosimetry in radiation therapy, nuclear medicine, space medical science, Monte Carlo simulations.
- Continuous education and training in medical physics through our comprehensive postgraduate research program, and strong national and international collaborations.
- Translational research into clinical environments and commercialisation of our research, aimed at improving the results of cancer treatment.
- Develop new radiation oncology modalities, including synchrotron micro-beam therapy, Image Guided Radiation Therapy (IGRT), MRI-LINAC, Volumetric Modulated Arc radio Therapy (VMAT), and new methods of radiation diagnostics.

The CMRP has a strong applied research in hadron therapy (including proton and carbon ion therapy), Intensity Modulated Radiation Therapy (IMRT), Image Guided Radiotherapy/Adaptive Radiotherapy, Brachytherapy (HDR and LDR) to treat prostate, breast cancer and eye melanoma, Synchrotron Micro-Beam Radiation Therapy for brain cancer, Radio-Magneto-Therapy and MRI guided-LINAC radiotherapy.

Projects Include:

- Radiation Detection and Instrumentation for radiotherapy Quality Assurance
- Micro- and nano- dosimetry and new radiation oncology modalities
- Silicon microdosimetry for radiotherapy, space and avionics
- Real time semi-conductor dosimetry for external beam therapy and brachytherapy (MOSkin, spectroscopy dosimetry, MEDIPIX dosimetry, Dose Magnifying Glass (DMG), Magic Plate neutron dosimetry)
- Radiation probes, Positron Emission Tomography (PET) detector modules and gantry for small animal imaging
- Semi-conductor detectors for micro-dosimetry in mixed radiation fields,
- Radiation instrumentation for High Energy Physics and homeland security
- Dosimetry for targeted radionuclide therapy
- Contribution to the development of the Geant4 Monte Carlo simulation toolkit (www.geant4.org) for medical physics applications.
- Applied medical imaging including film dosimetry, radiological dosimetry, image fusion for radiotherapy planning
- Single Photon Emission Computed Tomography for targeted radionuclide therapy dosimetry
- Imaging with high resolution pixelated detector
- Proton computer tomography
- Radio-biology for hadron therapy and Radio-Magneto therapy
- Monte Carlo radiation transport simulations for medical physics applications, including micro- and nano-dosimetry
- Proton computed tomography
- PET for in-vivo range verification in proton and carbon ion therapy

CONDENSED MATTER PHYSICS AND TERAHERTZ OPTOELECTRONIC

The School conducts world-leading research in condensed matter physics, thin film technology (TFT), magnetism and superconductivity, and terahertz science in the **Centre for Quantum Devices, Optics and Solids (qDOS)**. qDOS is as a key part of the Institute for Superconducting and Electronic Materials (ISEM), conducting both experimental and theoretical work. Some notable areas of research garnering international attention have been in the areas of graphene, ultrafast magneto-optical imaging of superconductors, hybrid thin films and nanolayers, superconducting/magnetic devices and nanostructures in complex oxides and metals, spin-charge interactions at interfaces, dosimeters for X-ray microbeam radiation therapy, optical isolation and terahertz radiation production from unwinding sticky tape.

qDOS has vibrant research collaboration links with a number of Universities and Research Organisations, spreading Australia-wide and around the globe: the Australian Nuclear Science and Technology Organisation (ANSTO, Lucas Heights), the Australian Synchrotron and Commonwealth Scientific and Industrial Research Organisation (CSIRO, Sydney), University of Melbourne, University of Western Australia, Mesaplexx Pty. Ltd. (Australia), HYPRES Inc. (USA), Sao Paulo State University (Brazil), Institute for Metal Physics (Kiev, Ukraine), Institute for Superhard Materials (Kiev, Ukraine) University of Oslo (Norway), National Research Nuclear University (MEPhI - Moscow Engineering Physics Institute, Russia), University of Twente (The Netherlands), Northeastern University (Boston, USA), University of Sydney, Tianjin Polytechnic University (China), Stanford University (USA), California Institute of Technology (USA), University of Surrey (UK), Shanghai University (China), Xian University (China).

Terahertz Science, Solid State Physics Group

Although known for quite a while terahertz science is one of the most exciting emerging fields. Advances in terahertz technology offer enhanced national security, prosperity and quality of life. The fundamental aspects of terahertz research are closely underpinned with solid state physics, which is by far most important research field helping us to understand physical phenomena observed in wide range of materials. Researchers associated with this group are working in following projects:

- Quantum transport in low dimensional systems and topological materials
- Surface plasmon polaritons and plasmonics
- Physics of graphene and topological materials
- Quantum transport in low dimensional systems
- Thermionics and thermoelectrics study in nanomaterials High efficiency terahertz emitters
- Developing advanced materials and structures for terahertz science and technology
- Terahertz applications in medicine and biology
- Hydrogen bonds in molecular crystals
- Frustrated spin systems
- Industrial applications of terahertz technology.
- Terahertz techniques for authentication of art pieces and cultural objects.
- Novel terahertz optics using 3D-printing.

Applied Superconductivity, Magnetic Materials, And Thin Film Technology

Superconductivity is regarded as one of the most astonishing phenomena in the world of science. Superconductors offer great potential for development of new generation materials for power transmission, electrical motors, fault current limiters, magnetic sensors, medical imaging, and other electronic devices. Magnetism is the fundamental property driving all chemical element existence, preventing stars from collapsing into black holes, and being used in large variety of existing and emerging application, which range from nuclear fusion, medical diagnostics and treatments, to spin-based devices (including hard drives). Thin Film Technology is the advanced approach used to miniaturize functional components of electronic devices and make them both powerful and portable, like smartphones and computers. The research carried out by this group covers a wide range of projects from materials aspects to theoretical modelling, which combine these phenomena and technology to develop new functionalities and properties in nanoscale structures and 2D interfaces.

Projects Include:

- Development of new thin film, multilayer, and hybrid structures
- Ultrafast magneto-optical imaging of superconducting and magnetic materials
- Spin-charge Interaction at 2D interfaces
- Superconducting thin films for telecommunications, medicine, and space applications
- Magnet-driven cell rapture and drug delivery
- New structures for photon and radiation detectors
- Development of new nanostructures for electronic devices
- New technologies for High Temperature Superconductors for electricity and energy handling
- New design of tunneling junctions
- Micro- and nano-structuring, optical and electron beam lithography

For details of condense matter and terahertz research, please see the ISEM annual report: https://isem.uow.edu.au/index.html

Bibliography: Institute for Superconducting and Electronic Materials, *Annual Report 2017,* isem.uow.edu.au

Susanna Guatelli is an international leading expert of Monte Carlo radiation transport simulation codes for radiation physics and, in particular, medical physics.

Josip Horvat's research areas include superconductivity, magnetic nanoparticles, terahertz spectroscopy, DFT modelling, frustrated spin systems.

Michael Lerch applies his expertise of electronic properties of semiconductors to the design and development of novel, solid state based sensors and instrumentation for application in radiation medicine.

Roger Lewis works in the area of terahertz science and technology and is also an accomplished classroom teacher and winner of several teaching awards

Alexey V Pan is a leader of Thin Film Technology program exploring the areas of condensed matter physics, superconductivity and magnetism, materials science and nanotechnology, he is the recipient of a number of Australian Research Council fellowships and other awards, and serves as a member on a number of international expert committees.

Anatoly Rozenfeld is the Director and founder of CMRP, and is world renowned for his research work on semiconductor radiation detectors and their application for mini- and micro- dosimetry in radiation therapy, radiation protection, nuclear medicine and space sciences.