Australian and New Zealand Institutes of Physics

43rd Annual Condensed Matter and Materials Meeting

Charles Sturt University, Wagga Wagga, NSW
5th February – 8th February, 2019

CONFERENCE HANDBOOK

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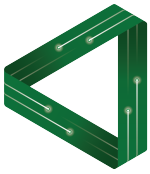

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Conference Program

Tue	Wed	Thu	Fri
	7:30 BREAKFAST	7:30 BREAKFAST	7:30 BREAKFAST
	8:45 CONF. OPENING	8:45 Jennifer MacLeod	8:45 Sahinur Reja
	9:00 Susan Coppersmith		9:00 David Cavanagh
		9:15 Tilo Söhnel	9:15 Philip Brydon
	9:30 Samuel Bladwell	9:30 Junwei Li	
	9:45 David Broadway	9:45 Alexey Pan	9:45 David Jamieson
	10:00 Chris McNeil		10:00 Alex Hamilton
	10:15 Sean Injac	10:15 CONF. PHOTO	10:15 Jesper Levinsen
	10:30 MORNING TEA	10:30 MORNING TEA	10:30 MORNING TEA
	11:00 Clemens Ulrich	11:00 Sven Rogge	11:00 Hui Hu
	11:15 Nicolas de Souza	11:15 Oleg Tretiakov	11:15 Jia Wang
	11:30 Ben Powell	11:30 Kirrily Rule	11:30 Vincent Mourik
	12:00 Elise Kenny	12:00 Yaroslav Kharkov	12:00 Laszlo Frazer
	12:15 I. di Bernardo	12:15 Shinichiro Yano	12:15 Eliezer Estrecho
	12:30 LUNCH	12:30 LUNCH	12:30 CLOSING
	14:00 Götz Uhrig	14:00 Michael Fuhrer	12:35 LUNCH
14:30 Registration	14:30 Chris Ling	14:30 Dimi Culcer	
	14:45 David Cortie	14:45 Amie Khosla	
	15:00 Nitish Kumar	15:00 Aydin Cem Keser	
	15:15 Alina Deac	15:15 Antonija Crubisic-Cabo	
	15:45 Tribute to Guy White	15:45 S. Bhattacharyya	
	16:00 Poster Session	16:00 Mandeep K. Hooda	
		16:15 Poster Session	
18:00 DINNER		18:00 DINNER	
19:00 Get Together	18:30 Conference Dinner After-Dinner Talk David Jamieson	19:30 Trivia Night Lindsay Davis Cup	

Invited Talks
25+5 min

Contributed Talks
12+3 min

NAME OF PARTICIPANTS

Mustafa	AL-qurainy	University of Wollongong
Jay	Archer	University of Wollongong
Semonti	Bhattacharyya	Monash University
Samuel	Bladwell	University of New South Wales
Alex	Brown	University of Sydney
David	Broadway	University of Melbourne
Philip	Brydon	University of Otago, New Zealand
Sean	Cadogan	University of New South Wales
Stewart	Campbell	UNSW Canberra
John	Cashion	Monash University
David	Cavanagh	University of Queensland
Sagen	Cocklin	University of Illinois at Chicago, USA
Stephen	Collocott	CSIRO
Susan	Coppersmith	University of New South Wales
David	Cortie	University of Wollongong
Daniel	Crawford	University of Melbourne
Dimitrie	Culcer	University of New South Wales
Alina	Deac	Helmholtz Zentrum Rossendorf, Germany
Wenzhe	Deng	University of Melbourne
Nicolas	de Souza	ACNS - ANSTO
Iolanda	Di Bernardo	Australian National University
Eliezer	Estrecho	Australian National University
Trevor	Finlayson	University of Melbourne
Jorge Sauceda	Flores	University of New South Wales
Laszlo	Frazer	Monash University
Michael	Fuhrer	Monash University/FLEET
Tyler	Gardener	University of Melbourne
Antonija	Grubisic-Cabo	Monash University
El-Abed	Haidar	University of Sydney
Alex	Hamilton	University of New South Wales
Alaa	Hammood	University of Wollongong
Mandeep Kumar	Hooda	Indian Institute of Technology Mandi, India
Hui	Hu	Swinburne University of Technology

Wayne	Hutchison	UNSW Canberra
Gail	Iles	Royal Melbourne Institute of Technology
Sean	Injac	University of Sydney
David	Jamieson	University of Melbourne
Julie	Karel	Monash University
Elise	Kenny	University of Queensland
Aydin Cem	Keser	University of New South Wales
Yaroslav	Kharkov	University of New South Wales
Amie	Khosla	University of Queensland
Zeb	Krix	University of New South Wales
Nitish	Kumar	University of New South Wales
Jesper	Levinsen	Monash University
Roger	Lewis	University of Wollongong
Guangyao	Li	Monash University
Junwei	Li	University of Sydney
Weizhe	Liu	Monash University
Chris	Ling	University of Sydney
Jennifer	MacLeod	Queensland University of Technology
Nazrul	Makmor	UNSW Canberra
Jeff	Mccallum	University of Melbourne
Chris	McNeill	Monash University
Vincent	Mourik	University of New South Wales
Alexander	Nguyen	Monash University
Jaan	Oitmaa	University of New South Wales
Alexey	Pan	University of Wollongong
Meera	Parish	Monash University
Matthew	Pinson	University of Divinity
Ben	Powell	University of Queensland
Stephan	Rachel	University of Melbourne
Sahinur	Reja	University of Queensland
Sven	Rogge	University of New South Wales
Rosanna	Rov	University of Auckland, New Zealand
Kirrily	Rule	ANSTO
Hatem	Saad	UNSW Canberra
Jeffrey R	Sellar	Monash University
Ardita	Septiani	UNSW Canberra

Birender	Singh	Indian Institute of Technology, India
Tilo	Söhnel	University of Auckland, New Zealand
Glen	Stewart	UNSW Canberra
Oleg	Sushkov	University of New South Wales
Oleg	Tretiakov	University of New South Wales
Götz	Uhrig	TU Dortmund, Germany
Clemens	Ulrich	University of New South Wales
Harish	Vallury	University of Melbourne
Jia	Wang	Swinburne University of Technology
Matt	Westlake	University of Wollongong
Sebastian	Wolf	University of Melbourne
Qingbo	Xia	University of Sydney
Shinichiro	Yano	NSRRC, Hsinchu, Taiwan

James	Carter	NanoVacuum
Sebastien	Voisin	EzzyVision
Yatin	Mange	SkiTek
Andrea	Fielder	John Morris
Mirko	Weidner	John Morris
Andy	Taylor	John Morris
Michael	Anderson	Domo-Technica

LIST OF TALKS

Wednesday

Wed 9.00	Susan Coppersmith	Building a quantum computer using silicon/silicon-germanium quantum dots
Wed 9.30	Samuel Bladwell	A quantum point contact as a (near) perfect spin polariser
Wed 9.45	David Broadway	Multi-modal imaging of condensed matter systems with quantum diamond microscopy
Wed 10.00	Chris McNeil	Nature and Extent of Solution Aggregation Determines the Performance of Polymer Thin-Film Transistors
Wed 10.15	Sean Injac	Characterisation of Os7+ Quantum Magnets With the Scheelite Structure Type

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Wed 11:00	Clemens Ulrich	Investigation on the Nature of the Verwey Transition in Cu-doped Fe_3O_4
Wed 11:15	Nicolas de Souza	EMU – high-resolution neutron backscattering spectroscopy at ANSTO
Wed 11:30	Ben Powell	Spin-state ice
Wed 12:00	Elise Kenny	Direct exchange in $Me_{4-n}Et_nX[Pd(dmit)_2]_2$ – evidence for a quasi-one-dimensional spin model from broken symmetry density functional theory
Wed 12:15	Iolanda Di Bernardo	Role of Cerium in Activating Solar Fuels Production in Transition Metal-Oxides

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Wed 14:00	Götz Uhrig	Electronic and nuclear spins in driven quantum dots: Paradigm for non-equilibrium states with induced coherence
Wed 14:30	Chris Ling	Hydration mechanisms and proton conduction in the mixed ionic-electronic conductors $Ba_4Nb_2O_9$ and $Ba_4Ta_2O_9$
Wed 14:45	David Cortie	Beyond the Age of Silicon: Ion Beam Engineering Magnetic Surfaces
Wed 15:00	Nitish Kumar	Defect-driven structural distortions at the surface of relaxor ferroelectrics
Wed 15:15	Alina Deac	Towards THz spin-torque oscillators
Wed 15:45	Stephen Collocott	*Tribute to Guy White*

Wed 19:00	David Jamieson	The unfinished story of the rediscovery of Australia: how condensed matter physics may provide answers

Thursday

Thu 8:45	Jennifer MacLeod	Molecule-by-molecule positioning using template-guided self-assembly
Thu 9:15	Tilo Söhnel	Perfect Frustration? Structure and geometrically frustrated magnetism of layered oxide-cluster compounds
Thu 9:30	Junwei Li	Layered metal oxide photocatalysts for hydrogen evolution
Thu 9:45	Alexey Pan	Magnetic interactions at the interfaces of nano-multilayers

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Thu 11:00	Sven Rogge	Single-site spectroscopy of erbium in silicon
Thu 11:15	Oleg Tretiakov	(Anti)Skyrmions and Bimerons in (Anti)ferromagnets
Thu 11:30	Kirrily Rule	Down the rabbit hole: A journey into the curiouser and curiouser world of low-dimensional, copper-oxide, quantum-magnets
Thu 12:00	Yaroslav Kharkov	Unusual properties of skyrmions and spin spirals in thin films of Cu_2OSeO_3
Thu 12:15	Shinichiro Yano	Recent highlights from the cold triple axis spectrometer SIKA

Thu 14:00	Michael Fuhrer	Atomically thin films of Na_3Bi: A platform for topological electronics
Thu 14:30	Dimitrie Culcer	Spin-orbit coupling and magnetotransport in 2D hole systems
Thu 14:45	Amie Khosla	Designer Hamiltonians in multinuclear organometallic molecular crystals
Thu 15:00	Aydin Cem Keser	Effect of spin-charge disorder correlations on the AHE in 2D Dirac Fermions
Thu 15:15	Antonija Grubisic-Cabo	Electron dynamics in two-dimensional metals and semiconductors, and the influence of the underlying substrate on electronic properties
Thu 15:45	Semonti Bhattacharyya	Probing topological phase transition using quantum transport
Thu 16:00	Mandeep Kumar Hooda	Quantum oscillations in $ZrTe_5$

Friday

Fri 8:45	Sahinur Reja	Triplet superconductivity in coupled odd-gon (e.g., triangular) unit systems
Fri 9:00	David Cavanagh	Penetration Depth Measurements Distinguish Between Different d-wave States: Umklapp Scattering in Unconventional Superconductors
Fri 9:15	Philip Brydon	Surprises in time-reversal symmetry-breaking multiband superconductors
Fri 9:45	David Jamieson	Superconductivity in carbon allotropes – failure and success with boron doped tetrahedral carbon
Fri 10:00	Alex Hamilton	Semiconductor holes: More spin for quantum information and topological superconductivity
Fri 10:15	Jesper Levinsen	Impurities in quantum matter

Fri 11:00	Hui Hu	Quantum anomaly of a quasi-two-dimensional Fermi superfluid
Fri 11:15	Jia Wang	Localization of a Polaron in a non-Abelian Aubry-André-Harper model with p-wave superfluidity
Fri 11:30	Vincent Mourik	Coherent electrical control of a high spin nucleus in silicon
Fri 12:00	Laszlo Frazer	Photochemical Upconversion Light Emitting Diode (LED): Theory of Triplet Annihilation Enhanced by a Cavity
Fri 12:15	Eliezer Estrecho	Imaging single realisations of exciton-polariton condensatio

LIST OF POSTERS

1.	Matthew Pinson	Distinguishability of disturbances in marginal granular materials
2.	Qingbo Xia	Magnetic Properties of the Cathode Material $Na_4Ni_7(PO_4)_6$ for Sodium-ion Batteries
3.	Matt Westlake	Characterization and dynamics investigations into undoped and silver doped lanthanum manganite nano particles for hypothermia treatment of cancer cells
4.	Roger A. Lewis	Reflectance of materials as a function of angle of incidence
5.	J. D. Cashion	Unravelling the Iron Coordination in the Mössbauer Spectra of SFCA
6.	R. Finlayson	The Martensitic Transformation in In-Tl Alloys Revisited
7.	Jaan Oitmaa	Hyperhoneycomb Lattices and the Kitaev Model
8.	Jaan Oitmaa	A New Class of Frustrated Antiferromagnets - The A-Site Spinels
9.	Laszlo Frazer	Phonon kinetics cast a shadow on excitons
10.	El-abed Haidar	Electronic transport investigation of redox-switching Azulenequinones/Hydroquinones via first-principle studies
11.	Jorge S. Flores	Raman Scattering in Pure and Doped Iridates
12.	Alex Brown	Structure and Magnetic Frustration of Layered Honeycomb Oxide: $Li_3Co_2SbO_6$
13.	Sebastian Wolf	Unconventional superconductivity in the 2D Hubbard model
14.	Daniel Crawford	Towards high-temperature topological superconductors
15.	Ardita Septiani	Structural, ^{57}Fe Mössbauer and Magnetic Properties of Non-Stoichiometric Barium M-type Hexaferrites Prepared by the Solid State Reaction Method
16.	Birender Singh	Correlated Paramagnetism and Interplay of Magnetic and Phononic Degrees of Freedom in 3d-5d Coupled La_2CuIrO_6
17.	Nazrul Makmor	Synchrotron studies on substitution of R for Sm in $Sm_{1-x}R_xMn_2Ge_2$
18.	Hatem M. H. Saad	Crystal and Magnetic structure of the GdNiAl intermetallic compound
19.	Rachel White	New Sample Environment projects and developments at the Australian Centre for Neutron Scattering
20.	Guangyao Li	Microscopic description of exciton-polaritons
21.	Weizhe Liu	Quantum Dynamics of Impurities Coupled to a Ultra-Cold Fermion Cloud
22.	Oleg P. Sushkov	Lifshitz point quantum critical spin liquids: Heisenberg versus easy-plane frustrated magnets
23.	Rosanna Rov	The effect of doping on the formation of stable skyrmion lattices in single crystals of Cu_2OSeO_3
24.	Glen A. Stewart	An ^{166}Er-Mössbauer study of $ErCrO_4$
25.	Alexander Nguyen	Extremely Large Anomalous Hall Effect in Amorphous Fe-Co-Si Thin Films
26.	Mustafa Al-Qurainy	Artificial ferromagnetic dot arrays for the critical current enhancement in superconducting $YBa_2Cu_3O_{7-\delta}$ thin films
27.	Alaa Hammood	Enhancement of critical current density in $YBa_2Cu_3O_7$ superconducting thin films by changing magnetic environment

28.	Harish Vallury	The promise of superconducting boron doped CVD diamond devices fabricated by ion beam techniques
29.	Stewart Campbell	Negative thermal expansion of Ni-doped MnCoGe around room temperature – magnetic tuning
30.	Gail Iles	Complex Dusty Plasma device at RMIT
31.	Gail Iles	Space physics research projects at RMIT Physics
32.	Zeb Krix	Modelling artificial graphene in an out of plane magnetic field

TALKS WEDNESDAY

(Pages 12 – 29)

Building a quantum computer using silicon/silicon-germanium quantum dots

Susan Coppersmith

School of Physics, University of New South Wales, Sydney, Australia

This talk will discuss the progress and physics challenges that arise in the development of qubits using quantum dots in silicon/silicon-germanium heterostructures. In particular, recent progress towards the implementation of high fidelity one- and two-qubit gates will be discussed.

