Honours Projects 2022

Applied Physics
Nanotechnology

The projects in this booklet are indicative – you are welcome to negotiate research topics with potential supervisors.

Contents

What is Honours?

The Honours course is an advanced research program following the completion of the BSc degree. Honours is a full-time course (48 credit points) conducted over 37 weeks and may be commenced in either Autumn or Spring session. The main component of the course is a research project conducted within one of the UTS research groups, or jointly with an external organisation. This will prepare you in aspects of planning and executing a research program to address a specific scientific or technological problem. In addition, two course-work subjects provide detailed knowledge in several areas of contemporary significance in physics and nanotechnology. The skills learnt in the Honours program are the appropriate starting point for a career in commercial research and development or for higher degree research-based qualifications.

How to apply

After discussing and deciding on a project with a supervisor, you will need to fill out two separate application forms.

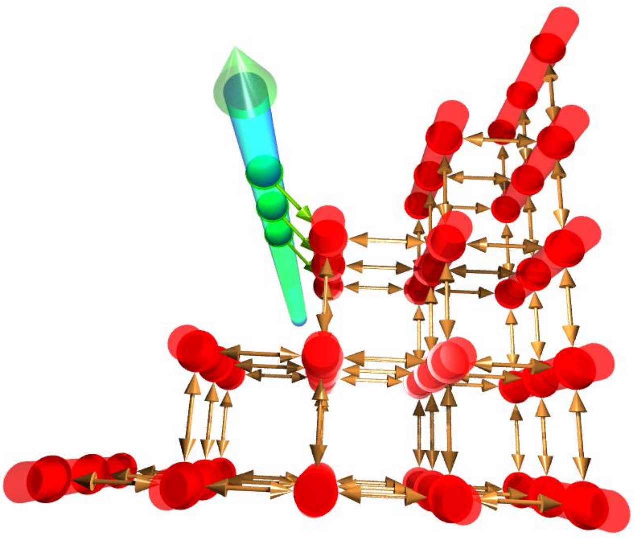
The first form is UTS Direct Application Form.
https://www.uts.edu.au/sites/default/files/2020-08/2021-General-Hons-FILLABLEv2.pdf
To apply for Honours in Applied Physics, use the course code C09035.
To apply for Honours in Nanotechnology, use the course code C09046.
Once completed, the form should be submitted to the Student Centre for processing.

Alternatively you can complete the online form via the My Student Portal, which can be accessed through the link below.
https://www.uts.edu.au/study/undergraduate/admission-requirements/application-process/direct-applications

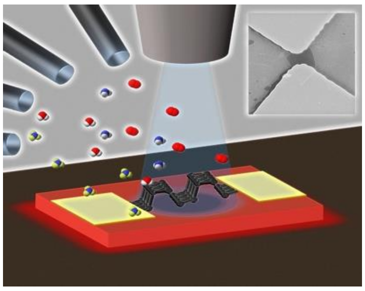
The second form is Faculty of Science Supplementary form with details of the Honours project you are interested in. This form is to be completed online via the My Student Portal.

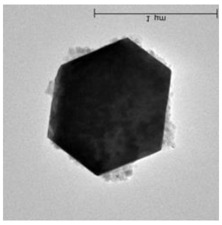
For more information about Honours please contact the Applied Physics or Nanotechnology Honours Coordinator A/Prof Cuong Ton-That, email: cuong.ton-that@uts.edu.au.

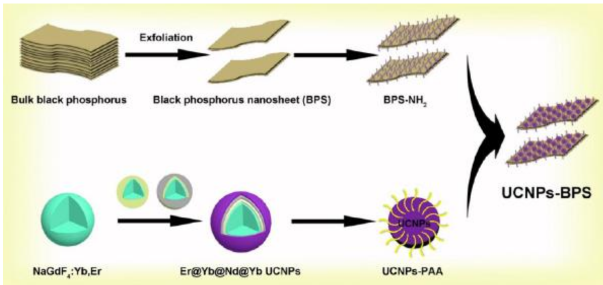
Projects

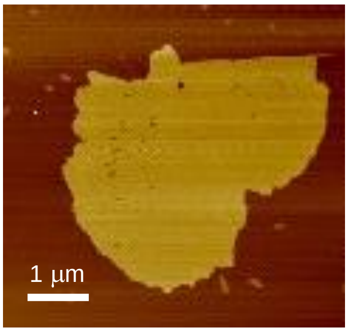
Project title	**Quantum walks**
Name of supervisor(s)	Alexander Solntsev
Email address	Alexander.Solntsev@uts.edu.au
Project description & aims (Include a relevant image here, 250 words max)	Quantum walks have emerged as a powerful paradigm with applications in quantum search. In 2021, the development of new experimental platforms in photonics enabled large scale quantum walk implementations with nonlinear interactions. The general theoretical framework has been established by our group. Now we aim to study this process in detail via numerical modelling, which will form the basis of this project. 
Techniques the student would be working with	Quantum optical modelling using existing tools developed in Matlab
Infrastructure and support required for project execution	All infrastructure available locally
Degree (Applied Physics, Nanotechnology or Biomedical Physics)	Applied Physics, Nanotechnology

