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Dark Modes in Open Disordered Media: Analytical, Numerical, and Experimental Results

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Abstract:

We explore numerically, analytically, and experimentally the relationship between quasi-normal modes (QNMs) and transmission resonant peaks (TR) in the transmission spectrum of one-dimensional (1D) and quasi-1D open disordered systems, both optical and electron. It is shown for the first time that for weak disorder there exist two types of the eigenstates: ordinary QNMs which are associated with a TR, and dark QNMs which do not exhibit peaks in transmission or within the sample. In addition, unlike ordinary QNMs, the lifetimes of dark modes goes down or increase anomalously slowly as disorder increases. Over a wide range of the strength of disorder, the ratio N_{res}/N_{mod} of the number of transmission peaks N_{res} to the number of QNMs N_{mod} is insensitive to the type and degree of disorder and is close to the value $\sqrt{\frac{2}{5}}$ which we derive analytically in the weak-scattering approximation. Dark modes have been also discovered experimentally in quasi-1D open disordered samples. Our microwave measurements and modal analysis of transmission in the crossover to localization in quasi-1D systems give a ratio of $N_{res/Nmod}$ close to $\sqrt{\frac{2}{5}}$. In diffusive quasi-1D samples, however, $N_{res/Nmod}$ falls as the effective number of transmission eigenchannels, M, increases. Once N_{mod} is divided by M, the ratio $N_{res/Nmod}$ is close to the ratio found in 1D.