PLASMA-ASSISTED DEFLAGRATION-TO-DETONATION TRANSITION

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Motivation and Objectives

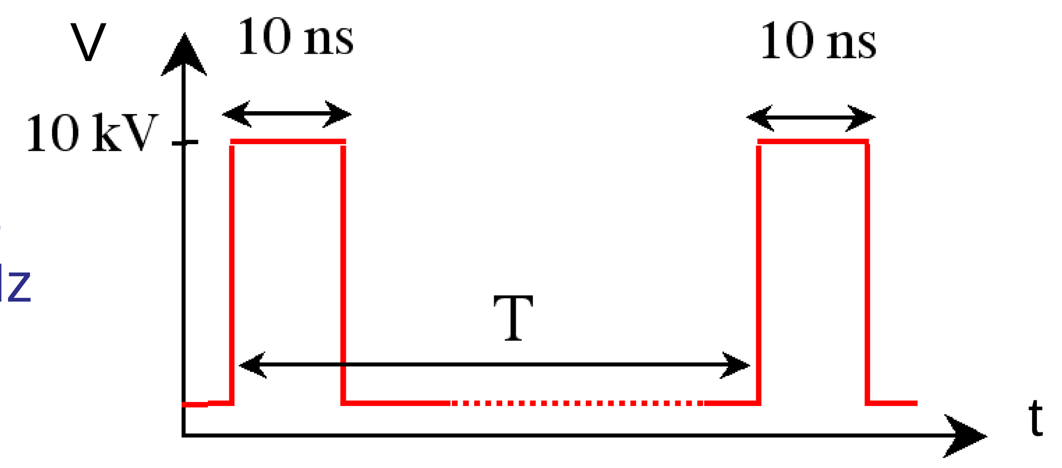
In the last decade, nanosecond repetitively pulsed (NRP) discharges have shown promising ability for combustion enhancement and ignition. For example, NRP discharges have been successfully used to decrease the ignition delay time and the lean flammability limits of gaseous mixtures. They were also successfully applied for the control of flame dynamics [1] & the ignition of detonable mixtures [2].

In this study, we propose a new potential application of these non-equilibrium plasma: the decrease of the deflagration-to-detonation transition (DDT) distance of hydrogen-air mixtures.

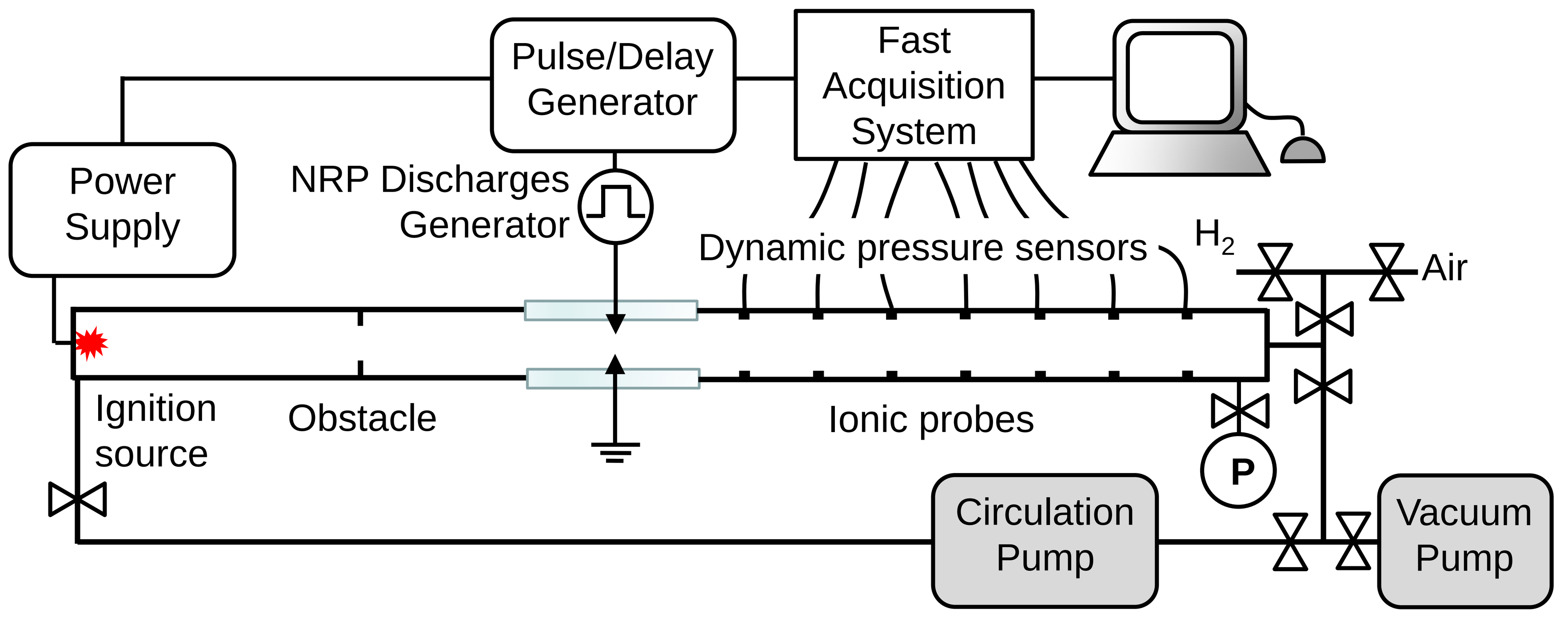
Nanosecond Repetitively Pulsed (NRP) Discharges