A quantum point contact as a (near) perfect spin polariser

Samuel Bladwell

University of New South Wales, School of Physics, Kensington, UNSW, Australia

The prototypical spintronic device is the spin field effect transistor (spin-FET), which consists of a spin polarising injector, and gate controllable spin-orbit interaction, and a spin sensitive detector [1]. While the spin-FET has spawned many progeny, all have this same basic setup, and considerable effort has been devoted to developing "all electric" spin polarisers, using elaborate gating potentials, and electron-electron interactions for use in spin-FETs [2, 3].

In this talk, I present an alternative, single particle approach to obtaining spin-polarised injection from a quantum point contact (QPC) with a strong spin-orbit interaction. The effect emerges due to an anti-crossing between spin 'up' states of one sub-band, and 'down' states of another [4]. In the limit of perfectly adiabatic transport through the anti-crossing region, a 100% polarised beam can be obtained. I'll show that some recently published experimental results in InGaAs devices present compelling and unique evidence for this mechanism of spin polarisation [5]. Finally, I'll discuss the possible extension of this to hole systems, where more complex spin-orbit interactions complicate this simple picture!

[1] S. Datta and B. Das, Appl. Phys. Lett. 56, 665 (1990).

[2] P. Debray, S. Rahman, J. Wan, R. Newrock, M. Cahay, A. Ngo, S. Ulloa, S. Herbert, M. Muhammad, and M. Johnson, Nat. Nanotechnology 4, 759 (2009).

[3] M. Kohda, S. Nakamura, Y. Nishihara, K. Kobayashi, T. Ono, J.-I. Ohe, Y. Tokura, T. Mineno, and J. Nitta, Nat. Commun. 3, 1082 (2012).

[4] M. Eto, T. Hayashi, and Y. Kurotani, J. Phys. Soc. Japan 74, 1934 (2005).

[5] P. Chuang, S.-C. Ho, L. Smith, F. Sfigakis, M. Pepper, C.-H. Chen, J.-C. Fan, J. Griffiths, I. Farrer, H. E. Beere, et al., Nat. Nanotechnology 10, 35 (2015).

Multi-modal imaging of condensed matter systems with quantum diamond microscopy

David Broadway

Centre for Quantum Computation and Communication Technology, School of Physics, University of Melbourne, Parkville, Australia

Solid-state quantum sensors are an emerging technology that is well suited to applications in condensed matter physics, thanks to their unprecedented combination of small size, sensitivity and robustness. In particular, the nitrogen-vacancy (NV) defect centre in diamond has become one of the most popular platforms for quantum sensing and especially for magnetometry, as illustrated by the recent demonstration by our group of current flow imaging in graphene using a quantum diamond microscope [1]. Here we show that it is possible to integrate other sensing modalities to this quantum diamond microscope, namely electric field and strain sensing. On the one hand, imaging the electric field at the diamond surface allows us to study the surface band bending from different surface terminations and then from a two-terminal device based on the two-dimensional hole gas formed at the surface of hydrogen-terminated diamond [2]. On the other hand, we show that the full stress tensor can be mapped with sub-micron resolution, and we apply this capability to the quantitative imaging of elastic deformation in the diamond induced by localized implantation damage, nano-indents, scratches as well as from functional electronic devices fabricated on the diamond [3]. The addition of new sensing modes to quantum diamond microscopy opens up new opportunities for the study of condensed matter systems.

[1] J.-P. Tetienne, N. Dontschuk, D. A. Broadway, A. Stacey, D. A. Simpson, L. C. L. Hollenberg, *Quantum imaging of current flow in graphene*, Science Advances, **3**, e1602429 (2017).

[2] D. A. Broadway, N. Dontschuk, A. Tsai, S. E. Lillie, C. T.-K. Lew, J. C. McCallum, B. C. Johnson, M. W. Doherty, A. Stacey, L. C. L. Hollenberg, J.-P. Tetienne, *Spatial mapping of band bending in semiconductor devices using in situ quantum sensors*, Nature Electronics, **1**, 502 (2018).

[3] D. A. Broadway, B. C. Johnson, M. S. J. Barson, S. E. Lillie, N. Dontschuk, D. J. McCloskey, A. Tsai, T. Teraji, D. A. Simpson, A. Stacey, J. C. McCallum, J. E. Bradby, M. W. Doherty, L. C. L. Hollenberg, J.-P. Tetienne, *Microscopic imaging of elastic deformation in diamond via in-situ stress tensor sensors*, arXiv:1812.01152 (2018).

Nature and Extent of Solution Aggregation Determines the Performance of Polymer Thin-Film Transistors

Chris McNeill

Monash University, Clayton, Australia

Semiconducting polymers are interesting materials that are being developed for a wide range of applications including polymer solar cells, polymer field-effect transistors and polymer light emitting diodes. The thin film microstructure of semiconducting polymers critically influences the performance of such devices. Since semiconducting polymers have to be processed from solution, the way in which polymer chains behave in solution can influence the resulting thin film microstructure. In this presentation it will be shown that the way in which chains of the well-known n-type polymer P(NDI2OD-T2) aggregate in solution strongly affects the resulting transistor performance. The nature of aggregation is varied by using P(NDI2OD-T2) chains of different molar mass and by varying the solvent quality. In general, poor solvents are found to be better for transistor performance, with the strong aggregation of P(NDI2OD-T2) chains in poor solvents promoting elongated rod-like aggregates. These large, rod-like aggregates facilitate the correlated packing of polymer backbones in thin film leading to larger orientational correlation lengths and higher charge transport mobilities. Aggregation is not always found to be beneficial, with the weak aggregation of longer P(NDI2OD-T2) chains in tolerably good solvents frustrating the correlated ordering of backbones compared to shorter chains that maintain a more open conformation. To assess thin-film microstructure a range of techniques including synchrotron based scattering and spectroscopy techniques are used.

Characterisation of Os7+ Quantum Magnets With the Scheelite Structure Type

Sean Injac

University of Sydney, School of Chemistry, Australia

A number of novel perosmate oxides taking the form $AOsO_4$ (A = K, Rb, Cs), which crystallise in the scheelite structure type have been synthesized and characterized. In these compounds Os occupies a tetrahedral coordination environment, resulting in an Os7+ 5d1, $S = 1/2$ ground state, the isolated nature of the OsO_4 tetrahedra within the scheelite structure remove oxygen mediated superexchange pathways, resulting in essentially isolated $S = 1/2$ magnetic moments. The lack of superexchange allows for investigation into the magnetic properties of 5d1 electrons with magnetic interactions limited to low dimensional spin-spin interactions, spin orbit coupling also results in reduction of the magnetic moment, further weakening the magnitude of these interactions. The increasing ionic radii of the A+ cation (K = 1.51$\mathring{A}$, Rb = 1.61$\mathring{A}$, Cs = 1.74$\mathring{A}$) allows for direct tuning of the magnetic interaction pathway length, as the OsO4 tetrahedra are further separated with increasing ionic radii. Rietveld analysis was undertaken against combined neutron powder diffraction and synchrotron powder diffraction datasets, collected at Echidna, the high-resolution diffractometer at ANSTO's OPAL reactor and the Australian Synchrotron's powder diffraction beamline respectively. At ambient conditions $KOsO_4$ and $RbOsO_4$ were determined to crystallise in the archetypal scheelite structure type in tetragonal space group I41/a and $CsOsO_4$ was determined to crystallise as a pseudo scheelite type structure in orthorhombic space group Pnma. Variable temperature X-ray diffraction data, collected at the Australian Synchrotron between 90 K and 700 K indicates that $KOsO_4$ and $RbOsO_4$ remain in space group I41/a for all temperatures, until the onset of decomposition at 500 K. $CsOsO_4$ was determined to undergo a 1st order phase transition to the scheelite structure in space group I41/a above 420 K. A low temperature, reconstructive phase transition at 140 K is also observed. Bulk magnetic susceptibility, and heat capacity measurements indicate an antiferromagnetic ground state for A = K, Rb, with $T_N = 35\,\mathrm{K}$ and $20\,\mathrm{K}$ respectively, $CsOsO_4$ was observed to show Curie Weiss type paramagnetism to 2 K, with $\Theta = -1.1$. Effective magnetic moments for all compositions were determined to be below the expected spin only value, likely as a result of pronounced spin orbit coupling, associated with the diffuse nature of the 5d orbitals. A magnetic structure was determined for $KOsO_4$ by analysis of neutron powder diffraction data collected at the WISH diffractometer at ISIS at 1.5 K. The magnetic structure was indexed to a $k = 0, 0, 0$ k vector, and consists of Os7+ spins orientated anti parallel along the c axis. A small

ordered moment of 0.46(18) μB was determined. Further investigation into the low temperature phase of $CsOsO_4$ is being undertaken.

Investigation on the Nature of the Verwey Transition in Cu-doped Fe_3O_4

Clemens Ulrich

School of Physics, University of New South Wales, Sydney, Australia

Magnetite (Fe_3O_4), the oldest known magnet, is still a hotly debated material in scientific research, due to its complex magnetic, electronic and transport properties. One of the most interesting physical phenomena associated with Fe_3O_4 is the occurrence of a metal-insulator transition at $\sim$120 K (T_V), the so-called Verwey transition, which is associated to a charge ordering below T_V, accompanied with a structural transition from the cubic phase to the monoclinic phase. However, its origin is not fully understood yet and different charge ordered and bond-dimerized ground states have been proposed. In order to contribute to the solution of this problem, we have investigated Cu-doped Fe_3O_4 and have determined the stability range of the Verwey phase in the phase diagram of $Fe_{1-x}Cu_xFe_2O_4$.

Using neutron diffraction and high resolution X-ray synchrotron diffraction we have investigate both the crystallographic and magnetic structure of Cu-doped Fe_3O_4 ($Cu_xFe_{3-x}O_4$ with $x = 0$ to $x = 0.95$) in order to elucidate the effect of doping on the Verwey transition. The Data indicate that the Verwey transition temperature and the magnetic structure remains unchanged up to highest doping levels of more than 80% Cu-substitution. The large stability range of the Verwey phase is a surprising result and did require a systematic investigation. The analysis of our high resolution X-ray synchrotron diffraction data in combination with the neutron diffraction data did allow us to extract detailed information on the precise doping mechanism, for example if the Cu-ions are placed on tetrahedral or octahedral sites in the spinel structure. The obtained diffraction data provide therefore valuable information on the charge order transition, i.e. the Verwey transition.

EMU – high-resolution neutron backscattering spectroscopy at ANSTO

Nicolas de Souza

ACNS - ANSTO, Lucas Heights, Australia

EMU, the high-resolution neutron spectrometer installed at the OPAL reactor, ANSTO [1] delivers 1 μeV FWHM energy transfer resolution for an accessible ± 31 μeV energy transfer range. The spectral resolution is achieved by neutron backscattering from Si (111) on the primary and second flight paths, which also determines the accessible 0.35 to 1.95 $\mathring{A}^{-1}$ momentum transfer range. Two years of user operation document strong demand for QENS characterization of microscopic diffusion processes in energy materials such as solid-state electrolytes, and increasingly in bio-related soft materials [2,3]. Over the same time frame most experiments were carried out with standard cryo-furnaces (2 to 800 K temperature range). Spectrometer beam-time access is merit-based, thus welcoming experiments beyond the first two-year 'sample', and including experiments that may require other ancillary equipment such as (existing) controlled-gas delivery, pressure, applied fields, etc. Examples of the spectrometer capabilities will be shown, with an emphasis on QENS line shape and mean-square displacements analyses. Scientific support is presently focused on enabling data analysis of the collected data, and on the instrumental side reaching the design 0.1 $\mathring{A}^{-1}$ minimum momentum transfer range and growing signal-to-noise ratio beyond its current $\sim$ 1650:1 value.

[1] N. R. de Souza *et al.*, Neutron News **27**, 20 (2016).

[2] D. L. Cortie *et al.*, J. Phys. Chem. C **121**, 18762 (2017).

[3] M. K. Rasmussen *et al.*, accepted EPJ Special Topics (2018).

Spin-state ice

Ben Powell

University of Queensland, School of Mathematics and Physics, Brisbane, QLD, Australia

I will discuss spin crossover materials, crystals composed of molecules with two thermodynamically accessible spin-states: one low-spin (LS) and the other high-spin (HS). I will show that frustrated magneto-elastic interactions can give rise to a new phase of matter: spin-state ice. The low-energy physics is described by an emergent divergence-less field with a gap to topological excitations that are deconfined quasi-particles with spin fractionalized midway between the LS and HS spin.

Direct exchange in $Me_{4-n}Et_nX[Pd(dmit)_2]_2$ – evidence for a quasi-one-dimensional spin model from broken symmetry density functional theory

Elise Kenny

University of Queensland, Australia

Strong electronic correlations and geometric frustration in the $Me_{4-n}Et_nX[Pd(dmit)_2]_2$ family of organic crystals result in many interesting phases of matter, including spin-liquids, valence bond solids, and superconducting states. We are particularly interested in the spin-liquid candidate, X=Sb, n=1. Effective spin models have previously been constructed with ab initio tight-binding parameters, giving an anisotropic triangular structure. We argue that such models are insufficient; they include superexchange, but neglect other exchange interactions such as direct exchange. Using broken-symmetry density functional theory to parametrize an effective Heisenberg Hamiltonian, we show that the full nearest neighbour exchange interactions lead to a quasi-one-dimensional structure. We calculate the expression for the three dimensional Néel temperature from the chain random phase approximation (CRPA), including ring exchange. We show that this gives a good qualitative and even semi-quantitative description of the trends observed in the Néel temperatures of this family of materials – including the absence of long-range order in $Me_3EtSb[Pd(dmit)_2]_2$.

Role of Cerium in Activating Solar Fuels Production in Transition Metal-Oxides

Iolanda Di Bernardo

Australian National University, Canberra, Australia

Earth abundant and environmentally friendly transition metal oxides are attracting broad research for thermochemical redox cycles. Despite progress, a major challenge is ensuring fast and reversible redox kinetics and large oxygen exchange capacities.

We provide insights on the role of Ce dopants in unlocking the redox capacity of manganese oxide. We perform a detailed analysis of the structural evolution and elemental distribution of the material during the redox steps as a function of the cerium content by combining synchrotron-based spectroscopy (NEXAFS, in-depth XPS profiling) and in-house microscopy (SEM, TEM). We observe that the cerium atoms migrate in and out the material, and that the presence of cerium in 3+ oxidation state both within the lattice of the metal oxide and on its surface is essential to achieve high and stable reduction kinetics. This is optimally achieved for a cerium content of 3%. Smaller Ce content are insufficient to stabilize the redox reactions resulting in the rapid growth of the manganese oxide grains, while higher content cause the rapid segregation and inactivation of Ce.

