Spectroscopic and shadowgraphic investigation of nanosecond underwater discharge

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Shadowgraphic and spectroscopic analysis with 2 ns time resolution of underwater nanosecond discharges is presented. Optical emission spectra of positive streamer in water demonstrate hihgly broadened atomic Hα and OI(777nm) line profiles. Shadowgraphic imaging of streamer channel expansion gives the pressure values exceeding 1 GPa at the discharge inception. The role of Van Der Waals and Stark broadening of spectral lines is discussed.

Electrical discharges in water and other dielectric liquids have been extensively studied since almost fifty years, however the mechanism of discharge initiation and propagation is still disputable. The proper measurement of plasma parameters is necessary to calibrate existing models of underwater discharge. The experimental techniques developped for meausrement of electronic density (N_e) and temperature (T_e) in gas phase discharges can not be easily applicable in liquids. Optical emission spectroscopy (OES) seems to be a promissing tool for studying electrical discharge in liquid phase [1]. Profiles of emission Balmer lines are very sensitive to the presence of macro- and microscopic electrical fields and are extensively used for determination of N_e and T_e in laboratory and interstellar plasmas[2].

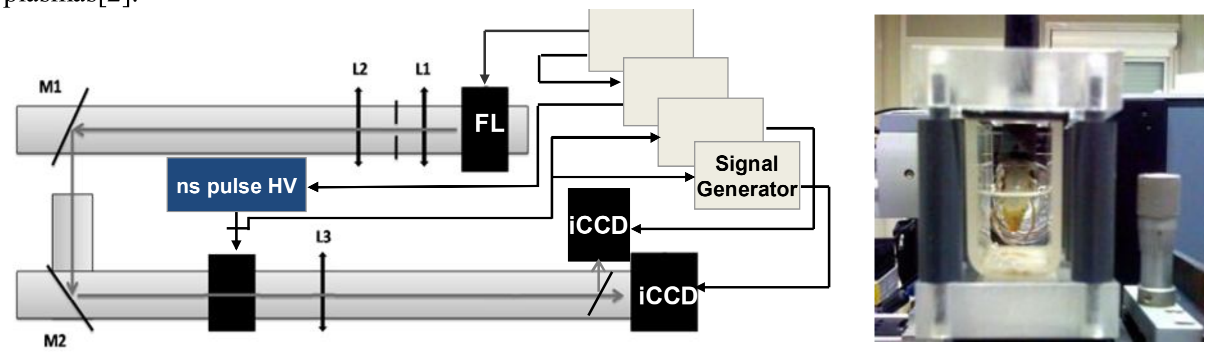

Fig. 1: Experimental setup. Shadowgraphic scheme and discharge device

Experimental setup (Fig.1) is described in detail in [3] and consists of a classical shadowgraph scheme with a Xe flash lamp as a backlight source, an objective producing the parallel beam, imaging lens, beam splitter and two iCCD cameras (ANDOR iStar 734). Time-resolved spectroscopic study is performed with a Shamrock SR-303i spectrometer equipped with a 600 l/mm grating. Discharge device has a poin-to-wire geometry with nickel pin electrode of ~1 m and interelctrode gap of 2 mm. Plasma is generated by nanosecond high voltage pulser with a 5 ns rise time, 30 ns duration (FWHM) and 10 kV amplitude (FID GmBH). Experiments are carried out in 50 ml quartz optical cell.

Single streamer discharge (Fig.2.a) is obtained at 6 kV of applied voltage propagating to the maximal length of 300 m. Expansion of the discharge channel is measured with the help of two iCCD cameras during the streamer formation phase and in the post-discharge. Analytical model of cylindrical cavity expansion in nonviscous incompressible liquid is applied to get pressure evalution inside the discharge channel. Figure 2.b demonstrates an exponential decay of discharge pressure from 1.3 GPa at 5 ns after ignition to 0,2 GPa at the end of applied voltage pulse. Time-resolved spectrum demonstrates a strong broadening of Balmer lines (Fig.3.a) with almost continuum emission in the region 300-700 nm and weak broadened OI(777nm) line. The best fit of Hα profiles is obtained as a sum of two lorentzian functions. Figure 3.b shows temporal evolution of HFHM for each component of Hα two-lorentzian fit.

