PhD proposal

Photonic sensors for the detection of ultralow-weight molecules

Laboratory and research group : INL, i-Lum
Location: INL UMR CNRS 5270 – INSA de Lyon/Ecole Centrale de Lyon

Keywords: Photonic metasurfaces, sensors, optical characterizations, clean room processes

Profile: Physics/Material Science, Optics/Photonics.

Application deadline: 2020-05-15

Background, Context:

Currently, research efforts in optical sensors are aimed at improving the sensitivity, reliability and high throughputs. Increasing sensitivity and limit of detection will permit to detect very small molecules (molecular weight lower than 1 kDa) and/or to measure chemical interactions at very low concentration. However, achieving extremely low limits of detection remains very challenging, from the device design to the sensitive system of detection. One promising approach for the next generation of optical sensors is the exploration of electromagnetic singularities arising in sub-wavelength dielectric or metallic periodic metasurfaces. In such structures, these singularities are experimentally observed through polarization or phase vortices, or in the very peculiar dispersion characteristics in momentum-space [1-3]. Some of these singularities, such as exceptional points, are characterized by an increased sensitivity to external perturbations, especially for extremely small perturbations [4]. However, two major challenges prevent the potential applications in low weight molecule sensing : first of all the design and the fabrication of periodic metasurfaces that support such singularities; secondly, the development of optical characterizations that allow to reach very low limit of detection, at the single molecule level.

In this PhD's project, we aim at experimentally as well as numerically demonstrating an innovative optical platform for the sensing of low weight molecules (< 1kDa) by addressing both challenges:

(1) Design and fabrication of photonic crystal metasurfaces: periodically patterned dielectric or metallic nano-structures, with a periodicity in the micron or submicron range can exhibit various outstanding optical singularities such as bound state in the continuum [1], exceptional points [2], and peculiar dispersion features [3,5] that can lead to enhanced sensitivity.

(2) An extremely sensitive and stable detection technique: in this project, contrary to classical sensing experiments based on the detection of a wavelength shift, we develop an alternative detection method based on phase interrogation through the wavefront shape engineering with a spatial light modulator (SLM). Our optical setup allows for greatly enhanced sensing performances (ultra-low limit of detection) and high-throughput multiplexed sensing. Besides, our system of detection is very original and has been proposed anywhere else.

Research subject, work plan:

The topic focusses mainly on the realization and experimental demonstration of the whole system (photonic metasurfaces + optical setup). This PhD thesis is thus strongly oriented towards experimental work. It will be organized around the following 3 aspects:

- **Device conception:**

The metasurface design will be based on the photonic concepts developed within the i-Lum team (Bound States in the continuum, Bloch Surface Waves, Exceptional Points, etc [3,5]). The PhD student will use standard numerical simulations (RCWA, FDTD) to design the photonic crystal sensors with the desired properties in terms of sensitivity and sensibility to the presence of small molecules. She/he could contribute to the development of new photonic concepts within the i-Lum team.

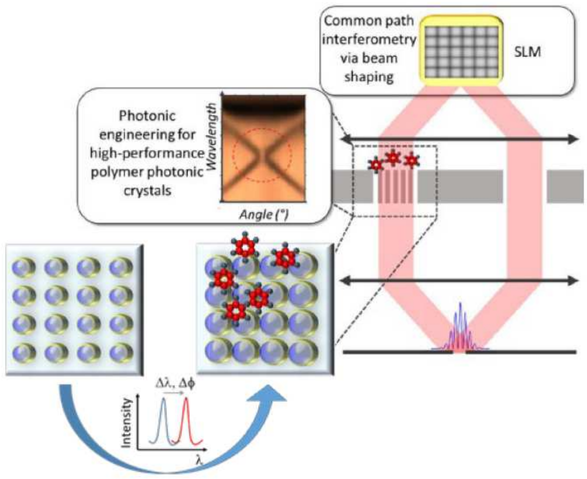
- **Device fabrication:**

The fabrication of the photonic devices will require several clean-room nanotechnology processes such as electron-beam lithography, dielectric as well as metallic deposition, lift-off technique etc. All techniques are well known in the i-Lum and mature clean room processes will be exploited in this project. This aspect of the work will benefit greatly from the skills and tools of the Nanolyon platform of the INL.

- **Optical characterization using holography and wavefront beam shaping:**

The optical characterization of the metasurfaces will be first performed using Fourier space imaging setups to check the dispersion characteristics of the structures. Then, the demonstration of the sensor function will be carried out on the optical setup combining beam shaping and common path interferometry. A particular attention will be paid to the stability and reproducibility of the system. Key properties such as limit of detection will be retrieved : performances 10 to 100 times better than actual state of the art are expected.

Fig 1. Sketch of the sensing principle: upon exposure to small molecules, a photonic metasurface – (periodic arrangement of dielectric materials) can swell leading to a change of its geometric parameters and refractive index. The monitoring of the resonance shift allows to deduce the molecule concentration. In this project, we will focus on the phase shift monitoring on a dedicated optical setup based on wavefront beam shaping and holography.



<u>Candidate profile:</u>

The candidate should have a solid background in physics and/or optics and should be specifically interested in nanophotonics and nanotechnologies with a strong taste for experimental work (optical setups, nanofabrication). Optical spectroscopy skills will be considered as a strong advantage.

Contacts :

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References

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