Electronic and nuclear spins in driven quantum dots: Paradigm for non-equilibrium states with induced coherence

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The spin of localized electrons or holes in quantum dots is an interesting candidate for a quantum bit. Hence one aims at keeping its coherence as long as possible. First, we discuss the main mechanism for the decoherence of the dynamics of the electronic spin. Second, we discuss the phenomenon of mode-locking observed in ensembles of quantum dots which leads to a coherent response of a large fraction of quantum dots. This mode-locking is achieved by long trains of repeated laser pulses inducing a state far from equilibrium. In an outlook, we discuss if this mechanism is able to generate quantum coherence.

Hydration mechanisms and proton conduction in the mixed ionic-electronic conductors $Ba_4Nb_2O_9$ and $Ba_4Ta_2O_9$

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Mixed conductors – materials that exhibit significant mobility of more than one type of charge carrier such as oxide ions, protons and electrons – have a range of important applications including solid oxide fuel cell membranes, electrodes, batteries and sensors. We recently studied the behaviour of hydrogen in the mixed ionic-electronic conductors γ-$Ba_4Nb_2O_9$ and 6H-$Ba_4Ta_2O_9$, using a combination of experimental (neutron diffraction and inelastic neutron scattering) and computational (ab initio molecular dynamics) methods. While these compounds have isostructural low-temperature polymorphs, they adopt distinct forms in the high-temperature conducting regime. We found that they also have distinct mechanisms for hydration and ionic conduction. Hydration of γ-$Ba_4Nb_2O_9$ is localised to 2-D layers in the structure that contain a 1 : 1 ratio of isolated but adjacent NbO_4 and NbO_5 polyhedra. $OH-$ and $H+$ ions combine with two polyhedra respectively to form complete layers of NbO_4OH polyhedra, giving rise to a stoichiometric hydrated form γ-III-$Ba_4Nb_2O_9.1/3H_2O$. Protons then diffuse through these 2-D layers by "hopping" between oxygen atoms on adjacent polyhedra. In the case of 6H-$Ba_4Ta_2O_9$, hydration occurs by intercalating intact water molecules into the structure up to a maximum of $\sim$0.375 H_2O per formula unit. This explains the unusual local and long-range structural distortions in the hydrated form observed by neutron diffraction. Diffusion then occurs by water molecules moving between neighboring symmetry equivalent positions. These fundamentally different hydration and proton conduction mechanisms explain why 6H-$Ba_4Ta_2O_9$ has the less well-defined and higher maximum water content, while γ-$Ba_4Nb_2O_9$ has the higher proton conductivity.

Beyond the Age of Silicon: Ion Beam Engineering Magnetic Surfaces

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Ion-beam implantation has been the preferred method for doping commercial silicon since the 1970's [1]. Consequently, implantation has remained the largest industrial use of particle accelerators. However, a paradigm shift is underway, as silicon-based electronics continue to fall behind Moore's law owing to fundamental limitations. There is an international race to find suitable replacements for ultrafast, low voltage electronics.

Magnetic nanolayers serve as the main component in several recent proposals using concepts from spintronics and topological electronics. This presentation will explore how the next-generation of nanomagnets can be prepared using ion-beams. Through exploiting the beam-matter interaction, it is possible to achieve a range of material-science functions including doping, embedding magnetic nanoparticles, modifying surface morphologies and controlling local chemical order parameters [2,3,4]. Radioactive ion-beams afford further possibilities for in situ characterization of magnetic structures [5]. Experimental demonstrations will be presented based on polarized neutron reflectometry using PLATYPUS at ANSTO, complemented by soft X-ray spectroscopy and density functional theory.

[1] A. Baudrant, Silicon Technologies: Ion Implantation and Thermal Treatment, Wiley (2013).

[2] D. L. Cortie et al., ACS Appl. Mater. Interfaces, 9 , 8783 (2017).

[3] D. L. Cortie et al., J. Appl. Phys, 073901 (2014).

[4] G. Causer / D. L. Cortie et. al., ACS Appl. Mater. Interfaces, 10, 16216 (2018).

[5] D. L. Cortie et al., Phys. Rev. Lett. 116, 106103 (2016).

Defect-driven structural distortions at the surface of relaxor ferroelectrics

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Surface or skin layers are known to exhibit physical properties distinct from the bulk in thick ferroelectric crystals. Skin layers have been extensively studied for Pb-based relaxor ferroelectrics because they cause ambiguity in structural determinations and can influence the overall functionality of the ceramics. However, the origin of such skin structures and their presence in Pb-free relaxor ferroelectrics have remained elusive. Here, we report the presence of a $\sim$20μm skin structure in the well-known lead-free piezoelectric ceramic (Na1/2Bi1/2)TiO_3-$BaTiO_3$. We show that the combined action of oxygen vacancies and internal chemical pressure has a tremendous impact on the stability and structure of the skin layer. In particular, our scanning synchrotron X-ray diffraction, experiments show that the skin structure is anisotropic and textured out-of-plane along the surface normal. Meanwhile, oxygen vacancies provide the internal pressure that induces out-of-plane expansion, as we demonstrate by varying the oxygen vacancy concentration through non-stoichiometry and annealing and with density functional theory calculations. This work provides new insights into the origin of skin layers in relaxor ferroelectrics, and thus opens new avenues to control functionality in polar materials.

Towards THz spin-torque oscillators

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Since the discovery of giant magnetoresistance, metal spin electronics has seen unprecedented advances, from the realisation of ultra-high magnetoresistance ratios to substantial output power from spin transfer torque oscillators based on Fe/MgO/Fe-type tunnel junctions which function in the GHz range [1]. The recently discovered class of almost compensated ferrimagnetic manganese gallium pseudo-Heusler alloys, due to their widely tunable magnetic properties [2], could enable the design of spin torque oscillators which work in the range of hundreds of GHz, i.e., covering the THz gap. To investigate the resonance modes in such compounds, we first conducted high-field magnetotransport measurements [3] on selected films with different composition and, therefore, different compensation temperatures (Tc) and effective anisotropies. In manganese ruthenium gallium (MRG), for instance, both the transverse Hall resistivity and longitudinal resistivity were recorded in magnetic fields up to 58 T, at variable temperature. MRG exhibits a large spontaneous Hall angle of 2%, coercivity exceeding 1 T at room temperature (and several Teslas close to T_c) and has very low net magnetisation of 25 kA/m. Despite having no net magnetic moment at T_c, the magnitude of the Hall signal does not become zero, indicating both a half-metallic nature of the material and that the magnetotransport is dominated by one sublattice only. An additional feature is observed in the transport data, which resembles a spin-flop transition. By comparison to analytical and mean-field calculations of the sublattice magnetisation directions, we can estimate both the sublattice anisotropy (Hk) and interlayer exchange coupling (Hex). Based on these values, the out-of-phase and in-phase magnetic resonance modes are estimated to lie in the range of 0.3 THz and 2 THz, respectively. Furthermore, magnetoresistance ratios as high as 40% at 4.2 K and 12% at room temperature can be obtained when integrating MRG in magnetic tunnel junctions [4]. The out-of-phase resonance mode was also directly measured for ferrimagnetic $Mn_{3-x}Ga$ thin films as function of anisotropy and applied magnetic fields (up to 10 T). At low applied fields, we find that the resonance frequency ranges between 200 and 350 GHz for films with different compositions (i.e. anisotropy), providing proof of concept for efficient on-chip emitters of coherent, narrow-band light pulses in the THz gap [5].

This work was supported by the Helmholtz Young Investigator Initiative Grant VH-N6-1048 and the EU FET-Open Project TRANSPIRE DLV-737038.

[1] Baibich M.N. et al., Physical Review B, 61, 2472 (1988), Ikeda S. et al., Applied Physics Letters, 93 082508 (2008), Tsunegi S. et al., Applied Physics Letters, **109**, 252402 (2016).

[2] Kurt H. et al., Physical Review Letters, **112**, 027201 (2014).

[3] Fowley C. et al., Journal of Physics D : Applied Physics, **48**, 164006 (2015).

[4] Borisov K. et al., Applied Physics Letters, **108**, 192407 (2016).

[5] Awari N. et al., Applied Physics Letters, **109**, 032403 (2016).

After dinner speech

The unfinished story of the rediscovery of Australia: how condensed matter physics may provide answers

David N. Jamieson

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Would it surprise you to know the Australian continent was discovered and colonized by modern humans long before Europe and the Americas? That ancient human artefacts in Australia are too old for carbon dating? That despite the colonization of the Australian continent by its original discovers in deep antiquity, mystery shrouded the continent of Australia long after the coastlines of the Americas, Africa and Asia were thoroughly mapped by European explorers. Why was that? Did Cook already have a map of the Australian east coast when he arrived in 1770? This lecture looks at the unfinished story of the rediscovery of Australia and some techniques from condensed matter physics that may provide sensational new chapters.

TALKS THURSDAY

(Pages 31 – 47)

Molecule-by-molecule positioning using template-guided self-assembly

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Achieving precise control of molecular self-assembly to form designed three-dimensional (3D) structures is a major goal in nanoscale science and technology. Using scanning tunnelling microscopy and density functional theory calculations, we have investigated the use of a single-atom-thick 2D covalent organic framework (COF-1) to template solution processed guest molecules [1]. This versatile approach can be used to trap and organize molecules at the solution/solid interface and in the subsequently obtained dried films. The molecular adsorption geometries depend on the solvent used for processing, and through the use of different solvents different (pseudo)polymorphs can be obtained. The transition from two-dimensional to three-dimensional molecular films has been observed, and indicates that these nanoscale COF-1 templates may enable novel packing geometries for device applications [2]. The approach can also be used to pattern molecules with intrinsic barriers for forming periodic lattices, such as those with five-fold symmetry, demonstrating that monolayer templates may allow molecules designed for function, rather than crystallization into regular lattices, to be used in applications where crystallinity is desirable [3].

[1] Cui, D., MacLeod, J. M., Ebrahimi, M., Perepichka, D. F. and Rosei, F. (2015). Solution and air stable host/guest architectures from a single layer covalent organic framework. Chemical Communications, 51(92), 16510-16513.

[2] Cui, D., Ebrahimi, M., Rosei, F. and Macleod, J. M. (2017). Control of fullerene crystallization from 2D to 3D through combined solvent and template effects. Journal of the American Chemical Society, 139(46), 16732-16740.

[3] Cui, D., Ebrahimi, M., Macleod, J. M. and Rosei, F. (2018). Template-driven dense packing of pentagonal molecules in monolayer films. Nano Letters, 18, 7570-7575.

Perfect Frustration? Structure and geometrically frustrated magnetism of layered oxide-cluster compounds

Tilo Söhnel

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Layered oxides containing third row transition metals possess interesting crystal and electronic architectures, which may exhibit novel multiferroic properties such as ferroelectricity and giant magnetoresistance.[1] $Fe_4Si_2Sn_7O_{16}$ as the parent compound for this presentation, can be described as a layered composite of intermetallic ($FeSn_6$) clusters and perfect kagomé lattice type (FeO_6)/(SnO_6) oxide layers within the one structure.[2] SiO_4 tetrahedra separate these layers which leads to electronic and magnetic isolation of the repeated layers by about 7 $\AA$ resulting in a nearly perfectly 2D oxide system comparable to a one layer thick oxide "thin film". This combination of features therefore allows us a unique opportunity to study the electronic interaction of two materially independent features in the one material. In this study we have replaced iron positions with cobalt and/or manganese [3] in order to study the change in structure and material properties. Refinements of the structures based on synchrotron and neutron diffraction data show the distinct different behaviour of Mn and Co replacement in MSn_6 octahedral layer in these materials. Compounds containing both iron and cobalt may result in the first 19-electron cluster seen in these tin systems. The resulting electronic structure will be discussed based on Mössbauer and XANES measurements. ^{57}Fe-Mössbauer spectra confirm the observation from neutron diffraction studies and show that Mn has a strong affinity for the oxide layer positions, whereas Co preferably occupies the of intermetalic Sn layer. The $Fe_4Si_2Sn_7O_{16}$ and $Fe(Mn_{3-x}Fe_x)Si_2Sn_7O_{16}$ show antiferromagnetic ordering below 3 K.[3] The magnetically frustrated structures could be solved using low temperature neutron powder diffraction data and ^{57}Fe-Mössbauer spectroscopy.[4]

[1] Cheong, S.W. and Mostovoy, M. Nature Mater. 2007, 6, 13.

[2] Söhnel, T., Böttcher, P., Reichelt, W. and Wagner, F. E. Z. Anorg. Allg. Chem. 1998, 624, 708.

[3] Allison, M.C., Avdeev, M., Schmid, S., Liu, S., Söhnel, T. and Ling, C.D. Dalton Trans. 2016, 45, 9689-9694.

[4] C. D. Ling, M. C. Allison, S. Schmid, M.Avdeev, J. S. Gardner, C.-W. Wang, D. H. Ryan, M. Zbiri, and T. Söhnel. Phys. Rev. B 2017, 96, 180410(R).

Layered metal oxide photocatalysts for hydrogen evolution

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Layered metal oxides have been studied for photocatalytic hydrogen evolution by water splitting. Two classes of oxides are under investigation, namely the honeycomb layered structure [1] ($Na_3Co_2SbO_6$, $Na_3Cu_2SbO_6$, $Na_3Ni_2SbO_6$ and $Na_3Zn_2SbO_6$) and layered perovskite material [2] ($KLaTiO_4$, $KCa_2Nb_3O_{10}$ and $K_{2.5}Bi_{2.5}Ti_4O_{13}$). Polycrystalline samples were prepared using standard solid-state synthesis method that involved mixing stoichiometric quantities of the appropriate metal oxides/carbonates and heating the mixtures in air.

The crystal structures, and sample purity, was determined using X-ray powder diffraction. The structures have been refined by the Rietveld method using synchrotron X-ray diffraction data. The band gap of each sample was determined by diffuse reflectance spectroscopy, with the band gap ranging from 2.08 eV for $Na_3Co_2SbO_6$ to 4.69 eV for $Na_3Zn_2SbO_6$. Hydrogen evolution was tested by illuminating a suspension of powder sample in water. Evolved gases were identified and quantified using gas chromatography.

[1] C. Wong, M. Avdeev, C. D. Ling, *Zig-zag magnetic ordering in honeycomb-layered $Na_3Co_2SbO_6$*, Journal of Solid State Chemistry **243**, 18 (2016).

[2] T. Oshima, D. Lu, O. Ishitani, K. Maeda, *Intercalation of Highly Dispersed Metal Nanoclusters into a Layered Metal Oxide for Photocatalytic Overall Water Splitting*, Angewandte Chemie International Edition **54**, 2698 (2015).

Magnetic interactions at the interfaces of nano-multilayers

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Thin film technology utilising rare-earth elements in complex oxides and transition metal oxides has been shown to exhibit novel states at interfaces that are not possible in bulk materials. Tailoring electronic properties of oxide thin film heterostructures and superlattices with atomically sharp interfaces gives rise to new functionalities, which are enhanced by complexity of the oxides and their interactions at the interfaces. These new phenomena have a potential to be implemented in a design of new electronic systems providing an avenue for superconducting electronic, spintronic and multiferroic technologies. The manipulation of properties in these systems by external parameters, such electric fields, currents, magnetic fields or strains is also of high interest for potential applications. A number of different interfacial interactions between different oxides, exhibiting superconducting, (ferro)magneticis, multiferroic and insulating properties, is discussed on the basis of structural, magnetic, transport, and polarised neutron reflectometry measurements.

