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STUDY OF A FAST GAS HEATING: EXPERIMENTAL APPROACH

E. Mintusov(1), D.A. Lacoste(2), S.J. Pendleton(3), N.A. Popov(4), G.D. Stancu(2), C.O. Laux(2), S.M. Starikovskaia(1)

(1) Laboratoire de Physique des Plasmas, Ecole Polytechnique, Palaiseau, FRANCE

(2) Laboratoire EM2C, CNRS UPR 288, Ecole Central Paris, Châtenay-Malabry, FRANCE

(3) Department of Physics and Astronomy, University of Southern California, Los Angeles, USA

(4) Skobeltsyn Institute of Nuclear Physics, Moscow State University, Moscow, RUSSIA

(*) **svetlana.starikovskaya@lpp.polytechnique.fr**

So-called fast gas heating, which is the energy release in the discharge or post-discharge due to the relaxation of energy stored in the electronic degrees of freedom, has been investigated for decades. The detailed kinetic mechanism has been developed and verified for N_2:O_2 mixtures for E/N less than 250 Td [1]. The experimental evidence of a fast energy release has been demonstrated in pulsed discharges, in particular, in a surface nanosecond barrier discharge used for flow control in aerodynamics [2]. Nevertheless there is no any predictive model describing such energy relaxation at high electric fields. The aim of our study is to develop experimental approach allowing detailed direct measurements of a fast gas heating for high electric fields and to develop the kinetic mechanism of a fast gas heating for these conditions.

For that, we suggested to use high-voltage nanosecond discharge in the form of a fast ionization wave (FIW). The main reasons for that are the discharge spatial uniformity, high values of reduced electric field during the discharge development (100-1000 Td), short duration of the discharge allowing separation of the discharge action and of the relaxation process and the fact that FIWs are relatively well studied and characterized [3].

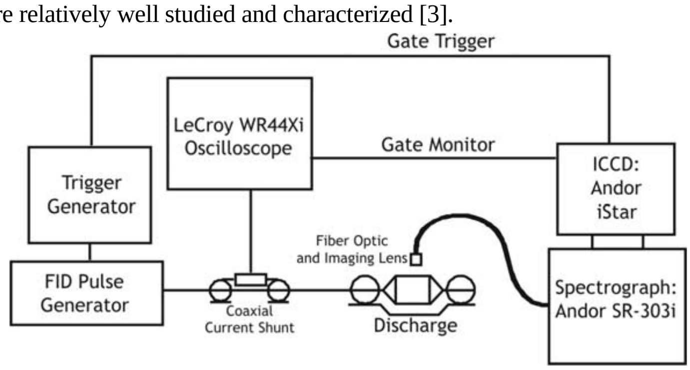

Fig. 1 Scheme of the experimental setup for measurements of energy input and gas temperature.

The following parameters are suggested to be measured during the discharge propagation: current and voltage waveforms, energy input, reduced electric field *vs* time and electron density. These experiments must be combined with two-photon absorption laser induced fluorescence (TALIF) measurements for O-atoms density and cavity ring-down (CRDS) measurements for $N(A^3\Sigma_u^+)$ density measurements. The discharge setup has been developed and tested for CRDS applications. The discharge cell consists of a quartz tube with hollow metal electrodes (the diameter of the orifice in each electrode is 5 mm), the distance between electrodes is 20 cm, and the tube diameter is 9 mm. The tube is connected to two glass side tubes with valves to pump and fill the system with a gas. The end plates of the glass tubes are the CRDS mirrors separated by 70 cm. The uniformity of the discharge between the electrodes has been checked, and the emission intensity between the electrodes and in the side tubes have been compared.

As far as the gas heating due to relaxation of electronically excited species is expected to be the most efficient and not yet influenced strongly by loss processes between 1 and 100 μs, the experiment was organized so that the additional nanosecond pulse came to the discharge cell electrodes 1.6 μs after the main pulse. The temperature was measured on the basis of emission of the second positive system of molecular nitrogen. The scheme of the experimental setup is given by Fig. 1. The measurements showed gas heating of tens K (depending on the conditions) in the post discharge. Numerical modelling performed on the basis of experimental data demonstrates a reasonable correlation between the experimental results and calculations (see Fig. 2a).

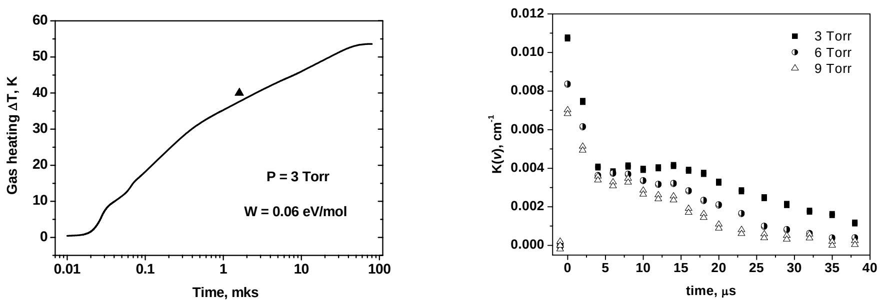

Fig. 2 (a): calculations (curve) and experimental measurements (triangle) of temperature increase for similar FIW conditions in air; (b) CRDS measurements of $N_2(A^3\Sigma_u^+)$ (v'=0–v''=2) absorption in synthetic air in the FIW afterglow for different pressures.

Cavity ring-down spectroscopy (CRDS) have been be used to measure $N_2(A^3\Sigma_u^+)$ density in near afterglow of the discharge. The CRDS cavity consists of two plano-concave mirrors (Los Gatos Research) of reflectivity R > 99.97 % and radius of curvature r= 0.5 m. The beam of a tunable pulsed dye laser, Continuum ND 6000, pumped with a Precision PL 8010 Nd:YAG laser is used to initiate the CRDS signal. The output laser energy per pulse is up to 40 mJ at 770 nm, the laser spectral width is 0.1 cm^{-1}, and the repetition frequency used of both laser and discharge is equal to 2 Hz. As far as the decay of CRDS signal is a few microseconds, the single measurement gives a point on the density curve. The delay between the high-voltage discharge and probe laser pulse is adjusted with the help of Berkeley Nucleonics 555 four channel gate and delay generator. Preliminary results (Fig. 2b) demonstrate different decays of $N_2(A^3\Sigma_u^+)$ density for 3 considered pressures, 3, 6 and 9 Torr, for experiments in synthetic air. Time means the time delay between the discharge and measurements. Sharp decay during a few first nanoseconds needs a special analysis, and the main decay is due to quenching by molecular oxygen and it is in reasonable correlation with preliminary numerical modelling. The work was partially supported by ANR (PREPA Project) and EOARD AFOSR, grant FA8655-09-1-3077.

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