M2 internship
2025

Laboratory : PIIM/Turbulence Plasma team

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Subject : Optical electric field diagnostic in a magnetized plasma by Lyman-alpha stimulated emission (EFILE)

Subject description :

Project framework and experiment description:

Plasma, result from the partial or total ionization of neutral gases. Coupling between fields (electric, magnetic) and charged particles leads to collective effects and turbulence, specific to these media. Their behavior and their fields of application depend on the ion temperature: cold plasmas are used in industry for surface treatment (etching of circuits, deposits, production of reactive species, etc.); hot plasmas are produced in tokamaks (Tore-Supra, ITER...) in order to produce energy from controlled fusion. In both cases, it is essential to determine the fundamental parameters associated with the charged species present in the plasmas.

The Turbulence Plasma team has developed an optical diagnostic (EFILE) for direct measurement of an electric field in vacuum or in plasma [1, 2]. This diagnostic is based on the emission of the Lyman-α line by a hydrogen probe beam in the 2s state submitted to an electric field. As a result of the 2s-2p coupling created by the field, atoms in the 2s (metastable) level is transferred to the 2p level, which then rapidly de-excites to the ground level. The intensity of the electric field-induced Lyman-α emission is proportional to the square of the field amplitude. This diagnostic was experimentally validated in a simple cylindrical configuration, in vacuum and in a non-magnetized plasma.

Objective and description of the subject:

The objective of the thesis is to measure the electric field in a magnetized plasma. The EFILE diagnostic is being implemented on the MISTRAL machine of the Turbulence Plasma team of the PIIM laboratory. The MISTRAL machine [3, 4] produces a cold plasma column in a linear magnetic field, over a wide range of parameters. It is a fundamental research machine whose linear configuration simplifies the study of instabilities in a magnetized plasma (compared to tokamaks where the curvature of the magnetic field induces more complex phenomena). Mistral is the ideal device to validate the EFILE diagnostic which is a unique way of measurement of the electric field in a direct and non-intrusive way.

Present work is focused on the study of the influence of the magnetic field on the diagnostic and the measurement of an electric field at different points along the radius of the machine. These two aspects are studied in vacuum or in a plasma, independently of each other, in order to fully understand the capabilities of the diagnostic.

The selected PhD student will proceed to the measurement of the electric field which, together with the magnetic field, is responsible for rotating non linear instabilities of the plasma column [5, 6].

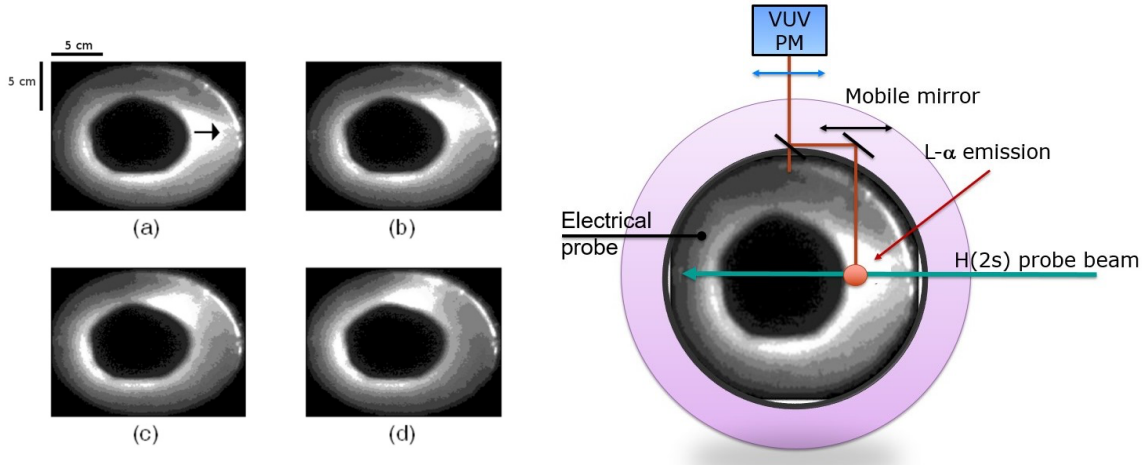

Figure 1:
(left) fast camera images placed at the end of the plasma column ;
(right) Installation of EFILE on MISTRAL.

The general objective of this work is to develop a diagnostic for the absolute measurement of a static or oscillating electric field that can be transferred to different systems and applied to various current research problems in plasma physics. Within this framework, the diagnostic will be applied by the PhD student to the study of plasma sheaths, a cross-disciplinary issue involving cold plasmas, hot plasmas, applied mathematics, theories, simulations, and experiments [4].

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Références

[1] L. Chérigier-Kovacic, P. Ström, A. Lejeune and F. Doveil, Review of Scientific Instruments 86, 063504 (2015); doi: 10.1063/1.4922856
[2] L. Chérigier-Kovacic, Static and RF electric field direct measurement based on Lyman-α emission from a hydrogen probe beam ; Invited talk @ XXXIV ICPIG conference, July 14-19 2019, Sapporo, Japan.
[3] A. Escarguel, ExB workshop, nov 2018, Princeton Plasma Physic Lab, USA.
[4] Atelier Gaine Plasma 4-6 novembre 2024, Marseille, https://gaine2024.sciencesconf.org/?lang=fr (consulté le 30 novembre 2024).