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Induced modulation instability and recurrence in nonlocal nonlinear media

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Plane waves, propagating in a nonlinear self-focusing medium are unstable and small perturbations of the plane wave result in an amplification of the initial perturbations along the propagation. This phenomenon is referred to as modulation instability and it is present in a number of subfields of physics. In this work, we are not only interested in the initial gain of the perturbation, but also in the long term evolution of the beam propagation. In the early 1950s, Fermi, Pasta and Ulam numerically studied the long term energy transfer between spectral modes in the context of nonlinear discrete systems. One would believe that after some time, the system would exhibit 'thermalization', which is an equal distribution of the energy over the different modes, but instead they found that the system exhibits a complicated quasi-periodic behavior, with only a few modes involved. After this observation, a lot of theoretical and numerical work has been carried out, showing that FPU recurrence is possible for many nonlinear wave equations. Experimentally, FPU recurrence has been demonstrated in the temporal optical domain in optical fibers and recently it has been demonstrated in the spatial optical domain in nematic liquid crystals. The spectral dependence of the modulation instability has been investigated experimentally by launching two broad elliptical beams into the cell. The beam intensity exhibits an initial sinusoidal perturbation along one direction and the spatial frequency is controlled by changing the angle between the two beams. Beside the experiments, a theoretical model of the recurrence has been elaborated. The model incorporates a nonlocal Kerr nonlinearity of either exponential or Gaussian nature. The influence of the nonlocality of the nonlinearity on the recurrence phenomenon is investigated by changing the nonlocal parameter. The model also allows an analytical solution of the recurrence for spatial frequencies close to the cut-off frequency. But it also provides inside at the beam evolution for smaller frequencies. For these small frequencies no periodic behavior is possible, which was also observed in the experiments. This is due to the fact that a larger number of orders are amplified for small spatial frequencies.

Keywords: spatial solitons, nematic liquid crystals, optical reorientational nonlinearity, Fermi-Pasta-Ulam recurrence