第 568 回物性セミナー

Correlated electrons in tunable domain-wall networks of moiré bilayers

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場　所　先端科学総合研究棟 302S

In this seminar, I will discuss our recent investigation on domain wall networks in moiré bilayer systems under an interlayer bias (Fig. 1). I will first present our recent development of a bosonized model for the correlated domain wall network [1,2]. In this framework, we show that the strength of electron-electron interactions can be tuned by adjusting the interlayer bias, modifying the screening length, and selecting different dielectric materials [1]. Furthermore, by incorporating electron-phonon coupling, we construct phase diagrams (Fig. 2) based on correlation functions, which reveal a variety of exotic electronic orders, including density waves and superconductivity, with electrically tunable phase transitions.

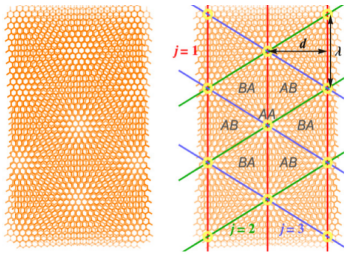

Fig. 1. Moiré pattern formed by AB- and BA-stacking domains and domain wall network in twisted bilayer moiré systems. These domain walls can host a network of gapless electron modes.

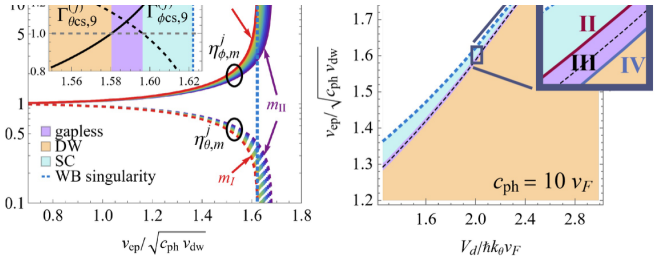

Fig. 2. Left: Scaling exponents of density and current operators, as a function of electron-phonon coupling $v_{\rm ep}$; the two characterize density wave (DW) and superconducting (SC) instabilities, respectively. Right: Phase diagram for the interlayer bias V_d and $v_{\rm ep}$.

In addition, I will discuss general scattering operators that characterize different scattering processes within the network. Here, we identify processes that generate gapped bulk states with gapless edge modes [2], giving rise to (fractional) quantum anomalous Hall states. We predict spectroscopic and transport signatures that should be observable in these states. Moreover, our network models integrate concepts from the quantum Hall effect [3], the quantum anomalous Hall effect [2], and the quantum spin Hall effect [4], highlighting their broad applicability to topological and correlated electronic states.

Finally, if time permits, I will discuss the formation of a two-dimensional spin helix in the domain wall network in the presence of magnetic adatoms [5]. By tuning system parameters, we find that the system exhibits a magnon-induced singularity with potentially observable features. Overall, these results highlight the moiré domain wall network as a novel platform for realizing exotic electronic orders.

[1] Hao-Chien Wang and Chen-Hsuan Hsu, 2D Mater. **11**, 035007 (2024).
[2] Chen-Hsuan Hsu, Daniel Loss, and Jelena Klinovaja, Phys. Rev. B **108**, L121409 (2023).
[3] Charles L. Kane et al., Phys. Rev. Lett. **88**, 036401 (2002).
[4] Jelena Klinovaja and Yarolav Tserkovnyak, Phys. Rev. B **90**, 115426 (2014).
[5] Yung-Yeh Chang, Kazuma Saito, and Chen-Hsuan Hsu, arXiv:2412.14065.

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