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Solitary waves and their linear stability in nonlinear lattices

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(Submitted on 1 Jul 2011)

Solitary waves in a general nonlinear lattice are discussed, employing as a model the nonlinear Schr\"odinger equation with a spatially periodic nonlinear coefficient. An asymptotic theory is developed for long solitary waves, that span a large number of lattice periods. In this limit, the allowed positions of solitary waves relative to the lattice, as well as their linear stability properties, hinge upon a certain recurrence relation which contains information beyond all orders of the usual two-scale perturbation expansion. It follows that only two such positions are permissible, and of those two solitary waves, one is linearly stable and the other unstable. For a cosine lattice, in particular, the two possible solitary waves are centered at a maximum or minimum of the lattice, with the former being stable, and the analytical predictions for the associated linear stability eigenvalues are in excellent agreement with numerical results. Furthermore, a countable set of multi-solitary-wave bound states are constructed analytically. In spite of rather different physical settings, the exponential asymptotics approach followed here is strikingly similar to that taken in earlier studies of solitary wavepackets involving a periodic carrier and a slowly-varying envelope, which underscores the general value of this procedure for treating multi-scale solitary-wave problems.

Comments: To appear in Stud. Appl. Math
Subjects: **Optics (physics.optics)**; Pattern Formation and Solitons (nlin.PS)
Cite as: **arXiv:1107.0331 [physics.optics]**
(or **arXiv:1107.0331v1 [physics.optics]** for this version)

Submission history

From: Jianke Yang [view email]
[v1] Fri, 1 Jul 2011 20:36:35 GMT (40kb)

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