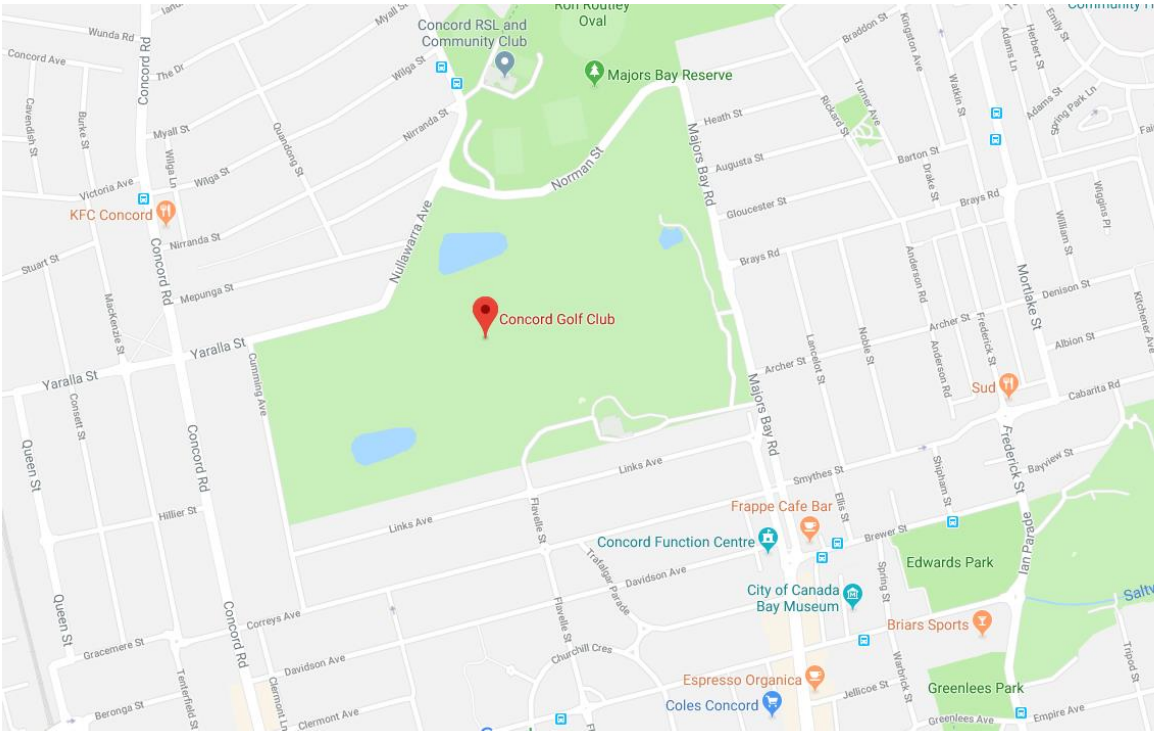
Australian Institute of Physics NSW Branch

2022 Postgraduate Awards Event Schedule

The 2022 Awards Event is sponsored by:

2022 AIP Postgraduate Awards

The **NSW AIP Branch** will hold its **Annual Postgraduate Awards event** on **Tuesday 8 November 2022 at the Concord Golf Club, 190 Majors Bay Road Concord (Entry via Flavelle Street).**



Each University has invited a postgraduate physics nominee to compete for the **AIPNSW Postgraduate medal** and the **RSNSW Jak Kelly prize.**

These awards have been created to encourage excellence in physics postgraduate work, and all nominees who participate in the Postgraduate Awards Day will receive a **special award** recognising the nominee's high standing.

Students will 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 as included in the judges' criteria.**

Event Schedule

- Presentations at the **Concord Golf Club, 190 Majors Bay Road Concord (Entry via Flavelle Street)** – **10.00am**
- Presentation of *Awards and Prizes* – **1.00pm**
- See further details in the Schedule on page 5

2022 Judging Panel

- Dr Jesse Shore – **Prismatic Sciences**
- Tibor Molnar – **Honorary Research Associate, Department of Philosophy, University of Sydney**
- Dr Timothy Van der Laan – **Australian Institute of Physics NSW**
- Dr Erik Aslaksen **– The Royal Society of New South Wales**

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Criteria for AIP 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 15-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