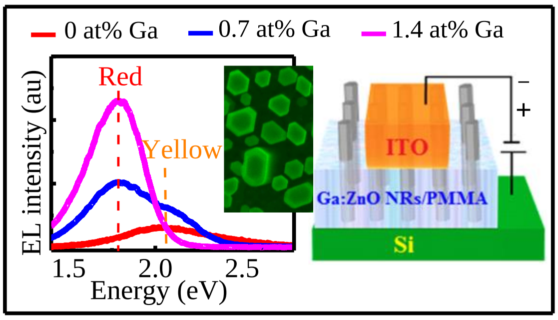
Project title	**Merging data science and time-domain astrophysics using the Australian Square Kilometre Array Pathfinder**
Name of supervisor(s)	Martin Bell
Email address	Martin.Bell@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	In this project, you will work with data collected from one of Australia's most state-of-the-art radio telescopes - the Australian Square Kilometre Array Pathfinder (ASKAP). The science goals of this large project are to detect transient and variable phenomena, for example, exploding stars and merging black holes. With this dataset, however, previous Honours students have gone on to detect entirely new phenomena i.e. plasma density ducts in the upper atmosphere (see https://www.youtube.com/watch?v=ymZEOihlIdU). The main focus of this project will be to study the time-variable signatures of supermassive black holes at the centres of active galaxies. You will specifically work on applying cutting-edge statistical and data science techniques to extract new insight from this time-series data and images. You will work with our software package to filter out the truly exciting astronomical signals from the noise. You will also work on developing new visualisation techniques to best display your results. A good proficiency in programming is desirable for this project. 
Techniques the student would be working with	Data science, computational astrophysics, time-domain statistics, time-series analysis, computer visualisation.
Infrastructure and support required for project execution	Linux workstation or log-in to an appropriate Linux environment.
Degree	Applied Physics

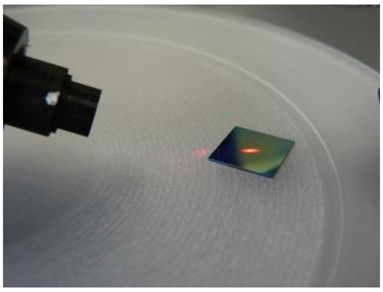
Title	**Fabrication of water desalination and antifouling membranes based on graphene and other atomically thin materials**
Name of supervisor(s)	A/Prof. Charlene Lobo, Dr. Donghan (Michael) Seo
Email address	Charlene.lobo@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	Plasma chemistry involves the dissociation of chemical precursors using reactive plasmas rather than heat (as in the more conventional techniques of chemical vapour deposition and molecular beam epitaxy). This project will focus on developing new precursor chemistries and techniques for fabrication and functionalization of graphene, MoS_2, and other two-dimensional materials. The functionalized materials will be printed on substrates using an inkjet printer, and employed as water desalination and antifouling membranes.  The honours student will have the opportunity to collaborate with researchers in Civil and Environmental Engineering, UTS, and with other students working on applications of the developed plasma chemistries (eg, in fabrication of photonic and optoelectronic devices).
Techniques the student would be working with	Inkjet printing, Chemical and photochemical synthesis, x-ray photoelectron and Raman spectroscopy, FTIR, UV-VIS, reactive plasma techniques, electron microscopy.
Infrastructure and support required for project execution	All facilities are in the MAU, Chemical Technologies Unit, and School of Civil and Environmental Engineering, UTS.
Degree	Applied Physics or Nanotechnology

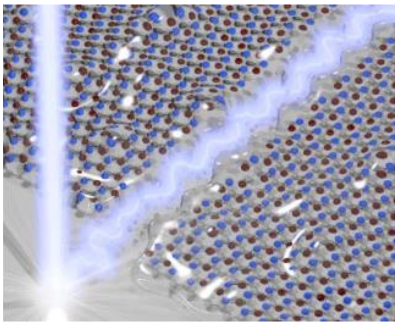
Project title	**Development of novel Er^{3+}/Yb^{3+} co-doped $KMgF_3$ perovskites for high temperature sensing applications**
Name of supervisor(s)	A/Prof. Charlene Lobo, Dr. Helen Xu
Email address	Charlene.lobo@uts.edu.au
Project description & aims (Include a relevant image here, 250 words max)	Non-contact methods of temperature sensing are of high interest in a diverse range of fields including deep-tissue bioimaging, nanomedicine[1], thermoelectrics[2] and power electronics. Optical temperature sensing methods are particularly promising because optical spectra exhibit many temperature-dependent changes, including predictable changes in the population of excited states, which vary according to the Boltzmann distribution. Upconversion nanoparticles (UCNPs) are unique optical temperature sensors containing lanthanide ions which are able to convert two or more low energy photons (typically in the red region of the visible spectrum) to higher wavelengths[3]. These higher energy photons can then be employed as cellular temperature sensors and optical probes of cellular processes[1] in applications such as fluorescent microscopy, deep-tissue bioimaging, and nanomedicine. This project will develop a hydrothermal method of synthesizing high brightness UCNP-doped $KMgF_3$ nanoparticles with tuneable photoluminescence (PL) emission in the red, green and UV regions of the EM spectrum. $KMgF_3$ is a fluoride perovskite with high thermal conductivity and excellent mechanical properties[4], as well as having very low phonon energies that make it highly suitable as a host lattice for lanthanide dopants in efficient upconversion materials. These UCNP-doped $KMgF_3$ phosphors are as bright as those based on sodium yttrium flouride[5] ($NaYF_4$), but have a different crystal structure, while also displaying a variety of shapes, from hexagonal to rod-like[6]. The hexagonal particles have typical edge lengths ranging from several hundred to 1000 nm (Fig. 1), while the rod-like particles have lengths of 1-5 µm and diameters of 50 nm.  **Fig. 1. Bright field TEM image of hexagonal UCNPs.**
Techniques the student would be working with	In combination with X-ray diffraction and EDS measurements, soft x-ray spectroscopy (XPS and NEXAFS) experiments at the Australian synchrotron will be used to analyze the structure and doping level of UCNP-doped $KMgF_3$ perovskite nanoparticles and thin films, and to correlate the dopant concentration and distribution in the perovskite lattice with the previously measured optical properties (photoluminescence, time-resolved photoluminescence).
Infrastructure and support required for project execution	See above
Degree	Applied Physics, Nanotechnology