NRP discharges are obtained by applying high voltage pulses, during an ultrashort period of time, and repeated at high frequency. These non-equilibrium plasma discharges are very efficient in terms of gas heating and chemical activation, at low energetic cost.

★ V = 10 – 25 kV
★ Pulse duration = 10 ns
★ PRF = 1/T = 1 -100 kHz



Experimental Setup



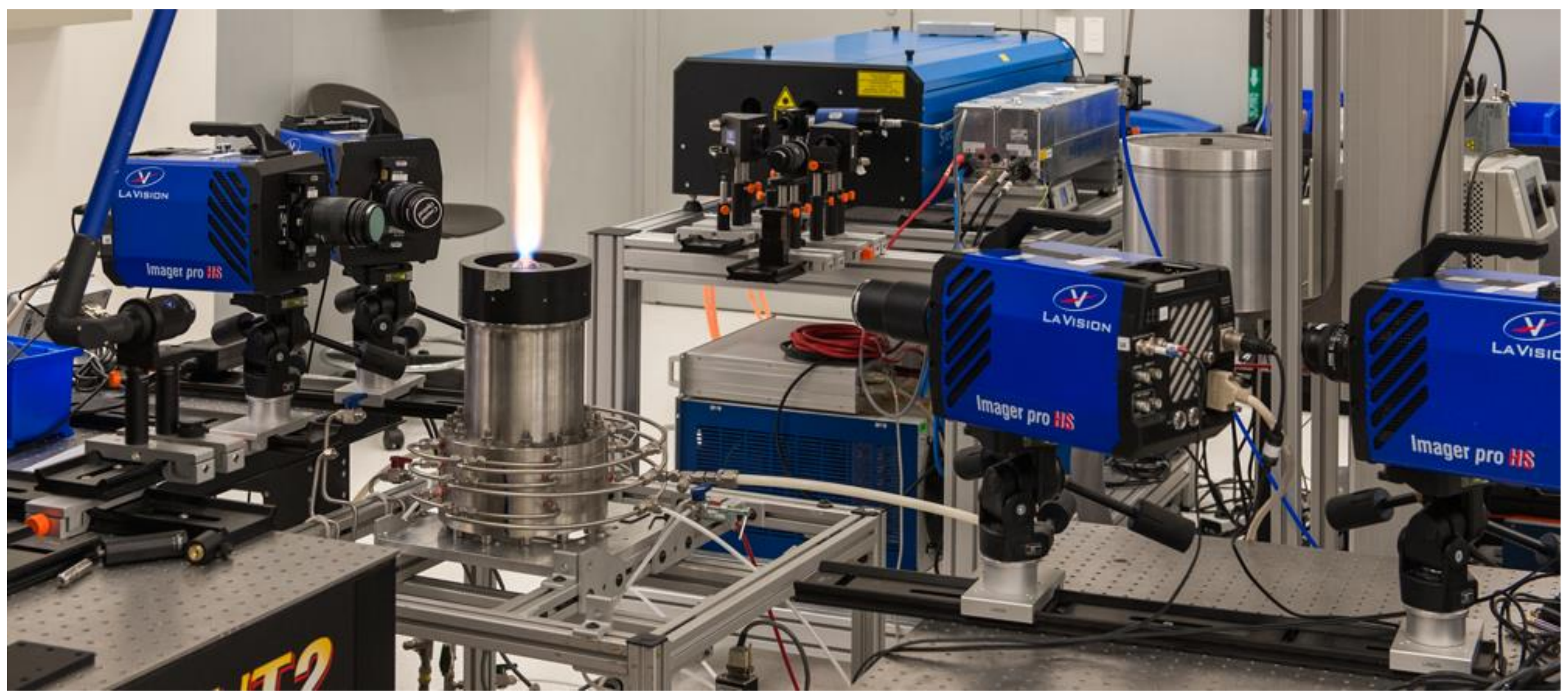
The experimental setup comprises a detonation tube equipped with a PMMA tube for optical access, an ignition system, and the system for generation of NRP discharges. All electrical systems, including acquisition, are synchronized. Below, a few characteristics:

