Non-Gaussian Spatial Correlations Dramatically Weaken Localization

H. Javan Mard (FSU, Physics); V. Dobrosavljevic (NHMFL,FSU, Physics); E. Miranda(Unicamp U., Brazil, Physics), E.C. Andrade (Dresden U., Germany)

Introduction

According to the scaling theory of localization [1], any amount of disorder suffices to localize all (non-interacting) electrons at T=0 in dimension d<=2 . In the presence of electron-electron interactions, however, no such general statement exists, and the transport behavior of disordered interacting electrons remains an outstanding open problem[2]. Previous studies provided evidence that repulsive electron-electron interactions generally increase the conductance in small systems. In principle, interactions could modify either the amplitude or the form of spatial correlations of the renormalized disorder potential. Despite this progress, several important questions remained unanswered: (1) What is the dominant physical mechanism for disorder screening, and can it qualitatively modify the non-interacting picture? (2) Can the interaction effects overcome Anderson localization and stabilize the metallic phase in low dimensions?

Results and Discussion

We perform variational studies of the interaction-localization problem to describe the interaction-induced renormalizations of the effective (screened) random potential seen by quasiparticles. We performed careful finite-size scaling studies on the conductance of disordered Hubbard chains at half-filling and zero temperature. While our results indicate that quasiparticle wave functions remain exponentially localized even in the presence of moderate to strong repulsive interactions, we show that interactions produce a strong decrease of the characteristic conductance scale g* signaling the crossover to strong localization (see Fig. 1). This effect, which cannot be captured by a simple renormalization of the disorder strength, instead reflects a peculiar non-Gaussian form of the spatial correlations of the screened disordered potential, a hitherto neglected mechanism to dramatically reduce the impact of Anderson localization (interference) effects.

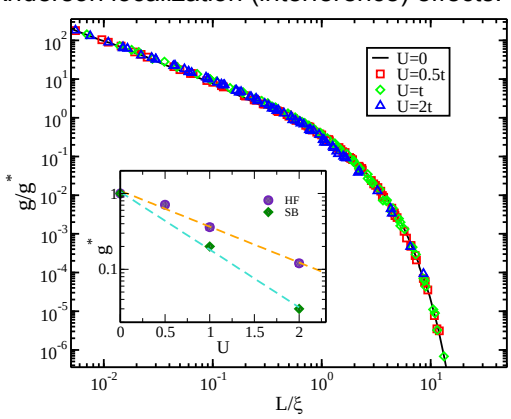

Figure 1.Conductance scaling curves for different U values collapse onto a single universal curve after rescaling both L, and g.

Conclusions

Our careful numerical studies show that the typical value of the scaled conductance has a large decrease of the conductance scale g*(U) signaling the crossover to the strongly localized regime. Surprisingly, we find that the form of the spatial two-point correlation function B_{ij} characterizing the renormalized disorder potential is not enough to explain this shift. This indicates that non-gaussian (higher order) correlations play a crucial role in decreasing localization effects, a mechanism overlooked in previous works.

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