# CDT-CMP Annual Conference 2021

## Friday 17th September, 2021

## Chancellor's Building Lecture Theatre 1.11, University of Bath

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| 9:45 am | Arrival | |
| 10:00 am | Introductory Remarks | Prof. Simon Bending |
| Session One, chair Morgan Grant | | |
| 10:15 am | Gallium Oxide: Anisotropic Thermal Transport as seen through Molecular Dynamics | Alexander Petkov |
| 10:30 am | Sculpturing of AlN nanostructures to realise sites for quantum dots | Robert Armstrong |
| 10:45 am | Charge density waves and Fermi-surface reconstruction in the clean overdoped cuprate superconductor Tl2Ba2CuO6+δ | Charles Tam |
| 11:00 am | Break and Poster Session *(Chancellor's Building Level 1 Foyer)* | |
| Invited Academic Speaker, chair Prof. Simon Bending | | |
| 11:30 am | Superconductors and magnets studied by scanning tunnelling microscopy at very low temperatures. | Prof. Hermann Suderow |
| 12:20 pm | Lunch and Poster Session *(Chancellor's Building Level 1 Foyer)* | |
| Invited Industrial Speaker, chair Prof. Stephen Hayden | | |
| 1:30 pm | HTS magnet technology for spherical tokamaks | Matt Bristow |
| Session Two, chair Will Luckin | | |
| 2:00 pm | Characterising Anionic Disorder in Off-Stoichiometric Uranium Oxide Thin Films | Jarrod Lewis |
| 2:15 pm | Optical activity in harmonic Rayleigh scattering | Lukas Ohnoutek |
| 2:30 pm | Optical pulse dynamics in Lithium Niobate nanostructures | Will Rowe |
| 2:45 pm | Break *(Chancellor's Building Level 1 Foyer)* | |
| Session Three, chair Jarrod Lewis | | |
| 3:15 pm | Residual spin susceptibility in superconducting Sr2RuO4 observed by polarised neutron scattering | Alexander N. Petsch |
| 3:30 pm | The Spin Hall effect of CuPt | Oliver McHugh |
| 3:45 pm | Isolation of semiconducting TMD monolayers via laser irradiation | Will Campbell |
| 4:00 pm | Closing remarks, prize-giving and departure/social | Prof. Simon Bending |

Centre for Doctoral Training in Condensed Matter Physics

University of BRISTOL

UNIVERSITY OF BATH

# Oral Contributions

## Invited Speaker

### Superconductors and magnets studied by scanning tunneling microscopy at very low temperatures

Hermann Suderow[1]

[1] *Universidad Autonoma de Madrid, Madrid, Spain*

Scanning Tunneling Microscopy probes the sample down to atomic scale and serves to directly visualize the electronic properties around impurities or defects. Moreover, the bandstructure can be measured above and below the Fermi level with an energy resolution down to a few microeV, orders of magnitude below what can be done using other techniques. It is thus an important complement to bulk and other probes of electronic excitations in solids. I will review the basics of the technique and try to present a few recent and hopefully instructive examples. I will first discuss Fe magnetic impurities in $NbSe_2$ and the series $NbSe_{2-x}S_{1-x}$ ($x<0.8$), explaining how these create localized states inside the superconducting gap through the exchange interaction with Cooper pairs. I will show how these localized states modify vortices, making their density of states electron-hole asymmetric. If time permits, I will then switch over to a heavy fermion material, $URu_2Si_2$ and show how we can create two-dimensional heavy fermions at the surface of this material and how these follow electron-in-a-box quantization by a confining potential.

## Invited Speaker

### HTS Technology for Spherical Tokamaks

Matt Bristow[1]

[1] *Tokamak Energy Ltd*

Tokamak Energy Ltd are a UK company developing spherical tokamaks and novel REBCO-HTS magnet technology in the pursuit of commercial fusion energy in the 2030s. This talk will provide an overview of their magnet development programme, including discussion of fabrication, testing, and multiphysics simulations of HTS coils of increasing scale and complexity.