★ Tube: 3.5 m long, 38 mm inlet diameter.
★ Hydrogen-air mixtures at room temperature and initial pressure up to 1 bar.
★ Recirculation pump to homogenize the mixture prior to ignition.
★ Distance between pressure sensors = 270 mm.
★ NRP discharges: 20 kV pulses at a frequency up to 100 kHz.
★ Pin-to-pin electrodes with a gap distance = 36 mm.
★ Blockage ratio of the obstacle = 0.43.

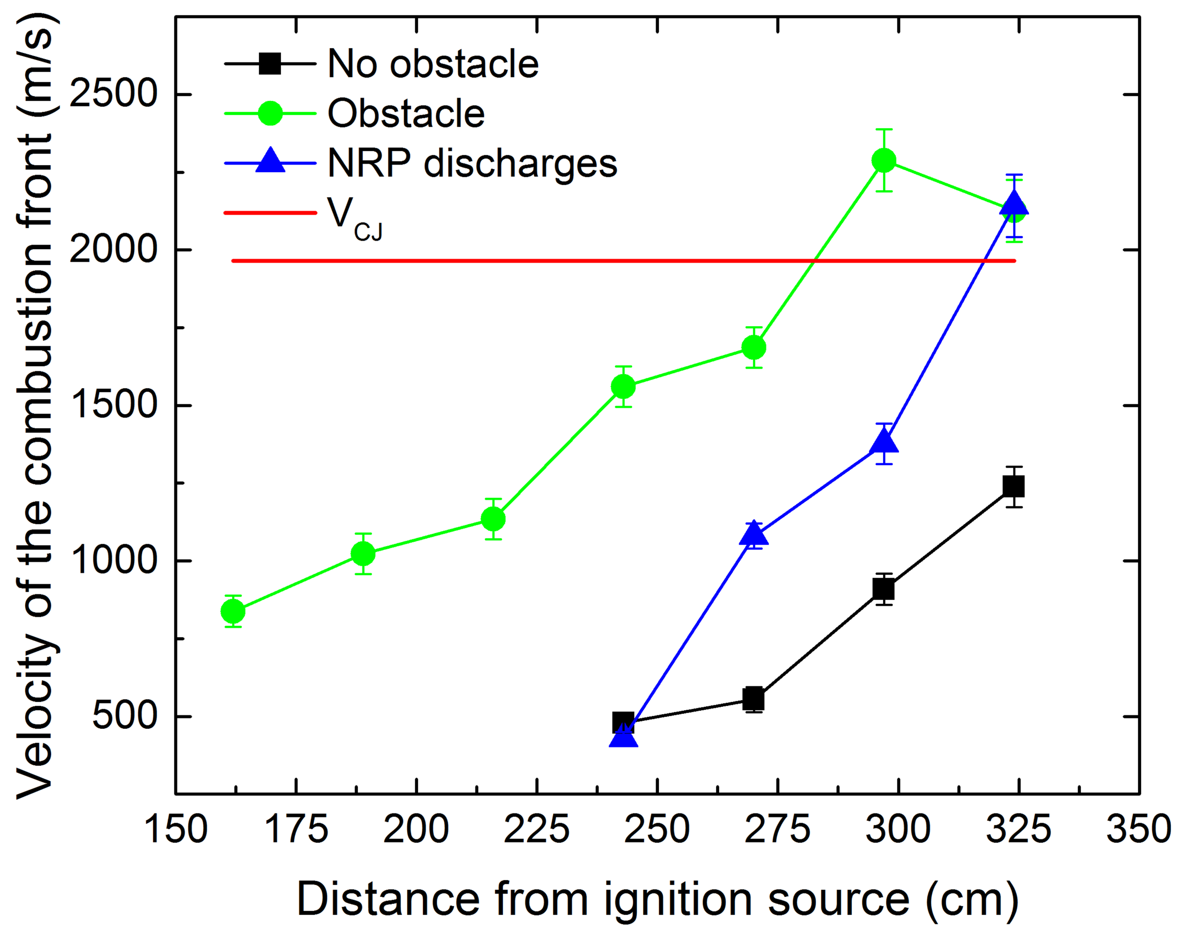
Diagnostics

The electrical, pressure and optical diagnostics used in this study allow the measurement of:

★ Electrical energy deposited at ignition and by the NRP spark discharges.
★ Velocity of the combustion front: 8 ionic probes.
★ Velocity of the pressure waves: 8 piezoelectric sensors PCB.
★ Hydrodynamic (thermal) effect of the NRP glow discharges on the flame-pressure wave propagation: fast-imaging (15 kHz) of the schlieren front in the actuation area.
★ Chemical impact of the NRP glow discharges on the flame-pressure wave propagation: OH Planar Laser Induced Fluorescence (PLIF).



Preliminary Results & Future Work



