Coupled nonlinear Schrödinger equations, Lotka-Volterra models, and control of soliton collisions in broadband optical waveguide systems.

Abstract:

Transmission rates in broadband optical waveguide systems are enhanced by launching many pulse sequences through the same waveguide. Since pulses from different sequences propagate with different group velocities, intersequence pulse collisions are frequent, and can lead to severe transmission degradation. On the other hand, the energy exchange in pulse collisions can be beneficially used for controlling the transmission.

In this work we show that collision-induced amplitude dynamics of soliton sequences of $N$ perturbed coupled nonlinear Schrödinger (NLS) equations can be described by $N$-dimensional Lotka-Volterra (LV) models, where the model’s form depends on the perturbation. To derive the LV models, we first carry out single-collision analysis, which is based on the method of eigenmode expansion with the eigenmodes of the linear operator describing small perturbations about the fundamental NLS soliton. We use stability and bifurcation analysis for the equilibrium points of the LV models to develop methods for achieving robust transmission stabilization and switching that work well for a variety of waveguides. Further enhancement of transmission stability is obtained in waveguides with a narrowband Ginzburg-Landau gain-loss profile. We also discuss the possibility to use the relation between NLS and LV models to realize transition to spatio-temporal chaos with NLS solitons.