The nonlinear Hall effect in two-dimensional superlattices

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The recently discovered nonlinear Hall effect (NHE) in a few non-interacting systems provides a novel mechanism to generate second harmonic electrical Hall signals under time-reversal-symmetric conditions. Here, we introduce a new approach to engineering NHE by using twisted moiré structures. We will first show that the twisted bilayer WSe_2 exhibits a NHE when tuning the Fermi level to the moiré flat bands. Near half-filling of the first hole moiré band, the nonlinear Hall signal shows a sharp peak with the generation efficiency at least two orders of magnitude larger than those in previous experiments. We propose that the giant NHE and diverging generation efficiency originate from a mass-diverging type continuous Mott transition, which is evidenced by resistivity measurements. Though the observation of quantum anomalous Hall effect and nonlocal transport response reveals nontrivial band topology governed by the Berry curvature in twisted bilayer graphene, some recent works reported nonlinear Hall signals in graphene superlattices which are caused by the extrinsic disorder scattering rather than the intrinsic Berry curvature dipole. Here, we will also show that the Berry curvature dipole could play a dominant role in generating the nonlinear Hall signal in high-quality graphene superlattices. We will demonstrate that the application of the displacement field substantially changes the direction and amplitude of the nonlinear Hall voltages in twisted bilayer graphene devices, along with a field-induced sliding of the Berry curvature hotspots.

References

[1] M Huang, Z Wu, Ning Wang, et al. National Science Review, 4 (2023) nwac232.
[2] M Huang, Z Wu, Ning Wang, et al. ArXiv preprint (2022) arXiv:2212.12666.

Figures

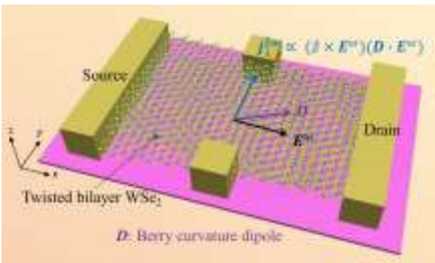

Figure 1: Schematic of the two-dimensional superlattice nonlinear Hall device.

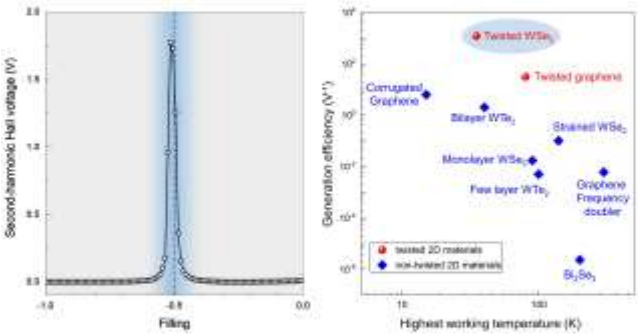

Figure 2: Giant nonlinear signal observed in two-dimensional superlattices.