Evidence of helical states in bismuth

S. Guéron,
A. Bernard, M. Bard, Y. Peng, A. Kasumov, R. Deblock, M. Ferrier, F. Fortuna, V. T. Volkov, Yu. A. Kasumov, Y. Oreg, F. von Oppen, H. Bouchiat, S. Guéron

Université Paris Saclay and CNRS, Laboratoire de Physique des Solides, 91405 Orsay

Sophie.gueron@universite-paris-saclay.fr

Bismuth is possibly the first discovered Second-Order Topological Insulator, a relatively new state of matter characterized by topologically protected helical states, i.e counter-propagating 1D states whose spin orientation is locked to the propagation direction. Such states open many possibilities, from dissipationless charge and spin transport to new avenues for quantum computing. Connecting bismuth nanowires to superconducting contacts has revealed the ballistic character of the Andreev Bound States, suggesting topological protection [1,2]. We have also found the tell-tale high frequency signature of protected Andreev level crossings, a peaked absorption at phase pi [3]. More recently, through the statistical distribution of the switching current of a bismuth nanoring Josephson junction, we have determined that pairs relax relatively slowly compared to quasiparticles, an indication that helical states with opposite helicity are physically separated, a key feature of Second-Order Topological Insulators [4]. Finally, I will address the role played by helical states in generating non-reciprocal effects in bismuth, in the form of bilinear magnetoresistance in the normal state and Josephson diode in the superconducting state [5].

References

[1] A. Murani et al, Nature Communications 8, 15941 (2017).
[2] F. Schindler et al, Nature Physics 14, 918–924 (2018).
[3] A. Murani et al, Phys. Rev. Lett. 122, 076802 (2019).
[4] A. Bernard, Y. Peng et al, Nature Physics 19, 358 (2023).
[5] M. Bard, H. Bouchiat et al, in preparation.