Numerical Analysis of Kerr Effect in the Core of a Photonic Crystal Fiber

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1. Background:

As light travels in the core of a photonic crystal fiber, many phenomena are observed like the parametric nonlinearities from the third-order susceptibility composed of Kerr Effect and the Stimulated Raman Scattering. In this report, the Kerr effect in the core of a photonic crystal fiber is examined by using the Z transform. The 2D FDTD is used as numerical technique, and Z transform is applied instead of the Fourier Transform. As the numerical examples, the square lattice phonic crystal fiber is considered as simulation structure. We observed only the weak Kerr Effect in the propagation pulse.

2. Cross-section of the phonic crystal fiber

The square lattice PCF studied has a silica core, obtained by creating a defect in the middle of the waveguide simply by removing one cylinder.

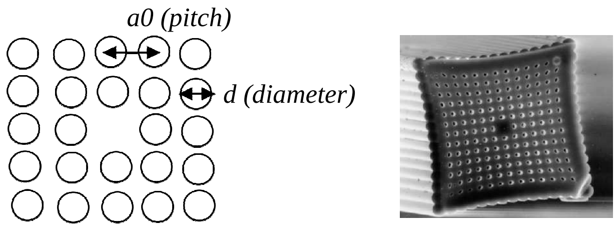

Fig1. *Square lattice Photonic crystal fibers*

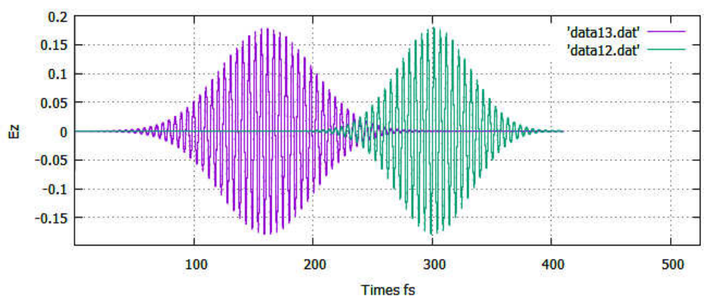

Fig2. *Propagation of the linear pulse at t=160,300 fs and* $\chi^{(3)} = 0$

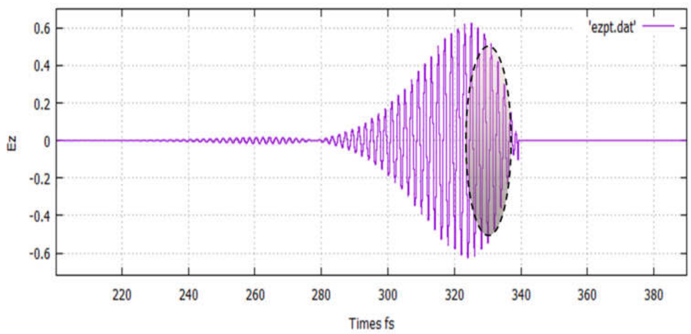

Fig3.*Propagation of nonlinear pulse pulse with* $\chi^{(3)} = 0.07$

3. Methodology:

The 2D FDTD method is used as numerical method with a Mur's boundary condition. By applying the Z transform to the linear polarization (P_L), the nonlinear Kerr Effect (P_K) and Raman scattering (P_R) we got the following expressions:

Time domain

$P_L(t) = \varepsilon_0 \int_0^t \chi^{(1)}(t-\tau).E(\tau)d\tau$ 2.1

$P_K(t) = \varepsilon_0 \chi^{(3)} \alpha E^3(t)$ 2.2

$P_R(t) = \chi_0^{(3)}(1-\alpha)E(t)\int_0^t \varepsilon_0 g_R(t-\tau)E^2(\tau)d\tau$ 2.3

After Z transform

$P_L^n = \varepsilon_0 S_L^{n-1}$ 2.4

$P_K^n = \varepsilon_0 \chi^{(3)} \alpha\{3(E^{n-1})^2 E^n - 2(E^{n-1})^3\}$ 2.5

$P_R^n = \chi_0^{(3)}(1-\alpha)E^n S_L^{n-1}$ 2.6

Where α is a real valued constant in the range of $0 \le \alpha \ge 1$. It parameterizes the relative strengths of Kerr and Raman interaction [1]. When $\alpha = 1$ the Raman Scattering (P_R) is equal to zero ($P_R = 0$) equation (2.6). Only the Kerr effect (P_K) will remain in the electric field expression as follow:

$$\boldsymbol{E^n} = \frac{D^n/\varepsilon_0 - S_L^{n-1} + 2\chi_0^{(3)}(E^{n-1})^3}{\varepsilon_\infty + 3\chi_0^{(3)}(E^{n-1})^2} \quad 2.7$$

4. Simulations and discussions

Table1. *Represent the different parameters of the PCF.*

Pitch a0	2*d
Nx	3001
Ny	101
Core diameter	0.7 μm
$\chi^{(3)}$(core)	0.07(v/m)$^{-2}$
$\varepsilon_\infty(core)$	2.25
$\varepsilon_\infty(clad)$	2.1

In Fig.2, we observed a uniform pulse propagating at different time but in Fig4 we observed a little transformation at the end of the pulse which represents the nonlinear Effect.

5. Conclusions

The Kerr effect is a weak effect that affects the propagation pulse. By using the Z transform,we observe only the Kerr effect in the nonlinear propagation pulse. So in a square lattice photonic crystal fiber, the Kerr effect is weak in the core area as shown in fig3, we see a slightly deformation at the end of the pulse. The square lattice photonic crystal fiber is promised to be a very important tool for the long distance transmission.

6. Reference

[1] A.Taflove, S.C. Hagness "*Computational electrodynamics the finite Difference Time Domain Method*"third Ed, Artech house,2005.