Amalfi – Italy – 11-13 April

OSS2018

Oxide Superconducting Spintronic Workshop

OSS2018 is organized within the Core-to-Core Oxide SuperSpin International Network involving experimental and theoretical groups in UK, Japan, South Korea, and Italy. The aim of OSS2018 is to bring together members of the Network along with leading scientists in the field of advanced materials and heterostructures to discuss frontier research in the area of novel superconductivity at oxide superconductor interfaces with magnetic materials.

Through a better understanding of materials processing and properties, one can envision achieving full control over superconducting symmetry at oxide interfaces and to be able to gain access to the fundamental mechanisms underlying the science of advanced oxide interfaces and unconventional superconductivity.

The workshop will cover both theoretical and experimental aspects of the field, with a focus on structural, magnetic and electronic properties of superconducting heterostructures, correlated electron matter, topological insulators and semimetals, surface states of topological systems and their interplay with conventional orders.

Conference Chairs

Mario Cuoco	CNR-SPIN Salerno
Antonio Vecchione	CNR-SPIN Salerno

Program Commitee

Y. Asano	Hokkaido University
Y. Maeno	Kyoto University
T. Noh	IBS & Seoul National Univerity
J. Robinson	University of Cambridge

Scientific Committe

C. Attanasio	University of Salerno
F. Miletto Granozio	CNR-SPIN Napoli
C. Noce	University of Salerno
A. Romano	University of Salerno

Organizing Committee

C. Cirillo	CNR-SPIN Salerno
F. Forte	University of Salerno
P. Gentile	CNR-SPIN Salerno
V. Granata	University of Salerno
M.T. Mercaldo	University of Salerno

Technical Support Committee

S. Abate	CNR-SPIN Salerno
B. Amoruso	University of Salerno
C. D’Apolito	University of Salerno
V. Di Marino	University of Salerno
I. Nunziata	CNR-SPIN Salerno

Wednesday, April 11th

8:45 *OPENING*

Chair: Mario Cuoco

9:00 | **Norman O. Birge** | *Phase-Controllable Josephson Junctions for Cryogenic Memory*

9:40 | **Javier E.Villegas** | *Quasiparticle tunneling electro-resistance in cuprate based junctions*

10:10 | **Mark H. Fisher** | *Superconductivity without inversion and time-reversal symmetries*

10:30 | **Carmine Autieri** | *Role of square planar coordination in the magnetic properties of Na_4IrO_4*

10:50 COFFEE BREAK

Chair: Alfonso Romano

11:20 | **Jan Aarts** | *Triplet supercurrents in Co disks*

11:50 | **Takuto Kawakami** | *Higher Winding Topological Superconductivity in Antiperoskite Oxides*

12:10 | **Shingo Yonezawa** | *Anomalous magnetic-field-angle dependence of the specific heat of Sr_2RuO_4*

12:30 LUNCH

Chair: Antonio Vecchione

14:15 | **Geetha Balakrishnan** | *Single crystals of superconductors, magnetic and topological materials*

Chair: Carmine Attanasio

15:00 *POSTER SESSION 1 min. preview*

16:00 COFFEE BREAK

16:30 *POSTER SESSION*

Chair: Antonio Vecchione

17:00 | **Zaher Salman** | *A local spin probe perspective of magnetism at oxide interfaces*

17:30 | **Angelo Di Bernardo** | *Superconducting devices and unconventional proximity effects with oxides*

17:50 | **Gianni Profeta** | *Weakly-Correlated Nature of Ferromagnetism in Nonsymmorphic CrO_2*

18:10 | **Jose Lado** | *Topological superconductivity with antiferromagnetic insulators*

Thursday, April 12th

Chair: Yoshiteru Maeno

9:00 | **Laurens W. Molenkamp** | *Topological Physics in HgTe-based Quantum Devices*

9:40 | **Eun-Ah Kim** | *Topological Superconductivity in Metal/Quantum-Spin-Ice Heterostructures*

10:10 | **Jason W. A. Robinson** | *Electron pair conversion at oxide superconductor / ferromagnet interfaces*

10:30 | **Wojciech Brzezicki** | *Exotic topological states in hybrid transition metal oxides*

10:50 COFFEE BREAK

Chair: Yasuhiro Asano

11:20 | **Giorgio Sangiovanni** | *Edge state reconstruction from strong correlations in quantum spin Hall insulators*

11:50 | **Antonio Caretta** | *Short vs long range orbital domain dynamics in layered half-doped manganites*

12:10 | **Katsuhisa Taguchi** | *Magnetoelectric effect due to the dynamical theta-term*

12:30 | **Adolfo Avella** | *Defects, Disorder, and Strong Electron Correlations in Orbital Degenerate, Doped Mott Insulators*

12:50 - 12:55 *Malvern Panalytical Presentation*

13:00 LUNCH

14:30 - 16:00 *POSTER SESSION*

16:15 - 18:30 *EXCURSION*

19:30 *SOCIAL DINNER*

Friday, April 13th

Chair: Canio Noce

9:00 | **Jeroen van den Brink** | *The axion electromagnetic response at topological insulator – superconductor interfaces*

9:40 | **Andrea D. Caviglia** | *Tunable superconducting electronics at oxide interfaces*

10:10 | **Holger Thierschmann** | *Transport regimes of a superconducting quantum point contact in the two-dimensional $LaAlO_3/SrTiO_3$ superfluid*

10:30 | **Götz Seibold** | *Theory of the Spin Galvanic Effect at Oxide Interfaces*

10:50 COFFEE BREAK

Chair: Tae Won Noh

11:20 | **Johan Chang** | *Multi-orbital Physics in Oxides*

11:50 | **Yoshiteru Maeno** | *Controlling Oxide Mott Insulator States by DC Current*

12:10 | **Dan G. Porter** | *Magnetic Anisotropy and Orbital Ordering in Ca_2RuO_4*

12:30 LUNCH

Chair: Jason Robinson

14:15 | **Alexey V. Kimel** | *Cold opto-magnetic recording in magnetic dielectrics at the edge of time*

15:00 | **Bohm-Jung Yang** | *Magnetic-field induced topological phases in pyrochlore iridates*

15:30 COFFEE BREAK

Chair: Fabio Miletto-Granozio

16:00 | **Marco Salluzzo** | *The 2DEG at the (001) and (111) $SrTiO_3$ titanate surface and $SrTiO_3$ based heterostructures*

16:30 | **Marco Grilli** | *Intrinsic inhomogeneity in LXO/STO oxide interfaces*

16:50 | **Jinho Lee** | *SI-STM Investigation of a magnetically doped TI using metallic and oxide superonducting tips*

17:20 *CLOSING*

Contents

Wednesday, April 11th

Phase-Controllable Josephson Junctions for Cryogenic Memory

Norman O. Birge
Michigan State University, Dept. of Physics & Astronomy, East Lansing, MI 48824, USA

Large-scale computing facilities and data centers are using electrical power at an ever increasing rate. Projections suggest that a fully superconducting computer would consume considerably less power than conventional semiconductor-based computers, even taking into account the power used in cooling the system to cryogenic temperatures [1]. Building a large-scale memory for such a computer is a challenge. One approach is to use Josephson junctions containing ferromagnetic (F) materials as the basic memory element for such a memory [2,3]. The basic device is a Josephson junction containing two ferromagnetic layers whose magnetization directions can be switched between being parallel or antiparallel to each other, just as in a conventional spin valve. If the thicknesses of the ferromagnetic layers are chosen appropriately, those two magnetic states will result in the junction having a ground-state phase of either 0 or pi. We have demonstrated that such a junction can indeed be controllably switched between the "0" phase state and the "pi" phase state, from measurements of two junctions in a SQUID geometry [4]. An alternative approach is to use a junction containing three ferromagnetic layers, which is designed to carry spin-triplet supercurrent. We have recently realized controllable 0 - pi switching in such a spin-triplet junction [5]. Spin-triplet junctions may have a technological advantage in that the precise thicknesses of the ferromagnetic layers are less critical than in the spin-valve devices. We will report on our continued progress in optimizing both of these systems.

This research is supported by the Office of the Director of National Intelligence (ODNI), Intelligence Advanced Research Projects Activity (IARPA), via U.S. Army Research Office contract W911NF-14-C-0115.

[1] D.S. Holmes, A.L. Ripple, & M.A. Manheimer, IEEE Trans. Appl. Supercond. **23**, 1701610 (2013).
[2] A.Y. Herr & Q.P. Herr, US Patent 8,270,209 (2012).
[3] I. M. Dayton et al., arXiv:1711.01681.
[4] E. C. Gingrich, B. M. Niedzielski, J. A. Glick, Y. Wang, D. L. Miller, R. Loloee, W. P. Pratt Jr., and N. O. Birge, Nature Phys. **12**, 564 (2016).
[5] J.A. Glick, V. Aguilar, A. Gougam, B.M. Niedzielski, E.C. Gingrich, R. Loloee, W.P. Pratt, Jr., and N.O. Birge in preparation.

Quasiparticle tunneling electro-resistance in cuprate based junctions

J. E. Villegas*

Unité Mixte de Physique, CNRS, Thales, Univ. Paris-Sud, Université Paris Saclay, 91767 Palaiseau, France

Ferroelectric tunnel junctions show the so-called tunneling electro-resistance: a large (orders-of-magnitude) reversible switching between (at least) two remnant resistance states, which is produced upon application of voltage pulse across the junction. This effect is the basis of a new class of random access memories and application in the booming field of neuromorphic computing.

While tunneling electro-resistance has been widely studied in junctions with normal-metal electrodes, here we investigate junctions based on oxide superconductors (cuprates), expanding the electro-resistance concept to the tunneling of quasiparticles. Interestingly, this allows us underpin the governing electro-resistance mechanisms, a subject largely debated in the researcher field. We will discuss the new opportunities brought by the use of superconducting electrodes, both for fundamental studies and electronic applications.

Work supported by the ERC grant Nº 64710 and French ANR grant ANR-15-CE24-0008-01 and COST "Nanoscale Coherent Hybrid Devices For Superconducting Quantum Technologies" - Action CA16218 .

***** *in collaboration with V. Rouco, R. El Hage, A. Sander, M. Varela, J. Santamaría, J. Briatico, J . Lesueur, N. Bergeal, A. Barthélémy,*

Superconductivity without inversion and time-reversal symmetries

Mark H. Fischer [1], Manfred Sigrist[1], and Daniel Agterberg[2]
[1]*Institute for Theoretical Physics, ETH Zurich, 8093 Zurich, Switzerland*
[2]*Department of Physics, University of Wisconsin-Milwaukee, Milwaukee, WI 53201*

Traditionally, the symmetries that protect superconductivity are time-reversal and parity. Here, we examine the minimal symmetries protecting superconductivity in two dimensions and find that time-reversal symmetry and inversion symmetry are not required, and having a combination of either symmetry with a mirror operation on the basal plane is sufficient. We classify superconducting states stabilized by these two symmetries, when time-reversal and inversion symmetries are not present, and provide realistic minimal models as examples. Interestingly, several experimentally realized systems, such as transition metal dichalcogenides and the two-dimensional Rashba system fall into this scenario, when subject to an applied magnetic field.

Role of square planar coordination in the magnetic properties of Na_4IrO_4

Carmine Autieri[1], Xing Ming[1,2], Kunihiko Yamauchi[3], and Silvia Picozzi[1]
[1]*Consiglio Nazionale delle Ricerche CNR-SPIN, UOS L'Aquila, Sede Temporanea di Chieti, 66100 Chieti, Italy*
[2]*College of Science, Guilin University of Technology, Guilin 541004, People's Republic of China*
[3]*ISIR-SANKEN, Osaka University, 8-1 Mihogaoka, Ibaraki, Osaka, 567-0047, Japan*

Iridates supply fertile ground for unconventional phenomena and exotic electronic phases. With respect to well studied octahedrally coordinated iridates, we focus our attention on a rather unexplored iridate, Na_4IrO_4, showing an unusual square planar coordination. The latter is key to rationalizing the electronic structure andmagnetic property of Na_4IrO_4, which is here explored by first-principles density functional theory calculations andMonte Carlo simulations. Due to the uncommon square planar crystal field, Ir 5d states adopt an intermediate-spin state with double occupation of the dz^2-r^2 orbital, leading to a sizable local spin moment, at variance with many other iridates.
The square planar crystal-field splitting is also crucial in opening a robust insulating gap in Na_4IrO_4, irrespective of the specific magnetic ordering or treatment of electronic correlations. Spin-orbit coupling plays a minor role in shaping the electronic structure, but leads to strong magnetocrystalline anisotropy. The easy axis perpendicular
to the IrO_4 plaquette, well explained using perturbation theory, is again closely related to the square planar coordination. Finally, the large single-ion anisotropy suppresses the spin frustration and stabilizes a collinear antiferromagnetic long-range magnetic ordering, as confirmed by Monte Carlo simulations predicting a quite low Néel temperature, expected from almost isolated IrO_4 square planar units that act as crystalline building blocks.

- S. Kanungo, B. Yan, P. Merz, C. Felser, and M. Jansen, Angew. Chem., Int. Ed. 54, 5417 (2015).
- Xing Ming, Carmine Autieri, Kunihiko Yamauchi, and Silvia Picozzi Phys. Rev. B 96, 205158 (2017).

Triplet supercurrents in Co disks

K. Lahabi, A. BenHamida, J. Aarts
Huygens – Kamerlingh Onnes Laboratory, University Leiden

Spin-triplet Cooper pairs generated in superconductor-ferromagnet (SF) hybrid structures are the centerpiece of the newly emerging field of superconducting spintronics. Since triplets are generated by magnetically inhomogeneous structures, control over the magnetic structure in principle allows control over both the magnitude and the distribution of the supercurrent. Earlier we reported results on a device which allows such control, based on a cobalt microdisk with a diameter of 1 μm and as salient feature a magnetic vortex at its center [1]. A Nb/Cu/Ni stack, covering two halves of the disk and with a trench in the middle was used to generate triplet pairs in the Co layer. The ferromagnet in the stack has the role of providing magnetic non-collinearity in order to convert singlets to triplets. It turns out, however, that in the disk geometry triplets can also be generated without that extra magnetic layer; the exchange field gradients in the Co layer itself, induced by the circular geometry, are enough to generate a triplet supercurrent which again also depends on the position of the magnetic vortex.

Various examples will be given for the dependence of the (triplet) critical current of such a Nb/Cu/(Co-disk) device as function of in-plane field along different directions.

[1] K. Lahabi *et al*, ‘Controling supercurrents and their spatial distribution in ferromagnets’, Nat. Comm **8**, 2056 (2017).

Acknowledgments
This work is supported by the Netherlands Organisation for Scientific Research (NWO / OCW) as part of the Frontiers of Nanoscience program. Support from COST Action 16218 is also acknowledged.

Higher Winding Topological Superconductivity in Antiperoskite Oxides

Takuto Kawakami[A], Tetsuya Okamura [A], Shingo Kobayashi [B,C], Masatoshi Sato [A]
[A]*Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto 606-8502, Japan*
[B]*Institute for Advanced Research, Nagoya University, Nagoya 464-8601, Japan*
[C]*Department of Applied Physics, Nagoya University, Nagoya 464-8603, Japan*

Antiperovskite oxides have attracted much attention because they have the effective higher spin 3/2 degrees of freedom due to mixture of the spin and orbital angular momentum. In addition, two sets of the spin 3/2 states with *p* and *d* orbital appear near the Fermi level in these materials. According to the first principle calculations [1,2], the band inversion of two orbitals may occur at the center of the Brillouin zone. As a result, normal state of these materials falls into the topological crystalline insulator. Furthermore, very recently, superconducting transition was experimentally observed in the antiperovskite Sr_3SnO with the hole doping [3].

We theoretically investigate possible superconductivity of the antiperovskite oxides [4] in terms of the k・p Hamiltonian describing general systems with spin 3/2 and different parity orbitals. In this system, the higher spin and orbital degrees of freedom enrich variety of Cooper pairs. In particular, the interorbital pairing states are the odd-parity superconductivity even if the gap function is independent on the momentum. Numerically solving the linearized gap equation, we found that a superconducting state belonging to A_{1u} representation of the O_h point group is the most stable in the interorbital ones.

In this presentation, we discuss the topological property of the A_{1u} state [4]. We demonstrate that although the A_{1u} state is the simplest odd-parity superconductivity carrying spin J=0, it is exotic topological superconductivity with higher winding number. Moreover, we clarify that this property originates from the higher spin 3/2. Finally, we show that the surface state of this higher winding topological superconductor exhibits the characteristic twisted dispersion relation associated with multiple helical Majorana fermions.

[1] T. Kariyado and M Ogata, J. Phys. Soc. Jpn **80**, 083704 (2011).
[2] T. H. Hsieh, J. Liu, and L. Fu, Phys. Rev. B **90**, 081112 (2014).
[3] M. Oudah, et al, Nat. Commun. **7**, 13617 (2016).
[4] T. Kawakami, T. Okamura, S. Kobayashi, M. Sato in preparation.

Anomalous magnetic-field-angle dependence of the specific heat of Sr_2RuO_4

Shingo Yonezawa, Tomohiro Kajikawa, Yoshiteru Maeno
Department of Physics, Graduate School of Science, Kyoto University

Sr_2RuO_4 is one of the leading candidates for chiral-*p*-wave spin-triplet superconductors, and thus can be potentially utilized for novel superconducting and spintronics devices. Nevertheless, there are still unresolved issues on its superconducting wavefunction. For example, the superconducting transition in magnetic fields $\boldsymbol{H}$ parallel to the crystalline *ab* plane becomes the first-order transition [1], which cannot be easily described within the ordinary spin-triplet scenario. A recent theory proposed a new scenario that the first-order transition may be due to a novel "orbital pair-breaking" effect [2]. In addition, it is theoretically predicted that in-plane symmetry breaking fields such as magnetic fields or uniaxial strain should cause a phase transition from the chiral $k_x \pm ik_y$ state to a non-chiral state such as k_x, k_y, and $k_x \pm k_y$ states [3]. However, such non-chiral transition has never been observed. Therefore, detailed investigations of bulk superconducting properties are still highly required.