# Gallium Oxide: Anisotropic Thermal Transport as seen through Molecular Dynamics

Alex Petkov[1]

*[1]CDTR, University of Bristol, UK*

Gallium Oxide is an ultra-wide bandgap semiconductor with high breakdown field (8 MV $cm^{-1}$) but low anisotropic thermal conductivity. As such, thermal management is vital for any potential ultra-high-voltage device based on that material. Molecular Dynamics is one means of simulating the thermal behaviour of gallium oxide on its own as well as in tandem with other materials. Its crystal anisotropy is examined in simulation and is shown to result in different thermal boundary resistances when conjoined to diamond. The adhesion energy between diamond and the different crystallographic orientations of gallium oxide is also found to vary.

# Characterising Anionic Disorder in Off-Stoichiometric Uranium Oxide Thin Films

Jarrod Lewis[1], Jacek Wasik[1], Lottie Harding[1], Steven Conradson[2], Chris Bell[1], and Ross Springell[1]

[1] *University of Bristol, UK*
[2] *Washington State University, USA*

One of the defining characteristics of the uranium oxides is how readily they incorporate additional oxygen atoms into the crystal lattice [1], increasing anion disorder and thus changing the local environment of the uranium atoms. We aim to study the material properties of these highly irregular compounds as a function of oxygen stoichiometry, such as the modulation of majority charge carrier behaviour previously reported [2].

To carry out these experiments, stoichiometrically varied single crystals of the uranium oxides are required, and here we report a fabrication method to produce these samples. Synthesis of stoichiometric fluorite uranium dioxide ($UO_2$), intermediate oxides with distorted fluorite structures ($U_4O_9$/$U_3O_7$), and orthorhombic triuranium octoxide ($U_3O_8$) have been studied using extended x-ray absorption fine structure (EXAFS) measurements. These are presented, in conjunction with in-situ x-ray diffraction measurements taken during oxidation, to support our methodology of obtaining stoichiometrically varied single crystals of the uranium oxides. The presented synthesis process will enable further investigations into the role of interstitial oxygen in the novel physics of the uranium oxides.

[1] R.J. McEachern and P. Taylor, Journal of Nuclear Materials 186-254, 87-121 (1997).
[2] P. Garcia et al., Journal of Nuclear Materials 400, 112-118 (2010).

# The Spin Hall effect of CuPt

Oliver I. W. McHugh[1], Dr. Martin Gradhand[1], Dr. Derek A. Stewart[2]

[1] *University of Bristol, UK*
[2] *Western Digital Corp., USA*

Magnetoresistive random access memory (MRAM) devices are a non-volatile and effective way to store data. However, the current generation of spin transfer torque (STT) based devices suffer issues with high power consumption and large currents reducing the endurance of such devices. However, by utilising the spin-orbit torque (SOT) instead, we can reduce the power usage of these devices and at the same time reduce their switching currents.

SOT-MRAM devices may utilise the spin Hall effect (SHE). One way to quantify the SHE is the spin Hall angle $\theta_{SH}$, which is defined as the ratio of the material's transverse spin conductivity over its longitudinal charge conductivity. Of all the transition elements in their most commonly naturally occurring crystal structures, Pt has the largest $\theta_{SH}$ of ~0.1. Studies have shown that θSH can be enhanced by alloying Pt with other metals [1, 2, 3]. However, there is a shortage of systematic theoretical $\theta_{SH}$ calculations across the entire alloy composition ranges for these alloys. By utilising the spin polarised relativistic Korringa-Kohn-Rostoker SPR-KKR code [4] within the coherent potential approximation (CPA) [5], we can analyse the SHE across the entire alloy composition range for several of these alloys in order to optimise the peak of the $\theta_{SH}$. Aiming to model these peaks analytically with simplified material parameters we plan to reduce the computational cost for such demanding alloy calculations.

In this talk I will focus on our results for the CuPt system to explain the approach used and how we describe such a complicated system and its spin-dependent transport properties.

