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Abstract

Quasistatic and Quantum-Adiabatic Otto Engine for a Two-Dimensional Material: The Case of a Graphene Quantum Dot †

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The concept of quantum heat engines (QHEs) was introduced by Scovil and Schultz-Dubois in Ref. [1], in which they demonstrate that a three-level energy maser can be described as a heat engine operating under a Carnot cycle. This important research gave way to the study of quantum systems implemented as the working substances of heat machines with the goal of realizing efficient nanoscale devices. These devices are characterized by the structure of their working substance, the thermodynamic cycle of operation, and the dynamics that govern the cycle [2,3]. In this study, we analyze the performance of a quasi-static and quantum-adiabatic magnetic Otto cycle for a two-dimensional material: the case of a graphene quantum dot [4]. For graphene quantum dots [5,6], the low-energy approach using the Dirac equation with boundary conditions is an excellent approximation. Modulating an external/perpendicular magnetic field, in the quasistatic approach, we found behaviors in the total work extracted that are not present in the quantum-adiabatic formulation. Additionally, we find that, in the quasi-static approach, the engine yielded a higher performance in terms of total work extracted and efficiency as compared with its quantum-adiabatic counterpart. In the quasi-static case, this is due to the working substance being in thermal equilibrium at each point of the cycle, maximizing the energy extracted in the adiabatic strokes.

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