Thermal diode effect on the surface of three-dimensional topological insulators

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Thermo-electric devices are utilized for nano-scale refrigeration or to harness waste heat to produce electric power in electronic circuits. These devices usually require semiconductor materials or complex geometries to induce thermo-electric effects which may suffer from a narrow range of operation or poor efficiency. To counteract these shortcomings, we propose a simple device consisting of a ferromagnet (F) in proximity to a Dirac semi-metal (N) creating a ballistic NFN junction with a large operating window. We theoretically study the heat and electric currents through the junction and show strong Seebeck and Peltier effects arising from the Dirac physics and Klein tunnelling in the ballistic junction. We use the device's high tunability to create a thermal diode allowing for refrigeration of a hot reservoir or for power production induced by a temperature gradient. Finally, we discuss refrigeration efficiency and the effective electron cooling temperature taking into account the phonon contribution in quasi-two-dimensional materials, like graphene or topological insulators.

Figures

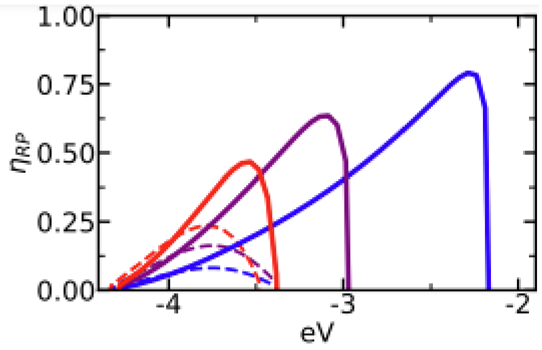

Figure 1: Refrigeration efficiency of the device vs eV, for different temperature gradients. The dashed lines corresponding to a short ferromagnetic junction of 100nm and the solid ones to a long junction of 1μm. The gradient relative to ambient temperature is for the 10%, (blue), 20% (purple) and 30% (red).

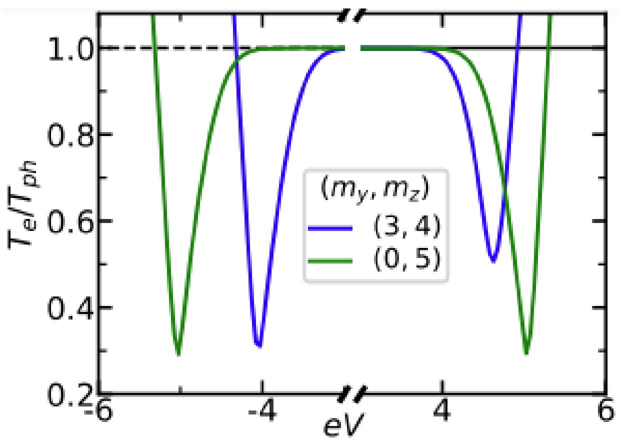

Figure 2: The electron temperature relative to a photonic bath of temperature (T_{ph}) coupled through scattering. We compare two different orientations of the magnetic Zeeman field: along the y-z plane (blue) and out of plane (green).