[1] L. Zhu, D. C. Ralph and R. A. Buhrmann, Phys. Rev. Applied 10, 031001
[2] M.-H. Nguyen, M. Zhao, D. C. Ralph and R. A. Buhrmann, Appl. Phys. Lett. 108, 242407 (2016)
[3] S. Lowitzer, M. Gradhand, D. Ködderitzsch, D. V. Federov and H. Ebert, Phys. Rev. Lett. 106, 056601 (2011)
[4] D. Ködderitzsch, K. Chadova, and H. Ebert, Phys. Rev. B 92, 184415 (2015)
[5] J.S. Faulkner and G.M. Stocks, Phys. Rev. B 21, 3222 (1980)

# Charge density waves and Fermi-surface reconstruction in the clean overdoped cuprate superconductor $Tl_2Ba_2CuO_{6+\delta}$

Charles Tam[1,2], Mengze Zhu[1], Jake Ayres[1], Kurt Kummer[3], Flora Yakhou-Harris[3], John Cooper[4], Antony Carrington[1], Stephen Hayden[1]

[1] *University of Bristol, UK*
[2] *Diamond Light Source, Harwell Campus, UK*
[3] *ESRF, The European Synchrotron, France*
[4] *University of Cambridge, UK*

The overdoped region of the cuprate phase diagram can display a number of unusual features in its electronic transport that are seemingly unconnected to the pseudogap, which strongly influences the electronic structure in the underdoped regime. Here we show that the clean overdoped single-layer cuprate $Tl_2Ba_2CuO_{6+\delta}$ displays charge density wave (CDW) order with a remarkably long correlation length $\xi \approx 200$Å, which disappears above a hole concentration $p_{CDW} \approx 0.265$. As $p$ is decreased through $p_{CDW}$, the Hall number starts to decrease [1], high-frequency quantum oscillations disappear [2] and the T-linear component in the resistivity becomes stronger [3]. We argue that the first two of these phenomena are naturally explained by a Fermi surface reconstruction which accompanies the emergence of the CDW. Our results demonstrate the importance of charge correlations in overdoped cuprates and show that CDWs can occur in cuprates in the absence of the pseudogap.

[1] C. Putzke et al., Nat. Phys. 17, 826 (2021)
[2] P. M. C. Rourke et al., New J. Phys. 12, 105009 (2010)
[3] N. E. Hussey et al., J. Phys. Condens. Matter 20, 123201 (2008)

# Sculpturing of AlN nanostructures to realise sites for quantum dots

Robert Armstrong[1]

[1] *University of Bath, UK*

Quantum dots have applications in quantum information processing (QIP), such as quantum optical computing and quantum key distribution applications. One requirement of such quantum dots is that they act as single photon sources (SPSs), displaying anti-bunching emission phenomena. Essentially, this means the emission of one photon and only one photon, on demand. Whilst very pure SPS's have been demonstrated in material systems such as the III-As, this phenomenon, typically can only be observed at 10K or lower. In contrast, GaN/AlGaN in the III-N's have demonstrated single photon emission (SPE) above room temperature. It is certainly feasible that the effects of quantum confinement could be improved further by the creation of a GaN/AlN quantum dot system. This could therefore lead to even higher temperature SPE.

Whilst research into the so called self-assembled quantum dots, grown via the Stranski-Krastanov growth mode has reached some maturity, applications for actual QIP devices is limited as they are randomly distributed in location and size. The distribution in size will lead to different confinement effects in different dots leading to different energy structures and the random position will hinder device fabrication. As such, site-controlled quantum dots are desirable as, in theory, their position and sizes are predetermined, making integration into devices much easier. Although top-down etching combined with bottom-up regrowth can be used to create AlN nanostructures with sites suitable to house quantum dots, the regrowth step can introduce defective material into the structures.

