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Simultaneous 3D CH_2O LIF and tomographic PIV measurements at 10 kHz in lifted turbulent jet flames

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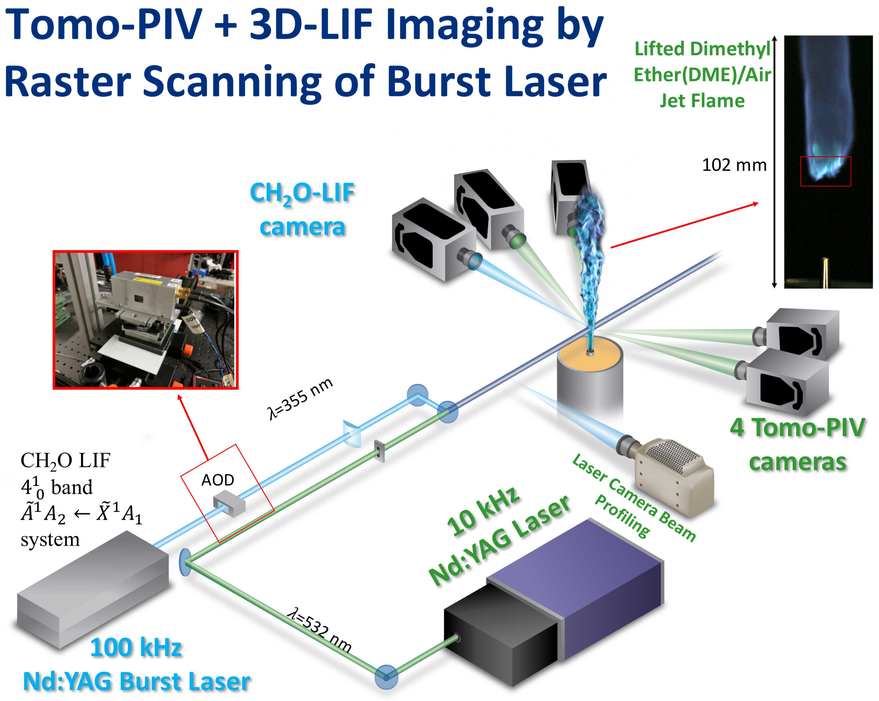
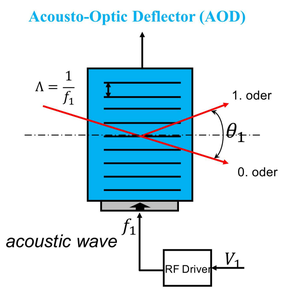
Turbulent combustion involves thousands of chemical reactions that interact with turbulent flows over a wide spectrum of spatio-temporal scales. These interactions are highly non-linear, and inherently evolves in both spatial and temporal dimensions. Expanding diagnostic capabilities from conventional 10 Hz two-dimensional imaging to time-resolved three-dimensional (3D) visualization of key quantities (e.g. velocity and species) is a necessity to understand the dynamics of turbulent combustion phenomena. We demonstrate development of a new capability that extends species imaging (CH_2O) to time-resolved 3D measurements by employing a 100 kHz pulse-burst laser and an acoustic-optic deflector scanning system in a lifted turbulent jet flame. Temporal dynamics of the complex CH_2O topology and its interaction with the flow field in lifted turbulent jet flames are needed to better understand the flame propagation/stabilization mechanisms.

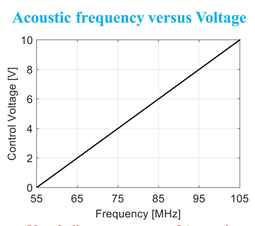
Tomo-PIV + 3D-LIF Imaging by Raster Scanning of Burst Laser



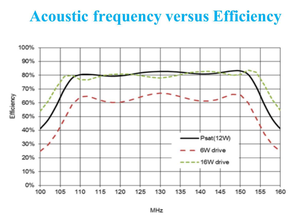
Jet Mixture	Jet Bulk Vel.	Jet Phi	Coflow Mixture	Coflow Bulk Vel.
DME/Air	13.5 m/s	9.5	Air	0.2 m/s

