Spin-orbit coupling effects on transport properties of electronic Lieb lattice in the presence of magnetic field

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Introduction

In this paper, the transport properties of a two dimensional Lieb lattice Figure1 that is a line-centered square lattice , includes three atoms in a unit cell, are investigated in the presence of magnetic field and spin-orbit coupling[1]. A Lieb lattice has attracted much attention both theoretically and experimentally as its novel topological properties. It has been suggested that the Lib lattice can be realized in various physical systems, such as cold atoms in optical networks and light scattering in photon crystals[2-5]. The intrinsic spin-orbit coupling is applied to the Lieb lattice so that a topologic bulk gap is opened and it gives rise to the quantum spin Hall effect. It was found that intrinsic spin-orbit coupling plays an important role on the topological properties of nano structures[6].

Method

In this study, we have used the Green's function approach and Hamiltonian of the Ken-Mele model[7], consists of a hopping to the nearest neighbor and an intrinsic spin-orbit term.Also, the effect of magnetic field has been studied via adding the Zeeman term to the original model Hamiltonian. After diagonalizing of the Hamiltonians, the band structure of electrons and the electronic Green's function have been found. Utilizing the linear response theory, the thermal and electrical conductivity are obtained in the presence of magnetic field and spin-orbit coupling. The thermal and electrical conductivity are related to the gradients electric potential and the temperature ,respectively, by transport coefficients L_{ab}(a;b = 1; 2). Using the Kubo formula and performing calculations, finally the static transport properties of the system are calculated based on the band structure and the imaginary part of The electronic Green's function.

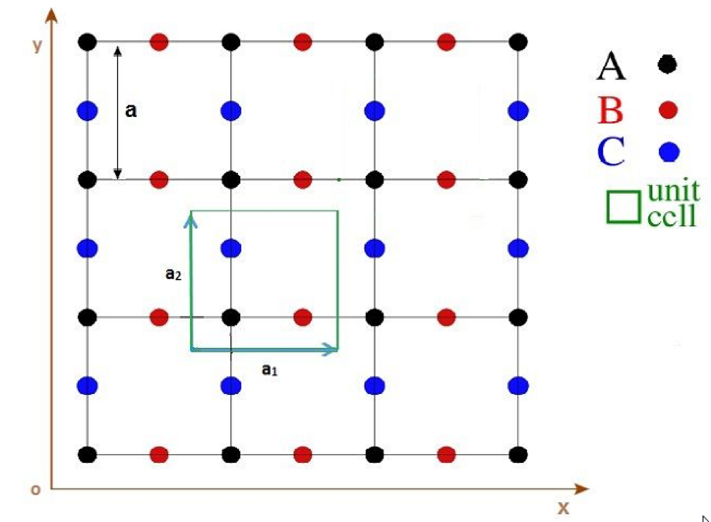

Figure1:Two-dimensional Lieb lattice with three atoms in a unit cell.

