TT 50: German-French Focus Session: Superconducting Junctions and Quantum Circuits

Superconducting junctions are important building blocks for various applications including qubits. The importance of superconductivity to probe macroscopic quantum physics has been underlined by the Nobel prize in physics 2025. Current research activities in the field of superconducting quantum circuits bridge from fundamental symmetry aspects of superconductivity to material science for improved performance of superconducting electronics. Beyond these activities, superconductivity has developed as a tool to probe also unconventional normal conducting properties. The scope of this focus session is to showcase recent activities in this field in France and Germany and to tighten the interaction between the very active research communities in both countries.

Coordinators: Clemens Winkelmann (CEA/UGA Grenoble), Guillaume Weick (University of Strasbourg), Elke Scheer (University of Konstanz).

Time: Wednesday 15:00–18:30 Location: HSZ/0003

Topical Talk TT 50.1 Wed 15:00 HSZ/0003

Josephson Quantum Tunneling at Odd Parity — Manuel Houzet[1], •Julia S. Meyer[1], and Yuli V. Nazarov[2] — [1]Univ. Grenoble Alpes, France — [2]Delft University of Technology, The Netherlands

When a Josephson junction is embedded in an electromagnetic circuit, the superconducting phase difference across the junction becomes a quantum-fluctuating variable. The resulting quantum mechanics of the Josephson effect is the core ingredient for quantum technologies with superconducting circuits. On a microscopic level, the Josephson effect is related to Andreev bound states in the junction and depends on their occupation. When a single quasiparticle is trapped in an Andreev bound state–a situation known as quasiparticle poisoning–the junction is in the odd-parity sector. Because of parity conservation, such a poisoned state may exhibit a long lifetime. Our work opens a new avenue in this field by showing that the Josephson quantum mechanics in the odd-parity sector differs fundamentally from the conventional behavior in the even-parity sector. We uncover a rich phenomenology that contrasts with the naïve expectation of a simple supercurrent quench, which prevailed so far. Covering several representative cases, we predict a variety of novel effects that can be probed in upcoming experiments. Hybrid superconductor-semiconductor-superconductor junctions, that have been intensively studied in recent years both with nanowires and two-dimensional electron gases, provide a promising platform for observing these phenomena.

Topical Talk TT 50.2 Wed 15:30 HSZ/0003

Superconducting qubits and amplifiers resilient to Tesla-scale magnetic fields — •Ioan Pop — KIT, Karlsruhe, Germany

Superconducting qubits with quantum non-demolition readout and active feedback can act as information engines to probe and control microscopic degrees of freedom, both engineered and environmental. However, performing such experiments in magnetic fields above tens of mT poses a significant challenge for conventional superconducting qubits. We demonstrate a fluxonium qubit with a granular aluminum nanojunction (gralmonium) that maintains spectral stability and coherence above 1 T [1]. This robust performance enables exploration of spin environment dynamics and supports hybrid quantum architectures integrating superconducting qubits with spin systems [2].

[1] Günzler & Beck et al., Nature Comm. 16, 9564 (2025)
[2] Günzler et al., Phys. Rev. B 112, 115424 (2025)

Topical Talk TT 50.3 Wed 16:00 HSZ/0003

Josephson metamaterials as near-quantum-limited microwave amplifiers — •Nicolas Roch — Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Neel, 38000 Grenoble, France

Josephson meta-materials have recently emerged as a highly promising platform for superconducting quantum science and technology. Their unique potential lies in the ability to engineer these materials at subwavelength scales, allowing for complete control over wave dispersion and nonlinear interaction. In this seminar, I will demonstrate how Josephson meta-materials can be utilized as microwave amplifiers with added noise that approaches the quantum limit. These materials are already widely used in experiments ranging from quantum information processing with superconducting qubits to dark matter detection. In the second part, I will present a recent experiment demonstrating a microwave amplifier that exhibits intrinsic isolation and can be used to read out a superconducting qubit without the need for magnetic isolators.

This research is conducted in collaboration with the company Silent Waves.

15 min. break

Topical Talk TT 50.4 Wed 16:45 HSZ/0003

Second Order Topological Insulators probed with mesoscopic physics — •Sophie Gueron — Laboratoire de Physique des Solides Universite Paris-Saclay France

Second Order Topological Insulators (SOTIs) are a new family of materials, predicted to be insulating in the bulk and surfaces, and perfectly conducting along dimensional crystal hinges. Similarly to Quantum Spin Hall edges states in 2D Topological Insulators, the hinge states are expected to carry current with no dissipation and no backscattering, due to their unique spin-momentum-locked configuration, also called helicity. I will present various mesoscopic physics experiments that have uncovered the special properties of SOTIs. Firstly, experiments with superconducting contacts have led to the discovery that Bismuth was a Second Order Topological Insulator, by providing evidence of hinge states and their topological character. We have also recently extended our experiments to new SOTI materials and to non-superconducting contacts, as well as to the investigation of the current-induced spin polarization due to spin-momentum locking in the hinge states. Finally, I will present a new detection scheme to explore orbital currents in 2D materials, that has the potential to reveal persistent currents circulating at the hinges of a mesoscopic SOTI crystal.

