A novel model of Cross Phase Modulation in WDM optical systems

A. Carena[1,2], P. Cobetto Ghiggia[1], V. Curri[1,2]

[1]Politecnico di Torino, Optical Communications Group, C.so Duca degli Abruzzi 24, 10129 Torino, Italy

www.optcom.polito.it optcom@polito.it

[2] Alps Telecommunications Software Srl, via Pier Carlo Boggio 61, 10138 Torino, Italy

www.alps-telsoft.com info@alps-telsoft.com

Abstract

We propose a novel model for the evaluation of intensity and phase distortion due to XPM in WDM optical systems. The XPM effect is modeled as a perturbing term multiplying the undistorted signal.

Motivation

- XPM is the main performance limiting phenomenon for long-haul high-capacity WDM systems
- Simulation of Nonlinear Schroedinger equation based on the Split-Step method is not a viable approach: highly time consuming, allows only to study few realizations and does not separate different effects
- Previously proposed models, based on pump and probe approach, can not be extended to the practical case of a modulated probe

Math

Starting point: the Nonlinear Schroedinger equation

$$\frac{\partial a_i(z,t)}{\partial z} = -\alpha a_i(z,t) + \frac{1}{2} j\beta_{2i} \frac{\partial^2 a_i(z,t)}{\partial t^2} - j\gamma \left[|a_i(z,t)|^2 + 2\sum_{\substack{k=1\\k\neq i}}^{N_{ch}} |a_k(z,t)|^2 \right] a_i(z,t)$$

The innovative assumption:
XPM perturbation is a multiplicative factor

$a_{i0}(z,t)$ signal propagated in single channel condition

$\rho(z,t)$ XPM multiplicative factor

$$a_i(z,t) = a_{i0}(z,t) \cdot \rho(z,t)$$

$$\frac{\partial \rho(z,t)}{\partial z} = \frac{1}{2} j\beta_{2i} \frac{\partial^2 \rho(z,t)}{\partial t^2} - 2j\gamma \sum_{\substack{k=1\\k\neq i}}^{N_{ch}} |a_k(z,t)|^2 \rho(z,t) + j\beta_{2i} \left[\frac{1}{a_{i0}(z,t)} \frac{\partial a_{i0}(z,t)}{\partial t} \frac{\partial \rho(z,t)}{\partial t} \right]$$

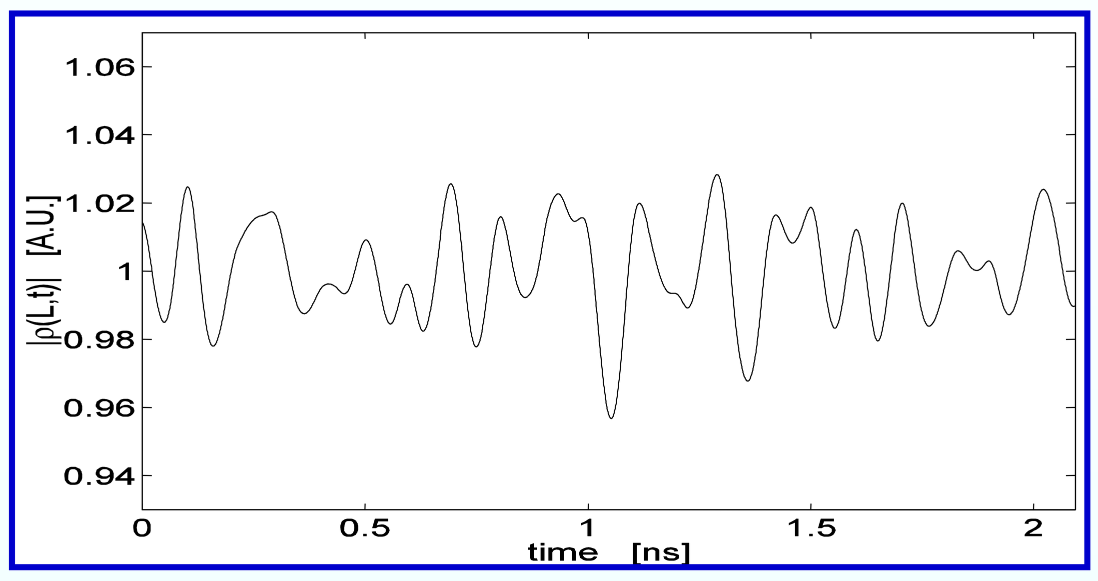
$$\frac{\partial \rho(z,t)}{\partial z} = \frac{1}{2} j\beta_{2i} \frac{\partial^2 \rho(z,t)}{\partial t^2} - 2j\gamma \sum_{k=1,k\neq i}^{N_{ch}} |a_k(z,t)|^2 \rho(z,t)$$

