PhD topic proposal

Title: Exploration of photonic devices for biosensing applications

Laboratory: INL (Lyon Institute of Nanotechnology at INSA Lyon)

Research team: Nanophotonics

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Description of PhD topic:

The continuously growing and aging world population has a well-known dramatic impact on healthcare demands and costs. In this context, there is an urgent need for the development of low-cost point-of-care diagnosis systems, i.e., devices that enable to obtain quick and reliable diagnosis outside hospitals, for instance at the patient's home or at the local doctor's office. If some solutions already exist for some specific applications (e.g., pregnancy tests), today most diagnosis tools are expensive and/or they require access to large medical facilities; in particular, there is a strong lack of systems providing cost-effective and high-throughput biomolecular screening for early disease detection (e.g., cancer or infectious diseases). This particular issue is the underlying motivation for the proposed PhD project.

In the case of application to biomolecular screening, optical techniques are the preferred tools as they offer a direct compatibility with array-based sensing, in which each element of the array can target a different biomarker, hence enabling biomolecular screening via multiple parallel sensing. Among the optical devices suitable for biomolecular screening, photonic crystals are highly promising, because they offer a large flexibility in light control and engineering, including the possibility to design:

- devices yielding enhanced light-matter interaction, which is an essential property for the detection of biomolecules via an optical technique,
- surface-addressable arrays of devices that can be directly excited from a light beam at normal incidence, which is of high interest for low-cost array-based sensing.

However, photonic crystals also suffer from a few drawbacks that have strongly limited their application as point-of-care tools so far. First, photonic crystals are constituted of small periodic features with dimensions that are usually in the order of 100-500 nm, which often require the use of expensive and low-throughput nanofabrication techniques such as electron-beam lithography. Secondly, the spatial overlap between the regions of strong light intensity and the position of the target molecules (mostly located at the surface and on the etched walls of the periodic features) can be quite poor, hence limiting the strength of light-matter interaction and the overall sensitivity with respect to concurring techniques such as plasmonics.

In this context, the proposed PhD topic follows a double objective:

- first, we propose to explore new ideas of photonic-crystal structures, in views of obtaining stronger light-matter interactions and higher sensitivities; the idea is to experimentally realize and study the photonic-crystal structures that will be designed via a collaboration with other members of the research team,
- secondly, we aim at investigating alternative nanofabrication techniques that offer a better compatibility with low-cost production, such as laser-interference lithography or nanoimprint.

The proposed PhD project is therefore very exploratory and mostly experimental. It will be divided into 2 main parts:

- Technological developments for device fabrication: this part is dedicated to the development of alternative nanofabrication processes for the fabrication and study of new photonic structures. It will be performed using the Nanolyon facilities at INL laboratory. During his/her work, the PhD student should acquire a deep expertise of nanofabrication processes, such as lithography and etching techniques, as well as a good experience in structural characterization techniques such as scanning electron microscopy.

- Optical characterization of the fabricated devices: this part aims at the optical study of the fabricated devices and will be performed using a dedicated optical setup for micro-reflectivity/micro-transmission measurements. Several different measurement conditions can be envisaged: standard optical characterization of the device performances in air and in liquid environment, as well as sensitivity studies on bio-functionalized devices. The sample functionalization will be performed in collaboration with the Chemistry and Nanobiotechnologies team at INL.

Candidate profile:
The student should have a degree in physics, optics and/or material science, with a taste for experimental work and a real motivation for the field of biosensors. Good knowledge in the areas of nanotechnologies and/or chemistry would be a strong asset.