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# Effects of pulsed gliding arc plasma on non-premixed CH<sub>4</sub>/CO<sub>2</sub>-Air flame stability

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## Introduction

### Investigation of flame characteristics:

- Effects of CO<sub>2</sub> 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 CH<sub>4</sub>/CO<sub>2</sub>-Air flames in a coaxial swirl burner.

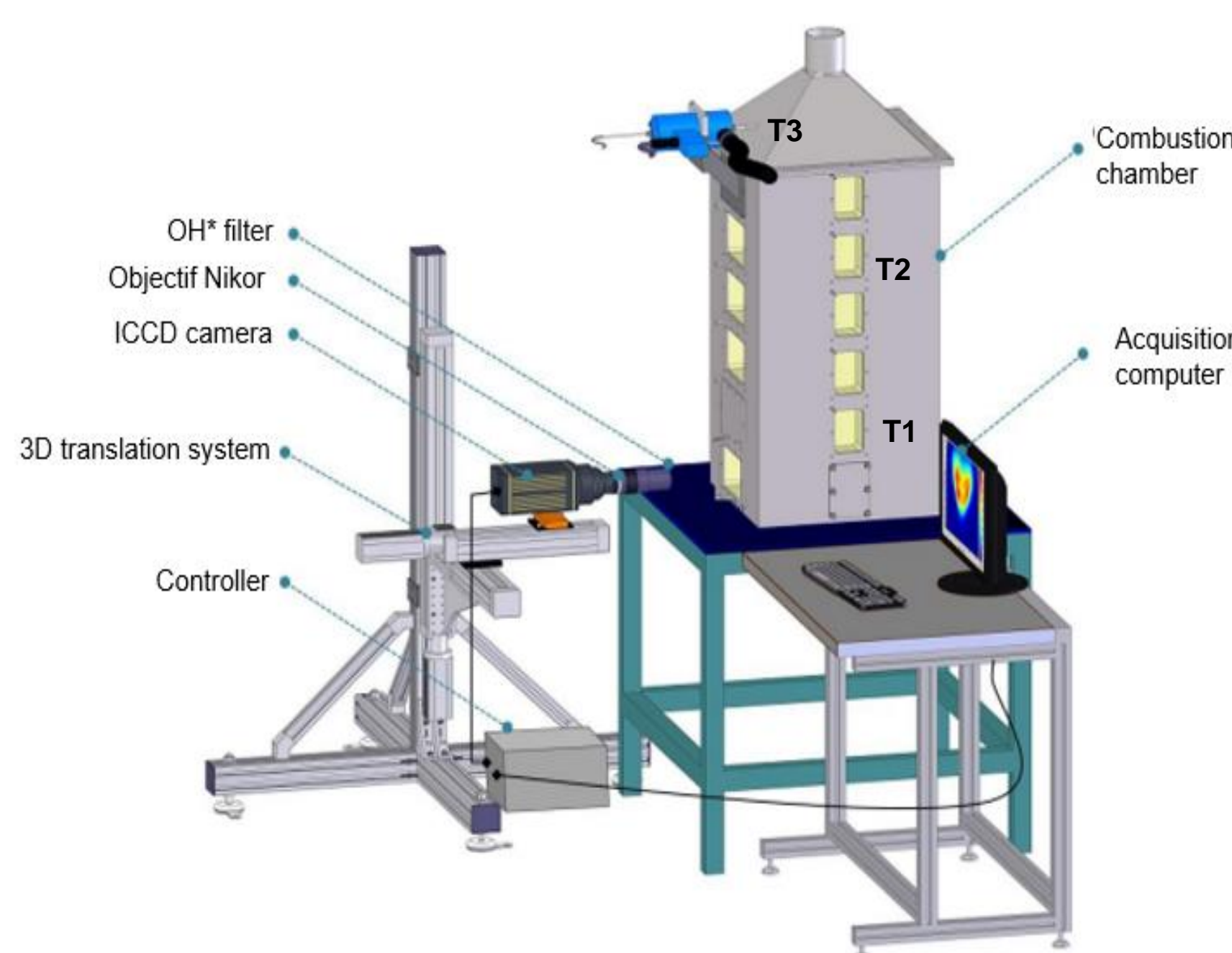
