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A model based simulator for integrated optical circuits and free space

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Abstract

A circuit-oriented simulator operating in the spectral domain is presented as a very powerful instrument for advanced analysis of integrated and free-space optical devices. By combining elementary optical building blocks, which can be modelled at different levels of accuracy, complex optical circuits (filters, multiplexers, switches and so on) can be easily generated and their spectral properties fully derived. Computational times are order of magnitude lower than those required by electromagnetic methods.

Summary

The state of the art of numerical simulators in optics is represented by very advanced 3D electromagnetic (EM) methods for a very accurate modelling of wave propagation in optical structured media. Despite different algorithms have been optimised to speed up simulations, any electromagnetic approach is extremely time consuming and is not applicable to the analysis of complex optical circuits including many components.

In this contribution an Advanced Simulator for Photonic Integrated Circuits (ASPIC) is presented, which can be very powerful for the modelling of optical components realized both in integrated optical technologies and free-space. The key-point of the circuit-oriented simulator is that any generic circuit consists of sets of elementary optical building blocks (e. g. waveguides, bends, power splitters, delay lines and so on), each one associated to a suitable model. A model is a set of mathematical equations describing a device with a desired level of accuracy and focusing only on particular properties of the same. Therefore, for each building block, the model is not unique, but several models are available in libraries and even customisable by the user, for instance on the basis of some EM simulations, performed by means of suitable commercial simulators. In this way the accuracy of the simulation can be improved only if and where it is strictly necessary inside the circuit. This approach leads to a computational time reduction of several order of magnitude with respect to any electromagnetic simulator, allowing in that way to simulate circuits as complex as the that one represented in Fig. 1.

This circuit, including many ring resonators, Bragg gratings, directional couplers, can be used as an optical add-drop multiplexer (OADM) for wavelength division multiplexing (WDM) optical systems .

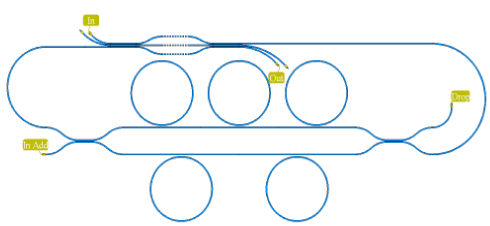

Fig. 1. Representation of an integrated optical circuit. Almost impossible to simulate with electromagnetic simulators, this circuit takes just few seconds for several hundreds of wavelengths to be analysed with a model based simulator.

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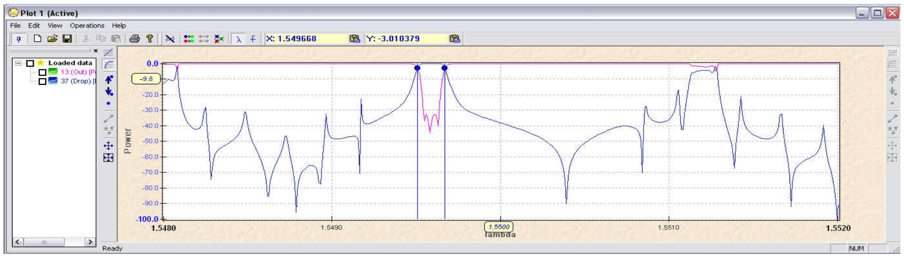

Fig. 2. Simulated spectral response of the circuits represented in fig. 1.

All the computation is carried out in the spectral domain, but an extension to the time domain is in progress. The spectral behaviour of the circuit can be returned in terms of amplitude (Fig.2), phase, group delay, dispersion and polarization state. Several independent light sources, each one with its own spectrum, can be placed in different point of the circuit and each portion of the circuit can be monitored itself as an output port, simply after one simulation run.

The parameters of each component can be defined by variables (or expressions). Variables can be noisy, described through a formatted file and they can be used as indipendent variable to perform the simulation. As an example in the optical isolator represented in Fig. 3, consisting of a Faraday rotator sandwiched between two suitably oriented polarizers, the scanned variable is the rotation angle (theta)that the field experienced passing throgh the Faraday rotator. Results are plotted in Fig. 4.

Fig 3. Representation of the optical isolator.
Sources are present at both sides.

Fig. 4. Output power at the left side (red) and the right side (blue). Since the polarizer placed on the right side is oriented 45° clockwise with respect to the one on the left, there is a maximum transmitted power at an imposed field rotation of 45° (clockwise) passing from left to right and a minimum entering from the opposite side.

In conclusion, this approach is very flexible and can find many applications at different levels of expertise. In educational environments it could permit to increase the learning efficiency through an attractive process: students are able to “play” with circuits seen in the classroom, while professors could exploit it as a useful support during their lessons.