Single-site spectroscopy of erbium in silicon

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Optical transitions of erbium in silica enable telecom communication world wide and erbium in crystals such as YSO is a key candidate for quantum memories and repeater applications. Erbium embedded in silicon retains the same attractive telecommunication transitions but shows a broad spectrum due to large inhomogenous broadening. Here we present a technique based on optical excitation of erbium in silicon combined with single electron charge sensing of sufficiently high resolution that single sites can be identified in the broad spectrum. Different optical transitions and ions can be addressed in one device based on frequency selection with a narrow excitation source. Magnetic field rotation spectra allow the identification of the site symmetry. As an example, the spectrum of two coupled erbium ions is presented. Here the high resolution spectrum allows the direct comparison and parametrisation of a simple model with dipolar magnetic coupling. In addition, the excitation process is analysed based on sub 1us excitation pulses combined with single shot latched readout. Finally, the concept of erbium ions utilised as atomic-scale sensors is presented with high-resolution strain and electric field measurements that enable metrology applications in nano-transistors.

(Anti)Skyrmions and Bimerons in (Anti)ferromagnets

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Skyrmions are topologically protected magnetic hedgehogs, which can be used in spintronic devices for information storage and processing. Ferromagnetic skyrmions attracted a lot of attention because they are small in size, better than domain walls at avoiding pinning sites, and can be moved very fast by electric current in ferromagnet/heavy-metal bilayers due to novel spin-orbit torques [1,2]. Meanwhile, the ferromagnetic skyrmions also have certain disadvantages to employ them in spintronic devices, such as the presence of stray fields and transverse to current dynamics. To avoid these unwanted effects, we propose a novel topological object: the antiferromagnetic skyrmion. This topological texture has no stray fields and its dynamics are faster compared to its ferromagnetic analogue [3]. More importantly, I will show that due to unusual topology it experiences no skyrmion Hall effect, and thus is a better candidate for spintronic applications [4,5]. I will also discuss the lifetimes of both antiferromagnetic and ferromagnetic skyrmions at finite temperatures [6]. Then I will talk about antiskyrmions - unusual anisotropic topological objects, which have been recently observed in the systems with anisotropic Dzyaloshinskii-Moriya interaction [7]. I will explain their lifetimes and current-driven dynamics based on the spin transformation between skyrmion and antiskyrmion in (anti)ferromagnets. Lastly, I will discuss the topological analogues of skyrmions - bimerons [8], I will make predictions of their dynamics and the possibility to observe a pure topological Hall effect in this novel system.

[1] K. Litzius, I. Lemesh, B. Kruger, P. Bassirian, L. Caretta, K. Richter, F. Buttner, K. Sato, O. A. Tretiakov, J. Forster, R. M. Reeve, M. Weigand, I. Bykova, H. Stoll, G. Schutz, G. S. D. Beach and M. Klaui, Nature Phys. 13, 170 (2017).

[2] I. Ado, O. A. Tretiakov and M. Titov, Phys. Rev. B 95, 094401 (2017).

[3] J. Barker and O. A. Tretiakov, Phys. Rev. Lett. 116, 147203 (2016).

[4] C. A. Akosa, O. A. Tretiakov, G. Tatara and A. Manchon, Phys. Rev. Lett. 121, 097204 (2018).

[5] L. Shen, J. Xia, G. Zhao, X. Zhang, M. Ezawa, O. A. Tretiakov, X. Liu and Y. Zhou, Phys. Rev. B 98, 134448 (2018).

[6] P. F. Bessarab, D. Yudin, D. R. Gulevich, P. Wadley, M. Titov and O. A. Tretiakov, arXiv:1709.04454, submitted to Phys. Rev. Lett. (2018).

[7] A. K. Nayak, V. Kumar, T. Ma, P. Werner, E. Pippel, R. Sahoo, F. Damay, U. K. Rössler, C.

Felser and S. S. P. Parkin, Nature 548, 561 (2017).

[8] B. Gobel, A. Mook, J. Henk, I. Mertig, and O. A. Tretiakov, arXiv:1811.07068, submitted to Phys. Rev. Lett. (2018).

Down the rabbit hole: A journey into the curiouser and curiouser world of low-dimensional, copper-oxide, quantum-magnets

Kirrily Rule

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Low dimensional quantum magnets offer a rich playground with which we can explore competing magnetic interactions, which can include frustration, anisotropy effects as well as the weak interactions afforded by separating magnetic ions into reduced dimensional topologies. This can lead to a whole host of exotic ground states and exited phases. I would like to talk about a few systems which we have studied recently – systems which do not appear to behave classically. In particular I would like to highlight the role of inelastic neutron scattering and extreme sample environments which have been employed to probe the world of low dimensional magnets.

As part of this presentation I will discuss recent results on Linarite and Atacamite as well as future materials we plan to study. In particular the role of theoretical modelling will be highlighted throughout this talk.

Unusual properties of skyrmions and spin spirals in thin films of Cu_2OSeO_3

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Topologically nontrivial spin textures such as vortices, skyrmions, merons are promising candidates as information carriers for future quantum information science. However, their controlled manipulation remains an important challenge towards practical applications and further exploration of their emergent phenomena. Here, we report controlled evolution of the helical and skyrmion phases in thin films of a chiral magnet Cu_2OSeO_3 as function of material thickness, Te-doping, temperature, and magnetic field from direct imaging using in-situ Lorentz transmission microscopy. In thin films with variable thickness sections, we found that helical-to-skyrmion phase transition systematically proceeds by anisotropic scaling of spiral helical phase periodicities, edge-enhanced skyrmion nucleation, and gradual skyrmion channelling to thicker sections. We found unusual strongly anisotropic behaviour of spin helices in the present of a perpendicular magnetic field.

Based on our theoretical model, the effect is attributed to the helix phase tilting towards field direction, similar to the tilted spin spiral observed in bulk measurements with neutron scattering. Observed phenomena might be relevant for envisaging designing of new skyrmion-operated devices for spintronics applications.

Recent highlights from the cold triple axis spectrometer SIKA

Shinichiro Yano

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Triple axis spectrometers have been one of most useful neutron scattering instruments for many areas of condensed matter physics. With using cold neutron, triple axis spectrometer can investigate physical phenomena with high energy and momentum resolution.

In this talk, I will introduce our cold triple axis spectrometer SIKA. The SIKA project has been funded by the Ministry of Science and Technology Taiwan to build a cold neutron triple-axis spectrometer at the OPAL reactor in ANSTO since 2005. We are now running user program since 2015 July. The components, capabilities, sample environment, software, and statistics will be presented in this talk. I will try to compare SIKA with other inelastic instruments in ANSTO. Then, I will present some of our recent scientific outcomes.

Since SIKA was built by Taiwanese team, we are getting healthy number of Taiwanese users while we would like to have more local Australian users. I hope audience in this conference will be interested in SIKA.

Atomically thin films of Na_3Bi: A platform for topological electronics

Michael Fuhrer

ARC Centre of Excellence in Future Low-Energy Electronics Technologies

The semiconductor industry recognizes a need for a new computing technology with vastly lower energy consumed per operation than silicon CMOS. The discovery in the last decade of topological phases of matter offers a new route to low-energy switches based on the conventional-to-topological quantum phase transition (QPT), a so-called "topological transistor" in which an electric field tunes a material from a conventional insulator "off" state to a topological insulator "on" state, in which topologically protected edge modes carry dissipationless current. I will discuss our recent work on atomically thin films of Na_3Bi (a topological Dirac semimetal in bulk) as a platform for a topological transistor. We study thin films of Na_3Bi grown in ultra-high vacuum by molecular beam epitaxy, characterized with electronic transport, scanning tunneling microscopy (STM), and angle-resolved photoemission spectroscopy. When thinned to a few atomic layers Na_3Bi is a large gap (> 300 meV) 2D topological insulator, i.e. quantum spin Hall insulator, with topologically protected edge modes observable in STM. Electric field applied perpendicular to the Na_3Bi film, either by potassium doping or by proximity of an STM tip, closes the bandgap completely and reopens it as a conventional insulator. The large bandgap of 2D Na_3Bi, significantly greater than room temperature, and its compatibility with silicon, make it a promising platform for a topological transistor.

Spin-orbit coupling and magnetotransport in 2D hole systems

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Classical charge transport, such as longitudinal and Hall currents in weak magnetic fields, is usually not affected by quantum phenomena. Yet relativistic quantum mechanics is at the heart of the spin-orbit interaction, which has been at the forefront of efforts to realize spin-based electronics, new phases of matter, and topological quantum computing. In this work we demonstrate that quantum spin dynamics induced by the spin-orbit interaction is directly observable in classical charge transport. We determine the Hall coefficient RH of two-dimensional hole systems at low magnetic fields and show that it has a sizable spin-orbit contribution, which depends on the density p, is independent of temperature, is a strong function of the top gate electric field, and can reach ∼20% of the total. We provide a general method for extracting the spin-orbit parameter from magnetotransport data, applicable even at higher temperatures where Shubnikov–de Haas oscillations and weak antilocalization are difficult to observe. Our work will enable experimentalists to measure spin-orbit parameters without requiring large magnetic fields, ultralow temperatures, or optical setups [1].

[1] H. Liu, E. Marcellina, A. R. Hamilton, and D. Culcer, Phys. Rev. Lett. 121, 087701 (2018).

Designer Hamiltonians in multinuclear organometallic molecular crystals

Amie Khosla

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Spin-orbit coupling (SOC) is a relativistic effect that entangles orbital and spin degrees of freedom such that neither remain good quantum numbers. It splits otherwise degenerate sets of orbitals. The combination of SOC and strong electronic correlations can lead to a variety of novel phases such as topological Mott insulators and quantum spin liquids. To date much of this research has been focused on inorganic atomic crystals with partially filled d-orbitals, in particular transition metal oxides. We show how in molecular crystals the form of the SOC is importantly different than in atomic crystals: it is based on molecular orbitals rather than single atomic orbitals. Because of this feature, molecular crystals provide a novel playground for understanding the combined effect of strong SOC and electron correlations as we can tune these interactions via chemical changes to these organic and organometallic systems.

Calculating the exact form of the SOC is a difficult task. Thus SOC is often treated by only attributing its effects to the heaviest atoms in the molecule and assuming that the spherical symmetry of a single atom remains. In this work we present a new approach to determining the form of the SOC for organometallic systems and present the emergence of a Spin Molecular Orbital Coupling (SMOC) that is unlike what might be expected.

I will discuss ongoing work on deriving the SOC Hamiltonians for all 32 Point Groups, starting with the simplest case of cyclic symmetry [1] and moving on to the larger groups of higher symmetry. We invoke group theoretical techniques to derive the exact form of the SOC Hamiltonian. We make use of not only the geometric symmetry of the system but also time reversal symmetry. This method allows us to determine terms in the Hamiltonian are allowed to exist based on the symmetry alone, without the need for atomistic calculations.

[1] A. L. Khosla, A. C. Jacko, J. Merino and B. J. Powell, *Spin-orbit coupling and strong electronic correlations in cyclic molecules*, Phys. Rev. B **95**, 115109 (2017).

Effect of spin-charge disorder correlations on the AHE in 2D Dirac Fermions

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The anomalous Hall effect is a result of time reversal symmetry breaking,and coupling of (pseudo-)spin and orbital degrees of freedom. A minimal model that captures this effect is the 2D massive Dirac fermion, for which the disorder effects become important when the Fermi level rises above the gap. Although, the effects of scalar disorder and arbitrary disorder in all parameters in the gapped and critical regimes are studied in the literature, the interplay of charge disorder with 'mass' disorder due to magnetic impurities is not well understood when the Fermi level is tuned above the gap. Given that magnetic impurities tend to order ferromagnetically, we assume correlations between spin and charge impurity sectors and express the conductivity tensor in terms of strengths and correlation coefficients of such disorder potentials. We find interesting effects including a sign change in the AHE and relative enhancement due to such correlations.

Electron dynamics in two-dimensional metals and semiconductors, and the influence of the underlying substrate on electronic properties

Antonija Grubisic-Cabo

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Two-dimensional transition metal dichalcogenides (2D TMDCs) have generated significant interest in the scientific community thanks to their remarkable optical and electronic properties. Due to the reduced dimensionality and atomic thickness, the electronic properties in 2D TMDCs, including the band gap, are drastically different from those in their parent compounds. The electronic properties of 2D materials are determined not only by the material, but are also influenced by the environment and are, for example, extremely sensitive to the properties of the supporting substrate. Consequently, the properties of the material can be changed depending on the substrate in use, the environment surrounding the TMDC, and even the carrier concentration within the 2D material. Besides control of the electronic band gap, control of the spin- and valley-degrees of freedom has been suggested as a new, potential tuning knob for carrier dynamics, and semiconducting 2D TMDCs are particularly promising candidates for new spin- and valley-tronic devices. Furthermore, metallic 2D TMDCs have recently been studied at the single-layer limit and can be investigated out of equilibrium. In this talk, I will present work from my PhD at Aarhus University on the ultrafast dynamics of free carriers and on the valley-degrees of freedom in 2D TMDCs (MoS_2, WS_2) probed by the time- and angle resolved photoemission spectroscopy (TR-ARPES) technique [1-3]. I will also present ongoing work on a 2D metal (TaS_2), and more recent work from Monash University on the effect of substrate properties on the electronic structure and optoelectronic properties of WS_2.

[1] Grubišić Čabo, A., Miwa, J. A., Grønborg, S. S., Riley, J. M., Johannsen, J. C., Cacho, C., Alexander, O., Chapman, R. T., Springate, E., Grioni, M., Lauritsen, J. V., King, P. D. C., Hofmann, P. and Ulstrup, S., 9 Sep 2015, Nano Letters. 15, 9, p. 5883-5887

[2] Ulstrup, S., Čabo, A. G., Miwa, J. A., Riley, J. M., Grønborg, S. S., Johannsen, J. C., Cacho, C., Alexander, O., Chapman, R. T., Springate, E., Bianchi, M., Dendzik, M., Lauritsen, J. V., King, P. D. C. andHofmann, P., 28 Jun 2016, ACS Nano. 10, 6, p. 6315-6322

[3] Ulstrup, S., Čabo, A. G., Biswas, D., Riley, J. M., Dendzik, M., Sanders, C. E., Bianchi, M., Cacho, C., Matselyukh, D., Chapman, R. T., Springate, E., King, P. D. C., Miwa, J. A. and Hofmann, P., 23 Jan 2017, In : Physical Review B. 95, 4, 5 p., 041405.

Probing topological phase transition using quantum transport

Semonti Bhattacharyya

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Topological insulators (TIs) are a new class of materials characterised by linear gapless surface states, which emerge in the bulk band gap due to non-trivial topology of the band structure. These boundary states, protected from back-scattering because of their spin-polarized nature, make field effect transistors of topological insulators promising building blocks for future low-power electronics. Because of the gapless nature of the surface states, the only way to switch off these transistors is to induce a topological phase transition, *i.e.*, transforming topological insulator to a trivial insulator. This topological phase transition can be induced by different ways: for example breaking the time reversal symmetry by introduction of a magnetic field or introduction of ferromagnetic order, or creating a band inversion through strain, electric field, etc.