## Experimental setup

### OH\* chemiluminescence technique

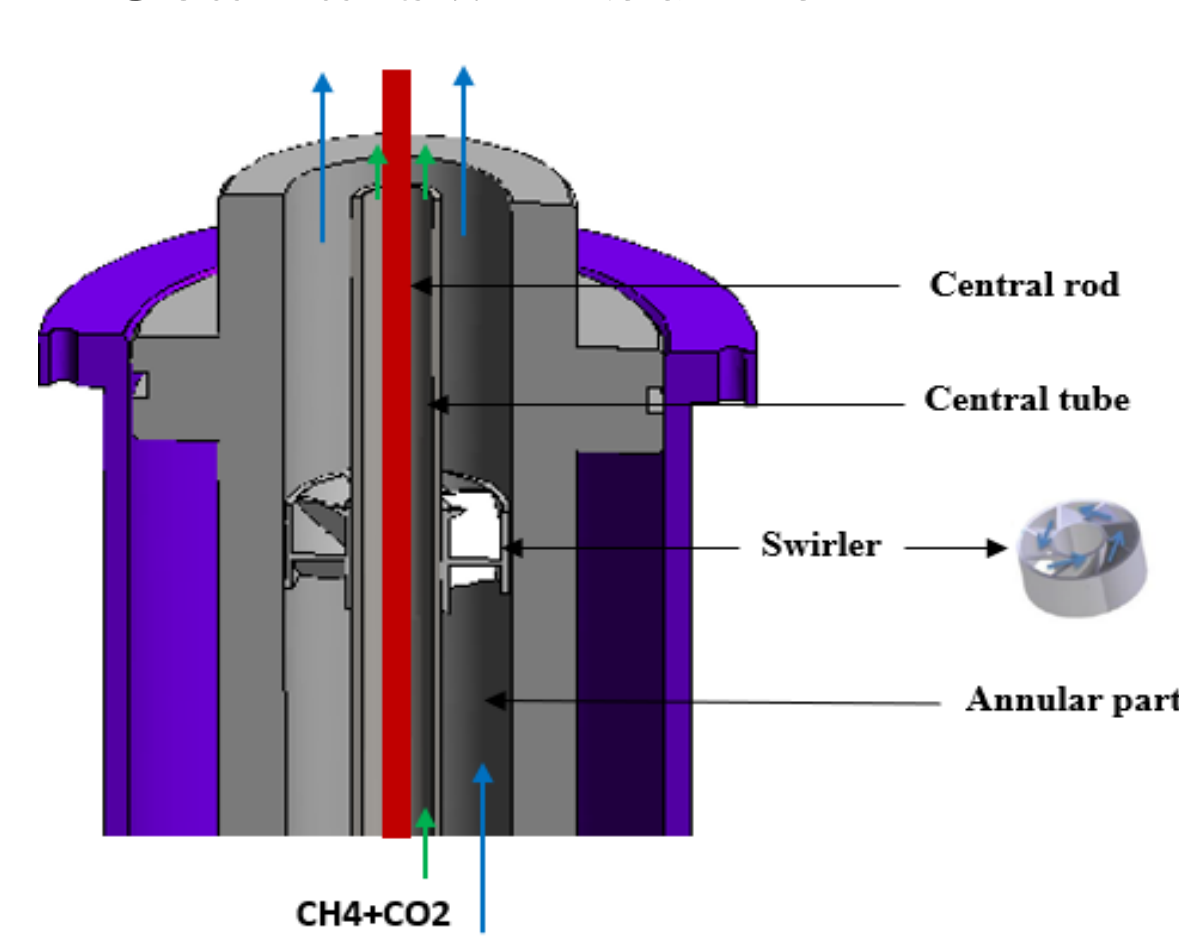
- **Apparatus** : ICCD camera, a 105 mm UV lens, a 325±55nm band-pass filter, an acquisition card with a computer.
- **Visualization of flame front** : stability, lift-off heights and flame lengths.

### Measurements and analysis of flue gases

- Concentrations of NO<sub>x</sub>, CO, CO<sub>2</sub>, O<sub>2</sub> and SO<sub>2</sub> in flue gases are measured.
- HORIBA PG250 multi-gas analyzer.