We thus investigate in-plane field-angle φ and field strength H dependences of the specific heat C of a very clean single crystal of Sr_2RuO_4. Anomalous dip structures in $C(\varphi)$ curves are found above a characteristic field $\mu_0 H^* \sim 1.15$ T [4]. This result indicates that the superconducting state for H // [100] and that for H // [110] are thermodynamically distinguishable above H^*. We attribute this behavior to the field-angle-induced switching among non-chiral superconducting order parameters. In this scenario, H^* corresponds to the long-sought transition among chiral and non-chiral states in Sr_2RuO_4. The observed development of in-plane anisotropy in the upper critical field as well as the strong enhancement of quasiparticle excitation above H^* supports this scenario of non-chiral phase formation.

In this presentation, we explain details of our experimental data and discuss the possible non-chiral transition scenario.

[1] S. Yonezawa, T. Kajikawa, and Y. Maeno, Phys. Rev. Lett. **110**, 077003 (2013); J. Phys. Soc. Jpn. **83**, 083706 (2014).
[2] A. Ramires and M. Sigrist, Phys. Rev. B **94**, 104501 (2016).
[3] D. F. Agterberg, Phys. Rev. Lett. **80**, 5184 (1998).
[4] S. Yonezawa *et al.*, in preparation.

Single crystals of superconductors, magnetic and topological materials

Geetha Balakrishnan
Department of Physics, University of Warwick, Coventry CV4 7AL, UK

In order to make progress in the understanding the physics of interesting materials, high quality single crystals are absolutely essential. In recent years several new and exotic classes of materials have been discovered and there is a need for high quality materials for crucial experiments. In this talk I will describe the basic techniques that are generally employed to obtain large and high quality single crystals of a wide variety of materials, ranging from superconductors (intermetallic and non-centrosymmetric, layered transition metal dichalcogenides), magnetic materials (frustrated magnets, low dimensional magnets, and magnetic materials exhibiting skyrmions) and topological insulators (chalcogenides and Kondo Insulators including borides). Special emphasis will be placed on the crystal growth techniques being used for this work at Warwick. I will also provide some examples of the type of investigations performed on the different crystals produced.

A local spin probe perspective of magnetism at oxide interfaces

Z. Salman,[1] M. Radovic,[2] W. A. MacFarlane,[3] T. Prokscha,[1] A. Suter,[1] R. F. Kiefl[4]

[1]*Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland*
[2]*Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland*
[3]*Department of Chemistry, University of British Columbia, Vancouver, BC, Canada V6T 1Z1*
[4]*Department of Physics and Astronomy, University of British Columbia, Vancouver, BC, Canada V6T 1Z1*

One of the big hopes in material science is the capability of producing materials and devices which satisfy a list of requirements/functions on demand. Interfaces between transition metal oxides (TMOs) are proposed as a route to achieve this aim, combining a variety of physical properties and ground states including magnetic, superconducting, insulating and conducting. Few experimental methods are capable of examining local properties of buried interfaces and in a depth resolved manner on nanometer scale. This can be achieved using novel depth resolved low energy μSR and β-NMR techniques. In this talk I will present an investigation of the magnetic properties of thin films and superlattices involving interfaces between the Mott insulator $LaTiO_3$ and the band insulators $SrTiO_3$ and $LaAlO_3$.

In the case of $LaAlO_3/SrTiO_3$ interfaces, we detect a weak spin glass-like ground state, which requires that both, the $LaAlO_3$ and $SrTiO_3$ layers, be over a critical 3-4 unit cell thickness. In contrast, we find that while $LaTiO_3$ undergoes antiferromagnetic ordering when deposited on $LaAlO_3$, it becomes paramagnetic when grown on $SrTiO_3$. Surprisingly, we observe a clear interface proximity effect at the $LaTiO_3/SrTiO_3$ interface, where the magnetism becomes gradually stronger as we probe further away from the interface. The effect is attributed to charge reconstruction effects and the reported metallicity at this interface. These results demonstrate the potential of tunability of the magnetic and electronic properties of a Mott insulator by interface engineering.

Superconducting devices and unconventional proximity effects with oxides

A. Di Bernardo[1], C. Palomares-Garcia[1], S. Komori[1], Y. Yuuki[2], O. Millo[3], H. Alpern[3], G. Livanas[4], G. Divitini[1], P. Gentile[4,5], R. Fittipaldi[4,5], V. Granata[4,5], M.T. Mercaldo[5], A. Romano[4,5], A. Ferrari[6], J. Linder[7], M. Blamire[1], Z. Salman[8], Y. Maeno[2], A. Vecchione[4,5], M. Cuoco[4,5], J.W.A. Robinson[1]

1. Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge CB2 1TP, United Kingdom
2. Department of Physics, Kyoto University, Kyoto 606-8502, Kyoto (Japan).
3. Racah Institute of Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel
5. Department of Physics, University of Salerno, Via Giovanni Paolo II, Salerno 84084, Italy
4. CNR-SPIN, UoS di Salerno, Via Giovanni Paolo II, 132, I-84084 Fisciano (SA), Italy
5. Department of Physics, University of Salerno, Via Giovanni Paolo II, Salerno 84084, Italy
6. Cambridge Graphene Centre, University of Cambridge, 9 JJ Thomson Avenue, Cambridge CB3 0FA, United Kingdom.
7. Department of Physics, Norwegian University of Science and Technology, Trondheim 7491, Norway
8. Paul Scherrer Institute, Villigen 5232, Switzerland.

The development of the field of superconducting spintronics [1] to date has mainly relied on superconductor/ferromagnet (S/F) heterostructures with conventional (*s*-wave) S, where spin-triplet correlations are generated from spin singlets via spin-mixing and spin-rotation processes occurring at S/F interfaces [2]. Evidence for the generation of spin-triplets in such systems has been demonstrated both indirectly via long-ranged proximity effects in S/F/S Josephson junctions [3-4] and directly via spectroscopic measurements [5-7].
To extend the operating range of superconducting spintronics devices up to temperatures above 4.2 K and exploit the rich physics and high-quality interfaces provided by single-crystal metal-oxide materials, our group has recently performed experiments based on the coupling of unconventional superconductivity and magnetism at S/F metal-oxide interfaces. In this context, I will report on the triggering of a *p*-wave superconducting state in single-layer graphene proximity-coupled to the electron-doped high-temperature superconductor $Pr_{1.85}Ce_{0.15}CuO_4$ (T_c ~ 20.5 K) and discuss our most recent experiments that on full-oxide superconducting spin valves with $YBa_2Cu_3O_7$ and the investigation of unconventional proximity effects occurring at $YBa_2Cu_3O_7/Sr_2RuO_4$ interfaces using low-energy muon spectroscopy.

[1] J. Linder, J. W. A. Robinson, *Nat. Phys.* **11**, 307–315 (2015).
[2] F. S. Bergeret, A. F. Volkov, K. B. Efetov, *Phys. Rev. Lett.* **86**, 4096–4099 (2001).
[3] J. W. A. Robinson, J. D. S. Witt, MG Blamire, *Science* **329**, 59 (2010).
[4] R. S. Keizer et al., *Nature* **439**, 825-827 (2006).
[5] A. Di Bernardo et al., *Nat. Comm.* **6**, 8053 (2015).
[6] A. Di Bernardo et al., *Phys. Rev. X* **5** (4), 041021 (2015).
[7] A. Di Bernardo et al., *Nat. Comm.* **6**, 14024 (2017).

Weakly-Correlated Nature of Ferromagnetism in Nonsymmorphic CrO_2

G. Profeta[1], F. Bisti[2,3], V. A. Rogalev[2], M. Karolak[4], S. Paul[5], A. Gupta[5], T. Schmitt[2], G. Güntherodt[6], V. Eyert[7], G. Sangiovanni[4], and V. N. Strocov[2]

1 Dipartimento di Scienze Fisiche e Chimiche and CNR-SPIN, Universita' dell'Aquila, Italy
2 Swiss Light Source, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland
3 ALBA Synchrotron Light Facility, 08290 Cerdanyola del Valle`s, Spain
4 Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland Campus Süd, 97074 Würzburg, Germany
5 MINT Center, University of Alabama, Tuscaloosa, Alabama 35487, USA
6 II. Physikalisches Institut, RWTH Aachen University, 52074 Aachen, Germany 6
7 Materials Design SARL, 42, Avenue Verdier, 92120 Montrouge, France

Chromium dioxide CrO_2 belongs to a class of materials called ferromagnetic half-metals, whose peculiar aspect is that they act as a metal in one spin orientation and as a semiconductor or insulator in the opposite one.
Despite numerous experimental and theoretical studies motivated by technologically important applications of this material in spintronics, its fundamental properties such as momentum- resolved electron dispersions and the Fermi surface have so far remained experimentally inaccessible because of metastability of its surface, which instantly reduces to amorphous Cr_2O_3.

In this work, we demonstrate that direct access to the native electronic structure of CrO_2 can be achieved with soft-x-ray angle-resolved photoemission spectroscopy whose large probing depth penetrates through the Cr_2O_3 layer.

For the first time, the electronic dispersions and Fermi surface of CrO_2 are measured, which are fundamental prerequisites to solve the long debate on the nature of electronic correlations in this material.

Since density functional theory augmented by a relatively weak local Coulomb repulsion gives an exhaustive description of our spectroscopic data, we rule out strong-coupling theories of CrO_2. Crucial for the correct interpretation of our experimental data in terms of the valence-band dispersions is the understanding of a nontrivial spectral response of CrO_2 caused by interference effects in the photoemission process originating from the nonsymmorphic space group of the rutile crystal structure of CrO_2.

Topological superconductivity with antiferromagnetic insulators

Jose Lado and Manfred Sigrist
Institute for Theoretical Physics, ETH Zurich, Switzerland

Two dimensional topological superconductivity has attracted great interest due to the emergence of Majorana modes bound to vortexes and propagating Majorana modes at the edges.[1] However, due to its rare appearance in natural compounds, its experimental replication relies on delicate artificial engineering by combination of helical states, magnetic fields and conventional superconductors [2]. Here we introduce a platform alternative to those mechanisms, by showing that a class of three dimensional antiferromagnets can be used to engineer a two dimensional topological superconductor. Our proposal [3] relies on the appearance of solitonic states at the interface between an antiferromagnet and a superconductor, that become topologically gapped by intrinsic spin-orbit coupling. We show that those interfacial states do not require fine tuning between the superconducting and the antiferromagnetic exchange fields, as its existence is protected by asymptotic boundary conditions. Our findings open the venue of using three dimensional antiferromagnetic insulators as a solid state platform to engineer topological superconductivity.

[1] Steven R. Elliott and Marcel Franz, Rev. Mod. Phys. 87, 137 (2015)
[2] C.W.J. Beenakker, Annual Review of Condensed Matter Physics 4:1, 113-136 (2013)
[3] J. L. Lado and M. Sigrist, in preparation (2018)

Thursday, April 12th

Topological Physics in HgTe-based Quantum Devices

L.W. Molenkamp
Institut für Theoretische Physik und Astrophysik, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Suitably structured HgTe is a topological insulator in both 2- (a quantum well wider than some 6.3 nm) and 3 (an epilayer grown under tensile strain) dimensions.
The material has favorable properties for quantum transport studies, i.e. a good mobility and a complete absence of bulk carriers, which allowed us to demonstrate variety of novel transport effects. One aspect of these studies is topological superconductivity, which can be achieved by inducing superconductivity in the topological surface states of these materials. Special emphasis will be given to recent results on the ac Josephson effect. We will present data on Shapiro step behavior that is a very strong indication for the presence of a gapless Andreev mode in our Josephson junctions, both in 2- and in 3-dimensional structure. An additional and very direct evidence for the presence of a zero mode is our observation of Josephson radiation at an energy equal to half the superconducting gap.
Controlling the strain of the HgTe layers strain opens up yet another line a research. We have recently optimized MBE growth of so-called virtual substrates ((Cd,Zn)Te superlattices as a buffer on a GaAs substrate), that allow us to vary the strain from 0.4% tensile to 1.5% compressive. While tensile strain turns 3-dimensional HgTe into a narrow gap insulator, compressive strain turns the material into a topological (Weyl) semimetal, exhibiting clear signs of the Adler-Bell-Jackiw anomaly in its magnetoresistance. In quantum wells, compressive strain allows inverted energy gaps up to 60 meV.

Topological Superconductivity in Metal/Quantum-Spin-Ice Heterostructures

Jian-Huang She[1], Choong H. Kim[2], Craig J. Fennie[2], Michael J. Lawler[1,3], Eun-Ah Kim [1]

1 Department of Physics, Cornell University, Ithaca, New York 14853, USA
2 School of Applied and Engineering Physics, Cornell University, Ithaca, NY 14853, USA
3 Department of physics, Binghamton University, Vestal NY 13850, USA

In 1987, Anderson proposed a non-phononic mechanism of superconductivity that makes use of a quantum paramagnet (QPM), a system that refuses long-range magnetic order due to quantum fluctuations. This proposal of obtaining a superconductor by doping a QPM that has fractionalized charge and spin carriers is yet to be realized. Here we propose an alternative strategy of using QPM to achieve an unconventional superconductor: use a QPM as a substrate for heterostructure growth of metallic films to design exotic superconductors. By spatially separating the two key ingredients of superconductivity, i.e., charge carriers (metal) and pairing interaction (QPM), the proposed setup naturally lands on the parameter regime conducive to a controlled theoretical prediction. Moreover, the proposed setup allows us to ``customize" electron-electron interaction imprinted on the metallic layer. The QPM material of our choice is quantum spin ice well-known for its emergent "gauge-like" vector potential description of spin frustration. Assuming the metallic layer forms an isotropic single Fermi pocket, we predict that the coupling between dynamic spin fluctuation and the electrons of the metallic layer will drive topological odd-parity pairing. We further present guiding principles for materializing the suitable heterostructure using ab initio calculations and describe the band structure we predict for the case of $Y_2Sn_{2-x}Sb_xO_7$ grown on the (111) surface of $Pr_2Zr_2O_7$. Using this microscopic information, we predict topological odd-parity superconductivity at a few Kelvin in this heterostructure, which is comparable to the T_c of the only other confirmed odd-parity superconductor Sr_2RuO_4.

Electron pair conversion at oxide superconductor / ferromagnet interfaces

J. W. A. Robinson
Department of Materials, 27 Charles Babbage Road, Cambridge CB3 0FS, United Kingdom

Superconducting spintronics is a new area of research, which involves the equilibrium coexistence of spin-polarization and superconducting phase coherence [1]. This field has emerged over the past decade following rapid developments in the understanding and coupling of unconventional superconductivity at superconductor interfaces with magnetic materials. Highlights from my group, include the discovery of singlet-to-triplet pair conversion at magnetically inhomogeneous superconductor / ferromagnet (S/F) interfaces [2], spin-selectivity of triplet pairs in superconducting spin-valves [3], the paramagnetic Meissner effect at an S/F interface [4], and unconventional superconductivity at a d-wave superconductor / graphene interface [5].

In my talk I will overview my group's recent results on coupling unconventional superconductivity and magnetism at oxide S/F interfaces. This will include superconducting spin-valves and density of states measurements in devices containing oxide superconductors and half-metallic ferromagnets.

[1] J. Linder and J.W.A. Robinson. Nature Physics **11**, 307 (2015).
[2] J.W.A. Robinson, J.D.S. Witt, M.G. Blamire**.** Science **329,** 59 (2010).
[3] N Banerjee et al. Nature Com**.** **5**, 3048 (2014).
[4] A Di Bernardo et al., Phys. Rev. X **5**, 041021 (2015).
[5] A Di Bernardo et al., Nature Com**.** **8**, 14024 (2017).

Exotic topological states in hybrid transition metal oxides

Wojciech Brzezicki
International Research Centre MagTop at Institute of Physics, Polish Academy of Sciences, Aleja Lotników 32/46, Warsaw PL-02668, Poland

The interplay between localized 3d and more delocalized 4d states in hybrid transition metal oxides tunes the competition between correlated metallic and Mott-insulating states and can significantly influence the hierarchy between the spin-orbital-lattice degrees of freedom. For instance, doping of the $3d^3/3d^2$ ions in the $4d^4$ host realizes orbital/charge doping scenario [1] lowering the symmetry in the orbital space and strongly modifying spin and orbital order of the host [2]. The intrinsic competition between localized antiferromagnetism and itinerant ferromagnetism can lead to 1D zigzag magnetic structures [3] whose non-symmorphic symmetries stabilize exotic Dirac semi-metal phases with multiple topological protection, unusual degeneracy, hidden symmetry features [4] or even nodal superconductivity in 2D [5]. On the other hand, breaking of the U(1) symmetry due to the d^2 doping in the d^4 system, leads to a pairing mechanism and can open a gap in the orbital spectrum leading to an effective non-uniform Kitaev model [6] in 1D. Such model exhibits an emergent Lorentz symmetry in the parameter space and hosts topologically non-trivial phases even in a disordered case.

[1] W. Brzezicki, M. Cuoco and A.M. Oleś, J. Supercond. Nov. Magn. 30, 129 (2017).
[2] W. Brzezicki, A. M. Oles, and M. Cuoco, Phys. Rev. X 5, 011037 (2015).
[3] W. Brzezicki, C. Noce, A. Romano, M. Cuoco, Phys. Rev. Lett. 114, 247002 (2015).
[4] W. Brzezicki and M. Cuoco, Physical Review B 95, 155108 (2017).
[5] W. Brzezicki and M. Cuoco, arXiv:1711.11233 (2017).
[6] W. Brzezicki, A.M. Oleś, and M. Cuoco, Phys. Rev. B 95, 140506(R) (2017).

