Nitrogen atoms ps-TALIF in atmospheric pressure nanosecond volume DBD plasma

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Nanosecond (ns) discharges are studied for different applications, where dissociation of molecules often plays a key role. Because of their high electric fields, nanosecond discharges can be efficient for excitation of electronic levels of atoms as well as molecular excitation and dissociation. In the present work, picosecond Two-Photon Absorption Laser-Induced Fluorescence (ps-TALIF) was used to measure the absolute density of N-atoms produced in an atmospheric pressure ns Dielectric Barrier Discharge (DBD) in pin-to-plane configuration. The density measurements were calibrated by performing similar ps-TALIF experiments in Kr gas contained in a gas cell.

Applied voltage and discharge current waveforms were measured by a homemade back-current shunt (BCS) soldered in the shielding of a long coaxial high voltage (HV) cable so that the distance from the BCS to the HV generator and the distance from the BCS to the discharge setup are equal.
A volumetric DBD was ignited by applying 5.1 kV to room atmospheric air in the form of a ns pulse burst containing five pulses, with a 200 ns interpulse period (5 MHz), delivered by a HV generator (FPG-12-1NM FID; rise time 4 ns, pulse width 29 ns and 5 Hz burst repetition rate).

The electrode system (Fig. 1a) consists of a stainless steel needle (HV electrode), an aluminium plate (grounded electrode) covered with a 0.3 mm PVC layer, with 1.8 mm interelectrode gap.

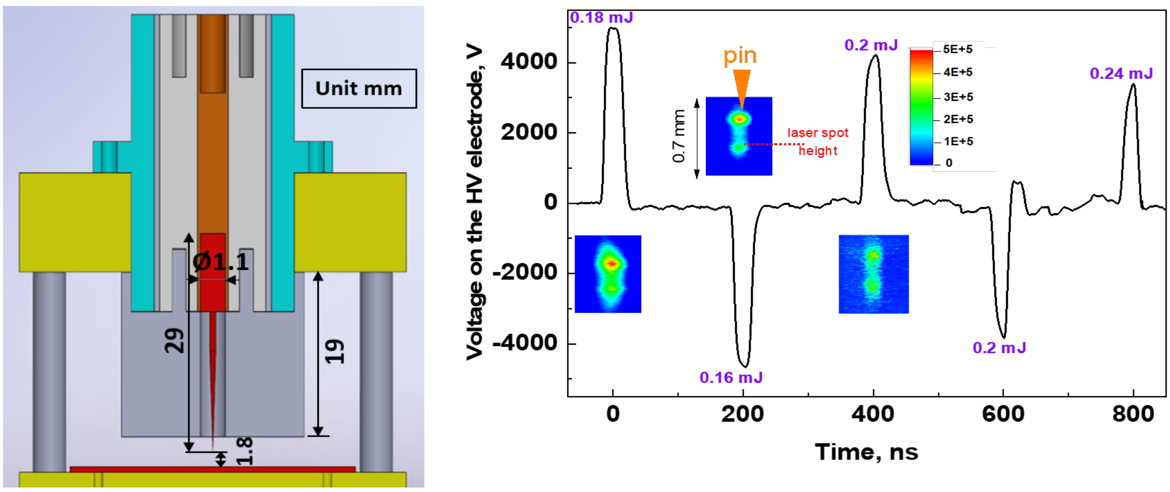

Fig. 1: a) schematic of ns DBD arrangement; b) applied voltage signal on the HV electrode, with delivered energy per pulse and streak camera images for the first three discharges, with a 450 ns time range. The intensity of the third image is multiplied by a factor of 40.

The total deposited energy was estimated to be 0.96 mJ, see Fig. 1b, quasi-equally provided by the five discharges (lowest at 0.16 mJ for the second discharge and highest at 0.24 mJ for the fifth discharge).

The emission of the second positive system of molecular nitrogen was measured with the help of the streak-camera (Hamamatsu C10910-05). The streak camera images corresponding to the first 3 discharge pulses are presented in Fig. 1b.