2022 AIP Postgraduate Schedule

- ***10.00am*** **Welcome by Dr Frederick Osman (AIP Awards Coordinator)**
- ***10.05am*** **Saurabh BHARDWAJ, Macquarie University, School of Mathematical and Physical Sciences**

  Femtosecond laser inscribed point-by-point Bragg gratings in few-mode optical fibre
- ***10.30am*** **Yuanming WANG, University of Sydney, School of Physics**

  Studying Extreme Time-Domain Phenomena with the Australian Square Kilometre Array Pathfinder
- ***10.55am*** **Giovanni PIEROBON, University of New South Wales, School of Physics**

  Exploring the invisible: axion dark matter in the galaxy
- ***11.20am*** **Shankar DUTT Australian National University, Research School of Physics**

  Sensing one molecule at a time: A pathway to personalized healthcare and early detection of Alzheimer's and MS
- ***11.45am*** **Ivan ZHIGULIN, University of Technology Sydney, School of Mathematical and Physical Sciences**

  Revealing the nature of blue quantum emitters in hexagonal Boron Nitride via the Stark effect
- ***12.10pm*** **Levi MADDEN, University of Wollongong, School of Physics**

  Optical dosimeters for radiotherapy with MRI-LINACs
- ***1.00pm*** **Presentation of NSW Community Outreach to Physics Award and AIP NSW Postgraduate Awards**

Femtosecond laser inscribed point-by-point Bragg gratings in few-mode optical fibre

Saurabh BHARDWAJ

School of Mathematical and Physical Sciences, Macquarie University

Abstract

Fibre Bragg gratings (FBGs) are critical devices in numerous application areas such as sensing, optical communications and laser sources, and there have been continuous efforts in improving their characteristics. A class of FBGs of growing importance is one in which damage features are written point-by-point (PbP) using micro-explosions induced by a femtosecond laser. These FBGs have many unique characteristics compared to conventional UV laser inscribed gratings. For PbP gratings, each individual grating site is inscribed one at a time, with tightly focused femtosecond laser pulses, resulting in a unique morphology. This morphology combined with the flexibility of inscribing individual modifications anywhere inside the optical fibre provides practical ways to inscribe complex gratings, whose properties are determined by the interaction of the grating sites with the spatial profile of the fibre modes. In this work we explore these areas in detail and provides new insights regarding the fundamental workings of PbP gratings.

By employing several different material characterisation techniques, we provide new insights into the grating's morphological changes. This includes directly measured refractive index profiles, which are of significant practical importance in engineering the grating properties. The PbP gratings interaction with the fibre modes determines the spectral characteristics of the grating. With a combined theoretical and experimental approach, we discuss this in detail and draw contrasts between two different theoretical approaches, namely the coupled mode theory (CMT) and the photonic bandgap (PBG) approach. For strong PbP gratings, CMT starts to fail but the PBG approach provides a clear and accurate picture of the fibre mode interaction with the grating sites. Finally, building on this knowledge we demonstrate ways to control mode coupling in few-mode optical fibres and discuss how the different mode coupling can be tuned in few-mode fibre Bragg grating by changing the spatial position of the grating sites inside the fibre core.

These results provide a new understanding of the fundamental properties of PbP gratings and open a path to new ways of controlling mode coupling in few-mode fibre Bragg gratings.

Studying Extreme Time-Domain Phenomena with the Australian Square Kilometre Array Pathfinder

Yuanming WANG
School of Physics, University of Sydney

Abstract

Short bursts, flares, scintillation and other radio time-domain phenomena usually imply extreme astrophysical environments (e.g. strong magnetic fields). Therefore, these objects can be used as a laboratory to study extreme physics that cannot be studied on Earth. This time-domain parameter space, however, is relatively unexplored historically, mainly limited by instrumental sensitivity and field-of-view (FoV). In this talk I will present unusual time-domain transient events I have discovered with the Australian Square Kilometre Array Pathfinder (ASKAP) telescope, and then discuss their nature, origin, and the implications for physics more broadly.

I have used ASKAP to probe timescales of seconds to hours, searching for rapidly varying radio sources. With the advantage of the large FoV, I discovered a group of fast-scintillating galaxies arranged linearly on the sky, spanning approximately 2 degrees. Using this unlikely sky distribution, I inferred the presence of a nearby, straight, and high-pressured plasma filament between the Earth and those galaxies, which produces extreme scintillation.

