Experimental study on dynamic effects of H^- and D^- negative ions in an ECR-plasma source

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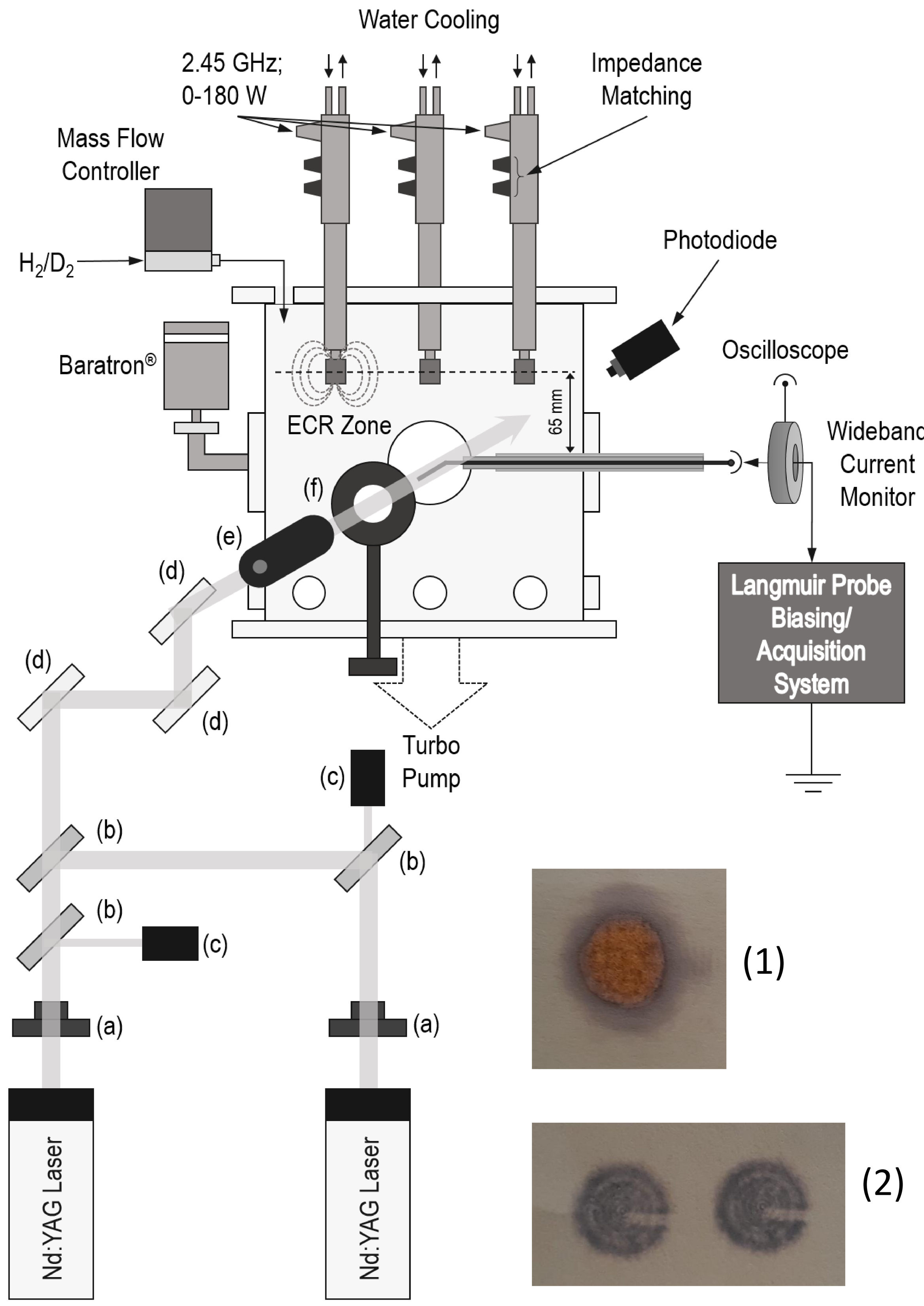
Introduction

Laser induced photo-detachment with one laser beam is a well-known and widely applied diagnostic technique and has been broadly applied since many decades to measure the H^- and D^- negative ion densities. On the other hand, full exploitation of the photo-detachment technique, i.e., with two laser beams in order to determine the negative ion energies-temperatures is reported in very few works. The present work is devoted to this topic, in the ECR-plasma source Prometheus I.

