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► **To cite this version:**

Ahlem Ghabi, Thibault Darny, Sébastien Dozias, Eric Robert, Pablo Escot-Bocanegra, et al.. Effects of pulsed gliding arc plasma on non-premixed CH₄ /CO₂ -Air flame stability. The 13th European Conference on Industrial Furnaces and Boilers, Apr 2022, Albufeira, Portugal. hal-04039399

HAL Id: hal-04039399

<https://cnrs.hal.science/hal-04039399v1>

Submitted on 21 Mar 2023

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Effects of pulsed gliding arc plasma on non-premixed CH₄/CO₂-Air flame stability

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Introduction

Investigation of flame characteristics:

- Effects of CO₂ addition to the fuel on flame stability and pollutant emissions.

Study of pulsed gliding arc plasma (PGA) assisted combustion:

- Impact of PGA plasma on the characteristics of non-premixed CH₄/CO₂-Air flames in a coaxial swirl burner.

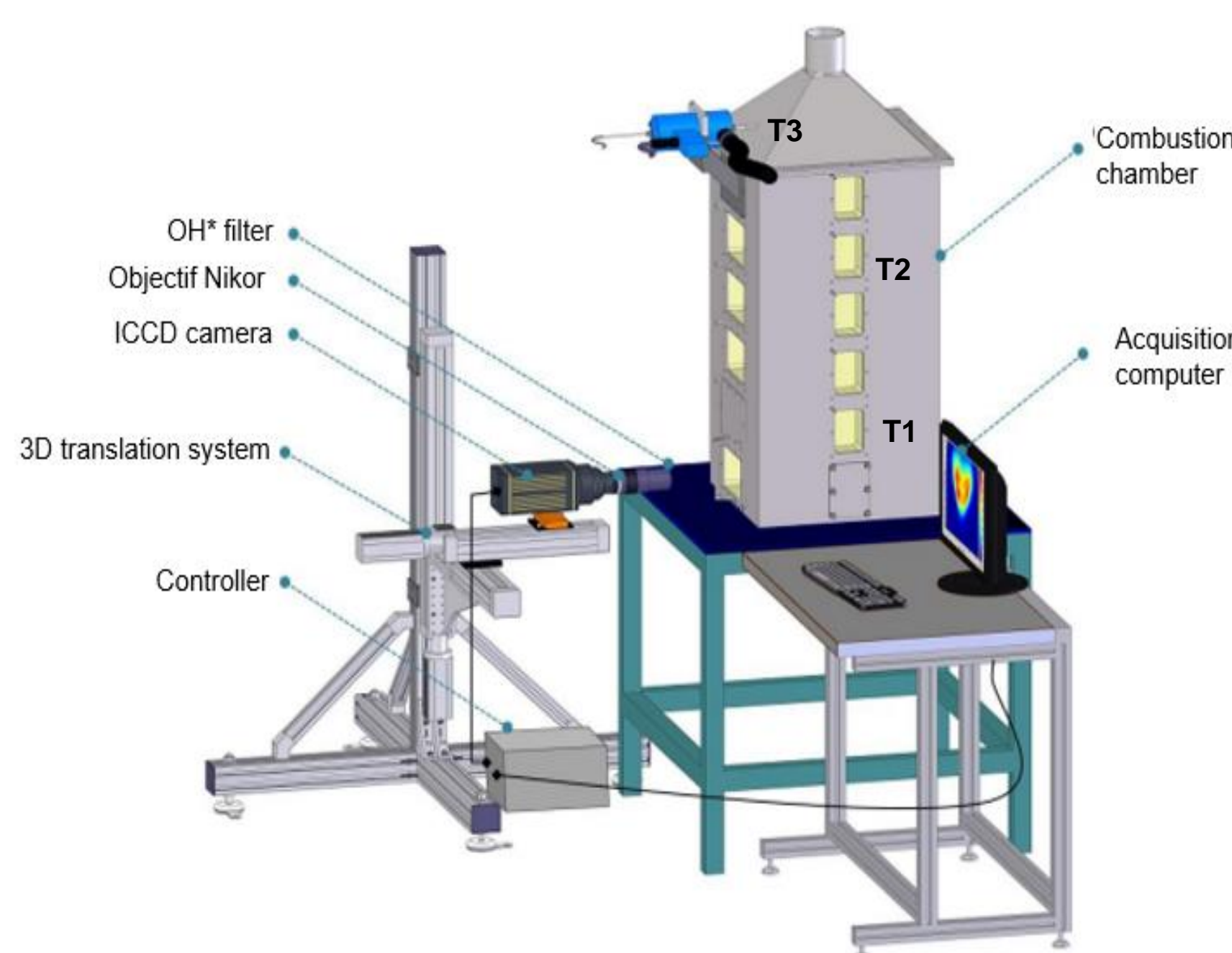
Experimental setup

OH* chemiluminescence technique

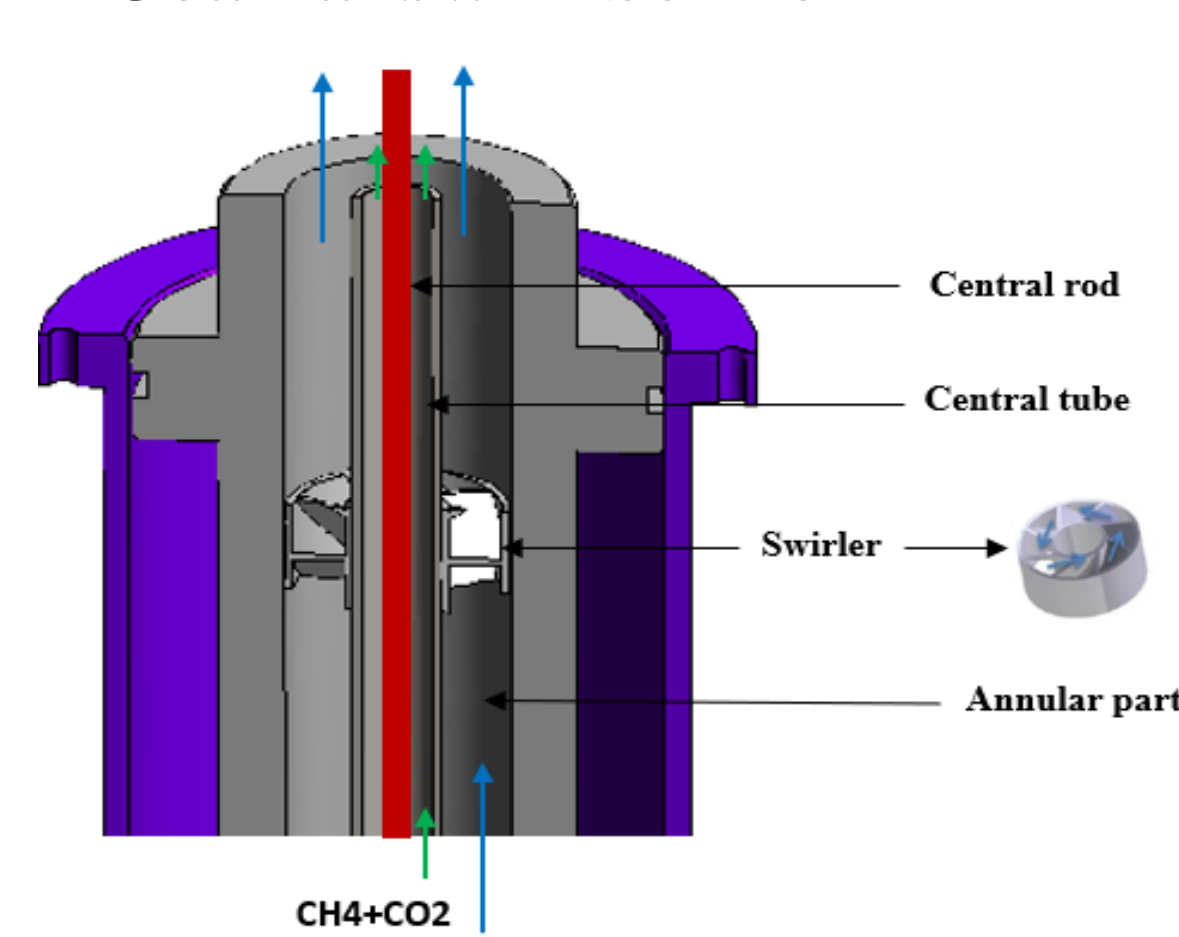
- **Apparatus** : ICCD camera, a 105 mm UV lens, a 325±55nm band-pass filter, an acquisition card with a computer.
- **Visualization of flame front** : stability, lift-off heights and flame lengths.

Measurements and analysis of flue gases

- Concentrations of NO_x, CO, CO₂, O₂ and SO₂ in flue gases are measured.
- HORIBA PG250 multi-gas analyzer.

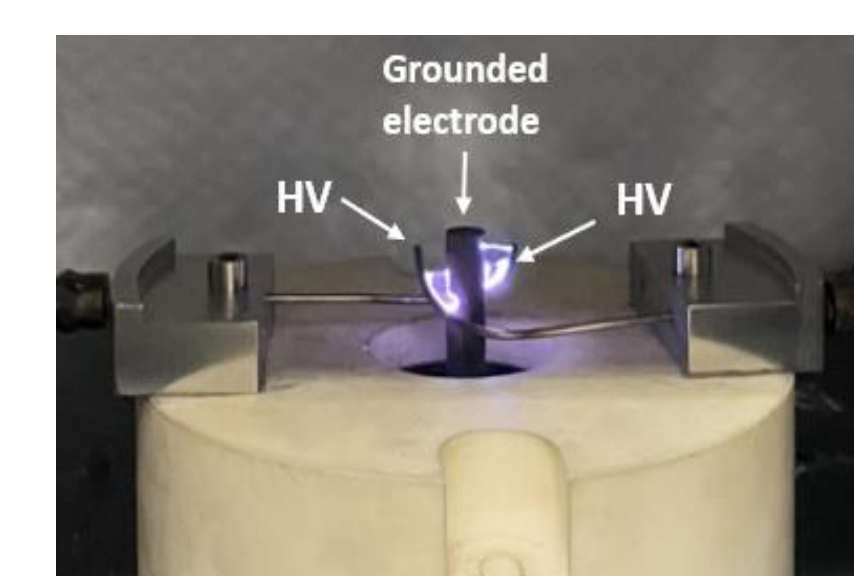


Coaxial swirl burner



- 2 concentric tubes with a swirler in the annular part and a central metal rod used as a cathode for the plasma.

