Abstract book

Workshop on Quantum Materials and Devices at the Nanoscale

Towards manipulation of coherent quantum states

7-9th March, 2022

NANOSCALE COHERENT HYBRID DEVICES FOR SUPERCONDUCTING QUANTUM TECHNOLOGIES

cost

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Contents

Aims and Scope

The control over electronic properties at nanoscopic length scales unveils new features in superconductors. These will be key to develop superconducting devices with improved functionalities for computation or for current carrying applications. The workshop aims to gather experts addressing the problem of nanoscale superconductivity from different perspectives. We will discuss the most pressing problems in basic superconductivity, with a focus on phenomena that occur at the nanoscale, either at tunneling barriers, interfaces, pinning centers, inhomogeneities, reduced dimensionality nanowires or two-dimensional layers and address recent advances in superconducting devices close to applications.

Topics include:

- Iron based and cuprate superconductivity
- Superconductivity in two dimensional materials
- Current carrying applications
- Josephson junction devices
- High frequency detectors and resonators
- Proximity induced superconductivity in semiconducting nanowires and related devices
- SQUID technology
- Hybrid superconducting devices
- Interface superconductivity
- Devices for quantum computation
- Electronic correlations and high critical temperature superconductivity

Organizers

Organizing committee

Bending, Simon
Csonka, Szablocs
Guillamón, Isabel
Herrera, Edwin
Lee, Eduardo
Palau, Anna
Puig, Teresa
Rodrigo, Jose Gabriel
Tafuri, Francesco
Stornaioulo, Daniela
Suderow, Hermann

Scientific Advisory Committee

Aarts, Jan
Anahory, Yonathan
Babaev, Egor
Badica, Petre
Barbiellini, Bernardo
Bell, Christopher
Black-Schaffer, Annica
Blamire, Mark
Blatter, Gianni
Burnell, Gavin
Buzdin, Alexandre
Crisan, Adrian
Custers, Jeroen
Dimitrov, Dimitre
Dobrovolskiy, Oleksandr
Ertekin, Ercan
Fomin, Vladimir
Gencer, Ali
Georgieva, Milena
Georgios, Sirakoulis

Grivel, Jean-Claude
Hakonen, Pertti
Hassanien, Abdou
Hassel, Juha
İbrahim, Belenli
Ivanovic, Krsto
Kabanov, Viktor
Kakazei, Gleb
Kalisky, Beena
Koelle, Dieter
Lang, Wolfgang
Lazarević, Nenad
Leridon, Brigitte
Li, Chuan
Lombardi, Floriana
Maggio-Aprile, Ivan
Milosevic, Milorad
Mirković, Jovan
Mishonov, Todor
Moschopoulou, Evangelia
Novotný, Tomáš
Ostaszewski, Ryszard
Paladi, Florentin
Pedarnig, Johannes D.
Pešić, Jelena
Petrisor, Traian
Popović, Zorica
Pribulová, Zuzana
Robinson, Jason
Roditchev, Dimitri
Safran, Serap
Samuely, Peter
Samuely, Tomáš
Sevik, Cem
Silhanek, Alejandro V.
Sobolewski, Roman
Sørensen, Mads Peter
Stern, Raivo
Tsindlekht, Menachem I.
Van de Vondel, Joris
Villegas, Javier E.
Zaleski, Andrzej Janusz
Zinner, Nikolaj Thomas

Local organizing committee

Marta Fernández-Lomana
Jose Antonio Moreno
Raquel Sánchez-Barquilla
Irene González Martín

Grant Manager

Irene González Martín

Sponsors & Supporters

Invited Speakers

Surname	Name	Institution
Anahory	Yonathan	Hebrew University
Aragón	Jazmín	MPI Dresden and Bariloche
Ast	Christian	MPI Stuttgart
Babaev	Egor	KTH Royal Institute of Technology
Baldoví	José	University of Valencia
Bauch	Thilo	Chalmers University
Böhmer	Anna	University Bochum
Buzdin	Alexandre	University of Bordeaux
Calderón	Maria José	ICMM-CSIC
Cayao	Jorge	Uppsala University
Chakraborty	Debmalya	Uppsala University
Crisan	Adrian	National Institute of Materials
Dobrovolskiy	Oleksandr	University of Vienna
Farrar	Liam	St Andrews
Fomin	Vladimir	Moldova State University
Gaggioli	Filippo	ETH Zürich
Geshkenbein	Vadim	ETH Zürich
Giazotto	Francesco	NEST Pisa
Giraldo-Gallo	Paula	University Los Andes
Gomez	Alicia	CAB-INTA
Hassanien	Abdou	Stefan Institute
Kalaboukhov	Alexei	Goteborg University
Koelle	Dieter	Tübingen University
Lado	Jose	Aalto University
Lang	Wolfgang	University of Vienna
Leridon	Brigitte	ESPCI-Paris
Martínez-Pérez	Maria José	University of Zaragoza
Mañas	Samuel	University of Valencia
Massarotti	Davide	Naples University
Menghini	Mariela	IMDEA Nanoscience
Mishonov	Todor	Bulgarian Academy of Sciences

Novotny	Tomas	Charles University
Nuelens	Lukas	KU Leuven
Poggio	Martino	Basel University
Ridderbos	Joost	University of Twente
Roditchev	Dimitri	ESPCI-Paris
Rogero	Celia	CFM-UPV/EHU
Steffensen	Gorm	Universidad Autónoma de Madrid
Szabo	Pavol	Slovak Academy of Sciences
Willa	Roland	Karlsruhe Institute of Technology
Ye	Jianting	University of Groningen
Zalom	Peter	Czech Academy of Sciences

Program

	Monday 7 March	Tuesday 8 March	Wednesday 9 March
8:45	**Opening**		
	Session 1: Topological SC	**Session 5: Josephson junctions and SQUID**	**Session 8: Vortex Matter**
9:00	Roditchev	Massarotti	Geshkenbein
9:25	Ast	Poggio	Gaggioli
9:50	Bauch	Koelle	Dobrovolskiy
10:15	Cayao	Giazotto	Menghini
10:40	Rogero	Nulens	Aragón
11:05	**Coffee Break**	**Coffee Break**	**Coffee Break**
	Session 2: Hybrid SC devices	**Session 6: Pnictide SC**	**Session 9: Low dimen-sional SC**
11:30	Zalom	Böhmer	Buzdin
11:55	Novotný	Leridon	Kalaboukhov
12:20	Hasanien	Chakraborty	Willa
12:45	Steffensen	Crisan	Fomin
13:10	Ye	Szabó	Ridderbos
13:35	**Lunch**	**Lunch**	**Lunch**
	Session3: Coexisting phases in layer materials	**Session 7: Other unconventional SC**	**Session 10: Josephson junctions and resonators**
15:00	Anahory	Lang	Lado
15:25	Baldoví	Mishonov	Martínez-Pérez
15:50	Mañas	Farrar	Gómez
16:15	Calderón	Babaev	**Closure**
16:40	Giraldo-Gallo	**Coffee Break**	
17:05	**Coffee Break**	**Free time Guided Walk Madrid (18:00-20:00)**	
17:40	**Poster Session 1**		
	19:00 Cocktail Dinner	**20:00 Conference Dinner**	

7 March 2022, from 8h45 to 13h00 CET

Zoom Session, day 1:

https://us02web.zoom.us/j/84376949987?pwd=S004cVV6eFN6bWZ1WitBc0RaTmpCQT09

ID: 843 7694 9987
Code: 595594

08h45-09h00: **Organizers**, opening.

Session 1: Topological superconductivity. Chair: Hermann Suderow

09h00-09h25: **Dimitri Roditchev**, ESPCI-Paris, "*Resonant transmission of Josephson current in Nb-$Bi_2Te_{2.3}Se_{0.7}$-Nb junctions via Andreev bound states*".

09h25-09h50: Online. **Christian Ast**, MPI Stuttgart, "*Supercurrent Reversal through Atomic Scale Yu-Shiba-Rusinov States*".

09h50-10h15: Online. **Thilo Bauch**, Chalmers University, "*Circuit-QED probing of Majorana bound states in TI nano Josephson junctions*".

10h15-10h40: **Jorge Cayao**, Uppsala University, "*Highly tunable exceptional points in non-hermitian Rashba superconductors*".

10h40-11h05: **Celia Rogero**, CFM-UPV/EHU, "*Ferromagnetic insulator/superconductor interfaces as a platform for the superconducting-based nanodevices*".

11h05-11h30 BREAK

Session 2: Hybrid superconducting devices. Chair: Eduardo Lee

11h30-11h55: **Peter Zalom,** Czech Academy of Sciences, "*Fast numerical renormalization group algorithms for multiterminal quantum dot devices*".

11h55-12h20: **Tomás Novotný**, Charles University, "*Critical reassessment of YSR states in quantum impurities in contact with superconductors: effects of the quantum spin degree of freedom*".

12h20-12h45: **Abdou Hasanien,** Stefan Institute, "*Self-assembled antiferromagnetic chains within a single layer of organic superconductor*".

12h45-13h10: **Gorm Steffensen,** Universidad Autónoma de Madrid, "*Direct Transport between Superconducting Subgap States in a Double Quantum Dot*".

13h10-13h35: Online. **Jianting Ye**, University of Groningen, "*Field Effect Control of Quantum Phases in 2D Materials*".

13h35-15h00 LUNCH BREAK

7 March 2022, from 15h00 to 17h05 CET

Session 3: Coexisting phases in layered materials. Chair: Dimitri Roditchev

15h00-15h25: **Yonathan Anahory,** Hebrew University, "*Interior and edge magnetization in thin exfoliated CrGeTe3 films*".

15h25-15h50: **Jose Baldoví**, University of Valencia, "*Electronic structure and magnetism in 2D van der Waals materials*".

15h50-16h15: **Samuel Mañas**, University of Valencia, "*Superconductivity in strongly correlated van der Waals heterostructures*".

16h15-16h40: **Maria José Calderón**, ICMM-CSIC, "*Correlated states in ABC trilayer graphene/hBN moiré heterostructures*".

16h40-17h05: Online. **Paula Giraldo-Gallo**, University Los Andes, "*Charge Density Wave Formation In The Quasi-1D Transition Metal Tetrachalcogenides*".

Session 4: Poster session.

8 March 2022, from 09h00 to 13h00 CET

Zoom Session, day 2:

https://us02web.zoom.us/j/81715064843?pwd=YVZCdHNGbGlnOEF2TURwc2NobTl2Zz09

ID: 817 1506 4843
Code: 794028

Session 5: Josephson junctions and SQUID. Chair: Yonathan Anahory

09h00-09h25: **Davide Massarotti**, Naples University, "*Unconventional Josephson devices and circuits for quantum architectures*".

09h25-09h50: **Martino Poggio**, Basel University, "*Magnetic, thermal, and topographic imaging with a nanometer-scale SQUID-on-lever scanning probe*".

09h50-10h15: **Dieter Koelle**, Tübingen University, "*Niobium nanosquids patterned by Helium or Neon Focused ion beams*".

10h15-10h40: Online. **Francesco Giazotto**, NEST-CNR Pisa, "*Quantum interference superconducting thermal nanovalve*".

10h40-11h05: **Lukas Nulens**, University of Leuven, "*Metastable states and hidden phase slips in nanobridge SQUIDs*".

11h05-11h30 BREAK

Session 6: Pnictide Superconductivity. Chair: Wolfgang Lang

11h30-11h55: **Anna Böhmer**, University Bochum, "*Local nematicity in iron-based superconductors induced by random strain fields*".

11h55-12h20: **Brigitte Leridon**, ESPCI Paris, "*Granular metallicity and inhomogeneous superconductivity in thin films*".

12h20-12h45: **Debmalya Chakraborty**, Uppsala University, "*Disorder-robust phase crystal in high-temperature superconductors from topology and strong correlations*".

12h45-13h10: **Adrian Crisan**, National Institute of Materials, "*Multi-harmonic Susceptibility, DC Magnetization and Magnetic Relaxation Measurements in Iron-based Superconducting Single Crystal* $CaKFe_4As_4$".

13h10-13h35: **Pavol Szabó**, Slovak Academy of Sciences, "*Interface induced pair-breaking effects in strongly disordered superconducting MoN ultra-thin films*".

13h35-15h00 LUNCH BREAK

8 March 2022, from 15h00 to 17h05 CET

<u>Session 7</u>: Other unconventional superconductors. Chair: Alexandre Buzdin

15h00-15h25: **Wolfgang Lang**, University of Vienna, "*Probing the anisotropic properties of YBCO with vicinal-grown films*".

15h25-15h50: **Todor Mishonov,** Bulgarian Academy of Sciences, "*Hot and cold spots along the Fermi contour of High-Tc cuprates in the framework of Shubin-Kondo-Zener s-d exchange interaction*".

15h50-16h15: Online. **Liam Farrar,** St Andrews, "*Superconducting Quantum Interference in Twisted van der Waals Heterostructures*".

16h15-16h40: Online. **Egor Babaev,** KTH Royal Institute of Technology, "*Superconducting boundary states*".

16h40-17h05 BREAK

9 March 2022, from 09h00 to 13h00 CET

Zoom Session, day 3:

https://us02web.zoom.us/j/87129237980?pwd=RHZkRG1FanBmZW81bDc3dVBHMjhzUT09

ID: 871 2923 7980
Code: 553841

Session 8: Vortex Matter. Chair: Jose Luis Vicent

09h00-09h25: **Vadim Geshkenbein**, ETH Zurich, "*Flux creep and the Campbell response in type II superconductors*".

09h25-09h50: **Filippo Gaggioli**, ETH Zurich, "*Strong pinning transition with arbitrary defect potentials*".

09h50-10h15: **Dobrovolskiy Oleksandr**, University Vienna, "*Vortex jets in superconductors*".

10h15-10h40: **Mariela Menghini**, IMDEA Nanoscience, "*Vortex dynamics and phase diagram modifications induced by magnetic nanostructures*".

10h40-11h05: **Jazmín Aragón**, MPI Dresden, Bariloche, "*Disordered hyperuniform vortex matter with rhombic distortions in FeSe at low fields*".

11h05-11h30 BREAK

Session 9: Low Dimensional Superconductivity. Chair: José Baldoví

11h30-11h55: **Alexandre I. Buzdin**, University of Bordeaux, "*Influence of a circular polarized radiation on the spontaneous current generation in superconducting ring*".

11h55-12h20: **Alexei Kalaboukhov**, Goteborg University, "*Probing unconventional superconductivity in the $LaAlO_3$ /$SrTiO_3$ interface using transport in nanowires*".

12h20-12h45: **Roland Willa**, KIT, "*Inhomogeneous strain causes Time reversal symmetry breaking in Sr_2RuO_4*".

12h45-13h10: Online. **Vladimir Fomin**, Moldova State University, "*Topological transitions in ac/dc-driven open superconductor nanotubes*".

13h10-13h35: Online. **Joost Ridderbos**, University of Twente, "*Induced superconductivity in Ge-Si core-shell nanowires*".

13h35-15h00 LUNCH BREAK

8 March 2022, from 15h00 to 16h40 CET

Session 10: Josephson junctions and resonators. Chair: Dieter Koelle

15h00-15h25: **Jose Lado**, Aalto University, "*Topological and nodal superconductivity in van der Waals materials*".

15h25-15h50: **Maria José Martínez-Pérez,** University of Zaragoza, "*Interfacing magnonic and superconducting quantum circuits*".

15h50-16h15: **Alicia Gómez**, IMDEA Nanoscience, "*Superconducting Resonators for Space and Quantum Applications*".

Abstracts

RESONANT TRANSMISSION OF JOSEPHSON CURRENT IN Nb-$Bi_2Te_{2.3}Se_{0.7}$-Nb JUNCTIONS VIA ANDREEV BOUND STATES

V. S. Stolyarov[1], D. Roditchev[2,*], V. L. Gurtovoi[1], O. V. Skryabina[1], V. M. Vinokur[3], A. A. Golubov[1,4]

1 Center for Advanced Mesoscience and Nanotechnology, Moscow Institute of Physics and Technology, Dolgoprudny, 141700 Moscow, Russia

2 Laboratoire de Physique et d' Étude des Matériaux (LPEM), UMR-8213, ESPCI Paris, PSL Research University, CNRS, Sorbonne Université, 75005 Paris, France

3 Terra Quantum AG, St. Gallerstrasse 16A, CH-9400 Rorschach, Switzerland

4 Faculty of Science and Technology and MESA+ Institute of Nanotechnology, 7500 AE Enschede, The Netherlands

A new type of resonant oscillations of the critical Josephson current in the magnetic field is observed in DC-transport response of ballistic Nb-$Bi_2Te_{2.3}Se_{0.7}$-Nb proximity junctions at temperatures below 500 mK [1]. The unexpectedly fine (~ 1 Oe) period of oscillations along with the upwards peaked maxima are attributed to the resonant transmission of quasiparticles through low-lying Andreev bound states forming at the superconductor-topological insulator interfaces owing to the p-wave component of the induced superconducting order [2].