This work is a collaborative work conducted in the Mesoscopic Physics group at Laboratoire de Physique des Solides

Topical Talk TT 50.5 Wed 17:15 HSZ/0003

Proximity superconductivity in chiral Kagome antiferromagnets — •Piet Brouwer, Adam Chaou, Gal Lemut, and Felix von Oppen — Freie Universität Berlin, Dahlem Center for Complex Quantum Systems, Fachbereich Physik, and Halle-Berlin- Regensburg Cluster of Excellence CCE, Arnimallee 14, 14195 Berlin

Recent experiments on the chiral Kagome antiferromagnet Mn_3Ge have provided strong evidence of proximity-induced spin-polarized superconductivity. We introduce and explore a minimal model which exhibits a rich phase diagram as a function of chemical potential and spin canting. We find a valley-singlet superconducting phase for chemical potentials and canting consistent with the experimental system. This phase transitions into a Chern insulator at larger canting and gives way to topological superconducting phases with Chern numbers $C_{\mathrm{BdG}} = \pm 1, \pm 3$ at other chemical potentials. Our results show that proximity-induced superconductivity in Kagome antiferromagnets is a promising route towards superconductivity with spin-polarized Cooper pairs.

TT 50.6 Wed 17:45 HSZ/0003

Spectroscopy of a nanowire fluxonium — •Hugues Pothier[1], Joan Caceres[1], Diego Sanz[1], Jon Ortuzar[1], Emmanuel Flurin[1], Jesper Nygard[2], Cristian Urbina[1], and Marcelo Goffman[1] — [1]Quantronics group, SPEC (CNRS UMR 3680), CEA-Paris Saclay, University Paris-Saclay, 91191 Gif-sur-Yvette, France — [2]Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, Universitetsparken 5, 2100 Copenhagen, Denmark

We fabricated a fluxonium qubit [1] in which the Josephson junction is replaced with a semiconducting nanowire weak link. The Josephson effect in the nanowire is associated with Andreev bound states, which themselves have been shown to behave as qubits [2-4]. Through precise analysis of the spectroscopy data, we searched for evidence of strongly transmitted channels [5] and for an hybridization of the two types of qubits.

[1] V.E.Manucharyan, J.Koch, M.H.Devoret, Science 326, 113 (2009).
[2] C. Janvier et al., Science 349, 1199 (2015).
[3] M. Hays et al., Phys. Rev. Lett. 121, 047001 (2018).
[4] M. Hays et al., Science 373, 430 (2021).
[5] M. Pita-Vidal et al., Phys. Rev. Applied 14, 064038 (2020).

TT 50.7 Wed 18:00 HSZ/0003

Multiterminal Josephson Junctions: non-hermiticity, topology and reflectionless modes — •David Christian Ohnmacht, Wilhelm Valentin, Weisbrich Hannes, and Belzig Wolfgang — Universität Konstanz, Konstanz, Germany

In multiterminal Josephson junctions (MTJJs), the Andreev bound state energies depend on multiple phase differences, enabling band structure engineering. MTJJs are predicted to host non-trivial topological phases and associated Weyl nodes in the synthetic Brillouin zone spanned by these superconducting phases [1]. In [2], spectroscopic measurements were performed on four-terminal Josephson junctions with phase control of all three superconducting phase differences, unveiling the presence of a tri-Andreev molecule, compatible with a topologically non-trivial model. We predict that such MTJJs, in the presence of additional normal leads, host non-trivial non-Hermitian topology, leading to spectral topology in the form of point gaps and Weyl disks [3]. Additionally, we predict that reflectionless scattering modes in MTJJs are a source of topological phase boundaries [4]. Our work provides an effective bulk boundary correspondence by demonstrating a relationship between unity transmission modes and boundaries between topologically trivial and non-trivial regions, like in quantum Hall systems.

[1] R.-P. Riwar et. al., Nature Commun. 7, 1 (2016)
[2] T. Antonelli et. al., Phys. Rev. X 15, 031066 (2025)
[3] D. C. Ohnmacht et. al., Phys. Rev. Lett. 134, 156601 (2025)
[4] D. C. Ohnmacht et. al., arXiv:2503.10874 (2025)

TT 50.8 Wed 18:15 HSZ/0003

From Shapiro steps to photon-assisted tunneling in microwave-driven atomic-scale Josephson junctions with a single (magnetic) adatom — •Martina Trahms[1,2], Bharti Mahendru[1], Clemens B. Winkelmann[2], and Katharina J. Franke[1,3] — [1]Fachbereich Physik, Freie Universität Berlin, Berlin, Germany — [2]Univ. Grenoble Alpes/CEA/Grenoble-INP/IRIG-Pheliqs, Grenoble, France — [3]Fachbereich Physik and Halle-Berlin-Regensburg Cluster of Excellence CCE, Freie Universität Berlin, Berlin, Germany

Understanding Josephson junctions (JJs) on the atomic scale yields insights for the prospect of superconducting circuits in future technological applications. We form JJs between a superconducting tip and sample in a scanning tunneling microscope (STM). The phase dynamics of the JJ such as dissipation and coherence of the tunneling processes are investigated by high-frequency (HF) irradiation. Shapiro steps indicate coherent Cooper-pair tunneling while incoherent tunneling processes are described by photon-assisted tunneling. With increasing HF irradiation amplitude, the STM JJs transition from the coherent to the incoherent tunneling regime due to the increase of thermal fluctuations. Introducing a magnetic adatom into the junction reduces the Josephson coupling and increases the quasiparticle tunneling rate which leads to a suppression of coherence. We highlight the presence of phase coherence in atomic scale JJs and ascribe the transition from coherent to incoherent Cooper-pair tunneling processes to the interplay of thermal fluctuations and the Josephson coupling strength.