Master 2 POSITION (F/M/X)

Process and Material Sciences Laboratory (LSPM), Villetaneuse, France

Implementation of advanced optical diagnostics in reactive plasmas

Hosting Group: Plasma/Surface Interaction and Microplasmas (IPS – MP)

The **IPS–MP** group belongs to the **Plasma, Nanostructures and Thin Films Processes (PPANAM)** research axis of the **LSPM** and is specialized on the design, implementation, and characterization of plasma processes related to novel materials and applications.

IPS–MP has undergone a quasi-reconversion in recent years, moving from the study of plasma-carbon surface interaction to plasma-metal surface interaction (W, Al). These activities are essential for the study of the behavior of materials relevant for fusion (tokamak edge plasmas). The experimental devices dedicated until now to the studies realized by **IPS–MP** in the context of “on-board plasmas” are also used for exploratory studies of synthesis of materials of interest (e.g., carbon-metal composites). Nanostructured thin films (rather oxides) are also synthesized by sol-gel processes and functionalized by plasma to test their performances for various applications (photovoltaic, …). Besides, the design of atomic sources (nitrogen in particular) is a new important axis of study using:

(a) High energy density microwave plasmas for studying dissociation processes involving excited electronic states of N_2 : *(i)* low-pressure microwave reactor (ECR among others), and *(ii)* atmospheric pressure microplasma torch.

(b) Micro-hollow cathode discharges for the synthesis of advanced material such as hexagonal boron nitride (intra-collaboration with “**Diamond and Carbon Materials**” group of **LSPM**).

Besides well-known material characterization tools (Photoluminescence, Raman spectroscopy, …), advanced optical diagnostics are implemented to better understand the behavior of the different plasmas and optimize them for the targeted applications. Among others, fast (*ns* timescales) and ultrafast (*ps* timescales) laser diagnostics, ultrafast detectors (e.g., *ps* streak camera) and high-resolution optical emission spectrometers/monochromators are installed (or under implementation) in the group. These diagnostic tools are also useful for the characterization of other plasma sources (e.g., cold plasma jets, rf plasmas, surface DBDs) available in the group in the frame of national and international projects.

Context – Duties – Skills – Allowances

6-month Master 2 Internship followed by a PhD contract (36 months) depending on student’s performance.

Keywords
Optical diagnostics, emission spectroscopy, ultrafast laser, streak camera, reactive (micro)plasmas.

Research topic – Duties
Atmospheric pressure reactive plasmas are increasingly used in advanced technologies for materials, environment, plasma medicine, agriculture, etc. However, the physics and chemistry behind these plasmas are only partially understood today, which limits potential technological breakthroughs for many applications. The physicochemical properties of atmospheric pressure discharges in a reactive environment can be significantly different from low pressure plasmas, due to their high collision frequency, transient nature, and the small size of the reactors (cm–µm scale) used to generate plasma at atmospheric pressure. Thus, to detailly characterize these plasmas, advanced in situ and non-intrusive diagnostics with a very good spatial (mm–µm) and temporal (ns–ps) resolution will have to be developed for identifying and quantifying the reactive species generated in plasma (charged, excited and neutral species, and transient atomic and molecular radicals). In addition, the evaluation of temperature, electron density and electric field gradients is particularly important, since these are factors that affect the kinetics of heavy particles, the

nature of reactive species and the heat fluxes that will interact with plasma-treated surfaces. Recently, the study of pulsed plasma jets at atmospheric pressure (APPJ) having (at least) a micrometric dimension (μm-APPJ) has been useful for the ionization/detection of different analytes (explosives, drugs, etc.). In addition, microwave APPJ (MW-APPJ) are also of interest for applications relating to the deposition of carbon nanomaterials. However, their in-depth characterization is necessary to better understand the kinetics of reactive species generated and the physical properties of the two discharges, which will allow us to optimize them for relevant applications. This internship plans fundamental studies of μm-APPJ and MW-APPJ by advanced optical diagnostics. The studies concern the impact of discharge parameters (voltage, flow, frequency, gas, etc.) on the spatial and temporal behavior of emissive species, gas temperature (T_{Gas}), electron density (n_e), electric field (E_{Field}) , and absolute density of reactive atoms (H, N, O, C, etc.). The successful candidate will have the opportunity to implement advanced diagnostics at LSPM: (i) optical emission spectroscopy (OES) with a high resolution spectrometer for the determination of and T_{Gas}, n_e, E_{Field}, etc., (ii) two-photon laser-induced fluorescence using an ultrafast laser (pulse duration: 5 ps; energy: 100 μJ/pulse at 206 nm) and an ultrafast streak camera for in depth studies of the kinetics of reactive species generated.

Relevant references

[1] Progresses on the use of two-photon absorption laser induced fluorescence (TALIF) diagnostics for measuring absolute atomic densities in plasmas and flames, K. Gazeli, G. Lombardi, X. Aubert, C. Y. Duluard, S. Prasanna, K. Hassouni, Plasma 4 (1) 145-171 (2021) (https://doi.org/10.3390/plasma4010009).
[2] Picosecond two-photon absorption laser induced fluorescence (ps-TALIF) in krypton: the role of photoionization on the density depletion of the fluorescing state Kr 5p´[3/2]2, K. Gazeli, X. Aubert, S. Prasanna, C. Y. Duluard, G. Lombardi, K. Hassouni, Phys. Plasmas 28, 043301 (2021) (https://doi.org/10.1063/5.0041471).
[3] Investigation of N(^{4}S) kinetics during the transients of a strongly emissive pulsed ECR plasma using ns-TALIF, E. Bisceglia, S. Prasanna, K. Gazeli, X. Aubert, C. Y. Duluard, G. Lombardi, K. Hassouni, Plasma Sources Sci. Technol. 30 095001 (2021) (https://doi.org/10.1088/1361-6595/ac0da1).
[4] Absolute N atom density measurement in a Ar/N_2 Micro Hollow Cathode Discharge jet by means of ns-Two-photon Absorption Laser Induced Fluorescence, A. Remigy, X. Aubert, S. Prasanna, K. Gazeli, L. Invernizzi, G. Lombardi, C. Lazzaroni, Phys. Plasmas 2022 (https://doi.org/10.1063/5.0110318).

Expected Skills

- Diploma in Physics (ideally plasma/laser Physics) corresponding to 240 – 270 ECTS
- Good background on optical diagnostics such as optical emission spectroscopy
- Strong computer skills and capacity in data analysis using scientific software/tools
- Organization and methodology, autonomy, commitment
- High efficiency in preparing reports
- Communicative personality
- Fluent in English and (ideally) in French

Allowances
About 600 €/month.

Starting Date
March 2023

Application Procedure

The candidate should send via e-mail to Prof. Guillaume Lombardi (guillaume.lombardi@lspm.cnrs.fr) and Dr. Kristaq Gazeli (kristaq.gazeli@lspm.cnrs.fr) the following files:

- CV and relevant diploma (240 – 270 ECTS)
- A motivation letter (one page)
- Two recommendation letters