PHYSIKALISCHES KOLLOQUIUM

Sommersemester 2025

Das Kolloquium findet (soweit nicht anders angegeben) **jeweils montags um 14:15 Uhr in Präsenz im Röntgen-Hörsaal** des Physikalischen Instituts, Hubland Campus Süd, Universität Würzburg **und online via Zoom statt**.
Zugangsdaten siehe https://www.physik.uni-wuerzburg.de/aktuelles/veranstaltungen-aus-der-physik/physikalisches-kolloquium/

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From Majorana to Andreev and back

Abstract

The interplay of spin–orbit coupling, Zeeman fields and low densities in semiconducting devices (InAs, InSb) proximitized by superconductors can induce a quantum phase transition into a topological superconducting phase with Majorana zero modes (MZM)s. Quite remarkably, MZSs do not follow fermion statistics, unlike the original particles predicted by Majorana, but rather possess non-Abelian exchange statistics. This property, together with their topological protection against local noise, holds promise for applications in fault-tolerant topological quantum computing [1]. However, after more than ten years of intense experimental effort towards the unambiguous detection of Majoranas, it has become evident that distinguishing them from subgap Andreev bound states (ABS)s near zero energy, which are ubiquitous in such hybrid semiconductor-superconductor devices due to various physical mechanisms, is extremely difficult. Interestingly, this Majorana versus Andreev controversy [2] has helped us to understand that, far from being a disadvantage, the presence of ABSs can be used to design new qubit concepts. One promising route is to encode a qubit in the spin of a quasiparticle occupying an ABS in a quantum dot-based Josephson junction [3,4].

Embedding such superconducting spin qubit in a superconducting transmon circuit, allows an intrinsic spin-supercurrent coupling providing an optimal interface with circuit quantum electrodynamics for coherent control, readout and strong coherent qubit–qubit coupling [5]. By extending this idea to Josephson junctions based on a minimal chain of four quantum

dots one could demonstrate a minimal Majorana-Transmon qubit based on non-local fermion parity [6].

[1] Majorana qubits for topological quantum computing, Ramón Aguado, Leo P Kouwenhoven, Physics Today 73 (6), 44-50 (2020).

[2] From Andreev to Majorana bound states in hybrid superconductor-semiconductor nanowires, Elsa Prada, Pablo San-Jose, Michiel WA de Moor, Attila Geresdi, Eduardo JH Lee, Jelena Klinovaja, Daniel Loss, Jesper Nygård, Ramón Aguado, Leo P Kouwenhoven, Nature Review Physics,2, 575–594 (2020).

[3] Singlet-Doublet Transitions of a Quantum Dot Josephson Junction Detected in a Transmon Circuit, Arno Bargerbos, Marta Pita-Vidal, Rok Žitko, Jesús Ávila, Lukas J. Splitthoff, Lukas Grünhaupt, Jaap J. Wesdorp, Christian K. Andersen, Yu Liu, Leo P. Kouwenhoven, Ramón Aguado, Angela Kou, and Bernard van Heck, PRX Quantum 3, 030311 (2022).

[4] Spectroscopy of Spin-Split Andreev Levels in a Quantum Dot with Superconducting Leads, Arno Bargerbos, Marta Pita-Vidal, Rok Žitko, Lukas J. Splitthoff, Lukas Grünhaupt, Jaap J. Wesdorp, Yu Liu, Leo P. Kouwenhoven, Ramón Aguado, Christian Kraglund Andersen, Angela Kou, and Bernard van Heck, Phys. Rev. Lett. 131, 097001 (2023)

[5] Direct manipulation of a superconducting spin qubit strongly coupled to a transmon qubit, Marta Pita-Vidal, Arno Bargerbos, Rok Žitko, Lukas J Splitthoff, Lukas Grünhaupt, Jaap J Wesdorp, Yu Liu, Leo P Kouwenhoven, Ramón Aguado, Bernard van Heck, Angela Kou, Christian Kraglund Andersen, Nature Physics, 19, 1110 (2023)

[6] Minimal Kitaev-transmon qubit based on double quantum dots, D Michel Pino, Rubén Seoane Souto, Ramón Aguado, Phys. Rev. B, 109, 075101 (2024)

Für die Dozentinnen bzw. Dozenten der Fakultät

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