

Boltzmann theory of the inverse Edelstein effect in a two-dimensional Rashba gas

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Abstract: We investigate spin-to-charge conversion at Rashba interfaces coupled to ferromagnets, showing how spin-orbit coupling and exchange interactions define distinct transport regimes and control the inverse Edelstein effect within a transparent semiclassical Boltzmann framework.

The inverse Edelstein effect (IEE) is a fundamental mechanism of spin-to-charge conversion in systems with strong spin-orbit coupling and broken inversion symmetry. It enables the generation of a transverse charge current in response to a non-equilibrium spin accumulation, typically at interfaces hosting Rashba-type electronic states. Microscopically, the effect originates from spin-momentum locking, which converts a spin imbalance into a net momentum shift of charge carriers, making the IEE a key ingredient of modern spintronics.

Here [1] we investigate the inverse Edelstein effect in a non-homogeneous system consisting of a ferromagnetic layer coupled to a Rashba two-dimensional electron gas, a prototypical platform for spin-charge interconversion at oxide interfaces. Within a semiclassical Boltzmann framework, we derive analytical expressions for the charge and spin currents, explicitly accounting for the interplay between interfacial exchange and spin-orbit coupling, and analyze their dependence on key parameters such as the chemical potential and the Rashba coupling strength. We demonstrate how these competing interactions jointly control the efficiency of spin-to-charge conversion, giving rise to distinct transport regimes characterized by qualitatively different responses. In particular, we identify parameter regions where the conversion efficiency is enhanced or suppressed due to the combined effects of band structure and spin texture. A central outcome of our work is the availability of closed-form analytical results, which provide direct physical insight and enable a transparent and quantitative benchmarking with experiments on complex oxide interfaces, such as $\text{LaAlO}_3/\text{SrTiO}_3$, and related spintronic heterostructures.

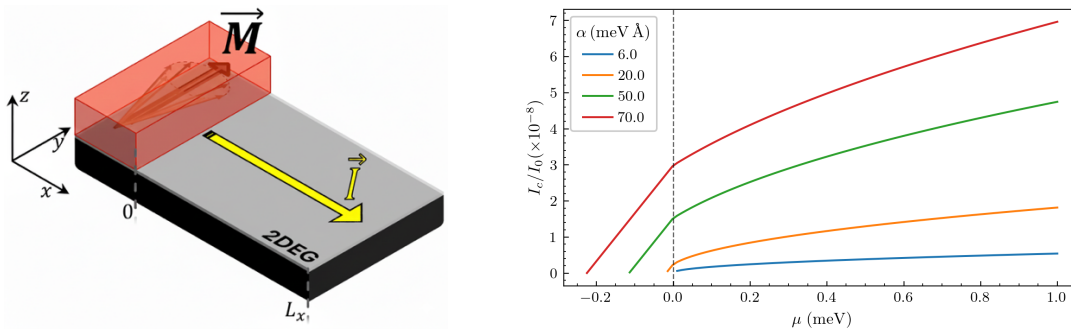


Fig. 1. (Left) Schematic illustration of the non-homogeneous Rashba system coupled to a ferromagnetic layer and corresponding band structure with spin-momentum locking induced by spin-orbit coupling and interfacial exchange interaction. (Right) Charge and spin transport responses associated with the inverse Edelstein effect, showing their dependence on chemical potential and Rashba coupling, and highlighting distinct regimes of spin-to-charge conversion efficiency.

Example References

[1] I. Gaiardoni, M. Trama, A. Maiellaro, C. Guarcello, F. Romeo, and R. Citro, "Boltzmann theory of the inverse Edelstein effect in a two-dimensional Rashba gas," arXiv:2601.02473 (2026).