

Manipulating Interlayer Coupling and Quantum States in Graphene Devices

Dong-Keun Ki^{1,2,3}

¹*Department of Physics, The University of Hong Kong, Pokfulam Road, Hong Kong, China*

²*HK Institute of Quantum Science & Technology, The University of Hong Kong, Pokfulam Road, Hong Kong, China*

³*State Key Laboratory of Optical Quantum Materials, The University of Hong Kong, Pokfulam Road, Hong Kong, China*

The atomically thin structure of graphene makes it a powerful platform for controlling quantum transport. In this talk, I will outline our recent work on dual-gated twisted bilayer graphene, both with and without ultra-thin, tunable hBN spacers, which provides near-atomic control of interlayer coupling and enables moiré band engineering. I will then discuss how cavity-coupled graphene (arXiv:2506.21409) and dielectric engineering can be used to tailor disorder and the electromagnetic environment, offering additional handles to tune electronic properties. Finally, I will describe how van der Waals (vdW) heterostructures with semiconducting transition metal dichalcogenides [Nat. Commun. **14**, 6124 (2023)] and 2D magnetic materials introduce spin-orbit and magnetic effects into graphene while preserving its excellent transport properties. Together, these approaches demonstrate that vdW heterostructures enable fine control over interlayer, spin-orbit, and magnetic couplings, as well as the surrounding electromagnetic landscape, opening routes to new quantum phenomena in graphene-based systems. Financial support from the UGC/RGC of Hong Kong SAR (AoE/P-701/20, 17309722, 17301424, and 17300725) and the State Key Laboratory of Optical Quantum Materials is gratefully acknowledged.