References

[1] V.S. Stolyarov et al. Commun Mater 1, 38 (2020). https://doi.org/10.1038/s43246-020-0037-y

[1] V.S. Stolyarov et al. Adv. Quantum Tech. 2100124 (2022) https://doi.org/10.1002/qute.202100124

**Presenting author email: dimitri.roditchev@espci.fr*

Supercurrent Reversal through Atomic Scale Yu-Shiba-Rusinov States

Christian R. Ast[1,*]

1 Max-Planck-Institute for Solid State Research, Heisenbergstraße 1, 70569 Stuttgart, Germany

Magnetic impurities on superconductors give rise to discrete bound states inside the superconducting gap known as Yu-Shiba-Rusinov (YSR) states. Varying the impurity-superconductor coupling induces a quantum phase transition (QPT) as the YSR state energy passes through zero. The concomitant sign change in the Josephson current – a long sought for hallmark of this QPT – has remained elusive so far. Using scanning tunneling microscopy (STM), we demonstrate such a 0 to π transition of a Josephson junction through a YSR state as we continuously change the impurity-superconductor coupling. We detect the sign change in the Josephson current by exploiting a second transport channel as a reference in analogy to a superconducting quantum interference device (SQUID), which provides a rudimentary phase sensitivity for the STM. The change in the Josephson current through the QPT is significant and demonstrates the role of the impurity spin as well as the parity change across the QPT.

**Presenting author email: c.ast@fkf.mpg.de*

Circuit-QED probing of Majorana bound states in TI nano Josephson junctions

A. Surendran[1], G. Kunakova[1,2], J. Andzane[2], D. Erts[2], F. Lombardi[1] and T. Bauch[1,*]

1 Quantum Device Physics Laboratory, Department of Microtechnology and Nanoscience, Chalmers University of Technology, SE-41296 Göteborg, Sweden

2 Institute of Chemical Physics, University of Latvia, LV-1586 Riga, Latvia

The interest in hybrid Topological Insulator (TI) Josephson junctions was boosted after the prediction by Fu and Kane of an unconventional chiral p-wave symmetry of the proximity induced order parameter into the topological surface states. The chiral induced p-wave is a prerequisite for the nucleation of localized Majorana states in a tri-junction geometry, which is instrumental for topological quantum computation. In a multimode hybrid TI Josephson junction with two terminal geometry, Majorana physics manifests as peculiar properties of a part of the Andreev bound states carrying the Josephson current: they give rise to an unconventional 4π periodic current phase relation (CPR) coexisting with a 2π periodic CPR of the conventional Andreev bound states. The relative weight between the 4π and 2π periodic Andreev bound states increases with the transparency of the junction and, in general, by reducing the number of channels. A direct way to achieve a low number of transport channels is to use TIs with reduced dimensionality like very thin and narrow nanoribbons. Indeed, quite recently, various theoretical proposals have shown the advantage to using Josephson junctions with TI nanoribbons, with suppressed bulk conduction, to realize Majorana fermions.

To obtain information about the bound state spectrum we have implement a circuit-QED readout scheme for our Al-Bi2Se3-Al hybrid junctions. Here we embedded a TI Josephson junction-based RF SQUID in a superconducting resonator. The microwave read out of the resonator/RF-SQUID setup allows us to extract information about the bound state spectrum of the TI junction. In fact, the low amplitude microwave readout ensures a relative low perturbation of the junction (in respect to the critical current) as compared to typical "Shapiro step" measurements, where the large microwave drive can cause undesirable population of higher lying bound states. Moreover, the microwave readout enables us to characterize decoherence sources eventually affecting the performance of a TI junction based topological quantum bit.

**Presenting author email: thilo.bauch@chalmers.se*

NANOSCALE COHERENT HYBRID DEVICES FOR SUPERCONDUCTING QUANTUM TECHNOLOGIES

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

HIGHLY TUNABLE EXCEPTIONAL POINTS IN NON-HERMITIAN RASHBA SUPERCONDUCTORS

J. Cayao[1,*], A. M. Black-Schaffer[1]

1 Department of Physics and Astronomy, Uppsala University, Box 516, S-751 20 Uppsala, Sweden

In this talk I will first discuss a simple but feasible route to induce non-Hermitian effects in superconducting systems coupled to normal leads. I will then use this approach to show the emergence of exceptional points, non-Hermitian degeneracies where eigenvalues and eigenfunctions coalesce, in non-Hermitian superconductors with Rashba spin-orbit coupling. I will finally discuss the controllability of these exceptional points by tuning the system parameters and also their detection in spectral observables.

References

[1] J. Cayao, A. M. Black-Schaffer, In preparation.

**Presenting author email: jorge.cayao@physics.uu.se*

Ferromagnetic insulator/superconductor interfaces as a platform for the superconducting-based nanodevices

C. Rogero[1,2,*]

1 Centro de Física de Materiales CSIC-UPV/EHU, Manuel de Lardizabal 5, E-20018 San Sebastian, Spain

2 Donostia International Physics Center, Manuel de Lardizabal 4, E-20018 San Sebastian, Spain

Ferromagnetic insulators (FI) can induce a strong exchange field in an adjacent superconductor (S) via the magnetic proximity effect. This manifests as spin splitting of the BCS density of states of the superconductor, an important ingredient for numerous superconducting applications. Recent discovery of giant thermoelectric effect taking place in superconductor/ferromagnetic insulator heterostructures [1] has been proposed to be used as an electromagnetic radiation detectors based on superconductors, such as the kinetic inductance detectors or the transition edge sensors. In our work, we explore the heterostructures based on EuS/Al multilayer [2] to develop these kind of sensors. For that we have explored and optimized the optimal chemical composition of the EuS layer, determine the quality of the interfaces between EuS and Al as well as determine the importance of the superconducting layer in the performance of the devices. For doing that, we combine the most powerfull surface science techniques with theoretical calculations.

References

[1] A. Ozaeta, P. Virtanen, F. S. Bergeret, and T. T. Heikkilä, Predicted Very Large Thermoelectric Effect in Ferromagnet-Superconductor Junctions in the Presence of a SpinSplitting Magnetic Field, Physics Review Letters 112 (2014)

[2] F. Katmis, V. Lauter, F. S. Nogueira, B A. Assaf, M. E. Jamer, P. Wei, B. Satpati, J. W. Freeland, I. Eremin, D. Heiman, P. J. Herrero & J. S. Moodera, A high-temperature ferromagnetic topological insulating phase by proximity coupling, Nature, 533 (2016) 513.

**Presenting author email: celia.rogero@ehu.eus*

Fast numerical renormalization group algorithms for multiterminal quantum dot devices

Peter Zalom [1],*

1 Institute of Physics, Czech Academy of Sciences, Na Slovance 2, CZ-18221 Praha 8, Czech Republic

Quantum dot-superconductor (QD-SC) devices represent promising building blocks for various applications, e. g. quantum and fast classical computing. Their unbiased theoretical description at any temperature is potentially possible via Numerical renormalization group (NRG) but is now limited only to relatively simple cases.

In this talk, the origin of the limitations is identified. First, we present a method for exact mappings of QD-SC devices into simpler systems, which, combined with the construction of Wilson chains from arbitrary tunneling self-energies [1], allows tackling the properties of multiterminal Josephson junctions. The approach is demonstrated to solve a three-terminal device composed of two phase-biased superconducting and one metallic lead [2]. The resulting spectral and transport properties are presented to be in accord with existing experimental and theoretical data. Generalization of the approach to the multiterminal Josephson case as well as to multiple QD devices is subsequently briefly discussed.

References

[1] R. Bulla, T. Pruschke, and A. C. Hewson, J. Phys. Condens. Matter 9, 10463 (1997).

[2] P. Zalom, V. Pokorný, and T. Novotný, Phys. Rev. B 103, 035419 (2021).

**Presenting author email:* peterzet@gmail.com

Critical reassessment of YSR states in quantum impurities in contact with superconductors: effects of the quantum spin degree of freedom

Tomáš Novotný[1,*]

1 Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Ke Karlovu 5, CZ-12116 Praha 2, Czech Republic

I will address the issue of nature and energies of bound in-gap states, usually but imprecisely called Yu-Shiba-Rusinov (YSR) states, for a spin 1/2 impurity weakly coupled to superconducting leads modelled by a superconducting variant of the Anderson model. I will show that for sufficiently weak coupling to the leads, the problem can be easily solved by the Brillouin-Wigner perturbation theory exhibiting an excellent agreement with the NRG results, but strong discrepancies from the YSR energies which neglect the quantum fluctuations of the spin degree of freedom. I will further sketch the so far uncovered anatomy of the 0-pi quantum phase transition in this model when the superconducting gap approaches 0 pushing the system into the Kondo regime.

**Presenting author email: tno@karlov.mff.cuni.cz*

Self-assembled antiferromagnetic chains within a single layer of organic superconductor

A. Hassanien[1,*], B. Zhou[2], A. Kobayashi[2]

1 J. Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia

2 Nihon University, Sakurajosui, Setagaya-ku, Tokyo 156-8550, Japan

We present scanning tunneling microscopy and spectroscopy to study the interplay between superconductivity and magnetism in a single layer of organic d-wave superconductors $(BETS)_2GaCl_4$ on Ag(111). Antiferromagnetic molecular chains of $GaCl_4$ are spontaneously formed within the superconducting single layer due to shortages of BETS dimers. Below transition temperature of 7K, the superconducting order masks the antiferromagnetic order and dominates the electronic properties showing a ubiquitous gap over the entire island with proximity effect across the island/Ag(111) interface. These features gradually decay with the rise in temperature giving way to a Kondo dip on $GaCl_4$ chains with additional inelastic vibronic features on $(BETS)_2GaCl_4$ stripes. The concurrent absence of these signals below Tc may be related to a renormalization process where both phonon and antiferromagnetic fluctuation exhibit a cooperative existence to mediate superconductivity in such d-wave superconductors.

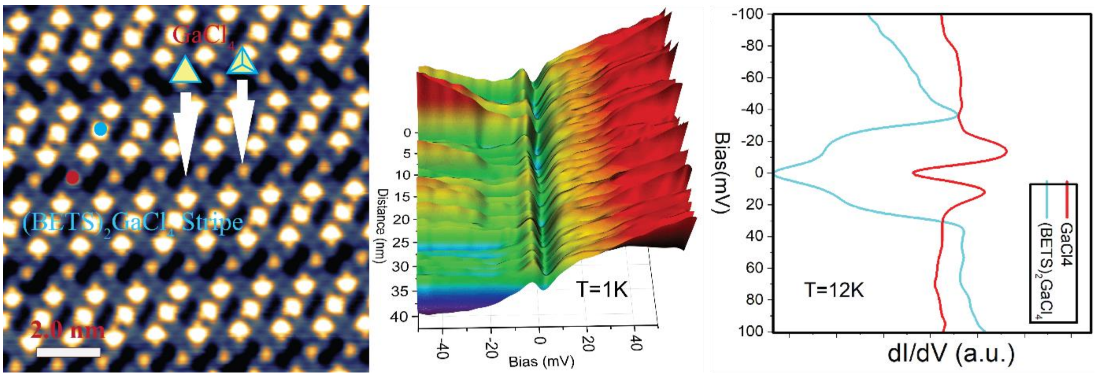


Fig. 1:. Atomically clean interfaces between superconducting stripes and antiferromagnetic chains are spontaneously formed within a single layer of charge transfer complex $(BETS)_2GaCl_4$. Low level excitations that dominate the higher temperature phase are absent below Tc which point to their possible renormalization to mediate superconductivity in such d-wave superconductors

References

[1] A. Hassanien B. Zhou and A. Kobayashi, Adv. Electron. Mater. 2000461, (2020).

[2] A. Hassanien, Adv. Electron. Mater. 1800247, (2019)

[3] A. Hassanien, physica status solidi (b) 256 (12) 1900346 (2019).

[4] K. Clark, A. Hassanien, S. Khan, K.-F. Braun, H. Tanaka and S.-W. Hla. Nature Nanotech 5, 261–265 (2010)

**Presenting author email: Abdou.Hassanien@ijs.si*

Direct Transport between Superconducting Subgap States in a Double Quantum Dot [1]

G. O. Steffensen[1,*], J. C. Estrada Saldana[2], A. Vekris[2], P. Krogstrup[2], K. Grove-Rasmussen[2] , J. Nygaard[2], A. L. Yeyati[1], J. Paaske[2]

1 Departamento de Fısica Teorica de la Materia Condensada, Universidad Autonoma de Madrid, 28049 Madrid, Spain

2 Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

In this talk I will present recent measurements of direct transport between opposing YSR states and accompanying theoretical analysis. This sub-gap transport relies on intrinsic quasiparticle relaxation, but the tunability of the device allows us to explore also an additional relaxation mechanism based on charge transferring Andreev reflections. The transition between these two relaxation regimes is identified in the experiment as a marked gate-induced stepwise change in conductance. I will present a transport calculation, including YSR bound states and multiple Andreev reflections alongside with quasiparticle relaxation, due to a weak tunnel coupling to a nearby normal metal, with which we find an excellent agreement to data.

References

[1] G. O. Steffensen, et al. arXiv, 2021.

**Presenting author email: Gorm.steffensen@uam.es*

Field Effect Control of Quantum Phases in 2D Materials

Jianting Ye[1,*]

1 Device Physics of Complex Materials, Zernike Institute for Advanced Materials, University of Groningen

Many recent discoveries on novel electronic states were made on 2D materials. Especially, by making artificial bilayer systems, new electronic states such as unconventional superconductivity and orbital ferromagnetism have been reported. In this talk, we will discuss quantum phase transitions and Ising superconductivity induced in 2D transition metal dichalcogenides. Using ionic gating, quantum phases such as superconductivity can be induced electrostatically on many 2D materials. In transition metal dichalcogenides, Ising-like paring states can form showing a strong orthogonal spin-protection and record-high upper critical field. Also, we will discuss how to couple two Ising superconducting states through Josephson coupling. The superconductivity in a suspended bilayer can be induced symmetrically using ionic gating on both surfaces. This method can access electronic states with broken local inversion symmetry while maintaining the global inversion symmetry. Field effect control of the Josephson and spin-orbit coupling is an essential step for realizing many exotic electronics states predicted for the coupled bilayer superconducting systems with strong spin-orbit interaction.

**Presenting author email: j.ye@rug.nl*

Interior and edge magnetization in thin exfoliated $CrGeTe_3$ films

Yonathan Anahory[1,*], Avia Noah[1], Hen Alpern[1,2], Sourabh Singh[1], Alon Gutfreund[1], Gilad Zisman[1], Tomer D. Feld[1], Atzmon Vakahi[3], Sergei Remennik[3], Yossi Paltiel[2], Martin E. Huber[4], Victor Barrena[5], Hermann Suderow[5], Hadar Steinberg[1], and Oded Millo[1]

1 The Racah Institute of Physics, The Hebrew University, Jerusalem, 91904, Israel

2 Department of Applied Physics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

3 Center for Nanoscience and Nanotechnology, Hebrew University of Jerusalem, Jerusalem, 91904, Israel

4 Departments of Physics and Electrical Engineering, University of Colorado Denver, Denver, CO 80217, USA

5 Laboratorio de Bajas Temperaturas, Unidad Asociada UAM/CSIC, Departamento de Física de la Materia Condensada, Instituto Nicolás Cabrera and Condensed Matter Physics Center, Universidad Autónoma de Madrid, E-28049 Madrid, Spain

$CrGeTe_3$ (CGT) is a semiconducting vdW ferromagnet shown to possess magnetism down to a two-layer thick sample. Although CGT is one of the leading candidates for spintronics devices, a comprehensive analysis of CGT thickness dependent magnetization is currently lacking. In this work, we employ scanning SQUID-on-tip (SOT) microscopy to resolve the magnetic properties of exfoliated CGT flakes at 4.2 K. Combining transport measurements of CGT/$NbSe_2$ samples with SOT images, we present the magnetic texture and hysteretic magnetism of CGT, thereby matching the global behavior of CGT to the domain structure extracted from local SOT magnetic imaging. Using this method, we provide a thickness dependent magnetization state diagram of bare CGT films. No zero-field magnetic memory was found for films thicker than 10 nm and hard ferromagnetism was found below that critical thickness. Using scanning SOT microscopy, we identify a unique edge magnetism, contrasting the results attained in the CGT interior.

