Australian Institute of Physics NSW Branch

2017

Postgraduate

Awards

Event

The 2017 Awards Event is sponsored by:

2017 Postgraduate Awards

The NSW AIP Branch will hold its Annual Postgraduate Awards Day on **Tuesday 14 November 2017 at the University of New South Wales, Business School Lounge on the top floor of the Australian School of Business, Kensington Campus.** Each New South Wales University is invited to nominate one student to compete for the **$500 prize** and **Postgraduate medal** on that day.

The Royal Society of NSW will also award the Jak Kelly Scholarship prize of $500 as a separate award category for this event. Students nominated for the awards will also be invited as guests for the NSW AIP Branch annual dinner that follows the presentations. These awards have been created to encourage excellence in postgraduate work, and all nominees who participate in the Postgraduate Awards Day will receive a **special certificate** recognising the nominee's high standing.

Students are asked to make a **20-minute presentation** on their postgraduate **research in Physics**, and the presentation will be judged on the criteria (1) content and scientific quality, (2) clarity and (3) presentation skills. **See further details below regarding the criteria for the 2017 Postgraduate Awards.**

Members and guests who are unable to attend the **Awards** are invited to join us from 6pm, for the **AGM** and will be followed by a talk by **Professor Warrick Couch, Director of the Australian Astronomical Observatory** which will be followed in turn by the Branch's Annual Dinner at **Giovanna Restaurant 285 Anzac Parade, Kingsford, Sydney.**

Entrance is FREE to the Awards and Talk by Prof Warrick Couch.

Prepared by: Dr Frederick Osman
2017 Awards Convenor

Event Schedule

- *Student presentations* at the **University of New South Wales, Business School Lounge on the top floor of the Australian School of Business, Kensington Campus** – **2.00 to 5.00pm**
- *Refreshments* **- 5.00 to 6.00pm**
- AIP NSW AGM **- 6.00 to 6.20pm**
- Presentation of *Awards and Prizes* **- 6.20 to 6.35pm**
- Guest speaker (*Professor Warrick Couch*) – **6.35pm**
- Annual dinner at *Giovanna Restaurant* – **8.00 to 10.00pm**
  Giovanna Restaurant, 285 Anzac Parade, Kingsford, Sydney

2017 Judging Panel

- Mr Stephen Foster – **The Australian Institute of Physics New South Wales Branch**
- Professor Warrick Couch – **Director of the Australian Astronomical Observatory**
- Dr Erik Aslaksen **– The Royal Society of New South Wales**

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Criteria for Postgraduate Awards

All candiates will present a **max 20-minute presentation** *(not including questions)*. The judges score and rank the candidates according to: (1) Content and Scientific Quality, (2) Clarity and (3) Presentation Skills. The judges combine their results to determine the winner. *Decisions by the panel are final*.

1. **Content and scientific quality are important criteria**. The presentation must be interesting, and the material should be seen to be significant within the field of research. Context is important for establishing what the state of current research in the field is and how the described research contributes to and extends current knowledge. The candidate must balance the competing demands of providing a clear explanation to the non-specialist and illustrating the techniques and methods to allow a meaningful assessment of the presenter's own understanding and contributions to the research. The context can be further clarified during the question-and-answer session.

1 = Strongly Disagree
3 = Neither Disagree nor Agree
5 = Strongly Agree

A. Content and Scientific Quality Matrix				**Total____/20**	
(i) Interesting	1	2	3	4	5
(ii) Significant	1	2	3	4	5
(iii) Addresses Research Gap/Need	1	2	3	4	5
(iv) Contributes and Extends Knowledge	1	2	3	4	5

2. **Clarity** is a skill which is required to communicate a subject requiring years of study into a 20-minute presentation. The judges are looking for the presenter's ability to communicate the essence of the research without becoming excessively encumbered with detail. A proper introduction, good exposition and meaningful conclusions are important factors in providing a clear presentation.

B. Clarity Matrix				**Total____/20**	
(v) Communicates Essence	1	2	3	4	5
(vi) Good Introduction	1	2	3	4	5
(vii) Good Exposition and Explanations	1	2	3	4	5
(viii) Meaningful Conclusion	1	2	3	4	5

3. **Presentation skills** include the best use of audio-visual aids, speaking ability, eye contact, efficient use of time, projecting a professional and confident attitude, preparedness and response to questions.