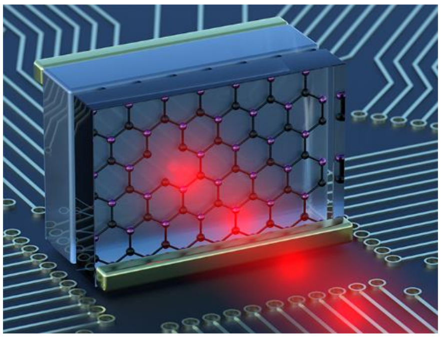
Project title	**Synthesis and biomedical applications of hybridized black phosphorus – upconversion nanoparticles**
Name of supervisor(s)	A/Prof. Charlene Lobo, Dr. Helen Xu
Email address	Charlene.lobo@uts.edu.au, XiaoxueHelen.Xu@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	Emerging two-dimensional (2D) materials such as hexagonal boron nitride (h-BN) and 2D black phosphorus (BP) have unique combinations of properties, including direct, tunable bandgaps (in the ultraviolet and infrared respectively) and biocompatability. Prior studies have demonstrated that unprotected BP nanoparticles undergo degradation in air and in aqueous buffer solutions, resulting in the formation of nontoxic phosphates and phosphonates[1-2]. This project will develop methods of fabricating and functionalizing stable BP nanoparticles for use as biomedical sensing probes and therapeutic agents. Nanoparticle synthesis will be conducted using conventional wet chemistry methods, and the synthesized nanoparticles will then be appropriately functionalized to yield well-dispersed nanoparticles in aqueous media. BP nanoparticles will then be hybridized with upconversion nanoparticles (UCNPs) to yield biocompatible imaging and contrast agents (see figure and references below).  References 1. Lee, H. U.; Park, S. Y.; Lee, S. C.; Choi, S.; Seo, S.; Kim, H.; Won, J.; Choi, K.; Kang, K. S.; Park, H. G.; Kim, H. S.; An, H. R.; Jeong, K. H.; Lee, Y. C.; Lee, J., Black Phosphorus (BP) Nanodots for Potential Biomedical Applications. *Small* **2016,** *12* (2), 214-219. 2. Shao, J. D.; Xie, H. H.; Huang, H.; Li, Z. B.; Sun, Z. B.; Xu, Y. H.; Xiao, Q. L.; Yu, X. F.; Zhao, Y. T.; Zhang, H.; Wang, H. Y.; Chu, P. K., Biodegradable black phosphorus-based nanospheres for in vivo photothermal cancer therapy. *Nat. Commun.* **2016,** *7*, 13.
Techniques the student would be working with	- To form stable BP nanoparticle suspensions in aqueous media - To hybridize the synthesized BP nanoparticles with upconversion nanoparticles (UCNPs) using previously developed methods. To demonstrate the suitability of the hybrid nanoparticles as optical markers for in vitro imaging of subcellular structures.
Infrastructure and support required for project execution	The project will be conducted using UTS facilities and equipment (Microstructural Analysis Unit, Chemical Technologies Laboratory, and Institute for Biomedical Devices)
Degree	Applied Physics, Nanotechnology

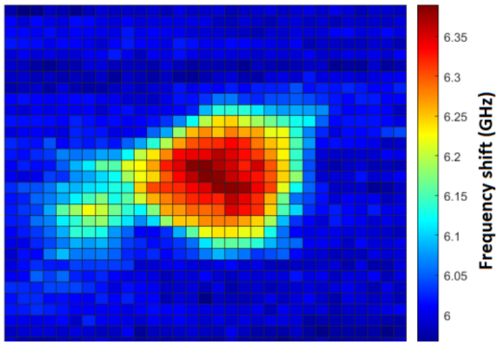
Project title	Synthesis of 2D oxide nanosheets and their optoelectronic properties
Name of supervisor(s)	A/Prof Cuong Ton-That, Dr Alexander Angeloski
Email address	Cuong.Ton-That@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	Two-dimensional (2D) oxides are attracting a great deal of attention due to their superior properties compared with three-dimensional (3D) bulk counterparts. Interest in semiconductor nanosheets is further stimulated by the possibility of forming lateral heterojunctions. We have recently demonstrated that nanosheets of gallium oxide (Ga_2O_3) and zin oxide (ZnO) are chemically stable in ambient conditions and exhibit tunable excitonic properties. This is an exciting discovery since the availability of nanosheets of these wide bandgap semiconductors opens the door for the development of novel 2D nanodevices. This project aims to synthesise few-atomic-layer thin oxide nanosheets using the liquid metal-based exfoliation method. The main challenge with the synthesis of oxide nanosheets is strong interlayer coupling compared with van der Waals crystals, which could introduce surface defects, compromising the optoelectronic properties. In this project methods will be developed to engineer the defect structure in nanosheets using plasma and heating treatments in oxidative or reductive environments. The project will make use of cutting edge nanocharacterisation tools, especially spatially correlated cathodoluminescence and photoluminescence spectroscopies. These techniques will be able to probe the optical and electronic properties of defects and impurities as well as to allow the mapping of their spatial distributions in individual nanosheets at nanometre resolution.  *AFM image of a 3-nm thick Ga_2O_3 nanosheet*
Techniques the student would be working with	Synthesis of nanosheets by exfoliation, plasma processing, thin film deposition, AFM, SEM, X-ray microanalysis, synchrotron-based X-ray spectroscopies, cathodoluminescence, Raman spectroscopy
Infrastructure and support required for project execution	All research facilities are currently available at UTS.
Degree	Nanotechnology or Applied Physics