**Presenting author email: yonathan.anahory@mail.huji.ac.il*

Electronic structure and magnetism in 2D van der Waals materials

Jose Baldoví[1],*

1 *Instituto de Ciencia Molecular (ICMol), Universitat de València, Paterna, 46980, Spain.*

Since the discovery of graphene, two-dimensional (2D) materials have been at the forefront of research in physics, chemistry and materials science, holding great promise to revolutionize several major areas both in academia and industry. This generation of ultrathin materials has expanded at an impressive pace, now covering a wide range of functionalities. Moreover, they can be assembled into different van der Waals (vdW) heterostructures, and twisted with respect to each other, to create novel multifunctional materials and devices, as well as exotic quantum phases of matter. While extensive research has been conducted on their electrical and optical properties, their magnetic behaviour has just started to become a highly topical focus of interest. In this context, the recent emergence of vdW magnetic materials that can retain long-range magnetic order down to the 2D limit has unlocked new horizons in fundamental physics while providing unprecedented opportunities for spintronics and magnonics.[1] Herein, we will provide a pedagogical overview of a general computational framework based on Hubbard-corrected density functional theory and a derived tight-binding Hamiltonian based on maximally-localized Wannier functions to study some of the most characteristic examples of 2D magnetism (e.g. CrI3, MPS3, CrSBr, etc.) using van der Waals materials [2,3] This approach provides an efficient and intuitive way to compute magnetic interactions, critical temperatures and spin wave spectrums. The external control of the properties using mechanical strain will also be overviewed. Finally, I will introduce the effect of magnetic substitutional Fe impurities in the surface of 2D layered superconductors such as 2H-$NbSe_2$ and 2H-$NbSe_{1.8}S_{0.2}$ simulated by DFT+U calculations. [4]

References

[1] (a) Huang, B.; Clark, G.; Navarro-Moratalla, E.; Klein, D. R.; Cheng, R.; Seyler, K. L.; Zhong, E.; Schmidgall, E.; McGuire, M. A.; Cobden, D. H.; Yao, W.; Xiao, D.; Jarillo-Herrero, P.; Xu, X. *Nature*, 2017, 546, 270–273. (b) Gong, C.; Li, L.; Li, Z.; Ji, H.; Stern, A.; Xia, Y.; Cao, T.; Bao, W.; Wang, C.; Wang, Y.; Qiu, Z. Q.; Cava, R. J.; Louie, S. G.; Xia, J.; Zhang, X. *Nature*, **2017**, 546, 265–269.

[2] Ramos, M.; Carrascoso, F.; Frisenda, R.; Gant, P.; Ma as-Valero, S.; Esteras, D. L.; Baldoví, J. J.; Coronado, E.; Castellanos-Gomez, A.; Calvo, M. R. *npj 2D Mat. And Appl.*, **2021**, 5(1), 1-9

[3] (a) Esteras, D. L.; Baldoví, J. J. *arXiv:2104.03023*, **2021**; (b) Montoya, A. R.; Esteras, D. L.; Rybakov, A.; Baldoví, J. J. *In preparation*, **2022**.

[4] Park, S.; Barrena, V.; Mañas-Valero, S.; Baldoví, J. J.; Fente, A.; Herrera, E.; Mompeán, F.; García-Hernández, M.; Rubio, A.; Coronado, E.; Guillamón, I.; Levy Yeyati, A.; Suderow, H. *Nature Commun*. **2021**, 12, 4668.

**Presenting author email: J.Jaime.Baldovi@uv.es*

Superconductivity in strongly correlated van der Waals heterostructures

Samuel Mañas-Valero[1],*, Carla Boix-Constant[1] and Eugenio Coronado[1].

1 Instituto de Ciencia Molecular (ICMol), Universitat de València, Paterna, 46980, Spain.

Layered materials are excellent candidates for studying the interplay between the in-plane and out-of-plane entanglement in strongly correlated systems. A relevant example is provided by 1T-TaS_2, which shows a multifaceted electronic and magnetic scenario due to the existence of several charge density waves (CDW) configurations, including quantum hidden phases, superconductivity and even quantum spin liquid (QSL) phases, that are highly dependent on the out-of-plane stacking of the CDW [1].

Here, we fabricate vertical van der Waals heterostructures based on few-layer graphene and superconducting $NbSe_2$ and we measure their transport properties. Different activation energies in the conductance and a gap at the Fermi level are observed, which make 1T-TaS_2 a potential candidate for hosting multiple QSL crossovers. In addition, an enhancement of the vdWH resistance is observed below the superconducting transition temperature of the $NbSe_2$ flakes, which overall behavior is consistent with the Bardeen–Cooper–Schrieffer theory [2,3].

This vdWH approach can be extended to other 2D materials, such as 2D magnets or topological insulators, with the aim of exploring the new emergent properties that may arise from such combinations.

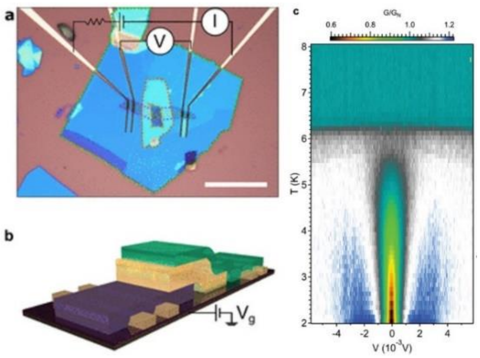


Fig. 1: Vertical van der Waals heterostructures (vdWH) based on 1T-TaS_2. (a) Optical image of the vdWH and electronic transport configuration. Scale bar: 20 μm. (b) Artistic representation –not to scale– of the vdWH. (c) Normalized conductance as a function of DC voltage bias and temperature.

References

[1] S. Mañas-Valero, B. M. Huddart, T. Lancaster, E. Coronado, F. L. Pratt, npj Quantum Mater. 2021, 6, 69.

[2] C. Boix-Constant, S. Mañas-Valero, R. Córdoba, J. J. Baldoví, Á. Rubio, E. Coronado, ACS Nano 2021, 15, 11898.

[3] C. Boix-Constant, S. Mañas-Valero, R. Córdoba, E. Coronado, Adv. Electron. Mater. 2021, 7, 2000987.

**Presenting author email: samuel.manas@uv.es*

Correlated states in ABC trilayer graphene/hBN moiré heterostructures

Elena Bascones[1], Alberto Camjayi[2], María J Calderón[1,*]

1 Instituto de Ciencia de Materiales de Madrid, ICMM-CSIC, Cantoblanco, E-28049 Madrid, Spain

2 Departamento de Física, Comision Nacional de Energía Atómica (CNEA), Avenida General Paz y Constituyentes, 1650 San Martín, Argentina

Shortly after the discovery of correlated states and superconductivity in twisted bilayer graphene, correlated insulating states were also detected in another graphene based moiré heterostructures: the ABC trilayer aligned with hBN. The influence of the moiré on the correlated states has been questioned by the recent report of ferromagnetism and superconductivity in ABC trilayer graphene without the moiré pattern induced by hBN. Using Dynamical Mean Field Theory we have studied the signatures of Mott physics which can be induced by the moiré pattern on the trivial valence band at half-filling. In the talk we will discuss the doping and temperature dependent spectral weight reorganization characteristic of Mott correlations and absent in standard symmetry breaking transitions, and a competing antiferromagnetic state present very close to half-filling.

**Presenting author email: mariaj.calderon@csic.es*

Charge Density Wave Formation In The Quasi-1D Transition Metal Tetrachalcogenides

P. Giraldo-Gallo[1,*], J. A. Galvis[2], A. Fang[3,4], D. Jiménez-Guerrero[1], J. Rojas-Castillo[1], J. Casas[2], O. Herrera[2], A. C. Garcia-Castro[5], E. Bousquet[6], I. R. Fisher[3,4], and A. Kapitulnik[3,4]

1 Department of Physics, Universidad de Los Andes, Bogotá 111711, Colombia

2 Faculty of Engineering and Basic Sciences, Universidad Central, Bogotá, Colombia

3 Department of Applied Physics and Geballe Laboratory for Advanced Materials, Stanford University, Stanford, California 94305, USA

4 Stanford Institute for Materials and Energy Sciences, SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94025, USA

5 School of Physics, Universidad Industrial de Santander, Carrera 27 Calle 09, 680002, Bucaramanga, Colombia

6 Physique Théorique des Matériaux, QMAT, CESAM, Université de Liège, B-4000 Sart-Tilman, Belgium

The quasi-1D transition metal tetrachalcogenides are a model system to explore the conjunction of correlated electronic states such as charge density waves (CDW) and superconductivity, with topological phases of matter, as they have been recently predicted to host Weyl points in their electronic structure. The understanding of the connection between these phases requires a thorough understanding of the characteristics of the individual states, which for the case of the CDW in these materials, is still missing. In this talk I will present our recent results which combine phonon-structure calculations and scanning tunneling microscopy measurements of one of the family members of the tetrachalcogenides, the $NbTe_4$, in order to provide a full characterization of the CDW state at low temperatures for this material. We find that the superstructure formed by the CDW in the Te-terminated cleaved surface is fully commensurate with the lattice parameters, consistent with our theoretical predictions. Moreover, our data reveals the presence of phase-slip domain walls separating regions of commensurate-CDW in the nanoscale, indicating that the low-temperature CDW in this compound is discommensurate. By comparison with the CDW characterization by previous diffraction experiments, we provide evidence of the presence of this discommensurate CDW phase at all temperatures below room temperature. Our results provide strong evidence to solve a long-standing discussion in terms of the nature and characteristics of the CDW in this material, and provide a strong basis for the study of the interplay between this state and other novel quantum electronic states.

**Presenting author email: pl.giraldo@uniandes.edu.co*

Unconventional Josephson devices and circuits for quantum architectures

D. Massarotti[1,*], H. G. Ahmad[2], L. Di Palma[2], A. Miano[2], R. Satariano[2], R. Ferraiuolo[2], M. Arzeo[3], L. Parlato[2], G. Ausanio[2], P. Lucignano[2], D. Montemurro[2], O. Muhanov[3], G. P. Pepe[2], F. Tafuri[2]

1 Dipartimento di Ingegneria Elettrica e delle Tecnologie dell'Informazione, Università Federico II di Napoli, via Claudio 80125 Napoli, Italy

2 Dipartimento di Fisica "E. Pancini", Università Federico II di Napoli, Complesso Universitario di Monte Sant'Angelo, via Cinthia 80126 Napoli, Italy

3 SeeQC-eu, Complesso Universitario di Monte Sant'Angelo, via Cinthia 80126 Napoli, Italy

The modern era of Josephson devices is strongly influenced by the continuous progress in material science and nanotechnologies, which is providing advanced applications in superconducting quantum technologies. Within this framework, digital control based on classical superconducting ultra-low power electronics is being adapted to perform qubit control and readout for scalable quantum architectures [1], thus leading to the development of innovative concepts for control and benchmarking in this linked digital-quantum hybrid system.

We will report on special properties of smart superconducting circuits and of hybrid tunnel-ferromagnetic Josephson junctions (JJs), which make possible alternative layouts for the superconducting modules inside a more general architecture. We will discuss how the macroscopic phase of a carefully designed superconducting circuit, namely the Josephson Digital Phase Detector (JDPD), can be manipulated to perform digital phase detection of weak coherent radiation, thus constituting a phase-readout protocol for a superconducting qubit [2]. Moreover, we will classify some significant behaviors of tunnel-ferromagnetic JJs [3] through a comparative study of fluctuations and of electro-dynamical properties [4]. The possibility to control and drive these hybrid junctions through different physical means allows for novel tuning mechanisms that are not susceptible to specific noise sources in a transmon configuration [5].

References

[1] R. McDermott et al., Quantum Sci. Technol. 3, 024004 (2018).

[2] L. Di Palma et al., in preparation.

[3] R. Caruso et al., Phys. Rev. Lett. 122, 047002 (2019); H. G. Ahmad et al., Commun. Phys. 5, 2 (2022).

[4] H. G. Ahmad et al., Phys. Rev. Applied 13, 014017 (2020); R. Satariano et al., Phys. Rev. B 103, 224521 (2021).

[5] H. G. Ahmad et al., under review in Phys. Rev. B.

**Presenting author email: davide.massarotti@unina.it*

Magnetic, thermal, and topographic imaging with a nanometer-scale SQUID-on-lever scanning probe

M. Wyss[1,2], K. Bagaini[1], D. Jetter[1], E. Marchiori[1], A. Vervelaki[1], B. Gross[1], J. Ridderbos[1], S. Gliga[3], C. Schönenberger[1,2,*], M. Poggio[1,2,*]

1 Department of Physics, University of Basel, 4056 Basel, Switzerland

2 Swiss Nanoscience Institute, University of Basel, 4056 Basel, Switzerland

3 Swiss Light Source, Paul Scherrer Institute, 5232 Villigen, Switzerland

Scanning superconducting quantum interference device (SQUID) microscopy is a magnetic imaging technique combining high field sensitivity with nanometer-scale spatial resolution. Here, we demonstrate a scanning probe that combines the magnetic and thermal imaging provided by an on-tip SQUID with the tip-sample distance control and topographic contrast of a non-contact atomic force microscope (AFM). We pattern the nanometer-scale SQUID, including its weak-link Josephson junctions, via focused ion beam milling at the apex of a cantilever coated with Nb, yielding a sensor with an effective diameter of 365 nm, field sensitivity of 9.5 nT/Hz1/2 and thermal sensitivity of 620 nK/Hz1/2, operating in magnetic fields up to 1.0 T. The resulting SQUID-on-lever is a robust AFM-like scanning probe that expands the reach of sensitive nanometer-scale magnetic and thermal imaging beyond what is currently possible.

**Presenting author email: martino.poggio@unibas.ch*

NIOBIUM NANOSQUIDS PATTERNED BY HELIUM OR NEON FOCUSED ION BEAMS

T. Griener[1], S. Pfander[1], J. Linek[1], U. Drechsler[2], T. Weimann[3], R. Kleiner[1], A. Knoll[2], O. Kieler[3], D. Koelle[1,*]

1 Physikalisches Institut, Center for Quantum Science (CQ) and LISA+, Auf der Morgenstelle 14, 72076 Tübingen, Germany

2 IBM Research Zürich, Säumerstraße 4, 8803 Rüschlikon, Switzerland

3 Department Quantum Electronics, Physikalisch-Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig, Germany

Nanopatterning of superconducting thin film structures with focused He or Ne ion beams (He/Ne-FIB) offers a flexible tool for creating constriction-type Josephson junctions (cJJs) and strongly miniaturized superconducting quantum interference devices (nanoSQUIDs) based on cJJs for applications in magnetic sensing on the nanoscale. We present our attempts to use He/Ne-FIB for fabricating Nb cJJs and Nb nanoSQUIDs which shall provide ultra-low noise and high spatial resolution for their application in scanning SQUID microscopy (SSM). The nanoSQUIDs are designed as sensors for magnetic flux and dissipation. They shall be integrated on custom-made Si cantilevers, which will provide the possibility of simultaneous conventional topographic imaging by atomic force microscopy (AFM). We will discuss the status of this project and challenges that have to be met on the way to combine SSM and AFM on the nanoscale.