C. Presentation Skills Matrix				**Total____/20**	
(ix) Preparation and Use of Time	1	2	3	4	5
(x) Use of Audio-Visual	1	2	3	4	5
(xi) Professional and Confident	1	2	3	4	5
(xii) Response to Questions	1	2	3	4	5

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2017 Postgraduate Schedule

- ***2.00pm*** **Welcome by Dr Frederick Osman (AIP Awards Coordinator)**
- ***2.10pm*** **Andrea De Lima Ribeiro, Macquarie University, Department of Physics and Astronomy**

  Optical Remote Sensing of Water Temperature
- ***2.35pm*** **Moritz Merklein, University of Sydney, School of Physics**

  A chip integrated optical buffer based on hyper-sound waves
- ***3.00pm*** **James Diacoumis, University of New South Wales, School of Physics**

  The Dark Frontier: A novel way to probe dark matter physics in the early universe
- ***3.25pm*** **Afternoon Tea**
- ***3.50pm*** **Kai Wang, Australian National University, Research School of Physics**

  How do we make camera for quantum light?
- ***4.10pm*** **Elette Engels, University of Wollongong, Department of Physics**

  New Advances in Nanoparticle-Enhanced, Image-Guided Microbeam Radiation Therapy
- ***4.35pm*** **Trong Toan Tran, University of Technology Sydney, School of Mathematical and Physical Sciences**

  Single photos from flatland
- ***5.00pm*** **Refreshments and Networking**
- ***6.00pm*** **Presentation of NSW Community Outreach to Physics Award and AIP NSW Postgraduate Awards**
- ***6.20pm*** **AIP NSW Annual General Meeting (AGM)**
- ***6.35pm*** **2017 Invited Speaker: Professor Warrick Couch**
- ***8.00pm*** **Annual Dinner: Giovanna Restaurant, 285 Anzac Parade, Kingsford**

Optical Remote Sensing of Water Temperature

Andrea De Lima Ribeiro
Department of Physics and Astronomy, Macquarie University

Abstract
The water Raman spectrum is temperature-dependent and both unpolarised and orthogonally polarised components can be used to calculate temperature markers. For the unpolarised Raman spectra, this marker is a ratio of intensities on either side of the isosbestic point ("two-colour" ratio); for polarised signal, the "depolarisation" ratio correlates intensities between perpendicular and parallel polarised components. My goal is to measure temperature in natural waters based on backscattered Raman signal. I've built two multi-channel Raman spectrometers able to collect both unpolarised and polarised components simultaneously and compatible with LIDAR methods: one system used pulsed blue excitation (473 nm) and the other used pulsed green light (532 nm).

Band Pass filters were used to select portions of the spectrum highly sensitive to changes in temperature. The samples were placed inside a temperature-controlled chamber and the Raman signal was collected by photomultipliers at four different channels (two parallel-polarised, two perpendicularly-polarised). Temperature markers were obtained by integrating the signals around their FWHM and calculating ratios between the channels.

The best RMSEs for blue (green) excitation were found for "two-colour" analysis and ranged from ±0.4°C to ±0.7°C (from ±0.4°C to ±0.6°C). Simulations revealed that, for coastal environments, both green and blue light have nearoptimal transmission in the water column (up to 30 m), but green Raman photons (blue excitation) propagate to further depths than red (green excitation). Using blue excitation also avoids overlapping of the Raman band (~ 560 nm) with other natural fluorescence signals as chlorophyll-a (~ 680 nm). Regarding the depolarisation method, this was the first time that portions of both polarised components were collected simultaneously and accuracies ranged from ±0.8°C to ±1.34°C. For enhanced temperature predictions, I built linear combination models with two-colour and depolarisation ratios from all four channels and had a general improvement of 33%, up to ±0.2°C.

A chip integrated optical buffer based on hyper-sound waves

Moritz Merklein
School of Physics, University of Sydney

Abstract
The research of my thesis works on realizing an integrated delay line memory based on sound waves that has the potential to revolutionize next generation computer chips. Photonic interconnects can solve one of the great challenges in computing, that is, connecting different processing units without generating heat, while offering a large bandwidth and data throughput. However, the large speed of light is imposing new challenges in integrated circuits, requiring an optical memory to slow down information for buffering, synchronization, re-routing and further processing. Controlling the speed of light is challenging and so far no method has been developed that reaches the required bandwidth, fractional delay, is compatible with complex optical data encoding schemes and least of all can be integrated in a photonic circuit.

Here we show for the first time an integrated optical buffer that is based on a transfer of optical information to high-frequency hyper-sound waves. The delay is caused by a 5-orders of magnitude difference between the speed of light and the speed of sound. This transfer of information from light to sound and back is achieved in carefully designed waveguides on a chip, which guide light waves as well as high frequency hyper-sound waves.

