Extending the Complex Jacobi Iteration method to simulate Kerr non-linear effects

Peter Vandersteegen, Peter Bienstman, Roel Baets

INTEC, Ghent University - IMEC, St Pietersnieuwsstraat 41, 9000 Ghent, Belgium

Peter.Vandersteegen@intec.UGent.be

In this paper we present a numerical method to simulate an area containing materials with a non-linear third order Kerr effect. This method is based on an extension of the recently introduced complex Jacobi Iteration method.

Keywords: numerical modelling, complex Jacobi iteration, non-linear, Kerr effect, PML

Achieving all-optical functionality in integrated components requires materials which exhibit non-linear effects. The almost instantaneous Kerr effect with its intensity dependent index change is considered a promising route to achieve fast optical switching functionality. Simulating a Kerr non-linear optical component in the frequency domain results in numerically solving a slighty adapted Helmholtz equation.

The recently introduced Complex Jacobi Iteration method [1] is a fast method to solve the linear Helmholtz equation. Starting with a discretized grid and Helmholtz operator, this method finds a solution by an iterative process. Each iteration step the calculated fields are refined until a desired error is achieved.

To model non-linear Kerr effects, an extra step is introduced in the iterative update scheme. At each iteration step a new refractive index is calculated based on the found field-intensity. A relative error smaller than 1.e-8 can be achieved.

Fig 1 shows the absolute E-field of a propagating soliton in an uniform material. The maximum relative index change - at the center of this soliton - is 15%. The use of a material with high non-linear Kerr effect only results in a slight increase of iteration steps. Good absorption at the boundaries is achieved by using perfectly matched layers (PML). The implementation of these PML is done with complex coordinate stretching .

(a) linear material   (b) non-linear material ($\chi^3 = 6.0\frac{\mu m^2}{V^2}$)
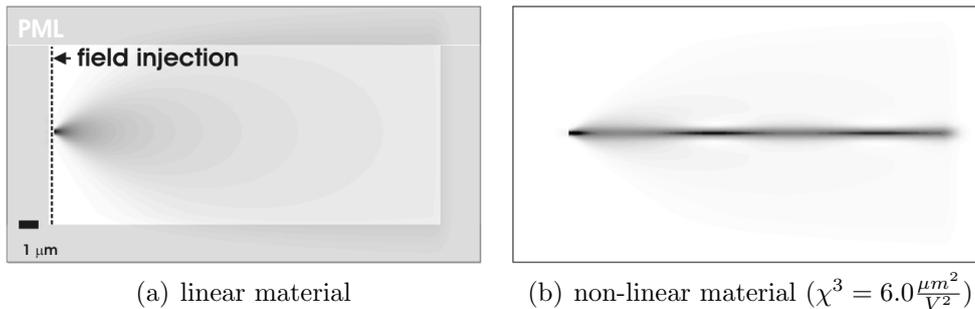
Fig. 1. Injecting a Gaussian bundle in a non-linear Kerr material results in a soliton.
($\epsilon = 12.96 - 0.001j$, E $= 1.0e^{\frac{-x^2}{2(0.1)^2}}$ $[\frac{V}{\mu m}]$)

[1] G. Ronald Hadley, 'Solving the 3D Helmholtz Equation By Complex Jacobi Iteration', *Optical Waveguide Theory and Numerical Modelling 2004*, **OWTNM'04**, p.15, 2004.