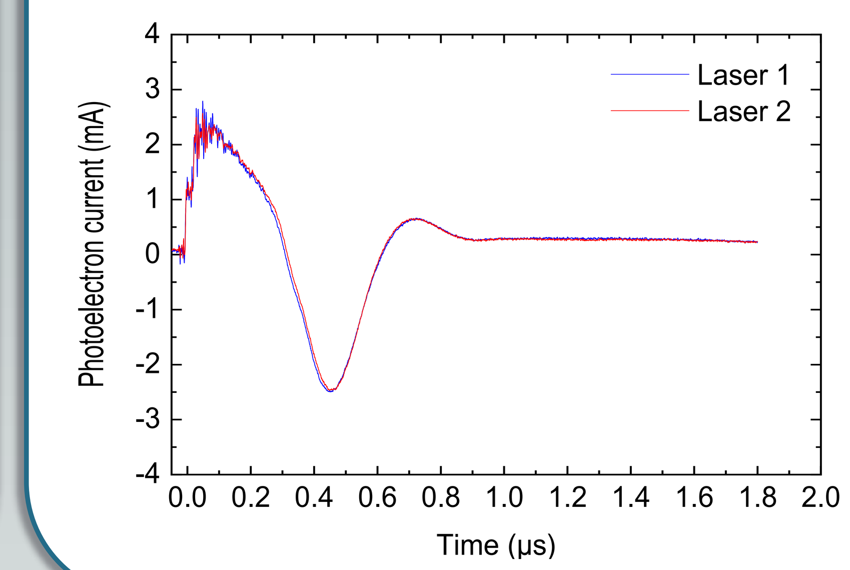
Concept

The fundamental physical concepts underlying this method when an electrostatic probe is used for the electron detection, implies: (i) the creation of a controlled perturbation in the negative ion density, followed by (ii) the measurement of the recovery of the negative ion density towards its initial value, and (iii) fitting the measured results to a physical model of the density recovery process, in which the ion thermal drift velocity plays a central role. In practice, a first laser shot detaches all negative ions in the irradiated volume and a photo-detachment signal is acquired. A second laser shot is triggered after a delay time Δt and it detaches all negative ions that have flowed into the laser irradiated volume during Δt. The probe records an additional photo-detachment signal, that lags the first one by Δt and its amplitude is proportional to the integrated ion flux. By varying the delay Δt, the time it takes for recovery of the ion density following the first photo-detachment can be tracked. The information about negative ion recovery is obtained by subtracting the signals of the single-laser-beam experiment and the two-laser-beam experiments, for various increasing delays between the two laser shots.

