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Mean-field models for spin-magnetization coupling in ferromagnetic materials and semiclassical limit

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The Schrödinger-Poisson-Landau-Lifshitz-Gilbert (SPLLG) system is an effective microscopic model that describes the coupling between conduction electron spins and the magnetization in ferromagnetic materials, based on which, we develop a mean-field model for describing the dynamics of spin transfer torque in multilayered ferromagnetic media. Specifically, we use the techniques of Wigner transform and moment closure to connect the underlying physics at different scales, and reach a macroscopic model for the dynamics of spin coupled with the magnetization within the material. This provides a further understanding of the linear response model proposed by [Zhang, Levy, and Fert, Phys. Rev. Lett. 88 (2002), 236601], and in particular we get an extra relaxation term which helps to stabilize the system. Fully three-dimensional numerical simulation is implemented and applied to predict current-driven domain wall motions. It shows a nonlinear dependence of the wall speed on the current density which agrees with the experiments in [Yamaguchi et.al., Phys. Rev. Lett., 96 (2006), 179904]. We rigorously prove the existence of weak solutions to SPLLG and derive the Vlasov-Poisson-Landau-Lifshitz-Glibert system as the semiclassical limit connected to the mean-field model. Diffusion limit of this semiclassical limit system will be also discussed.

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