The ps laser system (Ekspla) [1] used consisted of a Nd:YLF pump laser (PL3140), a harmonic generator and amplifier (APL2100), and a solid-state optical parametric generator (PG411). This provided

10 ps laser pulses at 5 Hz frequency and 206.625, 206.63, 206.635 and 206.64 nm wavelengths, which were synchronized with the discharge using adequate delay generators. The laser energy per pulse has been chosen around 11 μJ to avoid laser-induced secondary processes (such as photoionization ansd amplified stimulated emission(citation) that lead to satured TALIF signals. The laser beam focal spot (200 μm) used for ps-TALIF was positioned near the maximum of emission, 0.4 mm below the HV electrode pin. The ps-TALIF fluorescence around 744 nm was collected by an optical system consisting of 2 lenses and focused at the entrance slit of the streak-camera.

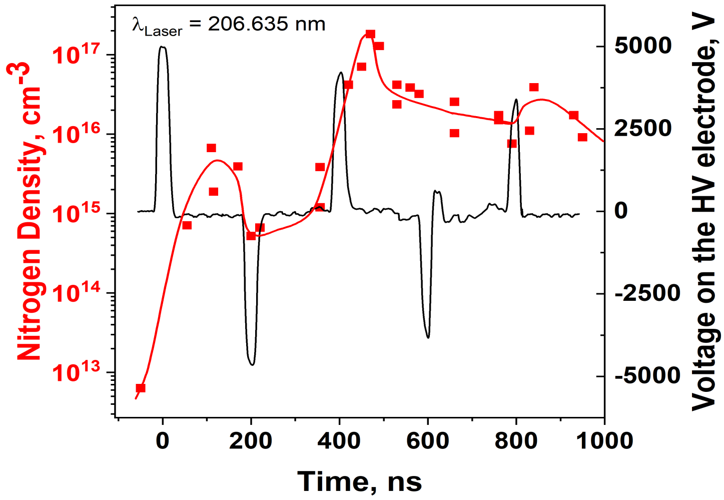

Fig. 2: Nitrogen absolute density evolution in time (red symbols) together with the applied voltage signal on the HV electrode (black curve).

The increase in N-atom density in the vicinity of the third discharge, see Fig. 2, is in correlation with a sharp drop of the fluorescence effective lifetime. Typical streak camera images of ps-TALIF signals are shown in Fig. 3. The decay time of emission was measured to be 150 ps at 200 ns (ie second voltage pulse), and 50 ps at 390 ns (ie third voltage pulse).

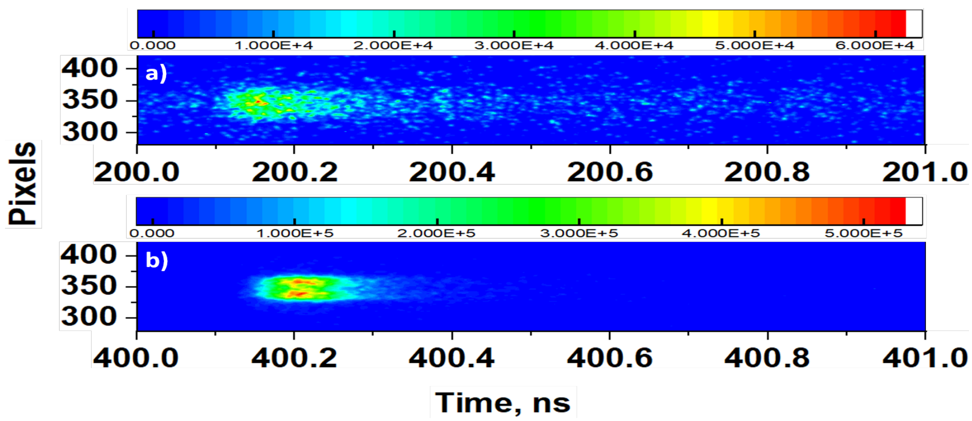

Fig. 3: Streak camera images of the ps-TALIF N-atom signals at a) 200 ns and b) 390 ns.

The maximum N atom absolute density is $2 \cdot 10^{17}$ cm^{-3} (measured after the end of the third pulse) corresponding to $\sim 1\%$ of dissociation of N_2. As far as the energy deposited in the third discharge is practically identical to that in the other discharges, an in-depth analysis of kinetic processes involved in the TALIF scheme will be needed to explain a sharp maximum at 400 ns observed experimentally.

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[1] L. Invernizzi, C. Y. Duluard, H. Hoeft, K. Hassouni and G. Lombardi, K. Gazeli, S. Prasanna, *Meas. Sci. Technol* (2023) 145–171.