Lamb shift and electric field measurement in plasmas

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1. Principles of the measurement

The interaction between a metastable H(2s) atomic hydrogen beam and an external electric field leads to the emission of the Lyman-α line. It originates in the Stark mixing of the near-degenerate $2s_{1/2}$ and $2p_{1/2}$ levels separated by the Lamb shift [1]. Theory predicts that the intensity of the radiation is proportional to the square of the electric field amplitude.

2. Description of the diagnostic

A sketch of the experiment is shown in Fig.1.

Hydrogen ions are produced in a magnetic multicusp source by a thermo-electronic discharge. The ions are extracted from the source, focused by a series of electrostatic lenses and accelerated to 500 eV. The beam interacts with cesium vapor that produces atoms in the metastable $2s_{1/2}$ state. In the diagnosed volume, the beam passes between a pair of plane electrodes separated by 5 cm. One of them is grounded; the other one is polarized to generate an electric field. The diagnosed volume can be kept under vacuum or exposed to argon plasma.

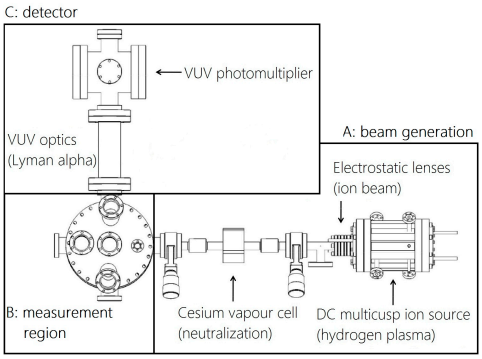

Fig. 1: *Sketch of the experiment*

3. Results

3.1. Results in vacuum

As shown in Fig.2, the quenched radiation proportional to the square of the electric field amplitude is recovered in vacuum. The VUV signal is recorded by a lock-in technique which gives an excellent signal to noise ratio. For larger electric field, saturation is observed and related to the beam finite transit time.

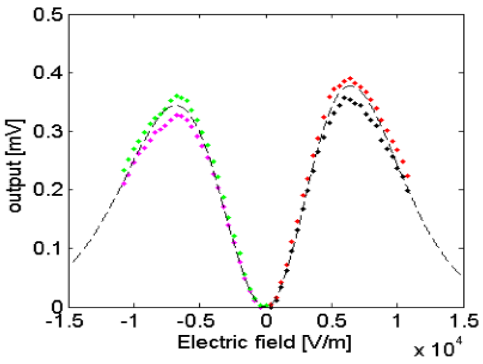

Fig. 2: *For each amplitude of the electric field applied between two plates in vacuum, upper (resp. lower) points give the maximum (resp. minimum) lock-in amplifier output for the measured Lyman-α intensity; dashed line is the calibration curve, quadratic near zero and taking into account saturation by geometrical effects at large fields*

We have also observed the strong enhancement of the signal when the field is oscillating at the Lamb shift frequency (1057 MHz) leading to a sensitivity as good as 0.1 V/cm [2].

3.2. Results in plasma

After calibration in vacuum, this technique is applied in plasma, offering an alternative way to measure static and fluctuating weak electric fields by direct and non-intrusive means [2, 3, 4]. In particular, the long standing experimental analysis of plasma sheaths is thus possible [3].

This work was the subject of A. Lejeune's PhD thesis, and P. Ström and M. Vallar's master thesis.

References

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