Probing Quantum Materials with Superconducting Quantum Technology

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Achieving scalable, fault-tolerant quantum computing demands a deep synergy between material science, device fabrication, electrical engineering, and fundamental physics. In this context, van der Waals (vdW) materials—spanning semimetals, insulators, semiconductors, ferromagnets, superconductors, and topological insulators—offer a compelling platform for next-generation quantum devices. The ability to assemble vdW heterostructures with atomic precision opens new opportunities for integrating these materials into superconducting circuits, enhancing qubit control, reducing device footprints, and suppressing unwanted couplings. Conversely, superconducting quantum circuits and cQED techniques provide a powerful toolset for probing the exotic physics of quantum materials, complementing traditional transport measurements.

In this talk, I will discuss the integration of vdW materials into superconducting quantum circuits and their potential for quantum technologies. I will highlight our recent studies on the kinetic inductance of 2D superconductors, including magic-angle twisted bilayer graphene (MATBG) and $NbSe_2$. Leveraging cQED techniques, we have uncovered key insights into pairing symmetry and the role of quantum geometry in flat-band superconductors. We have also demonstrated vdW superconductors with record-high sheet kinetic inductance in the clean limit, positioning them as promising candidates for high-coherence, lump-element devices for superconducting quantum circuits.

References

[1] M. Tanaka, J. Î-j. Wang, et al., Nature, 638 (2025) 99-105

[2] J. Î-j. Wang, M. Yamoa, et al., Nature Materials, 21 (2022) 398-403

[3] J. Î-j. Wang, Rodan-Legrain, et al., Nature Nanotechnology, 14 (2019) 120-125

Figures

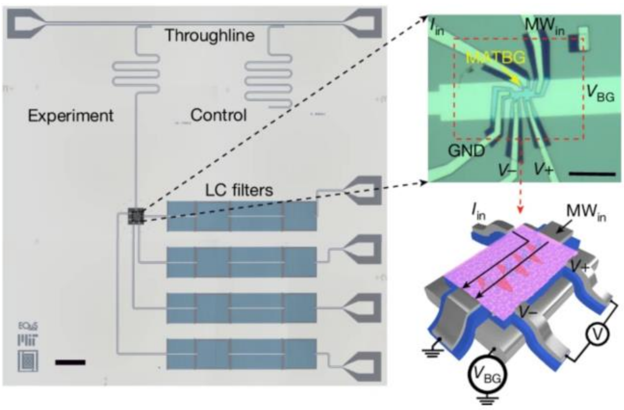

Figure 1: A superconducting microwave circuit designed for both AC and DC characterizations of van der Waals (vdW) superconductors [1].