We acknowledge the European Commission under H2020 FET Open grant 'FIBsuperProbes' (number 892427)

**Presenting author email: koelle@uni-tuebingen.de*

Quantum interference superconducting thermal nanovalve

N. Ligato[1], F. Paolucci[1], E. Strambini[1], and F. Giazotto[1,*]

1 NEST, Istituto Nanoscienze-CNR and Scuola Normale Superiore, Pisa, Italy

Superconducting materials are known to be good thermal insulators at sufficiently low temperatures thanks to the presence of the energy gap in their density of states (DOS). Yet, the proximity effect allows to tune the local DOS of a metallic wire by controlling the phase biasing imposed across it. As a result, the wire thermal resistance can be largely tuned by phase manipulation. In this talk I will show the experimental implementation of efficient control of thermal current by phase tuning the superconducting proximity effect. This is achieved by using the magnetic flux-driven modulation of the DOS of a quasi one-dimensional aluminum nanowire forming a weak-link embedded in a superconducting loop [1]. Moreover, phase-slip events occurring in the nanowire are able to induce a hysteretic dependence of its local DOS on the direction of the applied magnetic field. Thus, we also demonstrate the operation of the nanovalve as a phase-tunable *thermal* memory, thereby encoding information in the local temperature of a metallic electrode nearby connected. Besides quantum physics, our results are relevant for the design of innovative phase-coherent caloritronics devices such as thermal valves and temperature amplifiers, which are promising nanostructures for the realization of heat logic architectures.

References

N. Ligato, F. Paolucci, E. Strambini, and F. Giazotto, to be published in Nat. Phys. (2022).

**Presenting author email: francesco.giazotto@sns.it*

Metastable states and hidden phase slips in nanobridge SQUIDs

Lukas Nulens[1,*], Heleen Dausy[1], Bart Raes[1], Margriet J. Van Bael[1], and Joris Van de Vondel[1]

1 Quantum Solid-State Physics, Department of Physics and Astronomy, KU Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

In this work we fabricated an asymmetric nanoscale SQUID consisting of one nanobridge weak link and one Dayem bridge weak link [1]. The current phase relation of these particular weak links is characterized by multivaluedness and linearity. While the latter is responsible for a particular magnetic field dependence of the critical current (so-called vorticity diamonds), the former enables the possibility of different vorticity states (phase winding numbers) existing at one magnetic field value. In conventional transport measurements the observed critical current value is stochastic in nature, does not necessarily coincide with the current associated with the lowest energy state and critically depends on the measurement conditions. We unravel the origin of the observed metastability as a result of the phase dynamics happening during the freezing process and while sweeping the current. Moreover, we employ special measurement protocols to prepare the desired vorticity state and identify the (hidden) phase slip dynamics ruling the detected state of these nanodevices.

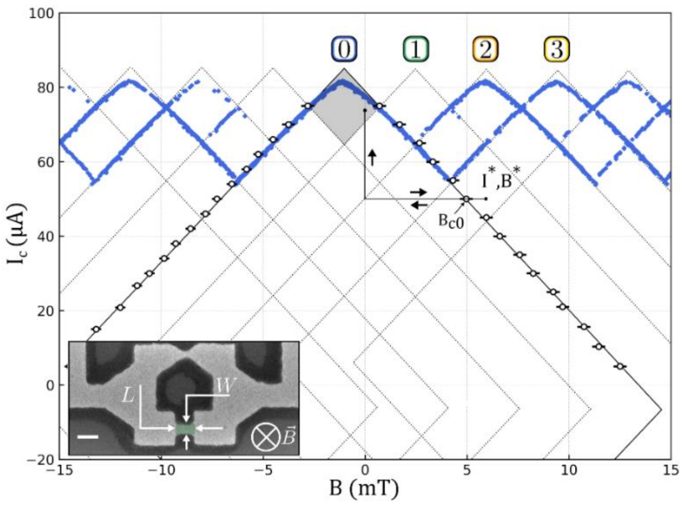


Fig. 1 : The inset shows a similar nanobridge MoGe SQUID as investigated, the white scale bar corresponds to 200 nm. The critical current field oscillations after a 'preparation' protocol for a similar nanobridge SQUID (L = 176 nm, W= 51 nm) are indicated by the blue datapoints. While the open circles with error bar obtained from a different measurement protocol, help to uncover the (hidden) phase slip dynamics.

References

[1] Heleen Dausy ,Lukas Nulens , Bart Raes , Margriet J. Van Bael , and Joris Van de Vondel

Phys. Rev. Applied 16, 024013 (2021)

**Presenting author email: lukas.nulens@kuleuven.be*

Local nematicity in iron-based superconductors induced by random strain fields

Paul Wiecki[1,2], Rui Zhou[3], Sergey Bud'ko[2], Paul Canfield[2], Yuji Furukawa[2], Marc-Henri Julien[3], Jörg Schmalian[1,4], Anna E. Böhmer*[1,5]

1 Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

2 Ames Laboratory, U.S. DOE and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

3 Laboratoire National des Champs Magnétiques Intenses–European Magnetic Field Laboratory, UPR3228 Centre National de la Recherche Scientifique, Université Grenoble Alpes, Institut National des Sciences Appliquées de Toulouse, Université Paul Sabatier, Grenoble, France

4 Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

5 Institut für Experimentalphysik IV, Ruhr-Universität Bochum, 44801 Bochum, Germany

The nematic phase transition prevalent in many iron-based superconductors is manifest as a tetragonal-to-orthorhombic lattice distortion and a dramatic change of the electronic properties. However, signatures of this C4 symmetry breaking and short-range nematic order have often been found well above the bulk nematic phase transition temperature, especially from local probe measurements using scanning tunneling microscopy (STM)and nuclear magnetic resonance (NMR). The nucleation of local-symmetry-breaking order in nominally symmetry-preserving phases is indeed an increasingly recognized phenomenon in a wide range of correlated electron systems, such as antiferromagnetic droplets in $CeCoIn_5$ or the nucleation of charge density wave order above the phase transition in $NbSe_2$. While the existence of local *nematicity in the tetragonal phase of the iron-based superconductors has been rationalized in terms of residual strains in the crystal, it is most naturally explained as a consequence of impurities and vacancies that locally break the fourfold rotation symmetry and thus act as random-field impurities for nematicity.*

The iron-based superconductor FeSe features a prominent bulk nematic transition at T_s=90K. On approaching T_s from above a prominent broadening of the NMR spectrum is observed, which is attributed to the formation of locally nucleated, short-range-ordered nematic domains. Here we establish a quantitative understanding of the nematic broadening of the NMR spectrum and, in particular, its relation to random-field defects and the nematic susceptibility. We find that the broadening of the NMR spectrum due to locally nucleated nematic order is proportional to the Edwards-Anderson parameter of a random-field Ising model at the mean-field level. Within this picture, the experimentally-observed pressure evolution of the NMR spectrum can be well explained.

References

P. Wiecki, M. Nandi, A. E. Böhmer, S. L. Bud'ko, P. C. Canfield, and Y. Furukawa, NMR evidence for static local nematicity and its cooperative interplay with low-energy magnetic fluctuations in FeSe under pressure, Phys. Rev. B 96, 180502(R) (2017).

Paul Wiecki, Rui Zhou, Marc-Henri Julien, Anna E. Böhmer, and Jörg Schmalian, Edwards-Anderson parameter and local Ising nematicity in FeSe revealed via NMR spectral broadening, Phys. Rev. B 104, 125134 (2021).

**Presenting author email: boehmer@physik.rub.de*

Granular metallicity and inhomogeneous superconductivity in thin films

B. Leridon[1,*]

1 LPEM, CNRS, ESPCI-PSL, Sorbonne Universités, Paris France

I will discuss the occurrence of a Log(1/T) term in the resistivity of bad metals and its possible interplay with superconductivity. This behavior has been reported in the literature both in low Tc and high Tc superconductors and its origin is not clearly identified. We propose that this behavior is related to a form of granular metallicity (either structural or spontaneous) that may interfere with superconductivity and in some cases produce a zero-dimensional regime of fluctuations. We also discuss the possibility of a minimal metallicity criterion in order to allow superconductivity at a given doping level. Several systems will be presented and discussed : in particular ultra-thin NbN films [1] or, in a more recent experiment, FeSe films doped using the ionic liquid gating technique [2].

References

[1] C.Carbillet et al. Physical Review B 93, 144509 (2016)

[2] MingYang Qin et al. Physical Review B 104, 174511 (2021)

**Presenting author email: Brigitte.Leridon@espci.fr*

Disorder-robust phase crystal in high-temperature superconductors from topology and strong correlations

Debmalya Chakraborty[1,*], Tomas Löfwander[2], Mikael Fogelström[2] and Annica M. Black-Schaffer[1]

1 Department of Physics and Astronomy, Uppsala University, Box 516, S-751 20 Uppsala, Sweden

2 Department of Microtechnology and Nanoscience - MC2, Chalmers University of Technology, SE-412 96 Göteborg, Sweden

Today there exists a strong research focus on topological effects in condensed matter. Initial studies were only focused on non-interacting electronic systems, but attention is now shifting towards the influence of electron-electron interactions and also the broken symmetry states they can generate. Real-world materials bring disorder as a third important component, as many symmetry broken states are sensitive to disorder. Hence, to understand many materials we need to keep a combined focus on topology, electronic correlations, and disorder. Copper oxide high-temperature superconductors (cuprates) with pair breaking edges host a flat band of topological zero-energy states, making them an ideal playground where strong correlations, topology, and disorder are strongly intertwined. Here, we show that the three way interplay in cuprates generates a new phase of matter: a fully gapped "phase crystal" state that breaks both translational and time reversal invariance, characterized by a modulation of the d-wave superconducting phase co-existing with a modulating extended s-wave superconducting order. In contrast to conventional wisdom, this phase crystal state is remarkably robust to omnipresent disorder, but only in the presence of strong correlations, thus giving a clear route to its experimental realization.

References

[1] Debmalya Chakraborty, Tomas Löfwander, Mikael Fogelström, and Annica M. Black-Schaffer, arXiv:2103.12756 (2021) (Accepted in npj Quantum Materials).

**Presenting author email: debmalya.chakraborty@physics.uu.se*

Multi-harmonic Susceptibility, DC Magnetization and Magnetic Relaxation Measurements in Iron-based Superconducting Single Crystal $CaKFe_4As_4$

A. Crisan[1,*], A.M. Ionescu[1] , A. Galluzzi[2] and M. Polichetti[1,2]

1 National Institute of Materials Physics Bucharest, 405A Atomistilor Str., 077125 Magurele, Romania

2 Department of Physics "E.R. Caianiello", University of Salerno, Via Giovanni Paolo II, 132, 84084 Fisciano (SA), Italy

Quite recently, a new type of iron-based superconductor, i.e., 1144-type with $CaKFe_4As_4$ as one of their representatives, has been found [1]. Its crystal structure is similar to the much larger family of 122-type compounds, having a tetragonal structure (P4/mmm), where the Ca and K layers stack alternatively along the c axis. Several properties of 1144-type compounds have been studied such as superconducting gap state, penetration depth, pressure effects on crystal structure, anisotropy of critical current density. We report on the multi-harmonic susceptibility, DC magnetization loops and magnetic relaxation measurements, in various conditions. The measurements were performed using a PPMS equipment with DC fields up to 14 T (9 T in some cases), and in a SQUID MPMS. The on-set of the third harmonic susceptibility which is due to non-linear dissipation only marks the temperature at which the vortex system becomes glassy, at the given DC field. Many such measurements allowed us to determine the vortex melting line in our 1144 single crystal, which proved to be very steep. From frequency-dependent susceptibility measurements we determined the pinning potential in certain temperature-DC field window. DC magnetization loops indicate a very high critical current density. From magnetic relaxation measurements we determined the normalized magnetic relaxation rate, as well as the activation energy Uo, that shows a gradual cross-over between elastic creep and plastic creep at peak values of Uo of about 1200 K (kB=1), at temperatures between 20 and 29 K, in DC fields between 1 and 5 T. Quite remarkably, the extrapolation of Uo(T, 1 T) towards 35 K gives almost the same value as Uo determined from multi-harmonic susceptibility in 1 T and at 35 K, about 200 K.

References

[1] A. Iyo, K. Kawashima, T. Kinjo, T. Nishio, S. Ishida, H. Fujihisa, Y. Gotoh, K. Kihou, H. Eisaki, and Y. Yoshida, J. Am. Chem. Soc. 138, 1410 (2016).

**Presenting author email: acrisan652@gmail.com*

Interface induced pair-breaking effects in strongly disordered superconducting MoN ultra-thin films

P. Szabó[1,*], M. Kuzmiak[1,2], M. Kopčík[1,2], F. Košuth[1,3], V. Vaňo[4], V. Komanický[3], and P. Samuely[1,3]

1 Centre of Low Temperature Physics, Institute of Experimental Physics, Slovak Academy of Sciences, SK-04001 Košice, Slovakia

2 Department of Physics, Faculty of Electrical Engineering and Informatics, Technical University of Košice, SK-04001 Košice, Slovakia

3 Centre of Low Temperature Physics, Faculty of Science, P. J. Šafárik University, SK-04001 Košice, Slovakia

4 Department of Applied Physics, Aalto University, FI-00076 Aalto, Finland

A strong disorder characterized by a small product of the Fermi vector kF and the electron mean free l drives superconductors towards insulating state. Such disorder can be introduced by making the films very thin. We present 3-nm Mo_2N film with kF*l~2 with a resistive superconducting transition temperature Tc = 2 K heavily suppressed in comparison with the bulk Tc. Superconducting density of states (DOS) with smeared gap-like peaks and in-gap states, so called Dynes DOS, is observed by the low temperature tunneling spectroscopy despite a sharp resistive transition. By scanning tunneling microscope the spectral maps are obtained and related to the surface topography. The maps show a spatial variation of the superconducting energy gap on the order of 20 % which is not accidental but well correlates with the surface corrugation: protrusions reveal larger gap, smaller spectral smearing and smaller in-gap states. In agreement with our previous measurements on ultrathin MoC films we suggest that the film-substrate interface introducing the local pair-breaking is responsible for the observed effects and generally for the suppression of the superconductivity in these ultrathin films.

**Presenting author email: pszabo@saske.sk*

PROBING THE ANISOTROPIC PROPERTIES OF YBCO WITH VICINAL-GROWN FILMS

W. Lang[1,*], G. Heine[1], R. Rössler[2], and J. D. Pedarnig[2]

1 Faculty of Physics, University of Vienna, Boltzmanngasse 5, A-1090 Wien, Austria

2 Institute of Applied Physics, Johannes-Kepler-University Linz, Altenbergerstrasse 69, A-4040 Linz, Austria

The physical properties of the copper-oxide high-Tc superconductors are strongly anisotropic because of their layered crystalline structure. The Montgomery method, applied to single crystals, is commonly used to determine the in-plane and out-of-plane electric transport properties. However, with tiny single crystals, imperfections of the sample shape and the sizeable area of the contacts, compared to the distance between them, introduce considerable uncertainty. Also, the injected current density varies enormously throughout the sample volume, which might be adverse for some investigations.

Using thin YBa2Cu3O7-δ (YBCO) films grown on off-axis cut substrates allows one to investigate these anisotropic transport properties in a planar and well-defined sample geometry employing a homogeneous current density. We present resistivity and Hall measurements and find that the Hall voltage probed parallel to the copper-oxide layers is positive and strongly temperature-dependent. In contrast, the out-of-plane Hall voltage is negative and almost temperature-independent [1].

In addition, we review some earlier measurements on vicinal YBCO films demonstrating that anisotropic photoconductivity and high-velocity Josephson vortices can be explored in this geometry.

References

[1] G. Heine, W. Lang, R. Rössler, J. D. Pedarnig, Nanomaterials 11 (2021) 675.

Presenting author email: wolfgang.lang@univie.ac.at

HOT AND COLD SPOTS ALONG THE FERMI CONTOUR OF HIGH-T_C CUPRATES IN THE FRAMEWORK OF SHUBIN-KONDO-ZENER s-d EXCHANGE INTERACTION

T.Mishonov[1,*], N. Zahariev[1], H. Chamati[1] and A. Varonov[1]

1 Georgi Nadjakov Institute of Solid State Physics, Bulgarian Academy of Sciences, 72 Tzarigradsko Chaussee Blvd., BG-1784 Sofia, Bulgaria

The anisotropy of the electron scattering rate and life time observed by Angle Resolved Photoemission Spectroscopy (ARPES) is evaluated using s-d Kondo-Zener exchange Hamiltonian used previously to describe superconducting properties of high-Tc cuprates; for correlation between Tc and BCS coupling constant, for example. The performed qualitative analysis reveals that ``cold spots'' correspond to nodal regions of the superconducting phase where the superconducting gap is zero because the exchange interaction is annulled. Vice versa, ``hot spots'' and intensive scattering in the normal state corresponds to the region with maximal gap in the superconducting phase. We have obtained that separable kernel postulated in the Fermi liquid approach to the normal phase is exactly the same kernel which is exactly calculated in the framework of the s-d approach in the LCAO approximation for CuO_2 plane and in this sense at least in the qualitative level the superconducting cuprates are described by one and the same Hamiltonian applied to their superconducting and normal properties.

