Unconventional charge transport nonreciprocity in the superconductor $ZrTe_3$

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The breaking of inversion and time-reversal symmetries is the basis behind nonreciprocal charge transport, making the electrical resistance dependent on the relative orientation between charge current and magnetic field [1]. In the past years, two-dimensional (2D) superconductors have emerged as an excellent platform for exploring this nonreciprocity [2, 3]. Near the superconducting state, the nonreciprocal signals are substantially enhanced, and the nonreciprocal transport appears due to the chirality of the supercurrent or of the Cooper pairs. Recently, this nonreciprocal transport has also been observed in the centrosymmetric CsV_3Sb_5 [4], where it was proposed that the nonreciprocity arises due to the symmetry breaking of an unconventional superconducting order parameter.

Here, we investigate the nonreciprocal transport of $ZrTe_3$, a centrosymmetric van der Waals material which displays a charge-density wave phase and superconductivity. We mechanically exfoliate $ZrTe_3$ into nanowires that become superconducting at ~3.5 K, and perform second harmonic resistance measurements close to its critical temperature. The second harmonic magnetoresistance is made up of several antisymmetric peaks with respect to the magnetic field. The magnitude and sign of the peaks are controlled by the applied current, which is indicative of a tuneable rectification effect. Moreover, a previously unexplored symmetric component that persists at zero magnetic field is also detected in the second harmonic magnetoresistance. This nonreciprocal transport is observed with an out of plane magnetic field as well as with in-plane magnetic fields, both perpendicular and parallel to the current. These results demonstrate that even without inversion symmetry breaking, a wide range of nonreciprocal effects are present in 2D superconductors, paving the way for potential applications in photodetectors, antennas, and rectifier devices [5].

References

[1] Rikken, G. L. J. A., & Raupach, E. Nature, 390, 6659 (1997) 493-494
[2] Wakatsuki, R., et al. Science advances, 3, 4 (2017) e1602390
[3] Zhang, E., et al. Nature communications, 11, 1 (2020) 5634
[4] Wu, Y., et al. npj Quantum Materials, 7, 1 (2022) 105
[5] Isobe, H., Xu, S. Y., & Fu, L. Science advances, 6, 13 (2020) eaay2497.