PHYSICS AND ASTRONOMY COLLOQUIUM

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Break the Symmetry and Couple the Motion: Learning How Spin and Charge Dance at Metal Interfaces

One of the most exciting moments in modern magnetism was the experimental discovery that, in the vicinity of an interface, charge transport can lead to magnetic or spin disequilibrium (also known as spin accumulation). Special combinations of spin-orbit-coupling and spatial-symmetry-breaking gives this unexpected effect, interest in which has led to a fifteen-year flurry of activity on the spin Hall effect, the Rashba-Edelstein effect, and spin orbit torque -- as well as their inverses. This does not include related effects, including those identified by the words Nernst, spin Nernst, and spin-locking (for the still-exotic category of materials known as topological insulators). Equally dizzying is the vast diversity of measurement methods to quantify the charge-spin interconversion process.

Rather than survey this vast field with the speed of a Gilbert and Sullivan aria, I will instead focus on two phenomena: the spin Hall effect (longitudinal charge disequilibrium can produce a transverse spin accumulation) and the inverse spin Hall effect (longitudinal spin disequilibrium can produce a transverse charge accumulation). As framework for this I will review the formalism of Onsager reciprocity [1] by which, to avoid violating the 2nd Law of Thermodynamics, the cross-coupling of force/flow relationships must under time-reversal have unique signatures (even or odd but not both). Before turning to our experiments I will then discuss the constraints provided by Onsager's theory of irreversible thermodynamics, where thermodynamic forces (e.g., gradients of voltage and temperature) drive thermodynamic flows (e.g., currents of electricity and heat).

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