TT 85: Topology: Majorana Physics II

Time: Friday 9:30–11:30 Location: H 3005

Invited Talk TT 85.1 Fri 9:30 H 3005

Majorana bound states in artificial Kitaev chains — •Srijit Goswami — QuTech, Delft University of Technology, The Netherlands

In the past decade superconductor-semiconductor hybrids have been studied intensively, with significant efforts towards studying Majorana bound states (MBSs). In this talk I will discuss a relatively new approach to realize MBSs using quantum dot-superconductor hybrids. I will focus on how MBSs can be systematically and reliably engineered in a two-dimensional electron gas by tuning the relative strengths of the different kinds of couplings between the quantum dots.

TT 85.2 Fri 10:00 H 3005

Magnet-superconductor hybrid systems, Majorana zero modes and topological quantum computing — •Stephan Rachel — School of Physics, University of Melbourne, Parkville, Australia

There has been significant experimental progress in recent years in establishing magnet-superconductor hybrid systems as a promising platform for Majorana physics. I will report about recent progress in this field and then explain how topological quantum computing can be enabled via braiding of Majorana zero modes. I will show examples of simple quantum algorithms that can be computed in a fault-tolerant way.

TT 85.3 Fri 10:15 H 3005

Exploiting the Dynamics of Majorana-Majorana Hybridisation — •Themba Hodge, Eric Mascot, Daniel Crawford, and Stephan Rachel — School of Physics, University of Melbourne, Parkville, Australia

Qubits built out of Majorana-Zero Modes (MZMs) have long been theorised as a potential pathway toward fault-tolerant topological quantum computation. However, almost unavoidable in these processes is the overlapping of the different Majorana wavefunctions that arise throughout the process. This leads to a qubit-error due to Majorana-Majorana hybridisation, changing the outcome of the computation. This work presents a method to track the dynamical evolution of the Majorana wavefunctions, allowing one to track transitions in the ground-state subspace and calculate time-dependent correlation functions that provide the output of quantum computations. This is compared to exact, time-dependent superconducting simulations utilising the method introduced in [1], to confirm the advantage of this approach to make accurate dynamical predictions without the need for full many-body calculations. We also show how Majorana-Majorana hybridisation enable arbitrary quantum gates, including the magic-gate.

[1] E. Mascot, T. Hodge, D. Crawford, J. Bedow, D. Morr, S. Rachel, Phys. Rev. Lett. 131 (2023) 176601

TT 85.4 Fri 10:30 H 3005

Poor man's zero modes in hybrid quantum dot devices — •Michael Wimmer, Chun-Xiao Liu, Mert Bozkurt, Sebastian Miles, Francesco Zatelli, Bas ten Haag, and Tom Dvir — QuTech, TU Delft, The Netherlands

We will give an overview of different types of Majorana zero modes that can appear in two quantum dots with tunable normal and superconducting couplings. In particular, we will discuss how their properties can be understood from the charge stability diagram, and how to identify them in transport properties. Finally, we will comment on the scaling to longer chains.

TT 85.5 Fri 10:45 H 3005

Protection of poor man's Majorana bound states in larger systems — •Viktor Svensson and Martin Leijnse — NanoLund and Solid State Physics, Lund University, Sweden

Majorana zero modes exhibit non-abelian properties that would be useful for quantum computation. In large systems the Majoranas can be well separated and thereby topologically protected, but this is difficult to realize experimentally. Small systems may be simpler to build, but as the Majoranas are closer together they are less robust. In a model with interacting quantum dots, we study how the protection of the Majorana bound states changes as the size of the system is varied.

TT 85.6 Fri 11:00 H 3005

Machine-learned tuning of artificial Kitaev chains to Majorana sweet spots — •Jacob Benestad[1], Athanasios Tsintzis[2], Rubén Seoane Souto[3], Martin Leijnse[2], and Jeroen Danon[1] — [1]Center for Quantum Spintronics, Norwegian University of Science and Technology — [2]Division of Solid State Physics and NanoLund, Lund University — [3]Instituto de Ciencia de Materiales de Madrid, Spanish Research Council

Artificial Kitaev chains have been proposed as a platform realising so-called "poor man's Majorana bound states" (PMMs), lacking the topological protection of genuine Majorana bound states but still retaining non-abelian properties. These PMMs are found at discrete "sweet spots" for the Hamiltonian parameters, and the challenge in an experimental setting would be to tune the system to such a sweet spot. A recent proposal for how to experimentally probe the quality of sweet spots in artificial Kitaev chains [1] opens the door for auto-tuning of such systems. We investigate the use of Machine Learning based on an evolutionary strategy to automatically tune the Hamiltonian parameters to a sweet spot that could host PMMs.

[1] Souto et al., Phys. Rev. Research 5 (2023) 043182

TT 85.7 Fri 11:15 H 3005

Exploration of topological states and multiple gaps in MgB_2 superconductors — •Nora Kucska[1], Andras Laszloffy[1], Laszlo Szunyogh[2], and Balazs Ujfalussy[1] — [1]HUN-REN Wigner Research Centre for Physics, Budapest, Hungary — [2]Budapest University of Technology and Economics, Budapest, Hungary

Unfortunately, most known topological superconductors possess low transition temperatures, impeding the experimental observation of Majorana fermions. MgB_2, a widely recognized high-temperature superconductor would consequently be an ideal subject to study due to the suspected topological properties of its band structure. This gives light to its intriguing quantum phase characterized by protected gapless surface/edge states within a bulk superconducting gap, possibly hosting Majorana fermions.

Using fully relativistic first-principles calculations, a Dirac-nodal line structure is investigated through the bulk and surface band structure of MgB_2. Adding magnetic impurities to the surface, the interaction between the topological system with the impurities is explored.

MgB_2 is also known for having multiple gaps in the superconducting state. Numerous experimental and theoretical studies find either one or two distinct gaps in the density of states, while a third gap was found in thin films of MgB_2 and by theoretical non-relativistic ab initio calculations. The multiple gap structure of MgB_2 was analyzed giving more insights on the topic. We study the so-called Yu-Shiba-Rusinov states in the context of this multi gapped superconductor.