Zero-field superconducting diode effect in small-twist-angle trilayer graphene

Jiang-Xiazi Lin,[1*] Phum Siriviboon,[1*] Harley D. Scammell,[2] Song Liu,[3] Daniel Rhodes,[3] K. Watanabe,[4] T. Taniguchi,[5] James Hone,[3] Mathias S. Scheurer,[6] and J.I.A. Li [1]

[1]*Department of Physics, Brown University, Providence, RI 02912, USA*
[2]*School of Physics, the University of New South Wales, Sydney, NSW, 2052 Australia*
[3]*Department of Mechanical Engineering, Columbia University, New York, NY 10027, USA*
[4]*Research Center for Functional Materials, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan*
[5]*International Center for Materials Nanoarchitectonics, National Institute for Materials Science, 1-1 Namiki, Tsukuba 305-0044, Japan*
[6]*Institute for Theoretical Physics, University of Innsbruck, Innsbruck, A-6020, Austria and*
[*]*These authors contributed equally in this work.*

Graphene moire systems turned out to host a variety of fascinating emergent phenomena due to its strong electron correlation nature, including spontaneous spin and valley symmetry breaking, quantum anomalous Hall effect, and superconducting behaviors that do not fall under the conventional BCS descriptions. These phenomena and the complicating interplay between them triggered intense interest and are still under vast investigation.

In this work, we study a twist trilayer graphene device with twist angle detuned from the 'magic angle'. Superconductivity persists in this small angle regime. Strikingly, here the superconductivity shows a non-reciprocal I-V character even without an external magnetic field, or in other words, a zero-field 'superconducting diode' effect.[1] This effect demonstrates that both inversion and time-reversal symmetries are spontaneously broken in the superconducting state.

To address this observation, we provide a hypothesis involving the imbalanced valley degree of freedom, which is unique to the small twist angle regime. This hypothesis is also consistent with our observation that at this small twist angle regime, long-range density wave states dominate over correlated insulator states at integer fillings.

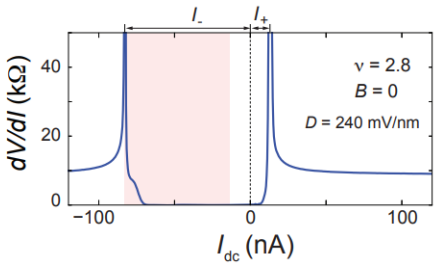

FIG. 1. Zero-field superconducting diode effect in small-twist-angle trilayer graphene.

[1] Jiang-Xiazi Lin, et al. arXiv:2112.07841 (2021)