Experimental aspects of plasma sheath associated with secondary electron emission

By nature, a plasma is composed of charged particles which, in response to electromagnetic fields they generate or which are applied to them, exhibit collective behaviors from which quasi-neutrality results on spatial scales larger than the Debye length. This property break-down when the plasma encounters a solid frontiers where non-neutral sheath forms at scales of a few Debye lengths and, potentially, deeply impact on the bulk dynamics, *i.e.* far from the frontiers. Ions and electrons dynamics, due to their mass difference, evolve with different temporal scales in the presence of sheaths, which may be the device boundaries in laboratory experiments or solid bodies in astrophysical contexts. Multi-scale physics phenomena emerge especially where the sheath is formed. The physics of plasma sheath is of major interest in the fields of, both, laboratory, astrophysics and fusion by magnetic confinement (tokamaks,...). Many studies have been devoted to the understanding of plasma sheaths in several configurations [1]. The situation is further complicated in the presence of magnetic fields or the emission of electrons from the surface. In the presence of surfaces that emit electrons, either from secondary emission or thermionic emission, the physics of the sheath is deeply modified. Modeling and numerical simulations predict an "inverse sheath" whose experimental observation is still elusive [2–4]. In that context, the long-term goal of the thesis is to improve comparison between magnetic sheath of an electrons emitted surface models and experiments. Models and experiments will be performed and compared at the laboratory PIIM and its partners by two PhD students.

Spatial scales involved in plasma sheaths and the breakdown of quasi-neutrality make it appropriate to use laser-induced fluorescence diagnostics to measure the ion velocity distribution function along the pre-sheath and the sheath. This non intrusive diagnostic already implemented and mastered at PIIM [5] will be used in the vicinity of metallic surface at a floating potential to confirm results from numerical simulations led by our partners. Despite some artefacts [6], its spatial definition is around 0.1mm, which allows to spatially resolve the sheath structure (spanning around 1mm in our experiment). The plasma source, a multipolar device, creates a quiescent Argon plasma with two electron populations: an ionizing energetic one emitted by filaments and a colder electron temperature population, which is the core electron plasma population.
Various experiments will be performed and compared to theories developed within a distinct PhD project, by a fellow PhD student funded by the same research grant:

- Explore the collisionality of the sheath physics, which are ubiquitous in nature and experiments, by changing the neutral pressure
- Measurements of the sheath structure of an thermionic, electron emissive surface (LaB6 heated ceramic)
- Measurements of the sheath structure in the case of surfaces with high secondary electrons emission rates, with a focus on the observation of an "inverse" sheath structure.
- Explore the effect of magnetic fields on the sheath structure, in regimes where only the electrons will be magnetised. The influence of the the angle between the surface and the magnetic field is known to be a key player [7].

- Perform experiments in a linear magnetic plasma column[8]

The experimental datas on emissive sheath plasmas will be compared with theoretical/numerical results from PIIM laboratory.

The thesis work will be relevant for, both, space thrusters [9] and laboratory plasmas such as in a non magnetic low temperature plasma [5] and in an linear magnetic plasma column [10] devices of PIIM.
This experimental work could serve as a basis for understanding the magnetic sheath where ions are magnetized as is the case in fusion devices.

The student must have master's level knowledge in plasma and experimental physics to carry out experiments with laser and compare results with theoretical calculations.

The thesis will be carried out within the framework of A*MIDEX funding and a collaboration between the PIIM, the Laboratoire de Physique at Ecole Normale Supérieure de Lyon (LPENSL) and the Laplace laboratories for the theoretical part. The thesis will take place mainly at PIIM in Marseille although the future student will have to travel regularly to Lyon to the LPENSL.
The thesis will be directed by N. Claire (PIIM) and N. Plihon (LPENSL) and will be supervised by M. Muraglia (PIIM), G. Fubiani (Laplace) and O. Agullo (PIIM) for theoretical comparisons.
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