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Broad Band Solitons in a Periodic and Nonlinear Maxwell System

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We consider the one-dimensional Maxwell equations with low contrast periodic linear refractive index and weak Kerr nonlinearity. In this context, wave packet initial conditions with a single carrier frequency excite infinitely many resonances. On large but finite time-scales, the coupled evolution of backward and forward waves is governed by nonlocal equations of resonant nonlinear geometrical optics. For the special class of solutions which are periodic in the fast phase, these equations are equivalent to an infinite system of nonlinear coupled mode equations, the so called it extended nonlinear coupled mode equations, xNLCME. Numerical studies support the existence of long-lived spatially localized coherent structures, featuring a slowly varying envelope and a train of carrier shocks.

In this paper we explore, by analytical, asymptotic and numerical methods, the existence and properties of spatially localized structures of the xNLCME system, which arises for a refractive index profile consisting of periodic array of Dirac delta functions.

We consider the limit of small amplitude solutions with frequencies near a band-edge. In this case, stationary xNLCME is well-approximated by an infinite system of coupled, stationary, nonlinear Schr\"odinger equations, the extended nonlinear Schr\"odinger system, xNLS. We embed xNLS in a one-parameter family of equations, xNLS$^\epsilon$, which interpolates between infinitely many decoupled NLS equations ($\epsilon=0$) and xNLS ($\epsilon=1$). Using bifurcation methods we show existence of solutions for a range of $\epsilon\in(-\epsilon_0,\epsilon_0)$ and, by a numerical continuation method, establish the continuation of certain branches all the way to $\epsilon=1$. Finally, we perform time-dependent simulations of truncated xNLCME and find the small-amplitude solitons to be robust to both numerical errors and the NLS approximation.

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