Acousto-Optic Deflector (AOD)





Nearly linear response of Acoustic frequency to Control Voltage

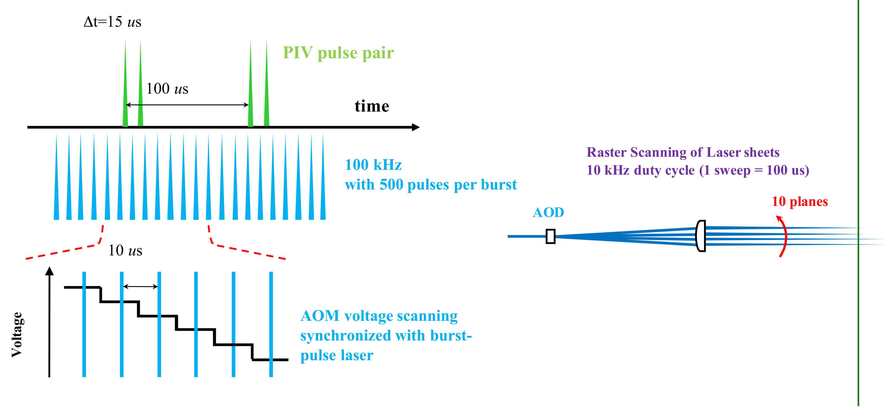


Acceptable efficiency (~ 80%) over wide frequency range

optic wavelength, acoustic frequency, acoustic velocity

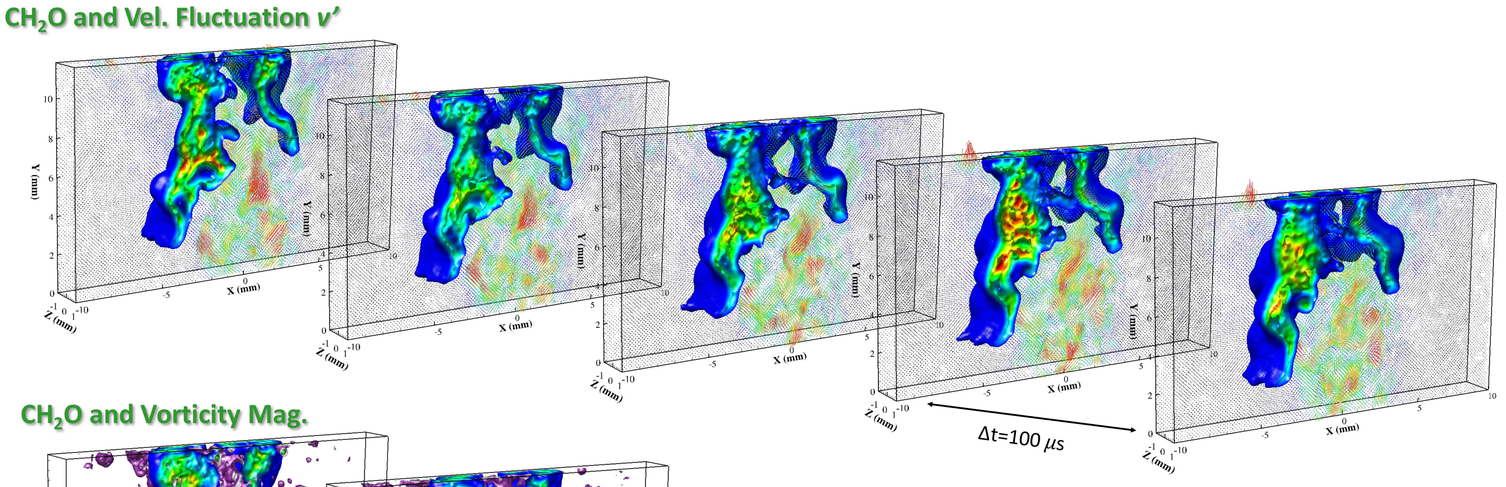
Scanning Angle: $\theta \approx \frac{\lambda \cdot f}{v}$

