Nonlinear envelope equation for broadband optical pulses in quadratic media

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Abstract:

We outline the derivation of a nonlinear envelope equation (NEE) to describe the propagation of broadband optical pulses in second order nonlinear materials. Our approach goes beyond the usual coupled wave description of $\chi^{(2)}$ phenomena and provides an accurate modelling of the evolution of broadband pulses also when the separation into different coupled frequency bands is not possible or not profitable.

The analysis of optical pulse propagation typically involves the definition of a complex envelope "slowly" varying with respect to the oscillation of a carrier frequency [1]. Different authors showed how to extend the validity of the envelope equation to pulse duration down to the single optical oscillation cycle [1] and to the generation of high order harmonics [2]. When second order nonlinearities are considered, the usual approach is to write coupled equations for the separated frequency bands relevant for the process. However if ultra-broadband $\chi^{(2)}$ phenomena take place, the different frequency bands might merge, generating a single broad spectrum, as observed in recent experiments [3, 4] and in these cases the coupled NEE description fails due to the overlapping between different frequency bands.

We derive here a single wave envelope equation to describe ultra-broadband $\chi^{(2)}$ interactions. To date, such a model is not available and the only way to numerically describe phenomena as those reported in [3, 4] is to solve directly Maxwell equations in time domain, with an immense computational burden. Our equation can be solved with a modest computational effort and can be easily generalized to include other kind of nonlinearities such as Kerr or Raman.

References:

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