In this talk I will present work from my PhD in IISc, India, on directly probing such topological phase transition in a 3D topological insulator ($Bi_{1.6}Sb_{0.4}Te_2Se$) as a function of a magnetic field with universal conductance fluctuations [1]. I will also highlight our recent endeavours at Monash University to engineer topological phase transitions in van der Waals heterostructures of topological insulators.

[1] Saurav Islam, Semonti Bhattacharyya, Hariharan Nhalil, Suja Elizabeth, and Arindam Ghosh, Phys. Rev. B **97**, 241412(R) (2018).

Quantum oscillations in $ZrTe_5$

Mandeep Kumar Hooda and C. S. Yadav

Indian Institute of Technology Mandi, Mandi, H.P., India

$ZrTe_5$ is a group IV transition metal penta-chalcogenide compound, well known due to resistivity anomaly [1]. The resistivity anomaly in $ZrTe_5$ is a result of bipolar conduction due to electrons and holes with different anisotropies and Te off-stoichiometry [2]. For perfectly stoichiometric compound, hole carriers are observed to be dominating which lead to p-type $ZrTe_5$ [2]. During last half decade, detailed studies on the electronic and topological features of Te deficient (bipolar) $ZrTe_5$ were reported in the literature [3], however much less attention was paid to explore the p-type material [2,4], which represents the actual behavior of $ZrTe_5$. Recenty H. Wang *et al.* have reported quantum oscillations periodic in logarithmic of magnetic field (B) in magnetoresistance (MR) study on p-type $ZrTe_5$ [5]. The oscillations was suggested to emerge from discrete scale invariance resulting from Efimov bound states [5]. We report our results on the quantum oscillations observed in MR study on p-type $ZrTe_5$ [6]. The observed quantum oscillations in the compound sustain up to 20 K. These oscillations are neither periodic in $1/B$ as Shubnikov de Haas (SdH) oscillations nor in $\log B$ as observed by Wang *et al.* [5]. Instead these show periodicity in B in contrast to SdH and $\log B$ oscillations. The fast Fourier transform analysis of these oscillations gives a single predominant oscillation frequency, very small cyclotron effective mass of ~ 0.05me and high mobility of $\sim 2.2 \times 104$ cm^2/V-s. The observation of very small effective mass and very high mobility suggests the origin of oscillations from topologically protected surface states which is further supported by zero cusp paramagnetic peak observed in magnetic data. We have compared various Fermi surface parameters obtained from the oscillations analysis on our p-type $ZrTe_5$ with bipolar $ZrTe_5$ and other topological insulators reported in the literature [3,6,7].

[1] F. J. Disalvo et al., Phys. Rev. B 24, 2935 (1981).

[2] P. Shahi et al., Phys. Rev. X 8, 021055 (2018).

[3] G. Zheng et al., Phys. Rev. B 93, 115414 (2016).

[4] A. Pariari and P. Mandal, Sci. Rep. 7, 40327 (2017).

[5] H. Wang et al., Sci. Adv. 4, eaau 5096 (2018).

[6] M. K. Hooda and C. S. Yadav, Phys. Rev. B 98, 165119 (2018).

[7] G. N. Kamm *et al.*, Phys. Rev. B 31, 7617 (1985).

TALKS FRIDAY

(Pages 49 – 59)

Triplet superconductivity in coupled odd-gon (e.g., triangular) unit systems

Sahinur Reja

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Shedding light on the nature of spin-triplet superconductivity has been a long-standing quest in condensed matter physics since the discovery of superfluidity in liquid 3He. Nevertheless, the mechanism of spin-triplet pairing is much less understood than that of spin-singlet pairing explained by the Bardeen-Cooper-Schrieffer theory or even observed in high-temperature superconductors. Here we propose a versatile mechanism for spin-triplet superconductivity which emerges through a melting of macroscopic spin polarization stabilized in weakly coupled odd-gon (e.g., triangle, pentagon, etc) systems. We demonstrate the feasibility of sustaining spin-triplet superconductivity with this mechanism by considering a new class of quasi-one-dimensional superconductors $A_2Cr_3As_3$ (A=K, Rb, and Cs). Furthermore, we suggest a simple effective model to easily illustrate the adaptability of the mechanism to general systems consisting of odd-gon units. This mechanism provides a rare example of superconductivity from on-site Coulomb repulsion.

Penetration Depth Measurements Distinguish Between Different d-wave States: Umklapp Scattering in Unconventional Superconductors

David Cavanagh

University of Queensland, Brisbane, Australia

We investigate how the superconducting penetration depth depends on the nodal structure of the superconducting gap. Naively, one would expect an exponentially activated temperature dependence in a conventional (s-wave) superconductor, where there are no nodes in the gap, and a power law temperature dependence when there are nodes in the gap. However, the penetration depth is activated in some materials known to have gaps with nodes (most notably the high temperature superconductors or cuprates). We show that this results from the interplay of the nodal structure and the shape of the Fermi surface. We show that recent measurements in organic superconductors of a quasiparticle relaxation rate that varies cubically with temperature can be explained entirely due to the Fermi surface and superconducting gap geometries. In so doing, we identify an application of the penetration depth, and quasiparticle scattering rate, as a more detailed probe of the superconducting gap structure than previously considered. We show how this result can be used to distinguish between proposed superconducting gaps in the quasi-2D organic superconductor κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Br, for which the symmetry of the superconducting order parameter remains a matter of debate.

Surprises in time-reversal symmetry-breaking multiband superconductors

Philip Brydon

University of Otago, Dunedin, New Zealand

Superconductors with spontaneously broken time-reversal symmetry represent an enigmatic state of matter, which has recently attracted much attention due to its nontrivial topological properties. Although all candidate materials for superconductivity with broken time-reversal symmetry are multiband systems (e.g. Sr_2RuO_4, URu_2Si_2, UPt_3, SrPtAs), the relevance of this to the superconductivity is often regarded as incidental. Here we show that the conventional wisdom is mistaken, and that the multiband character can in fact lead to surprising results. Specifically, we demonstrate [1] that for an even-parity nodal superconducting state which spontaneously breaks time-reversal symmetry, the low-energy excitation spectrum generally displays an intrinsic Fermi surfaces of Bogoliubov quasiparticles. This effect arises from the strong spin-orbit coupling, which produces interband pairing potentials, which in turn generate an effective magnetic-field-like term [2], inflating point or line nodes into spheroids or tori, respectively. These Fermi surfaces can be energetically stable [3], and are topologically protected by particle-hole and inversion symmetries.

[1] D. F. Agterberg, P. M. R. Brydon and C. Timm, Phys. Rev. Lett. **118**, 127001 (2017).

[2] P. M. R. Brydon, D. F. Agterberg, H. Menke and C. Timm, arXiv:1806.03773.

[3] H. Menke, C. Timm and P. M. R. Brydon, in preparation.

Superconductivity in carbon allotropes – failure and success with boron doped tetrahedral carbon

David Jamieson

University of Melbourne, School of Physics, Parkville, VIC 3010, Australia

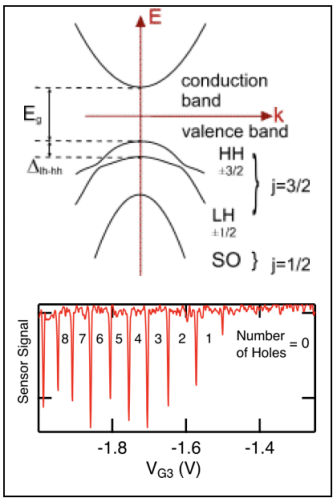
A reappraisal of the theory that describes superconductivity in light elements has led to predictions of high temperature transition temperatures, perhaps as high as 290K. From our previous work on the use of high energy ion implantation in diamond to make n-type material, we commenced an investigation of high fluence light isotope boron implantation ($> 10^{17}$ $10{-}\mathrm{B/cm^2}$) to fabricate buried layers of highly doped p-type diamond. The implantation is done at high temperature (600K) to maintain the diamond crystalline phase owing to the high internal pressure that exists surrounding the end-of-ion-range atom displacements that would otherwise relax the host matrix to graphite. Despite considerable success with this method and the fabrication of highly doped layers with a conductivity well above the metal-insulator transition, thought necessary for superconductivity, no transition to zero resistance was observed down to the base temperature of our measurement system ($\sim$10mK). However, with an alternative method, we were easily able to make superconducting natural boron isotope doped diamond layers by Chemical Vapour Deposition (CVD) on $< 111 >$ oriented diamond substrates with transition temperatures as high as 8K. In these samples we found boron implantation quenched the superconductivity with a partial recovery following annealing. No enhancement in the critical temperature was observed despite the increased boron concentration from the implantation step. Recent reports of quenched high temperature phases of boron doped diamond suggest superconducting transition temperatures as high as 100K. The challenge of unifying these results into a complete theory of superconductivity in this system is yet to be achieved. Nevertheless we propose novel devices making use of this new material for bolometers and SQUID devices.

Semiconductor holes: More spin for quantum information and topological superconductivity

Alex Hamilton

School of Physics, University of New South Wales, Sydney, Australia

Although half of all the transistors in a semiconductor chip use holes, it is only in the past decade that it has been realised how unique the spin properties of holes are. Valence band holes are spin-3/2 particles, which gives them very different properties to spin-1/2 electrons. This talk will describe why holes are so different to electrons, and why there is so much interest in using hole spins for quantum information applications.



Holes in quantum dots are attractive for quantum information applications, because the weak hyperfine coupling to nuclear spins allows long coherence times for spin quantum bits, while the strong spin-orbit interaction enables fast spin manipulation. In our experiments we can control and detect the number, and spin Holes in quantum dots are attractive for quantum information applications, because the weak hyperfine coupling to nuclear spins allows long coherence times for spin quantum bits, while the strong spin-orbit interaction enables fast spin manipulation. In our experiments we can control and detect the number, and spin states, of holes in silicon and gallium arsenide quantum dots, and use the strong spin-orbit interaction to change the Lande g-factor of holes by a factor of two or more [1,2]. These results pave the way to future high speed quantum bits and novel topological quantum states.

[1] R. Li ... A.R. Hamilton, *Pauli Spin Blockade of Heavy Holes in a Silicon Double Quantum Dot*, Nano Lett., 15, 7314 (2015); D.Q. Wang ... A.R. Hamilton, *Anisotropic Pauli Spin Blockade of Holes in a GaAs Double Quantum Dot*, Nano Lett. 16, 7685 (2016).

[2] S.D. Liles ... A.R. Hamilton, *Spin filling and orbital structure of the first eight holes in a silicon metal-oxide-semiconductor quantum dot*, Nature Communications 9, 3255 (2018).

Impurities in quantum matter

Jesper Levinsen

Monash University, School of Physics and Astronomy, Clayton, VIC 3800, Australia

Controllable impurities act as sensitive probes of how few-body correlations emerge in strongly correlated quantum matter. I will discuss recent progress in the understanding of quantum impurity physics, both in the context of ultracold atomic gases and in exciton-polariton systems. In particular, I will focus on the response of a Fermi gas to the sudden introduction of an impurity atom [1-2] and the possibility of observing quantum multi-point correlations in pump-probe spectroscopy of exciton-polaritons [3].

[1] Koschorreck *et al*, Science **354**, 96 (2016).

[2] Parish and Levinsen, Phys. Rev. B **94**, 184303 (2016).

[3] Levinsen, Marchetti, Keeling, Parish, arXiv:1806.10835.

Quantum anomaly of a quasi-two-dimensional Fermi superfluid

Hui Hu

Swinburne University of Technology, Melbourne, Australia

A two-dimensional (2D) harmonically trapped interacting Fermi gas is anticipated to exhibit a quantum anomaly and possesses a breathing mode at frequencies different from a classical scale invariant value $\omega = 2\omega_0$, where ω_0 is the trapping frequency. The predicted maximum quantum anomaly ($\sim 10\%$) has not been confirmed in experiments. Here, we theoretically investigate the zero-temperature density equation of state and the breathing mode frequency of an interacting Fermi superfluid at the dimensional crossover from three to two dimensions. We find that the simple model of a 2D Fermi gas with a single s-wave scattering length is not adequate to describe the experiments in the 2D limit, as commonly believed. A more complete description of quasi-2D leads to a much weaker quantum anomaly, consistent with the experimental observations. We clarify that the reduced quantum anomaly is due to the significant confinement-induced effective range of interactions, which is overlooked in previous theoretical and experimental studies.

Localization of a Polaron in a non-Abelian Aubry-André-Harper model with p-wave superfluidity

Jia Wang

CQOS, Swinburne University of Technology, Melbourne, Australia

We theoretically investigate the behavior of a mobile impurity immersed in a one-dimensional quasiperiodic Fermi system with topological p-wave superfluidity. This polaron problem is solved by using a standard variational approach, the so-called Chevy ansatz. The polaron states are found to be strongly affected by the strength of the quasidisorder and the amplitude of the p-wave pairing. We analyze the phase diagram of the polaron ground state and find four phases: two extended phases, a weakly localized phase, and a strongly localized phase.

Coherent electrical control of a high spin nucleus in silicon

Vincent Mourik

CQC2T, School of Electrical Engineering, University of New South Wales, Sydney, Australia

Nuclear electric resonance (NER) enables transitions of a high spin nucleus by modulating its electrical quadrupole interaction with an electric field. In this talk I will show how we found this effect in our single 123-Sb donor device in silicon, with nuclear spin of size 7/2. We demonstrate, for the first time, coherent, purely electrical control of a single high spin nucleus. I will share our current theoretical understanding of the microscopic mechanism at play in our device, based on analytical approximations and density functional theory calculations.

Photochemical Upconversion Light Emitting Diode (LED): Theory of Triplet Annihilation Enhanced by a Cavity

Laszlo Frazer

Monash University, Australia

Artificial lighting is a widespread technology which consumes large amounts of energy. Triplet–triplet annihilation photochemical upconversion is a method of converting light to a higher frequency. Here, it is shown theoretically that photochemical upconversion can be applied to Watt-scale lighting, with performance closely approaching the 50% quantum yield upper limit. The dynamic equilibrium of an efficient device consisting of an LED, an upconverting material, and an optical cavity is described from optical and thermal perspectives [1].

[1] L. Frazer, Adv. Theory Simul. 1800099 (2018); https://doi.org/10.1002/adts.201800099.

Imaging single realisations of exciton-polariton condensation

Eliezer Estrecho

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Exciton-polariton condensates are open-dissipative macroscopic quantum states in semiconductor microcavities. Subject to pump and decay, and coexistence with incoherent reservoir particles, the fundamental nature of these condensates are still under debate. Moreover, the ultrafast dynamics and extremely short lifetime prevent observation of dynamical and stochastic processes in typical averaged experiments. To gain insight into the condensation process, we implemented a real space imaging of single-realisations of exciton-polariton [1], without averaging over multiple condensate realisations. We found that the condensation is strongly influenced by the incoherent reservoir and that the spatial reservoir depletion is critical for the transition to the ground state. Condensates of photon-like polaritons exhibit strong shot-to-shot fluctuations and density filamentation due to the effective self-focusing associated with the reservoir depletion. In contrast, condensates of exciton-like polaritons display smoother spatial density distributions and are second-order coherent due to efficient energy relaxation. These experimental results are well replicated by theory demonstrating that the single-shot measurements offer an excellent opportunity to study fundamental properties of non-equilibrium condensation in the presence of a reservoir.

