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Talk Invited | Invited Talk

Wave Propagation in Nonlinear Disordered Chains

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The absence of wave packet diffusion in disordered linear models is well established and Anderson localization in one-dimensional chains is universal. When nonlinearity is introduced, interactions between localized eigenmodes may increase the localization length. Numerical studies in nonlinear disordered models even suggest that this length diverges and that Anderson localization is destroyed as a consequence of nonlinearities. Localization in disordered media originally received considerable attention in condensed matter physics, where nonlinearities may be present due to interactions (such as between electrons and phonons [1]). In recent experiments with nonlinear optical systems and Bose-Einstein condensates, the combined effects of disorder and nonlinearity were observed. Further theoretical and numerical work is required in order to determine the infinite time limit profile of initially localized states in spatially infinite nonlinear disordered chains.

We examine the long time evolution of wave packets in Discrete Nonlinear Schrödinger (DNLS) and related models. For initially localized packets of finite energy injected in isolated systems at some initial time, we present cases where there is absence of diffusion, i.e., localization is not destroyed by nonlinearity. Localized initial solutions in the form of stable intraband or extraband discrete breathers [2] persist for infinite time at zero temperature. When the initial wave packet is not an exact discrete breather solution, we prove that in DNLS models with strong enough nonlinearity, the participation number (a measure of localization) of the wave packet cannot diverge [3]. Besides these cases, where absence of diffusion is rigorously proven, we provide numerical evidence that localization persists in general in isolated systems. Even when nonlinearity induces an increase in second moment and participation number, the latter may not diverge. We describe results for DNLS-like models which are also norm conserving but with purely nonlinear nearest (and next nearest) neighbor interactions, where rigorous results are available at weak nonlinearity. For small enough nonlinearity, we observe nondiffusive quasiperiodic (KAM) solutions, in agreement with theorem predictions, and no spreading of initially localized wave packets. For higher nonlinearity, after an initial chaotic spreading, there is absence of diffusion.

Nonlinear transmission in externally driven systems is also discussed [4]. We study propagation in time-periodically driven disordered nonlinear chains. For frequencies inside the band of linear Anderson modes, we observe three different regimes with increasing driving amplitude: 1) Below threshold, localized quasiperiodic oscillations and no spreading; 2) Close to threshold, initially almost regular oscillations, weak chaos and slow spreading for intermediate times, and finally strong diffusion; 3) Immediate spreading for strong driving. The thresholds are due to bifurcations, obtained as turning-points of the nonlinear response manifold.

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