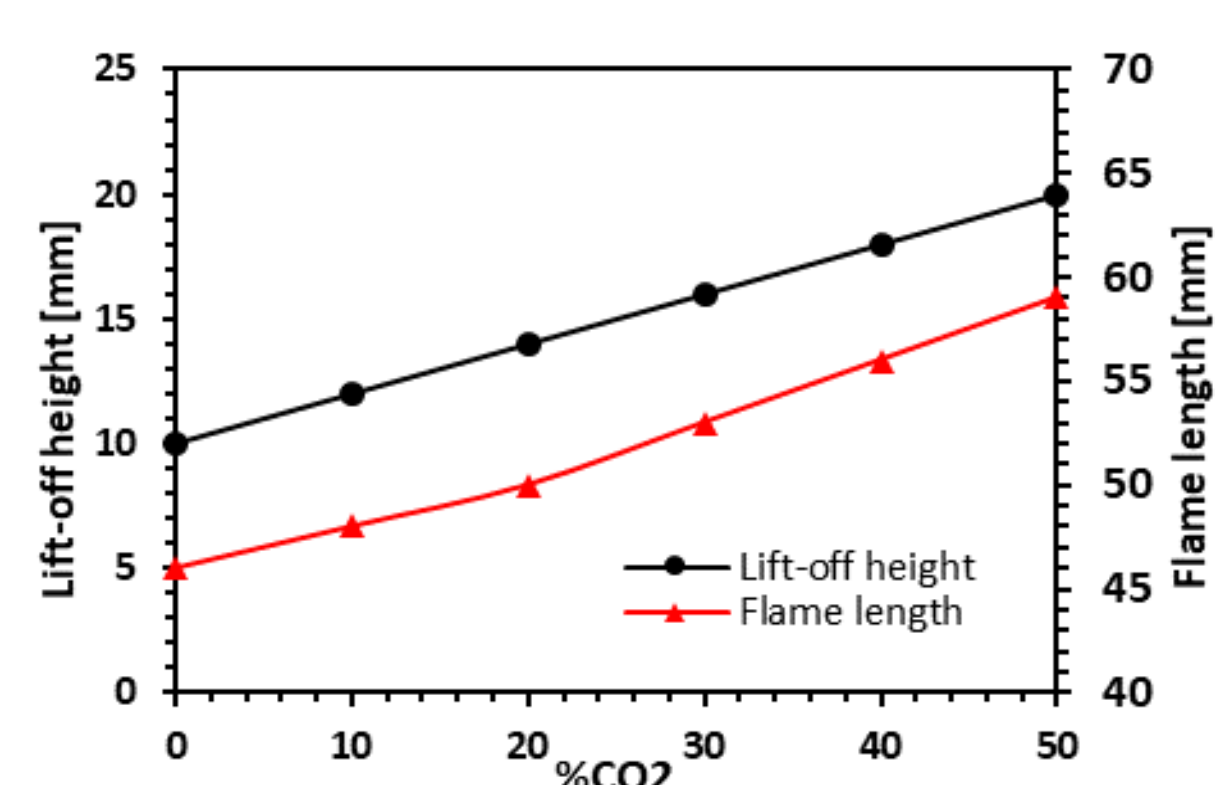
Plasma configuration



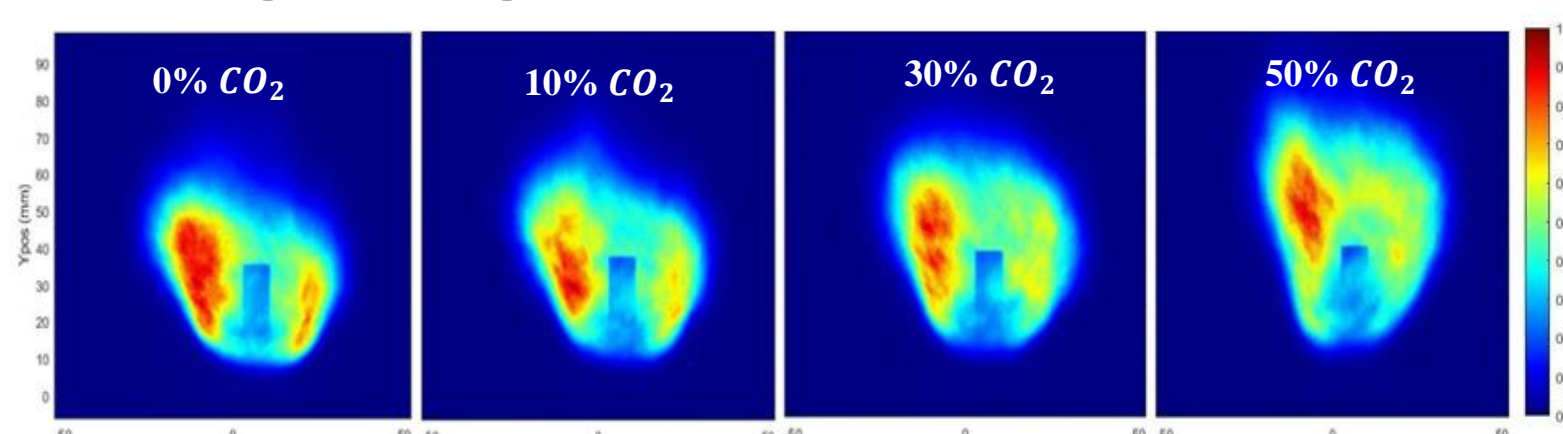
- The PGA plasma is generated between the grounded center rod of the burner (cathode), and two other high voltage (HV) electrodes symmetrically placed around the central rod.

Results

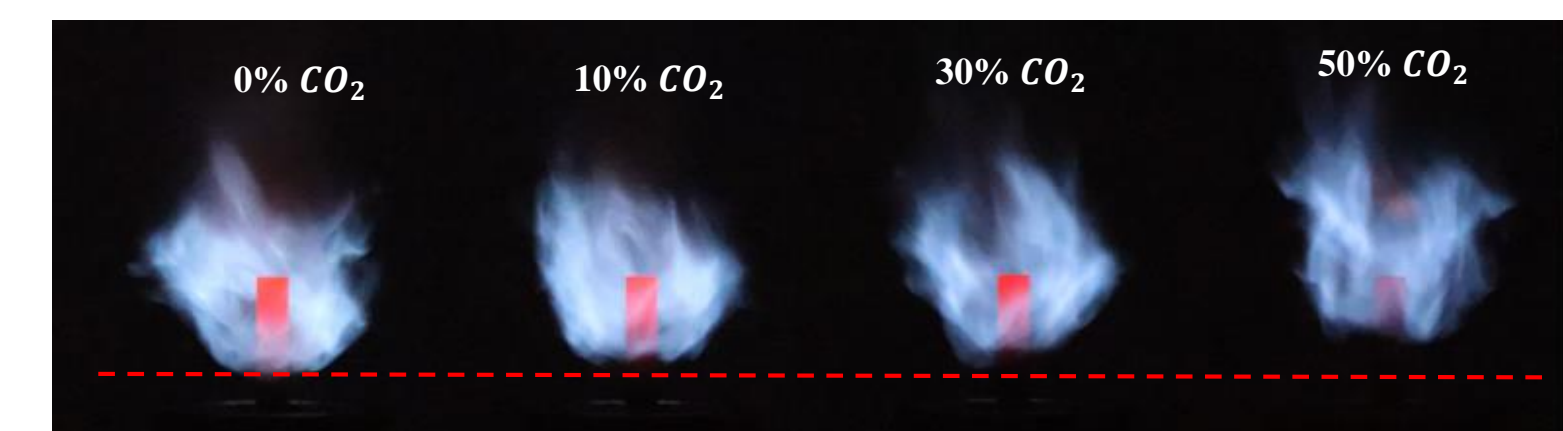
Lift-off height and flame length = f (%CO₂)