Method

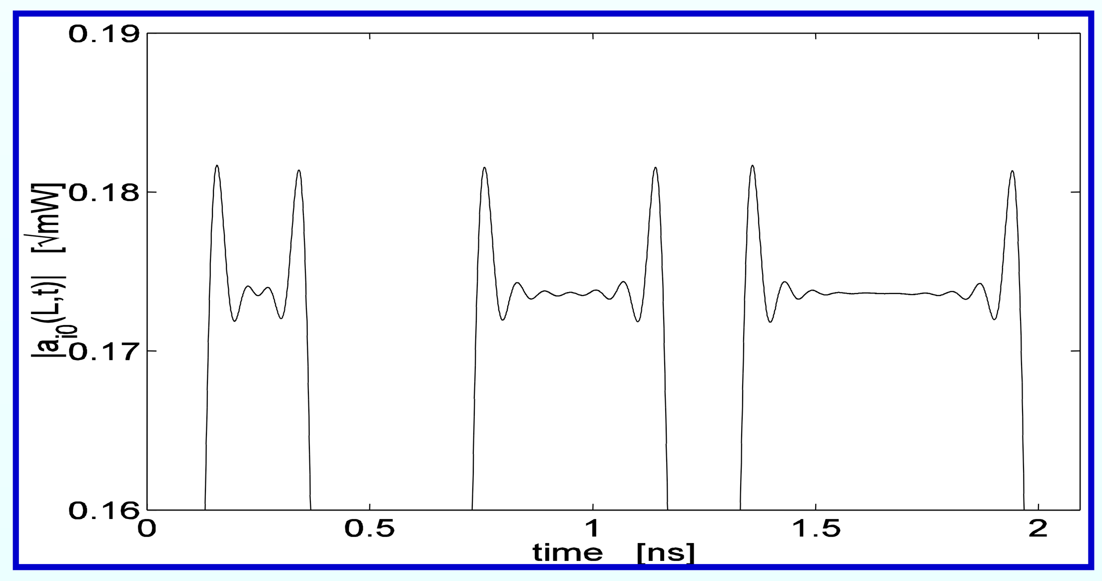
- Evaluation of $a_{i0}(L,t)$ using standard Split-Step method
  - Single channel simulation: very fast
- Evaluation of $\rho(z,t)$ by mean of the new derived equation
- Calculation of $a(L,t)$
- **Eventually**: Monte-Carlo study over thousands of realizations in order to statistically characterize the XPM perturbation

Validation

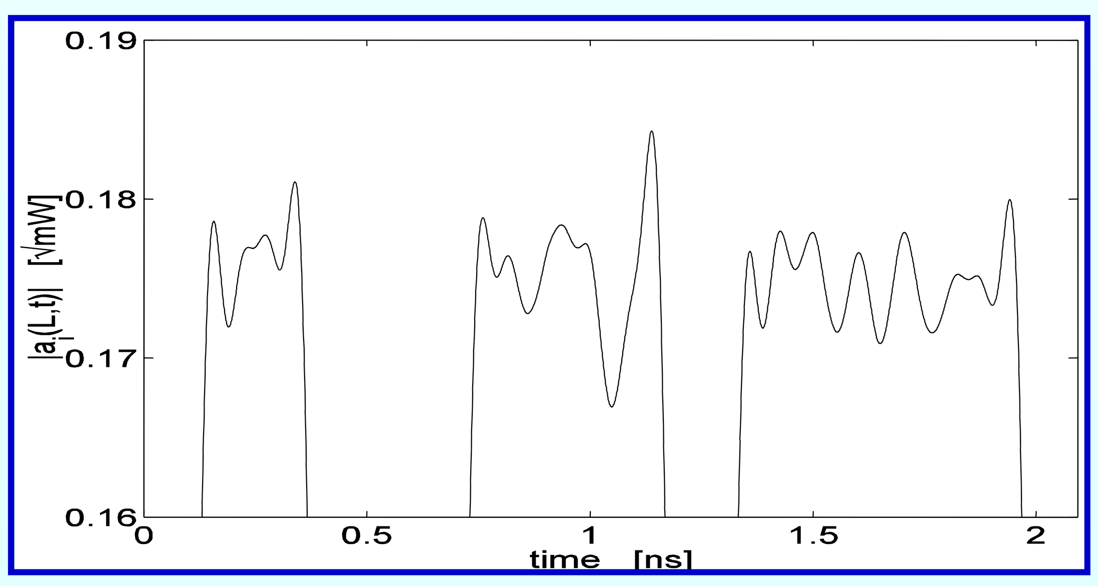
- WDM system: 9 channels @ 10 Gbit/s, Δf=100 GHz
- 100 km of NZDSF fiber (β_2=-5.74 ps^2/km, γ=1.84 W^{-1}km^{-1})
- Transmitted power: 0 dBm per channel



