Soliton nucleation in ultrafast periodically pumped 1D ferromagnetic chain by the pseudo-spectral Landau-Lifshitz equation

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Abstract

Ultrafast magnetism gives rise to intriguing far-from-equilibrium processes, including soliton nucleation [1] and novel phases of matter [2]. Studies in ultrafast magnetism are typically complement experiments with input from atomistic spin dynamics (ASD) simulations, or micromagnetics [3]. However, ASD requires significant computing and storage resources, and the micromagnetic model inflates the magnon frequency due to the continuum approximation. Thus, the dynamics between the two regimes have been difficult to resolve. We introduce a pseudo-spectral Landau Lifshitz equation (PS-LLE) to bridge the gap between ASD and micromagnetics. We apply this method to investigate ultrafast dynamics due to a pump grating with a period of 80 nm in a perpendicular magnetic anisotropy, quasi-one-dimensional chain. ASD predicts the nucleation of solitons, as shown in Fig. 1(a). The PS-LLE model also shows soliton nucleation in qualitative agreement with ASD, shown in Fig. 1(b). However, the micromagnetic model fails because of the inflated magnon frequencies and group velocities due to the continuum approximation, shown in Fig. 1(c). The PS-LLE also predicts other nonlinear phenomena including modulational instability [4] and dispersive shock waves [5]. Thus, with the capacity for multiscaled grids between atomistic and continuum models, our PS-LLE method opens the door for the exploration of nonlinear and far-from-equilibrium magnetization dynamics, including modulational instability [4], short-wavelength excitations [6], and three-dimensional topological textures [7].

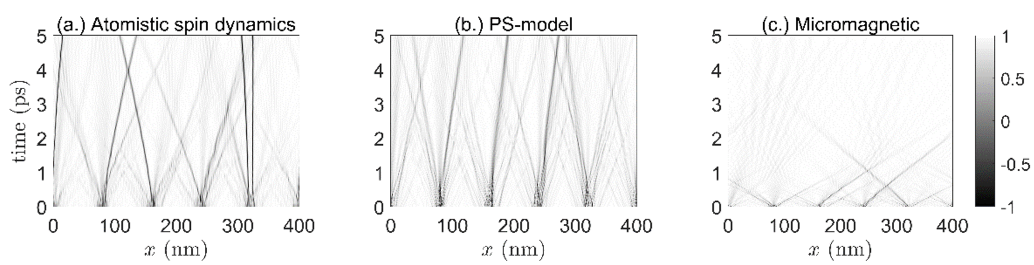

Figure 1: Comparison of soliton nucleation between ASD (a), PS-LLE (b), and micromagnetic (c).

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