

Spin Currents and Charge-to-Spin Conversion in Rashba Systems: A Unified Scattering Approach

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Abstract: We develop a unified scattering-matrix framework for spin and charge transport in Rashba systems, revealing how quantum confinement and interference govern charge-to-spin conversion and localization phenomena across multiterminal Hall bars and ballistic quantum dots.

In this talk, I will present a unified theoretical framework to describe spin and charge transport in low-dimensional systems with Rashba spin-orbit interaction, based on a generalized Büttiker scattering approach [1].

The formalism is adapted to both multiterminal Hall bar geometries [2] and ballistic quantum dots [3], allowing a direct comparison between extended and confined systems within the same microscopic picture.

I will show how this approach captures the interplay between quantum confinement, interference effects, and external fields, providing access to spatially resolved spin and charge currents as well as linear response functions.

In the Hall bar configuration, the method reproduces key features observed experimentally, offering a consistent description of spin-charge interconversion mechanisms.

In the case of quantum dots, where the system size is comparable to the Fermi wavelength, the same framework reveals a crossover from weak localization to weak antilocalization driven by Rashba coupling. This transition is directly reflected in the behavior of spin currents of Edelstein and spin Hall type, highlighting their connection to the underlying electronic wavefunction structure.

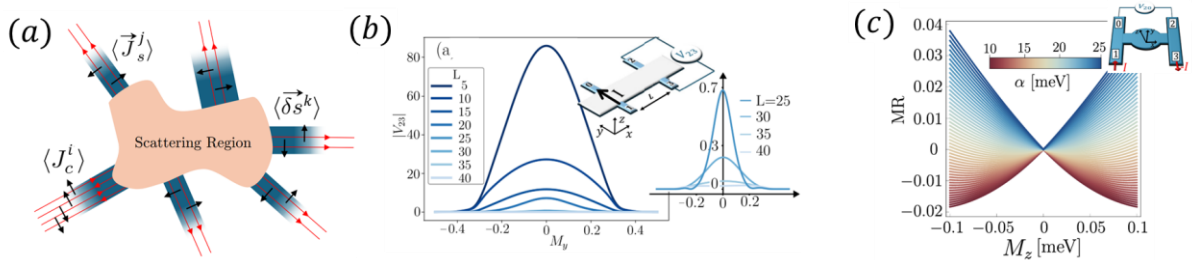


Fig. 1 (a) Schematic representation of a multiterminal scattering region through which spin-sensitive transport is measured. (b) Nonlocal voltage, $|V_{23}|$, as a function of the external magnetic field applied along y , M_y , in the Hall bar depicted in the inset. (c) Magnetoresistance MR between leads 2 and 0 as a function of Zeeman energy M_z , for spin-orbit coupling ranging from 10 to 25 meV in the quantum dot depicted in the inset.

Overall, the results establish a coherent picture of charge-to-spin conversion mechanisms across different geometries, bridging mesoscopic transport theory and experimentally relevant signatures.

References

- [1] M. Büttiker, *Scattering theory of current and intensity noise correlations in conductors and wave guides*, Phys. Rev. B 46, 12485 (1992).
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