Optical Science Centre – Microphotonics 2021 Physics Honours Projects

1. Modelling single cells

Supervisor: Prof. Damien Hicks

Contact: dghicks@swin.edu.au

Project Description: Projects are available to model the response of immune cells to cell death signals. This involves using Bayesian methods to infer molecular networks from single-cell data. The student will learn how to build simple models of biochemical processes, infer model parameters from data, and use the results to answer biomedical questions. Prospective students are expected to have a background in physics, be comfortable programming, and have an interest in working at the boundary between physics, statistical/machine learning and living systems.

2. Satellite ocean polariscopy

Supervisors: Dr S. H. Ng (data processing), Prof S. Juodkazis (polariscopy), Dr A. Codoreanu (high performance computing & Earth observation), Prof A. Duffy (high performance computing)

Contact: soonhockng@swin.edu.au

Project description: Observations of ocean waves, their orientation, and height play an important role in the study and modelling of the climate. This information can be used to track the effects of climate change or help with the prediction of severe weather events. This project will investigate adapting a polariscopy method developed for use at the Australian Synchrotron to satellite applications. The method involves taking transmission measurements at 4 different linear polarisations (0°, 45°, 90°, and 135°) and is able to determine orientation of a sample, even when the structures are far below the diffraction limit.

The project will involve processing of currently available altimeter, synthetic aperture radar, and scatterometer satellite data to determine the feasibility of applying this technique to Earth observation and in reflection. It will seek to understand how the low-level data can be processed to extract the required polarisations and if not, how this data can still be utilised. There is the possibility of experimentally validating the method in reflection (subject to easing of restrictions), and future prospects include design and implementation of an instrument for validation in space.

3. Micro-optics for astro-photonics (@ Optical and Astronomy Centers)

Supervisors: Dr V. Anand (optical design), Prof K. Glazebrook (astronomy devices), Dr S-H Ng (nanofabrication), Prof S. Juodkazis and T. Katkus (fs laser fab)
Contact: sjuodkazis@swin.edu.au

Project description: This project is set up to establish the modeling of micro-optical elements for observational astronomy. Coupling of light from the sky into a fiber-optical element for spectral measurement has to meet stringent constraints for angular light acceptance, collection, high efficiency of light transmission, and simplicity/robustness of design for fabrication of micro-optical elements.

In this 1 year project, we will establish the design and optimize for the collection of light by 5-m-diameter lens into an optical fiber with a 0.5 mm core. What micro-optical element(s) made out of pure silica or sapphire (for high UV-IR transmission) is(are) required will be established. The project will prepare a design that is amenable by femtosecond laser fabrication (3D printing). The optical design or laser fabrication can have the main focus of the project.

4. Silicon nanoparticle fabrication using femtosecond pulsed laser ablation for deep tissue biolabelling

Supervisors: Associate Professor James W. M. Chon, Professor Saulius Juodkazis
Contact: jchon@swin.edu.au

Project description: Silicon nanoparticles have the ability to pick up magnetic field of visible and near-infrared light. This provides wealth of choice for oscillation modes in the visible and NIR range, which makes silicon nanoparticle attractive for biomedical imaging contrast. It is proposed that these nanoparticles can penetrate deep into tissue for brain and neural network imaging. Recently fabrication methods of silicon nanoparticles have greatly improved with femtosecond pulsed laser irradiation. In this project, we use amplified femtosecond pulsed laser to synthesise silicon magnetic nanoantennas and characterise them using multiphoton microscopy and spectroscopic technique. We plan to fabricate monodisperse silicon nanoparticles with controlled sizes from 50 -250 nm in diameters, with high throughput. Students are expected learn nonlinear optics, plasmonics, numerical simulation methods and spectroscopic techniques.

5. Acoustic frequency comb generation

Supervisor: Dr Ivan Maksymov
Contact: imaksymov@swin.edu.au

Project description: This project is an excellent opportunity for a student interested in theoretical and numerical modelling to work on the emergent and interdisciplinary topic of acoustic frequency combs. Similar to an optical frequency comb, an acoustic frequency comb is a spectrum consisting of a series of discrete, equally spaced elements that have a well-defined phase relationship between each other. Acoustic combs will benefit marine sciences, underwater positioning and navigation, also opening up novel opportunities for industries using unique properties of liquids, droplets and bubbles (e.g. biomedicine). In this project, we will investigate nonlinear physical phenomena in acoustic, microfluidic and optical systems by developing and using computational codes based on finite-difference methods (FDTD) and other numerical techniques. There would also be opportunities to be involved into experimental research.

