Local and nonlocal thermoelectric effects and Onsager relations in two- and three-terminal proximity systems

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We study thermal and charge transport in a three-terminal setup consisting of a superconducting and two ferromagnetic contacts. We predict that the simultaneous presence of spin-filtering and of spin-dependent scattering phase shifts at each of the two interfaces will lead to very large nonlocal thermoelectric effects both in clean and in disordered systems. [1] The symmetries of thermal and electric transport coefficients are related to fundamental thermodynamic principles by the Onsager reciprocity. Our results show that a nonlocal version of the Onsager relations for thermoelectric currents holds in a three terminal quantum coherent ferromagnet-superconductor heterostructure including spin-dependent crossed Andreev reflection and coherent electron transfer processes.

Finally, we propose a realization to measure local thermoelectric effects in superconductor heterostructures. As shown in [1], due to the simultaneous effect of spin-dependent scattering and spin-filtering, a huge thermoelectric effect can be achieved in superconductor-ferromagnet structures. We focus on the local effect to provide an easy way to proof the existence of such effects. We calculate the spin-resolved density of states and show how the interplay between spin-polarized transport and Andreev reflection determines the thermo-electric transport properties.

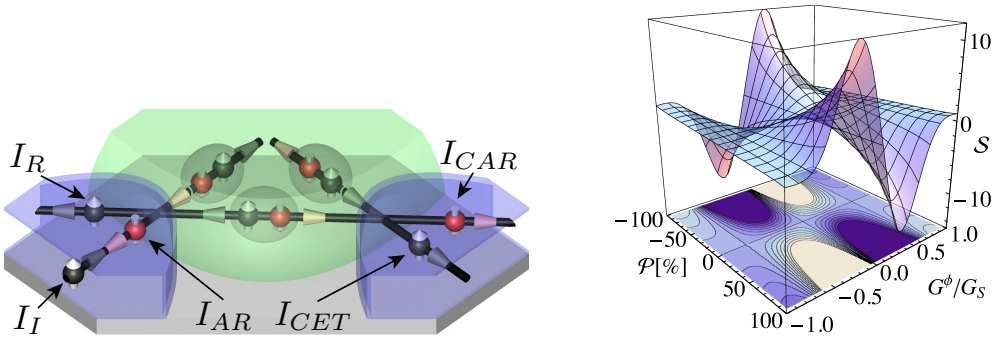

Figure 1: Left figure: Sketch of the three-terminal setup and the different transport processes. Injected (I_I), normally (I_R and Andreev (I_{AR}) reflected currents denote local processes. Crossed Andreev reflectionI_{CAR} and crossed electron transfer I_{CET} denote the non-local processes. Right figure: The non-local Seebeck coefficient $S = \Delta V_2/\Delta T_1$ as function of polarization G_{MR} and spin-dependent interface G_ϕ parameters.

[1] P. Machon, M. Eschrig, and W. Belzig, PRL **110**, 047002 (2013)