Thermoelectric effects due to spin-orbit interaction in carbon nanotube cross-junctions.

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One way to optimize modern electronic circuits is to transform the unavoidable waste heat they generate into useful electricity. However, such thermoelectric heat-to-work conversion is very inefficient in macroscopic devices. As electronic components are miniaturized to the nano-scale, quantum effects become dominant and can help overcome these limitations and provide efficient heat engines.

Superconducting hybrid junctions are very good platforms to implement thermoelectric devices, since the energy-dependent density of states in a superconductor is a key ingredient for strong thermoelectric effects. Then, breaking the electron-hole symmetry by some mechanism can generate charge currents from temperature gradients or heat flows from electric potentials.

In this project, we propose carbon nanotube cross-junctions (see Figure) as the element that breaks electron-hole symmetry in a controlled fashion [1]. Indeed, the spin-orbit interaction in the carbon nanotube results in very versatile spin-filtering effects, where an external magnetic field can switch between different spin filter directions or even reach full polarization [2].

The goals of this project are (i) to theoretically describe charge and energy transport in a superconductor-carbon nanotube cross-junction and (ii) to explore the influence of quantum effects on the efficiency of the resulting thermal engines. During your research, you will apply scattering theory to study quantum transport in the presence of superconducting correlations in a system that couples the electron spin, charge, and energy (or heat) degrees of freedom. You will also familiarize yourself with the concepts of quantum entanglement, phase-coherent transport, and topology in condensed matter systems.

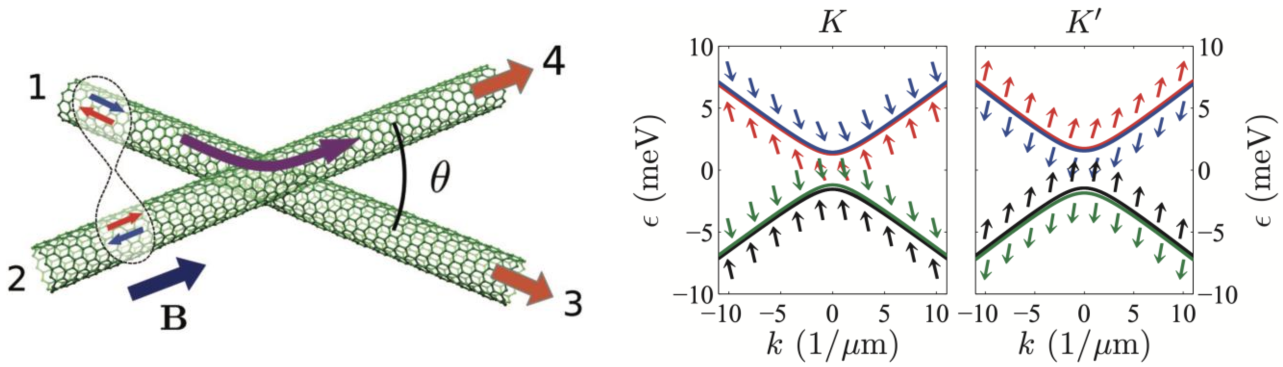

Figure. Left: Carbon nanotube cross-junction with four leads and angle θ between nanotubes. A magnetic field **B** is applied parallel to one of the nanotubes. Right: Lowest, spin-polarized energy bands closest to the Dirac points K and K’.

[1] F. Mazza, B. Braunecker, P. Recher, A. Levy Yeyati, Phys. Rev. B **88**, 195403 (2013).

[2] K. Flensberg, C. M. Marcus, Phys. Rev. B **81**, 195418 (2010).