Nonlinear Valley Hall Effect [1]

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Abstract :

The valleys are degenerate energy extrema of the electronic bands in momentum space. Control and manipulation of valley degree of freedom gave birth to the field of Valleytronics. In an inversion symmetry broken system, the valley contrasting Berry curvature (BC) pushes charge carriers of opposite valleys in opposite transverse directions generating pure valley current. This effect is coined as the linear Valley Hall effect (VHE) [2]. VHE is generally associated with the Orbital Hall effect since the polarized orbital magnetic moment (OMM) also travels with charge carriers and accumulates at opposite edges of the sample. However, the BC vanishes identically in systems preserving both fundamental symmetries, i.e., time reversal (T) and space inversion (P). This raises a fundamental question: How can we probe and manipulate the valley degree of freedom in nonmagnetic and inversion symmetric materials by electrical means? Our paper demonstrates that materials with both fundamental symmetries can exhibit a finite nonlinear valley Hall effect (NVHE), provided their band dispersion is anisotropic and valley contrasting. The origin of this NVHE is attributed to the Berry connection polarizability tensor. In this article, we also point out the subtle differences between the VHE and NVHE: i) in contrast to VHE, the NVHE does not have any disorder-induced extrinsic contributions, ii) the carriers from a single valley can move in either direction; however, the anisotropic Fermi velocity prefers one over another, iii) the electric field induces a correction to the intrinsic OMM (which is zero in P and T symmetric systems), which possess both positive and negative value across a valley but the total OMM (vanishes if tilt is zero) shows valley contrasting features. Hence, NVHE also accumulates opposite OMM at the transverse edges of the system. We have demonstrated our predictions in **strained graphene** and organic conductor through explicit tight-binding calculations. Experimentally one can probe the NVHE via non-local resistance measurement.

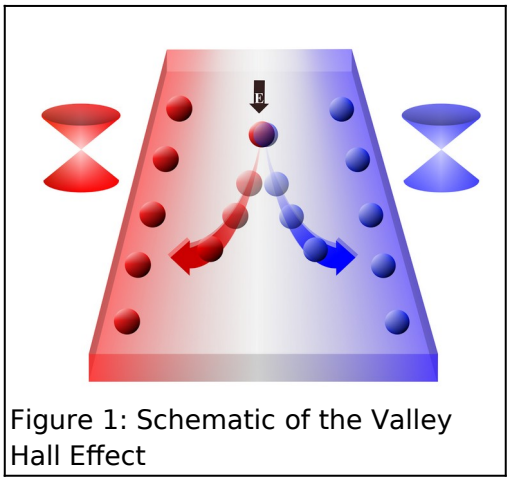

Figure 1: Schematic of the Valley Hall Effect

References :

[1] Kamal Das, **Koushik Ghorai**, Dimitrie Culcer, and Amit Agarwal, Phys. Rev. Lett. 132, 096302 (2024)

[2] Di Xiao, Wang Yao, and Qian Niu, Phys. Rev. Lett. **99**, 236809 (2007