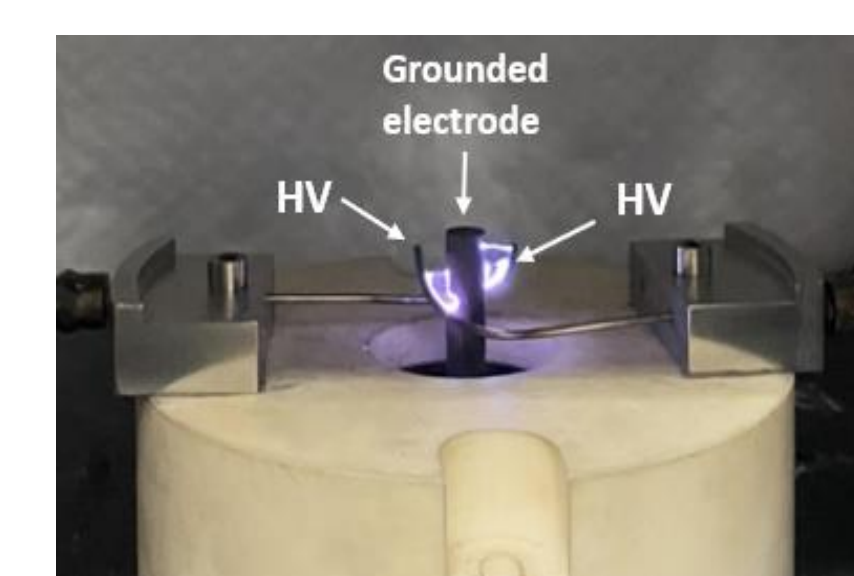


### Coaxial swirl burner



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

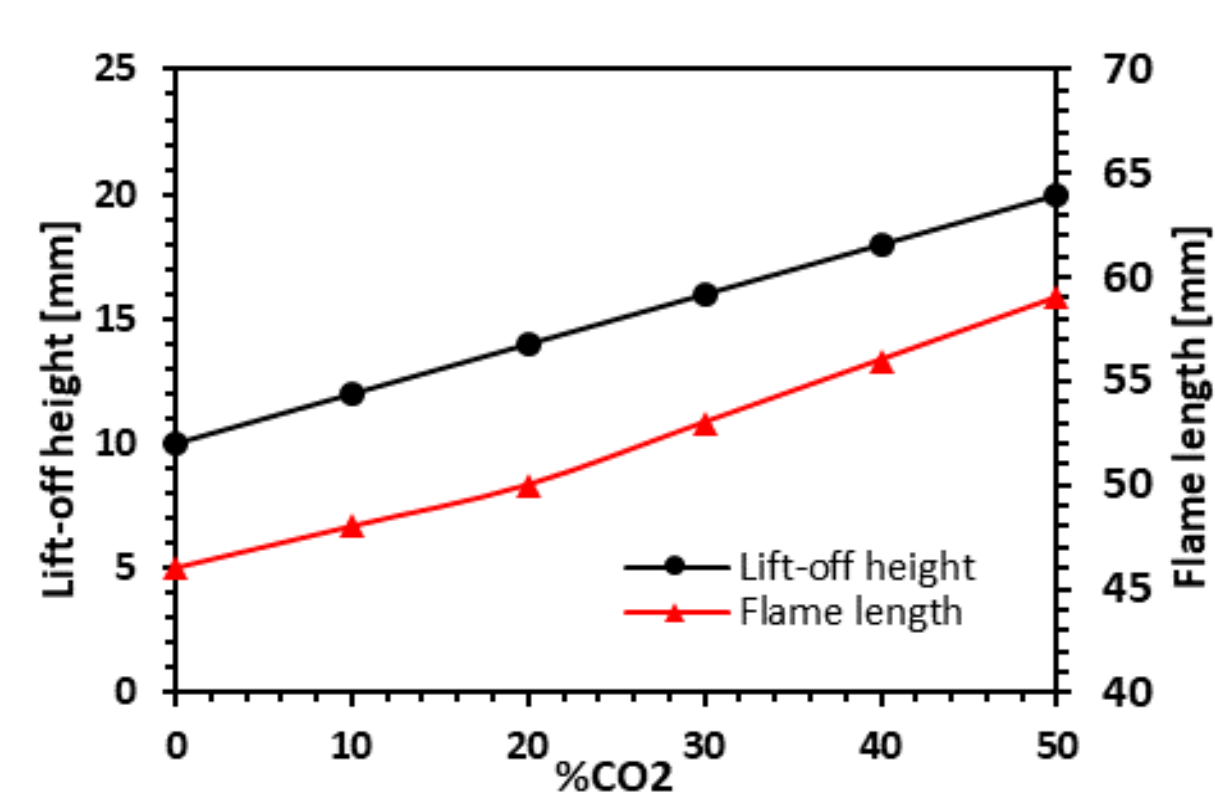
### Plasma configuration



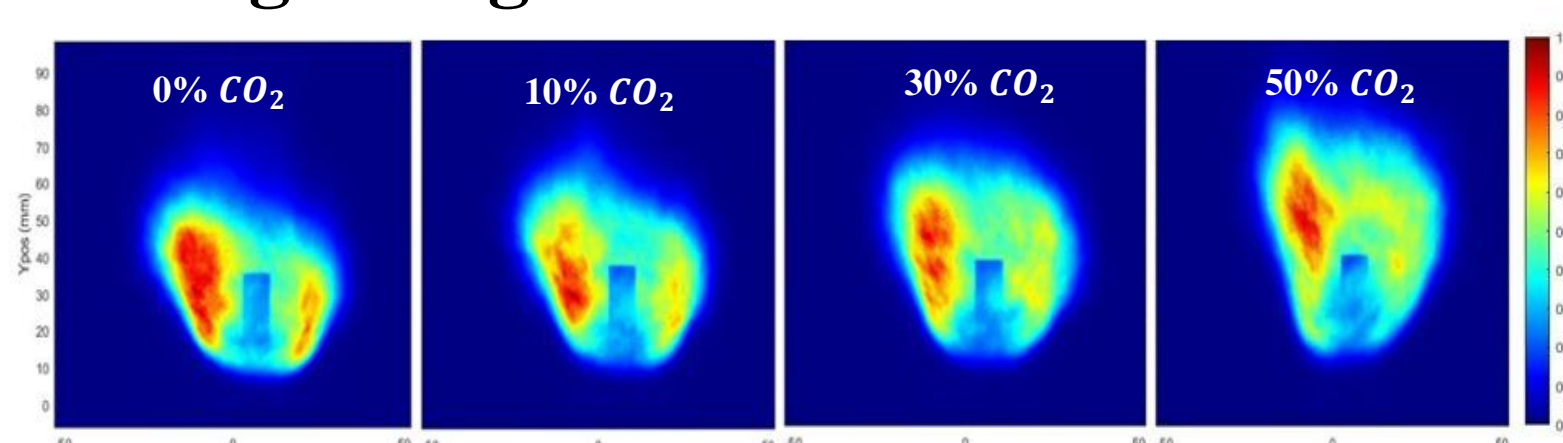
- The PGA plasma is generated between the grounded center rod of the burner (cathode), and two other high voltage (HV) electrodes symmetrically placed around the central rod.

