Time-resolved images of plasma bullet for different electrode geometries

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In this paper we will present time-resolved images of atmospheric pressure plasma jet obtained by using fast ICCD camera for several electrode settings. It will be shown that formation and position of the plasma bullet strongly depends on the electrode geometry. The main purpose of our investigation was the possibility of applying plasma bullet for the treatment of thermo-sensitive samples.

A possibility to obtain the discharges of various geometries at low gas/ion temperatures and at atmospheric pressure would be a good basis for numerous applications in the industry, biology and medicine [1-5]. Here we study properties of an atmospheric pressure plasma jet (APPJ) operating with sinusoidal voltage excitation at a frequency of 80 kHz. Construction of plasma jet [6, 7] allowed easy ICCD camera capturing of the time-resolved images of the discharge between and inside the electrodes, as well as, of the plasma bullet that is formed outside the tube/electrode system. Experimental setup is given in Fig. 1. We will use the common term "plasma bullet" for visible manifestations of plasma because these ionization fronts create appearance of a motion of a bullet even though plasma itself may have a very different motion.

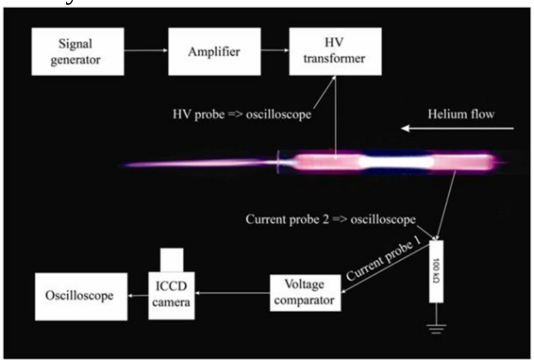

Fig. 1. Experimental setup

The body of a plasma jet was made of Pyrex glass tube 6 mm outer diameter and 4 mm inner diameter. The length of the coated PET electrodes was 15 mm and the distance between them was 15 mm. The distance between the electrodes was kept constant during all measurements. The right electrode was grounded and the other electrode, closer to the end of the glass tube, was the powered one (see Fig. 1.). The calculated mean power transmitted to the plasma was 4 W and the flow rate of the feeding gas (He) was 4 slm. The distance between the powered electrode and the end of the glass tube was varied and ICCD images were taken for distances of 7, 10, 30 and 50 mm. Voltage – current signals are shown in Fig. 2. with trigger position of 11.2 μs.

In order to obtain the time-resolved images we have used integration on the chip because the light emission in a single shot is not always sufficient to obtain clear images with gate widths of less than 25 ns. In Fig. 3. (A, B, C and D) we can see time-resolved image of plasma jet obtained by ICCD camera for 4 different electrode distances to the end of the tube while the rest of the geometry is unchanged. All images were obtained for the same parameters of electrical circuit and ICCD camera settings. It is shown that, when the distances of electrodes to the edge of the tube are shorter, the plasma bullet is formed (see Fig. 3. – A, B and C). At the same time there is no visible discharge in the powered electrode.

When plasma is moving through the tube, including both electrodes, it is at a much lower speed then the speed of the bullet. With an increase of the distance of the electrodes from the edge of the tube plasma bullet is formed but with lower emission intensity (Fig. 3. – C). For the longest distance bullet is not emerging from the plasma jet body throughout the whole cycle period of 12.5 µs. (Fig. 3. – D) and it simply dissipates.

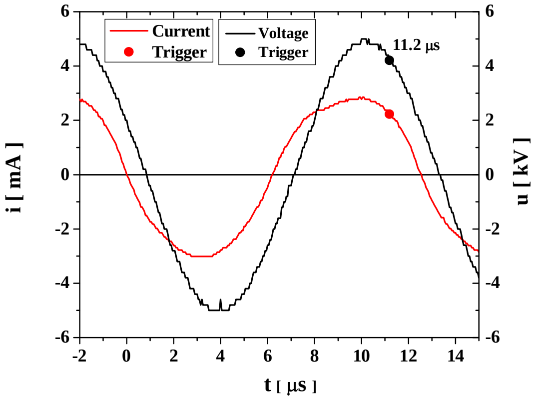

Fig. 2. Current – Voltage signals with 11.2 µs trigger position

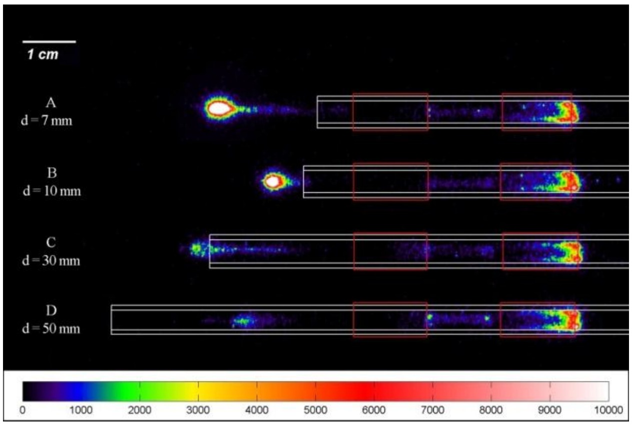

Fig. 3. Time resolved ICCD images for different geometry, delay of 11.2 µs, helium flow rate of 4 slm and average applied power of 4 W. Color bar represents intensities of emission.

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