Edge state reconstruction from strong correlations in quantum spin Hall insulators

Giorgio Sangiovanni
Institut für Theoretische Physik und Astrophysik, Universität Würzburg,
Am Hubland, D-97074 Würzburg, Germany

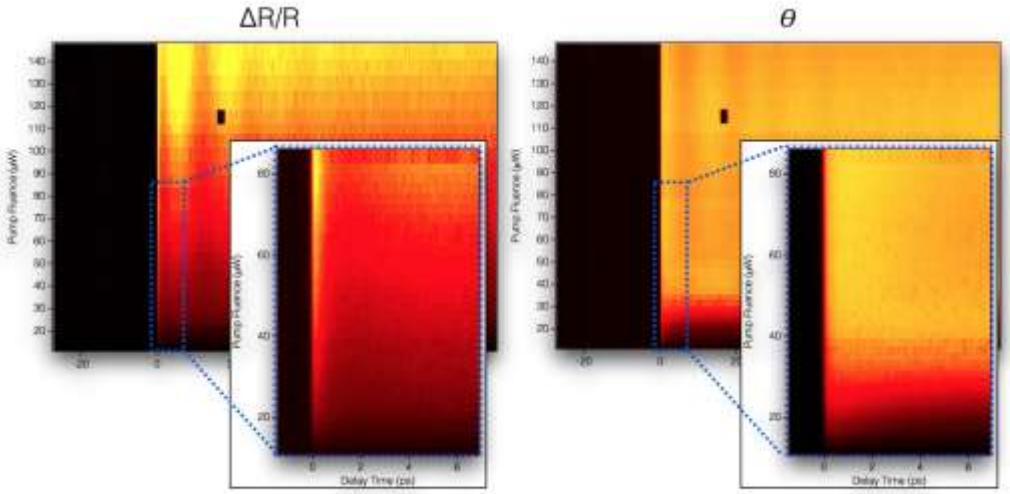
We study the fate of helical edge states in a quantum spin Hall insulators when the whole system is exposed to strong Coulomb interactions. Using dynamical mean-field theory, we show that the dispersion relation of the edge states is strongly affected by Coulomb interactions. In fact, the formerly gapless edge modes become gapped at a critical interaction strength. Interestingly, this critical interaction strength is significantly smaller at the edge than its counterpart in the bulk. Thus, the bulk remains in a topologically nontrivial state at intermediate interaction strengths where the edge states are already gapped out. This peculiar scenario leads to the reconstruction of gapless helical states at the new boundary between the topological bulk and the trivial (Mott insulating) edge. Further increasing the interaction strength triggers the progressive localization on the new boundary, the shrinking of the quantum spin Hall region, and the migration of the helical edge states towards the center of the system. The edge state reconstruction process is eventually interrupted by the Mott localization of the whole sample. Finally, we characterize the topological properties of the system by means of a local Chern marker.

A. Amaricci, *et al*, Phys. Rev. Lett. **114**, 185701 (2015)
A. Amaricci, *et al*, Phys. Rev. B **93**, 235112 (2016)
A. Amaricci, *et al*, Phys. Rev. B **95**, 205120 (2017)

Short vs long range orbital domain dynamics in layered half-doped manganites

Antonio Caretta[1], Barbara Casarin[2], Roberta Ciprian[1], Paul van Loosdrecht[3], Fulvio Parmigiani[1,3] and Marco Malvestuto[1]
1 Elettra-Sincrotrone Trieste S.C.p.A. Strada Statale 14 - km 163:5 in AREA Science Park 34149 Basovizza, Trieste, Italy.
2 Università degli Studi di Trieste, Via A. Valerio 2, 34127 Trieste, Italy.
3 International Faculty, University of Cologne, 50937 Cologne, Germany.

The interplay between charge, orbital, spin, and lattice degrees of freedom is the main cause of the rich phase diagram of manganite compounds. A typical example is colossal magnetoresistance, where a magnetic field strongly affects the material charge transport.
Orbital Ordering (OO) also affects the charge, the spin transport and the magnetic ordering, but it is harder to control externally. This is the reason why, combined with lack of direct experimental techniques, little is known about OO domains, or OO dynamics.
In order to further investigate the OO dynamics in manganite compounds we investigate half-doped layered $Pr_{0.5}Ca_{1.5}MnO_4$, showing robust OO below 320 K, by time-resolved birefringence experiments. Interestingly, we find that our experiments are not consistent with similar time-resolved Resonant X-Ray Diffraction (RXRD) experiments. We observe that ultrafast optical excitation affects birefringence, probing the long range OO, already at very low fluences. Oppositely, high excitation densities are required in RXRD experiments to destroy OO.
This is clear evidence of an ongoing complex domain dynamics, rather than simple OO melting, challenging the classical oversimplified picture of light-induced OO melting.



Time-Resolved reflectivity ΔR/R and birefringence experiments θ. θ saturates already at low fluences, due to the complete reduction of long range order upon photoexcitation.

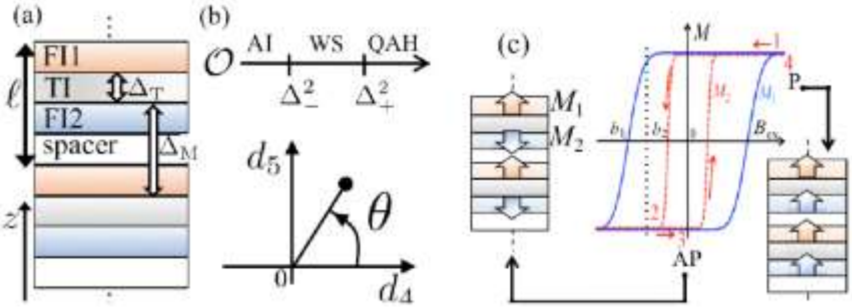
Magnetoelectric effect due to the dynamical theta-term

K. Taguchi[1], T. Imaeda[*], T. Hajiri[§], T. Shiraishi[‡], N. Kitajima[‡], and T. Naka[‡, §§]
1 Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto, 606-8502, Japan
** Department of Applied Physics, Nagoya University, Nagoya, 464-8603, Japan*
§ *Department of Materials Physics, Nagoya University, Nagoya, 464-8603, Japan*
‡ *Department of Physics, Nagoya University, Nagoya, 464-8602, Japan*
§§ *KMI for the Origin of Particles and the Universe, Nagoya, 464-8602, Japan*

Axion, in the context of high energy physics as well as in the cosmological context. Intriguingly, a similar Lagrangian of the dark matter axion can be realized in topological materials, such as magnetic-doped topological insulators (TIs), multilayers of magnetic TIs, Weyl semimetals, and superlattices of TIs. The axion in the topological materials is so-called theta-term. Under the theta-term, unconventional electromagnetic effects, which are unconventional electromagnetic effects, anomalous Hall effects, and chiral magnetic (Magnetic-field induced charge current), have been enthusiastically studied.

Among the theta-term physics, one of the most interesting phenomena is the electromagnetic effects via the dynamics of the theta-term, which could have analogy to the axion. So far, the unconventional optical effect [1] and electric field-induced magnetic field[2] have been discussed under the dynamics of theta-term, whose dynamics is caused by magnetic fluctuations, in materials with breaking time-reversal and inversion symmetry. Then, the time-average of the dynamical theta-term takes zero and its manipulation could be difficult by an external field.

Here, we theoretically study a way to drive the dynamics of the theta-term by an external magnetic field and consider electromagnetic effects via the dynamical theta-term in a magnetic superlattice with breaking both time- and inversion-reversal symmetry. The magnetic superlattice we consider is constructed by a TI and two ferromagnetic insulators (FIs) [FI1/TI/FI2/spacer]_n [Figure (a)], where FI1 and FI2 have perpendicular magnetic anisotropy and a different magnetic coercive field. Here, in order to clearly define the theta-term, we consider axion insulator phase in the superlattice [Figure(b)]. Then, its theta-term can be corresponded to magnetic configurations of the FIs, where parallel (P) and antiparallel (AP) magnetic configurations could be regarded as inversion-reversal symmetry and breaking along the layered direction, respectively [Figure(c)]. These configurations could be controlled by an external magnetic field because of different magnetic coercive fields. Through its control, the nonzero dynamical theta-term is induced during the process AP→P. Furthermore, we found unconventional electromagnetic effects under nonzero dynamical theta-term. Unlike to conventional (static) electromagnetic effects, the dynamical magnetic field-induced charge current and vice verse are generated.



Defects, Disorder, and Strong Electron Correlations in Orbital Degenerate, Doped Mott Insulators

Adolfo Avella[a,b,c] Andrzej M. Oleś[d,e] and Peter Horsch[d]
[a]*Dipartimento di Fisica "E.R. Caianiello," Università degli Studi di Salerno, Via Giovanni Paolo II, 132, I-84084 Fisciano (SA), Italy*
[b]*CNR-SPIN, UoS di Salerno, Via Giovanni Paolo II, 132, I-84084 Fisciano (SA), Italy*
[c]*Unità CNISM di Salerno, Università degli Studi di Salerno, Via Giovanni Paolo II, 132, I-84084 Fisciano (SA), Italy*
[d]*Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany*
[e]*Marian Smoluchowski Institute of Physics, Jagellonian University, Łojasiewicza 11, PL-30348 Kraków, Poland*

We elucidate the effects of defect disorder and e-e interaction on the spectral density of the defect states emerging in the Mott-Hubbard gap of doped transition-metal oxides, such as $Y_{1-x}Ca_xVO_3$. A soft gap of kinetic origin develops in the defect band and survives defect disorder for e-e interaction strengths comparable to the defect potential and hopping integral values above a doping dependent threshold; otherwise only a pseudogap persists. These two regimes naturally emerge in the statistical distribution of gaps among different defect realizations, which turns out to be of Weibull type. Its shape parameter k determines the exponent of the power-law dependence of the density of states at the chemical potential ($k - 1$) and hence distinguishes between the soft gap ($k \geq 2$) and the pseudogap ($k < 2$) regimes. Both k and the effective gap scale with the hopping integral and the e-e interaction in a wide doping range. The motion of doped holes is confined by the closest defect potential and the overall spin-orbital structure. Such a generic behavior leads to complex non-hydrogen-like defect states that tend to preserve the underlying C-type spin and G-type orbital order and can be detected and analyzed via scanning tunneling microscopy.

- A. Avella, P. Horsch, A.M. Oleś; Phys. Rev. B 87, 045132 (2013).
- A. Avella, A.M. Oleś, P. Horsch; Phys. Rev. Lett. 115, 206403 (2015).
- A. Avella, A.M. Oleś, P. Horsch; arXiv:1710.05171.

Friday, April 13th

The axion electromagnetic response at topological insulator – superconductor interfaces

Jeroen van den Brink
Institute for Theoretical Solid State Physics, IFW Dresden, Germany

In three-dimensional topological insulators (TI) the effective Maxwell action acquires a term that is absent in trivial insulators: the axion term. The form of the axion term implies that an electric field can induce a magnetic polarization, whereas a magnetic field can induce an electric polarization. It has been argued that the axion field in TIs can give rise to novel physical effects such as the formation of image magnetic monopoles. While this claim is rather contriversial, I will point out other consequences of the axion electromagnetic response: vortex lines at a superconductor-TI interface induce a variant of the Witten effect so that each flux quantum attains a fractional electrical charge of e/4. This induces an ac Josephson effect in the absence of any external voltage. The fractionally charged quasiparticle also carries a fractional angular momentum.

Tunable superconducting electronics at oxide interfaces

A.D. Caviglia

Kavli Institute of Nanoscience, Delft University of Technology, The Netherlands

Electronic states with unusual properties can be promoted at interfaces between transition metal oxides. A particularly fascinating system is the interface between band insulators LaAlO3 and SrTiO3, which displays conductivity with high mobility [1,2], gate tunable 2D superconductivity [3,4], magnetism and spin-orbit coupling [5,6]. We will discuss transport experiments that demonstrate nanoscale and control of electronic phases at oxide interfaces.

We will consider charge transport in nanostructures at oxide interfaces defined electrostatically via patterned gates. We develop a new paradigm for the creation of superconducting circuit elements, where local gates enable in-situ creation and control of Josephson junctions. We demonstrate that electrostatic gating enable reliable tuning of both the normal-state resistance and the critical (Josephson) current of the constrictions. The conductance and Josephson current show mesoscopic fluctuations, and the analysis of their amplitude enables the extraction of the phase coherence and thermal lengths [7, 8].

Using this approach, we realize the first superconducting quantum interference devices (SQUIDs) at the LaAlO3/SrTiO3 interface. These gate-defined SQUIDs are unique in that the entire device is made from a single superconductor with purely electrostatic interfaces between the superconducting reservoir and the weak link [9].

[1] A. Ohtomo, H. Y. Hwang Nature 427, 423 (2004).
[2] A.D. Caviglia, et al. Phys. Rev. Lett. 105, 236802 (2010).
[3] N. Reyren, et al. Science 317, 1196 (2007).
[4] A.D. Caviglia et al. Nature 456, 624 (2008).
[5] A.D. Caviglia et al. Phys. Rev. Lett. 104, 126803(2010).
[6] M. Diez et al. Phys. Rev. Lett. 115, 016803 (2015).
[7] S. Goswami et al. Nano Letters 15, 2627(2015).
[8] A.M. Monteiro et al. Nano Letters 17, 715 (2017).
[9] S. Goswami et al. Nature Nanotechnology 11, 861 (2016).

Transport regimes of a superconducting quantum point contact in the two-dimensional $LaAlO_3/SrTiO_3$ superfluid

Holger Thierschmann[1], Emre Mulazimoglu[1], Nicola Manca[1], Srijit Goswami[1,2], Teun M. Klapwijk[1,3] and Andrea D. Caviglia[1]

[1]Kavli Institute of NanoScience, Faculty of Applied Sciences, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands
[2]QuTech, Delft University of Technology, Lorentzweg 1, 2628 CJ Delft, The Netherlands
[3]Physics Department, Moscow State Pedagogical University, Moscow 119991, Russia

The observation of the quantized resistance in a quantum point contact formed with split gates in GaAs/AlGaAs heterostructures is one of the hallmark experiments of quantum transport. In these experiments the transmission could be controlled electrostatically and the devices represented in an ideal manner equilibrium reservoirs which are connected only through a few electron mode channel with certain transmission coefficients. Ever since these early days it has been a long standing goal to achieve similar experimental conditions also in superconductors, only achieved in mechanically tunable break junctions of conventional superconducting metals. There, however, the Fermi wavelength is so short that it leads to a mixing of quantum transport with atomic orbital physics.
Here we demonstrate the formation of a superconducting quantum point contact (SQPC) with split gate technology in the two-dimensional (2D) superfluid at the $LaAlO_3/SrTiO_3$ (LAO/STO) interface. We utilize the unique tunability of the 2D superconductor by means of electric field to control the transmission through the constriction. When we tune the constriction from open to pinch-off through the action of the gates, we distinguish three regimes of transport. 1) SQPC, for which only a few quantum transport channels carry the supercurrent. 2) Superconducting charge island which couples strongly to the equilibrium reservoirs. 3) Charge island which exhibits a discrete spectrum of energy states, being weakly coupled to the reservoirs. Our experiments highlight the unusual properties of the two dimensional superfluid at the LAO/STO interface. They demonstrate the feasibility of a new generation of all-superconducting quantum transport devices.

Theory of the Spin Galvanic Effect at Oxide Interfaces

Götz Seibold, Sergio Caprara*, Marco Grilli*, Roberto Raimondi#

Institut für Physik, BTU, Cottbus-Senftenberg, P.O. Box 101344, 03013 Cottbus, Germany
** Dipartimento di Fisica Università di Roma ‚La Sapienza', Piazzale Aldo Moro 5, I-00185 Roma, Italy*
#Dipartimento di Matematica e Fisica, Università Roma Tre, Via della Vasca Navale 84, 00146 Rome, Italy

The manipulation of spin degrees of freedom in order to generate a charge current and the inverse process are at the heart of spintronics devices. A prominent example is the spin-galvanic effect (SGE) where a charge current is converted into a non-equilibrium spin polarization. The SGE occurs in systems with strong spin-orbit coupling, in particular two-dimensional electron gases which lack inversion symmetry perpendicular to the gas plane and which are usually described with the Rashba hamiltonian. The situation is more complex in $LaAlO_3/SrTiO_3$ interfaces where the interplay between inversion asymmetry and atomic spin orbit coupling is at the heart of strong Rashba interactions.
Recently, two experiments [1,2] have demonstrated a strong SGE at such interfaces by generating a strong non-equilibrium spin-polarization at the interface and detecting the resulting charge current. The reported spin-to-charge efficiency is more than order of magnitude larger than in conventional metallic layers which suggests the LAO/STO interface as a promising system for spintronic devices.Here, we analyze the SGE for oxide interfaces within a tight-binding three-band model for the Ti t_{2g} orbitals, where we take into account atomic spin-orbit coupling and the lifting of inversion symmetry at the interface. As a result, the model displays an interesting variety of effective spin-orbit couplings in the individual bands that contribute differently to the spin-to-charge interconversion [3]. As a first step we derive an effective continuum Hamiltonian describing three spin-orbit split bands close to the Gamma point. Within such an effective model, we study the SGE by using the standard Green-function diagrammatic impurity technique for disordered electron systems. Our analytical approach is supplemented by a numerical evaluation of the Kubo formula for the spin polarization-charge current response. The numerical treatment evidences the importance of interband scattering processes, not taken into account in the effective model. Within the numerical treatment we also investigate the influence of disorder and temperature, which turns out to be crucial in providing an appropriate description of the experimental data.

[1] E. Lesne et al., Nature Materials **15**, 1261 (2016).
[2] Q. Song et al., Nature Communications, 10.1038 (2016).
[3] G. Seibold et al., Phys. Rev. Lett. **119**, 256801 (2017).

Multi-orbital Physics in Oxides

D. Sutter[1], C. E. Matt[1], T. Neupert[1], J. Chang[1], Y. Sassa[2], M. Kim[3,4], A. Georges[3,4,5], R. Fittipaldi[6,7], V. Granata[6,7], A. Vecchione[6,7]

1 Physik-Institut, Universität Zürich, Winterthurerstrasse 190, Zürich CH-8057, Switzerland
2 Department of Physics and Astronomy, Uppsala University, Uppsala S-75121, Sweden
3 College de France, Paris Cedex 05 75231, France
4 Centre de Physique Théorique, Ecole Polytechnique, CNRS, Univ Paris-Saclay, Palaiseau 91128, France
5 Department of Quantum Matter Physics, University of Geneva, Geneva 4 1211, Switzerland
6 CNR-SPIN, Fisciano, Salerno I-84084, Italy
7 Dipartimento di Fisica 'E.R. Caianiello', Università di Salerno, Fisciano, Salerno I-84084, Italy

This talk will presents recent synchrotron experiments on ruthenates and cuprates. In particular, angle resolved photoemission spectroscopy (ARPES) experiments reporting orbital hybridization at the Fermi level of La-based cuprates will be presented [1,2]. It will be followed by a discussion of the electronic structure of the Mott insulator Ca_2RuO_4 [3,4].