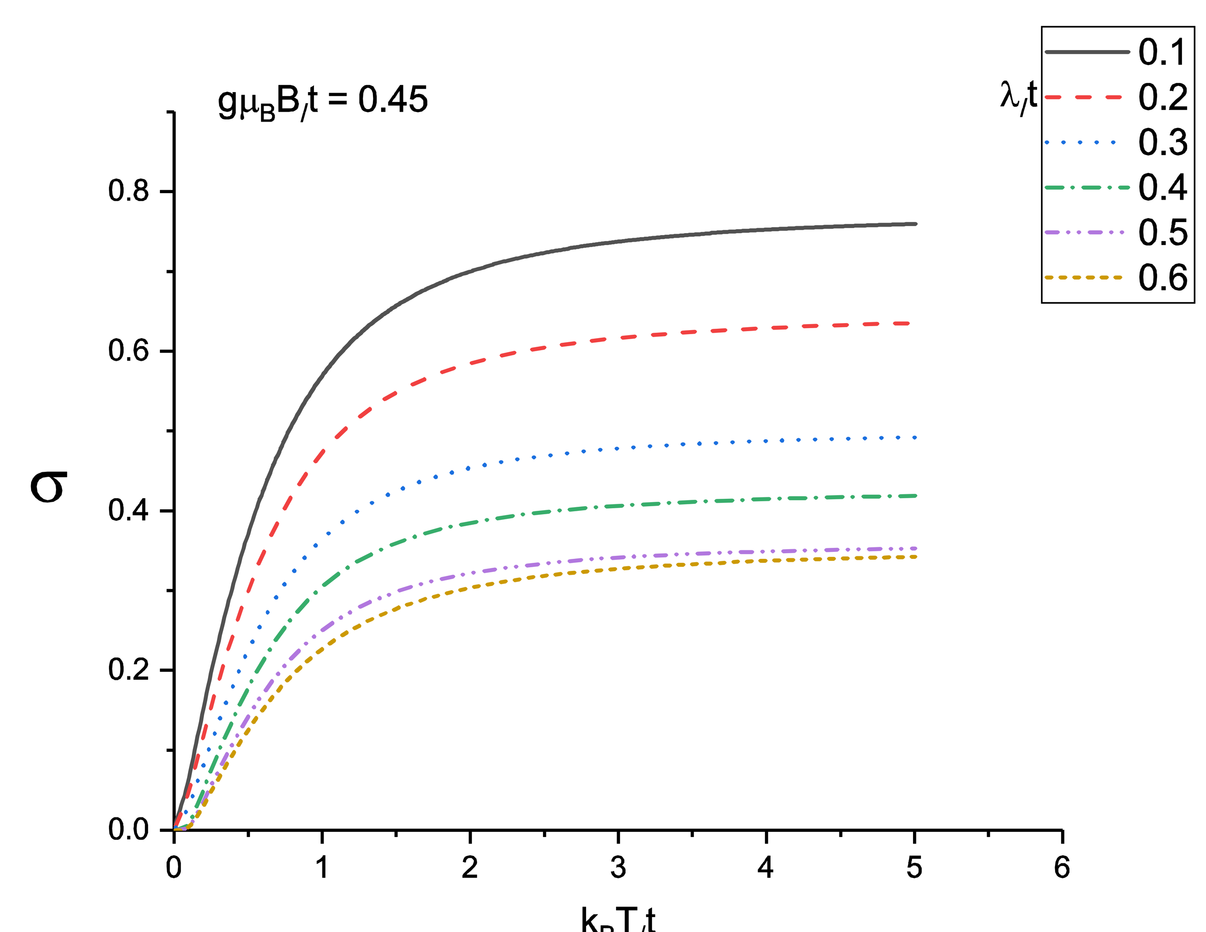

Figure2: Electrical conductivity of Lieb lattice as a function of kBT for different values of λ

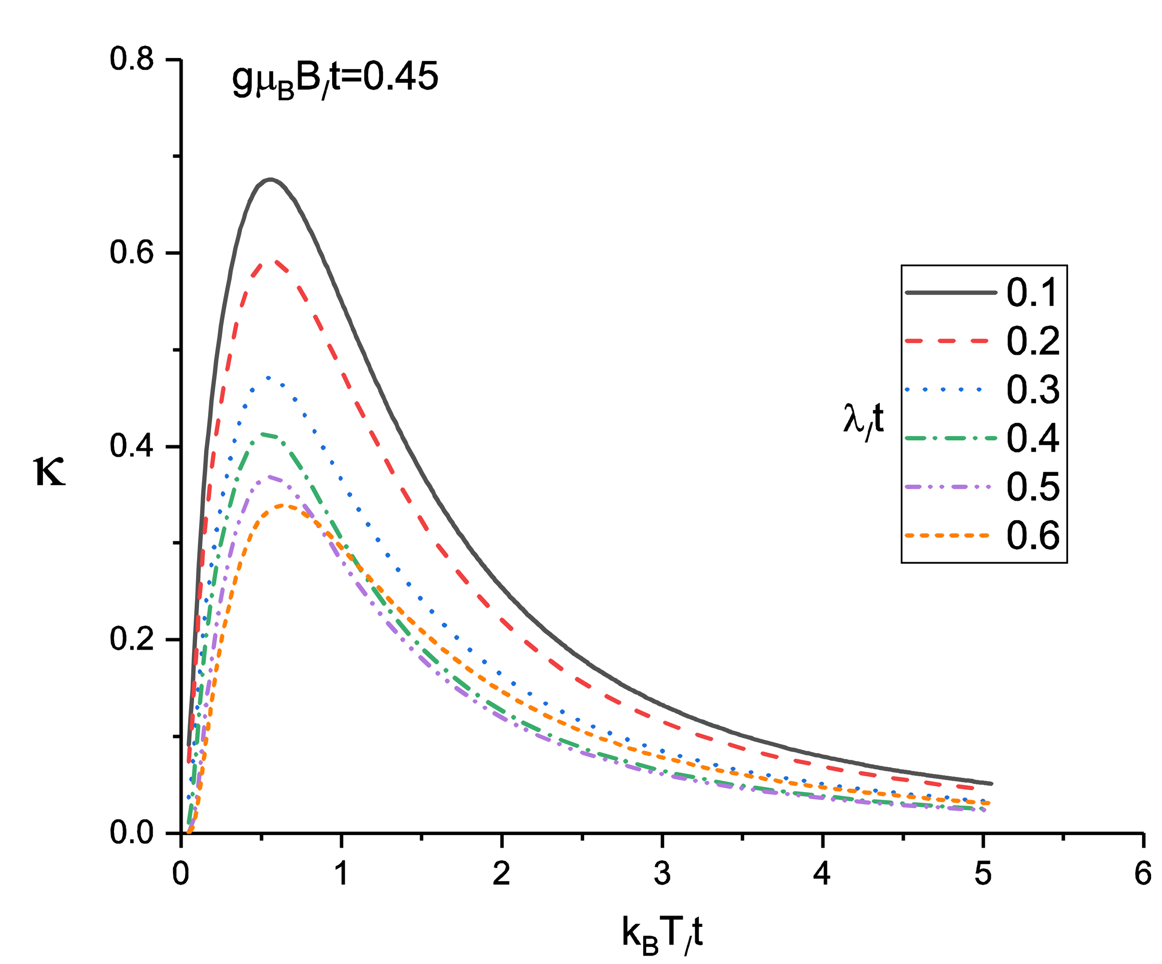

Figure3: Thermal conductivity of Lieb lattice as a function of kBT for different values of λ

Results

The temperature behavior of the electrical and thermal conductivity of the Lieb lattice for different values of the spin-orbit coupling λ and the constant magnetic field are plotted in Figure 2,3, respectively. It is to be noted that all numerical values are normalized. The static electrical conductivity curve, based on $k_B T$, shows that for $k_B T$ <1t an increase in $k_B T$ causes an increase σ and is constant for $k_B T$ higher than this value. Also at a certain temperature an increase λ leads to a decrease. The thermal conductivity diagram as a function of $K_B T$ for each value λ has a peak in $K_B T$ = 0.7t which is independent of λ and at a constant temperature an increase λleads to a decrease in κ.

Discussion

Increasing λ leads to an increase in the gap width in the density of state, and leads to decrease in σ and κ. In addition, the existence of peaks in κ is a result of competition between an increase in the transfer rate of electrons from the ground state to the excited state, and the scattering of electrons at higher temperatures.

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