Localization and transport in one-dimensional chains with long-range $1/r$ interactions

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We investigate localization and transport properties of one-dimensional (1D) chains with on-site disorder and long-range couplings. Transmission coefficient for such a system is found by studying transport of Gaussian wave packets through a long-range-coupled noisy chain placed between noiseless nearest-neighbor-coupled "leads". Transport characteristics are analysed as a function of chains' length and compared to standard measures of localization, showing a metal-insulator (localization-delocalization) transition.

The localization-delocatization transition in 3D disordered systems was predicted by Anderson. However, the recent extensive investigations have shown that in 1D or 2D systems with long-range interaction also exists disorder-induced metal-insulator transition [1]. This fact may be relevant in context of Frenkel excitons and magnons in the presence of diagonal disorder or semiconductor superlattices grown with random but correlated quantum well sequences [2]. It can also shed some light on the observed diffusion of excitation in quantum dot arrays [3].

The Hamiltonian of the investigated system consist of hopping integral between different lattice sites α and β in the form $t \sim 1/|\alpha - \beta|$ and random, uncorrelated site energies drawn from normal distribution with zero mean and a standard deviation σ. In the transmission study, we generate a Gaussian wave packet with initial width of Δk and strongly peaked around k_0, located in one of the leads. The wave packet's envelope consists of narrow range of frequencies and dispersion relation is approximately linear over that narrow range. The time evolution of the wave packet is found by diagonalization of the Hamiltonian, whereas the dependence of the transmission through the disordered segment is found as a function of the segment length. Two regimes of transport are observed (see Figure below): constant ballistic transmission for vanishing or sufficiently low disorder (metallic chain) and exponentially decaying tunneling transmission for sufficiently large disorder (insulating chain).

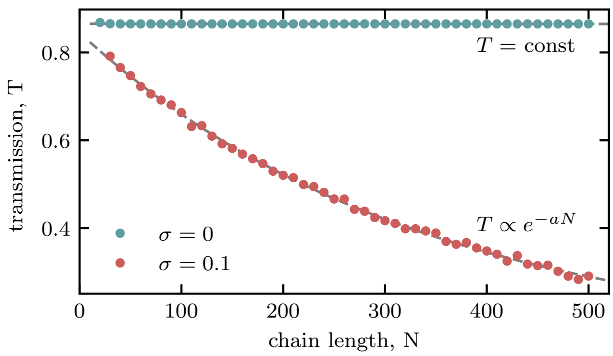

Figure 1: Dependence of the transmission function on the chain length.

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