Average images of OH* chemiluminescence

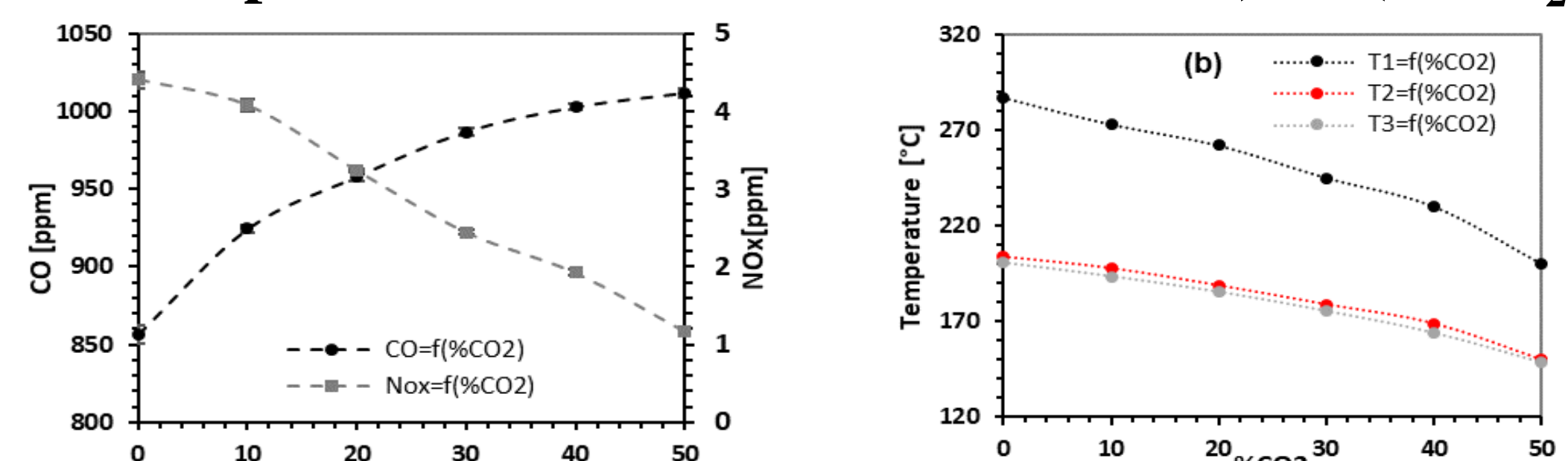


Direct photographs of flame, $\phi=0.4$, $Sn=0.8$



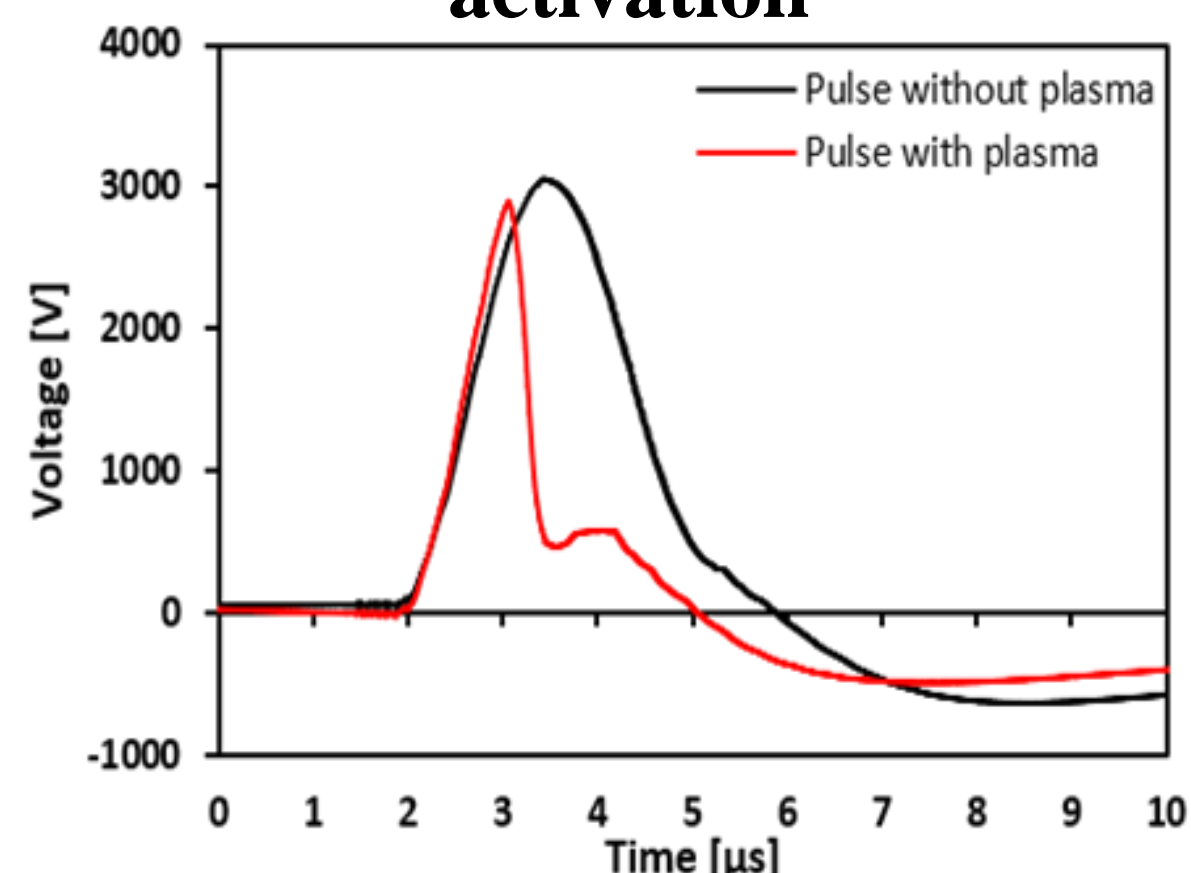
- $L_f \nearrow$ with the addition of CO₂ to the fuel due to the decrease of flame burning velocity and flame temperature which disadvantages the flame stabilization.