[1] C.M. Matt *et al.*, arXiv:1707.08491 (Accepted in Nat. Comm. 2018)
[2] M. Horio *et al.*, arXiv:1802.01376
[3] D. Sutter *et al.*, Nature Communications **8**, 15176 (2017)
[4] D. Sutter *et al.*, to be submitted February-2018

Controlling Oxide Mott Insulator States by DC Current

Yoshiteru Maeno, Chanchal Sow, Ryo Numasaki, Yukie Takasuka, Shingo Yonezawa, Fumihiko Nakamura*

Department of Physics, Kyoto Univ., Kyoto, Japan
** Kurume Institute of Technology, Kurume, Japan*

In the study of novel oxide superconductivity in hybrid structures, non-superconducting oxides with controllable properties may serve important roles. In this talk, we show that DC current can be a powerful control parameter to induce exotic states of oxides in the vicinity of the Mott transition.

We first present on novel phenomena in the Mott insulator Ca_2RuO_4, for which DC electric field and current not only trigger the insulator to metal transition but also maintain the metallic state down to low temperatures [1]. When the electric current is not very strong, the Mott-gap can be tuned to disappear gradually and giant *diamagnetism* emerges [2]. We will describe the "Mott semimetal" model to describe such a state. In addition, we will present on another ruthenium oxide which exhibits a very similar diamagnetism under DC current.

This work is done in collaborations also with S. Kitamura, T. Oka, K. Kuroki, D. Shibata, T. Yoshida, N. Kikugawa and S. Uji.

[1] F. Nakamura *et al.*, Sci. Rep. **3**, 2536 (2013).
[2] C. Sow *et al.*, Science **358**, 1084 (2017).

Magnetic Anisotropy and Orbital Ordering in Ca_2RuO_4

D.G. Porter[1], S. Di Matteo[2], V. Granata[3,4], R. Fittipaldi[3,4], A. Vecchione[3,4], and A. Bombardi[1, 5]

1. *Diamond Light Source Ltd., Harwell Science and Innovation Campus, Didcot, Oxfordshire, OX11 0DE, UK*
2. *Univ Rennes, CNRS, IPR (Institut de Physique de Rennes) - UMR 6251, F-35000 Rennes, France*
3. *CNR-SPIN, Fisciano, Salerno I-84084, Italy*
4. *Dipartimento di Fisica E.R. Caianiello, Universita' di Salerno, Fisciano, Salerno I-84084, Italy*
5. *Department of Physics, University of Oxford, Parks Road, Oxford OX1 3PU, United Kingdom*

Ca_2RuO_4 (CRO), the close neighbour of the famous superconductor Sr_2RuO_4 displays surprisingly different behaviour to its neighbour, exhibiting insulating behaviour below an irreversible metal-insulator transition at T_{MI} = 357K. In the insulating state CRO displays orbital ordering at T_{OO} = 260K and antiferromagnetic ordering below T_N = 110K. This material has been extensively investigated but still questions remain regarding the nature of the insulating state and whether Mott gaps are opened only on certain orbitals, or whether the insulating state is a result of purely structural change. While recent publications have tended towards the latter of these possibilities, previous results observing varying orbital concentrations with temperature have not been explained. Here we will discuss the recent literature on this compound and, using new resonant x-ray results and a systematic approach to understanding the different contributions to these signals will attempt to resolve the differences in the literature about the electronic and magnetic structures in this material.

Cold opto-magnetic recording in magnetic dielectrics at the edge of time

A.V. Kimel

Radboud University, Institute for Molecules and Materials, Nijmegen, The Netherlands

The ability to switch magnets between two stable bit states is the main principle of modern data storage technology. Controlling the magnetic state of media with the lowest possible dissipations and simultaneously at the fastest possible time-scale is a new and great challenge in fundamental and applied magnetism.

A femtosecond laser pulse is one of the shortest stimuli in contemporary condensed matter physics. Exciting magnets on a time-scale much faster than characteristic times of atomic, orbital and spin motion can steer magnetization dynamics along yet unexplored non-thermodynamic routes. In my talk I would like to discuss these routes for the cases of magnetic dielectrics [1-3] and propose the ways to design a medium for ultrafast and cold opto-magnetic recording.

[1] D. Afanasiev, B. A. Ivanov, A. Kirilyuk, Th. Rasing, R. V. Pisarev, and A. V. Kimel,Control of the Ultrafast Photoinduced Magnetization across the Morin Transition in DyFeO3, *Phys. Rev. Lett*. **116**, 097401 (2016).
[2] S. Baierl, M. Hohenleutner, T. Kampfrath, A. K. Zvezdin, A. V. Kimel, R. Huber, R. V. Mikhaylovskiy, Nonlinear spin control by terahertz-driven anisotropy fields, *Nature Photonics* **10**, 715 (2016).
[3] A. Stupakiewicz, K. Szerenos, D. Afanasiev, A. Kirilyuk, and A. V. Kimel, Ultrafast nonthermal photo-magnetic recording in a transparent medium, *Nature* **542**, 71–74 (2017).

Magnetic-field induced topological phases in pyrochlore iridates

Taekoo Oh[1,2] , Hirosaki Ishizuka[3] , and Bohm-Jung Yang[1,2]
Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea
IBS-CCES, Seoul National University, Seoul 08826, Korea
Department of Applied Physics, University of Tokyo, Bunkyo, Tokyo 133-8656, Japan

Pyrochlore iridate antiferromagnet is the first material in which Weyl fermions are predicted to exist in condensed matters. Although several promising experimental results, which may be originated from Weyl fermions, have been reported, an unambiguous proof for the presence of the Weyl semimetal in this system has not been achieved yet. In this work, we theoretically propose that applying magnetic field is a promising way to realize the Weyl semimetal phase in pyrochlore iridates since magnetic field not only can expand the range in which the Weyl semimetal phase exists but also can create new topological semimetal phases across additional band inversion. Here the central role is played by the presence of a quadratic band crossing with four-fold degeneracy in the paramagnetic band structure that exists before the time-reversal symmetry is broken. Due to the large degeneracy at the crossing point and the strong spin-orbit coupling, the degenerate states at the crossing point can show the anisotropic Zeeman effect, which can be described by the so-called q-term in the Luttinger Hamiltonian, as well as the conventional isotropic Zeeman effect. Moreover, the relative magnitude of these two different Zeeman terms can be controlled by varying the orientation of the four spins within the unit cell, which, in turn, manipulates the topological property of the iridium band structure. Such an intriguing behavior occurs due to the fact that the unit cell is composed of a cluster of four spins in a tetrahedron whose magnetic mulipole moments can be continuously tuned by varying the spin orientation within the unit cell. We propose the most general topological band structure under magnetic field, which would facilitate the experimental discovery of novel topological semimetal states in pyrochlore iridates.

The 2DEG at the (001) and (111) $SrTiO_3$ titanate surface and $SrTiO_3$ based heterostructures

M. Salluzzo

CNR-SPIN Complesso Monte Santangelo, via Cinthia, Napoli (Italy)

The steady dimensional scaling of components poses new challenges in microelectronics. Two-dimensional (2D) systems characterized by entirely new properties and functionalities, are emerging as the material choice for the next Spintronic and Quantum Electronics revolution.

Among 2D-systems, 2D electron gases (2DEGs) formed at the interface between insulating transition metal oxides, like $LaAlO_3$ and $SrTiO_3$, are characterized by a unique combination of high-mobility [1], strong spin-orbit coupling (SOC) [2], superconductivity (SC) [3,4], interfacial 2D-magnetism [5], and theoretically predicted topological states [6].

Recently our group realized a spin-polarized 2DEG by inserting few unit cells of antiferromagnetic $EuTiO_3$ between $LaAlO_3$ and $SrTiO_3$ oxides [7]. In this contribution, I will present an overview of the most recent studies performed by our team on the electronic and magnetic properties of the 2DEGs formed at the LAO/STO and delta-doped LAO/ETO/STO (001) and (111) interface. New insights on the phenomena were obtained from a combination of magnetotransport experiments and x-ray-spectroscopy, including polarized x-ray absorption spect-roscopy, angle resolved photoemission and resonant inelastic x-ray scattering.

[1]A. Ohtomo and H. Y. Hwang, Nature **427**, 423 (2004); Y. Z. Chen, et al. Nature Communications **4**, 1371 (2013).
[2] A.D. Caviglia, et al., Phys. Rev. Lett. **104**, 126803 (2010).
[3]N. Reyren, et al., Science **317**, 1196 (2007);
[4]A. D. Caviglia, et al., Nature **456**, 624 (2008).
[5] N. Pavlenko, et al. , Phys. Rev. B **86**, 064431 (2012).
[6] D. Doennig, W. E. Pickett, and R. Pentcheva, Phys. Rev. Lett. **111**, 126804 (2013); Manali Vivek, Mark O. Goerbig, and Marc Gabay, Phys. Rev. B 95, 165117 (2017).
[7] D. Stornaiuolo *et al*. Nature Materials **15,** 278–283 (2016).

Intrinsic inhomogeneity in LXO/STO oxide interfaces

M. Grilli[1], N. Bergeal[2], J. Biscaras[3], S. Caprara[1], S. Hurand[2], C. Feuillet-Pama[2], J. Lesueur[2], R. Raimondi[4], N. Scopigno[1], G. Seibold[5], G. Singh[2]

[1]*Dipartimento di Fisica, Università di Roma `Sapienza', Rome, Italy*
[2]*LPEM UMR8213/CNRS—ESPCI ParisTech, Paris, France*
[3]*Institut de Minéralogie, de Physique des Matériaux et de Cosmochimie, Paris, France*
[4]*Dipartimento di Matematica e Fisica, Università Roma 3, Rome, Italy*
[5]*Institut fur Physik, BTU Cottbus-Senftenberg, Cottbus, Germany*

Several experiments in oxide interfaces like $LaAlO_3/SrTiO_3$ or $LaTiO_3/SrTiO_3$ (LXO/STO), indicate that the 2D electron gas is inhomogeneous on the nanoscopic scale [1]. The self-consistent electrostatic electron confinement at the interface has recently been proposed as a possible mechanism of electronic instability [2]. This leads to an electronic phase separation (EPS) establishing a possible intrinsic origin for the inhomogeneous character of LXO/STO superconductors. The inhomogeneous character of the 2DEG, entailing an inhomogeneous Rashba Spin-Orbit Coupling opens the way to two interesting issues: i) a novel superconducting quantum criticality, and ii) inhomogeneous spintronics.

i) The unusual quantum critical behaviour of superconductivity in LXO/STO [3,4] has been investigated by tuning temperature, gating, and/or magnetic field finding a novel type of SC-to-metal quantum criticality related to the vanishing of the critical temperature of the EPS [5], where the critical superconducting fluctuations are coupled to and driven by the strong dynamical density fluctuations. Also the superfluid stiffness displays different behaviours in different regions of the phase diagram controlled by the competition between electron pairing and phase coherence [5].

ii) The softness of the 2DEG favours the engineering of specific structures where the RSOC can be modulated at the submicrometric scale. This opens the way to a variety of 2DEG structures, where spin-Hall effect [6], Spin-Galvanic Effect [7], and Majorana Fermions, could be obtained.

[1] S. Caprara, et al., Phys. Rev. B (Rapid Communications) **88**, 020504(R) (2013); S. Caprara, *et al.*, Superc. Sc. and Tech**. 28**, 014002 (2015.
[2] N. Scopigno, *et al.*, Phys. Rev. Lett. **116**, 026804 (2016).
[3] J. Biscaras, *et al.*, Nature Materials **12**, 542 (2013).
[4] S. Caprara, N. Bergeal, J. Lesueur, and M. Grilli, Phys.: Condens. Matter **27** 425701 (2015)
[5] G. Singh, *et al.*, Nat. Commun. **9**, 407 (2018).
[6] G. Seibold, S. Caprara, M. Grilli and R. Raimondi EPL, **112** 17004 (2015).
[7] G. Seibold, S. Caprara, M. Grilli, and R. Raimondi, Phys. Rev. Lett. **119**, 256801 (2017).

SI-STM Investigation of a magnetically doped TI using metallic and oxide superonducting tips

J. -J. Kim[1], J. H. Yoo[1], K. S. Lee[1], S. H. Joo[1], M. S. Park[1], S. J. Park[1], Genda Gu[2], and Jinho Lee[1]

[1]*CCES-IBS, Seoul National University, Seoul, Korea (the Republic of)*
[2]*CMP&MS Brookhaven National Laboratory, Upton, NY, United States.*

Magnetic impurities break a time-reversal symmetry of the topological insulator(TI) and generate a back scattering between the surface states. As a result, a gap opens at the time-reversal invariant momentum and the electronic properties of TI's undergo a drastic change – emergence of the ferromagnetic surface states and chiral edge states on the domain walls[1]. We investigated the local density of states(LDOS) of Cr doped TI ($Cr_{0.08}(Bi_{0.1}Sb_{0.9})_{1.92}Te_3$) using the spectroscopic imaging scanning tunneling microscopy(SI-STM) both in real and momentum space. Density of states (DOS) near the Fermi energy shows an spectroscopic feature reminiscent of the Fano line-shape suggesting an involvement of the local spins. The quasi-particle interference shows a trace of the back scattering which is prohibited in the undoped TI's. We also tried to apply Scanning Josephson Tunneling Microscopy (SJTM) technique[2] to create an SC-TI interface and the result will be discussed in this talk.

[1]K. Yasuda et al., *Science* **358**, 1311 (2017).
[2]M. H. Hamidian, S. D. Edkins, S. H. Joo et al., *Nature* **532**, 343 (2016).

POSTER SESSION

P01 - Nonlinear conduction phenomena in Ca_2RuO_4

G. Avallone, C. Cirillo, R. Fittipaldi, V. Granata, A. Ubaldini, A. Avella, A. Vecchione and C. Attanasio
CNR-SPIN Salerno and Dipartimento di Fisica "E.R. Caianiello," Università degli Studi di Salerno, Fisciano (Sa) I-84084, Italy

Mott insulators show compelling and intriguing quantum phenomena when they are perturbed by various stimuli. Metal-insulator transition is a prominent example.
In this work we report our findings about nonlinear conduction phenomena in two kinds of Mott insulators. Pure single crystals of Ca_2RuO_4 (CRO) with and without metallic Ru inclusions have been investigates.
With the aim of inducing a metal-insulator transition, we fed the samples by using both current and voltage bias. We analysed the different behaviour of the samples and the role of metallic Ru inclusions in CRO.
Moreover, the resistivity as a function of temperature with different driving currents has been measured. In both kinds of samples we show that an increase in the bias current results in a conductibility gain.

P02 - Superconducting critical temperature in NbRe/Co bilayers

C. Cirillo, M. Caputo, C. Attanasio
CNR-SPIN Salerno and Dipartimento di Fisica "E.R. Caianiello", Università degli Studi di Salerno, Italy

It is now generally accepted that the combined presence of Spin Orbit Coupling (SOC) and magnetic field can give rise to unconventional superconducting pairing. In particular, there are theoretical evidences that SOC can act as a generator of long-ranged spin triplet pairs in superconductor/ferromagnetic (S/F) hybrids [1,2], which are sensitive to the orientation of the exchange field. However, in the literature only the physics arising either when the SOC and the exchange field coexist in the F layer [1,2], or in presence of interfacial SOC [2-4] was explored.
In this work we present instead preliminary results obtained on NbRe/Co bilayers, where NbRe is a non-centrosymmetric superconductor with a significant SOC [5,6]. We studied the behavior of the superconducting critical temperature (T_c) as a function of the thickness of the Co layer (d_{Co}), which reveals a very slow decay if compared to the well-known $T_c(d_F)$ dependence obtained in the case of conventional Nb/Co control samples.

[1] I.V. Tokatly and F.S. Bergeret, Phys. Rev. Lett. **110**, 117003 (2013)
[2] H.T. Simensen and J. Linder, Phys. Rev. B **97**, 054518 (2018)
[3] N. Baneriee, J.A. Ouassou, Y. Zhu, N.A. Stelmashenko, J. Linder, and M.G. Blamire, arxiv:1709.03504v2
[4] N. Satchell and N.O. Birge, arxiv: 1803.01965v1
[5] C. Cirillo, R. Fittipaldi, M. Smidman, G. Carapella, C. Attanasio, A. Vecchione, R.P. Singh, M.R. Lees, G. Balakrishnan, and M. Cuoco, Phys. Rev. B **91**, 134508 (2015)
[6] C. Cirillo, G. Carapella, M. Salvato, R. Arpaia, M. Caputo, and C. Attanasio, Phys. Rev. B **94**, 104512 (2016)

P03 - Fabrication routes towards Josephson planar devices based on YBCO

F. A. Cuéllar, D. Sánchez Manzano, G. Orfila, A. Rivera and J. Santamaría
University Complutense of Madrid, Group Complex Materials Physics (GFMC). Pl. de Ciencias 1, Facultad de Ciencias Físicas, Departamento de Física de Materiales, 28040, Madrid, Spain

It is well established that oxygen content is a critical parameter determining the YBCO transition temperature [1]; and as an extreme case of oxygen depletion, YBCO can be led towards the insulating state. Also the oxygen chain damage and oxygen-loss by several ways of YBCO removal have been extensively studied [2][3].
We show here the different template-patterning and etching techniques we have studied, looking for an optimal fabrication protocol towards planar-geometry Josephson Junctions based on YBCO/ Mx / YBCO, where Mx stands for paramagnetic metallic or ferromagnetic metallic oxide. Prior to device fabrication, we check thin film quality with X-Ray Diffraction, X-Ray Reflectivity and Resistivity vs. Temperature measurements. We explore the device behavior by means of magneto-electrical characterization and Atomic Force Microscopy.
Our objective is to obtain a reliable and repeatable fabrication protocol that allows us to measure the ferromagnetic Josephson effect [4] in YBCO /manganite /YBCO systems, in a planar-device geometry.