Experimental Setup



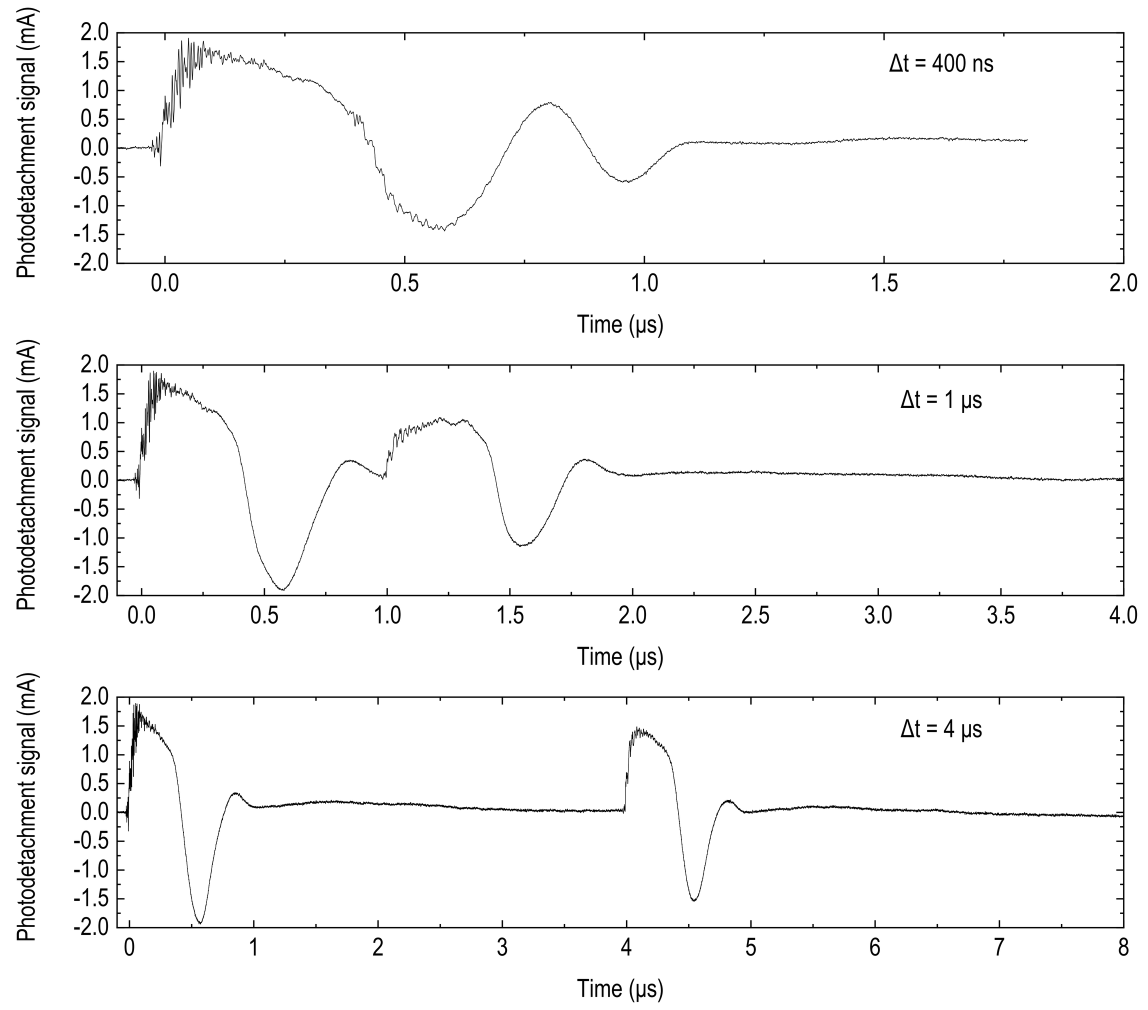
(a) ½ wave-plate on a rotation mount; (b) beam splitters; (c) beam dumps; (d) mirrors; (e) expander with Ø2.5 mm and Ø5 mm diaphragms; (f) pyroelectric laser beam energy sensor; (1) burn pattern of the verifying the concentric alignment of the two separate laser beams; (2) the corresponding burn pattern of the alignment of the two beams with the electrostatic probe used for measurements



To the left: Verification that the perturbation in the negative ion density, due to the two different laser beams, is identical. Hydrogen plasma: 10 mTorr, 900 W