**Presenting author email: mishonov@bgphysics.eu*

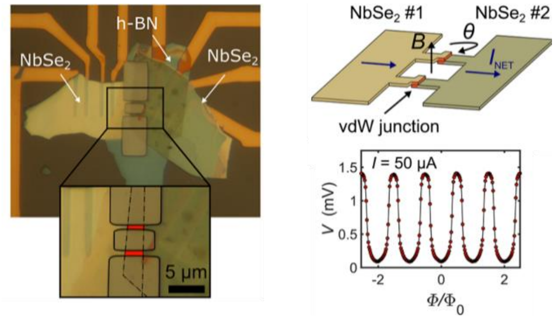
Superconducting Quantum Interference in Twisted van der Waals Heterostructures

Liam S. Farrar[1,*], Aimee Nevill[1], Zhen Jieh Lim[1], Geetha Balakrishnan[2], Sara Dale[1], and Simon J. Bending[1]

1 Department of Physics, University of Bath, Bath, BA2 7AY, United Kingdom

2 Department of Physics, University of Warwick, Coventry, CV4 7AL, United Kingdom

In this talk I will discuss recent work [1] on the formation of both Josephson junctions and superconducting quantum interference devices (SQUIDs) created by deterministically misaligning mechanically exfoliated flakes of NbSe2. The current–voltage characteristics of the resulting twisted NbSe2– NbSe2 junctions are found to be sensitive to the misalignment angle of the crystallographic axes, opening up a new control parameter for optimization of the device performance. A single lithographic process has then been implemented to shape Josephson junctions into SQUID geometries with typical loop areas of ~25 μm2 and weak links ~600 nm wide. At T = 3.75 K in an applied magnetic field, these devices display large stable voltage modulation depths of up to ΔV ~ 1.4 mV.



References

[1] Liam S. Farrar, Aimee Nevill, Zhen Jieh Lim, Geetha Balakrishnan, Sara Dale, and Simon J. Bending. Nano Letters 2021 21 (16), 6725-6731.

**Presenting author email: lsf1@st-andrews.ac.uk*

Superconducting boundary states

A. Samoilenka[1] M. Barkman[1], A. Benfenati[1], E. Babaev[1,*]

1 KTH The Royal Instutute of Technology Stockholm 10691 Sweden

Bardeen-Cooper-Schrieffer (BCS) theory describes a superconducting transition as a single critical point where the gap function or, equivalently, the order parameter vanishes uniformly in the entire system. We demonstrated that in superconductors described by standard BCS models, the superconducting gap survives near the sample boundaries at higher temperatures than superconductivity in the bulk [1,2]. Therefore, conventional superconductors have multiple critical points associated with separate phase transitions at the boundary and in the bulk. We show this by revising the Caroli–De Gennes–Matricon theory of a superconductor-vacuum boundary and finding inhomogeneous solutions of the BCS gap equation near the boundary, which asymptotically decay in the bulk. The existence of these boundary states can manifest itself as discrepancies between the critical temperatures observed in calorimetry and transport probes. At the level of Ginzburg-Landau theory, this implies also that the standard boundary conditions with zero normal derivative are incorrect and it is required to add a superface term microscopically derived in [3]. The superconducting boundary states are under certain conditions more robust for superconductor-dielectric interface [4].

References

[1] A Samoilenka, E Babaev Physical Review B 101 (13), 134512.

[2] A Samoilenka, M Barkman, A Benfenati, E Babaev Physical Review B 101 (5), 054506

[3] A Samoilenka, E Babaev Physical Review B 103 (22), 224516

[4] M Barkman, A Samoilenka, A Benfenati, E Babaev arXiv preprint arXiv:2201.11614

**Presenting author email: babaev.egor@gmail.com*

Flux creep and the Campbell response in type II superconductors

V. B. Geshkenbein[1,*], F. Gaggioli[1] and G. Blatter[1]

1 Institut für Theoretische Physik, ETH Zürich, CH-8093 Zürich, Switzerland

Applying the strong pinning formalism to the mixed state of a type II superconductor, we study the effect of thermal fluctuations (or creep) on the current-voltage characteristic and the penetration of an ac magnetic field as quantified by the so-called Campbell length λC. We show that thermal fluctuations produce a downward shift of the depinning current but preserve the overall shape of the excess-current characteristic typical of a strong pinning material. Motivated by the observation of typical excess-current characteristics and field-scaling of critical currents, we analyse IV curves measured on 2H-$NbSe_2$ and a-MoGe type II superconductors within the setting provided by strong pinning theory. The experimentally observed shift and rounding of the voltage-onset are in excellent agreement with the predictions of strong pinning in the presence of thermal fluctuations.

Within strong pinning theory, vortices get pinned by individual defects, with the jumps in the pinning energy (Δepin) and force (Δfpin) between bistable pinned and free states quantifying the pinning process. We find that the evolution of the Campbell length λC(t) as a function of time t is the result of two competing effects, the change in the force jumps Δfpin(t) and a change in the trapping area Strap(t) of vortices; the latter describes the area around the defect where a nearby vortex gets and remains trapped. Contrary to naive expectation, we find that during the decay of the critical state in a zero-field cooled (ZFC) experiment, the Campbell length λC(t) is usually nonmonotonic, first decreasing with time t and then increasing for long waiting times. Field cooled (FC) experiments exhibit hysteretic effects in λC; relaxation then turns out to be predominantly monotonic, but its magnitude and direction depends on the specific phase of the cooling–heating cycle. Furthermore, when approaching equilibrium, the Campbell length relaxes to a finite value, different from the persistent current which vanishes at long waiting times t, e.g., above the irreversibility line. Finally, measuring the Campbell length λC(t) for different states, zero-field cooled, field cooled, and relaxed, as a function of different waiting times t and temperatures T, allows to 'spectroscopyse 'the pinning potential of the defects

**Presenting author email: dimagesh@phys.ethz.ch*

Strong pinning transition with arbitrary defect potentials

F. Gaggioli[1,*], G. Blatter[1], M. Buchacek[1] and V. Geshkenbein[1]

1 Institut für Theoretische Physik, ETH Zürich, CH-8093 Zürich, Switzerland

The onset of strong pinning exhibits a striking correspondence to the physics of a critical point terminating a thermodynamic first-order transition, with the Labusch parameter κ that quantifies the pinning strength replacing the scaled temperature T/T_c. So far, this transition has been studied for isotropic defect potentials, resulting in a (mean-field type) critical exponent $\mu = 2$ for the onset of the strong pinning force density $F_{pin} \sim n_p f_p (\xi/a_0)^2 (\kappa-1)^\mu$, with n_p and f_p denoting the density and pinning force of the defects and ξ and a_0 the coherence length of the superconductor and the intervortex distance. This result is owed to the special rotational symmetry of the defect producing a finite trapping area $S_{trap} \sim \xi^2$ near the strong-pinning onset at $\kappa = 1$. The behavior changes dramatically when studying anisotropic defects with no special symmetries: the pinning originates from isolated points with length scales growing as $\xi(\kappa - 1)^{1/2}$, resulting in a different (mean-field type) exponent $\mu = 5/2$. Our analysis uncovers interesting geometrical structures in the strong pinning transition, with the appearance of unstable areas of elliptical shape marking the locations of vortex jumps, that grow and join in hyperbolic geometries. Correspondingly, we find the bistable areas of asymptotic vortex positions characteristic of strong pinning; they assume banana-shaped geometries growing with $\kappa > 1$ that join up into the ring-shaped structures previously encountered for isotropic defects. Making heavy use of the Hessian matrix associated with the pinning landscape, we study the geometrical evolution of these unstable and bistable areas with increasing pinning strength $\kappa > 1$ and present an interesting relation between a random 2D pinning landscape and the Euler characteristic of a planar graph.

**Presenting author email: filippog@phys.ethz.ch*

VORTEX JETS IN SUPERCONDUCTORS

A. I. Bezuglyj[1], V. A. Shklovskij[2], B. Budinska[3], B. Aichner[3], V. M. Bevz[2], M. Yu. Mikhailov[4], D. Yu. Vodolazov[5], W. Lang[3], and O. V. Dobrovolskiy[3,*]

1 Institute for Theoretical Physics, National Science Center-KIPT, 61108 Kharkiv, Ukraine
2 Physics Department, V. Karazin Kharkiv National University, 61022, Kharkiv, Ukraine
3 Faculty of Physics, University of Vienna, 1090 Vienna, Austria
4 B. Verkin Ins. for Low Temp. Phys. and Engi., Nat. Aca. of Sci. of Ukraine, 61103 Kharkiv, Ukraine
5 Institute for Physics of Microstructures, Russian Academy of Sciences, Nizhny Novgorod region 603087, Russia

The recent great interest in superconductor thin strips with the critical current Ic approaching the depairing current Id is caused by the required close-to-Id bias regime of microstrip single-photon detectors [1], ultra-fast vortex motion at large transport currents Itr [2,3], and the phenomena of generation of sound [4] and spin waves [5] at a few km/s vortex velocities. In this context, the issue of high Ic is related to blocking of the penetration of vortices via the strip edges, its control via material and edge-barrier engineering, and knowledge of the effects of various edge defects on the penetration and patterns of Abrikosov vortices [3,6]. At sufficiently large transport currents Itr, a defect at the edge of a superconducting strip acts as a gate for the vortices entering into it. These vortices form a jet, which is narrow near the defect and expands due to the repulsion of vortices as they move to the opposite edge of the strip, see Fig. 1(b), giving rise to a transverse voltage V⊥. Here, we experimentally demonstrate the appearance of V⊥ in MoSi strips with artificially created edge defects (notches) milled by a focused ion beam at different distances l = 16-80 nm from the transverse voltage leads. V⊥(Itr) is (i) local, i.e., can only be measured with voltage leads placed rather close to the edge defect, (ii) appears also in zero external magnetic field, (iii) changes its sign with the change of the coordinate l→ -l of the transverse voltage leads with respect to the edge defect, and (iv) appears because of the repulsion of several (at least two) vortices. We use the equation of vortex motion under competing vortex-vortex and Itr-vortex interactions to derive the vortex jet shapes in narrow and wide films and fit the observed nonmonotonic V⊥(Itr) dependence, Fig. 1(b). Our findings are augmented with the time-dependent Ginzburg-Landau simulations (TDGL) which reproduce the calculated vortex jet shapes and complement the analytical theory in the entire range of transport currents, Fig. 1(c) and (d).

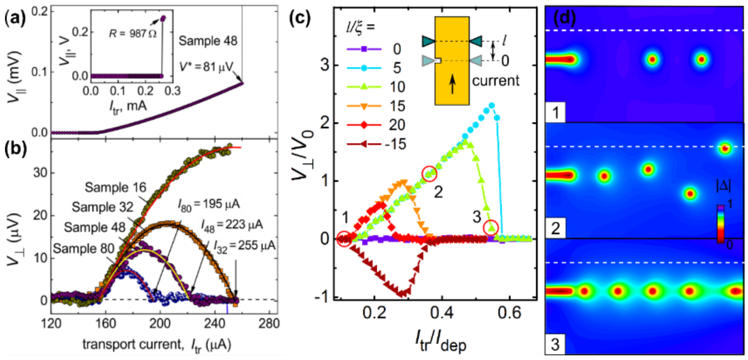


Fig. 1. Typical longitudinal I-V curve in the low-resistive regime. (b) Transverse I-V curves for all samples with an edge defect. Symbols: experiment; lines: fits to the derived expressions in the hydrodynamic model. (c) Transverse I-V curves for a strip containing an edge defect (TDGL equation modeling). (d) Snapshots of the modulus of the superconducting order parameter illustrating transitions from a vortex chain to a vortex jet and from the vortex jet to a vortex river with increase of the transport current.

References

[1] D. Yu. Vodolazov, Phys. Rev. Appl. 7 (2017) 034014.
[2] L. Embon et al., Nat. Commun. 8 (2017) 85.
[3] O. V. Dobrovolskiy et al., Nat. Commun. 11 (2020) 3291.
[4] L. N. Bulaevskii and E. M. Chudnovsky, Phys. Rev. B 72 (2005) 094518.
[5] O. V. Dobrovolskiy et al. arXiv:2103.10156 (2021).
[6] B. Budinska et al., arXiv:2111.13431 (2021).

**Presenting author email:*
oleksandr.dobrovolskiy@univie.ac.

VORTEX DYNAMICS AND PHASE DIAGRAM MODIFICATIONS INDUCED BY MAGNETIC NANOSTRUCTURES

M. Menghini[1,*], V. Rollano[1,2], M. C. De Ory[3], A. Gomez[3], A. Muñoz-Noval[2], M. Velez[4], E. M. Gonzalez[1,2] and J. L. Vicent[1,2]

1 IMDEA-Nanociencia, Cantoblanco, 28049 Madrid, Spain

2 Departamento Física de Materiales, Universidad Complutense, 28040 Madrid, Spain

3 Centro de Astrobiología (CSIC-INTA), Torrejón deArdoz, 28850 Madrid, Spain

4 Departamento de Física, Universidad de Oviedo, 33007 Oviedo, Spain

Superconductor-ferromagnet (SC-FM) hybrid systems have proven to be a fruitful playground to test and study different phenomena in vortex matter. This is due to the variety of magnetic properties and interactions that can be tailored by using different combinations of magnetic materials and nanostructure geometries.

In this talk, we will focus on two distinct SC-FM hybrid systems. In both cases the ferromagnet forms a periodic nanostructure but they are each engineered into a different geometry (multiply- and simple-connected) presenting different magnetic easy-axes (in-plane and out-of-plane). On one hand, we will show how local asymmetries in the potential formed by a disordered FM spin-ice configuration can lead to a macroscopic vortex ratchet effect [1]. On the other hand, we will demonstrate how the stray-field of magnetic nanostructures periodically arranged causes an enhancement of the region in the SC phase diagram dominated by the Little-Parks effect [2].

References

[1] V. Rollano et al., Sci. Rep. 11 (2021) 16617.

[2] M. C. De Ory et al., Sci. Rep. 10 (2020) 10370.

Presenting author email: mariela.menghini@imdea.org

Disordered hyperuniform vortex matter with rhombic distortions in FeSe at low fields

J. Aragón Sánchez[1,2]*, R. Cortés Maldonado[1], M. L. Amigó[1], G. Nieva[1], A. B. Kolton[1], Y. Fasano[1,2]

1 Centro Atómico Bariloche and Instituto Balseiro, CNEA, CONICET and Universidad Nacional de Cuyo, 8400 San Carlos de Bariloche, Argentina

2 Leibniz Institute for Solid State and Materials Research, Helmholtzstrasse 20, 01069 Dresden, Germany

In the quest for synthesizing hyperuniform materials, it is crucial to address the effect of disorder or particular coupling to electronic and elastic properties of the host medium where objects are nucleated since it can induce different types of imperfections affecting or even destroying the suppression of long-range density fluctuations. This work makes the fundamental discovery that if the host medium with weak point disorder is coupled to the objects introducing an anisotropic long-range interaction between the objects that constitute the system, instead of being ordered class-I hyperuniform the system becomes disordered class-III hyperuniform. Our findings are based on experimental evidence as well as realistic simulations of the vortex structure nucleated in the electronically rich FeSe superconductor. By imaging vortices in extended fields of view, we reveal that at low fields the vortex structure in FeSe is disordered but presents hexagonal symmetry with rhombic distortions. These distortions are quite likely produced by the magneto-elastic effect that introduces a weak, yet anisotropic and long-range, extra term in the vortex-vortex interaction. This polycrystalline system with quasi-long range orientational order along the Fe-Fe bond direction actually hides a class-III disordered hyperuniform order. Thus, our work paves the way to tailor the hyperuniformity class of material systems composed of elastic interacting objects by growing them on host media with particular elastic and electronic properties.

