

Optogalvanic spectroscopy measurements of the electric field strength in a hydrogen glow discharge

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Among the different plasma diagnostics methods, laser spectroscopy techniques based on two-photon absorption provides a high spatial and temporal resolution. In the Plasma Laser Spectroscopy Laboratory (University of Valladolid), electric fields measurements in the cathode fall region of a hollow cathode discharge by Doppler free two-photon optogalvanic spectroscopy are performed, applied to the 15-25 atomic transition in hydrogen. The electric field in a hollow-cathode discharge causes the Stark splitting and shifting of the 25 level of hydrogen. The comparison of these measurements with the theoretical calculations allows determining the value of the electric field.

Experimental arrangement

Pulsed UV laser radiation centred in 243 nm is generated by a 10 Hz injection-seeded Q-switched Nd:YAG laser (Continuum, Powerlite) and a tuneable laser (Mirage 500, Continuum) that provides a single longitudinal mode radiation, with a temporal duration of 3 ns, and spectral quality of 300 MHz bandwidth. In the experimental arrangement, the UV radiation is divided in two beams with the same optical path, overlapping in the upper central part of the cathode fall region in a volume of 150 μm of diameter and 10 mm of length. The quality of the focus is controlled at real time by a spectral profile analyser (LaserCam-HR-UV) that gives size and energy distribution information in every measurement. The detection of the 15-25 Stark components is done by the absorption of two photons circularly polarized. While tuning the laser frequency, the change of the voltage drop between the cathode and one anode is measured, and recorded shot by shot for each scan.



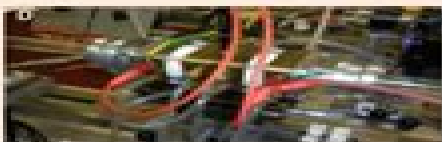
A: Tunable laser Mirage 500, based on non-linear crystals

B: Optogalvanic spectroscopy experiment

C: Optogalvanic spectroscopy experiment scheme

Hollow cathode discharge

Low-pressure hydrogen plasma is generated by a hollow-cathode discharge in glow-discharge regime. The outer structure of the lamp is a vacuum seal chamber made of brass. The discharge is operated in a wide range of pressures, covering different currents. It is also possible to vary the cathode diameter and material. Previous to the optogalvanic measurements, a complete study of the stability and reproducibility of the discharge has been performed.



D: Discharge lamp

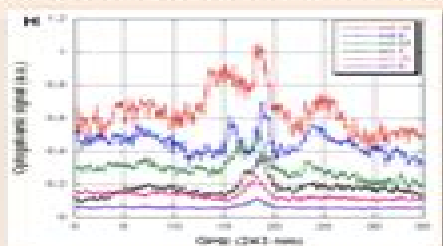
E: Scheme of the discharge lamp

F: Different aspects of the discharge

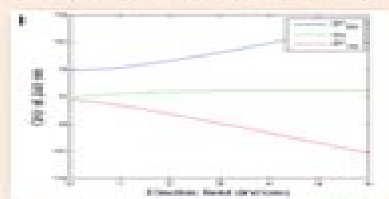
G: Study of the reproducibility of the discharge

Electric field measurements

Linearity of frequency laser tuning is controlled by the transmission curve of a monitor etalon with a free spectral range of 7 GHz. Data acquisition has been updated and optimized, with a great improvement in temporal resolution and stability, by a new oscilloscope (model D505104A, Keysight Technologies Inc) and LabVIEW programming. Electric field strength is determined via the Stark splitting of the 25 level of atomic hydrogen, measuring the difference in GHz between the components $2p_{1/2}$ y $2p_{3/2}$ and comparing with the theoretical calculations (Figure I). Electric field strength depends mostly on the distance to the cathode surface, also on the pressure and current of the discharge, see figures H and J. Recently, an improvement in the measurements is achieved, reducing noise as can be seen in Figure K, where the experimental data are shown without any processing. Also the theoretical fits are included in the figure.



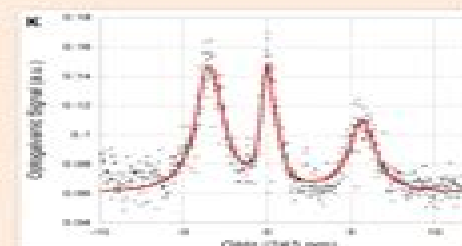
Optogalvanic spectra, with a pressure of 900 Pa and 100 mA of current in a 20 mm diameter stainless steel cathode.



Stark splitting calculation of the 25 level



Electric field strength vs distance from the cathode surface for a fixed current of 100 mA and 900 Pa



Optogalvanic spectrum with 500 Pa and 100 mA in a 10 mm diameter stainless steel cathode.

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