INSTITUT foton
Fonctions Optiques pour les Technologies de l'informatiON
http://foton.cnrs.fr
Enssat
6, rue de Kerampont
CS 80518
22305 Lannion cedex
T. 02 96 46 91 41
F. 02 96 37 01 99
UMR 6082

Thesis offer :
Surface enhancement based on an integrated optical nanoplatform for pollutant detection by Raman scattering - "LASERS

A 36-month thesis will start at Institut Foton on the development of SERS sensors in the visible range.

Start of thesis: *October 2024*
Thesis supervisor: *Joël CHARRIER* ***Thesis co-supervisors:*** Nathalie LORRAIN and Parastesh Pirastesh
Funding : *University of Rennes*
Team: *Photonic Systems (group),* located at ENSSAT-Lannion
Key words: *Integrated optics, visible, spectroscopic sensors*

Subject

The aim of this thesis topic is to develop an innovative, sensitive and miniaturized photonic device dedicated to the detection of pollutants in aqueous solutions or gaseous media by combining integrated optics, enhanced vibrational spectroscopies and nanotechnologies to develop an on-site sensor based on the SERS (Surface Enhanced Raman Scattering SERS) effect. The aim of the project is to develop specific detection in a complex system through direct, label-free identification of the analyte by Raman spectroscopy. Vibrational spectroscopies (Raman) can enable such identification, as the vibrational spectrum is a true molecular signature. To provide highly sensitive detection and achieve a very low limit of detection (LOD), the spectral signal can be considerably enhanced using surface-excited Raman scattering (SERS). This detection technique relies on the unique optical properties of metal nanoparticles, which act as a nano-antenna (NA). On-site or on-line analysis requires a compact, miniaturized instrument. We propose to build an integrated optics platform on a silicon substrate, consisting of chalcogenide glass (ChGs)-based waveguides (WGs) on whose surfaces the NAs will be deposited (Fig.1). Ribbon waveguides are used to propagate the NA excitation signal, while the NA acts on the device for the detection of analytes deposited on the waveguide. The use of integrated optics will enable us to increase the efficiency of the excitation signal in order to reduce the size of the device by avoiding the use of an optical microscope for the excitation functions. This detection platform will then be used and integrated into a complete detection device (Fig. 2), including integrated optical guides for collection. The samples to be analyzed will be injected into a micro-fluidic cell placed on the platform. SERS signals from the analytes will be transmitted either via an optical fiber, or via a second waveguide connected to optical fibers, and then analyzed using spectrometers to identify and quantify the analytes.

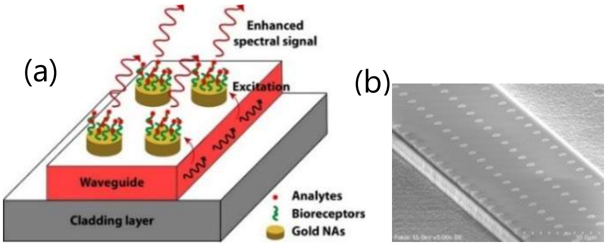

Fig. 1: (a) Concept of the nano-sensor based on a waveguide on whose surface gold nano-antennas have been deposited. (b) SEM image of the NA on the surface of the integrated waveguide based on chalcogenide layer.

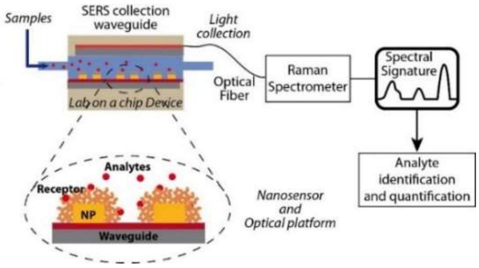

Fig. 2: Principle of detection

Two applications are envisaged:
- detection of pollutants in aqueous solution
- detection of volatile organic compounds (VOCs) in the food packaging and recycling industries