Another route to create sites for quantum dots is to sculpt nanostructures with sharp features via a purely subtractive process. By combining top-down etching and wet etching, AlN nanopyramids with sharp apices have been realised. In this talk, the realisation of such structures is presented and discussed. Interestingly, the angle of the inclined planes of the nanopyramids are found to be tunable. These structures show promise to house GaN or AlGaN site-controlled quantum dots.

# Optical activity in harmonic Rayleigh scattering

Lukas Ohnoutek[1]

[1] *University of Bath, UK*

Chiral molecules and nanostructures, i.e. those that lack mirror symmetry, have current and potential future applications in pharmaceuticals and new technology [1,2]. Characterisation of the chirality of these substances and materials typically relies on their selective interaction with polarised light – their optical activity. Optical activity in the general sense of the term, demonstrates itself as optical rotation and/or circular dichroism. In the linear optical regime, these effects tend to be weak, which means that measurements require large optical pathlengths. Nonlinear chiral optical effects have been shown to be stronger than their linear counterparts and hold promise for chiral optical characterisation in small volumes.

In this talk, I will discuss optical activity in harmonic Rayleigh scattering. Experimental observation of optical activity in second harmonic Rayleigh scattering was reported for the first time in 2019 [3]. Since then, we have demonstrated that the sensitivity of the method can reach the single nanoparticle level [4]. Very recently, we also observed optical activity in third harmonic Rayleigh scattering in suspensions of Ag nanohelices. Together, these two effects form the foundation of a new spectroscopic method, which can probe chirality in minuscule volumes.

[1] Collins, J. T. et al. Chirality and Chiroptical Effects in Metal Nanostructures: Fundamentals and Current Trends. Adv. Opt. Mater. 5, 1700182 (2017).
[2] Brandt, J. R., Salerno, F. & Fuchter, M. J. The added value of small-molecule chirality in technological applications. Nat. Rev. Chem. 1, 0045 (2017).
[3] Collins, J. T. et al. First Observation of Optical Activity in Hyper-Rayleigh Scattering. Phys. Rev. X 9, 011024 (2019).
[4] Ohnoutek, L. et al. Single Nanoparticle Chiroptics in a Liquid: Optical Activity in Hyper-Rayleigh Scattering from Au Helicoids. Nano Lett. 20, 5792 (2020).

# Optical pulse dynamics in Lithium Niobate nanostructures

William Rowe[1]

[1] *University of Bath, UK*

Our work focuses on modelling the propagation of optical pulses through nanostructured single-crystal devices. At the centre of this research is interaction between intense light and the material Lithium Niobate which produces strong quadratic and cubic nonlinear response in the polarisation field. Our analysis of specific waveguide geometries finds that they support the existence of nonlinear pulses which propagate without dispersion, these are known as solitons. Perturbations to these solitons including dispersive radiation and the Raman effect are introduced, showing that these systems provide a novel platform for efficient frequency conversion. We exploit the guided mode dispersion of our nanostructures by modelling an avoided crossing between two modes. This novel system provides modal group velocity matching between a fundamental frequency and its second harmonic within our structures allowing for low power soliton generation. This work lays the theoretical groundwork for low-power, efficient supercontinuum generation in nanowaveguides made from materials with quadratic nonlinearity.

# Isolation of semiconducting TMD monolayers via laser irradiation

William Campbell[1], Simon Bending[1], Daniel Wolverson[1]

[1] *University of Bath, UK*

2D transition metal dichalcogenide (TMD) semiconductors are of great interest in both academia and industry for a wide range of applications. There is currently a particular focus on the tungsten and molybdenum disulphides and diselenides because their band gaps crossover from indirect to direct as the materials are thinned down from bulk to a single layer. Monolayer TMDs can be readily isolated by mechanical exfoliation as adjacent layers are only held together by weak van der Waals forces but the control over the size of such thin flakes is severely limited. However, Castellanos-Gomez et al. [1] have demonstrated that few-layer $MoS_2$ crystals could be thinned down to monolayers by intense laser irradiation. In contrast, laser irradiation of W-based TMDs has been shown to oxidise the layers, rather than thin them down [2,3].