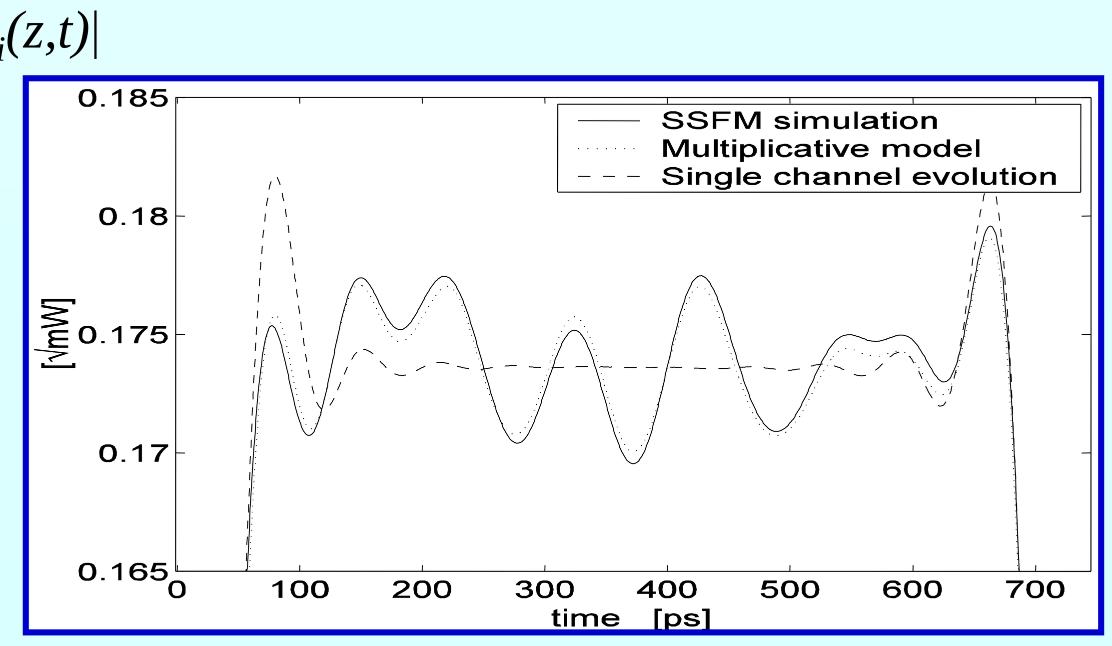
Plot of $|\rho(z,t)|$



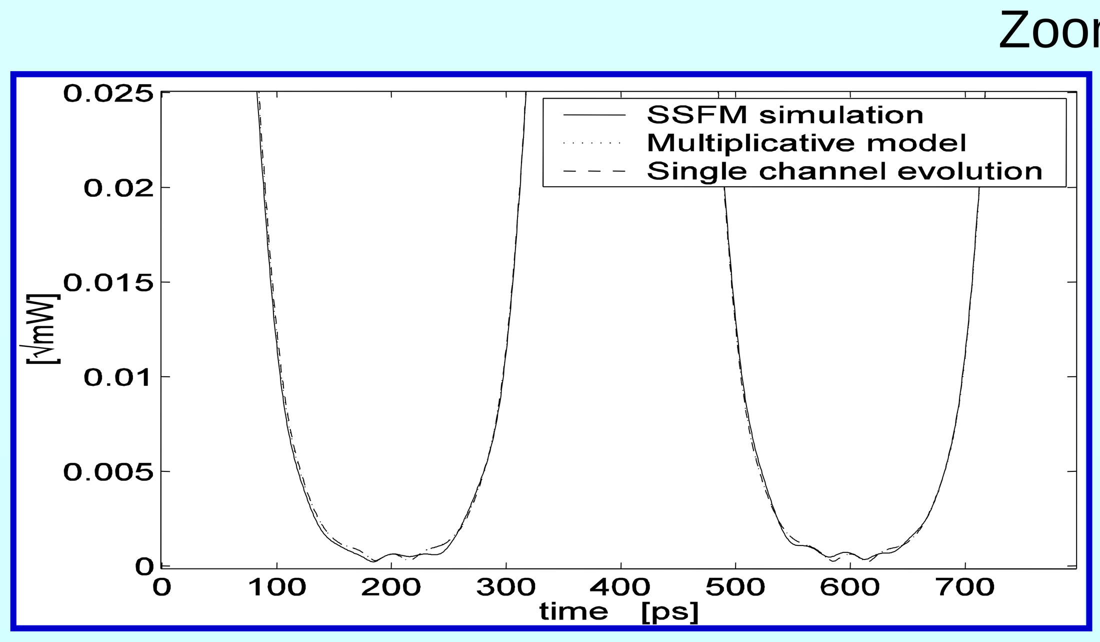
Plot of $|a_{i0}(z,t)|$



