Linear and nonlinear frozen light in waveguides

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Abstract:

We show theoretically that high-order stationary points (SPs), where $\Delta\omega \propto \Delta k^m$ for $m > 2$ (see Fig. 1a), can be created in the dispersion relation of optical waveguides using a (near) periodic refractive index perturbation. Near such SPs light can be coupled efficiently into low and even zero group velocities modes, leading to high field strength ("frozen light"). Stationary solutions to the nonlinear coupled mode equations for these systems, including the effects of a Kerr nonlinearity, are discussed.

When low-intensity light is tuned in the bandgap near a regular, quadratic band edge the field decays exponentially and so the energy in the structure is low and most incident light is reflected. At high intensities, the (positive) nonlinearity shifts the band features to lower frequencies, changing the transmission [1]. Because the field inside the structure is weak, this requires high intensities. In contrast, near a high-order stationary SP the structure has strong evanescent modes [2,3], which allow for the high coupling efficiency. As a consequence, even in the linear limit, the field inside the structure is substantial, and so increasing the input power causes a much larger shift, reducing the switching threshold. We modeled the switching in such structures and find regimes where the switching is stable and does not exhibit a bistability (see Fig. 1(b)). Higher input intensities lead to pulse trains due to modulation instability (Fig. 1(c)) [4]. These structures have multiple input channels and their exploitation requires the relative amplitude and phase of the two channels to be carefully chosen.

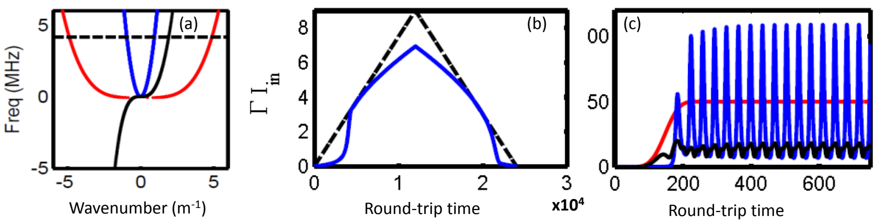

Figure 1: (a) Schematics of quadratic (blue), cubic (black) and quartic (red) stationary points. (b) Input and output intensities normalized to the nonlinearity versus time for a waveguide with quartic SP, showing stable all-optical switching. (c) Modulation instability in a quartic SP waveguide at moderately high intensities.

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