Investigations of Thermal-Fluid Behavior under Extreme Environments within Propulsion, Energy, and Transportation Systems

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Applications

Gas-Turbines

We study complex flows under extreme environments relevant to many advanced propulsion devices.

Reciprocating Engines

Hypersonic Engines and Vehicles

wardauto.com  aerospaceengineeringblog.com  ucdavis.edu
Gas Turbines

• Gas turbine combustors utilize either spray combustion for propulsion applications or natural gas for power generation.

• Here we study the effects of fuel-air mixture preparation and hydroxyl radical (OH) distribution on soot formation within the combustor.

Planar laser imaging system

Meyer et al., 2010
Rocket Spray and Combustion

• Understanding rocket sprays and combustion at high pressures is critical for predicting device performance and stability.

• Rocket combustion chambers generate optically dense fields that require advanced optical diagnostics such as ballistic photon imaging (see below), X-rays, etc.

Scattered vs. Ballistic Photons

Spray Image Utilizing Ballistic Photons

Courtesy of Edwards AFB
Internal Combustion Engines

• IC engine combustion chambers see extremely high pressures, high temperatures, and high turbulence levels
• We simulate those conditions in test chambers and study spray and combustion processes
• We are also investigating ways to study *in situ* engine and exhaust processes in collaboration with engine researchers

Diesel spray propagation during a single injection event imaged using UV planar laser-induced fluorescence

Meyer et al., 2010
Supersonics and Hypersonics

- High-speed fluid mechanics are important in space reentry and new high-speed propulsion concepts.
- Measurements must be careful to avoid perturbing the flow and capture fast transients.
- Advanced diagnostics can capture shock-flow interactions, turbulent transition, and flame stabilization.

NASA Facilities for up to Mach 10 Flow

MHz Rate Planar Laser Imaging

Jiang, et al. 2011
Turbulent Combustion

- Turbulent flows in practical devices are 3D and dynamic
- Need to capture 3D species and velocity distributions to validate models and predict performance
- We are studying turbulence-flame dynamics using advanced 3D laser-based imaging techniques

Enstrophy from 3D Velocity and Planar CH\textsubscript{2}O Distribution
Venkateswaran, et al. 2014

Flame Studies at AFRL

3D Laser Tomography of Soot
Gord, et al. 2015
Laser Diagnostics

• Our work pushes the boundaries of laser technology to allow high power output at high repetition rates to capture dynamic events in thermal-fluid systems

• The burst-mode laser we helped to develop below allows MHz imaging

• We are also developing new ways to exploit ultrafast (femtosecond and picosecond) lasers

• An example is the system shown above for temperature and species measurements using ultrafast fs/ps coherent anti-Stokes Raman spectroscopy
X-ray Imaging

Testing 3D CT in a Hollow Cone Spray

Validation of 3D CT of Sprays in an Impinging Jet Injector

Heindel, et al. 2007

Halls, et al. 2014

X-ray Tube Source 3D Computed Tomography

X-ray Tube Source Radiographic Image
Projects

- Ultrafast Time/Frequency Domain Coherent Anti-Stokes Raman Spectroscopy for Combustion and Plasma Systems
- High Speed Imaging Guided Large Eddy Simulation Model Development for Turbulent Flames
- Planar Liquid-Vapor Imaging of Jet Fuel Sprays for High-Speed Propulsion Environments
- MHz-rate Nonlinear Spectroscopy and Imaging for Transient and Nonequilibrium Flows
- Advanced Laser Based Diagnostic Techniques for Combustion and Propulsion Research
- In Situ Spectroscopy and Damage Assessment in Dynamically Deforming Materials
- High-Frequency Non-Intrusive Flowfield Measurements of Hypersonic Transition
- Multidimensional Measurements of Turbulence in Compressor Flows
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