[1] M. Faley *et al.*, "Variation of the Oxygen-content in YBa2Cu3O7-x films deposited by high oxygen-pressure DC-Sputtering," *IEEE Trans. appllied Supercond.*, vol. 3, no. 1, pp. 2–4, 1993.
[2] S. K. Mishra *et al.*, "Lithographic patterning of superconducting YBCO films," *J. Supercond.*, vol. 5, no. 5, pp. 445–449, 1992.
[3] M. S. Louis-Weber, V. P. Dravid, and U. Balachandran, "Facts and artifacts of TEM specimen preparation for YBa2Cu3O7-xsuperconductors," *Phys. C Supercond. its Appl.*, vol. 243, no. 3–4, pp. 273–280, 1995.
[4] F. S. Bergeret, a. F. Volkov, and K. B. Efetov, "Josephson current in superconductor-ferromagnet structures with a nonhomogeneous magnetization," *Phys. Rev. B*, vol. 64, p. 134506, 2001.

P04- Spin-orbit coupling effects on the electronic properties of CrAs

Carmine Autieri[1], Giuseppe Cuono[2], Filomena Forte[2,3] and Canio Noce[2,3]
[1] *Consiglio Nazionale delle Ricerche CNR-SPIN, UOS L'Aquila, Sede Temporanea di Chieti, I-66100 Chieti, Italy*
[2] *Dipartimento di Fisica "E. R. Caianiello", Università degli Studi di Salerno, I-84084 Fisciano (Salerno), Italy*
[3] *Consiglio Nazionale delle Ricerche CNR-SPIN, UOS Salerno, I-84084 Fisciano (Salerno), Italy*

Superconductivity under pressure was recently discovered in CrAs, the first Cr-based superconductor. CrAs exhibits a helimagnetic transition at $T_N \sim 265$ K and the bulk superconductivity with $T_C \sim 2$ K appears at the critical pressure $P_C \sim 8$ Kbar, where the magnetic transition is completely suppressed [1].
To investigate the electronic and magnetic properties of this compound, we have used a method that combines the tight-binding approximation and the Löwdin down-folding procedure [2].
Here, we analyze the effect of the spin-orbit coupling (SOC) on the electronic properties of the material, considering both the Cr 3*d* and the As 4*p* origin for the SOC.
The main effect of this interaction on the energy spectrum is the removal of the degeneration of the bands along XS and TZ lines (the k_y directions) of the orthorhombic Brillouin zone.

We also estimate that the SOC splitting of the bands along these directions is of the order of 10^{-2}eV. Moreover, under the action of the SOC term, the sheets of the Fermi surface are reduced from four to three.
This result suggests that the effect of the SOC interaction at the Fermi level is mainly due to the 3*d* orbitals of the chromium.

[1] W. Wu, J. Cheng, K. Matsubayashi, P. Kong, F. Lin, C. Jin, N. Wang, Y. Uwatoko and J. Luo, *Nat. Commun.* **5** 5508 (2014).
[2] C. Autieri, G. Cuono, F. Forte and C. Noce, *J. Phys.: Condens. Matter* **29** 224004 (2017).

P05 - Spin-orbit coupling at superconducting interfaces with Pt/Co for triplet Cooper pair creation

J.M. Devine-Stoneman, S. Komori, J.W.A. Robinson
Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Rd, Cambridge CB3 0FS, United Kingdom

Where previous studies on long-range triplet component (LRTC) generation in superconductors have focused on using magnetic inhomogeneities at superconductor/ferromagnet (S/F) interfaces [1-4], it has recently been proposed that spin-orbit coupling (SOC) may substitute the role of the magnetic inhomogeneity in interconverting the triplet states [5,6]. This may lead to the generation of LRTCs without the need for careful control of magnetic inhomogeneity. In addition, it is proposed that the charge and spin currents may be controlled independently through the superconducting phase difference in such a device [6]. In this poster we present results on Nb/Pt/Nb and Nb/Pt/Co/Pt/Nb nanopillar Josephson junctions in order to investigate the potential for triplet pair generation via the interaction of SOC and magnetic exchange fields. The SOC arises from the high atomic number of Pt and broken inversion symmetry at its interfaces, and is of pure Rashba type. When the SOC is purely Rashba, the exchange field of the ferromagnet must have an out-of-plane component to generate the LRTC.

[1] Khaire, S. T., Khasawneh, M., Pratt, W. P. Jr & Birge, N. O. *Phys. Rev. Lett.* 104, 137002 (2010).
[2] Robinson, J.W. A., Witt, J. D. S. & Blamire, M. G. *Science* 329, 59–61 (2010).
[3] Anwar, M. S., Czeschka, F., Hesselberth, M., Porcu, M. & Aarts, J. *Phys. Rev. B* 82, 100501(R) (2010).
[4] Keizer, R. S. et al. *Nature* 439, 825–827 (2006).
[5] Bergeret, F. S., & Tokatly, I. V. *Phys. Rev. B* 89(13), 1–13 (2014).
[6] Jacobsen, S., Kulagina, I., & Linder, J. *Sci. Rep.* 6:23926 (2015).

P06 - Signatures of anomalous Josephson current in InAs nanowire devices with strong spin-orbit coupling

Ofelia Durante[1], Roberta Citro[1,2], Elia Strambini[3], Mirko Rocci[3], Nadia Ligato[3], Lucia Sorba[3], Francesco Giazotto[3]
[1]*Dipartimento di Fisica "E.R. Caianiello", Università degli studi di Salerno, Fisciano (Sa), Italy*
[2]*Spin-CNR Unità, Via Giovanni Paolo II, 132, I-84084 Fisciano (Sa), Italy*
[3]*NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Piazza S. Silvestro 12, I-56127 Pisa, Italy*

The supercurrent in the Josephson junction (JJ), depends on the phase different φ between the superconducting leads forming the device. The current is strictly zero when φ vanishes but the supercurrent can be finite for φ =0. This phenomenon derives from the broken chiral and time-reversal symmetries which characterize the system. In this case, a phase shift $\varphi_0 \epsilon]0\text{-}\pi[$ in the current-phase relation results[1]. We report the study of a Josephson φ_0-junction based on InAs nanowire (NWs)[2]. The strong spin-orbit coupling present in the NWs is one of the requirements to induce Majorana bound states. Topological phase transitions can result in discontinuities and asymmetrical structures of the critical current (I_C)[3]. In this work, we use both a JJ and a superconducting quantum interferometer device (SQUID) to explore these new effects[4]. In JJs, we measured the temperature-dependence of I_C in the absence of a magnetic field, observing an electron transport regime intermediate between ballistic and diffusive. The presence of an external magnetic field gives asymmetric diffraction patterns of I_C with jumps between lobes. The jumps positions are temperature independent, making the jumps uncorrelated to the superconducting pairing potential (as in Ref.[3]). So, jumps cannot be ascribed to topological transitions. In NW-based SQUIDs, we observed a modulation of I_C depending on the intensity of an applied magnetic field, B_Z, and usual interference patterns. By applying other in-plane field components orthogonal to B_Z, a nontrivial phase shift, φ_0, depending also on the angle between the NW and the in-plane field, comes to light. A flux-controlled phase offset may pave the way for new possibilities towards the realization of superconductive phase batteries.

[1] D.B.Szombati, S.Nadj-Perge, D.Car, S.R.Plissard, E.P.A.M. Bakker, L.P. Kouwenhoven, Nat. Phys. **12**, 568 (2016)
[2] L.Viti, M.S.Vitiello, D.Ercolani, L.Sorba and A.Tredicucci, Nanoscale Res. Lett. **7**, 159 (2012)
[3] P.Marra, R.Citro, A.Braggio, Phys. Rev. B **93**, 220507 (2016)
[4] J.Paajaste, M.Amando, S.Roddaro, F.S.Bergeret, D.Ercolani, L.Sorba and F.Giazotto, Nano Lett. **15**, 1803 (2015)

P07 - Spin-Orbital excitations in Ca_2RuO_4 revealed by Resonant Inelastic X-ray Scattering

L. Das[1], F.Forte[2,3], R. Fittipaldi[2,3], C. G. Fatuzzo[4], V. Granata[2,3], T. Neupert[1], A. Vecchione[2,3], T. Schmitt[5], M. Cuoco[2,3], and J. Chang[1]

1*Physik-Institut, Universit¨at Z¨urich, Winterthurerstrasse 190, CH-8057 Z¨urich, Switzerland*
2 *CNR-SPIN, I-84084 Fisciano, Salerno, Italy*
3 *Dipartimento di Fisica "E.R. Caianiello", Università di Salerno, I-84084 Fisciano, Salerno, Italy*
4 *Institute of Physics, Ecole Polytechnique Federale de Lausanne (EPFL), CH-1015 Lausanne, Switzerland*
5 *Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland*

The strongly correlated insulator Ca_2RuO_4 is considered as a paradigmatic realization of both spin-orbital physics and a band-Mott insulating phase, characterized by orbitally selective coexistence of a band and a Mott gap. We present a high-resolution oxygen *K*-edge resonant inelastic X-ray scattering study of the antiferromagnetic Mott insulating state of Ca_2RuO_4. A set of low-energy (~80 and 400 meV) and high-energy (~1.3 and 2.2 eV) excitations are reported that show strong incident light polarization dependence. Our results strongly support a spin-orbit coupled band-Mott scenario and explore in detail the nature of its exotic excitations. Guided by theoretical modelling, we interpret the low-energy excitations as a result of composite spin-orbital excitations. Their nature unveils the intricate interplay of crystal-field splitting and spin-orbit coupling in the band-Mott scenario. The high-energy excitations correspond to intra-atomic singlet-triplet transitions at an energy scale set by the Hund's coupling. Our findings give a unifying picture of the spin and orbital excitations in the band-Mott insulator Ca_2RuO_4.

- L. Das et al., Phys. Rev. X **8**, 011048 (2018)

P08 - Theory of multi-orbital superconductivity in an interface electronic system

Yuri Fukaya, Shun Tamura, Keiji Yada, Yukio Tanaka, Paola Gentile*, Mario Cuoco*
Department of Applied Physics, Nagoya University, Japan
**CNR SPIN Institute, University of Salerno, Italy*

The interface of $LaAlO_3/SrTiO_3$ hetero-structure is the two-dimensional electronic system with a spin-orbit coupling due to the inversion symmetry breaking. It has been found that this system shows the superconductivity at T_c=200mK.[1] Recently, D. Storonaiuolo *et.al.*[2] reported the possibility of the unconventional superconductivity by the experiment of the Josephson junction. In this system, bands near the Fermi level are mainly composed of *d-xy*, *yz* and *zx*. Thus, this system is interesting as a multi-orbital superconductivity with the spin-orbit coupling.

In this study, we consider on-site pairings in the interface multi-orbital system. Here, we focus on the inter-band and spin-triplet pairing. We investigate the gap structure on the Fermi surface in these pairing by changing the direction and the magnitude of d-vector of the spin-triplet pairing. The irreducible representation and corresponding gap structure are different from the direction of d-vector.

We find that non-trivial point nodes appear in B_1 and B_2 representation in C_{4v} point group. These point nodes are protected by the chiral symmetry which is product of the particle-hole symmetry and the time-reversal symmetry.

[1] N. Reyren *et.al.* Science **317** 1196 (2007)
[2] D. Stornaiuolo *et.al.* PRB **95** 140502 (2017)

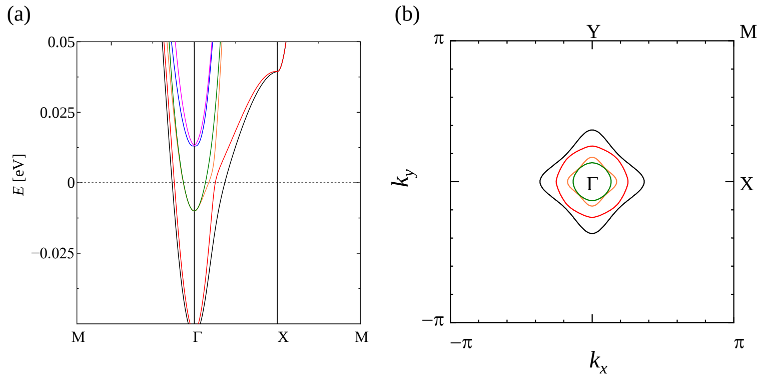


Fig. 1 (a) Band structure in the normal state (b) Fermi surface at μ=0.0eV.

P09 - Geometrically tunable spintronic platforms: towards curvatronics

Zu-Jian Ying[1,2], Paola Gentile[1,2], Carmine Ortix[3,4], Mario Cuoco[1,2]
[1]*CNR-SPIN, I-84084 Fisciano (Salerno), Italy*
[2]*Dipartimento di Fisica "E. R. Caianiello", Università di Salerno, Fisciano (Salerno), Italy*
[3]*Institute for Theoretical Solid State Physics, IFW-Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany*
[4] *Institute for Theoretical Physics, Center for Extreme Matter and Emergent Phenomena, Utrecht University, Princetonplein 5, 3584 CC Utrecht, The Netherlands*

Low-dimensional semiconducting nanomaterials have proven to be an ideal playground for the generation and manipulation of topological quantum states, which are at present at the centre of an intensive investigation. Apart from the conventional geometries, the most recent advances in nanotechnology have demonstrated the possibily to create flexible semiconductor nanomaterials which are bent into curved, deformable objects ranging from semiconductor nanotubes, to nanohelices, etc. Motivated by the excitement in both topological states of matter and novel shape deformed nanostructures, we have explored the impact that nanoscale geometry [1] has on electronic, topological and superconducting properties of low-dimensional materials, showing the possibility to exploit the interplay between geometry, Rashba spin-obit coupling (RSOC) and superconductivity as a tool for the realization of novel platforms for spintronics and superconducting spintronics. By considering the paradigmatic example of quantum wires with RSOC, which are periodically corrugated at the nanometer scale [2], we show that geometric effects in low-dimensional nanomaterials can lead to metal-insulator transition and promote the generation of topological states of matter. Relevantly, such a system, under the application of a rotating magnetic field, can realize the Thouless topological pumping protocol in an entirely novel fashion [3]. We also show that, in shape deformed nanostructures, geometric curvature effectively acts like a spin-torque, twisting the electron spin, thus driving non-trivial spin textures, which in turn affect the electron spin interference in closed loop configurations [4].
We finally show that in the presence of superconductivity, the interplay between RSOC and shape deformations can lead to novel paths for an all-geometric manipulation of the superconducting state, both for spin-singlet and spin-triplet quantum configurations [5], as well as of the supercurrent in weak links between Rashba coupled superconducting nanowires with geometric misalignment [6].

Acknowledgements: EU-FET OPEN project "CNTQC", grant agreement N. 618083 (http://www.nano2qc.eu/)

[1] P. Gentile, M. Cuoco, C. Ortix, SPIN, Vol. 3, No. 2, 1340002 (2013).
[2] P. Gentile, M. Cuoco, C. Ortix, Phys. Rev. Lett. **115**, 256801 (2015).
[3] S. Pandey, N. Scopigno, P. Gentile, M. Cuoco, C. Ortix, arXiv:1707.08773 (2017).
[4] Z.-J. Ying, P. Gentile, C. Ortix, M. Cuoco, Phys. Rev. B **94**, 081406(R) (2016).
[5] Z.-J. Ying, M. Cuoco, C. Ortix, P. Gentile, Phys. Rev. B **96**, 100506(R) (2017).
[6] Z.-J. Ying , M. Cuoco, P. Gentile, C. Ortix, 2017 16th International Superconductive Electronics Conference (ISEC), IEEE Xplore (2018).

P10 - A study of 2D electron gases at graphene-gated oxide heterostructures

A. Guarino[1,2], A. Sambri[2,3], E. di Gennaro[2,3], Daniela Stornaiuolo[2,3], F. Miletto Granozio[2], F.Motti[4], Giovanni Vinai[4], P. Torelli[4], I. Aliaj[5,7], Vaidotas Miseikis[5,6,7], Camilla Coletti[5,7], S. Roddaro[7,8]
1. CNR-DSFTM, NFFA-Trieste, Area Science Park - Basovizza Strada Statale 14, 34149 Trieste, Italy
2. CNR- SPIN Napoli, Via Cintia, I-80125 Napoli, Italy.
3. Physics Department, University of Naples Federico II, Via Cintia, I-80125 Napoli, Italy.
4. Laboratorio TASC, IOM-CNR, S. S. 14 km 163.5, Basovizza 34149 Trieste, Italy.
5. IIT Graphene Labs, Via Morego 30, I-16163 Genova, Italy.
6. CNIT, Via Moruzzi 1, I-56124 Pisa, Italy
7. NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, I-56127 Pisa, Italy
8. Dipartimento di Fisica "E. Fermi", Università di Pisa, Largo Pontecorvo 3, I-56127 Pisa, Italy

An in-operando XAS/XPS experiment has been performed on *ad-hoc* fabricated field effect devices. Graphene flakes have been positioned on patterned $LaAlO_3/SrTiO_3$ heterostructures hosting an interfacial 2D electron gas and employed as top-gate field-effect electrodes.
The idea of our experiment is to collect photoemission spectra simultaneously containing information from two distinct 2D electron systems (graphene and the buried electron gas) while the relative Fermi levels are shifted apart by the application of a gate voltage. At the same time, the I-V characteristics across the G/LAO/2DEG junction as well as the in-plane, its open circuit photovoltage and short circuit photocurrent, and the in-plane conducting properties of the 2DEG will be systematically measured as a function of photon energy, beam intensity and type/pressure of the background gas.