**Presenting author email: jaragon188@gmail.com*

Influence of a circular polarized radiation on the spontaneous current generation in superconducting ring

A. Buzdin[1,*], M. D. Croitoru[1,2], and B. Lounis[3]

1 University of Bordeaux, LOMA UMR-CNRS 5798, F-33405 Talence, France

2 Departamento de Física, Universidade Federal de Pernambuco, 50740-560, Recife-PE, Brazil.

3 University of Bordeaux, LP2N, F-33405 Talence, France.

We theoretically study the non-equilibrium dynamics of the order parameter of a superconducting ring quenched through its transition temperature in the presence of a circularly polarized electromagnetic radiation. Numerical simulations based on spectral decomposition of the time-dependent Ginzburg-Landau equation, reveal that the circularly polarized electromagnetic radiation strongly promotes the generation of current-carrying states with current directions controlled by the helicity of the radiation field. This effect is related with the imaginary part of the complex relaxation constant Γ. The imaginary part of Γ arises from the electron-hole asymmetry.

**Presenting author email: alexandre.bouzdine@u-bordeaux.fr*

Probing unconventional superconductivity in the $LaAlO_3/SrTiO_3$ interface using transport in nanowires

G. Singh[1], C. Guarcello[2,3], E. Lesne[4], D. Winkler[1], T. Claeson[1], T. Bauch[1], F. Lombardi[1], A. Caviglia[4], R. Citro[2,3,5], M. Cuoco[5], and A. Kalaboukhov[1,*]

1 Department of Microtechnology and Nanoscience – MC2, Chalmers University of Technology, SE-412 96 Gothenburg, Sweden

2 Dipartimento di Fisica "E. R. Caianiello", Università di Salerno, Via Giovanni Paolo II 132, I-84084, Fisciano, SA, Italy

3 INFN, Sezione di Napoli Gruppo Collegato di Salerno, Complesso Universitario di Monte S. Angelo, I-80126, Napoli, Italy

4 Kavli Institute of Nanoscience, Delft University of Technology Lorentzweg 1, 2628 CJ Delft, The Netherlands

5 SPIN-CNR, c/o Università di Salerno, I-84084, Fisciano, SA, Italy

The interface between two wide band-gap insulators, $LaAlO_3$ and $SrTiO_3$ (LAO/STO) has received much attention since it hosts a quasi-two-dimensional electron gas (q2DEG), two-dimensional superconductivity, ferromagnetism, and giant Rashba spin-orbit coupling [1]. A co-existence of two-dimensional superconductivity with gate-tunable spin-orbit coupling is of particular interest as theory predicts it may lead to the formation of unconventional superconducting order parameter [2]. This makes realization of topological superconducting states possible for future applications in quantum computing [3]. Recent experiments on superconducting weak links have indeed indicated possible existence of unconventional order parameter [4,5]. In this work, we present detailed investigation of superconducting transport in nanowires and weak links fabricated in the (100) LAO/STO interface as a function of gate voltage and temperature [6]. We observe an anomalous behaviour of critical current as a function of perpendicular magnetic field IC(H): the critical current is unexpectedly enhanced by a small magnetic field and the IC(H) dependence is anti-centrosymmetric with regards to magnetic field and critical current sign. These features cannot be accommodated within a scenario of canonical spin-singlet superconductivity. We demonstrate that the experimental observations can be described by a theoretical model based on the coexistence of Josephson channels with intrinsic phase shifts. Our results exclude a time-reversal symmetry breaking scenario and suggest the presence of anomalous pairing components that are compatible with inversion symmetry breaking and multi-orbital physics.

References

[1] S. Gariglio et al., APL MATERIALS 4 (2016) 060701.
[2] L. Fidkowski et al., Phys. Rev. B 87 (2013) 014436.
[3] C. A. Perroni et al., Phys. Rev. B 100 (2019) 094526.
[4] A. Kalaboukhov et al., Phys. Rev. B 96 (2017) 184525.
[5] D. Stornaiuolo et al., Phys. Rev. B 95 (2017) 140502(R).
[6] G. Singh et al., npj Quantum Materials 7 (2022) 2.

**Presenting author email: alexei.kalaboukhov@chalmers.se*

INHOMOGENEOUS STRAIN CAUSES TIME-REVERSAL SYMMETRY BREAKING IN Sr_2RuO_4

Roland Willa[1,*], Matthias Hecker[1], Rafael M. Fernandes[2], and Jörg Schmalian[1,3]

1 Institute for Theory of Condensed Matter, Karlsruhe Institute of Technology, Karlsruhe 76131, Germany

2 School of Physics and Astronomy, University of Minnesota, Minneapolis, 55455 Minnesota, USA

3 Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, Karlsruhe 76021, Germany

We show that the observed time-reversal symmetry breaking (TRSB) of the superconducting state in Sr2RuO4 can be understood as originating from inhomogeneous strain fields near edge dislocations of the crystal. Specifically, we argue that, without strain inhomogeneities, Sr2RuO4 is a single-component, time-reversal symmetric superconductor, likely with a dx2–y2 symmetry. Due to the strong strain inhomogeneities generated by dislocations, a slowly-decaying sub-leading pairing state contributes to the condensate in significant portions of the sample. As it phase winds around the dislocation, time-reversal symmetry is locally broken. Global phase locking and TRSB occur at a sharp Ising transition that is not accompanied by a change of the single-particle gap and yields a very small heat capacity anomaly. Our model thus explains the puzzling absence of a measurable heat capacity anomaly at the TRSB transition in strained samples, and the dilute nature of the time-reversal symmetry broken state probed by muon spin rotation experiments. We propose that plastic deformations of the material may be used to manipulate the onset of broken time-reversal symmetry.

References

[1]. R. Willa, M. Hecker, R.M. Fernandes, J. Schmalian, Phys. Rev. B 104, 024511 (2020).

**Presenting author email: roland.willa@kit.edu*

Topological transitions in ac/dc-driven open superconductor nanotubes

Vladimir M. Fomin[1,2,*] and Oleksandr V. Dobrovolskiy[3]

1 Institute for Integrative Nanosciences, Leibniz IFW Dresden, Helmholtzstraße 20, D-01069 Dresden, Germany
2 Laboratory of Physics and Engineering of Nanomaterials, Department of Theoretical Physics, Moldova State University, strada A. Mateevici 60, MD-2009 Chisinau, Republic of Moldova
3 SuperSpin Lab, Nanomagnetism and Magnonics, Faculty of Physics, University of Vienna, Währinger Str. 17, 1090 Vienna, Austria

Extending of nanostructures into the third dimension has become a major research avenue in condensed-matter physics, because of geometry- and topology-induced phenomena. Superconducting 3D nanoarchitectures feature magnetic field inhomogeneity, non-trivial topology of superconducting screening currents and complex dynamics of topological defects [1]. Such structures have been successfully fabricated from Nb [2], Nb-C [3] and W-C [4]. Signatures of vortex and phase-slip patterns in nanohelices have been experimentally identified and supported by numerical simulations based on the TDGL equation [4]. We have investigated [5] theoretically the dynamics of topological defects (vortices and slips of the phase) in open superconductor nanotubes under a modulated (dc+ac) transport current in a magnetic field orthogonal to the axis. Relying on the time-dependent Ginzburg-Landau equation, we have revealed novel patterns of topological defects, which include phase-slip regions extending along the transport current direction, their branching and coexistence with vortices. We have identified two qualitatively different regimes in the voltage response which can be accessed experimentally. The first regime is characterized by a pronounced first harmonic in the FFT spectrum of the induced voltage. This regime occurs when the dominant area of the open tube is in the superconducting or normal state. The second regime features a rich FFT spectrum of the induced voltage, because of the complex interplay between the dynamics of vortices and phase slips and the dynamics of the screening currents. Our findings shed light on the spatiotemporal evolution of the superconducting order parameter in open nanotubes and allow for its control via the induced voltage. The topological transitions between vortex-based and phase-slip transport regimes in curved nanoarchitectures open up a possibility to efficiently tailor the superconductor's voltage response via the 3D geometry and the topology of superconducting screening currents.

References

[1] V. M. Fomin, Self-rolled micro- and nanoarchitectures: Effects of topology and geometry, De Gruyter, Berlin–Boston (2021) 148 p.
[2] S. Lösch, A. Alfonsov, O. V. Dobrovolskiy, R. Keil, V. Engemaier, S. Baunack, G. Li, O. G. Schmidt and D. Bürger, ACS Nano 13 (2019) 2948-2955.
[3] F. Porrati, S. Barth, R. Sachser, O. V. Dobrovolskiy, A. Seybert, A. S. Frangakis and M. Huth, ACS Nano 13 (2019) 6287–6296.
[4] R. Córdoba, D. Mailly, R. O. Rezaev, E. I. Smirnova, O. G. Schmidt, V. M. Fomin, U. Zeitler, I. Guillamón, H. Suderow and J. M. De Teresa, 19 (2019) 8597-8604.
[5] V. M. Fomin, R. O. Rezaev and O. V. Dobrovolsiy, https://www.researchsquare.com/article/rs-991951/v1 (2021).

**Presenting author email: v.fomin@ifw-dresden.de*

Induced superconductivity in Ge-Si core-shell nanowires

J. Ridderbos[1,*], Z. Wu[1], C. Li[2], M. Brauns[1], A. Li[2], E. P. A. M. Bakkers[2], A. Brinkman[1] and F. A. Zwanenburg[1]

1 NanoElectronics Group, MESA+ Institute for Nanotechnology, University of Twente, P.O. Box 217, 7500 AE Enschede, The Netherlands

2 Photonics & Semiconductor Nanophysics Group, Department of Applied Physics, TU Eindhoven, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Ge-Si core-shell nanowires provide a versatile platform to study various quantum phenomena. The one-dimensional confinement, low disorder and strong 'first order' Rashba spin-orbit interaction (SOI) allow for advanced applications such as spin-orbit qubits, Andreev spin-qubits and strong spin-photon interaction in a circuit quantum electrodynamics approach. Like other semiconducting nanowire systems with SOI, when combined with an s-wave superconductor and a sufficiently large Zeeman field, Ge-Si nanowires should host Majorana fermions[1].

With the latter in mind, we use superconducting Al leads and obtain gate-tunable Josephson junctions and investigate different transport regimes ranging from continuous Josephson current in accumulation, to quasiparticle transport near depletion. The required contact transparency is obtained either by a temperature anneal or by using a thin (~3 nm) Pd inter-layer.

Finally, we explore the subtleties of making electrical contacts and design considerations for observing Majorana fermions, where we focus obtaining a controllable coupling between semiconductor and superconductor. This should allow to proximitize the nanowire without losing its semiconducting properties.

References

[1] Maier, F., Klinovaja, J., Loss, D., Majorana fermions in Ge/Si hole nanowires. Phys. Rev. B 90, 195421 (2014).

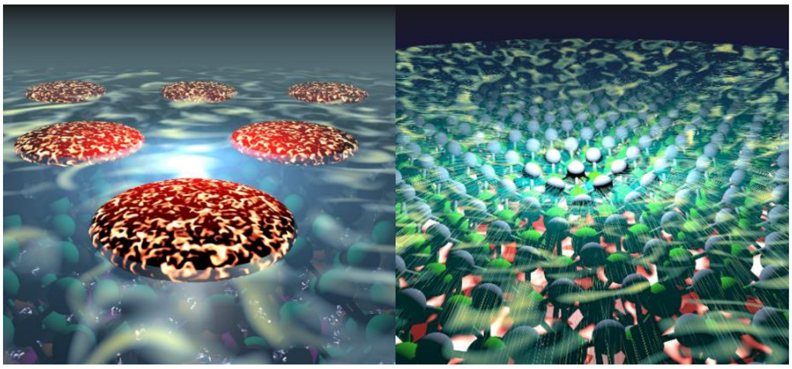
**Presenting author email: j.ridderbos@utwente.nl*

Topological and nodal superconductivity in van der Waals materials

Jose Lado[1,*]

1 Department of Applied Physics, Aalto University, Espoo, Finland

Van der Waals materials have allowed realizing a variety of emergent quantum states, including magnetic, correlated, and superconducting states. Interestingly, the tunability of these materials provides an outstanding playground to engineer elusive states of matter typical of complex correlated quantum materials. Here we show that van der Waals materials provide a natural materials platform realizing topological moire superconductors [1] and nodal superconductivity [2]. First, we will discuss how $CrBr_3/NbSe_2$ heterostructures provide a platform for engineering moire topological superconductivity [1]. We demonstrate the twist between the two materials gives rise to a moire Yu-Shiba-Rusinov electronic structure. The moire pattern further allows to open up topological states in regions of the phase space that would otherwise be topologically trivial, leading to a topological superconducting state whose topological edge states inherit the moire length. Furthermore, we will show how ultraclean 1H-TaS_2 monolayers realize a nodal topological superconductor with f-wave symmetry [2]. We demonstrate that in the presence of disorder, the nodal superconductor is driven to a conventional superconducting state as a direct consequence of the pair breaking effect of impurities in the nodal state. Furthermore, we show that, associated with the superconducting gap, strongly fluctuating many-body correlations emerge and discuss their potential role as the underlying pairing mechanism of the nodal state. Our results demonstrate the potential of van der Waals materials for realizing unconventional superconducting states, providing highly tunable platforms to explore exotic coherent states in quantum materials.



References

[1] Shawulienu Kezilebieke, Viliam Vaňo, Md N. Huda, Markus Aapro, Somesh C. Ganguli, Peter Liljeroth, and Jose L. Lado, Nano Lett. 2022, 22, 1, 328–333 (2022)

[2] Viliam Vaňo, Somesh Chandra Ganguli, Mohammad Amini, Linghao Yan, Maryam Khosravian, Guangze Chen, Shawulienu Kezilebieke, Jose L. Lado, Peter Liljeroth, arXiv:2112.07316 (2021)

**Presenting author email:* jose.lado@aalto.fi

Interfacing magnonic and superconducting quantum circuits

D. García-Pons[1], S. Martínez-Losa[1], J. Pérez[1], J.Sesé[1], B. Müller[2], J. Lin[2], R. Kleiner[2], D. Koelle[2], D.Zueco[1], F. Luis[1] and M.J. Martínez-Pérez[1,*]

1 Instituto de Nanociencia y Materiales de Aragón and Departamento de Física de la Materia Condensada, CSIC-Universidad de Zaragoza, 50009 Zaragoza, Spain

2 Physikalisches Institut – Experimentalphysik II and Center for Quantum Science (CQ) in LISA+, University of Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany

Solid state quantum computing and quantum sensing technologies are based on the strong coupling between qubits and a quantized field of excitations. Besides photons, the solid state offers a wide variety of bosonic excitations that can be emitted or absorbed such as, e.g., magnons, the quantum version of spin waves. Magnonic cavities offer the advantage of operating at reduced wavelengths compared to electromagnetic resonators of the same frequency. We investigate the integration of magnonic cavities based on topological magnetic solitons as, e.g., magnetic vortices along with superconducting quantum circuits. The former are extremely stable magnetic textures exhibiting a very rich dynamical behavior in the sub-GHz to tens of GHz range. We focus on the coupling between individual spin qubits, vortex cavities and superconducting resonators for sensing and quantum computing applications.

Presenting author email: pemar@unizar.es

Superconducting resonators for space and quantum applications

Alicia Gómez[1,*]

1 Centro de Astrobiología CSIC-INTA, 28850 Torrejón de Ardoz, Spain

Superconducting microwave resonators are crucial elements in many quantum science and technology applications such as quantum electrodynamics circuitry, quantum sensing and astronomy detectors. Particularly, we are focused on the development of Lumped Element superconducting Resonators (LERs). LERs are high-quality factor resonators based on a series inductance-capacitance superconducting circuit coupled in parallel to a single transmission line.

Kinetic Inductance Detectors (KIDs) are state-of-the-art radiation detectors based on the change of the kinetic inductance of LERs when a photon interacts with them. We are employing these devices in millimeter and submillimeter astronomical experiments such as the study of the Cosmic Microwave Background (CMB) radiation which require a great number of extra-high sensitivity detectors arranged in large format cameras. The main advantage of KIDs over other types of detectors is that LER architecture allows to lay out thousands of resonators all of them easily integrated within a single transmission line. This passive frequency-domain multiplexing is especially useful providing the wide field of view necessary to map the CMB.