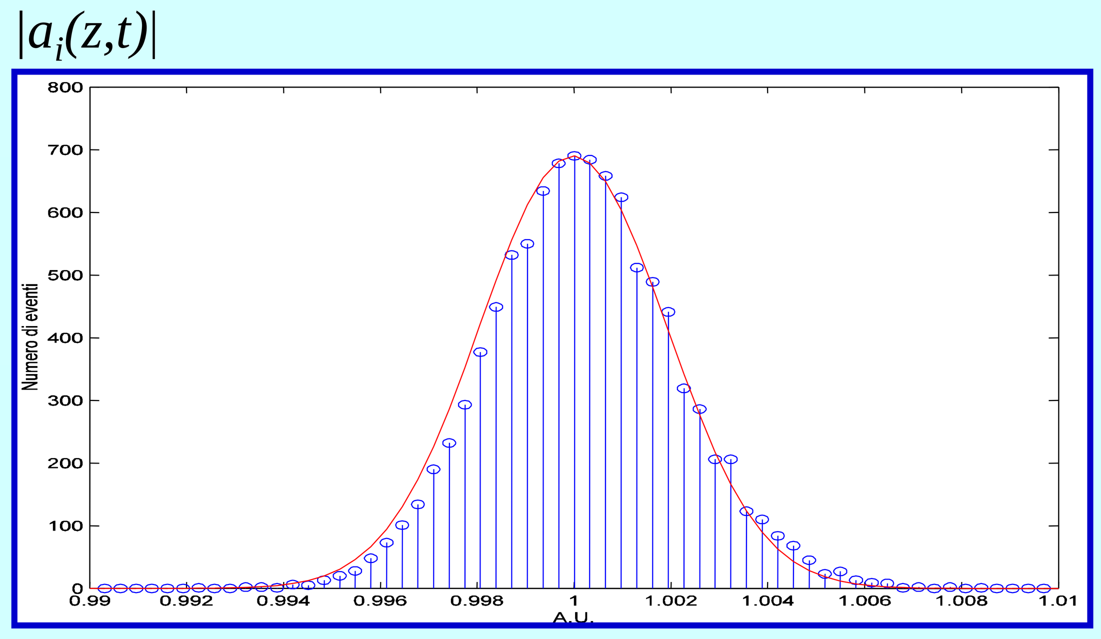
Plot of $|a_i(z,t)|$



Zoom on $|a_i(z,t)|$



Zoom on $|a_i(z,t)|$



Pdf Histogram of $|\rho(z,t)|$