Development of a 3D modeling tool to modelize integrated optical structure with complex profile

PHD subject, duration 36 months

Contact: alain.morand@univ-grenoble-alpes.fr

Photonic devices can be developed in different substrates (Silicon, Nitride, Glass …). To design integrated optic functions, numerical modelling tools are necessary as FDTD, FMM, BPM … These tools are already distributed commercially by different companies. All of these methods suffer from the staircase approximation. The space domain is in fact discretized in small sections (square most of the time) which don't follow exactly the boundary of a waveguide. An artificial roughness appears at the interface inducing reflection or scattering. The objective of this PHD is to develop a 3D tool to minimize this effect in order to reach the ideal structure. Complex profile or real roughness waveguide could after be simulated with a good accuracy using this kind of tool.

For few years ago, Fourier Modal Method has been developed in the world and in our lab [1 and 2]. And recently, we added a Fast Fourier Factorization module to eliminate the staircase problem [3, 4]. This module has been implemented firstly in a Differential Method tool used to modelize the scattering of grating structure from a plane wave excitation. We have implemented this module in the FMM to simulate 2D optical waveguide. This efficiency has been recently proved [5].

Now, we would like to add this combination in a 3D version. This tool could then be an excellent solution for all company developing integrated optic structure. A first goal, it is to be able to add a real roughness of the waveguide and to estimate its impact on the reflection, attenuation losses or shift wavelength resonance for resonator cavity. A second goal is to have the possibility to design plasmonic structure with different shape as triangular, cylinder which can be complicated to simulate with classical methods. Plasmonic excitation of the metal plane with a specifically roughness could also be analyzed. The domain of study is not limited when the tool is developed and can be very large.

The requested skills or knowledge of the student:

- Guided wave theory, electromagnetism (In optic or in radiofrequency domain)
- Computer science
- Python code and eventually C code

[1] J. P. Hugonin and P. Lalanne, "Perfectly matched layers as nonlinear coordinate transforms: a generalized formulalization", J. Opt. Soc. Am. A, 22, 1844-1849 (2005)
[2] D. Bucci, B. Martin and A. Morand, "Application of the three-dimensional aperiodic Fourier modal method using arc elements in curvilinear coordinates", JOSA A, Vol. 29 (3), pp. 367-373, 2012.
[3] E. Popov and M. Nevière, "Grating theory: new equations in Fourier space leading to fast converging results fo TM polarization", J. Opt. Soc. Am. A, 17, 1773-1784 (2000)
[4] H. Mohamad, S. Essaidi, S. Blaize, D. Macias, P. Benech and A. Morand, "Fast Fourier Factorization for differential method and RCWA: a powerful tool for the modeling of non-lamellar metallic diffraction gratings", Optical and Quantum Electronics, 52:127, (2020)
[5] H. Mohamad, S. Blaize, P. Benech and A. Morand, « An aperiodic differential method associated to the FFF: a numerical tool for integrated optic waveguide modelization », OWTNM in Berlin, (2020)

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