Project title	**Doped Ga_2O_3 nanowires for nanodevice applications**
Name of supervisor(s)	A/Prof Cuong Ton-That, Prof Matthew Phillips, Dr David Rogers
Email address	Cuong.Ton-That@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	Nanowires and related structures play an important role in the design of future functional nanodevices. We have demonstrated that light emitting diodes (LEDs) made from Ga-doped ZnO nanowires exhibit a tuneable emission wavelength and superior electroluminescence properties (see Fig.). Because of their large surface area and short charge transport length, these nanostructures can be exploited in high speed devices and ultrahigh sensitivity sensor technologies. Ga_2O_3 has recently emerged as the most promising material for power electronics and photonic devices with enhanced capabilities. Of major significance is the case in which doped nanowires and thin films can be fabricated with various n-type and p-type dopants as well as impurity-induced complexes. Like other wide bandgap oxides, p-type doping has proved difficult; however, recent advances in nanowire fabrication have confirmed that could be achieved by incorporating zinc or nitrogen atoms. This project aims to grow and characterise Ga_2O_3 nanowires that are doped with acceptor dopants by in-situ incorporation and post-growth ion implantation. Detailed characterisation of individual nanowires and nanowire assemblies will establish relationships between growth, doping conditions, electronic structure and device performance.  *Electroluminescence spectra of nanowire LEDs and schematic of the device structure*
Techniques the student would be working with	Nanowire growth, plasma processing, ion implantation, thin film deposition, electron microscopy, X-ray microanalysis, synchrotron-based X-ray spectroscopies, cathodoluminescence, photoluminescence, Raman spectroscopy
Infrastructure and support required for project execution	This is a joint project with our industrial partner, Nanovation (*www.nanovation.com*). The project will employ nanowire growth and characterisation facilities in the MAU.
Degree	Nanotechnology or Applied Physics

Project title	**Machine learning for parameter extraction and performance prediction of optical systems**
Name of supervisor(s)	Matthew Arnold and Angus Gentle
Email address	Matthew.Arnold-1@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	Machine learning is being extensively applied by both manufacturers and service providers (Facebook, Google, banks etc). In science there are many problems that would benefit from machine learning techniques. In this project you will investigate the application of machine learning to the optical properties of materials and/or devices, to extract key physical parameters from data and/or explore and optimize performance.  
Techniques the student would be working with	Machine learning; Optical simulation; Hacking together existing Matlab or Python libraries;
Infrastructure and support required for project execution	All infrastructure available locally – potential for access to National Computing Infrastructure.
Degree	Applied Physics

Title	**Direct-write nanofabrication using electron and ion beams**
Name of supervisor(s)	Milos Toth and Igor Aharanovic
Email address	milos.toth@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	The discovery of graphene, 15 years ago, kicked off the exponentially growing research field of 2D materials. Today a plethora of these materials is available with intriguing properties that are appealing for a broad range of applications in fields such as catalysis, nanoelectronics and quantum photonics. However, many 2D materials need precise shaping and functionalisation in order to be deployed in applications or integrated in devices, and this often can't be achieved using conventional material processing techniques. It can, however, be achieved using so-called "electron and ion beam chemistry" methods in which a nano-scale beam is used to drive chemical reactions that give rise to material growth, etching or functionalization. The techniques are sometimes described as a form nano scale 3D printing.  The student will develop new variants of these techniques designed to precisely etch and/or functionalize 2D materials such as graphene, hexagonal boron nitride and transition metal dichalcogenides. The project has the potential to be the foundation for a subsequent PhD research project. Examples of recent work done by the group in this field can be found in Ref [1-5]. [1] Froch et al., Nature Communications 11 (2020) 5039 [2] Shandilya et al., Nano Letters 19 (2019) 1343 [3] Bishop et al., ACS Nano 12 (2018) 2873 [4] Kim et al., Nature Communications 9 (2018) 2623 [5] Walia et al., Advanced Materials 29 (2017) 73
Techniques the student would be working with	Electron and ion beam microscopes, and associated material characterisation techniques.
Infrastructure and support required for project execution	The required infrastructure is available in the microstructural analysis unit (MAU).
Degree	Applied Physics or Nanotechnology

Title	**Solid state quantum photonics**
Name of supervisor(s)	Milos Toth and Igor Aharanovic
Email address	milos.toth@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	Technologies that encode information in individual photons underpin future generation quantum computing and unbreakable quantum cryptography technologies [1]. This project is focused on the fabrication and testing (nanophotonics) of new materials and devices for on-chip quantum photonics. The student will have the option to choose from a range of sub-projects focused on fabrication or processing and characterisation of nanophotonic materials and circuits. The work will be done in a dynamic UTS research group comprised of PhD students, postdocs and academic staff who collaborate on projects with the broad common aim of advancing the field of solid state quantum photonics. The project has the potential to be the foundation for a subsequent PhD research project. Roadmaps and examples of recent work done by the group can be found in Ref [1-5]. [1] Aharonovich et al., Nature Photonics 10 (2016) 631 [2] Aharonovich & Toth, Science 358 (2017) 170 [3] Tran et al., Science Advances 5 (2019) eaav9180 [4] Gottscholl et al., Nature Materials 19 (2020) 540 [5] Froch et al., Nano Letters 20 (2020) 2784 
Techniques the student would be working with	Nanofabrication techniques and scanning confocal photoluminescence characterisation techniques.
Infrastructure and support required for project execution	The required infrastructure is available in the microstructural analysis unit (MAU).
Degree	Applied Physics or Nanotechnology

