Proposal of PhD thesis subject

Scientific project:

Silicon photonics has raised an increasing interest in the last years due to the foreseen possibility of merging electronics and photonics on the same chips using large scale wafers and well-established technologies. Significant breakthroughs have been demonstrated on optical waveguides and passive optical devices to distribute light, filter optical signals, add-drop individual wavelength around $\lambda=1.5\mu$m, etc, as well as in the field of active structures for light emission, modulation, and detection. The main potential applications of this silicon (on insulator: SOI) photonics technology are optical interconnects within CMOS chips, optical telecommunications, and biophotonics. The main forthcoming challenges are to increase the data bit rates of active components beyond 40Gbits.s$^{-1}$, significantly reduce their power consumption, reduce the footprint of photonic structures, manage the temperature dependence of SOI devices, and improve the sensitivity of SOI-based bio-sensors. For all these items, the use of non-linear optical phenomena is perceived as an interesting opportunity. In this context, the proposed PhD topic is focused on the physical, numerical, and experimental investigation of nonlinear optical effects in silicon photonic compatible planar devices and structures.

The use of a high index contrast optical technology like the silicon one, as well as the exploitation of periodical structures (eg photonic crystals) or plasmonic ones leads to a dramatic enhancement of nonlinear light-matter interactions if compared, for example, with optical fibres. Simultaneously, a good understanding of optical effects at the nanoscale give rise to the need of advanced modelling techniques (use of full-vectorial mode solvers describing periodical and plasmonic structures) to tackle the best compromises leading to moderate optical losses, group velocity dispersion engineering, and filling of phase matching conditions.

The involved PhD student will enter the Minaphot silicon photonic group of IEF (http://silicon-photonics.ief.u-psud.fr/) and will primarily investigate the nonlinear optical effects enabled by periodical structures (eg photonic crystals) based on hollow core waveguides filled by nonlinear optical materials (organic polymers, functional oxides). Both slow light waveguide and photonic crystal cavity modes will be considered, with a special focus on coupled photonic crystal cavities. The possibilities of degenerate four-wave mixing in such structures will be considered by properly solving the nonlinear Schrödinger equation in those materials and waveguide configurations. One key aim will be the design and fabrication of low power and extremely compact optical switches in silicon photonics.

The recruited student will actively conduct his/her PhD project by addressing the modelling, the design, fabrication, and test of the structures. We intend to publish the results in good level journal papers, namely Optics Express, Optics Letters, Photonic Research, Applied Physics Letters, and so on.

Additional comments:

Our group has already welcome several Chinese PhD students: 4 Chinese students since 2009 having defended in 2011, 2013, 2015, respectively (+ defense that will be held in 2016). We can provide you their names and e-mail addresses to enter a discussion with them.

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**Figure 1**: Slow light photonic crystal waveguides for the enhancement of light-matter interactions

**Figure 2**: Hollow core slot photonic crystal waveguides: light is guided within the low index material
If you are interested in this research topic, send an e-mail to eric.cassan@u-psud.fr
I advise you also to apply to a Spring internship with me.

List of publications of our group with Chinese students in the last 3 years:

- W. He, E. Cassan, “Mid-infrared polarisation rotator based on an asymmetric Ge-strip-on-si waveguide”, IET Optoelectronics, 6 pp., DOI: 10.1049/iet-opt.2013.0126 (2014)

This proposal will enter in the frame of a CNRS sino-french research network in Photonics&Optoelectronics gathering 6 French universities and 6 Chinese ones, which name is Photonet.

GDRI Photonet:
- On the French side: Institut d’Electronique Fondamentale (IEF, UMR 8622, Orsay), Institut Fresnel (IF, UMR 7249, Marseille), Institut des Nanotechnologies de Lyon (INL, UMR 5270, Lyon), Moltech Anjou (UMR 6200, Angers), Fonctions Optiques pour les Technologies de l’information (FOTON, UMR 6082, Rennes et Lannion), Institut de Physique et Chimie de Strasbourg (ICMS, UMR 7504, Strasbourg)
- On the Chinese side: Huazhong University of Science and Technology (Wuhan), Fudan university (Shangai), The Shanghai Institute of Technical Physics of the Chinese Academy of Sciences (Shangaï), Tsinghua University (Beijing), Peking university (Beijing), Zhejiang University (Hangzhou).

Candidate’s required skills:
- Taste for electromagnetism, optics, as well as numerical modelling, scientific curiosity
- Hardworking capabilities
- Ability to communicate and work together in a relaxed but studious context
- Very good academic level in your Master program