Valley-dependent electron optics in bilayer graphene

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Abstract
We introduce electrostatically defined quantum dots (QDs) in bilayer graphene for valley-dependent electron optics, advancing valleytronics through controllable scattering mechanisms. Valleytronics exploits the valley degree of freedom in materials with two inequivalent energy extrema, offering a platform for next-generation electronic devices. Building on tunable dot platforms in monolayer graphene [1], we consider QDs in bilayer graphene oppositely gated in the two layers, creating a layer-asymmetric landscape that induces valley-dependent properties. When an electron beam is incident, strongly valley-resolved scattering responses emerge. Our approach combines analytical modeling and numerical simulations to predict how electrons from different valleys interact with the QDs. A four-band Dirac model describes the bilayer system, while a generalized Mie theory captures multi-dot scattering processes. We analyze the resulting scattering patterns and valley-polarized current distributions for various dot arrangements. A key feature of this platform is its ability to generate distinct angular currents for the two valleys, enabling a control of valley-polarized flows. By adjusting dot arrangements, switching individual dots on or off, or flipping their potential in situ, operational scenarios such as angular separation, valley splitting, valley-selective beam steering, and nearly pure valley filtering can be achieved. These results demonstrate an efficient and tunable route for controlling valley currents, highlighting the potential of oppositely gated QDs in bilayer graphene for future valleytronic and valley-based electron-optic devices.

Reference

[1] Ildarabadi, F., & Power, S. R., *ACS Applied Electronic Materials*, 7(23) (2025) 10631–10637.

Figures

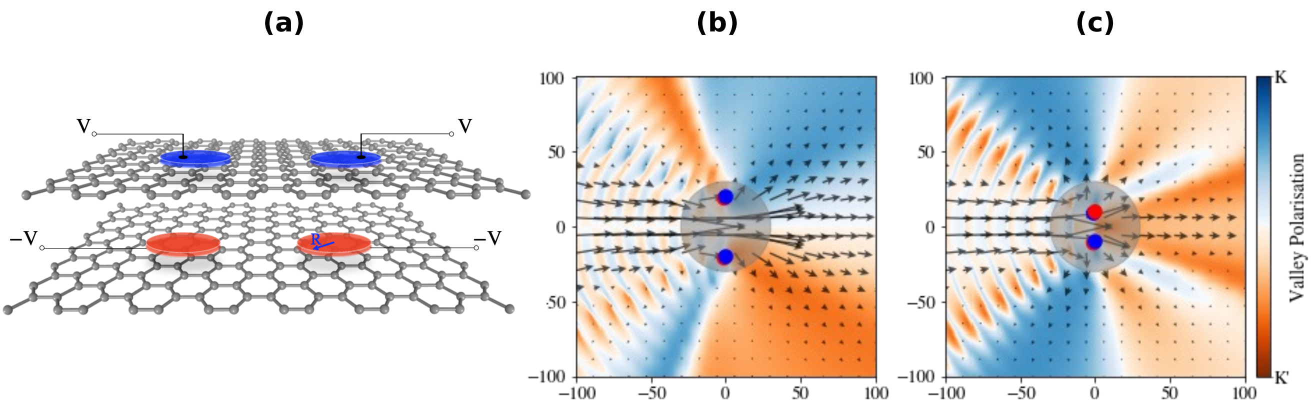

Figure 1: (a) Schematic of two oppositely gated QDs in bilayer graphene. (b, c) Total electron current flow (arrows) and valley polarization (color map) for a two-dot system. (b) Valley splitting is observed when the two QDs have identical potentials, resulting in spatial separation of currents from the K and K′ valleys. (c) Selective filtering of the K valley is achieved by oppositely gating the two QDs, where electrons from the K’ valley are preferentially transmitted.