P11 - Properties and Crystal Growth of the Antiperovskite Oxide Sr_3SnO

Atsutoshi Ikeda[1], Mohamed Oudah[1], Igor Marković[1, 2], Jan Niklas Hausmann[1,3], Shinji Kitao[4], Shingo Yonezawa[1], Makoto Seto[4], Yoshiteru Maeno[1]
[1]*Department of Physics, Kyoto University*
[2]*School of Physics and Astronomy, University of St Andrews*
[3]*Department of Chemistry, Humboldt-Universität zu Berlin*
[4]*Institute for Integrated Radiation and Nuclear Science, Kyoto University*

The antiperovskite oxide (APO) A_3BO is the metal-rich counterpart of the normal perovskite oxide (PO) ABO_3. In APOs an oxygen ion is surrounded octahedrally by six *A* ions [1] while in POs *B* is surrounded by oxygen ions. In this sense, the positions of the oxygen and metallic ions are inverted. Another characteristic is that the B^{4-} (Sn^{4-}, Pb^{4-}, etc.) state is expected in APOs when assuming A^{2+} and O^{2-}. In POs B^{4+} state is realized and therefore the signs of the oxidation states are flipped. Such metallic anions are rare in oxides. In 2011, Dirac cones are predicted in the band structures of some APOs using the first-principles calculations [2, 3]. Later in 2014, these APOs with slightly gapped Dirac cones are theoretically proposed to be topological crystalline insulators [4]. These proposals have been attracting a lot of experimentalists' interest [5, 6, 7, 8].
We recently found the first superconductivity among APOs in the strontium-deficient $Sr_{3-x}SnO$ [9]. This material has the possibility of exhibiting topological crystalline superconductivity reflecting the non-trivial topology of the normal-state electron wavefunctions. We synthesized polycrystalline $Sr_{3-x}SnO$ with various initial amounts of strontium [10] and investigated the relation between the starting composition and superconducting properties [11]. We found that the transition temperature is not sensitive to the strontium loading while the superconducting volume fraction on average varies. We also measured the Mössbauer spectra of Sn. Both stoichiometric and deficient samples absorb γ-ray with the energy consistent with the Sn^{4-} state. There is an additional absorbance of γ-ray with a different energy, which possibly originates from multiple oxidation states of Sn in $Sr_{3-x}SnO$. We will also report the current situation of the trial to grow single crystals of Sr_3SnO.

[1] A. Widera and H. Schafer, Mater. Res. Bull. **15**, 1805 (1980).
[2] T. Kariyado and M. Ogata, J. Phys. Soc. Jpn. **80**, 083704 (2011).
[3] T. Kariyado and M. Ogata, J. Phys. Soc. Jpn. **81**, 064701 (2012).
[4] T. H. Hsieh, J. Liu, and L. Fu, PRB **90**, 081112 (2014).
[5] Y. F. Lee *et al.*, Appl. Phys. Lett. **103**, 112101 (2013).
[6] J. Nuss *et al.*, Acta Cryst. B **71**, 300 (2015).
[7] Y. Okamoto, A. Sakamaki, and K. Takenaka, J. Appl. Phys. **119**, 205106 (2016).
[8] Y. Obata *et al.*, Phys. Rev. B **96**, 155109 (2017).
[9] M. Oudah *et al.*, Nat. Commun. **7**, 13617 (2016).
[10] J. N. Hausmann *et al.*, arXiv:1712.09484, submitted to SuST.
[11] M. Oudah *et al.*, submitted to PRB.

P12 - Study of 0-π phase transition in hybrid superconductor-InSb nanowire quantum dot devices

N.Kang[1], S. Li[1], D. X. Fan[1], P. Caroff[2], H. Q. Xu[1]
1. Key Laboratory for the Physics and Chemistry of Nanodevices and Department of Electronics, Peking University, Beijing 100871, China
2.E.M.N., UMR CNRS 8520, Avenue Poincare, BP 60069, F-59652 Villeneuve d'Ascq, France.

Hybrid InSb nanowire-superconductor devices are promising candidates for investigating Majorana modes in solid-state devices and future technologies of topological quantum manipulation.[1-3] Here, we reports on the realization of high-performance hybrid superconductor-quantum dot devices based on individual InSb nanowires grown by molecular-beam epitaxy. We demonstrate proximity-induced supercurrent together with clear signatures of multiple Andreev reflections, indicating phase-coherent transport within junction.[4-6] Furthermore, in a closed quantum dot regime, we observed two types of subgap resonance states within the superconducting gap, which can be attributed to gate-tunable Andreev bound states with different Kondo temperatures.[5] The presence of the gate-tunable 0 and π junction allow us to investigate the fundamental 0- π transition. Detailed magnetic field and temperature evolution of level spectroscopy demonstrate different behavior of two types of the Andreev bound states. Our results exhibit that the InSb nanowires can provide a promising platform for exploring phase coherence transport and the effect of spin-orbit coupling in semiconductor nanowire-superconductor hybrid device.

1 V. Mourik et al, Science 336 (2012), 1003.
2 M. T. Deng. et al, Nano Lett 12 (2012), 6414.
3 H. Zhang.et al, Nature Communications 8 (2017), 16025.
4 D. X. Fan. et al, Nanoscale 7 (2015), 14822.
5 S. Li. et al, Sci. Rep. 6 (2016), 24822.
6 S. Li. et al, Phys. Rev. B. 95 (2017), 014515.

P13 - Spin Orbit Torque in 4*d*/5*d* Epitaxial Oxide Heterostructure

B. Kim[1,2], P. E. Ko[1,2], W. Kim[1,2], J. Kim[1,2], H. Lee[1,2], and T. W. Noh[1,2*]
[1]*Center for Correlated Electron Systems, Institute for Basic Science (IBS)*
[2]*Department of Physics and Astronomy, Seoul National University (SNU)*

The Spin Orbit Torque (SOT) is one of the fascinating phenomena considering Magnetic Random Access Memory (MRAM) device. Because of strong Spin Orbit Coupling (SOC), the charge current going to be separate by spin up and down without external magnetic field, which means Spin Hall Effect (SHE). Therefore, fully spin polarized current can be generated and injected to the neighboring layer with spin-torque. This spin-torque is able to manipulate the direction of spin in the magnetic layer. The most important thing is the direction of spin can be switched by electric control. Therefore, this SOT will be very efficient tool for switching of spin in the future spintronic application. Considering $SrRuO_3/Sr_2RuO_4$ (FM/SC/FM) planner superconducting spin valve device, this 4*d*/5*d* heterostructure could pave a new pathway for realizing electrical operatable spin valve device by utilizaing of SOT.

Here, I would like to present SOT device with 4*d*/5*d* Oxide Heterstructure based on $SrIrO_3/SrRuO_3$ bilayer. Since the 5*d* material is well known as a strong spin orbit coupling material, the $SrIrO_3$ layer can generate spin-polarized current via SHE. We can expect the spin injection and spin torque. In addition, the $SrRu_3$ layer selected for Ferromagnetic metal layer. Thanks to the current advanced thin film growth technique such as Laser Molecular Beam Epitaxy (Laser MBE), The $SrIrO_3/SrRuO_3$

bilayer structure can be prepared by most advanced Laser MBE technique. The detail structure characterization of $SrIrO_3/SrRuO_3$ bilayer will be shown. Furthermore, the electric and magnetic property of $SrIrO_3/SrRuO_3$ bilayer structure related SOT behavior would be discussed.

P14 - The synthesization of s-wave /p-wave superconductor oxide heterojunction by using Pulsed Laser Deposition

Jinkwon Kim[1,2], Han Gyeol Lee[1,2], Bongju Kim[1,2], Tae Won Noh[1,2*]
[1]*Center for Correlated Electron Systems, Institute for Basic Science (IBS)*
[2]*Department of Physics and Astronomy, Seoul National University (SNU)*

The junction of spin singlet superconductor (SSC) and spin triplet superconductor (TSC) have affluent scientific issues related with proximity effect between their different orbital pairity. R. Jin *et al.* found a irregular behavior of the critical Josephson current in Pb(SSC)/Sr_2RuO_4(TSC)/Pb(SSC) trilayer, which is originated from the mixture of p-wave cooper pairs in Sr_2RuO_4 and s-wave pairs in Pb [1]. T. Nakamura *et al.* developed Pb (SSC)/Ru(N)/Sr_2RuO_4(TSC) heterojunction, which is the realization of topological superconducting junction [2].

Here, we suggest new SSC/TSC junction as $BaPb_{1-x}Bi_xO_3/Sr_2RuO_4$, which is a oxide heterostructure system. The oxide heterostructure has advantage that the interface could be atomically sharp and well defined, which ensure high quality junction properties. To realize this, we deposited $BaPb_{1-x}Bi_xO_3$ (T_c =12K, SSC) as thin film on cleaved Sr_2RuO_4 single crystal substrates, by using pulsed laser deposition system. The epitaxial heterostructure was confirmed by X-ray diffraction, and detail surface topography is confirmed by atomic force microscopy. Also the electronic and magnetic property will be discussed.

[1] R. Jin *et al.*, Phys. Rev. B, **59**, 4433 (1999).
[2] T. Nakamura *et al.*, Phys. Rev. B, **84**, 060512 (2011).

P15 - Spin-mixing at oxide superconductor/ferromagnet interfaces

G. Kimbell, C. Palomares-Garcia, A. Di Bernardo, A. Srivastava, S. Komori, J. Devine-Stoneman, M. Amado, J. W. A. Robinson
Department of Materials Science and Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge CB3 0FS, United Kingdom

Recent reports of long-range proximity effects at oxide ferromagnet/superconductor (S/F) interfaces have been inconsistent. For example, Visani *et al.* [1] showed long-range proximity effects in junctions containing superconducting YBCO ($YBa_2Cu_3O_{7-x}$) and the highly spin-polarised ferromagnet LCMO ($La_{0.67}Ca_{0.33}MnO_3$), but Petrzhik *et al.* [2] saw no long-range effect in a similar structure. In the case of ref. [1], triplet superconductivity is most likely caused by magnetic inhomogeneity at the S/F interface, the exact properties of which are difficult to determine and control. In 2014, Khaydukov *et al.* [3] reported long range supercurrents through YBCO/SRO/LSMO/Au mesa-structures, where SRO ($SrRuO_3$) is an itinerant ferromagnetic metal and LSMO ($La_{0.67}Sr_{0.33}MnO_3$) a highly spin-polarised ferromagnet. The SRO/LSMO layers possess an intrinsic magnetic non-collinearity due to a competition between magnetocrystalline anisotropy and antiferromagnetic exchange coupling between the two layers [4]. In other words, the SRO/LSMO interface could act as a ‘spin-mixer’ for electron pair conversion to a spin-polarised triplet state through the LSMO. The project presented in this poster builds on this work by investigating SRO spin-mixer interfaces in crystalline YBCO/LSMO heterostructures grown by pulsed laser deposition, initially with unpatterned triplet spin valves, and ultimately in nanopillar Josephson junctions.

[1] C. Visani, Z. Sefrioui, J. Tornos, C. Leon, J. Briatico, M. Bibes, A. Barthélémy, J. Santamaría, and J. E. Villegas, Nat. Phys. **8**, 539 (2012).
[2] A. M. Petrzhik, G. A. Ovsyannikov, A. V. Shadrin, K. I. Konstantinyan, A. V. Zaitsev, V. V. Demidov, and Y. V. Kislinskii, J. Exp. Theor. Phys. **112**, 1042 (2011).
[3] Y. N. Khaydukov, G. A. Ovsyannikov, A. E. Sheyerman, K. Y. Constantinian, L. Mustafa, T. Keller, M. A. Uribe-Laverde, Y. V. Kislinskii, A. V. Shadrin, A. Kalaboukhov, and others, Phys. Rev. B **90**, 035130 (2014).
[4] J. H. Kim, I. Vrejoiu, Y. Khaydukov, T. Keller, J. Stahn, A. Rühm, D. K. Satapathy, V. Hinkov, and B. Keimer, Phys. Rev. B **86**, 180402 (2012).

P16 - ^{101}Ru-NQR study on Sr_2RuO_4 under uniaxial strain

K. Kinjo, M. Manago, S. Kitagawa, K.Ishida, H. Suwa, T. Yamanaka* and Y. Maeno
Department of Physics, Graduate School of Science, Kyoto University, Kyoto 606-8502, Japan
**present address: Department of Physics, Faculty of Science and Technology,*
Tokyo University of Science, Noda, Chiba 278-8510, Japan

Sr_2RuO_4, discovered in 1994[1], is a quasi-two-dimensional strongly correlated metal showing unconventional superconductivity with a transition temperature T_c = 1.5 K. NMR Knight shift measurements at ^{17}O and ^{99}Ru sites[2,3] and spin-polarized neutron-scattering measurements[4] have revealed that spin susceptibility does not change across T_c, suggesting of the spin-triplet pairing realized in the superconducting state.

Hydrostatic pressure, as well as a small amount of impurities or defects, is reported to suppress T_c in Sr_2RuO_4[5], but the enhancement of T_c was reported in the Sr_2RuO_4-Ru eutectic system[6], a submicron Sr_2RuO_4 single crystal[7] and Sr_2RuO_4 under uniaxial pressure[8]. At present, the mechanism of the enhancement of T_c has been unclear. Recently, C. W. Hicks and his co-workers showed that T_c of Sr_2RuO_4 increases up to 3.4 K with applying compressive or tensile strains along [100] direction, but that [110] strains give a much weaker response. The calculation based on the tight-binding model indicate that the observed maximum T_c occurs at or near a Lifshitz transition when the Fermi level passes through a Van Hove singularity[9,10].

In order to investigate the mechanism of the enhancement of T_c from a microscopic point of view, we performed ^{101}Ru-NQR on single-crystalline Sr_2RuO_4 under uniaxial pressure along nearly [100] direction. For the application of uniaxial pressure, we used home-made cramp-type pressure cell with the Cu-Be alloy. We observed an increase the T_c onset under uniaxial pressure using the ac susceptibility measurements, which is consistent with previous reports[8]. In this poster presentation, I will show the preliminary experimental results of ^{101}Ru-NQR measurements and discuss possible mechanism of the enhancement of T_c under uniaxial pressure.

[1] Y. Maeno *et al*., Nature **372**, 532 (1994).
[2] K. Ishida *et al*., Nature **396**, 658 (1998).
[3] K. Ishida et al., Phys. Rev. B **63**, 060507(R) (2001).
[4] J. A. Duffy *et al*., Phys. Rev. Lett. **85**, 5412 (2000).
[5] N. Shirakawa *et al*., Phys. Rev. B **56**, 7890 (1997).
[6] Y. Maeno *et al*., Phys. Rev. Lett. **81**, 3765 (1998).
[7] H. Nobukane *et al*., Solid State Commun. **149**, 1212 (2009).
[8] S. Kittaka *et al*., Phys. Rev. B. **81**, 180510(R) (2010).
[9] C. W. Hicks *et al*., Science **344**, 283 (2014).
[10] A. Steppke *et al*., Science **355**, eaaf9398 (2017).

P17 - Cooper-pair spin current in planar spin valve device on top of Sr_2RuO_4 superconductor

P. E. Ko[1,2], B. Kim[1,2], S. B. Chung[1,2,3], T.W. Noh[1,2*]
[1]*Center for Correlated Electron Systems, Institute for Basic Science, Republic of Korea*
[2]*Department of Physics and Astronomy, Seoul National University, Republic of Korea*
[3]*Department of Physics, University of Seoul, Seoul 02504, Republic of Korea*

Sr_2RuO_4 is one of the most promising candidates as a spin-triplet superconductor. It is considered that there is not only charge current but also spin current in spin-triplet superconductor.
Planar spin valve device with $SrRuO_3$ on top of Sr_2RuO_4 has been proposed for detecting spin current in Sr_2RuO_4. For general spin valve structure (ferromagnet - normal metal- ferromagnet), spin current cannot exist in long distance because of short spin coherence length. However, there is a new theoretical prediction that spin current in spin-triplet superconductor can survive in longer distance [1]. Therefore, super spin current can be detected by transferring of spin current in long range spin valve device.
Here, we prepared $SrRuO_3$ (ferromagnetic metal) – Sr_2RuO_4 (spin-triplet superconductor) – $SrRuO_3$ structure device. Firstly, $SrRuO_3$ thin film was deposited by pulsed laser deposition (PLD) on top on Sr_2RuO_4 single crystal substrate. Detailed structure analysis was performed in terms of x-ray diffraction (XRD) and surface topography analysis. secondly, the planar spin valve structure was fabricated by e-beam lithography technique. In addition, we would like to present electric transport measurement considering super spin current.

[1] Suk Bum Chung *et al*., arXiv : 1802.01599 (2018)

P18 - Piezoelectric-based Uniaxial-strain Cell towards Tuning of Electronic Properties

Ivan Kostylev, Shingo Yonezawa, and Yoshiteru Maeno
Department of Physics, Kyoto University

Recently, it has been clarified that novel electronic states in strongly correlated systems can be induced or controlled by the application of uniaxial strain [1]. In order to control properties of various superconductors we utilized a piezo-stack-based device capable of applying both tensile and compressive strains. The device is capable of measuring the superconducting transition temperature and upper critical field of superconductors.
We developed a strain applying device where the strain is determined by monitoring the capacitance of a parallel plate capacitor system whose gap changes with applied strain. The device with the sample is then cooled by a dilution refrigerator equipped with an 11 T magnet. We can measure various physical quantities such as electric permittivity, AC magnetic susceptibility, and resistivity. Electric permittivity is measured by a three-wire measurement using a capacitance bridge. The AC susceptibility is measured by the concentric pair of coils surrounding the sample. Resistivity is measured by a four-probe method.
In this poster we will also present our experimental results attempting to induce ferroelectricity in the quantum paraelectric $SrTiO_3$ and tuning of T_c in the superconductor Nb-doped $SrTiO_3$ by bringing the system towards the quantum critical point of ferroelectric transition.

[1] C. W. Hicks *et al*., Rev. Sci. Instrum. **85**, 65003 (2014).

P19 - Spectroscopic Study of Coulomb Gap Driven Metal-Insulator Transition in $Sr_{2-x}La_xRhO_4$

Junyoung Kwon[1,2], Minsoo Kim[1,2], Dongjoon Song[3], Yoshiyuki Yoshida[3], Jonathan D. Denlinger[4], Wonshik Kyung[1,2], Changyoung Kim[1,2]
[1]*Center for Correlated Electron Systems, Institute of Basic Science, Seoul 08826 Republic of Korea*
[2] *Department of Physics and Astronomy, Seoul National University, Seoul 08826 Republic of Korea*
[3] *National Institute of Advanced Industrial Science and Technology, Tsukuba 305-8568, Japan*
[4] *Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley CA 94720 USA*

In this presentation, we discuss the metal-insulator transition (MIT) mechanism in $Sr_{2-x}La_xRhO_4$ in the context of Coulomb gap based on results from electronic structure studies. Transport study of newly grown single crystals shows doping dependent MIT occurring around x=0.4. Coincidently the electronic structure measured with angle-resolved photoemission spectroscopy (ARPES) shows transition from Jeff=1/2, 3/2 multi-band to Jeff=1/2 single-band structure due to electron doping. This transition may lower the hopping energy in the system, which triggers the enhancement of effective Coulomb interaction and introduces the Coulomb gap. Our systematic ARPES study is the first on the subject of Coulomb gap creation.