NO_x and CO emissions = f (% CO₂); (b) Flue gases temperature (at 3 different positions in the combustion chamber) = f (%CO₂)



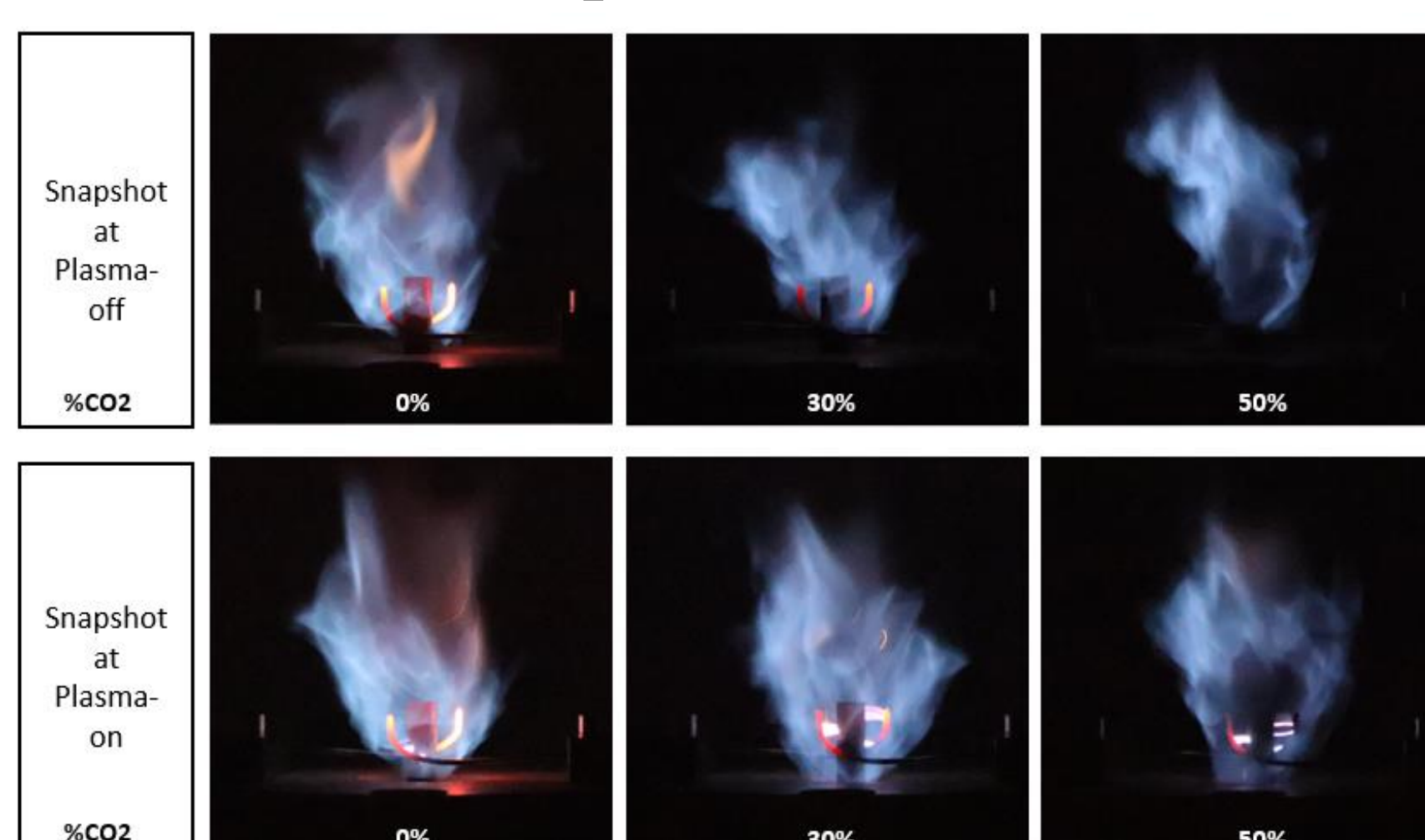
- Increasing 50% of CO₂ in the fuel increases CO to 18% in flue gases → Due to thermal dissociation of CO₂ in the high-temperature regions of the flame.
- Low concentration of NO_x in both cases without and with addition of CO₂.

Temporal evolution of the HV pulse without and with plasma activation



- Pulse frequency fixed at 10kHz, for both HV electrodes.
- The applied voltage is measured at between 3 and 3,5kV ± 350V at the different operational conditions.

Direct photographs of the flame in the case of plasma-OFF and plasma-ON (f=10kHz) = f(%CO₂), $\phi=0.4$, $Sn=0.8$

