Quantum transport in strongly disordered crystals: Electrical conductivity with large negative vertex corrections

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Backward scatterings of electrons on impurities contribute significantly to the electrical conductivity in strongly disordered lattices. They always lead to negative vertex corrections to the Drude term and may turn the sign of the conductivity negative in approximate treatments when the disorder strength is large.[1] A rearrangement of the Kubo formula for the electrical conductivity is necessary.

We propose a renormalization scheme of the Kubo formula for the electrical conductivity with multiple backscatterings contributing to the electron-hole irreducible vertex derived from the asymptotic limit to high spatial dimensions. We use this vertex to represent the two-particle Green function via a Bethe-Salpeter equation in momentum space. We further utilize the dominance of the diffusion pole in the irreducible vertex to an approximate diagonalization of the Bethe-Salpeter equation and a non-perturbative representation of the electron-hole correlation function. The latter function is then used to derive a compact representation for the electrical conductivity at zero temperature without the necessity to evaluate separately the Drude term and vertex corrections. The electrical conductivity calculated in this way remains nonnegative also in the strongly disordered regime where the localization effects become significant and the negative vertex corrections in the standard Kubo formula overweight the Drude term.

[1] V. Janiš and V. Pokorný, Phys. Rev. B **81**, 165103 (2010).