⇨ **Effect of NRP glow discharges on the DDT of H_2-Air mixture:** Proof-of-concept achieved for high-voltage NRP applied at 30 kHz, with a maximal voltage of 20 kV. In fresh mixtures, no discharge occurs, but after perturbation of the interelectrode volume by the propagation of pressure waves, there is generation of NRP spark discharges, able to enhanced the acceleration of the combustion front.

⇨ **Characterization of the plasma efficiency:** In order to assess if NRP spark discharges could be used in realistic detonation system, the energy deposited into the plasma actuation should be compared to the efficiency of increasing the ignition energy by the same quantity.

⇨ **Characterization of the plasma effect:** By using fast-schlieren visualization and OH PLIF, the effect of NRP spark discharges on the DDT will be investigated.

[1] J.P. Moeck, D.A. Lacoste, C.O. Laux, C.O. Paschereit, Control of combustion dynamics in a swirl-stabilized combustor with nanosecond repetitively pulsed discharges, AIAA 2013-0565, 51st AIAA ASM, Grapevine, TX, USA, Jan.7-10 2013
[2] J.K. Lefkowitz, P. Guo, T. Ombrello, S.H. Won, C.A. Stevens, J.L. Hoke, F. Schauer, Y. Ju, Schlieren imaging and pulsed detonation engine testing of ignition by nanosecond repetitively pulsed discharge, *Combust. Flame*, **162**(6), 2496-2507, 2015