## Results

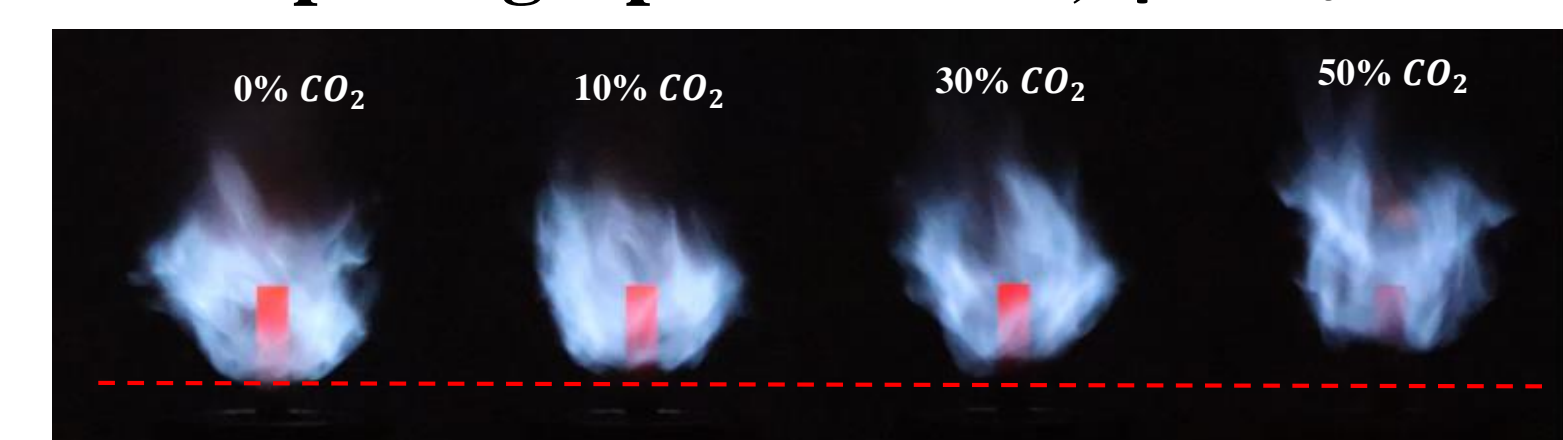
### Lift-off height and flame length = f (%CO<sub>2</sub>)