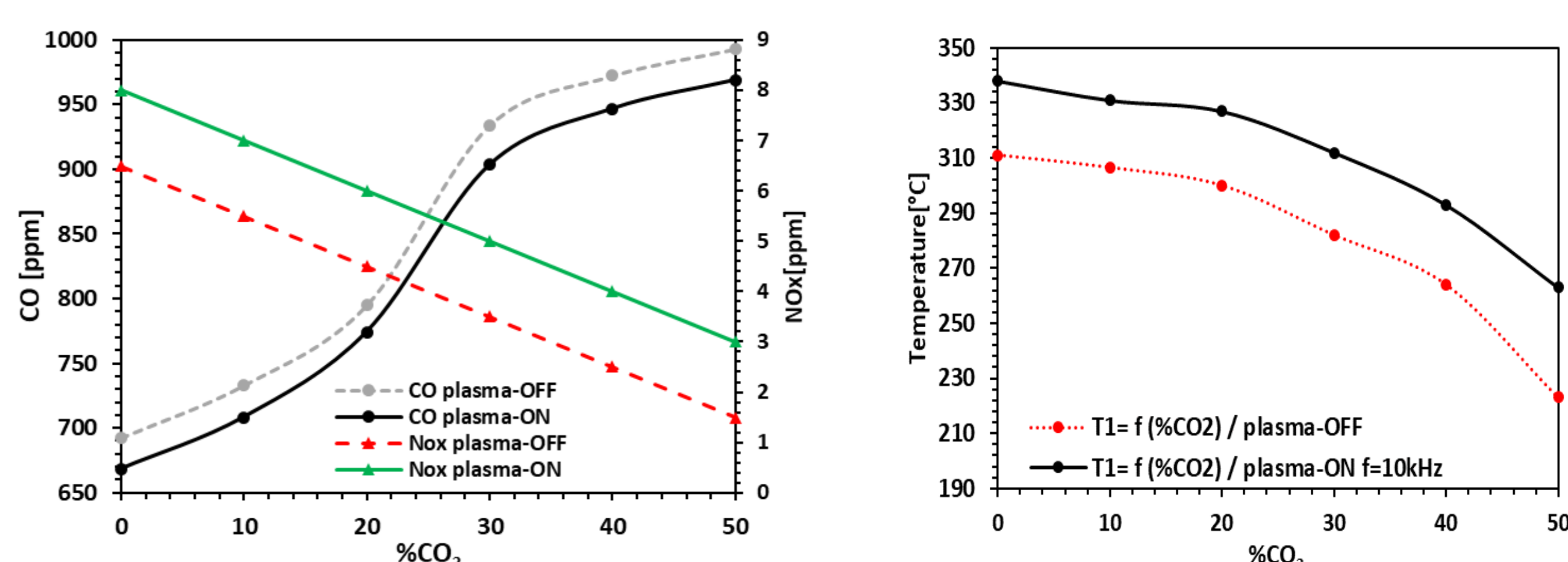


- With the presence of PGA plasma, the lift-off height decreases, by nearly a half time the initial one without plasma.

Conclusion

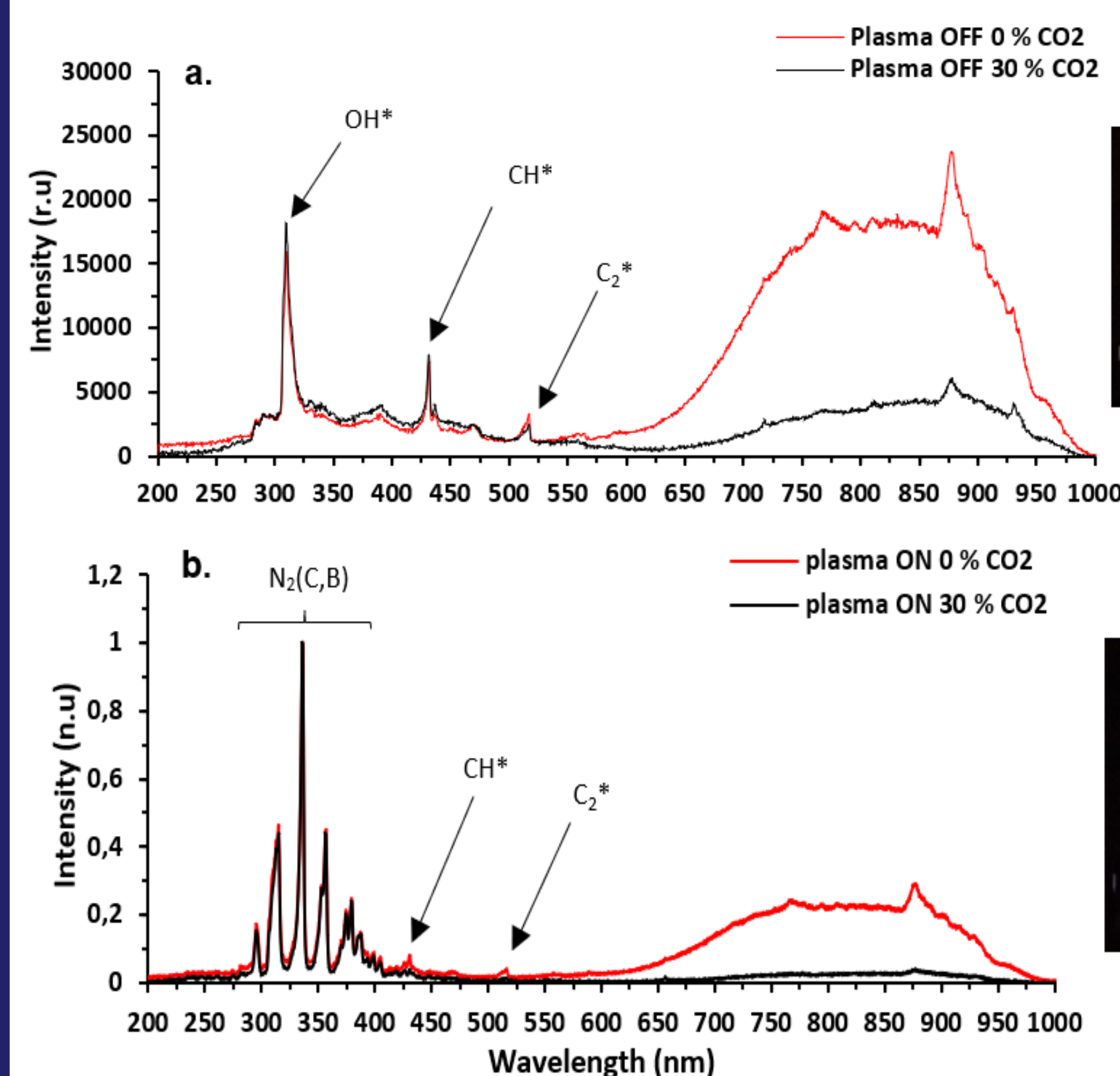
- The addition of CO₂ to the fuel leads to an increase of CO and a slight decrease of NO_x, with a reduction of combustion gases temperature.
- PGA plasma plays a role to stabilize the flame, the lift-off heights of the flames decrease with the presence of PGA plasma (due to the N₂* production).
- PGA plasma decreases CO (about 3%) production.