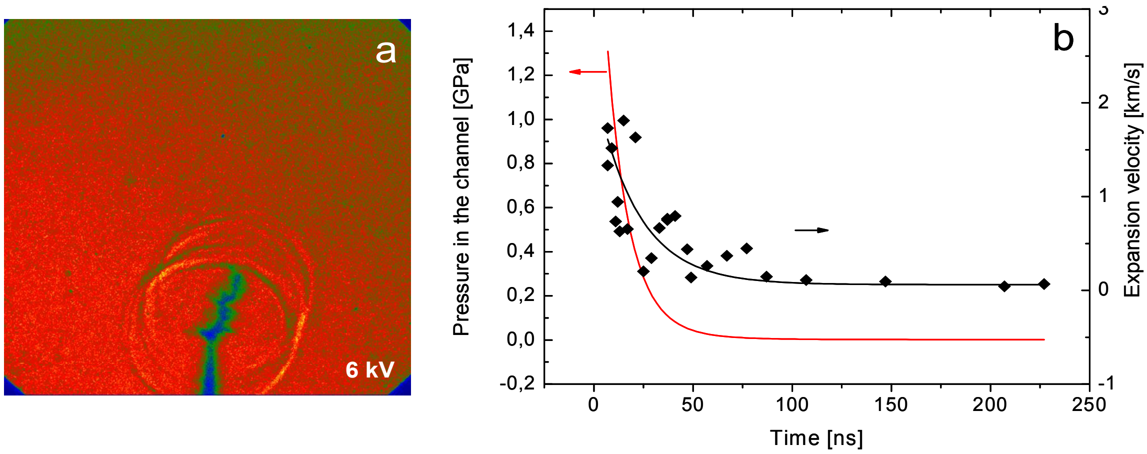

Fig. 2: a) Shadow image of the single discharge channel. Camera gate is 2 ns. b) Analytical calculation of discharge pressure

Since Stark and pressure broadening can be treated independently and both have lorentzian profile, one may suggest that complex Hα line profile is due to the combined contribution of Van Der Waals and Stark broadening. Analysis of Hβ and Hγ profiles is in progress.

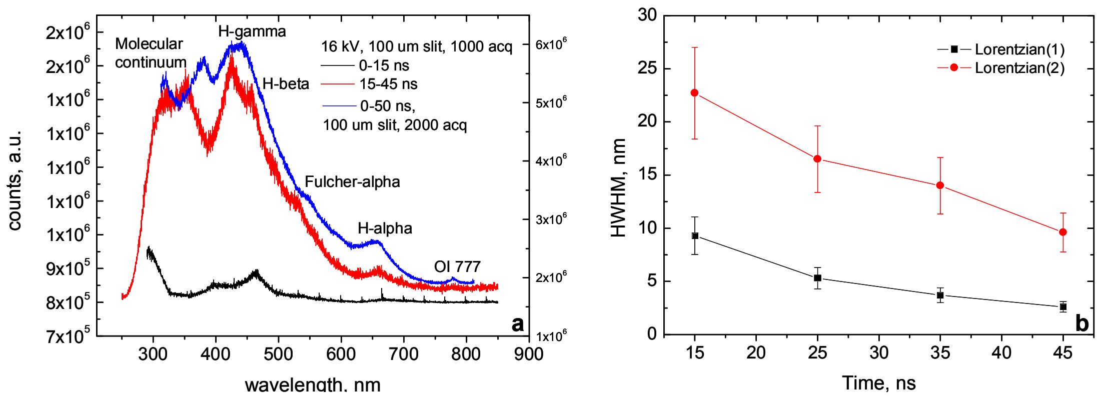

Fig. 3: a) Emission spectrum 300-820 nm avareged over 2000 discharge pulses. b) HWHM of two lorentzian fit of Hα line resolved in time during HV voltage pulse (2000 acq.)

References

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[3] I. Marinov, IEEE Transactions on Plasma Science, 39(11), (2011)