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Photoelectronic Transport In Semiconductor Quantum Dots

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Extended Abstract

Current technology relies on the transistor, whose role is crucial for the fabrication of devices such as processors and memory units. Moore's Law states that the number of transistors would double every two years [1], increasing current density and resulting in higher temperatures, which impact energy efficiency [2]. As transistors shrink to sizes on the nanometer scale, quantum effects begin to influence their operation, affecting transport properties and leading to performance alterations. Therefore, it becomes essential to study, both theoretically and experimentally, systems that harness the quantum states of matter for technological applications.

This project focuses on studying electron transport at a quantum dot (QD), considering the interaction with a polarization photon 1 (left circular polarization) within a quantum electrodynamics cavity (QED). The QD is connected to two metallic contacts, and its behavior is analyzed using two Hamiltonians: the Jaynes-Cummings one [3] , which describes the interaction between the QD and the photon, and the Tigh Binding [4] , which describes the coupling of QD electrons with contacts.

A toy model describes the electrons in contact (an effective level without Coulomb repulsion between electrons) and we focus on the subspace of total angular momentum 3/2. Using symmetries, the Hamiltonian can be reduced to a 6X6 matrix, which is diagonalized for different values of the QD energy (varied by an external voltage) thereby we get the spectrum of energies of the system [4] . This spectrum is compared with the system solution without metal contacts, and without light interaction, to analyze the relevance of these interactions in the system. Load fluctuation zones on the QD are of vital importance for transportation from one contact to another to be feasible.

From the comparison of energy spectra, three charge fluctuation points are identified at 0, 0.5, and 2.0 eV, corresponding to the electron energy values within the system. In these regions of interest, the transition probability of the system is analyzed, revealing that the system's conductance is significantly affected by the incidence of a photon, leading to an increase in the transition probability frequency. This suggests that state transitions can occur more rapidly compared to a system where photon incidence is not considered. Although the transition frequency increases due to this coupling, the transition probability tends not to reach its maximum value. This is because the coupling with light alters the state energies, creating gaps that modify the transport conditions and the overall conductance of the system.

References

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