AAP China Scholarship Council - CSC 2024

PROJET DE RECHERCHE DOCTORALE (PRD)

Titre du PRD : Quasi Bound states In the Continuum for the generation of chiral near-fields

DIRECTION de THESE

Porteuse ou porteur du projet (***doit être titulaire de l'HDR***) :

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Unité de recherche : Code (ex. UMR xxx) et Intitulé : UMR7588 - Institut des NanoSciences de Paris

Ecole doctorale de rattachement : ED397 - Physique et Chimie des Matériaux

Nombre de doctorants actuellement encadrés : 3 (starting second year, all in co-supervision)

CO-DIRECTION de THESE (HDR) ou CO-ENCADREMENT (Non HDR) :

NOM :

Prénom :

Titre : Sélectionner ou Autre :

Section CNU :

Email :

Unité de recherche : Code (ex. UMR xxx) et Intitulé :

Ecole doctorale de rattachement Sorbonne Université : Sélectionner ou autre :

Nombre de doctorants actuellement encadrés :

CO-TUTELLE INTERNATIONALE envisagée : ☐ OUI ☒ NON

DESCRIPTIF du PRD :

*Ce texte sera affiché en ligne à destination des candidates et candidats chinois : il ne doit pas excéder **2 pages** doit être rédigé en **ANGLAIS***

Chirality is at the heart of life, as most biological molecules are chiral. Biological reactivity is governed by their chirality, and differs not only according to their configuration (L or D) but also, in the case of proteins, according to their conformation. For applications such as antibacterial surfaces or biosensors, it is of crucial importance to be able to control the configuration as well as the conformation of biomolecules, which can be modified following their adsorption to surfaces. Using polarimeters, Circular Dichroism (CD) can be used to detect the in-solution configuration of chiral biomolecules, since these show a difference in absorption when exposed to right- or left-hand circularly polarized light. However, polarimeters are slow, require large quantities of material and therefore large analysis volumes, and operate in the UV part of the spectrum (typically around 200 nm). There is therefore a real need for methods that reduce the volume to be analyzed. It is also advantageous to transfer the measurement to the visible part of the spectrum: cost of optics, stability of plasmonic materials, reduced photochemical effects. With that aim, we are developping plasmon assisted CD measurements where the helicity of the light in the vicinity of chiral biological molecules is controlled and enhanced thanks to engineering of the nearfield of plasmonic resonators.

To generate chiral nearfields, complex, unrealistic nanostructures have been proposed, but the main focus has been on the use of chiral resonators. The detection relies on the use of two surfaces with two enantiomeric plasmonics. Apart from complicating the measurement, it is currently impossible to produce perfectly enantiomeric surfaces, which introduces irreducible variability into the measurement, and this presupposes that the coupling of biomolecules to the surface is perfectly identical between the two measurements. This observation is at the root of our decision to propose pseudo-chiral, or even achiral, surfaces, which make it possible to generate both types of superchiral fields (positive and negative) by controlling the illumination conditions of the same structure. We have proposed the use of pseudo-chiral resonators [ACS Appl. Opt. Mater. 1, 1360-1366 (2023)] and achiral resonators [ACS Photonics 10, 3850-3857 (2023)] to generate both helicities of light in the vicinity of resonators. Here, we propose to explore the excitation of plasmonic modes referred to as Bound states In the Continuum (BIC). These modes are found in resonators which can not be excited by light for symmetry reasons. However, small asymmetries introduced by illumination direction, slight shape asymmetry or adsorbates break the symmetry of the system allowing for the excitation of the BIC which are then called quasi-BIC. For some symmetries of resonators, the quasi-BIC are expected to generate chiral fields which would make the quasi-BIC strongly sensitive to the chiral environment.

The first objective is to optimize the resonant nanostructures to maximize the spatial overlap between the relevant quantities (intensity, chirality density, helicity) and thus maximize the response of the resonators to the chirality of the surrounding medium. Understanding the interaction mechanisms between the near-field of nanostructures and chiral molecules will be done at two levels: numerically using codes available at the INSP (based on FDTD-Lumerical and RCWA); experimentally by realizing plasmonic surfaces and characterizing their effects of the polarization state of light. The production of nanostructures will be based on the Paris Centre cleanroom network which has a facility at the INSP. For nano-resonators, manufacturing is routinely done in our cleanroom although some optimization will be necessary and will depend on the nanotructure chosen. The nanostructures will then be characterized on the polarimeter available at the INSP.

In a second step the surfaces will be coupled to synthetic chiral objects exhibiting intrinsic circular dichroism. These objects will be CdSe nanocrystals functionnalized with tartrate derivatives and they

will be obtained through an ongoing collaboration with another laboratory of Sorbonne University. The objective will be to investigate how the polarization properties of the nearfield of the resonators can be used to modify the response of the resonators in presence of the chiral objects.

This research project provides answers to important questions in photonics and biomolecule reactivity, and proposes an innovative conceptual and experimental approach for detecting biomolecules and their conformation in situ, with the aim of moving towards the single resonator, or even the single molecule.

AVIS de l'Ecole Doctorale :

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à l'école doctorale de rattachement et à csc-su@listes.upmc.fr