We demonstrate for the first time that all the characteristics of light commonly used in optical data transmission, amplitude, phase and wavelength, can be transferred to hyper-sound waves and unambiguously retrieved afterwards. We successfully store and retrieve multiple amplitude and phase levels with a GHz bandwidth, proving the compatibility of our approach with complex telecommunication encoding schemes. We also show that light with different wavelengths can be stored as different pitched sound waves and unambiguously retrieved afterwards, which is enabled by the unique phase matching condition between traveling light and sound waves that prevents cross-talk between the separate wavelength channels.

Prepared by: Dr Frederick Osman
2017 Awards Convenor

The Dark Frontier: A novel way to probe dark matter physics in the early universe

James Diacoumis
School of Physics, University of New South Wales

Abstract
The matter content of the universe is well-known to be dominated by a mysterious particle known as Cold Dark Matter which does not interact with light but is nonetheless needed to explain cosmological observables such as large scale structure and the 'oscillation' pattern in the leftover light from the Big Bang. Despite its enormous success at explaining physics on large length scales the Cold Dark Matter paradigm suffers from a number of known issues on small (sub-galactic) length scales, these include predicting the wrong amount of satellite galaxies for the Milky Way and predicting the wrong density profile in the inner cores of galaxies.

Solutions to this "small-scale crisis" usually involve modifying the Dark Matter content to wash out structure on small-scales where the Cold Dark Matter paradigm fares poorly while keeping the Dark Matter unchanged on large scales where it performs well. Since these models (by design) replicate Cold Dark Matter on large scales and possess the same gross phenomenology as each other on the small, the question arises as to whether these models can ever be observationally distinguished.

This challenge is especially formidable as small-scale modes are very difficult to probe with current experimental techniques and tell-tale distinguishable features of these models can be erased as a result of their evolution in the universe. In this talk I will introduce a novel way for distinguishing between Dark Matter solutions to this "small-scale crisis" which is projected to be within reach of future experiments such as PRISM.

How do we make cameras for quantum light?

Kai Wang
Nonlinear Physics Centre, Research School of Physics and Engineering,
The Australian National University

Abstract
The control of quantum states of photons promises a variety of applications in quantum information technologies by employing their multi-particle nature and hence nontrivial effects such as entanglement. Recent advances in ultra-sensitive and high-resolution imaging techniques, such as electron-multiplying CCD (EMCCD), make it possible to directly observe both temporal and spatial features of individual photons. However, the measurement of quantum states of several entangled photons, defined through the density matrix, remains challenging due to the inherent complexity of quantum tomography that requires a series of measurements with multiple reconfigurable optical elements in bulk setups.

My work suggests and experimentally demonstrates a novel concept that replaces conventional tomography setup with a single flat sub-wavelength-thin optical element, which reveals the quantum information encoded in multiple correlated photons by direct imaging onto a CCD. Specifically, I will present theoretical and experimental results on using a nanostructured metasurface to spatially split different components of quantum-polarization states of single and multiple entangled photons. I will show that the measurement of photon correlations with simple polarization-insensitive detectors enables full reconstruction of the multi-photon density matrix. We fabricate the nano-structure out of all-dielectric silicon-on-quartz materials via electron beam lithography, and observe a high transmission across a broad optical bandwidth. Finally, we realize experimentally the imaging of single photon and entangled photon pair with the metasurface and the reconstruction of their quantum states with high precision.

We anticipate that the camera for quantum light, combining our metasurface and an EMCCD, will boost the development of simple, fast and compact devices for various applications of photons in quantum information technology. In particular, our approach is highly suitable for end-user environments, since the sub-wavelength-thin metasurface provides an ultimate miniaturization, and can facilitate quantum state measurements by spatially-resolved imaging without a need of reconfiguration.

Prepared by: Dr Frederick Osman
2017 Awards Convenor

New Advances in Nanoparticle-Enhanced, Image-Guided Microbeam Radiation Therapy

Elette Engels
Department of Physics, University of Wollongong

Abstract
"There's Plenty of Room at the Bottom" – *R. Feynman.* Nanomedicine and nanoparticle research developments have stemmed from the fundamental understanding of physical and chemical behaviour in cells. In X-ray radiotherapy, high-Z nanoparticles increase the photon interaction probability inside tumour cells. Nanoparticles produce more secondary electrons, including auger electrons with high linear energy transfer (LET). Significant increases in local energy deposition and damage to tumour cells are then observed, particularly with kilovoltage X-rays where photoelectric effects dominate [1]. Microbeam radiation therapy (MRT) is a new irradiation method that allows superior normal tissue tolerance [2]. A synchrotron produces microscopic, spatially-fractionated, kilovoltage X-rays to treat deep-seated tumours [3]. There is potential for better dose conformity to the tumour using high-Z nanoparticles, to increase the damage of the microbeams selectively to the tumour. Nanoparticle enhancement with MRT in a local population of cells was initially calculated theoretically with Geant4 simulations [4, 5]. This work pioneers a more precise model for new metal oxide NPs and their uptake in cancer or normal cells under these novel X-ray irradiation conditions [6-8]. This work led to Geant4-DNA simulations to model chemical effects and more nanoparticle materials (ongoing), and *in vitro* cell experiments to confirm theoretical expectations at the Imaging and Medical Beam Line at the Australian Synchrotron, Clayton, VIC. Significant dose enhancement was obtained with nanoparticles in MRT, and characteristic trends were predicted and confirmed in terms of dependencies on nanoparticle configuration and beam energy. This work also presents new nanoparticle materials that can be used for CT and MRI, in addition to applications in radiotherapy. *In vivo* studies have also been undertaken to confirm nanoparticle image enhancement. A truly multi-modal approach to better target tumour treatment with radiation. "Consider the possibility that we too can make a thing very small which does what we want" – *R. Feynman.*

