Spatial characterization of N(^{4}S) in a microwave plasma jet at atmospheric pressure by fs-TALIF

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Non-thermal plasma jets at atmospheric pressure are effective sources of reactive species essential for applications in domains of energy, materials, environmental or biomedicine. Atomic radicals, such as atomic nitrogen, play a crucial role, for example, as precursors for species with a high economical value or for nitridation processes. Their characterization and understanding of generation mechanisms are key for development of many potential applications.

Two-Photon Absorption Laser-Induced Fluorescence (TALIF) enables *in situ* measurements of the atomic nitrogen ground state, N(^{4}S), with high spatial and temporal resolution. For ns-TALIF, the most commonly used technique, the signal analysis requires the consideration of quenching processes. Notice that quenching, acting as a competing decay path, can reduce fluorescence decay to a few hundreds of ps in atmospheric pressure plasmas, making the precise measurement of the ground state of atomic species challenging. Utilizing fs or ps lasers at very high intensity (> 100 GW/cm²) may provide a quench-free approach where stimulated emission and photoionization dominate over quenching processes [1].

Here, femtosecond laser pulses are produced by a Ti:sapphire laser system (Spectra Physics Solstice ACE) that generates pulses within the wavelength span of λ = 780–830 nm. The beam output of the Ti:sapphire laser is frequency-quadrupled to reach the TALIF wavelengths falling within the range of 204-207 nm. The fourth harmonic delivers around 20 μJ energy per pulse at a repetition rate of 1 kHz. To calibrate fs-TALIF, VUV absorption measurements of N(^{4}S) were performed in a low-pressure DC discharge, at the SOLEIL synchrotron facility, following the work of reference [2]. Because of the high accuracy of the VUV absorption cross sections, this method was preferred instead of the classical Kr calibration.

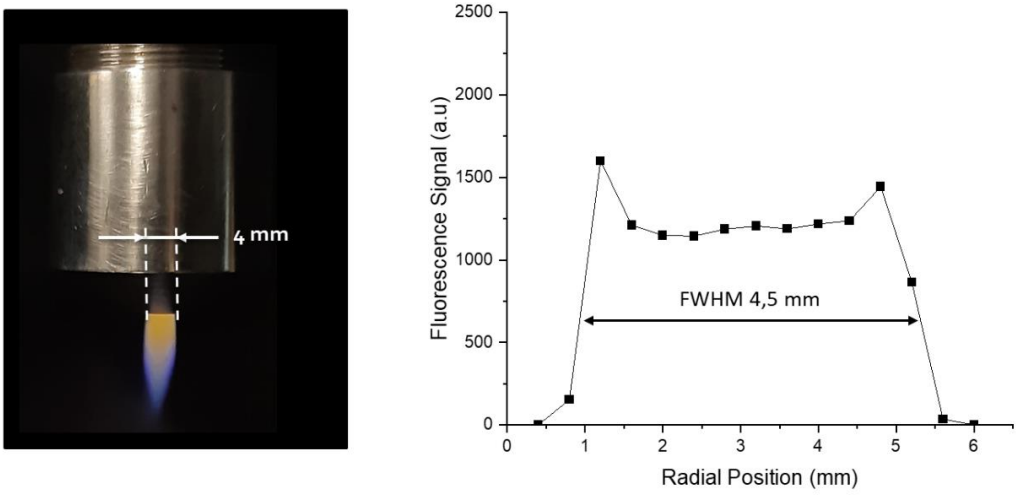

Fig. 1: Photograph of the microwave plasma jet (left). Radial nitrogen fluorescence profile measured using a laser intensity of a few TW cm^{-2} (right).

In this work, the density of $N(^4S)$ has been mapped in a microwave plasma jet operated at atmospheric pressure using the fs-TALIF technique. The MW jets were generated with powers in the range of few tens of watts, in gases containing pure nitrogen or mixture of air and argon and at flows of about a l/min. As shown in figure 1 (right), plasmas of about 4 mm diameter and 2 cm length were generated. In figure 1 (left) is presented a typical measurement of the fluorescence signal obtained radially across a pure nitrogen plasma jet at atmospheric pressure. This was performed using a laser intensity on the order of a few $TWcm^{-2}$.

In the present contribution the absolute spatially resolved $N(^4S)$ density measurements using calibrated fs-TALIF will be presented for different microwave plasma jet configurations.

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[2] Dumitrache C. et al. *Plasma Sources Sci. Technol.* **31** (2022) 015004