Project title	Rapid image acquisition by compressive Brillouin imaging
Name of supervisor(s)	Dr Irina Kabakova, Dr Fan Wang (FEIT)
Email address	Irina.kabakova@uts.edu.au
Project description & aims (Include a relevant image here, 250 words max)	**Brillouin imaging** is an emerging field of research that promises to deliver non-contact and label-free mechanical imaging at the microscale. The downside of this technology is long acquisition times, which for 3D samples can reach several hours.  Figure 1. Stiffness map of neuronal cell measured by a Brillouin microscope. Higher frequency shifts (red colour) coincide with nucleus area, indicating the stiffest component within the cell. In this project you will explore a new transformative approach to data acquisition based on **compressive imaging**. This method is based on saving the acquisition time by under-sampling the measurements and reconstructing the full image information based on supervised machine learning algorithms. **The hero experiments report improvement in speed by 64 folds!** Interestingly, compressive imaging has never been combined with Brillouin imaging, thus presenting a tremendous potential to improve the latter technology and transform it into fast imaging modality. You will work across 2 optical labs, supervised by Dr Kabakova (Faculty of Science) and by Dr Wang (Faculty of Engineering and IT). This will give you access to the most forefront imaging technologies of today and the wealth of experience in optimising optical imaging systems, signal processing and optical system design. The ultimate goal of this project is to explore combination of Brillouin microscopy with compressive imaging approach, in order to achieve significant improvement in the imaging speed.
Techniques the student would be working with	Brillouin microscopy, compressive imaging, ghost imaging, signal processing
Infrastructure and support required for project execution	Infrastructure: (1) Brillouin imaging system (2) Spatial light modulations system for compressive imaging Labs: (1) Brillouin Imaging Lab (2) Fluorescent imaging and characterization of Nanomaterials Lab (https://www.fanwanglab.com/)
Degree	Applied Physics (This project is suitable for students with a Biomedical Physics background.)

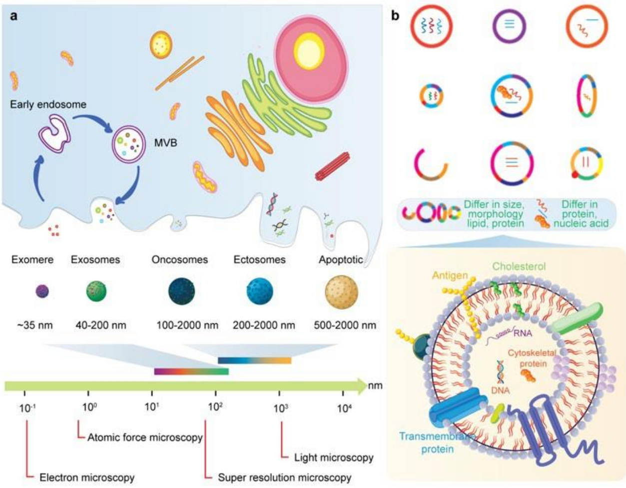
Project title	**Rapid milk protein detection**
Name of supervisor(s)	Jiajia Zhou
Email address	Jiajia.zhou@uts.edu.au
Project description & aims (Include a relevant image here, 250 words max)	This project aims to develop a novel device, comprising advanced spectral physics, nanoparticle conjugation chemistry, immunoassay technology and mobile phone detection, for quantification of milk protein variants. Milk quality is central to dairying and variants of proteins in milk affect its market value. No current milk protein detection technologies are readily applied in milk production quality control. This project aims to produce a device that can be used by milk producers and farms to profile protein variants with high sensitivity in a single test in 15 mins and screen unwanted protein contamination. The platform also has great potential for detecting other complex and low content analytes. It builds on innovations in nanoparticles and recent industry collaboration.
Techniques the student would be working with	Wet-chemistry synthesis nanotechnology; Transmission electron microscope (TEM); Dynamic Light Scattering (DLS) for measuring particle size; Zeta Potential measurement; Fluorescence spectroscopy; Polymer coating and bioconjugation chemistry; Lateral flow assay; Mobile phone imaging detection
Infrastructure and support required for project execution	Transmission electron microscope at MAU Proposed built confocal microscopies and spectrometers at IBMD DLS and Zeta potential measurement instrumentation at IBMD Strip preparation instrumentations at IBMD Other chemistry and physical lab based infrastructures
Degree	Applied Physics (This project is suitable for students with a Biomedical Physics background.)

<table>
<tr><td>Title</td><td>Design and fabrication of microfluidic devices for profiling extracellular vesicle heterogeneity</td></tr>
<tr><td>Name of supervisor(s)</td><td>Dr Gungun Lin</td></tr>
<tr><td>Email address</td><td>Gungun.lin@uts.edu.au</td></tr>
<tr><td>Project description & aims

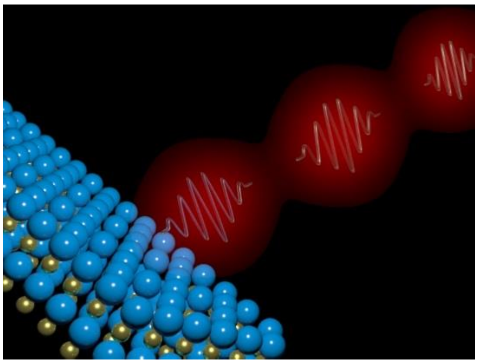
(Include relevant images here, 250 words max)</td><td>

Extracellular vesicles (EVs) are membrane-bound vesicles secreted by most cell types and exist in virtually all bodily fluids. They carry on a wealth of proteomic and genetic information including proteins, lipids, miRNAs, mRNA, non-coding RNA and other molecules from parental cells. In particular, accumulating evidence indicated that cancer- derived small EVs are unique and reflect heterogeneous biological changes associated with growing tumours. Accumulating evidence indicates that the promising clinical use of EVs reside in early stage tumour diagnosis. Small EVs has been found to act as early diagnostic markers of breast, colon, prostate, pancreatic, ovarian, colorectal cancers and glioblastoma. Increasing evidence shows that within populations of EVs, their biogenesis, physical characteristics (e.g. size, density, morphology) and cargos (e.g. protein, lipid content, nucleic acids) may vary substantially, which accordingly change their biological properties. To fully exploit the potential of EVs, it requires qualified methods to profile EV heterogeneity.