Synchronization of burse-pulse laser, AOD and TPIV laser



High-speed 3D Measurement of Flow Field and CH_2O LIF

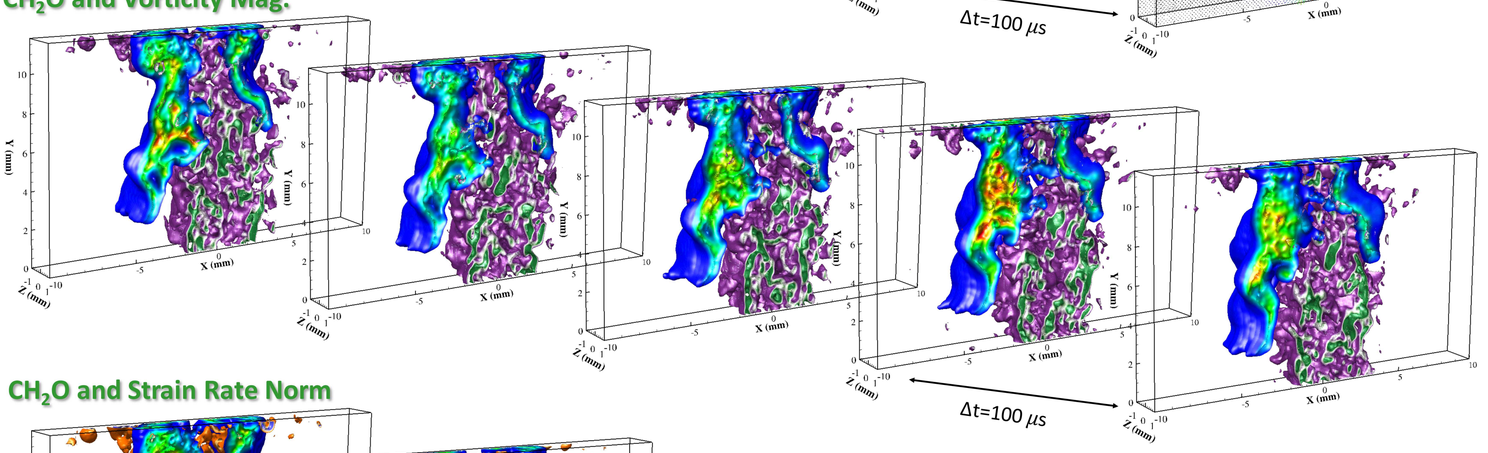
CH_2O and Vel. Fluctuation v'



Velocity Fluctuation $v' = v - \bar{v}$ (m/s): 4.0, 3.2, 2.4, 1.6, 0.8, 0.0

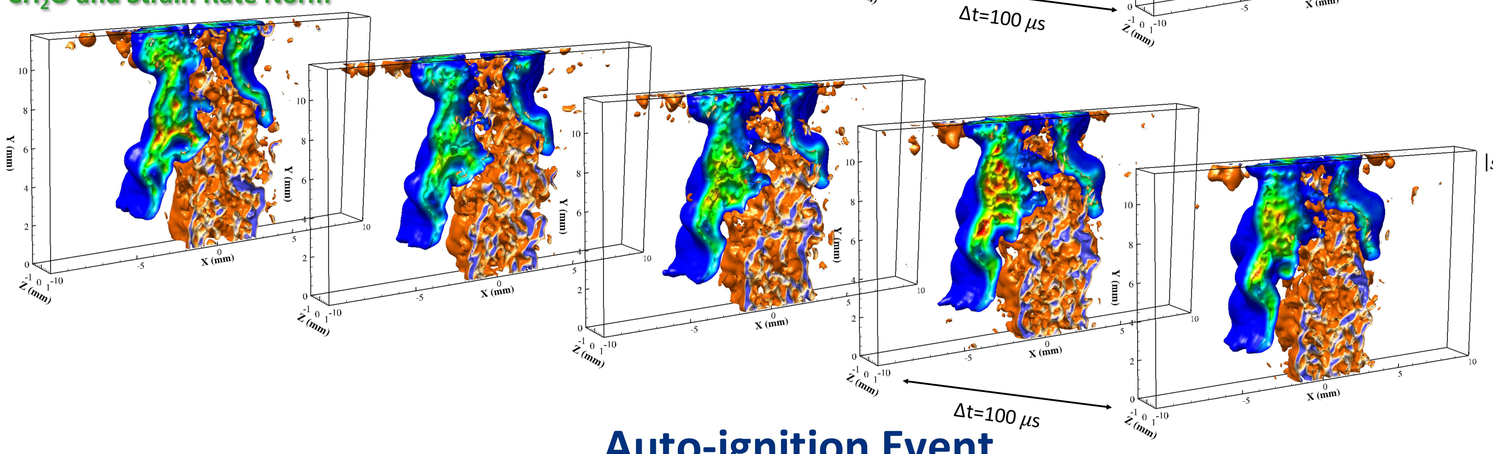
Normalized CH_2O-LIF Signal: 1.0, 0.9, 0.7, 0.5, 0.3, 0.1

