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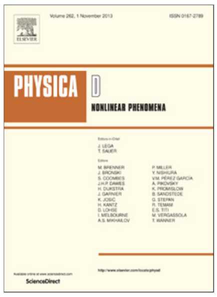

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Modeling Ultrashort Electromagnetic Pulses with a Generalized Kadomtsev-Petviashvili Equation

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Abstract

In this paper we derive a properly scaled model for the nonlinear propagation of intense, ultrashort, mid-infrared electromagnetic pulses (10-100 femtoseconds) through an arbitrary dispersive medium. The derivation results in a generalized Kadomtsev-Petviashvili (gKP) equation. In contrast to envelope-based models such as the Nonlinear Schrödinger (NLS) equation, the gKP equation describes the dynamics of the field's actual carrier wave. It is important to resolve these dynamics when modeling ultrashort pulses. We proceed by giving an orginal proof of sufficient conditions on the initial pulse for a singularity to form in the field after a finite propagation distance. The model is then numerically simulated in 2D using a spectral-solver with initial data and physical parameters highlighting our theoretical results.

Keywords: nonlinear optics, Kadomtsev-Petviashvili equation, filamentation

1. Introduction

The study of ultrashort laser pulse filamentation has advanced significantly over the past two decades [Bandrauk (2016)]. As the critical power for self-focusing scales directly with the square of the pulse's central wavelength, recent research has focused on studying longer wavelength beams with increasing filament energies. There has been particular interest in mid-infrared filament formation in the atmosphere which could lead to revolutions in long-range signal transmission and high intensity laser delivery systems, [Mitrofanov (2015)] and [Panagiotopoulos (2015)]. The nonlinear optics community has traditionally relied on a modified Nonlinear Schrödinger (NLS) equation to model filament formation. Although as pulse durations shrink