Theory of excitons, biexcitons, and trions confined in a gated bilayer graphene quantum dot

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There is currently interest in quantum dots (QDs) as building blocks of quantum circuits and nanophotonic devices. Following the development of QDs based on semiconducting materials, a new class of two-dimensional (2D) semiconductors was developed based on 2D materials, including bilayer graphene (BLG) [1-4]. In the BLG, an energy gap opens by applying a vertical electric displacement field, paving the way towards lateral electrical confinement of carriers. The energy gap can be tuned electrically in the terahertz to far infrared (FIR) range [2, 4]. Moreover, unlike in laterally gated semiconductor QDs, attracting only one carrier type and repelling another, in a BLG QD it is possible to confine electrically both electrons and holes [2, 4].

Here we present a theory of electronic and optical properties of an exciton, a biexciton, and a trion confined in a BLG QD [2, 4, 5]. We utilize the atomistic tight-binding approach to compute the single-particle energies and wave functions of quasiparticles confined in a BLG QD consisting of ~1.6 million atoms, followed by the microscopic calculation of Coulomb and dipole matrix elements. This allows us to formulate a Hamiltonian of interacting quasiparticles accounting for the BLG valleys, trigonal warping, and details of the displacement and lateral confinement potentials on equal footing.

We consider a strongly interacting exciton X, a biexciton XX, and a negatively charged trion X- confined in the BLG QD by solving the Bethe-Salpeter equation [2, 4, 5]. We find their energies to be tunable by voltage from the terahertz to FIR range. The conservation of spin, valley, and orbital angular momentum results in an X, XX, and X- fine structure with a band of dark low-energy states, making this system a promising candidate for constructing nanodevices for storage, emission and detection of photons in the terahertz range.

References

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