A quantum dot close to Stoner instability: The role of Berry's phase

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Physics of a quantum dot with electron-electron interactions is well captured by the so called "Universal Hamiltonian" if the dimensionless conductance of the dot is much higher than unity. Within this scheme interactions are represented by three spatially independent terms which describe the charging energy, the spin-exchange and the interaction in the Cooper channel. We concentrate on the exchange interaction and generalize the functional bosonization formalism developed earlier for the charging energy [1]. This turned out to be challenging as the effective bosonic action is non-Abelian due to the non-commutativity of the spin operators. We develop a geometric approach which is particularly useful in the mesoscopic Stoner regime, i.e., when the strong exchange interaction renders the system close the the Stoner instability. We show that it is sufficient to sum over the adiabatic paths of the bosonic vector field and, for these paths, the crucial role is played by the Berry phase. Using these results we were able to calculate the magnetic susceptibility of the dot. The latter, in close vicinity of the Stoner instability point, matches very well with the exact solution [2]. Furthermore, we extend our formalism for the case of an open quantum dot coupled to a non-magnetic lead and generalize the well known Ambegaokar-Eckern-Schoen formalism. Whereas the original AES effective action was developed for the U(1) phase related to the charge degree of freedom, ours describes the dynamics of a large spin in terms of the SU(2) Euler angles. Using the real-time Keldysh technique we derive the Landau–Lifshitz–Gilbert equations with unusual Langevin terms. Finally, we discuss how our theory could be confirmed, e.g., by performing spin resonance experiments.

[1] A. Kamenev and Y. Gefen, Phys. Rev. B 54, 5428 (1996).

[2] I.S. Burmistrov, Y. Gefen, and M.N. Kiselev, Pis'ma v ZhETF 92, 202 (2010).