ps-TALIF and streak camera diagnostics for measurements of atomic densities in microplasmas

K. Gazeli*[1], K. Giotis[2], Y. Agha[1], D. Stefas[1],
L. Invernizzi[1], H. Höft[3], P. Svarnas[2], G. Lombardi[1]

[1]*Laboratoire des Sciences des Procédés et des Matériaux, LSPM, CNRS, Université Sorbonne Paris Nord, UPR 3407, F-93430 Villetaneuse, France*
[2]*High Voltage Laboratory, Department of Electrical and Computer Engineering, University of Patras, Rion Patras 26504, Greece*
[3]*Leibniz Institute for Plasma Science and Technology (INP), Felix-Hausdorff-Str. 2, Greifswald, Germany*

Two Photon Absorption Laser Induced Fluorescence (TALIF) is a powerful diagnostic with excellent spatial and temporal resolution that can enable in situ, non-intrusive, and highly selective measurements of reactive atoms in different plasmas [1]. To achieve this, the decay times (τ) of the laser-excited states need to be precisely measured. However, this is particularly challenging at intermediate (typically 10s–100s mbar) and high ($\geq$1000 mbar) operating pressures where strong quenching of excited species may happen, making τ even smaller than 1 ns [2]. Picosecond (ps) TALIF has emerged as a promising technique to tackle this challenge. This is because ps lasers can effectively resolve the decay times of excited states since their pulse durations are significantly smaller than τ and, therefore, the decaying phase of the TALIF signals is not affected by the laser. To directly capture raw ps-TALIF signals with sufficient temporal resolution, the use of ultrafast detectors is essential. To this end, a streak camera is an ideal choice offering a temporal resolution down to a few ps [3]. Therefore, backing ps-TALIF with a streak camera allows measuring sub-ns decay times of fluorescing atomic states in microplasmas. However, the reliable implementation of streak cameras in ps-TALIF studies requires careful consideration of their peculiarities.

Here, we discuss the implementation of a ps-TALIF and streak camera system for measuring decay times and absolute densities of reactive atoms (such as H and N) in two microplasmas: a He microtube plasma jet ($\approx$500 μm inner diameter) and an air pin-dielectric-plane discharge (pin radius <200 μm). We highlight some important considerations for extracting accurate fluorescence signals. The duration of the laser pulse used is $\approx$6 ps at 205 nm. This is directly measured with the streak when operated in its smallest time range (TR=100 ps), reaching its highest temporal resolution of ~1 ps [3]. However, to capture the raw TALIF signals, the TR used needs to be of the order of few ns, which results in noticeable signal distortion due to a poorer corresponding temporal resolution [2,3]. This distortion is demonstrated using the laser pulse as a reference, which allows assessing the so-called apparatus function of the detector at different TR. Then, the actual TALIF signals are extracted from the raw recorded signals by applying a deconvolution method and correcting for the broadening of the profile due to the apparatus function. Therefore, our system allows measuring decay times as low as 50 ps and absolute densities $\geq 10^{14}$ cm^{-3}. The required calibration of the densities is done by applying ps-TALIF in krypton gas in a custom-made sealed gas cell (2 mbar).

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*Presenting author: kristaq.gazeli@lspm.cnrs.fr

Abstract classification – LTP: Laser-induced fluorescence.