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Coulombic subgap states in semiconductor-superconductor nanowires

Juan Carlos Estrada Saldaña[a*], Alexandros Vekris[a,b], Luka Pavesic[c,d], Peter Krogstrup[a,e], Rok Zitko[c,d], Kasper Grove-Rasmussen[a], and Jesper Nygård[a]

a. Center for Quantum Devices, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark
b. Sino-Danish College (SDC), University of Chinese Academy of Sciences
c. Jozef Stefan Institute, Jamova 39, SI-1000 Ljubljana, Slovenia
d. Faculty of Mathematics and Physics, University of Ljubljana, Jadranska 19, SI-1000 Ljubljana, Slovenia
e. Microsoft Quantum Materials Lab Copenhagen, Niels Bohr Institute, University of Copenhagen, 2100 Copenhagen, Denmark

* email : juan.saldana@nbi.ku.dk

Due to Coulomb blockade, charge is quantized and conserved in a superconducting island. The same applies for a quantum dot. When electrons can tunnel between these two objects, the individual conservation of charge in each of them is replaced by a global conservation. The ensuing redistribution of charge in the quantum dot-superconducting island system leads to the emergence of Coulombic subgap states in the superconducting island, a new class of subgap states [1].

Using a semiconductor nanowire hosting an ultrasmall superconducting island, we provide the first set of experimental evidence for the existence of these subgap states [2]. We also report their unusual properties:

1) Broken electron-hole energy symmetry, in contrast to any other type of subgap states such as Majorana, Yu-Shiba-Rusinov and Andreev bound states.

2) Energy discontinuities versus gate voltage, unique of Coulombic states.

3) Multi-degeneracy points, where up to five Coulombic subgap states are degenerate in the ground state.

4) Strongly renormalized g-factors; the measured values are three times below their Hamiltonian values.

The repercussions of the new states for the search of Majorana states in topological superconducting islands will be discussed.

[1] Pavešić, L., Bauernfeind, D., & Žitko, R. (2021). Yu-Shiba-Rusinov states in superconducting islands with finite charging energy. arXiv, 2101.10168.
[2] Estrada Saldaña, J. C., Vekris, A., Pavešić, L., Krogstrup, P., Žitko, R., Grove-Rasmussen, K., Nygård, J. (2021). Bias asymmetric subgap states mimicking Majorana signatures. arXiv, 2101.10794.