Superconducting states in nanostructures for quantum technologies

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The ongoing second quantum revolution holds promise for significant technological advancements in the future. Quantum computers are at the forefront of this revolutionary technology, as they possess the potential to solve problems that are currently intractable for classical computers. Superconductors play a crucial role in this context due to their macroscopic quantum properties and long coherence times. However, to achieve functional quantum devices, it is imperative to shrink the size of qubits while improving their coherent properties.

This proposed master's thesis project will focus on quantum dot systems coupled via nanoscale superconductors as a base for future quantum devices. This system has gained a lot of interest recently, with the aim of engineering Majorana states in artificial Kitaev chains [1,2]. Our primary objective is to gain a deeper understanding of the properties of these systems and analyze the bound states that form. We will extend the original geometry, see the Figure below, to additional quantum dots with the aim of engineering bound states that can store quantum information in a robust way, thereby contributing to the development of future technologies.

Methodology:

The central aim of this master's thesis project is to investigate the properties of quantum dot systems coupled to nanoscale superconductors. To achieve these objectives, the research will employ a combination of theoretical modelling and numerical simulations of superconducting systems. The models will include the competition between superconductivity and charging effects in the quantum dots. The proposed methods will help at identifying and characterizing parameter regimens with improved properties for quantum information processing and the engineering of topological states. Coherent properties of the system may be tested using master equations techniques.

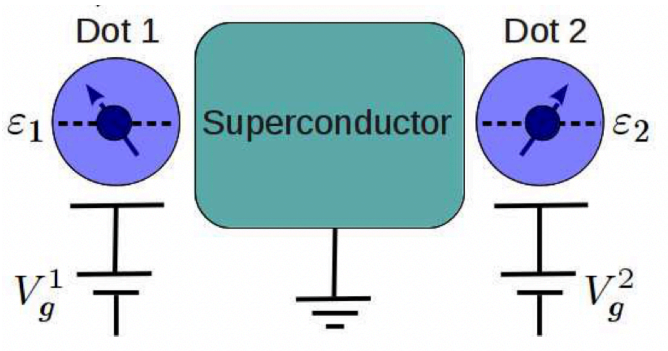

Figure 1: Simple setup used for a minimal Kitaev chain, where two quantum dots (blue) couple via a grounded superconductor (green). Figure adapted from Ref. [1]. This setup has been recently realized and measure, see Ref. [2]. In the proposed thesis, the student will generalize the geometry to additional dots, relevant for ongoing experiments.

[1] M. Leijnse et al. Phys. Rev. B **86**, 134528 (2012)

[2] T. Dvir et al. Nature **614**, 445–450 (2023)