[1] E. Estrecho *et al.*, Nat. Commun. **9**, 2944 (2018).

POSTER CONTRIBUTIONS

(Pages 61 – 94)

Poster Session Wednesday focusses on “even numbers”.

Poster Session Thursday focusses on “odd numbers”.

The poster sessions are sponsored by *Oxford University Press.*

1. Distinguishability of disturbances in marginal granular materials

Matthew Pinson

University of Divinity, Parkville, Victoria, Australia

A small, localised perturbation in an elastic material has an effect whose magnitude decays rapidly with distance from the site of perturbation. In an isostatic material, such as a jammed granular packing, the response to a localised perturbation does not decay at large distances. Thus measurements at one location in the material are able to detect the presence of a disturbance at a different location.

My computational work has aimed to answer the question, can such measurements also distinguish between different disturbances? In the case of a rectangular packing with periodic boundary conditions, with the disturbance applied one side, the distinguishability of different disturbances decays exponentially with distance, just as in an elastic material. Yet when a small hole is cut in a large granular packing, distinguishability is almost independent of distance, in contrast with the power-law decay found in an elastic material.

In this talk, I will explain these results and why they are to be generically expected. I'll discuss what isostaticity means, and why it is so important in allowing long-ranged disturbances. I'll also suggest some possible applications of these ideas to fields such as soft robotics.

2. Magnetic Properties of the Cathode Material $Na_4Ni_7(PO_4)_6$ for Sodium-ion Batteries

Qingbo Xia

School of Chemistry, University of Sydney, Australia

The magnetic structures and properties of sodium nickel phosphate $Na_4Ni_7(PO_4)_6$ have been investigated using magnetometry and low-temperature neutron diffraction. According to the magnetic susceptibility analysis and variable temperature neutron diffraction measurements, $Na_4Ni_7(PO_4)_6$ presents three successive antiferromagnetic ordering (Phase I, Phase II, and Phase III) at 9.1 – 17 K, 4.6 – 9.1 K and $<$ 4.6 K with the magnetic ordering vector $[0, 1, 1/2]$, $[0, 2/3, 1/2]$, and $[0.076, 2/3, 1/2]$ refer to the nuclear structure, respectively. The magnetic ordering shows distinct ferromagnetic (FM) Ni2+ strips and anti-ferromagnetic (AFM) arrangements between FM strips. The moment amplitude of all strips is same in Phase I but varies in Phase II. Phase III is an incommensurate one and should have a similar spin arrangement with Phase II. $Na_4Ni_7(PO_4)_6$ has large indirect band gap (2.39eV from DFT calculations and 2.07eV from reflection spectrum analysis). An obvious Na+ conductivity with diffusion activation energy of 1.04 eV was observed from impedance analysis of sintered $Na_4Ni_7(PO_4)_6$ pellet.

3. Characterization and dynamics investigations into undoped and silver doped lanthanum manganite nano particles for hypothermia treatment of cancer cells

Matt Westlake

University Of Wollongong, Australia

Our team is focused on research into the design, production, characterisation and implementation of optimized nanostructured particles for principally the diagnosis (as CT and MRI contrast agents) and treatment of cancer (using radiation, oncothermia and hyperthermia modalities). One magnetic nanoparticle of current interest is Lanthanum Manganite ($LaMnO_3$) and its silver doped counterpart ($La_{1-x}Ag_xMnO_3$). The high effective atomic number and magnetic moment of $LaMnO_3$ [1] makes this material appropriate for the basis of an MRI and CT contrast agent and enhancing radiation therapies. In addition La1-xAgxMnO3 is also considered as a good candidate for hyperthermia cancer therapy [2]. Nanoparticles where synthesised using spray pyrolysis using Lanthanum oxide manganese nitrate, and silver nitrate where used as precursors. Four different doping concentrations where produced (Undoped, 2.5%, 5% and 10%). All of which exhibited the oxygen rich phase and that is under the constraints of the Jahn-Teller distortion.

For the characterization of our samples we used XRD, PPMS, SEM, EDS and SEM. PPMS measurements revealed a change in Curie temperature with silver doping concentrations.Neutron diffraction was performed on ECHIDNA at ACNS/ANSTO at 4K and 300K. Form this data we were not only able to observe the change in crystalline parameters but also observed ferromagnetic peaks at low temperatures for all samples and small ferromagnetic peaks still being present in the 10% doped sample at 300K. A spin-phonon interaction was considered as a cause the change in Currie temperature, hence Time of Flight measurements where conducted on PELICAN at ACNS/ANSTO. With no spin waves being observed the focus was shifted to the phonon evolution with temperature between 1.5K and 300K. The measured density of states did not agree with the results of the bulk material presented in the literature [3].

With no sharp peaks being observed but instead a broad hump over an energy transfer of 0-80meV hence further neutron scattering was conducted on TAIPAN using the Beryllium filter. Results from TAIPAN showed peaks that where no different for the doped and undoped samples.

We hypothesized that the propagation of phonons is strongly impacted by the multiple finite sizes of the nanoparticles. Another hypothesis is linked to the Jahn-Teller lattice distortion due to the oxygen content in our materials that may also hampers the phonon propagation. Cell toxicity

testings and characterisations have begun on both cancer and normal cells in order to quantify the potential applications of our nanoparticles as cancer treatment and imaging agents.

[1] V. Markovich *et al.*, *Effect of particle size on magnetic properties of LaMnO3 nanoparticles*, Super lattices and Microstructures 44 (2008), 476-482.

[2] O.V. Melnikov *et al.*, *Ag - doped Manganite nanoparticles: New materials for temperature-controlled medical hyperthermia*, Journal of Biomedical Materials Research 2008, 1049-1055.

[3] U.D. Wdowik *et al.*, *Phonons in lanthanum manganite: Inelastic neutron scattering and density functional theory studies*, Physical Review B, 2012, 1-6.

4. Reflectance of materials as a function of angle of incidence

J. Archer, H. Zhang, J. Horvat and R. A. Lewis

Institute of Superconducting and Electronic Materials and School of Physics, University of Wollongong, Wollongong NSW 2522

The optical properties of materials are of interest in themselves and also may provide key insights into the electronic and magnetic properties. The variation of reflectance with angle of incidence is readily described by the Fresnel Equations but is more difficult to measure in practice, with most experimental reports restricted to normal incidence. The advent of the scattering-transmittance-absorbance-reflectance geminated-ellipsoidal-mirror technique has opened up experimental opportunities over a wide range of incidence angles. To illustrate the utility and versatility of the technique, we present data from metals (brass), semiconductors (ZnTe), insulators (quartz) and polymers (loaded and unloaded PAM).

5. Unravelling the Iron Coordination in the Mössbauer Spectra of SFCA

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Much of current ironmaking relies on the use of iron ore sinters to utilize iron ore particles which are otherwise too fine for direct feed into a blast furnace. Iron ore sinter is a complex composite material composed of iron ore fines, calcium silicates and glass, bonded by a matrix made from predominantly SFCA (silico-ferrite of calcium and aluminium) and SFCA-I. A typical SFCA found in iron ore sinter may contain 60-76 wt% Fe_2O_3, 13-16 wt% CaO, 3-10 wt% SiO_2 and 4-10 wt% Al_2O_3. SFCA-I is higher in iron (approximately 84 wt% of Fe_2O_3) at the expense of the silica and alumina.

The structure of these SFCA sinter phases is, not surprisingly, very complex [1,2]. In order to try and shed some light on the iron bonding we have taken room temperature Mössbauer spectra of 12 samples with differing compositions. However, the structure contains 11 distinct Fe or (Fe,Al) sites, and one may expect that many of them will be similar. Since the subspectra of each of the phases will be doublets, one is looking for up to 22 separate lines in spectra with very little resolution. Even when one can distinguish bumps in the spectral envelope, it is not clear how to match them into doublets.

We will describe the various approaches, mainly involving spectral subtraction techniques, which we have attempted in trying to analyze these spectra and get an interpretation in terms of the different iron coordinations and how they vary with change in composition.

[1] J. D. G. Hamilton *et al.*, Neues Jahrb. Miner Abh. **161**, 1 (1989).

[2] W. G. Mumme, J. M. F. Clout and R. W. Gable, Neues Jahrb. Miner Abh. **173**, 93 (1998).

6. The Martensitic Transformation in In-Tl Alloys Revisited

T. R. Finlayson[1], **G. J. McIntyre**[2], **K. C. Rule**[2], **A. Saxena**[3]

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The traditional view for the martensitic transformation in In-xat%Tl alloys, for $15.5 \leq x \leq 30.5$ was via a double shear such as: (101) $[\bar{1}01]$; (011) $[0\bar{1}1]$, on the basis of optical microscopy observations [1] and measurements of the $(c_{11} - c_{12})/2$ elastic constant [2]. However, this model was called into question following recent low-ζ measurements of the $[\zeta\zeta 0][\zeta\bar{\zeta}0]$ phonons [3]. An alternative model for the formation of coherent nuclei and growth along conjugate {111} planes was once proposed by Geisler [4]. This model is consistent with some electron diffuse scattering data [5] as well as yielding identical x-ray pole figure results as those for the double-shear mechanism. Appropriate nuclei could be generated by $\langle 111 \rangle \langle 11\bar{2} \rangle$ atomic displacements. To test such an idea we have measured the $[\zeta\zeta\zeta]$T phonon branch for a good quality In-Tl crystal in a recent experiment using the cold-triple axis facility, SIKA, at the OPAL Research Reactor. These results will be reported and compared with the predictions of a model for the dynamical behaviour of coherent interfaces and modulated structures based on topological solitons, first introduced by Barsch and Krumhansl and applied to the twins accompanying martensitic transformations [6].

[1] J.S. Bowles, C.S. Barrett and L. Guttman, Trans. Metall. Soc. AIME, **188**, 1478 (1950).

[2] D.B. Novotny and J.W. Smith, Acta Metall., **13**, 881 (1965).

[3] T.R. Finlayson, G.J. McIntyre and K.C. Rule, Proc. Int. Conf. on Martensitic Transformations: Chicago, eds. A.P. Stebner and G.B. Olsen (The Minerals, Metals & Materials, Society, 2018) p 291.

[4] A.H. Geisler, Acta Metall., **1**, 260 (1953).

[5] T.R. Finlayson, P.Goodman, A. Olsen, P. Norman and S.W. Wilkins, Acta Cryst., **B40**, 555 (1984).

[6] G.R. Barsch and J.A. Krumhansl, Proc. Int. Conf. on Martensitic Transformations (1992), eds. C.M. Wayman and J. Perkins (Monterey Inst. of Adv. Studies, 1993) p 53.

7. Hyperhoneycomb Lattices and the Kitaev Model

Jaan Oitmaa[1] **and R. R. P. Singh**[2]

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The Kitaev model [1] on the 2-dimensional honeycomb lattice is a remarkable spin model where the physics of a Z_2 quantum spin-liquid with emergent Majorana fermions can be rigorously shown. The model has bond-dependent exchange interactions with (xx),(yy) or (zz) coupling on three classes of nearest-neighbour bonds.

Subsequent work [2,3] has identified two types of 3-dimensional lattice ('hyperhoneycomb') which share the 3-fold coordination of the honeycomb lattice, and it has been argued that a Kitaev-type model on these lattices may describe the physics of the materials β-Li2IrO3 and γ-Li_2IrO_3 [4].

We have computed the entropy and specific heat of the Kitaev model on these lattices using high-temperature series expansions. While this method cannot probe the very interesting low temperature region, we find interesting features in the high-temperature thermodynamics which are quite different from those of the usual Heisenberg model.

[1] A. Yu Kitaev, Ann. Phys. (NY) 321,2 (2006).

[2] S. Mandal and N. Surendran, Phys. Rev. B79, 024426 (2009).

[3] I. Kimchi, J.G. Analytis and A. Vishwanath, Phys. Rev. B90, 205126 (2014).

[4] T. Takayama et al., Phys. Rev. Lett. 114, 077202 (2015).

8. A New Class of Frustrated Antiferromagnets - The A-Site Spinels

Jaan Oitmaa

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There have been numerous recent experimental studies of antiferromagnetic materials in which the magnetic ions lie on the A sites of the AB_2O_4 spinel structure [1]. The A-sites of this structure form a diamond lattice, which is bipartite and thus able to support a normal Néel antiferromagnetic state. However, many of the materials show evidence of strong frustration effcts, which implies the presence of strong second-neighbour exchange.

At a classical level the presence of frustrating second-neighbour interactions can stabilize a degenerate manifold of spiral phases [2]. Quantum fluctuations would be expected to lift this degeneracy and select spiral phases with particular wavevectors. Indeed, spirals of several types are observed in different materials, whereas others show no indication of long-range magnetic order down to the lowest temperatures.

In the present work we use series expansions at $T = 0$ to investigate the possible ground states of an $S = 1/2$ J_1–J_2 Heisenberg model on the diamond lattice, and locate the Néel-spiral transition at a critical ratio $(J_2/J_1)_c \sim 0.18$, considerably higher than the classical transition at 1/8. We also consider a tetragonally distorted system, and find that in this case the transition is from Néel to a $(0, 0, q)$ spiral, as realized in the material $CuRh_2O_4$ [3].

[1] AH. Takagi and S. Niitaka, in *Introduction to Frustrated Magnetism*, C.Lacroix, P. Mendels and F. Mila (Eds.) (Springer, 2011).

[2] D. Bergman *et al.*, Nature Physics 3, 487 (2007).

[3] L. Ge *et al.*, Phys. Rev. B 96, 064413 (2017).

9. Phonon kinetics cast a shadow on excitons

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The emission of phonons from electron–hole plasma is the primary limit on the efficiency of photovoltaic devices operating above the bandgap. In cuprous oxide (Cu_2O) there is no luminescence from electron–hole plasma. Therefore, we searched for optical phonons emitted by energetic charge carriers using phonon-to-exciton upconversion transitions. We found 14 meV phonons with a lifetime of 0.916 ± 0.008 ps and 79 meV phonons that are longer lived and overrepresented. It is surprising that the higher energy phonon has a longer lifetime [1].

[1] L. Frazer *et al.*, Physical Chemistry Chemical Physics **19**, 1151 (2017).

10. Electronic transport investigation of redox-switching Azulenequinones/Hydroquinones via first-principle studies

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We investigate the redox-switching for azulenequinones/hydroquinones molecules, categorised as non-alternant hydrocarbons using non equilibrium Green's function (NEGF) methodology alongside density functional theory (DFT). We examine the electronic transport properties of these molecules when subtended between gold electrodes. The current-voltage characteristics display a switching behaviour, with a switching ratio of 35, at low bias, in the 1,5-stable hydroquinone over quinone 2,6-azulene dithiolate, thus showing a redox molecular switch function. Our work provides the theoretical foundations for organic redox switching components in nano electronics circuits.