Further reading:

PhysicsWorld magazine, https://physicsworld.com/a/acoustic-frequency-comb-measures-up/;

YouTube, "Why you need an optical frequency comb",
https://www.youtube.com/watch?v=graq4kpd8-A

FDTD method, https://meep.readthedocs.io/en/latest/Introduction/

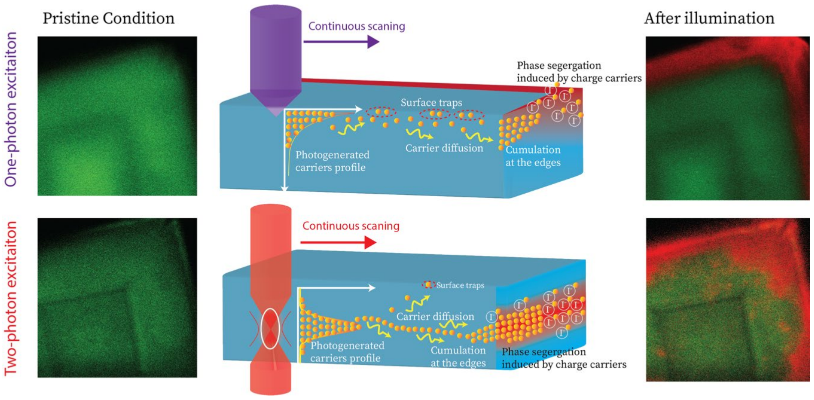
6. Laser illumination induced phase segregation and reversibility in mixed halide perovskite

Supervisor: Dr Xiaoming Wen, Contact: xwen@swin.edu.au, 9214 8625

Organic-inorganic hybrid perovskites have attracted considerable research interest due to the enormous potential for highly efficient optoelectronic applications such as solar cells, light-emitting diodes (LEDs) and photodetectors. Mixed-halide perovskites are very promising materials for optoelectronics due to their tunable band gap in the entire visible region. A challenge remains, however, in the photoinduced phase segregation, narrowing the band gap of mixed-halide perovskites under illumination thus restricting applications. In this project, combining time-resolved photoluminescence (PL), fluorescence lifetime imaging microscopy (FLIM) and micro-PL spectroscopy and other optical techniques, you will investigate the light illumination induced phase segregation. This study will reveal the physical mechanism of phase segregation in mixed perovskites, providing the details of correlation between the conditions of illumination and sample fabrication with the phase segregation and recovery.

Further Reading:

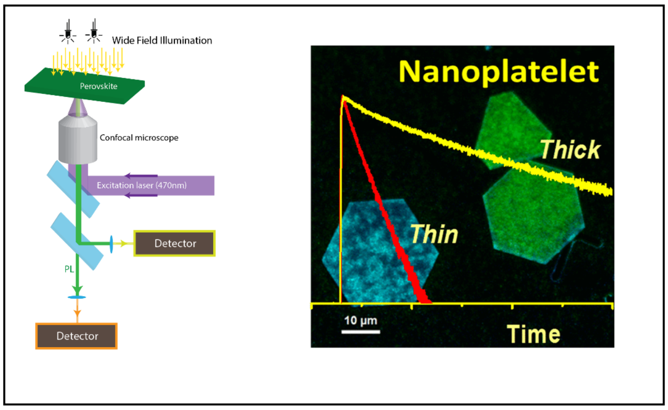
1. Illumination-Induced Halide Segregation in Gradient Bandgap Mixed-Halide Perovskite Nanoplatelets, **Advanced Optical Materials**, 1801107 (2018) **(IF 7.43**)
2. Dynamic study of the light soaking effect on perovskite solar cells by in-situ photoluminescence microscopy, **Nano Energy** 46, 356-364 (2018) **(IF 15.548**)
3. Tracking Dynamic Phase Segregation in Mixed-Halide Perovskite Single Crystals under Two-Photon Scanning Laser Illumination, **Small Methods**, 2019, 1900273



7. Investigation of photogenerated carrier dynamics by time-domain and frequency-domain spectroscopic techniques.

Supervisor: Dr Xiaoming Wen, Dr. Weijian Chen, Contact: xwen@swin.edu.au, 9214 8625

Time-resolved photoluminescence (PL) has been widely applied for investigating the photogenerated carrier dynamics, providing invaluable information of charge carrier recombination, photon-phonon scattering, carrier transfer and extraction; and intimately correlated with their applications of photovoltaics, photocatalysis, PED and lasing etc. photonics, therefore critically important for renewable energy and LED/display industries. Basically, time-resolved PL can be performed in the time domain and in the frequency domain. In this project, the carrier dynamics of hybrid perovskite will be investigated using both time domain and in the frequency domain techniques. Each will provide useful information for the physical understanding of photogenerated charge carriers in perovskites.