Indeed, the detection of pollutants in aqueous solution, in line with regulatory policy, is of paramount importance both to achieve good environmental status, to pave the way for early treatment of the environment, and to detect trace pollution/contamination before reaching the regulatory threshold and carry out analysis directly on site. Such detection remains a challenge at European level (European projects Green deal, Starfish Mission 2030) due to the complexity of the environments to be analyzed, the non-specificity of detection and the sensitivity and non-portability of current methods. (Collaboration with Ifremer)
Moreover, the detection of volatile organic compounds (VOCs) is also of paramount importance in the food packaging sector and the recycling industry: every year, 4.8 million tonnes of plastics are used in France, of which almost 46% is single-use packaging. Due to the multitude of materials and processes used in the food packaging sector, the recycling industry faces many challenges in meeting the ambitious targets of the national 3R2 (Reduce, Reuse and Recycle) strategy, namely 100% recycling of single-use plastics by 2025. Production-line detection of volatile organic compounds (VOCs) during extrusion or injection processing is a way for plastics manufacturers to incorporate more recycled materials into plastic packaging, and to boost the growing market for bio-sourced plastics, while guaranteeing their quality, traceability and genuine safety for consumers. This approach also goes hand in hand with the rejection of plastic in water (in collaboration with IPC).

[1] https://wwz.ifremer.fr/Espace-Presse/Communiques-de-presse/Mission-Starfish-2030
[2] LOI n° 2020-105 du 10 février 2020 relative à la lutte contre le gaspillage et à l'économie circulaire
[3] I. Tijunelyte, et al., «Diazonium Salt-Based Surface-Enhanced Raman Spectroscopy Nanosensor: Detection and Quantitation of Aromatic Hydrocarbons in Water Samples», Sensors, 17(6), 1198, 2017
[4] R. Gillibert, et al., «Surface enhanced Raman scattering sensor for highly sensitive and selective detection of ochratoxin A», Analyst, 143, 339, 2018
[5] R. Rich et al., “Advances in surface plasmon resonance biosensor analysis», Curr. Opin. Biotech. 11, 54, 2000
[6] J. Charrier, et al. «Evanescent wave optical micro-sensor based on chalcogenide glass », Sensors and Actuators B: Chemical, 468-476, 2012

Candidate profile

The thesis will require multidisciplinary skills in guided optics, integrated optics, materials physics and sensors. A Master's degree or engineering school diploma covering a significant part of these fields is required for this thesis. Skills in electromagnetic simulation, guided optics, technological implementation and/or optical characterization will be highly appreciated.

Partnership

Possible collaborations :

- IMMM (M. Lamy-de-la-Chapelle et F. Lagarde),
- ISCR (V. Nazabal), Equipe Verres et Céramiques de l'ISCR
- Ifremer (E. Prado, M. El-Rakwe et R. Courson).
- IPC (T. Falher et A. Littner)

Host laboratory: Photonic Systems Team, Institut Foton (CNRS, UMR6082), Lannion

The Institut Foton is a research laboratory involving CNRS, the University of Rennes 1 (Enssat and IUT Lannion), and INSA Rennes. The laboratort is structured into six thematic areas and three teams, spread over two sites: two teams in Rennes, Opto-electronics, Hetero-epitaxy and Materials (OHM, (INSA-Rennes) and (DOP, UR1); a Photonic Systems team in Lannion (Enssat-Lannion). The doctoral student will work in the Guided Optics and Sensors group of the Photonic Systems team, which has a staff of around 25 and is based in Lannion. This group has acquired extensive experience in the field of photonic integrated circuits, and has access to the resources of the CCLO technology platform (200 m² clean room, thin-film deposition racks (sputtering, electron gun evaporation), sub-micron photolithography, electronic lithography, ICP-RIE dry etching, Scanning Electron Microscope, etc.) as well as optical equipment and benches suited to optical characterization of integrated components. The doctoral student will thus be able to benefit from skills and resources not only for technological fabrication, but also for modeling, assembly and characterization of integrated optical circuits and optical fibers.

Further information – Contact

Further information can be obtained by contacting :

nathalie.lorrain@univ-rennes.fr,
parasteh.pirasteh@enssat.fr,
joel.charrier@univ-rennes.fr

Application

All applications must include the following:
- Cover letter

- Detailed CV
- Copy of Master's degree or equivalent
- Transcripts
- List of publications, if applicable
- Letters of recommendation if possible