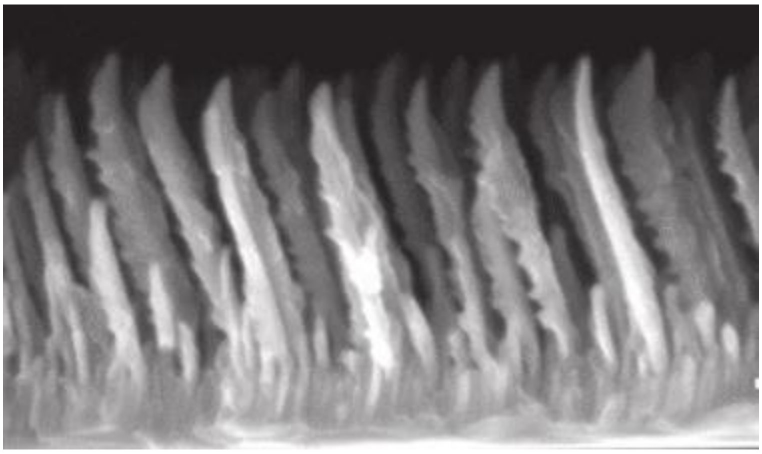
The project aims to design and fabricate microfluidic chips that facilitate the streamlined magnetic isolation and downstream optical analysis of extracellular vesicles. Outcome of this project will lead to new technology for EV analysis, new knowledge of EV heterogeneity and their potential indications for disease diagnosis.

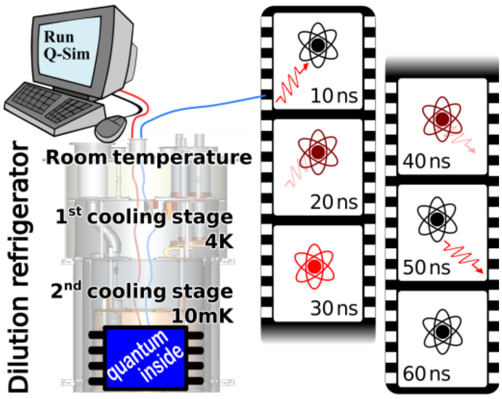


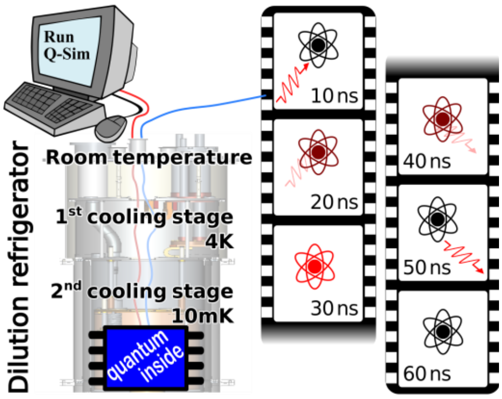
</td></tr>
<tr><td>Techniques the student would be working with</td><td>Microfabrication techniques including laser writing to pattern microfluidic channels, CAD design, lithography etc.
Bio-conjugation techniques, dye staining
Microscopic imaging</td></tr>
<tr><td>Infrastructure and support required for project execution</td><td>Biochemistry lab in building 7, level 5
Advanced microfabrication lab (funded by ARC LIEF)</td></tr>
<tr><td>Degree</td><td>Applied Physics
(This project is suitable for students with a Biomedical Physics background.)</td></tr>
</table>

Project title	**Indistinguishable photons from hBN point defects**
Name of supervisor(s)	Mehran Kianinia, Igor Aharonovich
Email address	Mehran.kianinia@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	Consecutive photons with identical wave packets (indistinguishable) are the main requirement for many applications in the field of quantum information technology. Two photon interference experiments based on Michelson interferometer will reveal the quality of the photons emitted by a single photon source. In this project the measurement will be done on single photon emitters in hBN to measure the coherence time of these sources at cryogenic temperatures. 
Techniques the student would be working with	Cryogenic micro photoluminescence, High vacuum system, Quantum Interferometer
Infrastructure and support required for project execution	All experimental setup are available at UTS or will be setup during the project.
Degree (Applied Physics or Nanotechnology)	Applied Physics

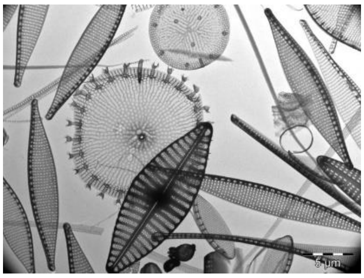
Title	**Optimization of rotating plasmonic edge modes**
Name of supervisor(s)	A/Prof Matthew Arnold and Prof Michael Cortie
Email address	Matthew.Arnold-1@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	Strong electromagnetic resonances are possible when light interacts with a metal or dielectric nanostructure. These oscillations are tuned to specific wavelengths of light, specific materials, and specific shapes of nanostructure. We have found that a very strong rotating 'edge mode' of surface plasmon is possible under some conditions. In the present project we want to see whether we can design a geometry that optimizes the intensity of these, and other, unusual modes of oscillation. The unusual symmetries of these non-dipolar modes may have applications in optical sensor devices or plasmonic logic circuits. The project will make use of the open source DDSCAT software to compute the optical properties under various scenarios of illumination and target geometry. The resulting fields can be rendered and visualized using Cortie's custom software, or you can write your own code. You will also have to write your own code to generate sequences of 'super-ellipse' shapes, as well as the scripts to set up and manage the calculations on a remote computing cluster.
Techniques the student would be working with	Scientific computing and programming. Latter could be in combinations of Python, C++, Matlab/Octave, FORTRAN, Pascal or something else. You will work on Linux systems and learn how to write bash scripts and run parallel jobs. You will probably develop advanced visualization (computer graphics) of your own to make exciting images and movies of the electromagnetic resonances. This project can be run without much face-to-face being required.
Infrastructure and support required for project execution	DDSCAT is open source software. Python and the other computer languages mentioned (except for MatLab) are free but UTS has licenses for MatLab. Cortie's visualization code is freely available for Linux and Windows. Programs can be run on the UTS Linux computer cluster, or on specific research machines that are available.
Degree	Applied Physics or Nanotechnology

