Sujet thèse / PhD subject 2024

Titre Thèse	Using strong coupling to detect gas traces in the THz range	
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Groupe(s)	Photonique THz	Web : https://photoniquethz.iemn.fr/
Projet phare (principal)	Nanocaracterisation	
Demande thèse labelisée IEMN (Materials ou IoT Make Sense)	**Non**	
Financement demandé	Contrat Doctoral Etablissement	ULille ☒ Centrale Lille ☐ JUNIA ☐
	Région – Autre ☐ Préciser :	Co financement (Préciser l'origine, demande en cours, acquis ou pas) :
Financement acquis ☐ **Financement partiellement acquis** ☐	Contrats de Recherche ☐ Préciser :	Autre ☐ Préciser :

Résumé du sujet :

Halogen (e.g. CH3X; OX and HX; XX being Cl, I, or Br) gases are produced by numerous industries, oceans, and several other biosystems. During the past decades, researchers demonstrated their major role in the atmosphere. They act on pollutants and particles through reaction cycles and are involved in radiative forcing. They are major players in the Earth's energy budget and global warming. Still, today no techniques exist able to measure these species at a realistic concentration in real-time.

The Terahertz (THz) frequency range occupies a unique space between electronics and photonics. Transistors in this range are not sufficiently fast, and the lasers have too high energy. However, recent technological progress has opened up a wide range of applications in recent years. THz spectroscopy, in particular, is known to be the most selective gas phase spectroscopy [**Erreur ! Source du renvoi introuvable.**] but the sensitivity must be improved. Recently, our team demonstrated that contrary to what was usually thought Time domain spectroscopy was able to capture all the information of gas phase spectroscopy including high resolution one [**Erreur ! Source du renvoi introuvable.**]. The use of this technics could revolutionize gas sensing when the sensitivity will be enhance by a cavity.

In this multidisciplinary doctoral thesis, we propose to implement an innovative physical concept shown in figure 1: coupling of the molecular frequency comb of halogen gas to the optical frequency comb of the Fabry-Perot cavity. This coupling will enhance the light-matter interaction and consequently enable it to detect extremely small concentrations of gas. We will probe this system using terahertz time-domain spectroscopy (TDS) and a dedicated algorithm developed by the team for the study of gas by TDS.

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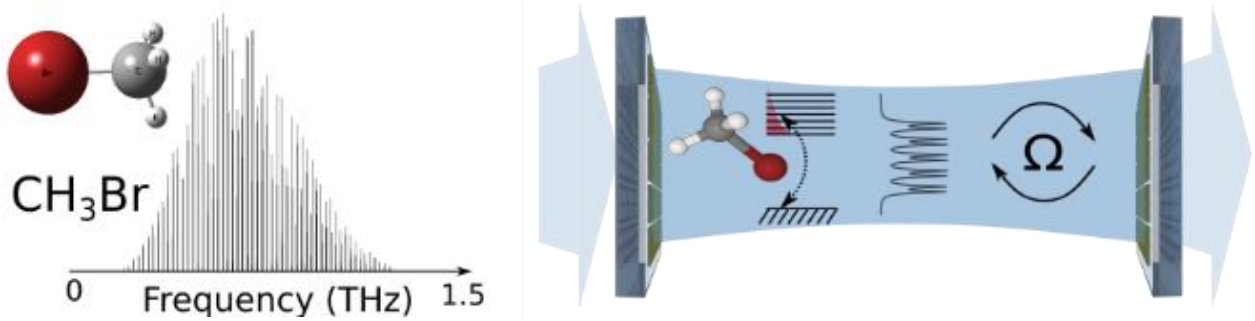

Figure 1 : Left, molecular frequency comb (MFC) of bromomethane given as an example (changing the halogen will not change much the spectrum; other radicals change he spectrum but keep the comb behavior). Right the cavity made by two

facing metasurface mirrors building the optical frequency comb (OFC) and enabling the coupling between the OFC and the MFC

Missions: The goal of this research internship is to launch this study together with a postdoctoral fellow who is working on the project on another institute of the consortium. The student will have to take over several of the many aspects gradually. The work includes a simulation phase where the mirror of the cavity made of metasurfaces will be designed using CST or Lumerical FDTD software, the fabrication of the mirrors which may be performed by the student or the postdoc responsible for the project's technological aspect. Characterization of the device follows and then the performance of the experiments. Given the variety of tasks in the project, the student's specific responsibilities will be discussed based on their interests, capabilities, and motivation.
We are looking for a physics or engineering master student or equivalent. Having one of the following skills would greatly increase the chance of success of any application:

- Optical experiments
- Spectroscopy
- Python coding
- Clean Room technology

How to Apply:
Do not hesitate to contact us by email for an unformal discussion before sending your application. We are happy to answer any questions you may have about the internship or the research project. Your formal application will include your resume and a cover letter detailing your interest for the subject and be sent by email to the PI before the end of November.

Environment: The student will work in a team of experienced researchers in the THz-Photonics group at IEMN Laboratory (https://www.iemn.fr/en/la-recherche/les-groupes/photonique-thz). The group has a long lasting experience in the conception and realization of THz optoelectronic devices. We have three state-of-the-art time domain spectroscopy setups with a dynamic range of 100 dB and a spectral resolution of 1 GHz. The Laboratory hosts a 1500m2 clean-room with state of the art growth and fabrication facilities. IEMN is located in Lille, the capital of French Flanders, a vibrant city close to the Belgian border at 50 min by train from Paris-CDG airport.