CH_2O and Vorticity Mag.



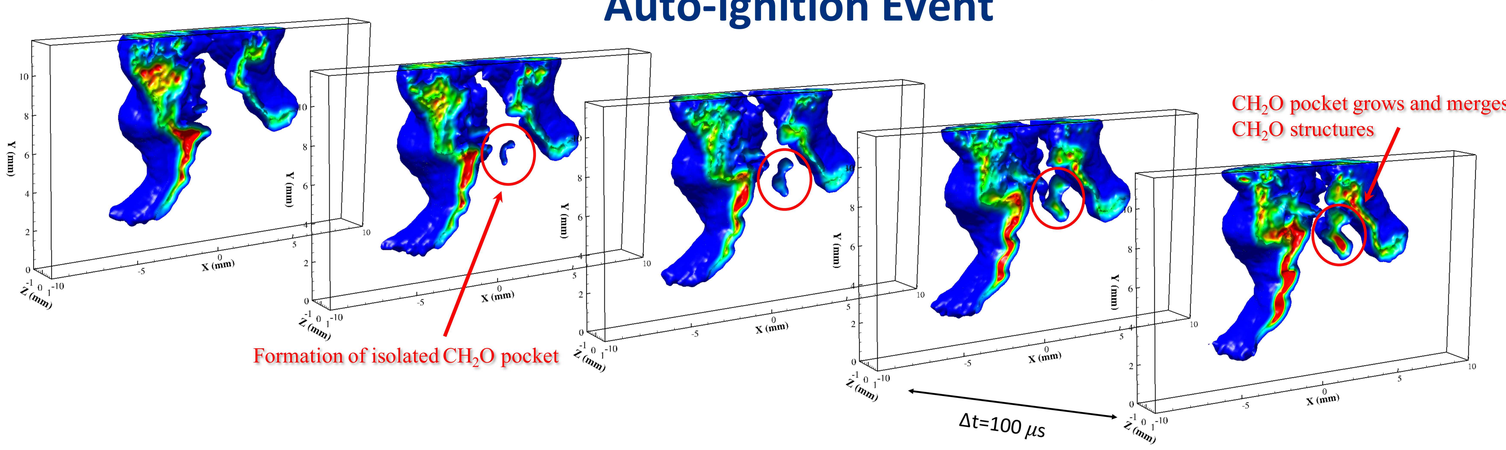
Vorticity Magnitude $|\omega| = |\nabla \times v|$ (s^{-1}): 7,000, 6,000, 5,000, 4,000

CH_2O and Strain Rate Norm



Strain Rate Norm $|s| = \sqrt{s_1^2 + s_2^2 + s_3^2}$ (s^{-1}): 7,000, 6,000, 5,000, 4,000

Auto-ignition Event



Summary

- Demonstrated feasibility of high-speed imaging of velocity field with 3D LIF imaging of formaldehyde using laser raster scanning
- Temporally correlated CH_2O and turbulence structures have been found. CH_2O pocket formation and propagation has been identified, suggesting occurrence of auto-ignition as a stabilization mechanism
- Next steps for Tomo-PIV/3D-LIF imaging data: Analyze dynamics of flame stabilization, propagation, and full 3D strain alignment

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