PhD proposal

Laboratory : PIIM/Equipe Turbulence Plasma

PhD supervisor : Alexandre Escarguel / Laurence Chérigier-Kovacic

Tel: 04 91 28 82 21

Title : Electric field diagnostic in a magnetized plasma by field-induced Lyman-alpha emission (EFILE)

Overview of the research :
Plasmas are often considered as the fourth state of matter. They results from partial or total ionisation of neutral gases. Coupling between fields (electric, magnetic) and charged particles leads to collective effects and turbulence, which are specific to these environments. Their behaviour and fields of application depend on the temperature (energy) of the ions: cold plasmas are used in industry for surface treatment (circuit etching, 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.

A diagnostic (EFILE) has been developed in the "Plasma Turbulence" team allowing direct measurement of an electric field in a vacuum or in a plasma [1, 2]. This diagnosis is based on emission of Lyman-α line by a probe beam of hydrogen in the 2s state induced by a local electric field. As a result of the 2s-2p coupling created by the field, atoms prepared in the 2s (metastable) level can pass into the 2p level, which then rapidly de-excites towards the fundamental level. The induced intensity of Lyman-α emission is proportional to the square of the amplitude of the field, making this diagnostic extremely sensitive. This diagnostic has been validated in vacuum and in a non-magnetized plasma in a dedicated experiment with a simple cylindrical configuration and a controlled electric field.

Objective and description of the subject :
The objective of the PhD is to measure the electric field with EFILE in the MISTRAL experiment dedicated to study of instabilities of a magnetized plasma column ("Plasma Turbulence" team of the PIIM laboratory). The MISTRAL experiment [3, 4] produces a cold plasma column in a linear magnetic field, with a wide range of parameters. Compared to complex tokamak plasmas, it is a fundamental research device whose linear configuration simplifies the study of plasma instabilities. Many diagnostics are already installed on MISTRAL (Langmuir probes, laser-induced fluorescence, emission spectroscopy, optical tomography, spectro-tomography), but none of them allow direct and non-intrusive electric field measurement like EFILE. Therefore, it is particularly well suited to validate EFILE diagnostic.

The proposed PhD work consists in finishing the implementation of the diagnosis on the MISTRAL machine, validating the diagnostic by specific experiments with a magnetic field, and applying it to large scale rotating instability study [5, 6].

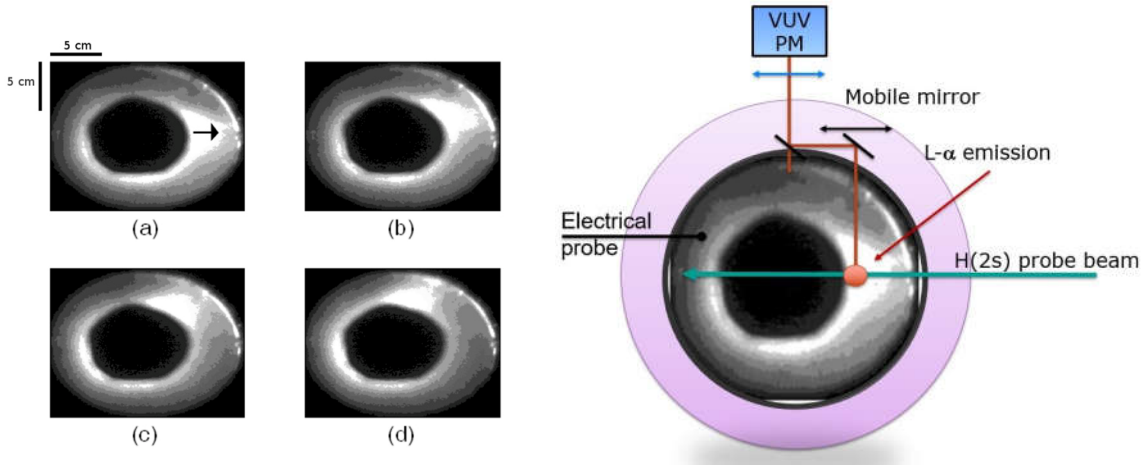

Figure 1: (left) fast camera results ; (right) setup of EFILE on MISTRAL ;
both images are end views of the plasma column.

This project was selected by the “Région Provence Alpes Côte d’Azur” for a three-year financial support for equipment, starting in 2019.

Outlook :

The final objective of this experiment is to develop an absolute measurement diagnostic of a static or oscillating electric field transferable to other devices. One of the projects is to provide an absolute value of the electric field in front of an ICRF heating antenna in an experimental test bench (IShTAR) reproducing the plasma edge conditions of a tokamak, in order to calibrate field maps obtained by simulation. Discussions are underway with the Jean Lamour Institute in Nancy, which is installing the IShTAR experiment on its premises. These perspectives should not be lost sight of during the thesis work.

Bibliography :

[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-□ emission from a hydrogen probe beam ; Invited talk @ XXXIV ICPIG conference, July 14-19 2019, Sapporo, Japan.

[3] Th. Pierre A. Escarguel, D. Guyomarc’h, R. Barni, C. Riccardi, « *Radial convection of plasma structures in a turbulent rotating magnetized plasma column* »,, Phys. Rev. Let. 92 6 (2004)

[4] M. Matsukuma, Th. Pierre, A. Escarguel, D. Guyomarc’h, G. Leclert, F. Brochard, E. Gravier and Y. Kawai, « *Spatiotemporal structure of low frequency waves in a magnetized plasma* », Phys. Let. A, 314, 163-167 (2003)

[5] V. Gonzalez-Fernandez et al., Spatially resolved determination of the electronic density and temperature by a visible spectro-tomography diagnostic in a linear magnetized plasma ; accepted in Scientific Reports

[6] A. Escarguel, ExB workshop, nov 2018, Princeton Plasma Physic Lab, USA.