Resonators based on LERs are also a fundamental component for quantum computers circuitry. Their flexibility in design and compact nature implies a great advantage over distributed resonators regarding scalability, speed, and fidelity. Their recent introduction to spin-based quantum computation promises to enhance this research field. In particular, the highly intense magnetic field produced by LERs allows initializing qubits codified within small spin ensembles, which offer coherence times far larger than the superconducting qubits used in other quantum platforms. In the future, these developments will produce highly compact units even able to perform their own error correction protocols. Furthermore, the capability of multiplexing different LERs along a single transmission line allows interaction with different spin-based qubits at the same time.

In this talk, I will present our efforts on developing and optimizing LERs for its use as Kinetic Inductance Detectors for astronomical experiments and as building blocks for Molecular Spin on-chip Quantum Processors.

This work was supported by Spanish Ministry of Science and Innovation under Grant PID2019-105552RB, Grant SEV-2016- 0686 and ONR-Global through Grant DEFROST N62909-19-1-2053. This project has also received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 862893 (FATMOLs). We also acknowledge support from CSIC Research Platform PTI-001

**Presenting author email: agomez@cab.inta-csic.es*

ABSTRACTS OF POSTERS

Poster #1

Superconducting gap and magnetoresistance of layered $AuSn_4$

Edwin Herrera[1], Beilun Wu[1], Alberto Montoya[2], Miguel Águeda[1,*], Pablo García Talavera[1], Víctor Barrena[1], Jon Azpeitia[3], Carmen Munuera[3], Mar García-Hernández[3], Paul C. Canfield[4], José J. Baldoví[2], I. Guillamón[1], and H. Suderow[1]

1 Laboratorio de Bajas Temperaturas y Altos Campos Magnéticos, Departamento de Física de la Materia Condensada,

Instituto Nicolás Cabrera and Condensed Matter Physics Center (IFIMAC), Unidad Asociada UAM-CSIC, Universidad Autónoma de Madrid, E-28049 Madrid, Spain

2 Instituto de Ciencia Molecular (ICMol), Universidad de Valencia, Catedrático José Beltrán 2, 46980 Paterna, Spain

3 Instituto de Ciencia de Materiales de Madrid, Consejo Superior de Investigaciones Científicas (ICMM-CSIC), Sor Juana Inés de la Cruz 3, 28049 Madrid, Spain

4 Ames Laboratory, Ames and Department of Physics & Astronomy, Iowa State University, Ames, IA 50011, United States of America

$PtSn_4$ and $PdSn_4$ are semimetals with huge linear magnetoresistance, possibly related to topological bandstructures [1,2]. $AuSn_4$ is isostructural to these materials while presenting a superconducting phase. Here we report on the synthesis and characterization of single crystals of $AuSn_4$. We present the Au-Sn binary phase diagram and discuss the possible single crystalline systems that can be obtained from it. We discuss solution growth [3] as a good method to obtain high quality single crystals of $AuSn_4$. We grow $AuSn_4$ and find platelet crystals oriented along the b-axis of the orthorhombic crystal structure (Nr 68). The crystal size is crucible limited. Samples can be very easily exfoliated into layers. We characterize these crystals via resistivity, finding a residual resistance ratio above 120, sizeably above previous reports in literature [4]. This indicates and excellent crystal quality and a low number of residual impurities and defects. The critical temperature is of T_C=2.35 K. We also discuss STM measurements of the density of states, where we find a superconducting gap which has an extremely large distribution of values over the Fermi surface. Furthermore, we observe the superconducting gap significantly above the bulk superconducting transition temperature (up to $1.1T_C$). We associate this finding with superconducting fluctuations or strain in detached layers [4,5,6,7]. We also discuss magnetoresistance, ARPES and bandstructure calculations.

References

[1] N. H. Jo et al., Phys. Rev. B, 96 (2017) 165145.

[2] E. Mun et al., Phys. Rev. B, 85 (2012) 035135.

[3] Paul C Canfield, *Rep. Prog. Phys.,* 83 (2020) 016501.

[4] D. Shen et al., Commun Mater, 1 (2020) 56.

[5] J.A.Galvis et al., Phys. Rev. B, 89 (2014) 224512

[6] J.A.Galvis et al., Phys. Rev. B, 87 (2013) 094502

[7] J.A.Galvis et al., Phys. Rev. B, 87 (2013) 214504

**Presenting author email: miguel.agueda@estudiante.uam.es*

Poster #2

Gate tunable supercurrent in the epitaxial superconducting shell in Ta/InAs nanowires

Martin Berke[1,*], Tosson Elalaily[1], Máté Kedves[1], Gergő Fülöp[1], Jesper Nygård[2], Péter Makk[1] and Szabolcs Csonka[1]

1 Department of Physics, Budapest University of Technology and Economics and Nanoelectronics 'Momentum' Research Group of the Hungarian Academy of Sciences, Budafoki út 8, 1111 Budapest, Hungary

2Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

Integrated circuits with superconducting building blocks would have several benefits, such as high speed and low power consumption. In recent years, surprisingly, field-effect control of the supercurrent in all-metallic transistors has been observed. This phenomenon can be used to fabricate gate controlled transistors from superconducting materials, analogous to the field effect transistors. The suppression of the supercurrent was investigated in several materials however there is no scientific consensus on the microscopical explanation [1-3]. In this work, we studied gate tunable supercurrents in Ta superconducting shells epitaxially grown on the top of of InAs nanowires. The investigated device switches from superconducting state to normal state by applying ~ ±5 V on the gate, which is really promising for standard electronical applications. Magnetic field dependence and switching current distribution measurements suggest that the gating effect does not stem from a simple thermal heating. Moreover, electric field driven collapse of superconductivity is not consistent with our experimental findings, however out of equilibrium phonon generation in the substrate is more likely to be the origin of this effect in our device.

References

[1] De Simoni, Giorgio, et al. "Nature nanotechnology 13.9 (2018): 802-805.

[2] Ritter, M. F., et al. Nature communications 12.1 (2021): 1-6.

[3] Alegria, Loren D., et al. Nature Nanotechnology 16.4 (2021): 404-408.

**Presenting author email: berke.martin01@gmail.com*

Poster #3

Implementation of high frequency techniques for measuring hybrid superconductor-semiconductor devices

I. Casal[1,*], A. Ibabe[1], M. Calero[2], A. Gómez[2], D. Granados[3], M. Hocevar[4], J. Nygard[5], and E. J. H. Lee[1]

1 Condensed Matter Physics Department, Universidad Autónoma de Madrid, Madrid, Spain

2 Centro de Astrobiología, CSIC-INTA, Madrid, Spain

3 IMDEA Nanoscience, Madrid, Spain

4 Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, Grenoble, France

5 Center for Quantum Devices & Nano-science Center, Niels Bohr Institute, University of Copenhagen, Denmark

Hybrid semiconductor-superconductor devices are currently at the center of intensive experimental exploration owing to their rich phenomenology and to their potential in quantum technologies [1] [2] [3]. Because of the growing complexity of experiments, high frequency microwave measurements appear as powerful tools for performing faster measurements [4] and for gaining new insights on the physics of the devices which are otherwise not possible with DC transport measurements [5]. In this work, I will present our ongoing efforts to implement high frequency techniques for studying devices based on proximitized nanowires. I will focus particularly on the development of a reflectometry experimental set-up which we have benchmarked by measuring quantum dots (QD) naturally occurring in InAs nanowires. Reflectometry has several advantages over DC transport techniques such as higher SNR with measurement times an order of magnitude lower and simpler fabrication at the nanoscale level (when compared to other charge detection techniques). Here, I will compare DC and reflectometry measurements where the latter was carried out up to three times faster than the former. I will also present our progress in the development of a gatemon qubit device which will consist of a proximitized InAs nanowire acting as a Josephson junction coupled to a superconducting island.

References

[1] Prada, E. et al. From Andreev to Majorana bound states in hybrid superconductor–semiconductor nanowires. Nature Reviews Physics 2, 575–594 (2020).

[2] Lee, E. J. H. et al. Spin-resolved Andreev levels and parity crossings in hybrid superconductor–semiconductor nanostructures. Nature Nanotech 9, 79–84 (2014).

[3] Hays, M. et al. Coherent manipulation of an Andreev spin qubit. Science 373, 430–433 (2021).

[4] Petersson, K. D. et al. Charge and Spin State Readout of a Double Quantum Dot Coupled to a Resonator. Nano Lett. 10, 2789–2793 (2010).

[5] Tosi, L. et al. Spin-Orbit Splitting of Andreev States Revealed by Microwave Spectroscopy. Phys. Rev. X 9, 011010 (2019).

**Presenting author email: ignacio.casal@uam.es*

Poster #4

Tunneling spectroscopy at very high magnetic fields in the iron based superconductor KFe_2As_2

M.Fernández-Lomana[1,*], B.Wu[1], E. Herrera[1], A. A. Haghighirad[2], H.Suderow[1,3] A.E. Böhmer[2,4] and I.Guillamón[1,3]

1 Laboratorio de Bajas Temperaturas, Departamento de Física de la Materia Condensada, Instituto de ciencia de Materiales Nicolás Cabrera, Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, E-28049

2 Institute for Quantum Materials and Technologies (IQMT), Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany

3 Unidad Asociada de Bajas Temperaturas y Altos Campos Magnéticos, UAM, CSIC, Cantoblanco, E-28049 Madrid, Spain 3 Segainvex, Universidad Autónoma de Madrid, 28049 Madrid, Spain

4 Institut für Experimentalphysik IV, Ruhr-Universität Bochum, 44801 Bochum, Germany

We present scanning tunneling spectroscopy measurements in KFe2As2. This system is a superconductor with Tc which is at the end of the Ba1-xKxFe2As2 series. It has been proposed to be a nodal superconductor. The electronic effective mass is strongly enhanced due to the proximity to an orbital-selective Mott transition [1]. Here we make first STM measurements at very low temperatures and high magnetic fields [2]. At zero field, we identify an unprecedented anisotropy of the superconducting gap. In the intermediate state, we observe the vortex lattice to very large values of the magnetic field. We finally present measurements of the bandstructure in superconducting and normal phases, obtained at zero magnetic field and at magnetic fields of 20 T from quasiparticle interference scattering.

References

[1] F. Hardy et al., Phys. Rev. Lett. 111, 027002 (2013)

[2] M. Fernández-Lomana et al, Rev. Sci. Instrum. 92, 093701 (2021)

Presenting author email: marta.fernandez-lomana@uam.es

Poster #5

The Josephson effect in full-shell Al-InAs nanowires in the Little-Parks regime

M. Gómez[1,*], A. Ibabe[1], I. Casal[1], J. Nygard[2], E. J. H. Lee[1]

1 Condensed Matter Physics Department, Universidad Autónoma de Madrid, Madrid, Spain

2 Center for Quantum Devices & Nano-science Center, Niels Bohr Institute, University of Copenhagen, Denmark

The experimental realization of a topological superconductor and Majorana zero modes (MZMs) has been a hot topic in Condensed Matter Physics during the last decade. One of the most promising proposed routes towards this goal is based on semiconducting nanowires with strong spin-orbit coupling, induced superconductivity, and an external magnetic field [1, 2]. Despite the remarkable improvements in the experiments over the past years, a fully conclusive demonstration of such an exotic phase is however still lacking. More recently, a proposal to realize the elusive Majorana quasiparticles using lower magnetic fields has been put forward. In this case, the topological phase transition results from the application of an odd number of magnetic fluxes in full-shell proximitized nanowires [3]. This system has been studied in the tunnel regime, whereby zero-bias peaks were interpreted in favor of a topological origin [4]. A detailed study of the Josephson effect in this type of hybrid nanowires is however still missing. In this work, we present our first measurements of the Little-Parks effect in Josephson Junctions based on InAs nanowires with a full epitaxial Al shell. We observe the characteristic oscillations of the superconducting gap, which is minimum at half-integer values of the magnetic flux and maximum at integer values. We observed a similar oscillatory behaviour in the excess and critical currents of our junctions. The Josephson effect can be used to shed further light onto the physics of full-shell superconductor-semiconductor nanowires.

References

[1] R. M. Lutchyn et al., Phys. Rev. Lett., 105, 077001 (2010)

[2] Y. Oreg et al., Phys. Rev. Lett., 105, 177002 (2010)

[3] R. M. Lutchyn et al., arXiv:1809.05512 (2018)

[4] S. Vaitiekenas et al., Science, 367, eaav3392 (2020)

**Presenting author email: mario.gomezg@uam.es*

Poster #6

TOWARDS HYBRID VAN DER WAALS JOSEPHSON JUNCTIONS BASED ON $NbSe_2$.

C. González Sánchez[1,*], J. Cuadra[1], V. Barrena[1], A. Spuri[2], E. Scheer[2], H. Suderow[1], A. di Bernardo[2], E. J. H. Lee[1]

1 Department of Condensed Matter Physics, Universidad Autónoma de Madrid, Ciudad Universitaria de Cantoblanco, Spain.

2 Department of Physics, Universität Konstanz, Universitätsstraße 10, Konstanz, Germany.

The emergence of van der Waals heterostructures has paved the way for a "designer" approach, in which novel devices and new physics can be obtained by combining the properties of distinct two-dimensional materials. Among the many possibilities in this context, heterostructures based on superconducting few-layer $NbSe_2$ attract great interest for studying Josephson effects and the superconducting proximity effect in 2D systems [1]. Interestingly, recent work has reported on signatures of a topological superconducting phase in heterostructures based on $NbSe_2$ and 2D ferromagnets [2]. Moreover, first demonstrations of magnetic vdW Josephson junctions have been very recently reported using a similar material combination [3, 4, 5, 6]. Motivated by the above developments, we present here our first steps towards the fabrication of nanodevices based on $NbSe_2$, including our first attempts to fabricate Josephson junctions with and without ferromagnetic and antiferromagnetic tunnel barriers.

References

[1] N. Yabuki et al., Nat. Commun, 7 (2016) 10616

[2] S. Kezilebieke et al, Nat., 588 (2020) 424–428

[3] H. Idzuchi et al., Nat. Commun, 12 (2021) 5332

[4] K. Kang et al., arXiv:2101.01327

[5] L. Ai et al., Nat. Commun, 12 (2021) 6580

[6] K. Kang et al., arXiv: 2201.09185

**Presenting author email: celia.gonzalezs@uam.es*

Poster #7

TUNING MAGNETIC ANISOTROPIES WITH SUPERCONDUCTIVITY AND SPIN-ORBIT INTERACTION IN EPITAXIAL FERROMAGNET-SUPERCONDUCTOR HYBRIDS

César González-Ruano[1,*], Diego Caso[1], Lina G. Johnsen[2], Coriolan Tiusan[3,4], Michel Hehn[4], Niladri Banerjee[5], Jacob Linder[2], Farkhad G. Aliev[1].

1 Departamento Física de la Materia Condensada C-III, Instituto Nicolás Cabrera (INC) and Condensed Matter Physics Institute (IFIMAC), Universidad Autónoma de Madrid, Madrid 28049, Spain.

2 Department of Physics, Center for Quantum Spintronics, Norwegian University of Science and Technology, 7491 Trondheim, Norway.

3 Department of Physics and Chemistry, Center of Superconductivity Spintronics and Surface Science C4S, Technical University of Cluj-Napoca, Cluj-Napoca 400114, Romania.

4 Institut Jean Lamour, Nancy Universitè, 54506 Vandoeuvre-les-Nancy Cedex, France.

5 Department of Physics, Loughborough University, Epinal Way, Loughborough LE11 3TU, UK.

Generation and control over long-range triplet (LRT) Cooper pairs is a key milestone for applications in superconducting spintronics. It has been commonly expected that these proximity effects require complex ferromagnetic multilayers, non-collinear magnetization or half-metals. With our work, we propose a new platform compatible with commercial spintronics.

We have studied all-epitaxial V/MgO/Fe junctions with competing in-plane and out-of-plane (OOP) magnetic anisotropies, and spin-orbit coupling (SOC) at the MgO interface. First, we experimentally demonstrated a thousand-fold increase in tunneling anisotropic magnetoresistance below the vanadium critical temperature (TC), which supports LRT formation depending on the mangetic configuration of the Fe layer [1]. Then we studied the converse effect: the transformation of the in-plane and out-of-plane magnetocrystalline anisotropies of the Fe layer driven by the superconductivity of vanadium through the SOC-bearing MgO interface. Under an in-plane rotation of an external magnetic field, new easy axes for the magnetization appear below TC, resulting in new stable in-plane magnetic configurations [2]. The effective perpendicular magnetic anisotropy (PMA) is also enhanced, inducing a partial OOP magnetization reorientation without any applied field, and a reduction of the field required to induce a complete OOP transition [3]. We modelled our results in terms of an additional contribution to the free energy of the ferromagnet arising from the controlled generation of triplet Cooper pairs, which depends on the relative angle between the exchange field of the ferromagnet and the spin-orbit field.