In this work, we show that both $MoS_2$ and $MoSe_2$ can be reproducibly thinned down to a single monolayer by laser irradiation. We also demonstrate that we can oxidise few-layer $WS_2$ and $WSe_2$ flakes by the laser irradiation process and controllably realise single monolayers embedded in oxide/TMD heterostructures. Detailed pre- and post-irradiation AFM, Raman, photoluminescence and EDX spectroscopy measurements will be presented that confirm these findings. Since the formation of $WS_2/WO_3$ heterostructures has previously been shown to drastically enhance the $WS_2$ PL signal [4], this approach could have important applications. In addition, it may prove to be a useful for surface passivation in order to improve electrical contacts to TMD devices. Finally, we will show that the laser irradiation technique can be extended to other TMD materials, e.g., rhenium diselenide ($ReSe_2$) and disulphide ($ReS_2$), which can also be thinned down to a single monolayer.

[1] Nano Lett. 2012, 12, 6, 3187–3192
[2] Sci. China Technol. Sci. 2020, 63, 1531–1537
[3] Sci Rep 7, 3125 (2017). https://doi.org/10.1038/s41598-017-03254-2
[4] J. Am. Chem. Soc. 2019, 141, 30, 11754–11758

**Virtual presentation**

# Residual spin susceptibility in superconducting $Sr_2RuO_4$ observed by polarised neutron scattering

Alexander N. Petsch[1], Mengze Zhu, Ursula Hansen Bendgaard, Mechthild Enderle, Zhiqiang Mao, Yoshiteru Maeno, Igor I. Mazin, Stephen Hayden

[1]*University of Bristol, UK*

The order parameter of superconducting $Sr_2RuO_4$ was considered to inhere an odd-parity state with an out-of-plane d-vector. While this proposal is now rejected due to the observation of a drop in 17O- NMR Knight shift below the superconducting transition [2] the order parameters are once again under debate. In this talk two polarised neutron scattering experiments [3] on $Sr_2RuO_4$ are presented. A first order transition and a large residual susceptibility at zero field and zero temperature are observed which significantly deviate from NMR results [2]. Further, current developments and plausible states are discussed.

[1] Maeno et al., Nature 372, 532 (1994); Rice et al., J. Phys.: Condens. Matter 7, L643 (1995)
[2] Pustogow et al., Nature 574, 72 (2019); Ishida et al., J. Phys. Soc. Jpn. 89, 034712 (2020); Chronister et al., PNAS 118 (25), e2025313118 (2021)
[3] Petsch et al., Phys. Rev. Lett. 125, 217004; +New data

# Poster Contributions

## Observation of the nonlinear Meissner effect in the iron-based superconductor LaFePO

Morgan Grant[1]

[1] *University of Bristol, UK*

The linear magnetic field dependence of the magnetic penetration depth, known as the nonlinear Meissner effect, is a key consequence of the theory of unconventional superconductivity [1]. The effect occurs due to a shift in the energy of quasiparticle states in the presence of a field induced superfluid velocity. However, its absence in the high temperature cuprate superconductors has remained a mystery for almost 30 years [2]. Presented here are our recent measurements on LaFePO, one of the first successful observations of this effect, following recent results in CeCoIn5 [3]. These results confirm the original theory and further establish the nonlinear Meissner effect as a tool for probing the gap structure of unconventional superconductors.

