Magnetometer based on superconducting diode in few layer $NbSe_2$

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Abstract

Magnetometers are essential tools for measuring magnetic fields across various domains, from fundamental physics to medical imaging. [1] However, achieving high sensitivity typically necessitates sophisticated architectures, such as SQUID loops, or ultra-clean materials, which complicates fabrication and limits spatial applications. [2] In this work, we demonstrate a novel, loop-less magnetometer based on the superconducting diode effect (SDE) in few-layer $NbSe_2$. [3] By utilizing deep reactive-ion etching to pattern one edge of the flake into a saw-tooth shape, we successfully break the inversion symmetry. Combined with the broken time-reversal symmetry induced by an external magnetic field, this generates a robust non-reciprocal superconducting transport. Our fabricated device exhibits a field sensitivity of 5.2 $\mu T/\sqrt{Hz}$ at 1.5 K. Furthermore, our theoretical model reveals that the field sensitivity diverges at zero field, indicating an extremely high sensitivity in this regime. Notably, this robust performance is intrinsically dominated by the material's geometry and London penetration depth, making it largely independent of local defects or sample degradation. We demonstrated the practical effectiveness of this highly compact sensor by successfully measuring the hysteresis loop, residual magnetization, and the Curie temperature (~7 K) of a proximal ferromagnet. This approach offers a straightforward fabrication process without complex interfacial engineering, a simple DC/AC measurement scheme, and an ultra-compact sensing volume, paving the way for next-generation, highly robust nanoscale magnetometry.

References

[1] Aharon-Steinberg, A. et al. Nature(2022)607, 74-80.
[2] Ando, F. et al. Nature (2020)584, 373-376.
[3] F. Gaggioli et al., Physical Review Research, 6 (2024) 023190.

Figures

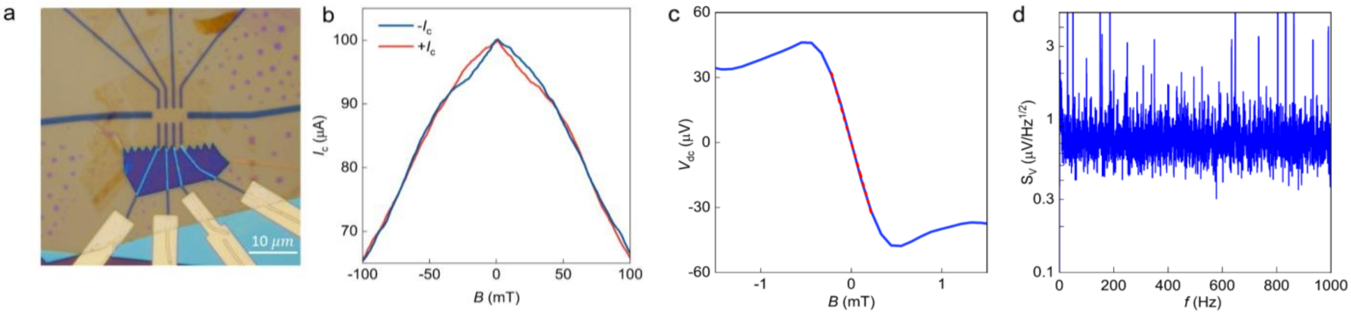

Figure a: An optical image of few layers $NbSe_2$ device with saw-tooth edge. Figure b: Magnetic field dependence of critical current for positive direction (red line) and negative direction (blue line). Figure c: The dependence of Vdc on magnetic field for one superconducting diode. Figure d: the noise spectrum of voltage.