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Incoherent Waves and Random-Phase Solitons in Nonlinear Periodic Systems

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The coherence of waves in periodic systems is crucial to their dynamics, as interference effects, such as Bragg reflections, largely determine their propagation. Most waves in nature, however, are only partially coherent, with fluctuations imparting a statistical character to their dynamics. While linear systems allow superposition, nonlinearity introduces a nontrivial interplay between the lattice structures, the coherence of the waves, and the nonlinearity. A major part of my doctoral research has been the theoretical and experimental study of the propagation of partially-incoherent light in nonlinear photonic lattices. Of particular importance was the prediction of incoherent lattice solitons, the characterization of their statistical properties and power spectra, and the first observation of random-phase solitons in nonlinear photonic crystals. My experiments in fact constitute the first observation of self-trapped incoherent wave-packets in any periodic system in nature. In addition, the experiments revealed that, under proper conditions, an incoherent beam with homogeneous **k**-space (momentum space) distribution can evolve into an incoherent lattice soliton. That is, during nonlinear propagation, there is a nontrivial energy transfer between the lattice modes. Further investigation of this energy-exchange led to the development of a new spectroscopy technique for periodic potentials, facilitating single-shot visualization of the extended Brillouin zones of the photonic lattice with the various bands and gaps, the spectrum of defects embedded in the lattice, and the regions of normal and anomalous diffraction. This research lays the foundation for all-optical studies of coherence dynamics that are universal to a variety of fields. Examples include photonic lattices, charge-density and spin waves in solids, phonons in biological molecules, and partially-condensed (finite-temperature) matter waves in periodic traps.