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ORIGINAL PAPER

Heat current rectification in a single quantum dot system with the presence and absence of the magnetic field

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Abstract: In this paper, heat current through a single-level quantum dot between two non-magnetic leads has been studied. The system is in non-equilibrium caused by different temperatures at leads. The Anderson model is used to model quantum dot with a single spin-degenerated level. The equations of the energy levels and their occupation of the quantum dot are solved self-consistently; then the heat current is calculated as a function of temperature difference with the effect of the magnetic field. According to my study, four parameters must be tuned to realize heat current rectification. These parameters are: the magnetic field, the Coulomb correlation, the coupling with the leads, and the lower level with the spin σ is blocked, while the upper one with spin σ must be opened.

Keywords: Anderson model; Quantum dot; Thermoelectric effect; Magnetic field

1. Introduction

Transport in the presence of electrical and thermal gradients is well studied in bulk systems [1]. Presently, the transport properties through quantum dots (QDs) devices become possible to explore the thermoelectric effects in nanostructured system [2, 3]. In the Coulomb blockade regime, transport properties of the QDs systems include current rectification [2, 4–6], where thermal rectification is one of the most important thermal properties [7]. Thermoelectric properties are affected by quantization of the energy levels as well as charging energy; also they are more sensitive to the electronic structures details [8]. To understand the mechanisms that cause thermal rectification, many experimental and theoretical studies for several systems have been performed [9–11]. The thermal rectification under some conditions in the semiconductor QD system with two states was reported experimentally in 2008 by Scheibner et al. [12], where the states with high orbital momentum tuned by the high in-plane magnetic field to achieve asymmetric couplings, which modifies the charge transport and the thermal properties. These experimental results are very beneficial since the rectifier is performed only without the phonon system (i.e., the quantum dot directly controls the heat transfer in the electronic device). This leads to more advanced electronic devices with high rectifying efficiency. By stimulating this experimental study, a theoretical study was performed by Chen et al.[13] for the heat transport through a quantum dot with two-level asymmetrically coupling with leads at different temperatures, since they examined the causes and conditions that result in thermal rectification. These calculations were in agreement with the experimental investigation of Scheibner et al. [12], since they showed that the coupling strength and the strong Coulomb interaction are necessary for thermal rectification to be occurred. Also, the experimental study [12] encouraged David M.T et al. to examine whether the quantum dot junction can represent a thermal rectifier [14]. By a multi-level Anderson model, the role of inter-dot Coulomb interactions in the linear and nonlinear regimes was investigated. They found that the inter-dot Coulomb interactions have an important role in the appearance of the thermal rectification. In the linear regime, the thermoelectric properties such as electric conductivity, thermal power and thermal conductivity have calculated, while thermal devices applications (thermal rectifiers and transistors) in the nonlinear regime require the understanding of the thermoelectric properties. Since, solar energy storage is one of the thermal rectifier's applications. For different quantum dot configurations, the thermal rectification in the Coulomb blockade regime has also investigated [15]. For a single quantum dot, they found

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