What is quantum spin torque: Spintronics meets nonequilibrium strongly correlated and long-range entangled quantum matter

Branislav Nikolic

University of Delaware, Department of Physics & Astronomy, 217 Sharp Lab, Newark, USA

The "standard model" of magnetization dynamics driven by current via conventional (Slonczewski-Berger) spin-transfer (STT) torque is based on [1] single-particle quantum transport treatment of flowing electrons and classical treatment of localized spins within a magnetic material via the Landau-Lifshitz-Gilbert equation. In the "standard model", the transfer of spin angular momentum between flowing electronic spins and localized spins occurs only if they are noncollinear. However, recent experiments [2] at low temperatures 1 K suggest that fully quantum nonequilibrium many-body framework is required to describe situations where conventional STT is apparently zero, such as collinear but antiparallel electron and localized spins [3], or localized spins whose expectation value is zero [4] in equilibrium due to entanglement as in the case of quantum antiferromagnets, Mott insulators and quantum spin liquids. To solve this long-standing problems, we have recently [3] adapted time-dependent density matrix renormalization (tDMRG) algorithms for "quantum STT," by which we term any situation where localized spins must be treated quantum-mechanically with their individual expectation values calculated only at the end. This reveals how quantum STT can generate highly entangled nonequilibrium many-body state of all flowing and localized spins with mutual information between localized spins at the FM edges remaining nonzero even at infinite separation as the signature of dynamical buildup of long-range entanglement [3]. Another prediction from tDMRG [4] shows that interaction of spin-polarized current pulses with the surface of antiferromagnetic Mott insulator (AFMI) will transmute zero expectation value of AFMI localized spins into nonzero values.

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