Heat Flow Calculation through FM-DQDs-FM System: Strong Coupling Regime

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Abstract. In this paper, we concentrate on the low-temperature domain to analyze and compute the heat current via a device with double quantum dots sandwiched between two ferromagnetic electrodes (FM-DQDs-FM), in the situation of an antiparallel magnetic arrangement. Non-equilibrium Greene's functions in a linear response regime were used to perform the research. By taking into account all the system-influencing coefficients, including the coupling between paired quantum dots and electrodes, the spin exchange interaction, the intra-dot Coulomb correlation energy, and spin-polarization on electrodes, our calculations were carried out in the strong inter-dot coupling regime. These findings were examined in relation to the temperature gradient and the effective energy levels of the quantum dots. No new changeable physical characteristics were produced when the spin-polarization was increased. According to our calculations, the spin exchange interaction had a ferromagnetic character when it was equal to 0 and 0.3 eV. These findings could pave the way for developing spin caloritronic and thermodynamic nanostructures.

Keywords: Double quantum dots, Heat current, Strong coupling regime, Temperature gradient, Spin exchange interaction

INTRODUCTION

The passage of electrons across ever-shrinking structures has been made easier recently because of developments in nano-creation processes. Electronics with sub-micron and nanoscale dimensions (mesoscopic systems) could be more rapid and less expensive than devices with a traditional macroscale design. Quantum transfer of charge and energy are two fundamental processes in mesoscopic systems [1–3]. The Wiedemann-Franz law states that heat transfer and charge transport occur more often [4,5]. But they have never been treated equally in the literature on mesoscopic physics. Charge transport has received greater attention recently [6–8] compared to energy transfer, which is more difficult to quantify both theoretically and practically. When a substantial amount of heat accumulates, the performance and stability of electrical equipment may be compromised. As a result, heat generation has emerged as a significant barrier in highly interconnected electronic systems. Numerous studies have been conducted on the creation, conversion, storage, and transit of heat in nano-devices [9]. The rules controlling heat generation are better understood as a result of such scientific research, which also makes it simpler to create energy-efficient electrical components.

The thermoelectric effect, which allows energy to be converted into heat and vice versa, may be used to collect waste heat and convert it into useable electric power [10]. For thermoelectric devices to function well, charge and heat conduction must be precisely controlled [11–14]. With an understanding of mesoscopic physics, it is possible to employ charge and heat transfer in ways that were previously unimaginable. The next generation of highly integrated electronic systems may be able to reduce heat emission thanks to spintronics, a promising new field of study. However, heat flow cannot be detected because spintronic devices are unable to produce electricity and because it is difficult to detect even the smallest temperature changes in such nano-structures. Research on thermal energy is expanding, also thermal and electrical transport connections are significant [15–17]. Heat without charge transport effects is demonstrated by energy harvesting throughout quantum dots [18,19] and rectification [20,21]. It is beneficial to work on creating (molecular) quantum dots with excellent thermal connections for electrodes or another heat source for electrical purposes. However, maintaining the strong temperature gradient required to produce large temperature variations through nano-scale connections may be difficult. To lessen the temperature differential across the quantum dot junction, several sequentially linked quantum dots must be considered. Changing the positions of the energy levels in an active region may generally be used to modify the transport properties of quantum dots junctions and other comparable systems [22,23]. Two closed quantum dots coupled to right and left reservoirs running at various temperatures makes up a typical apparatus for testing heat transfer capabilities.

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