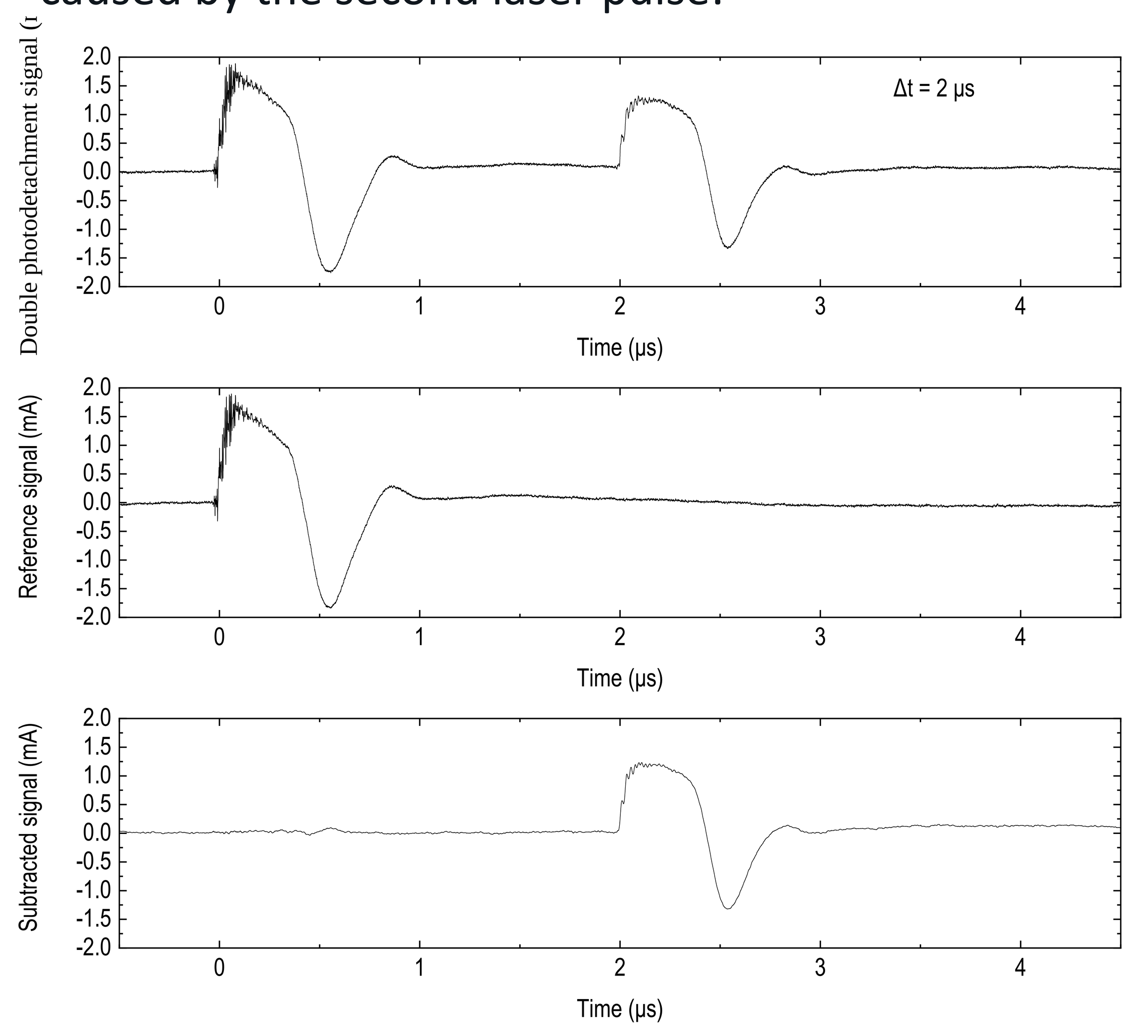
Procedure

- Recording signals with a variable delay Δt between them:



Representative photodetachment signals with a variable delay between the two laser shots. Deuterium plasma 10 mTorr, 900 W

