Joule heating effects in superconducting InAs nanowire islands

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Mesoscopic superconducting islands in hybrid superconductor-semiconductor nanowires have been intensively studied in the context of topological superconductivity, motivated by their potential for the realization of a topological qubit [1]. Interesting experimental results have been reported in the past years, including a 2e-to-1e transition in the periodicity of Coulomb oscillations and a related dependence with the island length, which has been interpreted in favor of topology and of exponential protection of Majorana zero modes [2-4]. Theoretical work has also put forward proposals for employing islands for realizing a topological quantum computer [1 and hexon]. Heating effects, however, have not been considered in the interpretation of the above experiments, nor has its impact been evaluated in the context of proposals for quantum devices.

In this work, we study Joule heating in devices based on hybrid mesoscopic Al/InAs islands. To this end, we employ a technique that is able to detect the transition of superconducting parts of a hybrid device to the normal state. Owing to the poor thermal conductivity of such devices, a Superconducting to normal phase transitionmanifest as dips in the differential conductance, reflecting the suppression of Andreev excess current [6], which can be detected by employing typical DC measurement schemes. We use this signal as a tool to study the dissipation of heat generated by the Joule effect in mesoscopic islands. Interestingly, we show that the islands undergo a transition to the normal state at relatively low powers - ~100pW, which could reveal som relevant information regarding the dominant heat transport mechanism in the island. We evaluate the impact of Joule heating for typical device operation conditions.

References

[1] D. Aasen, M. Hell, R. V. Mishmash, A. Higginbotham, J. Danon, M. Leijnse, T. S. Jespersen, J. A. Folk, C. M. Marcus, K. Flensberg, J. Alicea, Phys. Rev. X, 6 (2016) 031016.

[2] Whiticar, A.M., Fornieri, A., O'Farrell, E.C.T. *et al*. *Nat Commun* **11**, 3212 (2020).

[3] Alexandros Vekris, Juan Carlos Estrada Saldaña, Thomas Kanne, Thor Hvid-Olsen, Mikelis Marnauza, Dags Olsteins, Matteo M. Wauters, Michele Burrello, Jesper Nygård, and Kasper Grove-Rasmussen
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[4] S. M. Albrecht, A. P. Higginbotham, M. Madsen, F. Kuemmeth, T. S. Jerspersen, J. Nygard, P. Krogstrup, C. M. Marcus, Nature, 531 (2016) 206-209.

[5] Sukumar Rajauria, Hervé Courtois, and Bernard Pannetier, Phys. Rev. B 80, (2009) 214521

[6] M. Tomi, M. R. Samatov, A. S. Vasenko, A. Laitinen, P. Hakonen, D. S. Golubev, arXiv:2106.07503 (2021).