SPIN TRANSPORT IN TOPOLOGICAL INSULATORS: ANALYSIS OF KUBO TERMS

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ABSTRACT. Our long-term research project aims at investigating spin transport in 2-dimensional insulators, with the goal of establishing whether any of the transport coefficients corresponds to the Fu-Kane-Mele index which characterizes 2d time-reversal-symmetric topological insulators.

The first part of the project (reported in the talk by D. Monaco) consists in a new, first-principle derivation – based on techniques originating from space-adiabatic perturbation theory – of a Kubo-like formula for charge and spin conductivity in gapped (periodic) quantum systems. As far as charge transport is concerned, the result consists in a new derivation, which does not rely on the usual Linear Response Ansatz, of the usual Kubo formula for charge conductivity. On the other hand, when spin transport is considered, our new Kubo-like formula exhibits additional terms with respect to a naif generalization of the usual Kubo formula. The physical relevance of these new terms is now under investigation. [This first part of the project is a joint work with G. Marcelli, D. Monaco, and S. Teufel].

The second part of the project investigates instead the relation between the spin conductivity σ^{s_z} and the spin conductance G^{s_z}, a relation which is not trivial in view of the subtleties of spin transport. In a recent preprint (joint work with G. Marcelli and C. Tauber) we focus on the Kubo-type terms (thus neglecting the additional terms mentioned above) and we prove that for any gapped, periodic, near-sighted discrete Hamiltonian, the Kubo spin conductivity and spin conductance are mathematically well-defined and the equality $\sigma^{s_z}_K = G^{s_z}_K$ holds true. Moreover, we argue that the physically relevant condition to obtain the equality above is the vanishing of the mesoscopic average of the spin-torque response, which holds true under our hypotheses on the Hamiltonian operator. This vanishing condition might be relevant in view of further extensions of the result, e. g. to ergodic random discrete Hamiltonians or to Schrödinger operators on the continuum. A central role in the proof is played by the trace per unit volume and by two generalizations of the trace, the principal value trace and it directional version

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