### Average images of OH\* chemiluminescence

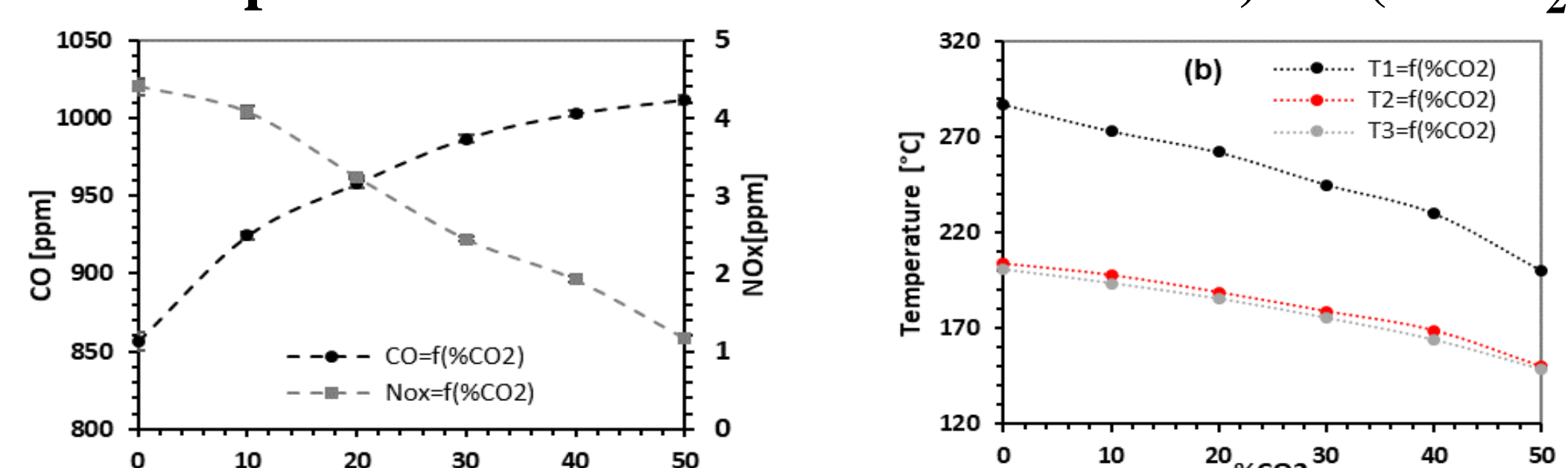


### Direct photographs of flame, $\phi=0.4$ , $Sn=0.8$



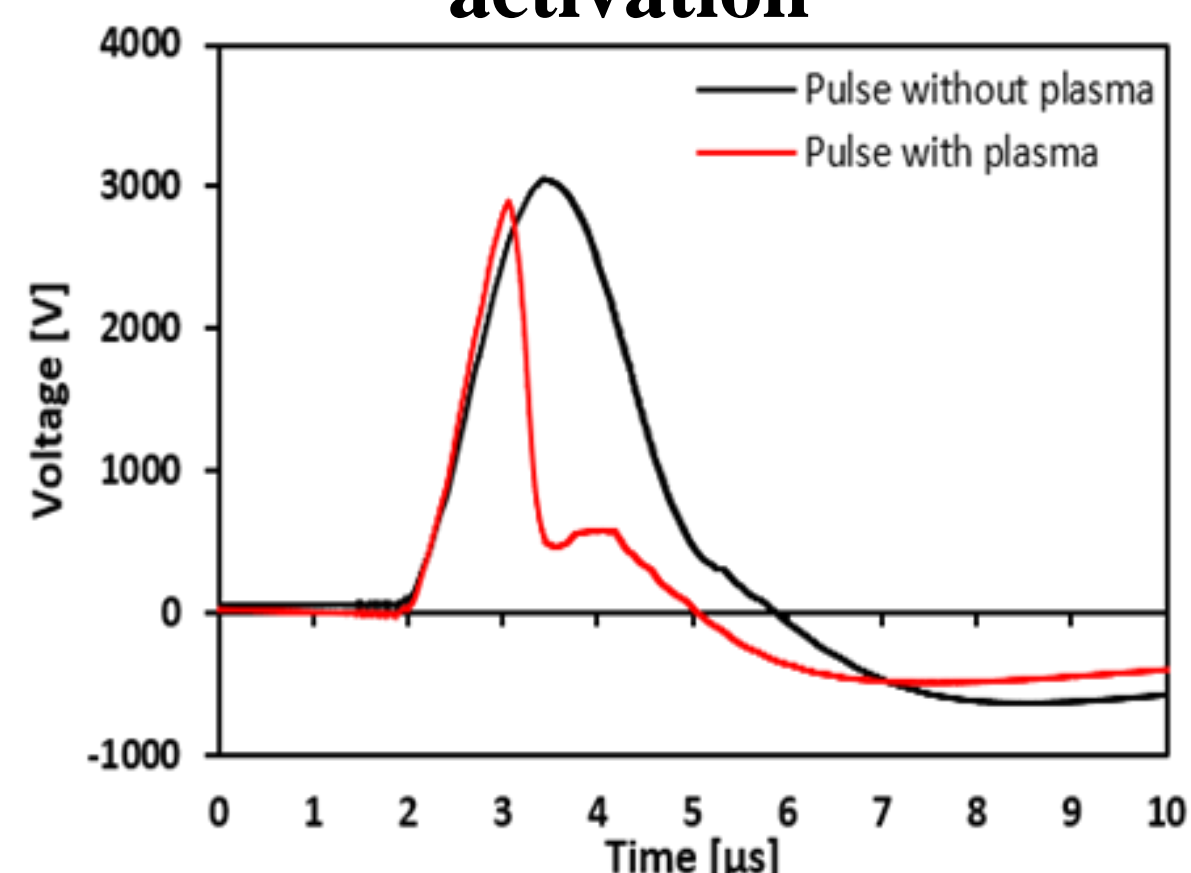
- $L_f \nearrow$  with the addition of CO<sub>2</sub> to the fuel due to the decrease of flame burning velocity and flame temperature which disadvantages the flame stabilization.