11. Raman Scattering in Pure and Doped Iridates

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Raman Scattering was used to study the doping evolution of magnetic and lattice excitations in the 2D AFM Sr_2IrO_4 [1,2]. With surface doping this iridate develops Fermi arcs [3] and *d*-wave gap at lower temperatures [4,5]. An intense two-magnon peak reflects strong in-plane exchange coupling, as determined by RIXS [1]. Observed Fano lineshapes in low-energy phonons above Néel temperature suggest unquenched orbital dynamics in Sr_2IrO_4. Upon doping the single- and two-magnon features are broader and softer, resembling results on hole-doped cuprates. Additionally, a higher energy phonon mode acquires Fano lineshape with increased doping, indicating electron-phonon interactions, as expected in doped Mott insulators.

[1] Jungho Kim it et al., Phys. Rev. Lett. 108, 177003 (2012).

[2] B. J. Kim *et al.*, Science 323, 1329 (2009).

[3] Y. K. Kim *et al.*, Science 345, 187 (2014).

[4] Y. K. Kim *et al.*, Nature Physics 12, 37 (2016).

[5] Y. J. Yan *et al.*, Phys. Rev. X 5, 041018 (2015).

12. Structure and Magnetic Frustration of Layered Honeycomb Oxide: $Li_3Co_2SbO_6$

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Over the last decade layered-honeycomb oxides have come to increasing prominence as materials that exhibit an array of interesting properties, including use as electrodes for Li-ion batteries, high electrical conductivity, low temperature magnetic phases, and spin-glass transitions.1 Layered oxides with the general formula AxM_2XO_6 (A = Li, Na; M = transition metals such as Co, Cu, Ni; X = Bi, Sb, Te; $0 \leq x \leq 3$) are termed 'honeycomb' where one third of the transition metal sites are doped with high charge cations such as Sb5+ and Te6+. More recently honeycomb lattices have come under increased scrutiny as Kitaev lattices and potential Quantum Spin Liquids (QSL) as has been suggested for RuCl3 [1].

My project involves the conventional solid-state synthesis of and structural determination of $Li_3Co_2SbO_6$. The focus is on investigating the magnetic behavior of these systems, including antiferromagnetism below the Néel temperature(TN) and magnetic frustration within the 2D honeycomb layers. Magnetic susceptibility data of the honeycomb phase shows low temperature AFM ordering below $T_N = 15\,\mathrm{K}$. Low-temperature neutron powder diffraction will also provide the means to investigate and solve the arrangement of magnetic spins below T_N. The spins are predicted to align in an antiferromagnetic 'zig-zag' arrangement [2].

In addition to the expected honeycomb phase, when excess Li is added during synthesis a partially order rock-salt superstructure forms, crystallizing in the Fdddz space group. The occurrence of this phase was unexpected but preliminary magnetic data shows that this phase has a significantly higher T_N than the honeycomb phase and is magnetic 'soft'. Further structural investigations are also required to determine the nature of any crystallographic phase change.

[1] Y. Meng *et al.*, Mater. Sci. Eng. R Rep. **73**, 52 (2012).

[2] A. Banerjee, C. Bridges, S. Nagler, *et al.*, Nat. Mater. **15**, 733 (2016).

[3] C. Wong, M. Avdeev and C. Ling, Journal of Solid State Chemistry **243**, 18 (2016).

13. Unconventional superconductivity in the 2D Hubbard model

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We employ the weak-coupling renormalization group approach to study unconventional superconducting phases emerging in the extended, repulsive Hubbard model on paradigmatic two-dimensional lattices. Repulsive interactions usually lead to higher-angular momentum Cooper pairing. By considering not only longer-ranged hoppings, but also non-local electron-electron interactions, we are able to find superconducting solutions for all irreducible representations on the square and hexagonal lattices, including extended regions of chiral topological superconductivity. For paradigmatic 2D lattices, we provide detailed superconducting phase diagrams as well as the coupling strengths which quantify the corresponding critical temperatures depending on the band-structure parameters, band filling, and interaction parameters. We discuss the sensitivity of the method with respect to the numerical resolution of the integration grid and show how to efficiently reach a high numerical accuracy [1]. One of our future goals is to study spin orbit coupled superconductors and thus the properties of the superconducting states that may arise in doped topological insulators and Weyl semimetals.

[1] S. Wolf, T. L. Schmidt, S. Rachel, Phys. Rev. B **98**, 174515 (2018); Editors' suggestion.

14. Towards high-temperature topological superconductors

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Chiral p-wave superconductors are a highly desirable phase of matter because they support non-Abelian anyons. These quasiparticles are foundational to building a topological quantum computer. Chiral p-wave superconductors can be constructed using heterostructures based on conventional s-wave superconductors. These devices require very low temperatures and so we are motivated to find an alternative design based on high-temperature superconductors. Here we discuss several candidate systems involving proximity-induced high temperature superconductivity (such as iron-based (pnictide) or cuprate systems).

15. Structural, ^{57}Fe Mössbauer and Magnetic Properties of Non-Stoichiometric Barium M-type Hexaferrites Prepared by the Solid State Reaction Method

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This work entails the investigation of the structural, magnetic, hyperfine and microwave properties of barium M-type hexaferrites using non-stoichiometric mixtures. Barium M-type hexaferrites, $BaFe_{12}O_{19}$, are versatile materials that are utilised in data recording, microwave devices and as permanent magnets [1]. Such M-type hexaferrites with differing iron contents from 8 to 12.5 were prepared using the solid state reaction method by heating mixtures of the starting materials to 1200°C and annealing for 6 hours. Rietveld refinement of the x-ray diffraction patterns was used to confirm M-type hexaferrite as the major phase in all samples. The presence of $BaFe_2O_4$ and other Ba-rich compounds were observed as minor components in the samples with Fe/Ba ratios of 10.5 or less, whereas residual α-Fe_2O_3 was noted for Fe/Ba ratios of 12.25 and 12.50. Samples with Fe/Ba ratios from 11 to 12 were single-phase.

Hysteresis curves obtained at room temperature using a Physical Property Measurement System (PPMS-ACMS) show a decrease in the saturation magnetisation (Ms) for lower Fe/Ba ratios. For example, Ms for the ratio Fe/Ba=8 is 63(1) Am^2kg^{-1} compared to 75(1) Am^2kg^{-1} for the Fe/Ba=12 stoichiometric mixture. Hyperfine parameters were obtained from ^{57}Fe Mössbauer spectroscopy. The magnitudes of the isomer shift which are relatively constant for each Fe site and for all values of the Fe/Ba ratio indicate Fe^{3+} oxidation states.

[1] R.C. Pullar, Prog. Mater. Sci. 57, 1191 (2012).

16. Correlated Paramagnetism and Interplay of Magnetic and Phononic Degrees of Freedom in 3d-5d Coupled La_2CuIrO_6

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Conventional Paramagnetism - a state with finite magnetic moment per ion sans long range magnetic ordering, but with lowering temperature the moment on each ion picks up a particular direction, breaking rotational symmetry, and results into long range magnetic ordering. However, in systems with competing multiple degrees of freedom this conventional notion may easily breaks and results into short range correlation much above the global magnetic transition temperature. La_2CuIrO_6 with complex interplay of spins ($s = 1/2$) on Cu site and pseudo-spin ($j = 1/2$) on Ir site owing to strong spin-orbit coupling provides fertile ground to observe such correlated phenomena. By a comprehensive temperature dependent Raman study, we have shown the presence of such a correlated paramagnetic state in La_2CuIrO_6 much above the long range magnetic ordering temperature (T_N). Our observation of strong interactions of phonons, associated with Cu/Ir octahedra, with underlying magnetic degrees of freedom mirrored in the observed Fano asymmetry, which remarkably persists as high as $\sim 3.5T_N$ clearly signals the existence of correlated paramagnetism hence broken rotational symmetry. Our detailed analysis also reveals anomalous changes in the self-energy parameters of the phonon modes, i.e. mode frequencies and linewidth, below T_N, providing a useful gauge for monitoring the strong coupling between phonons and magnetic degrees of freedom.

17. Synchrotron studies on substitution of R for Sm in $Sm_{1-x}R_xMn_2Ge_2$

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The application of the magnetocaloric effect (MCE) to magnetic cooling is often suggested to have advantages over the conventional refrigeration systems over appropriate temperature regions [1]. The discovery of the ternary intermetallic compounds of the RMn_2Ge_2 series (R = rare-earth) have attracted considerable attention because of the rich variety of interesting phenomenon [2]. Of particular note in this series is the interesting interplay between the magnetism of the layers of 3d and 4f atoms, and the strong dependence of the magnitude of the Mn moment and the magnetic state of the Mn sublattice of Mn-Mn interatomic distances [3].

In this work, the structural properties of $Sm_{1-x}R_xMn_2Ge_2$ (R = Dy, Ho and Er) are studied by combination of high-resolution synchrotron x-ray diffraction over the range 80 K to 500 K and magnetic measurements (5 K to 300 K). The introduction of the second rare-earth, replacing of 7% of the Sm, leads to a reduction in unit cell dimensions and modifications of the phase transition temperatures. Coexistence of canted ferromagnetic (Fmc) and canted antiferromagnetic (AFmc) has been observed in $Sm_{0.93}Ho_{0.07}Mn_2Ge_2$ and $Sm_{0.93}Er_{0.07}Mn_2Ge_2$ whereas in $Sm_{0.93}Dy_{0.07}Mn_2Ge_2$ a single phase only is observed. Our results show that coexistence of Fmc and AFmc phases can be tracked via the change in lattice parameters and unit cell volume as observed using synchrotron based XRD.

[1] N. T Trung, L. Zhang, L. Caron, K. H. J. Buschow and E. Bruk, Applied Physics Letters **96**, 172504 (2000).

[2] B. Emre, S. Aksoy, O. Posth, M. Acet, E. Duman, J. Lindner and Y. Elerman, Physical Review B **78**, 144408 (2008).

[3] P. Kumar. K. G. Suresh, A. K. Nigam, A. Magnus, A. A. Coelho and S. Gama, Physical Review B **77**, 224427 (2008).

18. Crystal and Magnetic structure of the GdNiAl intermetallic compound

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The RNiAl ternary equiatomic intermetallic compounds with R = Rare Earth (except Eu) are a series of interest that exhibits spin-glass behaviour and frustrated magnetism. The first study of the crystal structure of these compounds was reported by Oesterreicher *et al.* in 1967 [1] and 1973 [2]. These were followed by Dwight *et al.* in 1968 [3] and Ferro *et al.* in 1974 [4]. Within this series, an abrupt change in the unit cell parameters upon cooling was reported for GdNiAl at around 205 K. Furthermore, the electric and magnetic behaviours were found to be quite sensitive to this change [5]. GdNiAl orders ferromagnetically around 60 K with further magnetic transitions at 30 K and 14 K being reported [5, 6]. In the present work, the GdNiAl compound is examined using X-ray and neutron diffraction. The Rietveld refinement of the XRD patterns revealed that the change at ∼205 K is actually a transition between two different forms of the ZrNiAl-type structure; with these two forms coexisting over a temperature range of approximately 250 K down to 125 K. The refinement of the GdNiAl neutron diffraction patterns collected from 80 K down to 5 K indicate only the low temperature structural variant, with two different commensurate magnetic contributions: (1) A ferromagnetic component from ∼60 K down to 32.5 ± 1.7 K, and (2) a mixed Ferro/Antiferro-magnetic structure from 32.5 ± 1.7 K down to 5 K. Moreover, no additional transition was observed near 14 K in contrast to the earlier reports.

[1] H. Oesterreicher, W. Wallace, Journal of the Less Common Metals, 13 (1967) 91-102.

[2] H. Oesterreicher, Journal of the Less Common Metals, 30 (1973) 225-236.

[3] A. Dwight, M. Mueller, R. Conner, J. Downey, H. Knott, Trans Met Soc AIME, 242 (1968).

[4] R. Ferro, R. Marazza, G. Rambaldi, Zeitschrift für Metallkunde, 65 (1974) 37-39.

[5] J. Jarosz, E. Talik, T. Mydlarz, J. Kusz, H. Böhm, A. Winiarski, Journal of Magnetism and Magnetic Materials, 208 (2000) 169-180.

[6] F. Merlo, S. Cirafici, F. Canepa, Journal of Alloys and Compounds, 266 (1998) 22-25.

19. New Sample Environment projects and developments at the Australian Centre for Neutron Scattering

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Since the 2018 meeting the sample environment team at the Australian Centre for Neutron Scattering (ACNS) has progressed the design and construction of the new superconducting split-coil magnet, a fast cooling closed cycle cryostat and a new type of closed cycle dilution refrigerator. The first of the two fast cooling cryostats (compact closed cycle dry cryostats, 1.5 K to 800 K) will arrive in early 2019, with a tested sample cool down of 30 minutes. The new magnet is in the final stages of design, including a sample well for our time-of-flight spectrometer PELICAN. The new magnet will have active magnetic shielding and an asymmetric coil design to allow experiments with polarised neutrons. The expected arrival for the magnet is mid-2019. The closed cycle dilution refrigerator will have high cooling power and a very large sample space allowing a new class of experiments with neutrons at ultra-low temperature, arriving in March 2019. Also presented is the development of carbon fibre sample probes to enable faster cooling and quicker sample changes.

20. Microscopic description of exciton-polaritons

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We apply a microscopic description of exciton-polaritons that allows us to go beyond the simple two-level exciton-photon model and to determine the polariton-polariton interactions across a wide range of parameters. We show that the physical band gap is strongly shifted from its bare value in a manner akin to renormalization in quantum electrodynamics. Our results have implications for exciton-polariton systems both at low and at high density.

21. Quantum Dynamics of Impurities Coupled to a Ultra-Cold Fermion Cloud

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We computationally study the Ramsey-interferometry response of an impurity atom immersed in a fermion cloud at finite temperature by the variational approach. Our theoretical result agrees with the one obtained from the functional determinant approach, and our simulation fits very well with recent experiments on dilute ^{40}K atoms in a ^{6}Li ultra-cold Fermion cloud.

22. Lifshitz point quantum critical spin liquids: Heisenberg versus easy-plane frustrated magnets

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We solve the Lifshitz quantum critical problem for an easy plane antiferromagnet exactly. Using the solution we compare critical properties of the easy plane antiferromagnet with similar properties of the Heisenberg antiferromagnet. We find a qualitative difference between these two cases. The difference is in the span of the spin liquid phase: for the Heisenberg case the spin liquid occupies a domain on the phase diagram, for the easy plane case the domain shrinks to a point. The distinct properties are dictated by different character of topological excitations. In the Heisenberg case these are skyrmions, the energy of a skyrmion is zero at the critical point and hence skyrmions are relevant for the criticality. In the easy plane case the topological excitations are vortices, the energy of a vortex remains finite at the critical point and hence they are irrelevant for the criticality.