Circular polarisation is another poorly explored parameter-space. With ASKAP dual-polarisation beams, we identified a new pulsar (rapidly rotating neutron star) PSR J0523-7125 through its strong circularly polarised emission and variable behaviour. PSR J0523-7125 shows many unusual properties (e.g., upturn spectrum shape), which may shed light on the as-yet-unknown pulsar coherent emission mechanism.

Our discovery has filled gaps in this unexplored time-domain parameter space, and highlighted a new way of finding unusual pulsars – useful for future space-time experiments. The existence of a nearby, high-pressured plasma filament also changes our understanding of the origins of extreme scintillation, and requires new models to explain the underlying phenomenon, as existing theoretical models are incompatible with the structure we measured.

Exploring the invisible: axion dark matter in the galaxy

Giovanni PIEROBON

School of Physics, University of New South Wales

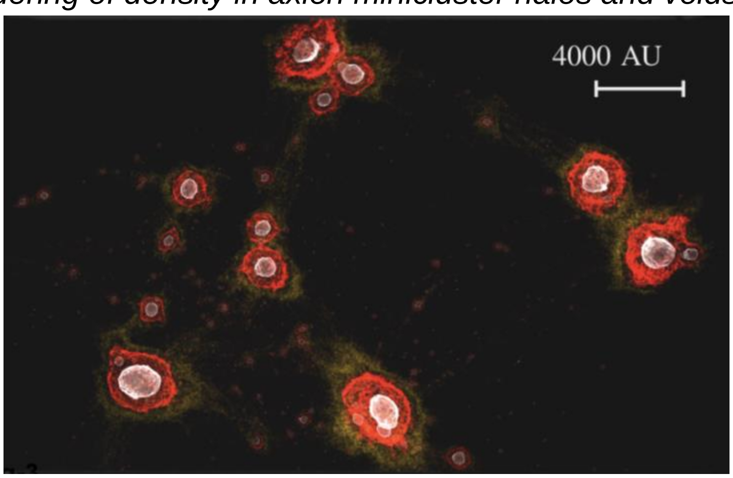
Abstract

Arguably the most famous flaw in our understanding of fundamental physics is dark matter (DM). With evidence from astronomical observations and gravitational effects on celestial bodies, dark matter is believed to be an elementary particle, although it has not been yet detected by any experiment.

The axion is amongst the most compelling dark matter particle candidates today. Originally postulated in 1977 as a solution to the so-called strong CP problem—an unsolved inconsistency between the theory and experiments of the strong force of quarks and nuclei—axion particles can be abundantly produced within the first second after the big bang and naturally act as a DM. Many experiments in the last decade have been set up to look for DM axions and future probes will contribute to this search. Experimental searches however, to maximise their discovery potential, need to know what and where to look for. Hence, the work of theorists is to model the axion production from the early Universe until today's time, in order to predict how many axions are around today and where they could be found within our own Galaxy.

My work at UNSW, with collaborators from Sydney and Spain, aims to improve the efforts of a larger and established community, on both these two fundamental questions, with an emphasis on where are axions distributed. In particular, we have been running state-of-the-art numerical simulations of axion production in the early Universe with different numerical methods. Within our Galaxy we modelled the formation of gravitational structures—called 'axion minicluster halos'—and the empty regions between them (see picture). Our preliminary estimates indicate that this non-trivial distribution of axion DM can modify the experimental signal by as much as a factor of four.

Volume rendering of density in axion minicluster halos and voids



Sensing one molecule at a time: A pathway to personalized healthcare and early detection of Alzheimer's and MS

Shankar DUTT
Research School of Physics, Australian National University

Abstract

Nearly one in twenty people worldwide suffer from neurological diseases. Early detection is crucial for these diseases because timely intervention can halt the progression of the condition and stop it from worsening. Early detection, however, relies on ultrasensitive biomarker detection, which is not possible with conventional diagnostic techniques. Neurodegenerative diseases can be detected by the presence or elevated levels of specific biomarkers in blood. The ability to identify single molecules reliably, swiftly, quantitatively, and affordably would thus offer up exciting new opportunities for a variety of biomedical applications.

