



Spectroscopy of bulk and ultrathin NbSe₂ with van-der-Waals tunnel junctions

Hadar Steinberg

Sharply defined topological quantum phase transitions are not limited to states of matter with gapped electronic spectra.

Superconductors of the transition metal dichalcogenide (TMD) family have seen a revival of interest subsequent to developments in device fabrication by mechanical exfoliation. Recent studies¹ show that at the ultrathin limit, NbSe₂ and similar TMDs can sustain superconductivity at very high in-plane magnetic fields, well beyond the Pauli limit². This apparent stability is associated with Ising spin-orbit coupling, which keeps spins oriented out of the sample plane, thereby providing strong protection against depairing. In my talk, I will report our recent spectroscopy measurements of NbSe₂ using vdW tunnel devices³. Our devices are fabricated by placing insulating barriers on top of exfoliated NbSe₂ using the mechanical transfer technique. The resulting tunnel junctions exhibit extremely stable currents, and are characterized by a hard gap. At milli-Kelvin temperatures, the tunneling spectra exhibit a well-resolved separation into a two-gap structure. We show that by applying in-plane magnetic fields to bulk devices (20-50 nm thick), it is possible to distinguish between the kinematics of quasiparticles which belong to different gaps. When probing ultra-thin devices (3-4 layers), we find the larger energy gap to be almost fully protected to depairing, an effect consistent with transport studies. Finally, I will discuss the implications of our technique to vortex-bound state spectroscopy.

1. X. Xi, Z. Wang, W. Zhao, J.-H. Park, K. T. Law, H. Berger, L. Forró, J. Shan & K. F. Mak. Ising pairing in superconducting NbSe₂ atomic layers. *Nature Physics* 12, 139-143 (2016).
2. J. M. Lu, O. Zheliuk, I. Leermakers, N. F. Q. Yuan, U. Zeitler, K. T. Law & J. T. Ye. Evidence for two-dimensional Ising superconductivity in gated MoS₂. *Science* 350, 1353-1357 (2015).
3. T. Dvir, F. Masee, L. Attias, M. Khodas, M. Aprili, C. H. L. Quay & H. Steinberg. Spectroscopy of bulk and few-layer superconducting NbSe₂ with van der Waals tunnel junctions. *Nature Communications* 9, 598 (2018).