P20 - Growth and characterization of anti-perovskite Sr_3SnO films

Han Gyeol Lee[1,2] Mohamed Oudah[3], Atsutoshi Ikeda[3], Bongju Kim[1,2], Yoshiteru Maeno[3], Tae Won Noh[1,2,*]
[1]*Center for Correlated Electron Systems (CCES), Institute for Basic Science (IBS)*
[2]*Department of Physics and Astronomy, Seoul National University*
[3]*Department of Physics, Kyoto University*

Topological superconductivity has attracted much attention in condensed matter physics. Among the various materials, anti-perovskite (AP) oxide is another promising material group that could have topological nature [1,2]. However the experimental approach of this intriguing phase has seldom been studied. Recently, Oudah *et al*. reported that superconductivity was found in Sr-deficient AP phase of $Sr_{3-x}SnO$ (SSO) poly-crystal [3]. Tough the superconductivity of this material is discovered, plenty of uninvestigated properties still remain. For examples,. the oxidation state of Sn in AP compound, Cooper pair symmetry, and its superconducting mechanism are unrevealed yet. In order to explore this physics, properly designed thin film could be a good starting point. Therefore, we synthesized SSO thin film with pulsed laser deposition technique First, the growth parameter dependence of its properties will be introduced. Second, the optimized growth condition for this material will be reported. Their structral properties are measured by X-ray diffraction and the electronic properties are investigated by low-temperature transport experiment. As a last, further optical measurement on thin-filmed SSO will be presented in more detail.

[1] Y. Sun *et al.*, Phys. Rev. Lett. **105**, 216406 (2010).
[2] T. H. Hsieh *et al.*, Phys. Rev. B **90**, 081112 (2014).
[3] M. Oudah *et al.*, Nat. Commun. **7** 13617 (2016).

P21 - Topological phases of a Kitaev ladder

Alfonso Maiellaro[1], Francesco Romeo[1,2], Roberta Citro[1,2]
[1] *Dipartimento di Fisica, Università degli Studi di Salerno, Via Giovanni Paolo II, 84084 Fisciano, Italy*
[2] *Spin-CNR, Unit of Salerno, Via Giovanni Paolo II, 84084 Fisciano, Italy*

We study topological phase transitions of a Kitaev ladder, i.e. a system made of two Kitaev chains coupled together site to site by transversal hopping and pairing term t_1 and Δ_1, respectively. By using an analytical and numerical approach, we demonstrate that topological phase transitions can be characterized by a combined analysis of the Pfaffian invariant and the finite size spectrum of the model. We obtain a phase diagram in the plane (t_1, μ) and using bulk-edge correspondence we test the consistency of the results in the direct and reciprocal space. Compared to the single Kitaev chain we find, beyond a non-topological phase, a topological phase either with four or two Majorana (zero energy) modes. In particular, we see that for some critical values of the transversal hopping t_1 the topological phase survives also when the Kitaev criterion for the single chain $(\Delta > 0, |\mu| < 2t)$ is violated.

P22 -Low temperature magnetodynamic properties of oxide ferromagnets

Lauren McKenzie-Sell[1,2], Mario Amado[1], Graham Kimbell[1], Chiara Ciccarelli[2] and Jason Robinson[1]
[1]*Department of Materials Science and Metallurgy, University of Cambridge, Cambridge, UK.*
[2]*Cavendish Laboratory, University of Cambridge, Cambridge, UK.*

When driven into ferromagnetic resonance (FMR), ferromagnets, can pump pure spin across an interface with non-magnetic materials[1], including superconductors[2,3], and probe their spin dynamics. The ferrimagnet yttrium iron garnet (YIG, $Y_3Fe_5O_{12}$), being highly insulating, can transfer spin independently of charge effects, while its low spin dissipation makes it particularly efficient at the spin pumping process[4]. High quality thin films of YIG have become an essential tool for spintronics, to act as an efficient spin pump while remaining sensitive to interfacial spin transfer.[5] However, for superconducting spintronics, these 10-100 nm-thick YIG films must perform in the low temperature limit, below superconducting critical temperatures, where their magnetodynamics are not yet well-characterised.
We use FMR to investigate the temperature-dependent microwave absorption and spin dissipation in YIG thin films, epitaxially grown to high quality by pulsed laser deposition on gadolinium gallium garnet substrates. Sensitive, low-temperature FMR measurements allow us to trace magnetodynamic properties through from the films' chemical structures and specific growth conditions. This informs the growth and material requirements for thin film YIG and other oxide ferromagnets to be effective at low-temperature spintronics, and for insulator magnetodynamics to serve as a pump and probe of spin dynamics in other materials, such as superconductors[6].

1. Tserkovnyak, Y., Brataas, A. & Bauer, G. E. W. Enhanced Gilbert Damping in Thin Ferromagnetic Films. *Phys. Rev. Lett.* **88,** 117601 (2002).
2. Bell, C., Milikisyants, S., Huber, M. & Aarts, J. Spin Dynamics in a Superconductor-Ferromagnet Proximity System. *Phys. Rev. Lett.* **100,** 47002 (2008).
3. Morten, J. P., Brataas, A., Bauer, G. E. W., Belzig, W. & Tserkovnyak, Y. Proximity-effect–assisted decay of spin currents in superconductors. *EPL (Europhysics Lett.* **84,** 57008 (2008).
4. Kajiwara, Y. *et al.* Transmission of electrical signals by spin-wave interconversion in a magnetic insulator. *Nature* **464,** 262–266 (2010).
5. D'Allivy Kelly, O. *et al.* Inverse spin Hall effect in nanometer-thick yttrium iron garnet/Pt system. *Appl. Phys. Lett.* **103,** 10–14 (2013).
6. Inoue, M., Ichioka, M. & Adachi, H. Spin pumping into superconductors: A new probe of spin dynamics in a superconducting thin film. *Phys. Rev. B* **96,** 1–10 (2017).

P23 - Magnetic manipulation of topological states in p-wave superconductors

Maria Teresa Mercaldo[1], Mario Cuoco[1,2], Panagiotis Kotetes[3]
[1]*Dipartimento di Fisica "E.R. Caianiello", Università degli Studi di Salerno, IT-84084 Fisciano (SA), Italy*
[2]*CNR-SPIN, IT-84084 Fisciano (SA), Italy*
[3]*Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark*

Substantial experimental investigation has provided evidence for spin-triplet pairing in diverse classes of materials and in a variety of heterostructures consisting of spin-singlet superconductors (SCs) interfaced with magnetic systems. One tantalizing perspective of this search is fabricating devices for topological quantum computing based on Majorana fermions, which naturally emerge in one-dimensional (1d) spinless p-wave superconductors (PSC) which constitute the prototypical topological superconductor.
A fundamental question, which arises when dealing with realistic materials, relates to the role of the order parameter of the PSC, which constitutes a vector in spin-space and its structure controls the topological behavior of the system. In this work, we show that the Cooper pair spin-configuration of a 1d PSC with an easy spin-plane and chiral symmetry experiences an intricate rearrangement in the presence of an intrinsically or extrinsically induced magnetization in its interior and at the interface with dramatic consequences on the topological properties. The non-self-consistent topological phase diagram, consisting of phases with Majorana modes at the edge, becomes modified when one allows to the d-vector to reorganize so to minimize the free energy and in response to the presence of a distinct magnetic pattern [1]. We reveal that this internal degree of freedom can open the path to topological phases with different numbers of Majorana modes per edge. In particular, we consider the possibility of a breakdown of the bulk-boundary correspondence due to the inhomogeneous profile of d-vector near the boundary and the accompanying induced magnetization.

[1] M.T. Mercaldo, M. Cuoco, P. Kotetes, Phys. Rev. B **94**, 140503(R) (2016).
[2] M.T. Mercaldo, M. Cuoco, P. Kotetes, Physica B (2017), https://doi.org/10.1016/j.physb.2017.11.007

P24 - Low-temperature magnetic and transport properties of $YBa_2Cu_3O_{7-\delta}$/Sr_2RuO_4 heterostructures

Takuto Miyoshi, Yuuki Yasui, Angelo Di Bernardo*, Sachio Komori*, Rosalba Fittipaldi**, Antonio Vecchione**, Shingo Yonezawa, Jason W. A. Robinson*, and Yoshiteru Maeno
Department of Physics, Kyoto University, Japan
**Department of Materials Science, University of Cambridge, United Kingdom*
***CNR-SPIN, Salerno Unit, and the University of Salerno, Italy*

A superconducting Josephson junction, consisting of two superconductors, is one of the most promising methods to examine unconventional properties of the superconductors [1]. A large number of experiments on such junctions have been performed. However, there are few experimental studies on junctions between a spin-triplet superconductor and a non-*s*-wave spin-singlet superconductor. Therefore, it is valuable to investigate junctions of Sr_2RuO_4 (SRO), a leading candidate for a spin-triplet *p*-wave superconductor [2], and $YBa_2Cu_3O_{7-\delta}$ (YBCO), a spin-singlet *d*-wave superconductor [3]. Although a YBCO/SRO heterostructure was reported in 1992, before SRO was known to be superconducting, the measurement was performed only down to 77 K, and hence the Josephson junction property was not studied [4].

In the present study, we investigate transport and magnetic properties of YBCO/SRO heterostructures down to 0.1 K. We used SRO single crystals grown by the floating-zone method, and deposited YBCO thin film epitaxially onto the SRO crystal by using the pulsed laser deposition technique. We measured their AC susceptibility and confirmed the transition temperature T_c of SRO to be 1.31 K. We also measured magnetization of the sample and confirmed T_c of YBCO to be around 45 K. To investigate the Josephson junction properties, we are studying their transport properties with a ^{3}He refrigerator.

In this poster, we report results of low temperature measurements of AC susceptibility, magnetization, and transport of the YBCO/SRO system.

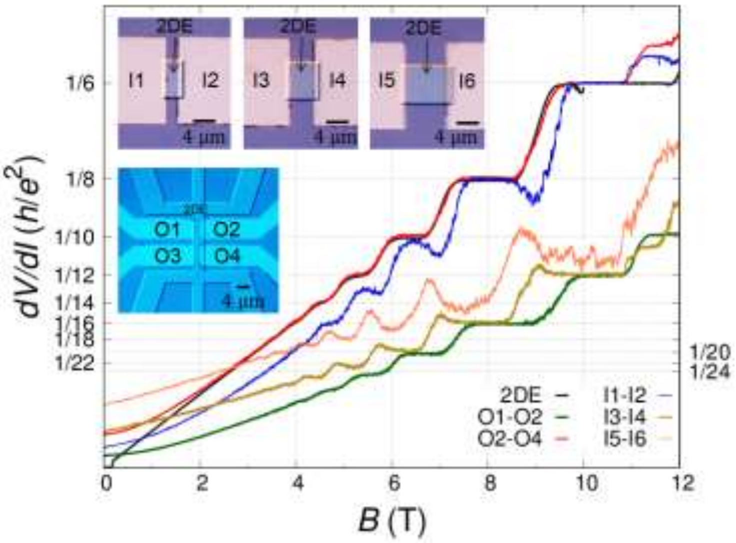
[1] Y. Hasegawa, J. Phys. Soc. Jpn. **67**, 3699 (1998).
[2] A. P. Mackenzie, Y. Maeno, Rev. Mod. Phys. **75**, 657 (2003).
[3] W.N. Hardy, *et al.*, Phys. Rev. Lett. **70**, 3999 (1993).
[4] F. Lichtenberg, *et al.*, Appl. Phys. Lett. **60**, 1138 (1992).

P25 - Doubled conductance in quantum Hall edge transport driven by Andreev reflection or impurity potentials

M. Onizaki, Y. Hashimoto, A. Endo, T. Nakamura and S. Katsumoto
Institute for Solid State Physics, University of Tokyo
5-1-5, Kashiwanoha, Kashiwa, Chiba 277-8581, Japan

Though a superconductor has an energy gap opening at the Fermi level, the Andreev reflection mechanism (ARM) connects metallic states and condensate of Cooper pairs adiabatically [1] at the metal-superconductor interface. Here a strong interest exists in the case we replace the metal with an insulator with non-trivial topology like a quantum Hall insulator (QHI). Some theories predict the conductive states at the quantum Hall edge are connected to the condensate adiabatically via the ARM. In such a situation a single edge state works both as an electron and a hole conduction channel, hence bares double of the quantum conductance $2G_q$ (G_q=$2e^2/h$). Here we report a transition from a normal transport to an ARM-dominated one in superconductor-QHI-superconductor junctions.

We fabricated NbTi/2-dimensional electron (2DE) /NbTi (N2N) junctions from InAs quantum wells with inverted modulation doping (the mobility and the concentration are 1.48 $\times 10^4$ cm^2/Vs and 1.88$\times 10^{12}$ cm^{-2} or 1.03 $\times 10^4$ cm^2/Vs and 1.95$\times 10^{12}$ cm^{-2} , respectively). In several trials, we prepared (N2N) junctions with different normal resistances. In some of them, the 2DE's are islands without connections other than those to NbTi (closed) while in the others the 2DE's have connections to normal metals (open). As shown in Fig.1, the magnetoresistances are always half of that in unprocessed 2DE for "closed" samples probably because the ARM opens the hole channel. Exceptionally observed double conductance in an "open" junction is due to some scar in the sample.



[1] P. W. Anderson, *Basic Notions of Condensed Matter Physics* (Benjamin, 1984).

Fig. 1: Differential resistance as a function of magnetic field. The inset shows optical micrographs of the samples.

P26 - Towards the growth optimization of superconducting thin-films of Sr_2RuO_4

Carla M. Palomares García[1], A. Di Bernardo[1], Y. Yasui[2], B. Kim[3], S. Komori[1], M. G. Blamire[1], TW Noh[3], Y. Maeno[2], J. W. A. Robinson[1]
1. *Department of Materials Science, University of Cambridge, United Kingdom*
2. Department of Physics, Graduate School of Science, Kyoto University
3. Institute of Basic Science, Center for Correlated Electron Systems, Seoul National University

Strontium ruthenate Sr_2RuO_4 (SRO) is an unconventional superconductor, in which the electron pairing is most probably spin-triplet with *p*-wave symmetry. Over the past couple of decades, SRO has been the subject of extensive study[1] with the vast majority of experiments performed on bulk single crystals because superconducting thin films are virtually unavailable[2,3,4]. This is because its superconductivity is highly sensitive to impurities such as defects and strain[5,6]. Nevertheless, fabrication of devices based on SRO thin films are crucial to improve our understanding of its superconducting properties.

Here, we report the growth of superconducting thin-films of SRO by Pulsed Laser Deposition. Instead of the conventional polycrystalline target, a single crystal of $Sr_3Ru_2O_7$ was ablated, and a laser heater was used to heat the substrate during the deposition. This enabled us to enhance the uniformity of the films and provided an excess of Ru, which is crucial for the deposition due to its volatility. In this poster, we present the structural-electronic properties of SRO after the optimization of the growth conditions.

1. Y. Maeno *et al.*, J. Phys. Soc. Japan **81,** 1–29 (2012).
2. Y. Krockenberger *et al.*, Appl. Phys. Lett. **97**, 2502 (2010).
3. J. Cao *et al.*, Supercond. Sci. Technol. **29**, 095005 (2016).
4. M. Uchida *et al.*, APL Mat. **5**, 106108 (2017)
5. A. P. Mackenzie *et al.*, Phys. Rev. Lett. **80,** 161–164 (1998).
6. Z. Q. Mao, Phys. Rev. B **60,** 610 (1999).

P27 - Tunable φ-Josephson junction with a Quantum Anomalous Hall Insulator

Keimei Sakurai, Satoshi Ikegaya, and Yasuhiro Asano
Department of Applied Physics, Hokkaido University, Japan

The Josephson effect is a fundamental phenomenon of superconductors. When two superconductors sandwich a material X, Josephson current J flows as a function of the phase difference between two superconductors (θ). The current-phase (J-θ) relationship (CPR) reflects well the electronic properties of X. When X is an insulator, the CPR is sinusoidal J=J_0sinθ with a critical current J_0. Such junction is called 0-junction because the junction energy is minimum at the zero phase difference. In a 0-junction, Josephson current J is absent at θ=0. The energy of junction some of time takes its minimum at $\varphi \neq n\pi$ (n is any integer). The CPR in such φ-junction J=J_0sin($\theta-\varphi$) suggests that the Josephson current flows even at the zero phase difference. In the view of device application, a φ-junction can be used as a phase battery or a superconducting rectifier. The phase shift φ is determined by characteristic electronic structures in X. So far, the realization of φ-junction has been discussed theoretically in various Josephson junctions with X being multilayered ferromagnets, quantum point contacts, quantum dots, nanowires and topologically non-trivial materials. In experiments, however, the realization of φ-junction has been reported only in a Josephson junction with a nanowire quantum dot. In the proposed φ-junctions, it is not easy to control the phase shift φ after fabricating Josephson junctions.

We theoretically study the Josephson current in a Josephson junction with a quantum anomalous hall insulator (QAHI) by using lattice Green function method. A QAHI is a topologically non-trivial material with chiral edge states protected by nonzero Chern number. When an in-plane external magnetic field is applied to the QAHI, the current-phase relationship becomes $(\theta)\propto\sin(\theta-\varphi)$ [See also Fig. 1]. The phase shift φ is proposal to the amplitude of Zeeman field, which implies the realization of a tunable φ-junction.

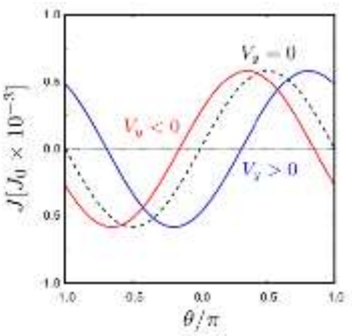


Fig. 1: Josephson current as a function of θ.

[1] K. Sakurai, S. Ikegaya, and Y. Asano, Phys. Rev. B **91**, 224514 (2017).

