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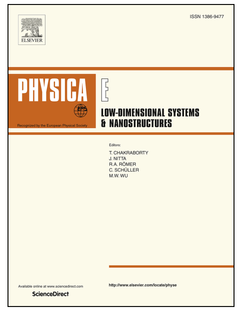

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Single-photon controlled thermospin transport in a resonant ring-cavity system

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Abstract

Cavity-coupled nanoelectric devices hold great promise for quantum technology based on coupling between electron-spins and photons. In this study, we approach the description of these effects through the modeling of a nanodevice using a quantum master equation. We assume a quantum ring is coupled to two external leads with different temperatures and embedded in a cavity with a single photon mode. Thermospin transport of the ring-cavity system is investigated by tuning the Rashba coupling constant and the electron-photon coupling strength. In the absence of the cavity, the temperature gradient of the leads causes a generation of a thermospin transport in the ring system. It is observed that the induced spin polarization has a maximum value at the critical value of the Rashba coupling constant corresponding to the Aharonov-Casher destructive interference, where the thermospin current is efficiently suppressed. Embedded in a photon cavity with the photon energy close to a resonance with the energy spacing between lowest states of the quantum ring, a Rabi splitting in the energy spectrum is observed. Furthermore, photon replica states are formed leading to a reduction in the thermospin current.

Keywords: Thermo-optic effects, Electronic transport in mesoscopic systems, Cavity quantum electrodynamics, Electro-optical effects
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1. Introduction

Thermoeletric properties have been so far investigated mainly in nanoscale systems to achieve high thermoelectric efficiency that would be useful for energy harvesting [1, 2]. To obtain a high thermoelectric efficiency, thermoelectrically active materials are used. These materials should have high electrical conductivity and low thermal conductivity. High electrical conductivity can be obtained by increasing the carrier mobility or their concentration that can be influenced in quantum structures. Consequently, the figure of merit and Seebeck effect can be enhanced in nanodevices [3, 4, 5]. Generally, there is a challenge in the conventional thermoelectric material because if the electrical conductivity is enhanced the thermal conductivity is increased as well. As a result, the Seebeck effect and the device efficiency are decreased.

An advantageous method relying on the Spin Seebeck effect has been used to decouple electrical conductivity from thermal conductivity. So the electrical and thermal conductivity can be separately controlled concurrently [6, 7]. In 2008, Saitoh and *et. al.* discovered the spin Seebeck effect when heat is applied to a magnetized metal. In a magnetically active material electrons reconfigure themselves according to their spin. In this way, unlike in a conventional electron transport, this rearrangement does not create heat as a waste product. The spin Seebeck effect can lead the way to the growth of smaller, faster and more energy-efficient microchips as well as spintronics devices [8, 9, 10].

On the other hand, the influences of light on thermoelectric effects have been investigated and shown that the thermoelectric power can be enhanced by increasing the intensity of light [11]. It was also found that a polarized light can induce a Fano-like resonance in the thermal conductance [12]. Therefore, The thermopower and the figure of merit may be enhanced near a Fano-like resonance. In addition, the polarized light and the increase of magnetic polarization may lead to a better thermoelectric performance, especially, a significant increase of the spin thermal efficiency may be obtained.

Influenced by the aforementioned studies, we try to explore the influences of a quantized photon field on thermospin transport through a quantum ring including the Rashba spin-orbit coupling. We model a quantum ring system coupled to two leads with different temperatures. The ring system is embedded in a cavity with a linearly polarized photon field. In our previous publications, we have seen that both thermoelectric and heat currents can be controlled by a polarized photon field [13, 14, 15, 16]. The aim of our study here is twofold. First, we induce a thermospin current through a multi-level quantum ring

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