### NO<sub>x</sub> and CO emissions = f (% CO<sub>2</sub>); (b) Flue gases temperature (at 3 different positions in the combustion chamber) = f (%CO<sub>2</sub>)



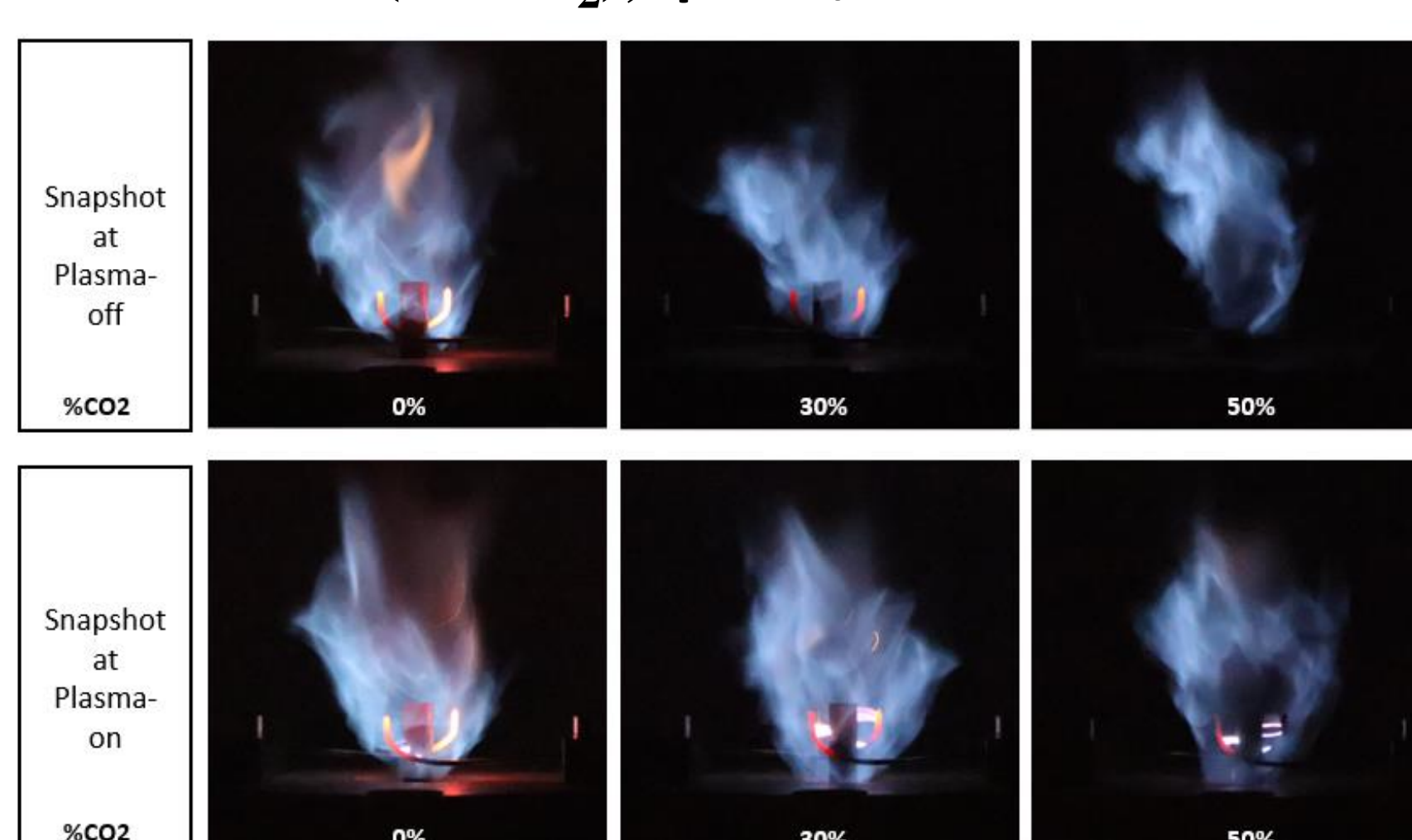
- Increasing 50% of CO<sub>2</sub> in the fuel increases CO to 18% in flue gases → Due to thermal dissociation of CO<sub>2</sub> in the high-temperature regions of the flame.
- Low concentration of NO<sub>x</sub> in both cases without and with addition of CO<sub>2</sub>.