P28 - Ferromagnetic resonance in superconductor/ferromagnet bilayers

David Sanchez-Manzano[1], M-W. Yoo[2], H. Naganuma[2], P. Mergny[2], A. Anane[2], J. Santamaría[1], J . E. Villegas[2]
[1] GFMC, Dpto F. Materiales, University Complutense of Madrid (Spain)
[2] CNRS -Thales, Unité Mixte de Physique, Palaiseau (France)

We study the superconductor/ferromagnet proximity effect via ferromagnetic resonance (FMR) [1] in S/F bilayers that combine the high-temperature superconductor YBa2Cu3O7 with different ferromagnets, either Permalloy (NiFe) or the half-metallic La0.7Ca0.3MnO3. We compare the results of this bilayers to reference ferromagnetic single layers to observe how the presence of the superconductor layer affects the FMR signal. The FMR linewidth is studied as a function of temperature (10K-293K) and frequency (up to 20 G Hz) to obtain the damping constant (α) above and below the superconducting critical temperature. The results will be discussed in the frame of the spin-pumping theory considering the superconductor a spin sink where part of the FMR generated angular momentum relaxes in the superconductor through spin-pumping. [2].

Work supported by the ERC grant N 64710, French ANR grant ANR-15-CE24- 0008-01 and Spanish MAT 2014 52405 C02

[1] Bells, C., Aarts, J. et al. Spin Dynamics in a Superconductor-Ferromagnet Proximity System. Phys. Rev. Lett. 100 047002 (2008)
[2] Yokoyama, T. & Tserkovnyak, Y. Tuning odd triplet superconductivity by spin-pumping. Phys. Rev. B 80, 104416 (2009)

P29 - Josephson effect in two-band superconductors

Akihiro Sasaki, Yasuhiro Asano
Department of Applied Physics, Hokkaido University, Sapporo 060-8628, Japan

Physical phenomena unique to such multiband superconductors have been a hot issue in condensed matter physics since the discovery of superconductivity in MgB_2, pnictides and a topological-material-based superconductor. In pnictides, for example, there are two or more overlapping bands at the Fermi level. Among them, two bands mainly contribute to the superconducting state. A number of theories and experiments have suggested that the order parameter exists in each conduction band and that the pairing symmetry belongs to spin-singlet *s*-wave. Therefore, in the mean field theory, it would be reasonable to assume two order parameters $\Delta_1=|\Delta_1|e^{i\varphi_1}$ and $\Delta_2=|\Delta_2|e^{i\varphi_2}$. Two types of superconducting states called s_{++} state and s_{+-} state are promising candidate of superconducting state. The former is characterized by the phase relationship $\varphi_1-\varphi_2=0$. The latter is described by $\varphi_1-\varphi_2=\pi$. Although pnictides have been actively studied focusing on these two states so far, it is still unclear which state is realized in real materials. Therefore, it is necessary to clarify how the internal phase difference is determined and how it affects physical phenomena.

Recently, we calculated the Green function of a two-band superconductor by solving Gor'kov equation analytically and studied the transition temperature in the presence of potential disorder[1]. The internal phase difference is derived from the phase of hybridization potential θ between the two band. We also showed that time-reversal symmetry is preserved in the Hamiltonian and the gap equation has a stable solution when a relationship $\varphi_1-\varphi_2=2\theta+2\pi n$ is satisfied. In addition, all the Hamiltonians satisfying this relationship can be unitarily transformed to each other. This means that s_{++} state and s_{+-} state are unitary equivalent to each other and are not distinguishable from each other. We focus on the Josephson effect in this study. Specifically, the purpose of this study is to clarify how Josephson current flows in the junction system of 2 two-band superconductors. The two pair potentials are assumed independently for each of the left and right superconductors, so four phases can be defined in total. By extending the formula of Josephson current to the case of two bands and using the Green function derived analytically, we obtain the following expression.

$$J = J_{a1}\sin(\varphi_{L1}-\varphi_{R1}) + J_{a2}\sin(\varphi_{L2}-\varphi_{R2}) + J_b \sin\left(\frac{\varphi_{L1}+\varphi_{L2}}{2}-\frac{\varphi_{R1}+\varphi_{R2}}{2}\right)$$

The first and second term represent the currents flowing in the band 1 and band 2, respectively. On the other hand, the third term cannot be expressed by a simple tunneling process. The results suggest that a finite current flows at the s_{++} / s_{+-} junction when those four phases are $\varphi_{L1}=\varphi_{L2}=\varphi_{R1}=0$ and $\varphi_{R2}=\pi$, for example. In the presentation, we will explain the origin of the third term and the physical meaning of the result.

[1] Y. Asano and A. Sasaki, Phys. Rev. B **92**, 224508 (2015); arXiv:1708.03443

P30 - Point-contact Andreev reflectivity at helimagnet/superconductor interfaces

Anand Srivastava[1], Andy Moskalenko[2], Karen A. Yates[2], Angelo Di Bernardo[1], Lesley F. Cohen[2], Jason W. A Robinson[2]

1 Department of Materials Science and Metallurgy, 27 Charles Babbage Road, Cambridge. CB3 0FS, United Kingdom

2 Blackett Laboratory, Imperial College London, London SW7 2AZ, UK.

The conical ferromagnet rare earth metal Ho is of interest in superconducting spintronics [1] due to its ability to intrinsically form a long-range superconducting state (LRSS) at a superconductor/Ho interface [2, 3]. Recently, scanning tunneling spectroscopy on superconducting Nb thin-films proximity-coupled to epitaxial Ho revealed sub-gap features in the superconducting density of states, indicative of an unconventional superconductivity [4] with spin-zero and spin-one triplet states. However, the spin-mixing role of Zeeman splitting in Nb versus the magnetic texture within Ho in forming the triplet states is unclear.

Point-contact Andreev reflectivity (PCAR) is a powerful spectroscopic technique for probing interface pair symmetry at superconductor/ferromagnet interfaces [5]. Ongoing PCAR measurements on Au/Ho/Nb multilayer thin-films are hoped to elucidate the pairing state in Ho-based superconducting devices. In this poster, we present preliminary PCAR results on Au/Ho/Nb films as a function of Au and Ho thicknesses, interrogating them using a superconducting Pb tip. Ultimately the experiment seeks to understand the role of Ho in generating the LRSS and its influence on proximity coupled normal metal layers.

[1] Robinson and Linder, *Nat. Phys.* **11**, 307 (2015)
[2] I. Sosnin *et al*., Phys. Rev. Lett. **96**, 157002 (2006)
[3] J. W. A. Robinson *et al*., Science **329** 5987 (2010)
[4] A. Di Bernardo *et al*., Nat. Comms **6** 8053 (2015)
[5] Usman *et al.*, Phys. Rev. B **83**, 144518 (2011)

P31 - Spin-Polarised Quasiparticle Injection at Superconductor/Magnet Interfaces

B. Stoddart-Stones, J. M. Devine-Stoneman, S. Komori, M. Amado, J. W. A. Robinson
Department of Materials Science & Metallurgy, University of Cambridge, 27 Charles Babbage Road, Cambridge CB3 0FS, United Kingdom

Single particle excitations from the Bardeen-Cooper-Schrieffer ground state of a superconductor are known as quasiparticles. Quasiparticles offer the potential for charge-spin separation in a superconductor, due to their energy-dependent properties[1]. By injecting quasiparticles in a non-equilibrium regime through a ferromagnet into a superconductor, a spin-polarised (non-superconducting) quasiparticle current may be generated and passed through the superconductor at the gap edge over a coherence length[2]. Spin-polarised quasiparticle decay lengths and lifetimes are determined by the spin diffusion length, recombination length and scattering lengths and in a magnetic device, Zeeman splitting and magnetic impurities are further factors to consider[3-5]. This poster will present results on the development of nanopillar lateral devices for investigating non-equilibrium spin-polarised quasiparticle currents in superconductors and ferromagnets using an exchange biased spin valve geometry with a superconductor spacer of Nb sandwiched between magnetically fixed and free layers of NiFe.

P32 - Majorana zero modes and their magnetic responses in a noncentrosymmetric superconductor

Keiji Yada, Katsuhiro Suzuki and Yukio Tanaka
Department of Applied Physics, Nagoya University,
Furo-cho, Chikura-ku, Nagoya, 464-8603, Japan

Superconductivity in noncentrosymmetric (NCS) system has been an important issue in condensed matter physics. NCS superconductors have been discovered in the system without bulk inversion symmetry such as $CePt_3Si$[1], Li_2Pt_3B[2] and $LaNiC_2$[3] or the two-dimensional gas at the $LaAlO_3/SrTiO_3$ heterointerface[4]. In NCS superconductors, parity mixture of the pair potential is inevitable due to the broken inversion symmetry. Thus, *s*+*p*-wave, *d*+*p*-wave and *d*+*f*-wave states are possible mixture and the ratio of even and odd parity pairing depends on their pairing interaction and the spin-orbit interaction originated from the inversion asymmetry.

In the above pairings, *d*+*p*-wave or *d*+*f*-wave pairing states have point nodes. It is known that these point nodes are topologically protected and zero-energy flat Majorana bands, which connect the projected point nodes on the surface Brillouin Zone, appear on the edge of the system[5]. This flat Majorana bands are protected by the chiral symmetry which is given by the product of the time reversal symmetry and the particle-hole symmetry. Thus, they are fragile against the magnetic field. However, depending on the direction of the magnetic field, remaining symmetry protect the Majorana zero-modes.

In this presentation, we study the Majorana zero modes and their magnetic responses in the system with the Rashba spin-orbit interaction (RSOI). Inversion asymmetry by the RSOI and the magnetic field lift the spin-degeneracy of the band dispersion. Then, normal Rashba metal (NRM), anomalous

Rashba metal (ARM) and Rashba ring metal (RRM) states appears by tuning the chemical potential. For these these three kinds of metallic states, we introduce *d*+*p*-wave pair potential. Then, Andreev bound states are calculated by using the lattice Green's function for (100) surface. We show the energy spectra and discuss the stability of the Majorana zero energy modes against the magnetic field.

[1] E. Bauer, *et al*., Phys. Rev. Lett. 92, 027003 (2004).
[2] M. Nishiyama, *et al*., Phys. Rev. B 71, 220505(R) (2005).
[3] A. D. Hillier, J. Quintanilla, and R. Cywinski, Phys. Rev. Lett. 102, 117007 (2009).
[4] N. Reyren, *et al*., Science 317, 1196 (2007).
[5] K. Yada *et al*., Phys. Rev. B 83, 064505 (2011)

P33 - Sr_2RuO_4 constriction devices to probe superconducting domain structures

Y. Yasui, K. Lahabi*, M. S. Anwar, S. Yonezawa, T. Terashima, J. Aarts*, and Y. Maeno
Department of Physics, Kyoto University
**Kamerlingh Onnes Laboratory, Leiden University*

Sr_2RuO_4 is a leading candidate of spin-triplet superconductors with an equal-spin pairing state [1]. For such a state, an unusual fluxoid state, the half-quantum fluxoid (HQF), can be realized because the Cooper pair has an additional degree of freedom in its wave-function phase. Although an observation of HQF in Sr_2RuO_4 micro rings using magnetic torque has been reported [2], detection with other experimental technique is desired. The Little-Parks experiment has been performed to aim for the detection of HQF [3]. However, the observed magnetoresistance oscillations correspond to the usual fluxoid quantization, and their amplitude is substantially larger than the expectation for the Little-Parks oscillations. Sr_2RuO_4 is also thought to be a chiral superconductor, where the time-reversal symmetry is broken [4]. In a chiral superconductor, the ground states are two-fold degenerate with different orbital angular momenta, and domains of the chirality are expected to form.

We have performed the Little-Parks magnetoresistance experiment aiming at a detection of HQF. We indeed observed peak splitting of magnetoresistance oscillations that is consistent with HQF [5]. However, some other Sr_2RuO_4 micro rings show large-amplitude oscillations in magnetoresistance, similar to that reported in ref. [3]. We further investigated their critical current and then found that the critical current also oscillates with magnetic field with the same oscillation period. Such behavior is known in DC-superconducting quantum interference devices (DC-SQUIDs). This result suggests a pair of "weak links" exists in the ring. In contrast, such DC-SQUID behavior was not observed in the other rings. Since these rings were fabricated using the same method, the different behavior in the critical current may originate from the difference in their superconducting domain structures.

In this presentation, we will discuss a possible origin of the DC-SQUID behavior with a relation to its chiral state.

[1] Y. Maeno *et al.*, J. Phys. Soc. Jpn. **81**, 011009 (2012).
[2] J. Jang *et al.*, Science **331**, 186 (2011).
[3] X. Cai *et al.*, Phys. Rev. B **87**, 081104(R) (2013).
[4] C. Kallin and J. Berlinsky, Rep. Prog. Phys. **79**, 054502 (2016).
[5] Y. Yasui *et al.*, Phys Rev. B **96**, 180507(R) (2017).

List of participants

Aarts Jan	aarts “at” physics.leidenuniv.nl
Asano Yasuhiro	asano “at” eng.hokudai.ac.jp
Attanasio Carmine	carmine.attanasio “at” sa.infn.it
Autieri Carmine	carmine.autieri “at” spin.cnr.it
Avallone Guerino	guavallone “at” unisa.it
Avella Adolfo	avella “at” physics.unisa.it
Balakrishnan Geetha	G.Balakrishnan “at” warwick.ac.uk
Birge Norman	birge “at” pa.msu.edu
Brzezicki Wojciech	w.brzezicki “at” gmail.com
Capogna Lucia	capogna “at” ill.fr
Caretta Antonio	antonio.caretta “at” elettra.eu
Caviglia Andrea	a.caviglia “at” tudelft.nl
Chang Johan	johan.chang “at” physik.uzh.ch
Cirillo Carla	carla.cirillo “at” spin.cnr.it
Citro Roberta	citro “at” sa.infn.it
Cuellar Jimenez Fabian Andres	facuella “at” ucm.es
Cuoco Mario	mario.cuoco “at” spin.cnr.it
Cuono Giuseppe	gcuono “at” unisa.it
Devine-Stoneman James	jms272 “at” cam.ac.uk
Di Bernardo Angelo	ad659 “at” cam.ac.uk
Durante Ofelia	odurante “at” unisa.it
Ferdeghini Carlo	carlo.ferdeghini “at” spin.cnr.it
Fischer Mark H.	mark.h.fischer “at” gmail.com
Fittipaldi Rosalba	rosalba.fittipaldi “at” spin.cnr.it
Forte Filomena	forte “at” sa.infn.it
Francica Gianluca	gianluca.francica “at” spin.cnr.it
Fukaya Yuri	fukaya.yuri “at” f.mbox.nagoya-u.ac.jp
Gentile Paola	paola.gentile “at” sa.infn.it
Granata Veronica	granata “at” sa.infn.it
Grilli Marco	marco.grilli “at” roma1.infn.it
Guarino Anita	guarino “at” sa.infn.it
Ikeda Atsutoshi	a.ikeda “at” scphys.kyoto-u.ac.jp
Kang Ning	nkang “at” pku.edu.cn
Kawakami Takuto	takuto.kawakami “at” yukawa.kyoto-u.ac.jp
Kim Bonju	plant0011 “at” gmail.com
Kim Changyoung	changyoug “at” snu.ac.kr
Kim Eun-Ah	eun-ah.kim “at” cornell.edu
Kim Jinkwon	kjink26 “at” gmail.com
Kimbell Graham	gk349 “at” cam.ac.uk
Kimel Alexei	a.kimel “at” science.ru.nl

Kinjo Katsuki	kinjo.katsuki.63v “at” st.kyoto-u.ac.jp
Ko Eun-Kyo	rhdmsry “at” snu.ac.kr
Kostylev Ivan	kostylev “at” scphys.kyoto-u.ac.jp
Kwon Junyoung	jykwonphy “at” gmail.com
Lado Jose	jose.lado “at” itp.phys.ethz.ch
Lee Han-Gyeol	lhg6872 “at” gmail.com
Lee Jinho	jinholee “at” snu.ac.kr
Maeno Yoshiteru	maeno “at” scphys.kyoto-u.ac.jp
Maiellaro Alfonso	amaiellaro “at” unisa.it
Malvestuto Marco	marco.malvestuto “at” elettra.trieste.it
McKenzie-Sell Lauren	lam98 “at” cam.ac.uk
Mercaldo Maria Teresa	mtm “at” physics.unisa.it
Miletto Granozio Fabio	fabio.miletto “at” spin.cnr.it
Miyoshi Takuto	miyoshi.takuto.82x “at” st.kyoto-u.ac.jp
Molenkamp Laurens	Laurens.Molenkamp “at” physik.uni-wuerzburg.de
Noce Canio	canio “at” sa.infn.it
Noh Tae Won	twnoh “at” snu.ac.kr
Onizaki Makoto	m.onizaki “at” issp.u-tokyo.ac.jp
Pace Sandro	pace “at” sa.infn.it
Palomares Garcia Carla Maria	cmp76 “at” cam.ac.uk
Porter Dan	dan.porter “at” diamond.ac.uk
Profeta Gianni	gianni.profeta “at” aquila.infn.it
Robinson Jason	jjr33 “at” cam.ac.uk
Romano Alfonso	alromano “at” unisa.it
Sakurai Keimei	keimei “at” eng.hokudai.ac.jp
Salluzzo Marco	marco.salluzzo “at” spin.cnr.it
Salman Zaher	zaher.salman “at” psi.ch
Sanchez-Manzano David	davidsan “at” ucm.es
Sangiovanni Giorgio	sangiovanni “at” physik.uni-wuerzburg.de
Sasaki Akihiro	a.sasaki “at” eng.hokudai.ac.jp
Seibold Götz	seibold “at” b-tu.de
Srivastava Anand	as2211 “at” cam.ac.uk
Stoddart-Stones Ben	bs507 “at” cam.ac.uk
Taguchi Katsuhisa	katsuhisa.taguchi “at” yukawa.kyoto-u.ac.jp
Thierschmann Holger	h.r.thierschmann “at” tudelft.nl
Van den Brink Jeroen	j.van.den.brink “at” ifw-dresden.de
Vecchione Antonio	antonio.vecchione “at” spin.cnr.it
Villegas Javier	javier.villegas “at” cnrs-thales.fr
Yada Keiji	yada “at” rover.nuap.nagoya-u.ac.jp
Yang Bohm-Jung	bjyang “at” snu.ac.kr
Yasui Yuuki	y-yasui “at” scphys.kyoto-u.ac.jp
Yonezawa Shingo	yonezawa “at” scphys.kyoto-u.ac.jp