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Transient gradient pulsed nanosecond plasmas for the initiation of a detonation wave: plasma characterisation with OES and O-TALIF

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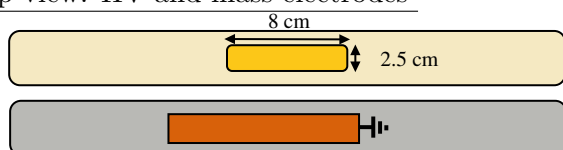
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1. Introduction

As the reality of climate change becomes increasingly undeniable, the role of combustion in our societies is coming under review. A sustainable combustion is necessary for both accompanying a successful transition and as a long-term sustainable source of energy generation. The classic constant pressure (Brayton cycle) combustion engine has been used since the end of the 18th century and refined over the last centuries to such an extent that very few improvements are feasible today. Switching to a pressure gain (Fickett-Jacobs) combustion cycle such as a detonation cycle could theoretically allow nearly 30% improvement in efficiency [1]. Extensive research has been performed on these alternate methods of combustion but many issues remain, one of which is the stability of ignition of these methods. One of the proposed methods for the ignition of a detonation wave is the chemical gradient mechanism of Zel'dovich [2]. This work introduces and characterizes a novel type of plane-to-plane discharge to generate a gradient of concentration of atomic oxygen along the span of the electrode.

2. Experimental setup and results

Top view: HV and mass electrodes



Side view: HV and mass electrodes

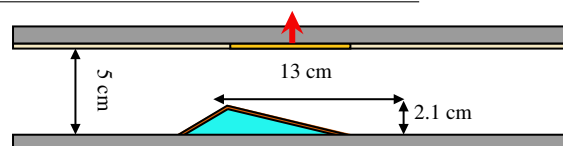


Fig. 1: Schematic of the electrode setup in top (HV electrode), side and bottom view (mass electrode). Red arrow indicates HV connection.

A varying section from a 2.9 to a 5 cm gap was imposed using a 3D-printed piece secured on the bot-

tom flange and covered with copper tape (Fig. 1).

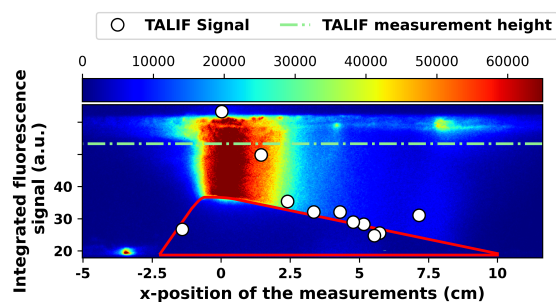


Fig. 2: ICCD imaging (20 ns gate) and O-TALIF signal intensity in 100 mbar of air.

An initial assessment of the plasma behaviour, performed using ICCD imaging (PI-MAX4 camera 200-800 nm, unfiltered, Fig. 2), showed that this type of electrode generates a diffuse plasma with a gradient of the intensity of emission along the axis of the widening of the gap. This trend, which seemed to indicate a variation in the energy deposition along the span, was confirmed by O-TALIF measurements (Fig. 2). Indeed it can be seen that a gradient of atomic oxygen density occurs, in correlation with the gap width. Optical emission spectroscopy (OES) and capacitive probe measurements were taken along the x-direction of the electrode to confirm the generation of a varying electric field. These results confirm the reduced electric field changes with the gap, as was expected. This discharge setup has been tested in stoichiometric H₂:O₂ mixtures at 100 to 250 mbar and was able to light a detonation wave over a large range of deposited energies. Further measurements are planned to confirm whether this is due to Zel'dovich gradient mechanisms.

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References

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- [2] Y. B. Zeldovich 1980 *Combust. Flame* **39** pp 241