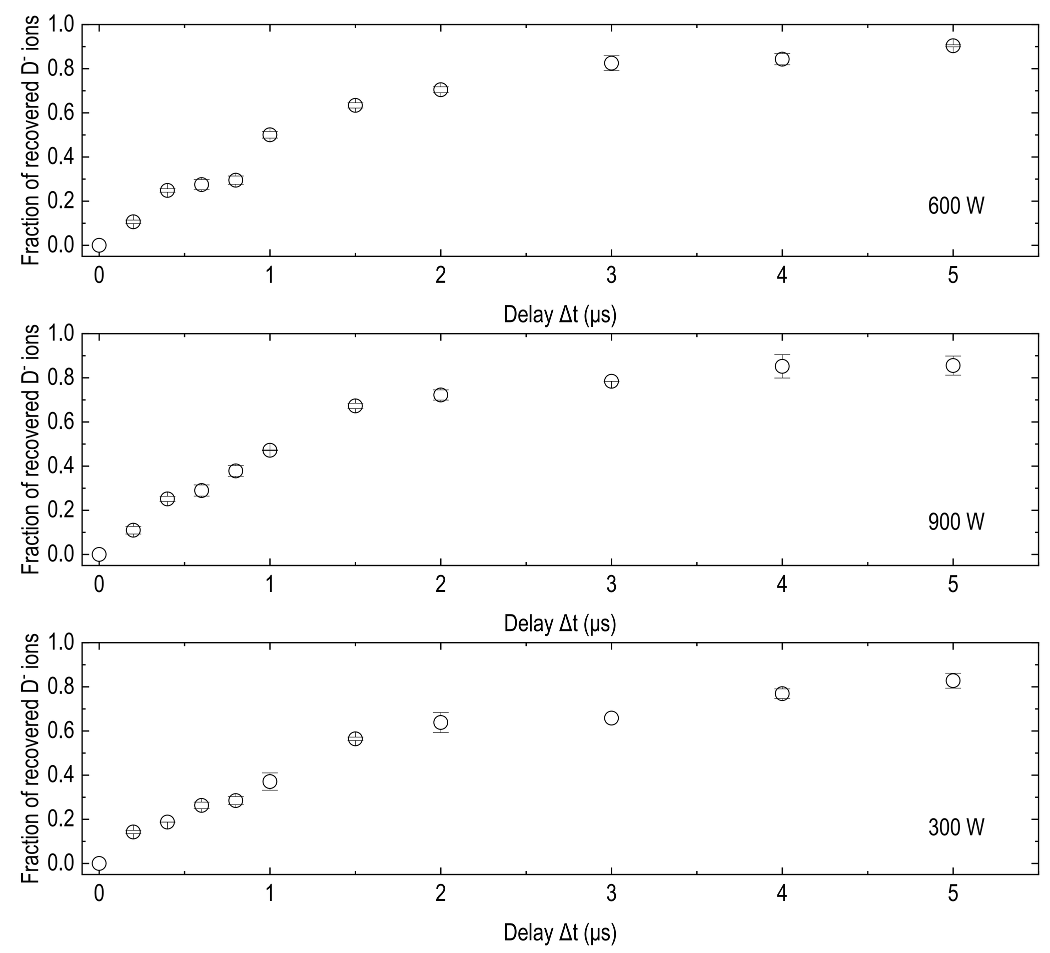
- At each delay Δt, the first signal is subtracted from the "double photodetachment signal" in order to distinguish the perturbation in the negative ion density caused by the second laser pulse:



Example of the subtraction process. Δt = 2 μs, deuterium plasma 10 mTorr, 900 W

Results

- The amplitude of the subtracted signal is recorded at each delay Δt and plotted relative to the amplitude of the initial signal leading to the ion recovery curve:



Ion recovery curves for a deuterium plasma 10 mTorr, for three representative microwave power values.

The function fitted to the ion recovery curves reveals the existence of two ionic populations, a "hot" and a "cold one":

$$y = A\exp\left(-\left(\frac{R_L}{U^-_{th,a}t}\right)^2\right) + B\exp\left(-\left(\frac{R_L}{U^-_{th,b}t}\right)^2\right),$$

$$A + B = 1$$

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