Nonlocal magnetolectric effects in diffusive conductors with spatially inhomogeneous spin-orbit coupling

Cristina Sanz Fernández [1,*]
Juan Borge [2], Ilya V. Tokatly [2,3,4], and F. Sebastián Bergeret [1,4]

[1] *Centro de Física de Materiales (CFM-MPC), Centro Mixto CSIC-UPV/EHU, 20018 Donostia-San Sebastián, Spain*
[2] *Nano-Bio Spectroscopy Group, Departamento de Física de Materiales (UPV/EHU), 2001820018 Donostia-San Sebastián, Spain*
[3] *IKERBASQUE, Basque Foundation for Science, 48011 Bilbao, Spain*
[4] *Donostia International Physics Center (DIPC), 20018 Donostia-San Sebastián, Spain*

cristina_sanz001@ehu.eus

We present a theoretical study of non-local magnetoelectric effects [1] in diffusive hybrid structures with an intrinsic linear-in-momentum spin-orbit coupling (SOC) which is assumed to be spatially inhomogeneous. Our analysis is based on the SU(2)-covariant drift-diffusion equations [2] from which we derive boundary conditions (BC) at hybrid interfaces for SOC of any kind. We demonstrate that the presence of extrinsic sources of spin relaxation (ESR), such as magnetic impurities and/or a random SOC at non-magnetic impurities, are present, the spin is no longer covariantly conserved, and spin Hall (SH) currents appear. We apply our model to describe a (2D) non-local spin valve with an interface separating two regions: one normal region without intrinsic SOC and one with a Rashba SOC [3] (see Fig. 1b). We first explore the inverse spin-galvanic effect, i.e., a spin polarization induced by an electric field (see Fig. 1c). We demonstrate how the spatial behavior of such spin density depends on both, the direction of the electric field and the strength of the ESR rate. We also study the spin-to-charge conversion (see Fig. 1d), and compute the charge current and the distribution of electrochemical potential in the whole system when a spin current is injected into the normal region. In systems with an inhomogeneous SOC varying in one spatial direction, we find an interesting non-local reciprocity between the spin density induced by a charge current at a given point in space, and the spatially integrated current induced by a spin density injected at the same point.

References

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Figures

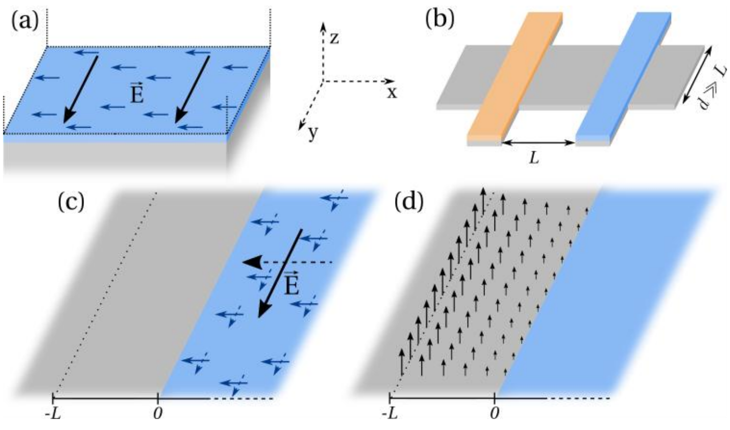

Figure 1: Different systems in which the magnetoelectric effects are usually studied. We focus in (2D) non-local spin valves (b), analyzing charge (c) and spin (d) injection. This study is based on the BC we develop at the interface between a normal (grey regions) and a Rashba (blue region) conductors.