Our findings, supported by theoretical and numerical modelling of the ferromagnet-superconductor interaction, offer the ability to tune magnetic anisotropies using superconductivity - a key step in designing future cryogenic magnetic memories. Additionally, a new and unexpected behavior was found, providing a robust increase of the tunnel magneto-resistance (TMR) with applied bias up to 0.5 V in a wide temperature range, and unprecedented high output voltage values in room temperature spintronics [4], which could push the applicability range of spintronic devices toward higher biases.

References

[1] I. Martínez et al; Phys. Rev. Appl. 13, 014030 (2020)

[2] C. González-Ruano et al; Phys. Rev. B, 102, 020405(R) (2020).

[3] C. González-Ruano et al; Sci. Rep. 11, 19041 (2021).

[4] C. González-Ruano et al, Adv. Elec. Mat. 210085 (2021).

**Presenting author email:* cesar.gonzalez-ruano@uam.es

Poster #8

Non-trivial Current Induced Magnetic Response in Ferromagnetic Insulator-Superconductor Heterostructure

A. Gutfreund[1]*, H. Matsuki[2], A. Noah[1], H. Alpern[1], O. Millo[1], J. Robinson[2], Y. Anahory[1]

1 The Racah Institute of Physics, The Hebrew University, 91904, Jerusalem, Israel

2 Department of Materials Science & Metallurgy, University of Cambridge, CB3 0FS, Cambridge, United Kingdom

The consequences of coupling between ferromagnetic insulators (FI) and superconductors (SC) are a topic of wide investigation. In particular, the proximity effect at the FI-SC interface combined with large Spin-Orbit Coupling (SOC) of the charge carriers was shown to strongly influence transport properties of the material. This is manifested in a dependance between the SC critical current and the magnetic state of the magnet. In this work, we employ scanning Squid-On-Tip (SOT) microscopy in order to image the magnetic response driven by a charge current. We present magnetic images that spatially resolve wave-like features characterized by a length scale on the order of $\sim 1\ \mu m$. These preliminary results suggest the existence of unconventional current distribution and/or in-homogeneous spin accumulation.

Presenting author email: alon.gutfreund@mail.huji.ac.il

Poster #9

Experimental study of superconductivity in strongly disordered molybdenum nitride thin films

M. Kuzmiak[1,2]*, M. Kopčík[1,2], F. Košuth[1,3], V. Latyshev[3], V. Komanický[3], P. Szabó[1] and P. Samuely[1]

1 Centre of Low Temperature Physics, Institute of Experimental Physics, Slovak Academy of Sciences, SK-04001 Košice, Slovakia

2 Department of Physics, Faculty of Electrical Engineering and Informatics, Technical University of Košice, SK-04001 Košice, Slovakia

3 Centre of Low Temperature Physics, Faculty of Science, P. J. Šafárik University, SK-04001 Košice, Slovakia

We studied physical properties of γ-Mo_2N thin films applying low temperature transport and STM measurements. Our samples are strongly disordered thin films with thicknesses between 30 nm and 1.5 nm, where the disorder is introduced into the samples by reducing their thickness. The subsequent reduction of the thickness has led to the superconductor-insulator transition (SIT). Our transport measurements showed that the SIT transition takes place at thicknesses between 3 nm and 2 nm. The superconducting properties observed down to 3 nm thickness show homogeneous superconductivity and unchanged strength of the superconducting coupling indicating Fermionic SIT. Transport measurements performed on thin films with 1.5 and 2 nm thickness do not exhibit superconducting properties and the locally measured STM density of states (DOS) shows quasi logarithmic reduction, which is typical for the disordered metals with enhanced electron-electron interactions. The influence of increased temperature and applied magnetic field to the logarithmically reduced normal state DOS will be discussed.

**Presenting author email: kuzmiak@saske.sk*

Poster #10

Scanning AC Josephson Spectroscopy

Jose Antonio Moreno[1,*], Víctor Barrena[1], Samuel Díaz Escribano[2], David Perconte[1], Marta Fernández Lomana[1], Edwin Herrera[1], Beilun Wu[1], Isabel Guillamón[1], Alfredo Levy Yeyati[2] and Hermann Suderow[1]

1 Laboratorio de BajasTemperaturas y Altos Campos Magnéticos, Departamento de Física de la Materia Condensada, Instituto Nicolás Cabrera and Condensed Matter Physics Center (IFIMAC), Unidad Asociada UAM-CSIC, Universidad Autónoma de Madrid, E-28049 Madrid, Spain

2 Departamento de Física Teórica de la Materia Condensada, Instituto Nicolás Cabrera and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Madrid, Spain

Scanning tunneling microscopy with superconducting tip is a powerful technique capable of enhancing the energy and spatial resolution of conventional STM with superconducting materials. Furthermore, with a superconducting tip we can probe superconductor-superconductor junctions and measure the Josephson effect between tip and sample, which can yield relevant information about correlated states. Here we have performed Josephson tunneling microscopy (JSTM) with a Pb tip on both Pb and 2H-NbSe2. We have characterized the recently discovered AC Josephson component using an AC amplification lock-in technique which allows for simultaneous measurements of the AC and DC signals. Our approach leads to an order of magnitude increase in the Josephson signal strength and allows to considerably improve studying the Josephson coupling as a function of the position.

**Presenting author email: josea.moreno@uam.es*

Poster #11

Tunable exchange bias in magnetic Weyl semimetal $Co_3Sn_2S_2$

Avia Noah[1,*], Filip Toric[1], Tomer D. Feld[1], Gilad Zissman[1], Alon Gutfreund[1], Dor Tsruya[1], Taget R. Devidas[1], Hen Alpern[1], Atzmon Vakahi[2], Hadar Steinberg[1], Martin E. Huber[3], James G. Analytis[4,5], Snir Gazit[1,6], Ella Lachman[4,5] and Yonathan Anahory[1]

1 The Racah Institute of Physics, The Hebrew University, Jerusalem, 91904, Israel

2 Center for Nanoscience and Nanotechnology, Hebrew University of Jerusalem, Jerusalem, 91904, Israel

3 Departments of Physics and Electrical Engineering, University of Colorado Denver, Denver, CO 80217, USA

4 Department of Physics, University of California, Berkeley, CA 94720, USA

5 Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, CA, 94720, USA

6 The Fritz Haber Research Center for Molecular Dynamics, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

Exchange bias is a phenomenon critical to solid-state technologies that require spin valves or non-volatile magnetic memory. The phenomenon is usually studied in the context of magnetic interfaces between antiferromagnets and ferromagnets, where the exchange field of the former acts as a means to pin the polarization of the latter. In the present study, we report an unusual instance of this phenomenon in the topological Weyl semimetal Co3Sn2S2, where the magnetic interfaces associated with domain walls suffice to bias the entire ferromagnetic bulk. Remarkably, our data suggests the presence of a hidden order parameter whose behavior can be independently tuned by applied magnetic fields. For micron-size samples, the domain walls are absent, and the exchange bias vanishes, suggesting the boundaries are a source of pinned uncompensated moment arising from the hidden order. The novelty of this mechanism suggests exciting opportunities lie ahead for the application of topological materials in spintronic technologies.

** Presenting author email: avia.noah@mail.huji.ac.il*

Poster #12

INTERFACING NUCLEAR SPINS THROUGH SUPERCONDUCTING LC RESONATORS

V. Rollano[1,2,*], M.C. de Ory[3], C. D. Buch[4], M. Rubín-Osanz[1,2], D. Zueco[1,2], C. Sánchez-Azqueta[5], A. Chiesa[6,7,8], D. Granados[9], S. Carretta[6,7,8], A. Gomez[3], S. Piligkos[4], and F. Luis[1,2]

1 Instituto de Nanociencia y Materiales de Aragón (CSIC – UNIZAR), 50009 Zaragoza, Spain
2 Departamento de Física de la Materia Condensada, Universidad de Zaragoza, 50009 Zaragoza, Spain
3 Centro de Astrobiología (CSIC – INTA), Torrejón de Ardoz, 28850 Madrid, Spain
4 Department of Chemistry, University of Copenhagen, DK-2100 Copenhagen, Denmark
5 Departamento de Física Aplicada, Universidad de Zaragoza, 50009 Zaragoza, Spain
6 Università di Parma, Dipart. di Scienze Matematiche, Fisiche e Informatiche, I-43124 Parma, Italy
7 UdR Parma, INSTM, I-43124 Parma, Italy
8 INFN–Sezione di Milano-Bicocca, gruppo collegato di Parma, 43124 Parma, Italy
9 IMDEA Nanociencia, Cantoblanco, 28049 Madrid, Spain

Nuclear spins are candidates to encode qubits due to their isolation from magnetic noise. This isolation results in potentially long coherence times, which is the time the quantum information can be maintained in a qubit. However, this advantage hampers their integration into circuit QED architectures (c-QED). Here, we utilize lumped-element LC superconductor resonators to interface with different nuclear spin states in an [173Yb(trensal)] molecule (Fig. 1a). This technology allows attaining this up-to-now elusive achievement. Moreover, [173Yb(trensal)] exhibits a I = 5/2 nuclear spin and a S =1/2 electronic spin. Hence, several qubits can be codified within its different spin transitions (Fig. 1b). We demonstrate a high cooperative coupling to all electronic and most nuclear [173Yb(trensal)] spin transitions. This result is a big leap towards the implementation of error-corrected and qudit-based protocols with molecular spins using a hybrid architecture.

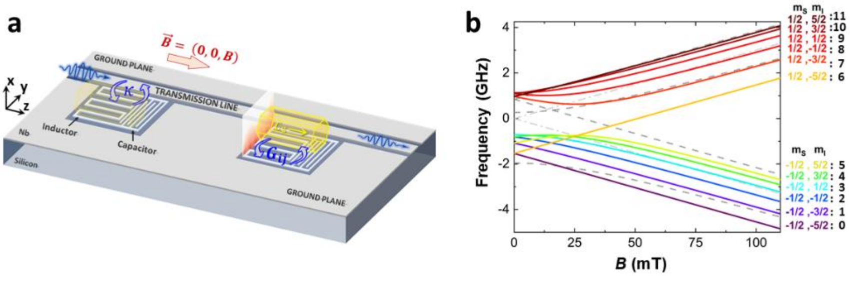


Fig. 1 a Scheme of an [Yb(trensal)] crystal (yellow) coupled to the cQED system. **b** Spin energy levels of [^{173}Yb(trensal)] as a function of external magnetic field. The magnetic field is parallel to the C_3 crystal anisotropy axis. Each level is characterized by its electronic (m_S) and nuclear(m_I) quantum numbers. Dashed grey lines correspond to the spin energy levels of [^{171}Yb(trensal)], with I = 1/2. The energy levels of all Yb isotopes with I = 0 are shown as dashed-dotted grey lines.

References

[1] R. J. Schoelkopf and S. M. Girvin, Nature 451, 664-669 (2008).
[2] R. Hussain, et al., J. Am. Chem. Soc. 140, 9814-9818 (2018).
[3] A. Gómez-León, F. Luis and D. Zueco, arXiv:2109.14639 (2021).
[4] S. Carretta, D. Zueco, A. Chiesa, A. Gómez-León and F. Luis, Appl. Phys. Lett. 118, 240501 (2021).

**Presenting author email: victor.rollano@unizar.es*

Poster #13

STM in the flat band kagome lattice compound $CO_3Sn_2S_2$

R. Sánchez-Barquilla[1,2,*], E. Herrera[1,2], X. Lin[3,4], S. L. Bud'ko[3,4], P. C. Canfield[3,4], H. Suderow[1,2] and I. Guillamón[1,2]

1 Laboratorio de Bajas Temperaturas y Altos Campos Magnéticos, Departamento de Física de la Materia Condensada, Instituto Nicolás cabrera and Condensed Matter Physics Center (IFIMAC), Universidad Autónoma de Madrid, Cantoblanco, E-2849 Madrid, Spain

2 Unidad Asociada de Bajas Temepraturas y Altos Campos Magnéticos, UAM/CSIC, Cantoblanco, E-28049 Madrid, Spain

3 Ames Laboratory, U.S. DOE, Iowa State University, Ames, Iowa 50011, USA

4 Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA

The system Co3Sn2S2 has a kagome lattice formed by Co atoms which leads to the formation of a flat band close to the Fermi level [1,2]. Here we present new STM measurements at magnetic fields up to 14T in high quality single crystals of Co3Sn2S2 [3]. We use the sample cleaving mechanism discussed in [4] and the coarse approach system of [5]. We discuss the different surface terminations, quasiparticle interference experiments at high magnetic fields and the Zeeman effect on the flat band. We compare our results with previous results at zero field and under magnetic fields of 8 T [1].

References

[1] J. Yin et al. Nature Physics, 15, 443 (2019)

[2] M. et al. Science, 365, 1286 (2019)

[3] Xiao Lin et al. Phylosophical Magazine, 92, 2436 (2012)

[4] H. Suderow et al., Rev Sci Instrum 82, 033711 (2011)

[5] M. Fernandez-Lomana et al., Acepted Rev. Sci. Instrum. (2021)

**Presenting author email: raquel.sanchezb@uam.es*

Poster #14

Characterization of GaAs-based near-surface InAs 2DEGs with an epitaxial Al layer

M. Sütő[1,*], E. Tóvári[1], P. L. Neumann[1], M. Kirti[2], A. Benali[2], G. Biasiol[2], P. Makk[1] and Sz. Csonka[1]

1 Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary

2 IOM CNR, Laboratorio TASC, Area Science Park Basovizza, 34149Trieste, Italy

InAs two-dimensional electron gases garnered great interest over the past decades due to their high carrier mobility, great density tunability and exotic topological phases as a consequence of spin-orbit coupling and superconducting proximity from an epitaxial Al layer. This system is promising as a topological quantum computational platform or as a host to Andreev-qubits due to better scalability than semiconductor nanowire-based realizations. In this contribution, I present the basic characterization of a new InAs 2DEG structure which is grown on a GaAs crystal by MBE. On the GaAs substrate first a step-graded buffer of InAlAs is used to alleviate the lattice mismatch, which is then followed by a 300 nm thick buffer layer to enhance the wafer properties for high-frequency measurements. We characterized this new heterostructure via low temperature transport measurements such as the observation of Shubnikov-de Haas oscillations, gate tunability measurements in large magnetic fields and Lifshits-Kosevich analysis. We found mobility values of 86000 cm2/(Vs) after the etching of the epitaxial Al layer, which exceeds previously reported values of samples grown on InP by a factor of two, and matches values measured on samples without the epitaxial Al layer. By defining quantum point contact geometry with local gates, we demonstrate the first quantized conductance plateau. Furthermore, by measuring a Josephson junction in the mK regime we observed large, tunable critical current and Fraunhofer pattern. Our results show that GaAs-based InAs 2DEGs are promising novel heterostructures for the realization of Andreev qubits.

**Presenting author email: suto.mate@ttk.bme.hu*

Poster #15

Possible zero sound in layered perovskites with ferromagnetic sign of the s-d exchange interaction

Todor M. Mishonov[1], Nedeltcho I. Zahariev[1,*], Hassan Chamati[1], Albert M. Varonov[1]

1 Georgi Nadjakov Institute of Solid State Physics, Bulgarian Academy of Sciences, 72 Tzarigradsko Chaussee Blvd., BG-1784 Sofia, Bulgaria

We analyze the conditions for observation of zero sound in layered perovskites with transition metal ion on chalcogenide oxidizer. We conclude that propagation of zero sound is possible only for ferromagnetic sign of the s-d interaction. If the s-d exchange integral Jsd has antiferromagnetic sign, as it is perhaps in the case for layered cuprates, zero sound is thermally activated dissipation mode, which creates only ``hot spots'' in the Angle Resolved Photoemission Spectroscopy (ARPES) data along the Fermi contour. We predict that zero sound will be observable for transition metal perovskites for which 4s and 3d levels will be close to the p-level of the chalcogenide. Lack of superconductivity, hot spots in ARPES data, and the proximity of these three levels, simultaneously is the significant hint for the choice of material with which the search should begin.

**Presenting author email: nedeltcho.zahariev@gmail.com*