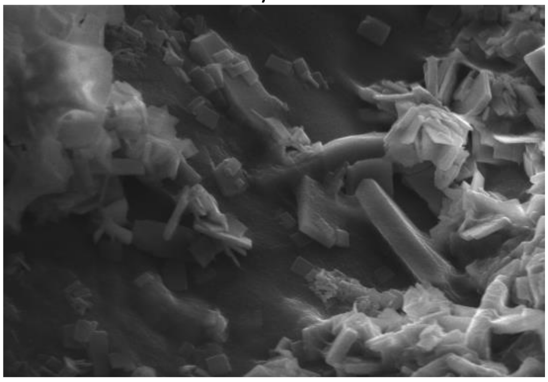
Project title	**High-performance optically-polarizing metallic nanostructures**
Name of supervisor(s)	Matthew Arnold
Email address	Matthew.Arnold-1@uts.edu.au
Project description & aims (Include a relevant image here, 250 words max)	Recently we discovered a new way to produce highly aligned metallic nanostructures and have demonstrated that these polarize light (https://doi.org/10.1088/1361-6528/aaa639). The aim of this project is to manipulate the growth to optimize the polarization of these structures, and ideally control the direction of polarization either in-plane and/or in the growth direction. The resulting polarizers have applications in advanced imaging sensors and instrumentation. 
Techniques the student would be working with	Sputtering and/or e-beam deposition; scanning electron microscopy; ellipsometry and reflectometry; thin film design software.
Infrastructure and support required for project execution	All equipment is available at UTS
Degree (Applied Physics, Nanotechnology or Biomedical Physics)	Applied Physics

Project title	**Simulating physics with small-scale quantum computing devices**
Name of supervisor(s)	Nathan Langford and JP Dehollain
Email address	nathan.langford@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	***Moore's law is dead, because classical digital electronics has hit the quantum regime!*** Quantum computing is making headlines globally for a new computer revolution, with major research programs at the world's largest IT tech giants (Google, IBM, Microsoft, etc) and circuit QED (superconducting quantum electronics) is a leading platform in the race [*Devoret & Schoelkopf, Science (2013)*]. The first, most important application of quantum computers will be to perform digital quantum simulations (see Fig.) of complex systems [*Cirac & Zoller, Nat Phys (2012)*]. Here, you will study small-scale circuit QED simulators [*Langford et al, Nat Comms (2017)*], to develop hardware-level routines for industrial quantum computers of the future.  **Figure 1.** A *digital quantum simulator* can realise complex dynamics by observing it in discrete interaction steps, like the frames in a stop-motion animation. Sydney is a world-leading quantum computing hub, with both research centres and industry groups. **If you want a taste of a research or industry career in this exciting field, join the Circuit Quantum Science (CirQuS) research laboratory for Honours.** You will work in a new, international group of PhD students, postdocs and academics with a state-of-the-art circuit QED lab for cryogenic microwave experiments covering all necessary high-tech quantum science & engineering skills. Depending on taste, a range of projects available include: **design of millikelvin quantum amplifiers** (used across top solid-state quantum computing platforms); **superconducting thin-film fabrication and characterisation**; **superconducting qubit design and characterisation**; **quantum system tomography; and quantum experiment simulation**.
Techniques the student would be working with	Fabrication (sputtering, reactive-ion etching, lithography, etc); Modelling (EM field solvers, quantum dynamics, etc); Cryogenics (incl. dilution refrigeration); Measurement (microwave & RF analysis, etc); Hardware & experiment design, assembly and interfacing; and more…
Infrastructure and support required for project execution	Fabrication will be carried out either locally or at the state-of-the-art Research & Prototype Foundtry at USyd. The CirQuS group and Millikelvin Quantum Science lab will provide all other infrastructure.
Degree	Applied Physics or Nanotechnology

Project title	**Simulating complex physical systems for advanced quantum processors**
Name of supervisor(s)	Nathan Langford and JP Dehollain
Email address	nathan.langford@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	***Quantum computing is leading a new information revolution for the 21st century, and the race is on to find the first applications for quantum processors that even the largest supercomputers cannot run and complete.*** The most promising such applications involve simulating the behaviour of complex quantum systems, which can be exponentially difficult for classical computers. These tasks will ultimately have important applications in areas like drug and vaccine design, high-tech materials development, and efficient energy generation. The Circuit Quantum Science (CirQuS) research laboratory led by A/Prof Nathan Langford and Dr JP Dehollain aims to study how to maximise the performance of these quantum simulators using superconducting quantum electronics.  **Figure 1.** A *digital quantum simulator* can realise complex dynamics by observing it in discrete interaction steps, like the frames in a stop-motion animation. ***In this project, you will use and develop a state-of-the-art software package created in the CirQuS group to study the quantum dynamics of custom quantum processors for advanced quantum simulations.*** A range of projects is available studying exotic physics like quantum phase transitions and quantum chaos in condensed matter physics and quantum chemistry. In your chosen topic, you will design a small-scale quantum device and experimental measurements that can be realised in superconducting devices in the CirQuS lab.
Techniques the student would be working with	You will develop and use an advanced numerical software package written in Python, one of the largest, fastest growing programming languages in the world. You will learn industry standard software development techniques such as test-driven development, and learn how to use high-performance computing facilities. You will learn advanced numerical methods for simulating quantum dynamics and will learn how to design superconducting quantum devices.
Infrastructure and support required for project execution	As appropriate, you will run your numerical simulations on a high-performance simulation workstation in CirQuS's Millikelvin Quantum Science lab, and UTS's high-performance computing facility (iHPC).
Degree	Applied Physics or Nanotechnology

