Temperature dynamics in plasma-assisted combustion of N_2/CH_4 mixture using hybrid fs/ps-CARS

Thomas Vazquez[1], Laila Dakroub[2], Michael Scherman[2], Brigitte Tretout[2], Christophe Laux[1], Sean McGuire[1]

1. *EM2C Laboratory, 2 rue Joliot Curie, Gif-sur-Yvette, 91190, France*
2. *DPHY, ONERA, Université Paris-Saclay, 91120 Palaiseau, France*

Plasma-Assisted Combustion (PAC) is a promising technique for stabilizing lean flames, offering a way to reduce emissions in aircraft engines and industrial burners. With the transition to sustainable aviation fuels (SAF) and carbon-neutral fuels like hydrogen (H_2), which are CO_2-neutral but still produce NOx and challenge combustion stability, this study investigates PAC in sustainable and carbon-neutral fuel-air mixtures. Our focus is on enhancing flame stability and minimizing NOx emissions. Specifically, we aim to measure the temporal evolution of vibrational temperature in N_2/CH_4 mixtures following nanosecond repetitively pulsed (NRP) discharges. These discharges are initiated with high-voltage pulses (~10 ns duration) at repetition frequencies of 10-100 kHz, and temperature is assessed using hybrid femtosecond/picosecond Coherent Anti-Stokes Raman Scattering (fs/ps CARS). These measurements will elucidate ultrafast processes linked to NOx formation, addressing limitations in PAC technology and supporting its industrial application.

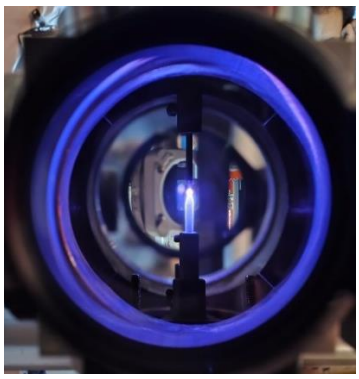

Figure 1. Plasma in air at 115 mbar

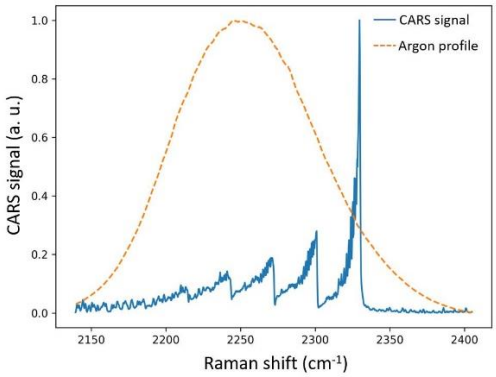

Figure 2. CARS signal from air plasma at 115 mbar

The experimental approach utilizes the hybrid femto/picosecond Coherent Anti-Stokes Raman Scattering (fs/ps-CARS) setup developed at ONERA, which we have adapted for the purpose of nanosecond repetitively pulsed (NRP) plasma studies (Fig. 1). This configuration employs a femtosecond laser system to enable time-resolved measurements of rotational and vibrational temperature on N_2 molecule [1] under combustion-relevant conditions. We have successfully acquired CARS ro-vibrational spectra on the Q-branch of N_2 in plasma generated in air (Fig. 2), in N_2 and in a N_2/CH_4 mixture at 115 mbar.

Acknowledgement

This work has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (grant agreement No. 101021538).

[1] L. Dakroub *et al.*, "Hybrid fs/ps-CARS Spectroscopy for Plasma Studies," AIAA 2025-0798. AIAA SCITECH 2025 Forum. January 2025.