TIME-RESOLVED HIGH-SPEED TOMOGRAPHIC LIF OF OH IN TURBULENT JET FLAMES

TECHNISCHE UNIVERSITÄT DARMSTADT

RSM Reaktive Strömungen + Messtechnik

LAVISION FOCUS ON IMAGING

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Motivation

- Auto-ignition (AI) of turbulent jets with a microwave-plasma heated co-flow.
- Turbulent flow phenomena are three-dimensional in nature.
- Unsteady auto-ignition process requires high temporal resolution.
- **Tomographic OH-LIF** imaging as an approach to yield three-dimensional OH distributions.
- **High-speed** tomographic LIF reveals information necessary to capture and follow auto-ignition processes.

Microwave plasma heater burner

The burner is designed for the investigation of auto-ignition of fuel jets propagating into a hot co-flow at high velocity and turbulence.

- Co-flow: Air, 82 mm nozzle diameter
- Jet: CH_4, 6 mm nozzle diameter

Table 1: Operating conditions

$Re_{co-flow}$ (-)	$T_{co-flow}$ (°C)	$U_{co-flow}$ (m/s)	Re_{jet} (-)	$T_{co-flow}$ (°C)	U_{jet} (m/s)
10,000	1050	25	3200	520	51
10,000	1100	27	3700	530	60

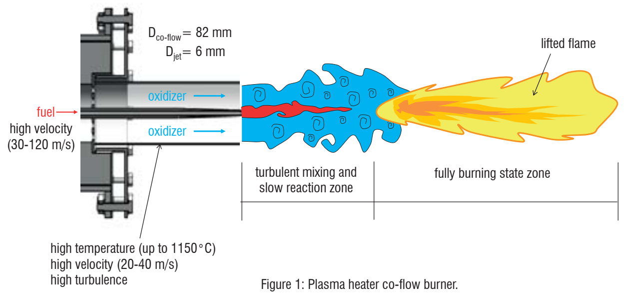

Figure 1: Plasma heater co-flow burner.

Experimental setup

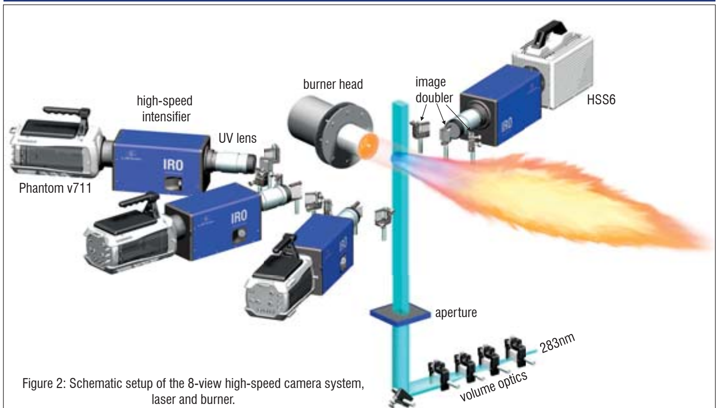

Figure 2: Schematic setup of the 8-view high-speed camera system, laser and burner.

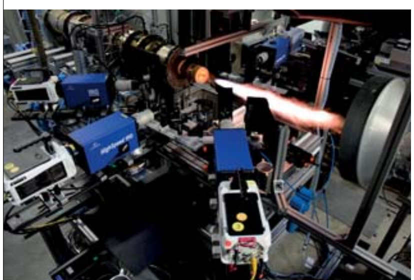

Figure 3: Photography of the setup with burner in operation.

Detection

- Four intensified high-speed cameras
- 10 kHz frame rate
- UV lens f/8 with image doubler
- 8 simultaneous views

Excitation

- High-speed pump laser at 10 kHz
- Frequency-doubled output of a high-speed dye laser tuned to excite the Q1(6) transition (λ = 283.01 nm) of the $A^2\Sigma \leftarrow X^2\Pi$ (v'=1, v"=0) band of hydroxyl radicals
- 0.2 mJ at sample volume of 2.0×1.5×0.9 cm^3

Tomographic reconstruction

- **S**imultaneous **M**ultiplicative **A**lgebraic **R**econstruction **T**echnique (SMART)
- 100 iterations
- Volume smoothing after each iteration with 3×3×3 voxel filter with smoothing factor of 0.5
- Computational time for 8 views @ 16 cores (3.10 GHz, 128 GB RAM):
  - 40 s for 32M voxel of 95^3 μm^3, no binning
  - 4 s for 4M voxel of 190^3 μm^3, 2×2 binning

