Electrically Tunable Excitons and Biexcitons in Gated Bilayer Graphene Quantum Dots with Trigonal Warping

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Bilayer graphene (BLG) is a semiconductor with an electrically tunable bandgap [1-4]. When lateral gates are applied, a quantum dot (QD) that confines both electrons and holes emerges [5-7]. We show the effects of a lateral confining potential and trigonal warping (TW) on the electronic structure, and the effects of electron-electron interactions on the optical properties of laterally gated BLG QDs. Employing an atomistic tight-binding model for millions of atoms, we compute the single-particle QD states and analyze the influence of TW on the energy spectrum as the confining potential depth varies, as seen in Fig.1. We find a regime where the QD conduction and valence band levels are dominated by the presence of three minivalleys for each *K*-valley.

Next, we compute dipole matrix elements and analyze the oscillator strengths and optical selection rules. We then include electron-electron interactions by computing the microscopic Coulomb matrix elements and solving the Bethe-Salpeter equation to obtain the excitonic spectrum [3,5,6]. Subsequently, we obtain the absorption spectrum for a shallow confining potential depth, which further amplifies the effects of TW on the optical properties. Our results predict the existence of two degenerate bright exciton states, each built of the three minivalley states. We predict the evolution of the QD energy levels and the exciton spectrum as a function of the confining potential depth and radius of the dot.

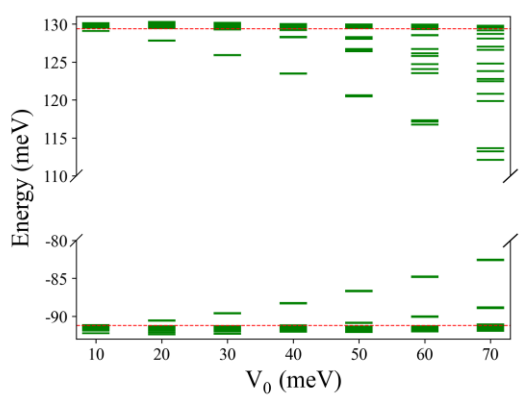

Fig.1. QD energy spectrum of the gated BLG QD as a function of the confining potential depth for a QD radius of 20 nm and an applied vertical potential difference of 380 meV.

Finally, we predict the biexciton spectrum using the configuration-interaction approach. We analyze the effect of exciton-exciton interactions, including the effect of electrons and holes distribution on the two graphene layers, biexciton-exciton cascade for entangled photon pair generation, and biexciton-exciton decay via Auger processes [8,9]. Understanding interacting electrons and holes in gated BLG QDs has potential for various applications in storage, detection [6], and manipulation of photons in the THz energy range.

References

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