Seminar Fakulteta za fiziku

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Jezik: engleski

The rocky road to Majorana bound states

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Abstract

Majorana bound states (MBSs) are predicted to appear at boundaries of topological superconductors. The non-Abelian statistics of MBSs make them highly promising candidates for fault tolerant topological quantum computing. However, so far, despite significant efforts, there has been no conclusive experimental observation of MBSs. Although the presence of zero-bias peaks (ZBPs) in local conductance measurements initially appeared to be promising evidence for MBSs in nanowire devices, it was subsequently realised that the same signature could be produced by trivial effects, e.g., Andreev bound states (ABSs) Recently it has been proposed that nonlocal conductance measurements in state-of-the-art three-terminal devices [1-2] can detect the bulk gap closing and reopening that is associated with the phase transition to topological superconductivity, potentially providing a signature for the bulk topology of the nanowire. In particular, Microsoft's so-called "topological gap protocol" (TGP) attempts to combine this nonlocal signature with ZBPs in local conductance [2]. I will show that multiple Andreev bound states in the bulk of the nanowire can form an Andreev band and can produce an apparent closing and reopening signature of the bulk band gap in the nonlocal conductance [3]. Furthermore, I will show that the existence of the trivial bulk reopening signature in nonlocal conductance is unaffected by the additional presence of trivial ZBPs. The simultaneous occurrence of a trivial bulk reopening signature and trivial zero-bias peaks mimic the basic features required to pass the so-called TGP. I will further demonstrate that an Andreev band can (easily) cause false positives in Microsoft's TGP [4], bringing into question the methodology of using nonlocal conductance to determine the phase transition to topological superconductivity [5]. Finally, I will briefly discuss alternative platforms that might be less prone to trivial signals mimicking those of topological superconductivity [6,7] due to cleaner materials and/or larger energy scales.

[1] Richard Hess, Henry F. Legg, Daniel Loss, and Jelena Klinovaja Phys. Rev. Lett. 130, 207001 (2023) [Editors' Suggestion]
[2] Pikulin et al. (Microsoft Quantum) arXiv:2103.12217 (2021)
[3] Richard Hess, Henry F. Legg, Daniel Loss, and Jelena Klinovaja Phys. Rev. B 104, 075405 (2021) [Editors' Suggestion]
[4] Henry F. Legg, Richard Hess, Daniel Loss, and Jelena Klinovaja arXiv:2308.10669 (2023)
[5] Morteza Aghaee et al. (Microsoft Quantum) Phys. Rev. B 107, 245423 (2023) [Editors' Suggestion]
[6] HF Legg, D Loss, J Klinovaja Physical Review B 104, 165405 (2021)
[7] Melina Luethi, Henry F Legg, Katharina Laubscher, Daniel Loss, Jelena Klinovaja PRB 108, 195406 (2023)

About speaker:

Dr Henry Legg studied his Bachelor and Master's degrees in Mathematics and Theoretical Physics at the University of St Andrews (Scotland) where he received the "Best Master's Project" award for his thesis on "Spin liquid mediated RKKY interactions". Subsequently he moved to the University of Cologne (Germany) where, under the supervision of Prof. Achim Rosch, he defended his PhD thesis in Nov. 2019 on "Transport and disorder in Dirac materials". Following his time in Cologne, he received a Georg H. Endress fellowship in the Quantum Theory of Condensed Matter and Quantum Computing Group of Prof. Jelena Klinovaja and Prof. Daniel Loss at the University of Basel (Switzerland). His thesis and subsequent work have also involved many experimental collaborations, especially with the group of Prof. Yoichi Ando (Cologne). Dr Legg's main research interests are in theoretical condensed matter physics and, in particular, the physics of topological quantum matter and quantum devices. His research aims to both predict and understand novel quantum effects that arise in exotic materials and devices, with the ultimate goal of developing new technologies based on these systems. His recent publications have focussed on topological insulators and superconductors, spintronic devices, transport effects (in particular effects beyond linear response theory), the superconducting diode effect, and platforms for quantum computation e.g. spin-qubits in germanium.