Further Reading:

1. Zheng et al. Triggering the Passivation Effect of Potassium Doping in Mixed-Cation Mixed-Halide Perovskite by Light Illumination, **Advanced Energy Materials**, 1901016 (2019) **(IF 24.884)**
2. Hole Transport Layer Free Inorganic $CsPbIBr_2$ Perovskite Solar Cell by Dual Source Thermal Evaporation, **Advanced Energy Materials** 6 (7), 1502202 (2017) **(IF 24.884)**
3. Acoustic-optical phonon up-conversion and hot-phonon bottleneck in lead-halide perovskites,
   Nature communications 8, 14120 (2017) **(IF 11.88)**

8. Fabrication 3D high-resolution multi-color pattern in Mixed-Halide Perovskite single crystal using Direct Femtosecond Laser Writing

Supervisor: Dr Xiaoming Wen, Prof. Baohua Jia, Contact: xwen@swin.edu.au, 9214 8625

Lead halide perovskites are widely applied in not only photovoltaics but also on-chip light sources and photon detection. Femtosecond (fs) laser fabrication is used to be demonstrated significant advantages of high spatial resolution, low surround damage and high processing efficiency. In this project, fs laser is used for directly fabricate 3-dimension high resolution, multiple color pattern in mixed-halide perovskite single crystal. The mechanism of the fs laser writing and controlling will be investigated for various perovskite material and their nanostructures.

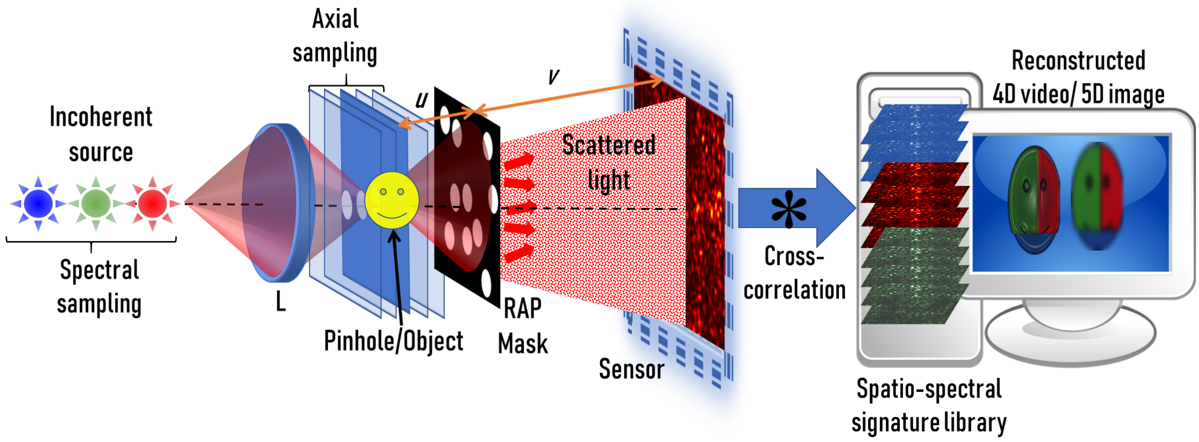
Further Reading:

1. Spatially Modulating the Fluorescence Color of Mixed-Halide Perovskite Nanoplatelets through Direct Femtosecond Laser Writing, **ACS Appl. Mater. Interfaces (**2019) **(IF8.456)**

2. Chemical dopant engineering in hole transport layers for efficient perovskite solar cells: insight into the interfacial recombination, **ACS Nano** 12 (2018), 10452 (**IF13.903**)

9. Lensless, Interferenceless, Motionless, Non-Scanning, High Field of View, Multidimensional Imaging Technology

Supervisor: Dr Vijay Anand, Contact: vanand@swin.edu.au



Techniques/Skills acquired in this project

Optical Engineering, Computational Optical techniques, Automation and Data Acquisition, Lithography and Mask fabrication

Application

Fluorescence microscopy, Astronomical telescope, Imaging through scattering layers, Spectrophotometry

Possible upgradation

Deep learning modules, Mobile computation, Metalens fabrication