[1] S. K. Yip & J. A. Sauls, "Nonlinear Meissner effect in CuO superconductors," Phys. Rev. Lett. 69 (1992)
[2] A. Carrington et al., "Absence of nonlinear Meissner effect in YBa2Cu3O6.95," Phys. Rev. B, 59 (1999)
[3] J. A. Wilcox et al., "Observation of the non-linear Meissner effect,"arXiv:2008.04050 (2021)

## Understanding the effect of hydrostatic pressure on the cuprates, and using uniaxial pressure to investigate competition between the CDW and SC

Greg Wallace[1]

[1] *University of Bristol, UK*

It has been shown that hydrostatic pressure increases the Tc of the cuprates, but how it does so is poorly understood. The common understanding is that the dopant atoms are pushed closer to the copper oxide layers as pressure is increased, causing charge to be more effectively transferred from the layers. This would make it analogous to doping. However, This cannot be the whole story, as much higher maximum Tc's are achieved under pressure which cannot be achieved at any ambient pressure doping. The extent to which charge transfer plays a role can be investigated by measuring the thermopower of the cuprates, as the room temperature thermopower is empirically tied to the hole doping in the copper oxide planes. By conducting thermopower measurements under pressure I have been mapping out the doping vs pressure phase diagram, and looking into what other processes might be affecting Tc under pressure.

Another key problem in the cuprates is how the rich variety of correlated electron phases interact with each other, and pressure potentially provides a way to tackle the problem. In addition to increasing Tc, Hydrostatic pressure also decreases the sign change of the Hall effect, suggesting a suppression of the CDW. Recently, it was shown that using x-ray scattering that uniaxial pressure along the a-axis could be used to reduce Tc as well as, crucially, stabilize a CDW order when T c was sufficiently suppressed. Therefore, I will be applying the same strain here and measuring the Hall sign change. This will allow us to further validate, or invalidate, the Hall sign change as a measure of the CDW strength, and therefore whether or not the CDW and superconductivity do indeed compete with each other.

Furthermore, the high magnetic field strain devices that have been designed allow quantum oscillations to be measured under uniaxial strain, allowing us to see the effect strain has on the Fermi surface reconstruction. This in turn will provide evidence of whether it is the CDW that drives the reconstruction, or some other order.

# The Life (and Death) of Hexagonal Uranium Thin Films

Rebecca Nicholls[1], Chris Bell[1], Ross Springell[1]

[1] *University of Bristol, UK*

As many of the light actinides are unstable at room temperature, epitaxial engineering is an appealing alternative to bulk crystal growth. By exploiting strain effects, particular crystal structures can be 'locked-in' via the growth of a thin overlayer onto a lattice matched substrate. Several unusual forms of uranium metal have already been stabilized in this way, and they often display markedly different electronic properties to the three bulk allotropes (orthorhombic α-U, tetragonal β-U and cubic γ-U) [1].

Studies have shown that thin films of a metastable, seemingly hexagonal close-packed phase of uranium can be stabilized on W(110) and Gd(0001) surfaces, but there is not yet consensus on the `bulk' lattice parameters of this phase [3]. This poster contains X-ray diffraction studies of stable W(110)-buffered U metal films, where a warped hexagonal film transitions into a perfectly hexagonal structure after annealing at 950°C. Also presented is the first evidence of room temperature growth of unstable hcp-U onto preferred orientation Cu (111) surfaces. A thickness study of U/Cu films (12.5-300 nm) is presented, and the gradual decay of one of these films into unexpected orientations of α-U has been tracked for the first time.

[1] R. Springell et al. Phys. Rev. B. 89, 245101 (2014)
[2] R. Springell et al., Phys. Rev. B. 78, 193403 (2008)
[3] M. Rafalowicz-Campbell, Stabilisation of High-Temperature Phases of Uranium (2014)

# Quantum oscillations in $YbNi_4P_2$

William Broad[1]

[1] *University of Bristol, UK*

The heavy fermion material $YbNi_4P_2$ exists near a ferromagnetic quantum critical point (FMQCP), which can be accessed by a small substitution of arsenic in to the phosphorus site[1]. Ferromagnetism is rarely seen to remain second order down to zero temperature, and current theory predicts either a change to first order or the appearance of another phase such as antiferromagnetism. The rarity of materials exhibiting a FMQCP makes $YbNi_4P_2$ an important material in the field of quantum criticality. Insight in to the Fermi surface should provide evidence for or against possible theories of how such a QCP can exist, such as whether $YbNi_4P_2$ is quasi-1D[2]. We present Shubnikov-De Haas oscillations as a function of angle. Spin-orbit DFT band structure calculations of $LuNi_4P_2$, with a shifted Fermi energy, are used to begin to interpret the Fermi surface. Our experimental results will be further analysed through the use of renormalised band structure calculations, which collaborators in TU Braunschweig are currently working on.