23. The effect of doping on the formation of stable skyrmion lattices in single crystals of Cu_2OSeO_3

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Copper oxide materials generates huge interest ever since the discovery of superconductivity in YBCO [1]. Recently it was discovered that Cu_2OSeO_3 is capable of hosting skyrmions, a rare skyrmion hosting system as most skyrmion system are metallic. A skyrmion is a topological stable particle-like object with the spin ordered in a vortex like fashion on the order of 50 nm. The skyrmion lattice forms in a narrow temperature and magnetic field range, forming a narrow pocket in the magnetic field-temperature phase diagram. Cu_2OSeO_3 is a multiferroic thus the individual skyrmions could be controlled through application of an external electric field. This offers the potential for a stable, more energy efficient, faster storage and retrieval of information in the application of data storage [2,3].

Here we present the mapping of the skyrmion phase in bulk Cu_2OSeO_3 and Te-doped Cu_2OSeO_3 using SANS instrument QUOKKA at ANSTO. Mapping of the Te-doped showed that an enlarged stability range for the skyrmion phase.

[1] Wu, M. K.; Ashburn, J. R.; Torng, C. J.; Hor, P. H.; Meng, R. L.; Gao, L.; Huang, Z. J.; Wang, Y. Q.; Chu, C. W., Superconductivity at 93 K in a new mixed-phase Y-Ba-Cu-O compound system at ambient pressure. Physical Review Letters 1987, 58 (9), 908-910.

[2] Seki, S.; Kim, J.-H.; Inosov, D.; Georgii, R.; Keimer, B.; Ishiwata, S.; Tokura, Y., Formation and rotation of skyrmion crystal in the chiral-lattice insulator Cu 2 OSeO 3. Physical Review B 2012, 85 (22), 220406.

[3] Fert, A.; Reyren, N.; Cros, V., Magnetic skyrmions: advances in physics and potential applications. Nature Reviews Materials 2017, 2, 17031.

24. An ^{166}Er-Mössbauer study of $ErCrO_4$

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The rare earth (R) chromates $RCrO_4$ have a tetragonal zircon-type structure ($I4_1/amd$, #141). They are of interest because of competing ferromagnetic and antiferromagnetic super-exchange interactions between the 3d (Cr^{5+}) and 4f (R^{3+}) sites, believed to be responsible for the giant magnetocaloric effect observed recently for R = Gd, Dy and Ho [1,2]. Furthermore, the development of ferroelectric order associated with a transition to a non-centrosymmetric $I\bar{4}2d$ structure has been observed around 100 K for R = Sm, Gd and Ho [3].

Earlier Mössbauer spectroscopy investigations of rare earth chromates $RCrO_4$ with R = Gd [4] and Tm [5] were able to be interpreted in terms of a superposition of two sub-spectra (approx. 4:1 area ratio), despite there being only a single crystallographic R(4a) site. In addition, the magnetic transitions exhibited first-order character, which is contrary to bulk magnetic measurements. However, more recent ^{161}Dy-Mössbauer data presented at Wagga 2016 revealed no such puzzling behaviour for $DyCrO_4$.

This is now supported by a new ^{166}Er-Mössbauer spectroscopy investigation of $ErCrO_4$. Moreover, these new local hyperfine interaction data are in close agreement with the low temperature neutron diffraction determination of the local Er^{3+} magnetic moment by Jimenez *et al.* [6]. In view of the discrepancy with the earlier Mössbauer results, we plan to revisit the Gd and Tm systems.

[1] A. Midya *et al.*, Appl. Phys. Lett. **103**, 092402 (2013).

[2] A. Midya *et al.*, J. Appl. Phys. **115** 17E114 (2014).

[3] A. Indra *et al.*, Phys. Rev. B **98** 014408 (2018).

[4] E. Jimenez-Melero *et al.*, J. Phys.: Condens. Matter **18**, 7893 (2006).

[5] E. Jimenez-Melero *et al.*, J. Magn. Magn. Mater. **568**, 272-276 (2004).

[6] E. Jimenez *et al.*, Physica B **350**, e293 (2004).

25. Extremely Large Anomalous Hall Effect in Amorphous Fe-Co-Si Thin Films

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Materials with a non-zero Berry curvature in their electronic band structure can exhibit exotic electronic properties. For instance in the anomalous Hall effect the Berry phase acts like a magnetic field on the electrons in reciprocal space leading to an anomalous Hall voltage with distinct origins from the ordinary Hall voltage [1,2]. In this work a large anomalous Hall effect has been found in amorphous $Fe_{1-y}Co_ySi$ thin films ($0.1 < y < 0.3$) grown with electron-beam co-evaporation. The thin films were fabricated into Hall bars using photolithography and wet etch techniques. An external magnetic field was applied normal to the plane of the hall bar and a current of 1.5 μA was applied. Using an AC lock-in technique with a frequency of 17 Hz a Hall voltage was measured. Previous anomalous Hall effect measurements made in crystalline $Fe_{1-y}Co_ySi$ have concluded that the anomalous Hall voltage is mostly due to spin orbit coupling in the electronic band structure, also known as the intrinsic mechanism [3]. The results shown here also indicate that the intrinsic mechanism may play a substantial role, despite amorphous materials lacking a well-defined reciprocal space. This coincides with very recent theoretical work that found the existence of an anomalous Hall conductivity due to local electron distributions as opposed to macroscopic origins from the solid's reciprocal space [4]. Such a strong anomalous Hall effect suggest these materials may be promising for spintronic applications.

[1] A.K. Nayak, J.E. Fischer, Y. Sun, B. Yan, J. Karel, A.C. Komarek, C. Shekhar, N. Kumar, W. Schnelle, J. Kuebler, C. Felser, S.S.P. Parkin, Science Advances, 2 e1501870 (2016).

[2] H. Chen, Q. Niu, A. H. MacDonald, Phys. Rev. Lett. 112, 017205 (2014).

[3] N. Manyala, Y. Sidis, J.F. Ditusa, G. Aeppli, D.P. Young, and Z. Fisk, Nature Materials 3, 255 (2004).

[4] A. Marrazzo and R. Resta, Physical Review B 95, (2017).

26. Artificial ferromagnetic dot arrays for the critical current enhancement in superconducting $YBa_2Cu_3O_{7-\delta}$ thin films

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Enhancing critical current density in high temperature superconductors is a significant goal and remains a major challenge for different technological applications. One alternative approach to conventional vortex pinning is to pin (localise) the magnetic flux rather than the vortex core. This possibility has not been studied to a large extent. Introducing a lattice of periodic magnetic dots has been shown to be useful for understanding interactions between superconducting vortices and these ferromagnetic arrays, as well as the resultant effects of vortex magnetic pinning dynamics and enhancement of the critical current density (J_c). The high quality superconducting $YBa_2Cu_3O_7$ (YBCO) thin films have been grown by pulsed laser deposition (PLD). Buffered arrays of ferromagnetic dots with different configurations have also been produced by PLD on top of YBCO films. The dimensions of the individual ferromagnetic dots are comparable to the magnetic field penetration depth. Magnetization measurements have been carried out in the YBCO thin films right after deposition and then also after producing the ferromagnetic patterns. The results show that some patterns produce a striking J_c enhancement of up to 24.5% over the high magnetic field range while it achieved 22% in low magnetic field in temperature 10 and 60K respectively. The enhancement is likely due to the flux localisation (pinning) effects, rather than magnetic shielding. The J_c changes seem to depend on rather minor variations in initial pinning and corresponding J_c level of the films.

27. Enhancement of critical current density in $YBa_2Cu_3O_7$ superconducting thin films by changing magnetic environment

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The hybrid systems consisting of superconducting $YBa_2Cu_3O_7$ thin films surrounded by ferromagnetic iron have been investigated. The magnetization measurement has been carried out and critical current densities of the thin films have been extracted. These characteristics have also been compared to the transport current values. The measurements show that the maximum critical current density J_c^{oc} (so called overcritical current densities) can exceed the critical current densities J_c^{bare} obtained in the same thin films without the iron environment. The results show that the critical current density is strongly dependent on the location of the iron environment, dimensions of the iron magnets and distance between the magnets and the thin films. The current density enhancement is attributed to the magnetic interaction between the soft ferromagnetic iron environment and superconducting thin films. This interaction is likely to result in a redistribution of supercurrents in within the films, removing excessive stray fields near the edges of thin films thereby making the supercurrent distribution more homogeneous. This prevents entry of magnetic flux in the form of vortices, hence the critical current densities determined by vortex pinning becomes less relevant. We show that the critical current density can be effectively manipulated by choosing the iron environment.

28. The promise of superconducting boron doped CVD diamond devices fabricated by ion beam techniques

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A reappraisal of BCS theory for light-element superconductors suggests high temperature superconductivity could be achieved in allotropes of boron and carbon compounds. We have grown boron doped diamond epitaxial films on $< 111 >$ oriented diamond substrates by Chemical Vapour Deposition (CVD) with critical temperatures as high as 8 K. Recent reports in the literature present data for a "quenched" high temperature phase of C:B with much higher critical temperatures above 50 K. We have found that our CVD films have a high upper critical magnetic field which makes the material attractive for superconducting device fabrication. Recently we have developed a process in which the superconducting material can be transformed to a normal phase by means of ion irradiation. In the near future we propose combining these two outcomes to fabricate devices such as SQUIDs by employing focused ion beams to directly write structures in the superconducting films.

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29. Negative thermal expansion of Ni-doped MnCoGe around room temperature – magnetic tuning

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Several materials have been shown to exhibit abnormal contraction with increasing temperature; the phenomenon of negative thermal expansion (NTE). Given this special property, NTE materials fulfill important functions in many modern technologies, such as electrodes of fuel cell, organic light-emitting diode (OLED), optical fibre, as well as high precision electronics and optical mirrors [1]. In general, NTE properties are associated with local structural distortions or phase transitions, such as transverse phonon vibration in rigid unit modes, flexible network of metal-organic framework, charge transfer, magneto-volume effect, ferroelectric transition, as well as displacive phase transition. Control or manipulation of NTE properties have become topics of increasing importance over the past two decades. Effective methods to produce materials with NTE properties include chemical doping, nanostructuralization, hydration and applied pressure [1].

Recently, MoCoGe-based compounds were considered as a group of materials that exhibit giant NTE, with this behaviour attributed to the displacive martensitic phase transformation [2]. In this investigation, we reported a new method to manipulate the NTE properties using applied magnetic fields. It is found that doping of 5% Ni on the Mn site could bring about a magneto-structural (MS) coupling in MnCoGe-based compounds. Magnetic-field-dependent neutron diffraction measurements demonstrated that an 8 T magnetic field could suppress the NTE by 31% at 295 K through this MS coupling.

[1] J Chen, L Hu, J Deng, X Xing, Chem. Soc. Rev. 2015, 44, 3522.

[2] Y Y Zhao, F X Hu, L F Bao, J Wang, H Wu, Q Z Huang, R R Wu, Y Liu, F R. Shen, H Kuang, M Zhang, W L Zuo, X Q Zheng, J R Sun, B G Shen, J. Am. Chem. Soc. 2015, 137, 1746.

30. Complex Dusty Plasma device at RMIT

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Dusty plasmas are those that contain particles, often up to the micrometre size scale. It is understood that the growth of such particles is an inherent behaviour of the plasma itself [1]. Once thought to be impurities, this field of study has become an active area of research as scientists attempt to understand the kinetics and structures formed by these particles. In particular, Coulomb crystallisation has been measured in dusty plasmas in the laboratory [2], although such studies are limited to two dimensions. Removal of the force due to gravity allows more complex dusty plasmas to be studied in three dimensions. A wealth of experiments has been conducted on Mir and the International Space Station, observing RF discharges with laser light scattering. A wide range of physical phenomena can be studied in a complex dusty plasma such as magnetisation, temperature, grain-charging, momentum exchange between different plasmonic species, electric potential and fluid behaviour. At RMIT we are building a vacuum chamber equipped with electrodes for the purposes of generating a plasma of a few eV. The plasma will be excited and controlled using argon gas. We present here the current status of the complex dusty plasma device currently under construction at RMIT and our plans to conduct parallel experiments using the PK-4 plasma facility [3] on the International Space Station.

[1] "Complex Dusty Plasmas" Ed. V. Fortov and G. Morfill. CRC Press. (2010)

[2] H. Thomas, G. Morfill, V. Demmel, J. Goree, B. Feuerbacher, D. Moehlmann. Phys. Rev. Lett. 73 (1994)

[3] M. Y. Pustylnik et al. Rev. Sci. Inst. 87 093505 (2016)

31. Space physics research projects at RMIT Physics

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The physics department at RMIT now contains the recently-formed Space Physics Group conducting a number of space-related projects two of which will be outlined in this abstract. Matter on the mesoscopic scale demonstrates a wealth of physical phenomena different from those observed in the macroscopic and atomic regimes. Magnetic interactions, in particular, can be manipulated atom by atom and magnetic dipole effects can be observed in self-agglomerating magnetic nanoparticles. Magnetic properties on this scale are of particular interest to electronics manufacturers as the hunt is always on for reducing the size of computer hard-drives – a magnetic technology that will be in use for many years to come. Ferromagnetic elements such as iron, cobalt and nickel use magnetic forces to self-assemble in suitable conditions. Ni nanoparticles grown in the lab differ from those grown in microgravity [1]. We are modelling the magnetic forces between nanoparticles grown in microgravity to ascertain the limitations on magnetic devices constructed in the laboratory [2]. Sounding rockets offer microgravity periods proportionate to their engine thrust [3]. We are building a magnetised ferrofluid device as the payload on a rocket providing ~ 1 minute of microgravity. Prior to launch in 2019, an operational laboratory model will be fully characterised in order to compare the magnetic behaviour in 1g with that in μg. We will observe the interactions between the magnetic particles and any agglomeration using an on-board camera that will transmit images live during the rocket's flight.

[1] S. Lösch, B. H. Günther, G. N. Iles, U. Büngener. Rev. Sci. Inst. 80 8 (2009).

[2] S. Butler, G. N. Iles. Physics Project, RMIT University (2018).

[3] "ESA User Guide To Low Gravity Platforms". M. Sabbatini. European Space Agency. HSO-K/MS/01/14, Issue 3 Revision 0 (2014).

32. Modelling artificial graphene in an out of plane magnetic field

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Artificial graphene comprises electrons confined to a two dimensional plane with an imposed periodic modulation of triangular symmetry. Such a symmetry implies the existence of Dirac points; points in the Brillouin zone around which the energy is a conical function of momentum. This is observed in graphene and resembles the dispersion of a relativistic massless particle. Artificial graphene provides, in principle, a system that mimics this property of graphene and has parameters which can be controlled (e.g. lattice parameter and modulation strength). For example, the Hofstadter spectrum becomes visible at experimentally accessible magnetic field strength (around 1-3 T) when the lattice parameter is on the order of 100 nm.

We have studied these triangular lattices theoretically when an out of plane magnetic field is applied. This is achieved by exact calculation of the Hamiltonian matrix in the basis of Landau eigenstates. We then perform numerical diagonalisation to obtain the spectrum of the system. Using this numerical method we are able to compute the density of states (around the chemical potential) as a function of magnetic field strength. The density of states calculated at constant electron density shows oscillations periodic in B with a period that corresponds to the addition of one half of the flux quantum to each unit cell.

This may provide a numerically simple way to compute the variation of Hall conductivity with magnetic field. Such calculations can be directly compared to experiments currently being conducted at UNSW.

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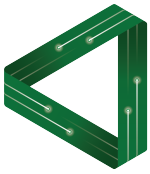

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