

## Self-Phase Modulation in Slow-Wave Structures: a comparative numerical analysis

Francesco Morichetti<sup>\*,†</sup>, Andrea Melloni<sup>\*,†</sup>, P. Bienstman<sup>†</sup>, G. Priem<sup>†</sup>, and J. Petráček<sup>‡</sup>

<sup>\*</sup>CoreCom, Via G. Colombo 81, 20133 Milano, Italy, [morichetti@corecom.it](mailto:morichetti@corecom.it)

<sup>†</sup>Dipartimento di Elettronica e Informazione, Politecnico di Milano, Via Ponzio 34/5, 20133 Milano – Italy

<sup>‡</sup>Department of Information Technology, Ghent University, Sint-Pietersnieuwstraat 41, 9000 Ghent, Belgium

<sup>§</sup>Institute of Physical Engineering, Brno University of Technology, 616 69 Brno, Czech Republic

### Summary

Recently increasing interest has been focused on optical Slow-Wave Structures (SWSs) made of cascaded coupled resonators, because of their interesting potentialities especially in nonlinear regime. The interplay of nonlinearities with the amplitude and phase spectral response of SWSs leads to a variety of novel phenomena that require accurate modelling and computationally efficient numerical techniques to be studied. In this contribution, Self-Phase Modulation effects in SWSs are investigated by means of several 1D approaches, operating either in time or frequency domain, being respectively: (1) a nonlinear extension of the Mode Expansion (ME) method that calculates iteratively nonlinear index changes inside the structure; (2) a Time Domain (TD) nonlinear method exploiting an effective equivalent circuit of the nonlinear Bragg reflector; (3) direct solution of Maxwell's equations in the Frequency Domain (FD) after suitable transformation in the form of coupled ordinary differential equations. The accuracy, computational efficiency (time and memory consume), versatility and limits of the proposed techniques are analysed and compared.

The SWS under investigation was proposed in the framework of COST P11 action [1] and consists of  $N$  Fabry-Pérot cavities, with optical length  $\lambda_0=1550\text{nm}$ , coupled each other by means of an intermediate quarter-wave layer, as shown in Fig. 1(a) for the case  $N = 2$ . The materials of the distributed Bragg reflectors ( $n_b=2.36$ ,  $n_a=2.6$ ) and the medium  $n_a$  filling the cavities are assumed to have the same Kerr nonlinearity ( $n_2 = 0.6 \cdot 10^{-13} \text{ cm}^2 / \text{W}$ ). Fig. 1(b) shows the spectral response of the double-cavity SWS of Fig. 1(a) for increasing input power, calculated by means of the proposed methods. A good agreement is found, with the only exception of the bistability region where the TD method appears less accurate in following sharp amplitude transitions versus frequency. On the other side, the TD method can be straightforwardly used to investigate nonlinear temporal effects occurring in SWS, such as optical limiting, solitary waves propagation and modulation instability.

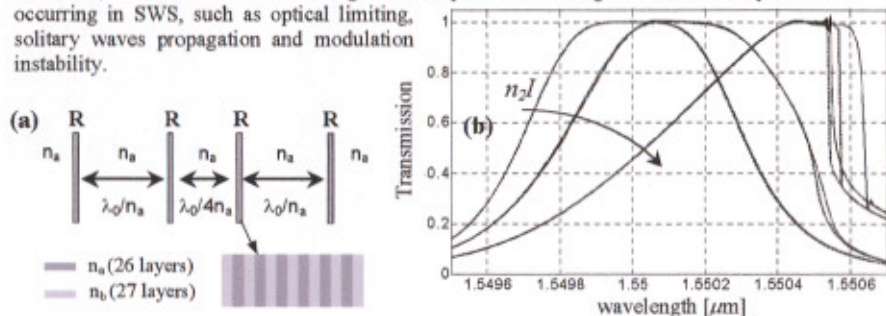


Fig 1: (a) Schematic of a double-cavity SWS. (b) Nonlinear response of the SWS shown in (a) for increasing input intensity  $n_2 I$  ( $0, 2.4 \cdot 10^{-6}, 9.6 \cdot 10^{-6}$ ): TD (continuous lines), ME (dotted lines), FD (dashed lines).

### References

[1] COST P11 website: <http://w3.uniroma1.it/energetica/>

# OWTNM 2006

XV International Workshop on  
Optical Waveguide Theory and  
Numerical Modelling

Proceedings



Varese, Italy 20-21 April 2006

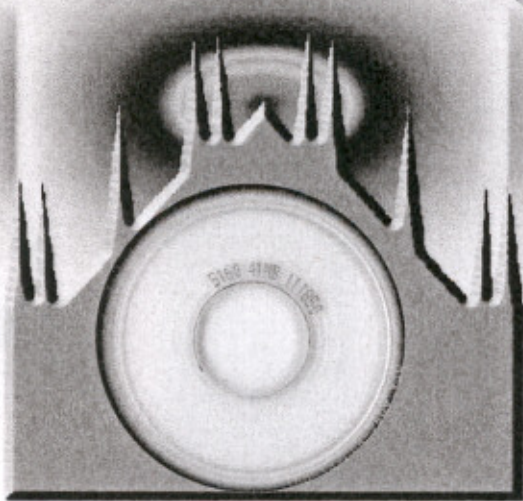
Editor:  
Andrea Melloni, PhD  
Associate Professor  
Politecnico di Milano  
Dipartimento di Elettronica e Informazione

Contact:  
Andrea Melloni  
Piazza Leonardo da Vinci, 32  
I - 20133 Milano, Italy  
e.mail: melloni@elet.polimi.it  
website: <http://www.elet.polimi.it/upload/melloni/index.html>

2006 Politecnico di Milano - Dipartimento di Elettronica e Informazione

ISBN 88-902405-0-4

Printed in Milano - Italy



**O W T N M 2006**  
XV International Workshop on  
Optical Waveguide Theory and Numerical Modelling

Varese, 20/21 April 2006  
Italy