[1] A. Steppke et. Al, Ferromagnetic Quantum Critical Point in the Heavy-Fermion Metal $YbNi_4(P_{1-x}As_x)_2$, Science 339, 933 (2013).
[2] H. Pfau et. Al, Cascade of magnetic-field-induced Lifshitz transitions in the ferromagnetic Kondo lattice material $YbNi_4P_2$, Phys. Rev. Lett. 119, 126402 (2017).

# Theoretical prediction of new CDW order in electron-doped 2H-$TaSe_2$

Will Luckin[1], Surani Gunasekera[1], Felix Flicker[2], Marcin Mucha-Kruczynski[1]

[1] *University of Bath, UK*
[2] *University of Cardiff, UK*

2H-$TaSe_2$ is a quasi-two-dimensional transition metal dichalcogenide with a commensurate charge-density wave (CDW) state with experimentally-observed ordering vector 2/3M [1]. Within an effective, two-orbital tight-binding framework, we calculate a self-consistent gap function and model the observed gaps forming at the Fermi surface of the material. We calculate the generalized electronic susceptibility, D2, and show that this quantity predicts a change in CDW order from 2/3M to 1/2K as a function of the chemical potential. We discuss features of this theoretical new ordering which could be detected at the Fermi surface by ARPES in doped thin crystals.

[1] Li, Y. W.; Jiang, J.; Yang, H. F.; Prabhakaran, D.; Liu, Z. K.; Yang, L. X.; Chen, Y. L. Folded Superstructure and Degeneracy-Enhanced Band Gap in the Weak-Coupling Charge Density Wave System 2H-TaSe2. Phys. Rev. B 2018, 97 (11), 115118.

# Novel formation route to $H_3S$

Isreal Osmond[1], Sam Cross[1]

[1] *University of Bristol, UK*

Understanding the formation pathways and characterising the superconductivity in the high-Tc hydride compounds is vital for further development of materials with high critical temperatures at lower pressures. Since its original discovery in 2015, sulphur hydride has been synthesised from liquified H2S[1] and from elemental sulphur and hydrogen[2], with both methods having substantial experimental difficulties. Here, we observe a sharp superconducting transition at 200K following the synthesis of superconducting Im-3m SH3 at 155GPa from elemental sulphur and ammonia borane as a hydrogen donor, similar to previous synthesis methods for the high Tc lanthanum and yttrium hydrides [3,4].

[1] A.P. Drozdov, M.I. Eremets et al, Nature 525 (2015)
[2] S. Mozafarri et al, Nature Communications 10 (2019)

# Heavy elements for superconducting spintronics

Syed Akbar Hussain[1], Chris Bell[1], Ross Springell[1]

[1] *University of Bristol, UK*

Materials that possess large spin-orbit coupling (SOC) interaction are of great interest within the field of spintronics to produce devices that utilise the production of spin polarised currents via the spin Hall effect to perform either logic operations or to produce memory devices. On the other hand, it was recently shown that combining materials with large SOC with singlet s-wave niobium (Nb) superconductors creates an avenue to produce spin- polarised triplet Cooper pairs. This new area of research known as super-spintronics, is of great fundamental and practical research because it creates the opportunity of having spin- polarised Cooper pairs exist within ferromagnetic layers forming the next generation of spintronic devices with reduced ohmic losses.

In my research, elemental uranium (U), which is the heaviest naturally occurring element, and hence, a material that has large SOC, will be used to create various U-based heterostructures in combination with ferromagnetic and superconducting Nb thin films. These heterostructures will be used to study the properties of these super-spintronic devices.