Poster

DISORDERED WAVE-GUIDES WITH ABSORPTION: TRANSMITTANCES DISTRIBUTIONS AT THE DIFFUSIVE-LOCALIZED CROSSOVER

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Propagation and localization of waves of various kinds in quasi-one dimensional disordered media have been studied intensively for several decades. Examples of particular interest are electron transport in disordered solid and electromagnetic wave propagation in random dielectric media. In contrast to electronic systems, where the total flux is conserved, in optical systems the transmittance may be affected as a result of absorption.
The conductance (transmittance) distribution in electronic system $P(T)$ is known to evolve from a Gaussian distribution $P(T)$ (deep in the diffusive regime) to a lognormal distribution (deep in the localization regime) [1]. The analysis of the conductance distribution for disordered wires in the diffusive-localization crossover shows a non-obvious transition of the distribution between both regimes [2].
The properties of the transmittance of a multi-channel random wave-guide with absorption have been computed within the Random Matrix framework [3,4]. In the limit of very strong absorption compared with the disorder, statistical properties have been calculated in the diffusive limit (the transmittance distribution is Gaussian) and the localized limit (lognormal distribution) [4]. The understanding of the transmittance properties in the crossover region between these limits and in systems where the disorder strength can be comparable with the absorption may be important in determining the onset of localization in photonic systems [5-8].
In this work disordered wave-guides have been modeled, both with and without absorption. The transport properties (distributions) of the wave-guides have been calculated as their length it is varied, covering the ballistic, diffusive and localization regimens and the crossovers between them. Absorption considered is strong compared with the disorder used but it is far from the limit considered in ref. [4]. In spite of this consideration and the few channel considered in our calculations, our results show a similar behavior to experimental findings of ref. [8]. Distributions are obtained from numerical calculations from the well-known "tight-binding" model.
To illustrate our finding, the results of two sets of wave-guides (with and without disorder) are discussed. Both sets have a width of $N=7$ and disorder strength $W=1$. The guides with absorption have an absorption length of $L_a=39$. The localization lengths are $\xi=108$ for the case of wave-guides with absorption ($L_a<\xi$, but far for the limit considered in ref [4] where L_a/ξ is used as a small parameter) and $\xi=161$ if there is not absorption. Note that a non-zero imaginary component of the on-site energy produces, as well as absorption, an increase of the scattering that results in a decreases of l and ξ. Distributions of the transmission $P(T)$ on the crossover show a smooth crossover between Gaussian and lognormal distribution (unlike the no-absorbing case [2]).
In figure 1 the product of $var(s_a)\xi/L$ is presented versus the system length L. The choice of this representation is due to make easier the comparison with experimental results of ref. [8]. Notice that localization lengths $\xi=(N+1)l$ are different if absorption is considered or not (and that $N+1$ can not be approximated by N due to its low value). The results of both cases are very similar in the semi-ballistic regime, showing an increase with the length. In the diffusive regime results start to diverge. Within this regime, the no absorbing case shows an

approximately constant value, close to $var(s_a)=2x/3L$ that it is predicted within the Random Matrix framework [9]. As L increases and the system leaves this regime entering into the localized one, $var(s_a)\cdot x/L$ increase again showing approximately a parabolic growth.

Wave-guides with absorption behave different after the semi-ballistic regime. At the beginning of the diffusive regime $var(s_a)x/L$ reaches the *2/3* value, then start to decrease as *L* increases. It presents a minimum (with value *»1/2*) around the localization length x, increasing again the ratio $var(s_a)x/L$ as the system goes deep into the localization regime. These results cannot be compared with theoretical ones from ref. [4], obtained under the assumption of $L_a/x<<1$. In spite of this, in that work it is predicted for $var(s_a)x/L$ a variation from 2/3 to 1/2 in the diffusive regime, but it assumed that it remains constant after the crossover.

On other hand, a similar behavior to our calculations was found in experiments of ref. [8], both the direct measurements with absorption ($var(s_a)x/L$ shows a minimum in that work near the crossover) and processed data where the absorption effect was eliminate ($var(s_a)x/L$ shows then a quadratic growth).

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Figures:

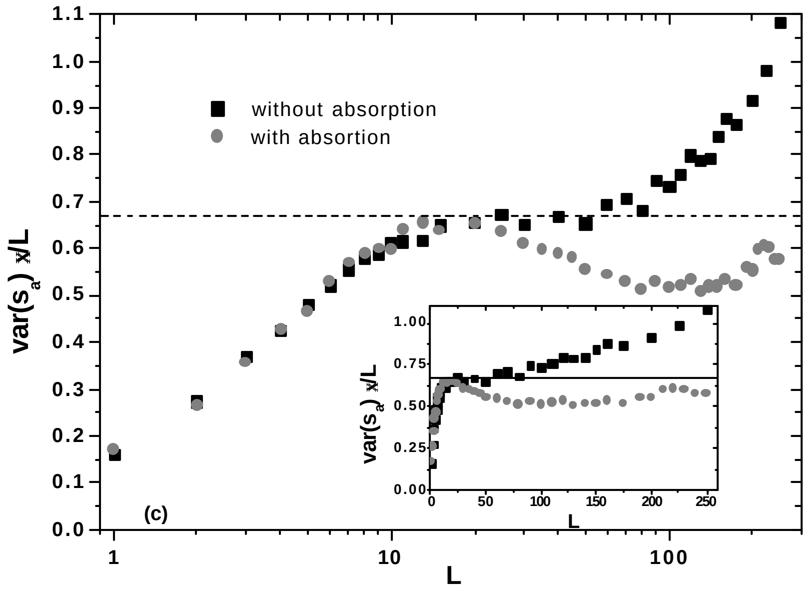

FIGURE 1. $var(s_a)\cdot x/L$ vs. the systems length *L* for two cases of wave-guides simulations: without absorption (black squares) and with a moderate amount of absorption (gray circles). Inset shows the same data using a linear scale for *L*. Dashed lines represent predictions of the Random Matrix approach for the diffusive regime: $var(s_a)=2x/3L$.