### 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(%CO<sub>2</sub>), $\phi=0.4$ , $Sn=0.8$

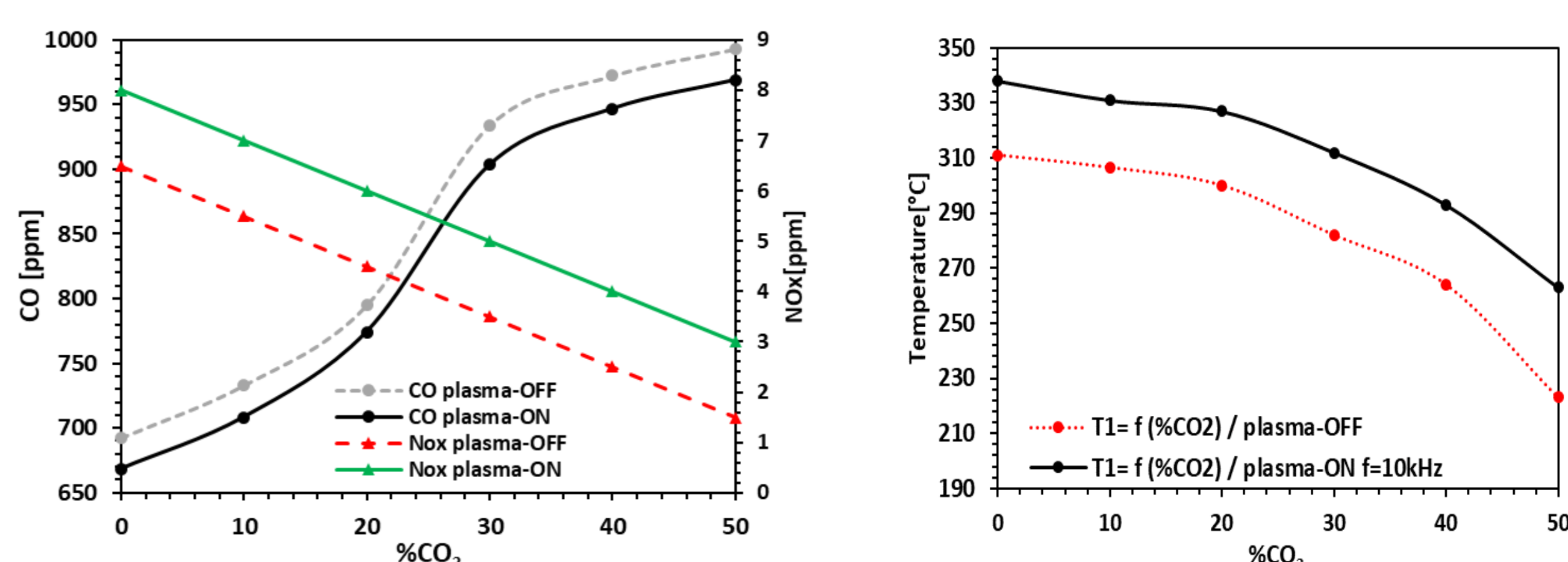


- With the presence of PGA plasma, the lift-off height decreases, by nearly a half time the initial one without plasma.

## Conclusion

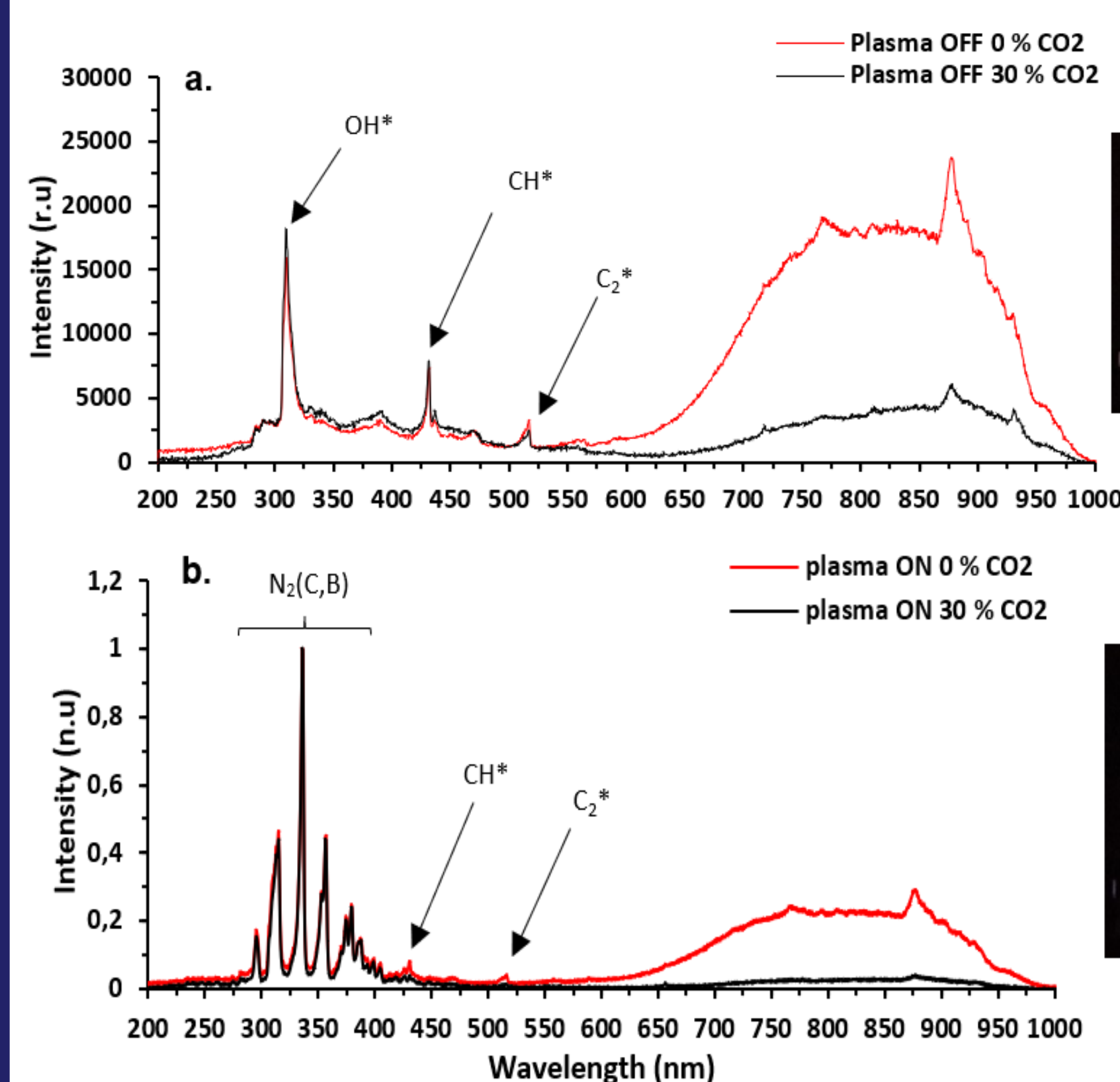
- The addition of CO<sub>2</sub> to the fuel leads to an increase of CO and a slight decrease of NO<sub>x</sub>, with a reduction of combustion gases temperature.
- PGA plasma plays a role to stabilize the flame, the lift-off heights of the flames decrease with the presence of PGA plasma (due to the N<sub>2</sub>\* production).
- PGA plasma decreases CO (about 3%) production.