We are investigating a unique nanopore-based sensing platform allowing reliable and highly sensitive detection and identification of different biomolecules in complex solutions. This platform employs scalable and controllable methods to fabricate silicon nitride membranes with effective thickness down to ~1.5 nm. Ultra-stable nanopores exhibiting high lifetime are fabricated in these membranes using controlled breakdown technique and track-etch technology. By adjusting the membrane composition as well as the nanopore structure, the translocation kinetics of the biomolecules can be tailored. Using this platform, we have demonstrated the detection of a number of isolated analytes, including DNA, proteins, and antibodies. We combine the novel nanopore sensor with artificial intelligence-based single-molecule identification algorithms with an aim to use the platform for the early diagnosis of neurodegenerative disorders. Artificial intelligence and on-the-fly data processing integrated with our novel nanopore platform may allow for the precise identification and measurement of the many biomarkers present in blood serum as well as 'real-time' diagnosis of Alzheimer's and Multiple Sclerosis.

Revealing the nature of blue quantum emitters in hexagonal Boron Nitride via the Stark effect

Ivan ZHIGULIN
School of Mathematical and Physical Sciences, University of Technology Sydney

Abstract

Single photons emitted from defects in two dimensional materials, such as Single photon sources in two-dimensional (2D) materials, such as hexagonal boron nitride (hBN) offer great prospects for integration in photonics, sensing and quantum communications devices. hBN allows for site-specific generation of blue emitters that exhibit a uniform wavelength of 436 nm[1] and GHz-range linewidths. Here we applied in-plane and out-of-plane electric fields to measure Stark shift of blue emitters under coherent photoluminescence excitation.

The effect was estimated from the Lorentz local field approximation given by $\Delta E = -\Delta\mu F - \frac{1}{2}\Delta\alpha F^2$ (1), where F is the electric field (MV/m), and $\Delta\mu$ and $\Delta\alpha$ are changes in permanent dipole moment and polarizability, respectively, of the ground and excited states. To accommodate different electric field directions, both vertical and horizontal devices were fabricated. Considering the narrow inhomogeneous linewidth of blue emitters, devices were cooled to 5 K for on-resonance measurements with high spectral resolution. We observe an insignificant linear shift in the out-of-plane electric field orientation and a large quadratic response in the in-plane configuration. According to Equation (1), it was deduced that the wavelength shift of blue emitters has minimal contribution from permanent transition dipole moments, and is mainly governed by the second term, transition polarizability. In comparison to other studied quantum emitters in hBN, which emit at longer wavelengths[2,3], our findings reveal that blue emitters are less susceptible to local field variations in the lattice due to small permanent dipoles. We also propose likely candidates for blue emitter defects via density functional theory (DFT) modelling.

[1] Gale, A., et. al. Site-Specific Fabrication of Blue Quantum Emitters in Hexagonal Boron Nitride. *ACS Photon*. **2022**, 8.
[2] Noh, G. et. al. Stark Tuning of Single-Photon Emitters in Hexagonal Boron Nitride. *Nano Lett.* **2018**, *18* (8), 4710–4715.
[3] Nikolay, N. et. al. Very Large and Reversible Stark-Shift Tuning of Single Emitters in Layered Hexagonal Boron Nitride. *Phys. Rev. Appl.* **2019**, *11* (4), 041001.

Optical dosimeters for radiotherapy with MRI-LINACs

Levi MADDEN
School of Physics, University of Wollongong

Abstract

In Australia, it is estimated that 1 in 2 males and 1 in 3 females will be diagnosed with cancer by their 85th birthday. For those that are diagnosed with cancer, approximately half are expected to benefit from radiation therapy as a part of their treatment. To ensure that radiation therapy treatments are delivered safely, measurements are required with the medical radiation sources using radiation detectors (referred to as dosimeters). In modern radiation therapy clinics, there exists conditions where dosimetry is challenging as the complexity of modern treatment techniques can affect many dosimeter's accuracies. Specialised dosimeters with properties that allow them to remain accurate in such conditions are required for such quality assurance measurements.

The research conducted during my studies focused on one such type of specialised dosimeter, Fibre-coupled luminescent dosimeters. These dosimeters possess a wealth of desirable properties that make them well suited to many conditions in modern radiation therapy clinics. In the studies, theory and techniques were developed to optimise the accuracy of these dosimeters. Using these techniques, fibre-coupled luminescent dosimeters were applied for measurements in some challenging measurement conditions that occur in modern radiation therapy clinics. Results of the measurements demonstrated that fibre-coupled luminescent dosimeters were effective and accurate in the challenging conditions, providing a means for the accurate measurement of radiation dose in these conditions.