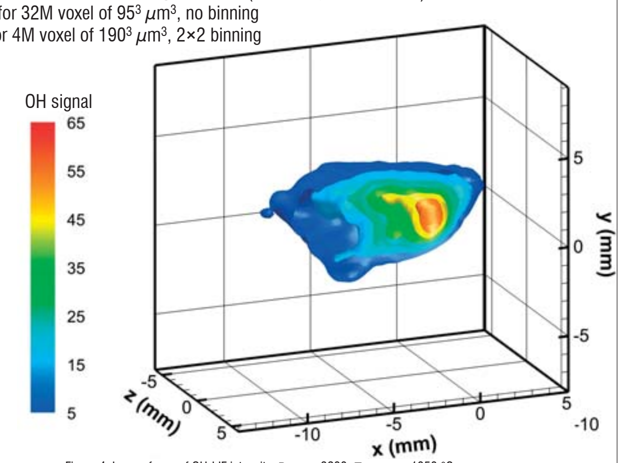

Figure 4: Iso-surfaces of OH-LIF intensity. Re_{jet} = 3200, $T_{co-flow}$ = 1050 °C

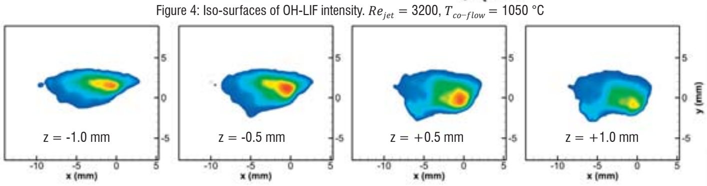

Figure 5: Reconstructed z-planes of OH-LIF from a flame kernel. Re_{jet} = 3200, $T_{co-flow}$ = 1050 °C

Time-resolved 3D-imaging

- Time-series of reconstructed tomographic OH-LIF images for different operating conditions
- Re-number of the jet and co-flow temperature have a strong effect on the auto-ignition of turbulent CH_4 jets

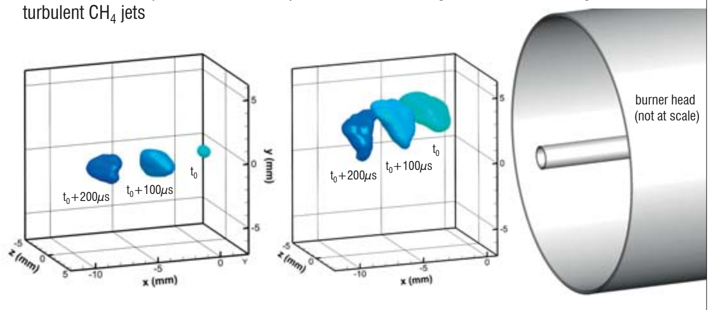

Figure 6: Propagation of auto-igniting kernels: overlay image of multiple time steps. Re_{jet} = 3700, $T_{co-flow}$ = 1100 °C

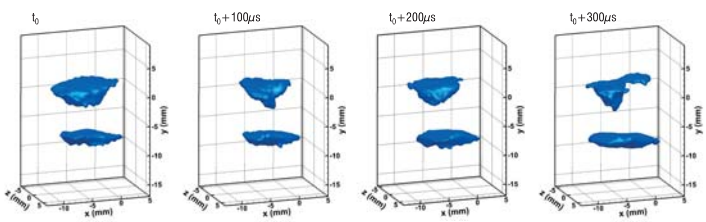

Figure 7: Time series of an auto-igniting CH_4 flame. Re_{jet} = 3200, $T_{co-flow}$ = 1050 °C

Conclusions

- Applications of high-speed tomographic OH-LIF successfully proven on turbulent auto-igniting jet flames.
- Reconstructions of the case with Re_{jet} = 3700 and $T_{co-flow}$ = 1100 °C showed the downstream-propagation and shape-evolution of auto-igniting flame kernels.
- 3D tomographic reconstructions of the case with Re_{jet} = 3200 and $T_{co-flow}$ = 1050 °C showed spatial and temporal propagation of auto-igniting flame base.
- Higher framing rates of the tomographic system are desired for future investigations of the temporal evolution of auto-igniting flames and kernels.