Theory of Andreev and noise spectroscopy in the topological superconductor UTe_2

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The superconductor UTe_2 has attracted considerable interest as a leading candidate for materials that host spin-triplet unconventional superconductivity. Several experimental observations support spin-triplet superconductivity, including extremely high upper critical fields in all directions and reentrant superconductivity at high magnetic fields. However, the pairing symmetry suggested by recent experiments remains controversial. For instance, Kerr effect measurements on high-quality samples with $T_{\rm c} = 2.1$ K have shown no evidence of broken time-reversal symmetry [1], while magnetic penetration depth measurements suggest broken time-reversal symmetry [2]. In another instance, thermal conductivity measurements yield conflicting results for the gap symmetries [3]. As a result, the gap symmetry have yet to be determined.

Here, we examine the pairing symmetry and topological superconductivity in UTe_2, focusing on surface bound states [4]. Recently, STM/STS using a superconducting tip has been performed in UTe_2 and a pronounced zero-bias conductance peak has been observed on the naturally cleaved (011) surface [5]. Motivated by this experiment, we have developed the theory for tunneling current between an s-wave superconducting tip and a topological superconducting sample. The tunneling current is primarily governed by Andreev reflection processes, where electrons and holes in the surface bound states of the topological superconductor tunnel into the s-wave superconductor tip and form Cooper pairs, and vice versa. We demonstrate that in the low-bias regime, the dI/dV characteristics are directly determined by the convolution of the sDOS of the superconducting sample. We discuss the possible pairing state in UTe_2 to explain recent STM/STS experiments using an Nb superconducting tip. Moreover, we extend the theory to incorporate noise spectroscopy and demonstrate that the Fano factor can unveil the physical origin of the peak structures in the differential tunneling conductance.

[1] M. O. Ajeesh *et al.*, Phys. Rev. X **13**, 041019 (2023)

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[3] S. Suetsugu *et al.*, Sci. Adv. **10**, eadk3772 (2024); I. M. Hayes *et al.*, Phys. Rev. X **15**, 021029 (2025)

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[5] Q. Gu et al., Science **388**, 938 (2025).