### Effect of PGA plasma on (a) NO<sub>x</sub> and CO emissions; (b) Combustion gas temperature (T1) with plasma-OFF and plasma-ON



- Same trend followed by the pollutant emissions (CO and NO<sub>x</sub>) and the temperature T1 in both cases plasma-OFF and plasma-ON.
- Addition of 50% of CO<sub>2</sub> to the fuel decreases the temperature T1 by 22% → Due to thermal and radiative properties of CO<sub>2</sub>.
- 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 CO<sub>2</sub> with plasma.
- Low concentration of NO<sub>x</sub> that remains almost same in both cases plasma-ON and Plasma-OFF.

### Emission spectra of (a.) CH<sub>4</sub>-Air and CH<sub>4</sub>/CO<sub>2</sub>-Air flames and (b.) plasma-flames. The integration time is 2 s in (a.) and 0.4 s in (b.)



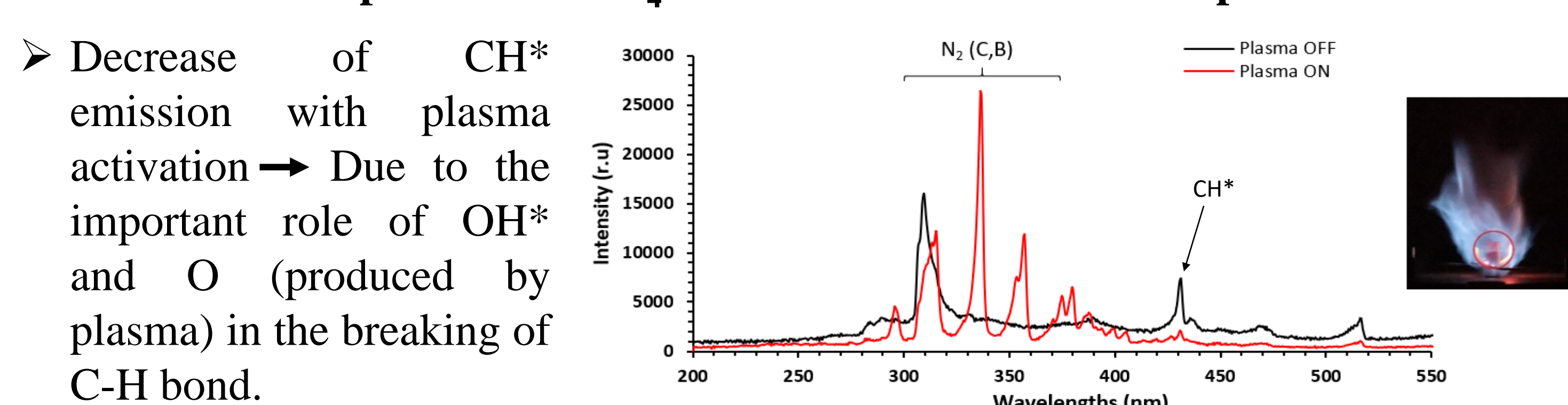
### Plasma-OFF

- More intense OH\* (308,9 nm) and CH (431,3 nm) emissions with CO<sub>2</sub> addition.

### Plasma-ON

- OH\* convoluted with the band structure of N<sub>2</sub>(1,0) emission at 315,9 nm.
- O (dissociation of O<sub>2</sub> with the excited N<sub>2</sub>) is hid by the continuum of emission.

### Emission spectra of a CH<sub>4</sub>-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.

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