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Prepared by: Dr Frederick Osman
2017 Awards Convenor

Single photons from flatland

Trong Toan Tran
School of Mathematical and Physical Sciences, University of Technology Sydney

Abstract
Realization of quantum technologies demands successful assembly of key building blocks. Quantum light sources, lying at the heart of this architecture, have attracted a great deal of research focus during the last several decades. Optically active defect-based centers in wide bandgap materials such as diamond and silicon carbide have been proven to be excellent candidates due to their high brightness and photostability. Integration of quantum emitters on an on-chip integrated circuit, however, favors low dimensionality of the host materials. Single photon sources embedded in two-dimensional lattices are, therefore, highly desired. In this work, we introduce a class of novel quantum systems hosted in hexagonal boron nitride (hBN) – a wide bandgap semiconductor in the two-dimensional (2D) limit. First, we demonstrate experimentally that the quantum systems possess a record high single photon count rate exceeding 4 MHz at room temperature [1]. By employing spin-resolved density functional theory (DFT) calculation, we suggest that the defect center is an antisite nitrogen vacancy (N_BV_N) and its zero phonon lines (ZPLs) can be tuned by applied strain field in the hBN lattice [2]. Additionally, we demonstrate the ability to create the emitters by means of thermal treatment, electron beam induced etching or ion implantation [3, 4]. Under harsh environment, strikingly, most of the emitters survive and preserve their quantum properties [2, 5]. Resonant excitation spectroscopy reveals a linewidth of ~6 GHz, and a high single photon purity confirmed from an emitter by on-resonance antibunching measurements [6, 7]. Next, coupling of quantum emitters in hBN to external cavities and waveguides is demonstrated, showing PL enhancement and efficient extraction of quantum emission [8, 9]. Lastly, we show that another 2D materials - tungsten disulfide (WS2) – when being oxidized also hosts quantum emitters at room temperature [10]. This observation, therefore, opens a prospect for further investigations on quantum emitters embedded in other 2D materials.

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2017 Invited Speaker
Professor Warrick Couch

Director of the Australian Astronomical Observatory

Title: **Australian Astronomy in the new ESO era**

Venue: University of New South Wales, Business School Lounge on the top floor of the Australian School of Business, Kensington Campus

Abstract: In the Federal Budget announced in May, the only major science measure was the funding for Australia to enter into a 10-year strategic partnership with the European Southern Observatory (ESO). This is one of the most significant events in the history of Australian optical astronomy, providing its astronomers with access to all the world-leading telescope facilities at ESO’s La Silla and Paranal Observatories, including the 8m Very Large Telescope. However, it comes at a cost in that the two primary functions of the Australian Astronomical Observatory (AAO) – the operation of the 4m Anglo-Australian Telescope (AAT) at Siding Spring Observatory, and its instrumentation development/construction program based in Sydney – will be passed over to the research sector to fund and govern. In this talk I will focus on three things: (i) the outstanding scientific and technological opportunities that will come from the strategic partnership with ESO, (ii) the important role the AAO’s instrumentation capabilities have to play in maximizing these opportunities, and (iii) maintaining the AAT as a scientifically competitive research facility in the new ESO era.

Speaker Bio: Warrick Couch is the Director of the Australian Astronomical Observatory (AAO) – Australia’s national optical astronomy observatory – as well as an adjunct professor at Swinburne University of Technology, and the Universities of Sydney and NSW. He has a distinguished research career in the field of galaxy evolution and cosmology spanning more than 30 years, having obtained his PhD in Astrophysics at the Australian National University in 1982. Warrick was the winner of the 2007 Gruber Prize in Cosmology, a member of the Supernova Cosmology Project whose leader (Saul Perlmutter) jointly won the 2011 Nobel Prize in Physics for the discovery of the accelerating universe, and a Fellow of the Australian Academy of Science.

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