Project title	**Advanced quantum tomography for quantum device characterisation**
Name of supervisor(s)	Nathan Langford, JP Dehollain and Chris Ferrie
Email address	nathan.langford@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	***As major industry and academic research efforts race to build ever larger quantum computers, accurate characterisation of quantum gates, states and measurements is a vital link in the development chain.*** During his PhD, A/Prof Langford developed a flexible suite of matlab software for carrying out maximum likelihood tomography on quantum states and processes. This software is still used in leading experimental quantum science labs across the world. In this project, you will work with members of the Circuit Quantum Science (CirQuS) research group to build a new, more advanced and flexible quantum tomography software package for Python, one of the world's most in-demand programming languages. The new software package will exploit and build on cutting-edge elements of the CirQuS group's existing software tools, and will be optimised for versatile use across a wide range of experimental platforms, and compatible with a range of state-of-the-art theoretical tomography techniques, such as maximum likelihood tomography and Bayesian estimation. You will then use the software package to numerically benchmark the performance of a range of cutting-edge theoretical approaches to quantum tomography, considering real-world experimental performance, and with a view to testing the protocols experimentally on cutting-edge quantum devices. In this project, you will learn industry standard software development techniques to build a modular, flexible software package. By the end of the project, the aim is to release the new software as an open-source package as part of the CirQuS group's QuanGuru software suite. This project is ideally suited for a student with a keen interest in coding.
Techniques the student would be working with	In this project, you will learn how to analyse advanced quantum experimental data and use and implement a range of state-of-the-art techniques in quantum tomography. You will learn important industry-relevant software development skills, like test-driven development.
Infrastructure and support required for project execution	For the benchmarking stage of the project, if required, you will run your numerical simulations on a high-performance simulation workstation in CirQuS's Millikelvin Quantum Science lab, and UTS's high-performance computing facility (iHPC).
Degree	Applied Physics or Nanotechnology

Title	**Enhancing the physical properties of medical implants with biodegradable, natural materials**
Name of supervisor(s)	Dr Annette Dowd and Prof Besim Ben-Nissan
Email address	Annette.Dowd@uts.edu.au
Project description & aims (Include relevant images here, 250 words max)	Biodegradable polymers such as poly L lactic acid are cheaply made from biomass. They can be used as implant coatings or scaffolding, however they tend to be brittle and fragile because of poor crystallisation. The mechanical properties can be improved with microscopic inorganic additives. Artificial SiO_2 mesoporous structures have previously been shown to be useful for improving wear resistance in polymer coatings when used as an additive. In addition these structures have been shown to act as a platform for storage and delayed release of drugs. A composite material combining both functionalities would play an important role in tissue and bone repair implants, providing a biocompatible scaffold for bone regeneration and simultaneously slowly releasing antibiotics. Diatoms are abundant algae that create intricately microstructured SiO_2 cell walls, which are nontoxic. The cell walls, as seen in the figure below, are mesoporous structures. In this project the student will investigate the potential dual role of diatoms in medical implant polymers: as a reinforcement agent and as a controlled drug release system.  Mixed marine diatoms, P. Ajani, C3 UTS, 2017. 5 micron scale bar.
Techniques the student would be working with	Scanning Electron Microscopy, X-Ray Diffraction Differential scanning calorimetry/Thermogravimetric analysis, Fourier transform infrared spectroscopy Cell culture
Infrastructure and support required for project execution	MAU, Chemistry and SOLS facilities.
Degree	Applied Physics (This project is suitable for students with a Biomedical Physics background.)

Project title	Microstructural Characterisation of Coral Skeletons
Name of supervisor(s)	Dr Annette Dowd, Dr Emma Camp and Prof Michael Cortie
Email address	Annette.Dowd@uts.edu.au
Project description & aims (250 words max, summary written for prospective students)	The impact of climate change on coral reef health is a subject of intense study however the focus has been on coral polyps (soft tissue). The hard coral skeleton, a biomineral known as aragonite, has been relatively neglected. There is preliminary evidence that the skeletal microstructure of a few coral species depends on environmental conditions although there is still little understanding of the underlying physical differences such as defects in the aragonite crystal structure. New characterisation techniques of coral variation will give marine biologists powerful tools for monitoring environmental impacts on coral reef growth. Moreover, variations in microstructure can have real implications for robustness of the coral reef. In this project the student will conduct a study the microstructure of the skeletal aragonite with several complementary spectroscopic and mapping techniques (see below). This will include studying recently acquired synchrotron data which showed anomalous low temperature behaviour of the biomineral. Specimens include several coral species collected from diverse environments by members of C3.  *Figure 1. SEM micrograph showing range of crystal morphologies in Seychelles coral biomineral skeleton by research student Anne Wright*
Techniques the student would be working with	X-ray diffraction (including synchrotron data), SEM-EDS, FTIR/Raman spectroscopy, biomineral specimen preparation
Infrastructure and support required for project execution	See techniques – all infrastructure is already available and in-place and specimen preparation techniques have been developed at UTS.
Degree	Applied Physics (This project is suitable for students with a Biomedical Physics background.)