Effect of PGA plasma on (a) NO_x and CO emissions; (b) Combustion gas temperature (T1) with plasma-OFF and plasma-ON



- Same trend followed by the pollutant emissions (CO and NO_x) and the temperature T1 in both cases plasma-OFF and plasma-ON.
- Addition of 50% of CO₂ to the fuel decreases the temperature T1 by 22% → Due to thermal and radiative properties of CO₂.
- Plasma activation (at f=10kHz) increases the temperature T1 by nearly 12%.
- Slight decrease of CO emissions with plasma → The enhance in conversion of CO to CO₂ with plasma.
- Low concentration of NO_x that remains almost same in both cases plasma-ON and Plasma-OFF.

Emission spectra of (a.) CH₄-Air and CH₄/CO₂-Air flames and (b.) plasma-flames. The integration time is 2 s in (a.) and 0.4 s in (b.)



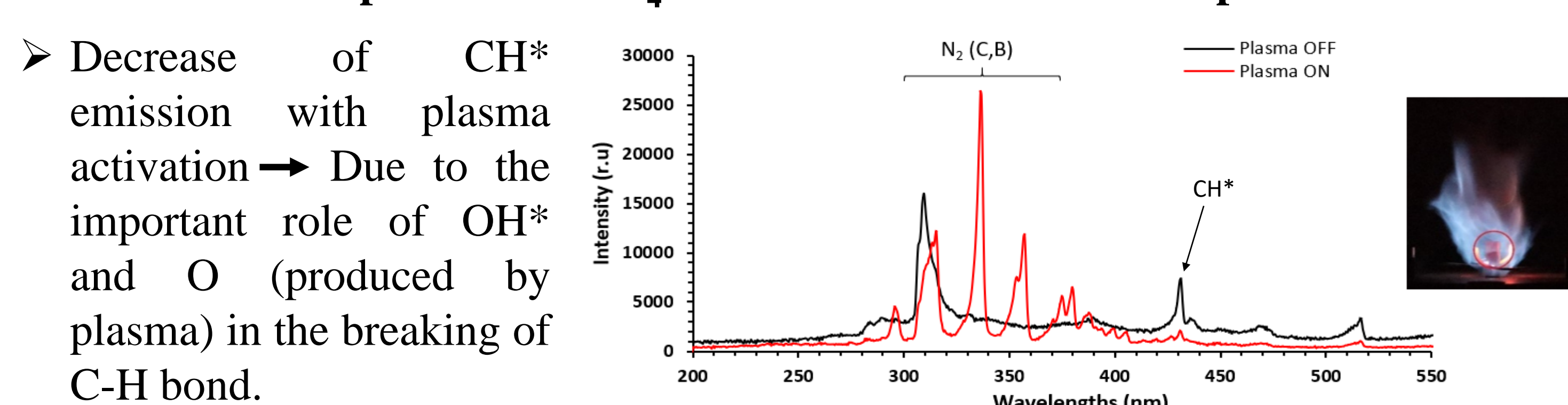
Plasma-OFF

- More intense OH* (308,9 nm) and CH (431,3 nm) emissions with CO₂ addition.

Plasma-ON

- OH* convoluted with the band structure of N₂(1,0) emission at 315,9 nm.
- O (dissociation of O₂ with the excited N₂) is hidden by the continuum of emission.

Emission spectra of a CH₄-Air flame with and without plasma



- Decrease of CH* emission with plasma activation → Due to the important role of OH* and O (produced by plasma) in the breaking of C-H bond.

Acknowledgements

The authors are grateful for the financial support of this work provided by the ANR (LABEX CAPRYSSES project) and the Centre Val de Loire Region (CAPRI project).