Combustion Zone Characterization of GO_2/GH_2 Rocket Using Laser-Induced Fluorescence of OH.

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With recent interest in gas/gas injectors for use in rocket combustors, there is a critical need for experiments that address this combustion process in terms of detailed flowfield measurements. Such measurements would also serve as a data base for validating computational fluid dynamic (CFD) computer codes. A series of studies have been undertaken at the Propulsion Engineering Research Center (PERC) at the Pennsylvania State University to measure various parameters such as velocity, species concentration , and temperature downstream of a shear coaxial injector in an optically accessible uni-element rocket chamber. Techniques applied to this study to date include the following: laser Doppler velocimetry (LDV) for velocity; laser light scattering (LLS) for flow visualization and estimating mixture fraction and density; laser-induced fluorescence (LIF) of hydroxyl radicals (OH) to determine the characteristics and extent of the reaction zone; and Raman spectroscopy to measure major species concentrations and temperature. The results of the LIF studies are presented here.

The OH molecule is a key intermediate in hydrocarbon and hydrogen combustion. High OH concentration, indicated by high fluorescence intensity, mark the location of the primary reaction zone where the oxidizer to fuel ratio is nearly stoichiometric. Two-dimensional imaging of LIF near the injector face provides a qualitative view of the reaction zone structure. Two-dimensional LIF was limited to qualitative measurements near the injector face due to poor signal to noise ratio with the present experimental setup.

One-dimensional measurements of LIF, which provide a radial profile of relative OH concentration, have been made at several axial locations in the combustion chamber. Results from multiple images, typically 120, have been averaged to yield average OH profiles at each axial location probed. Probability density functions (PDF) of OH peak widths and locations show that the reaction zone is thin near the injector face as expected and remains thin as the flow progresses downstream. Also, the increase in widths of the average OH peaks as the flow progresses downstream is due to movement of the thin reaction zone rather than an increase in individual OH peaks. This analysis indicates the flame is a wrinkled laminar flame front in the region probed.

COMBUSTION ZONE CHARACTERIZATION OF GO_2/GH_2 ROCKET USING LASER-INDUCED FLUORESCENCE OF OH

989

PENNSTATE

1855

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MOTIVATION

Need For *Low Cost, Reusable,* and *Reliable* Propulsion Systems Require Detailed Understanding Of Combustion Phenomena

- Full Scale Tests Are Expensive
- Computer Technology Enables Detailed Modeling
- Advances In Optical Diagnostic Techniques Enhance Measurement Capabilities

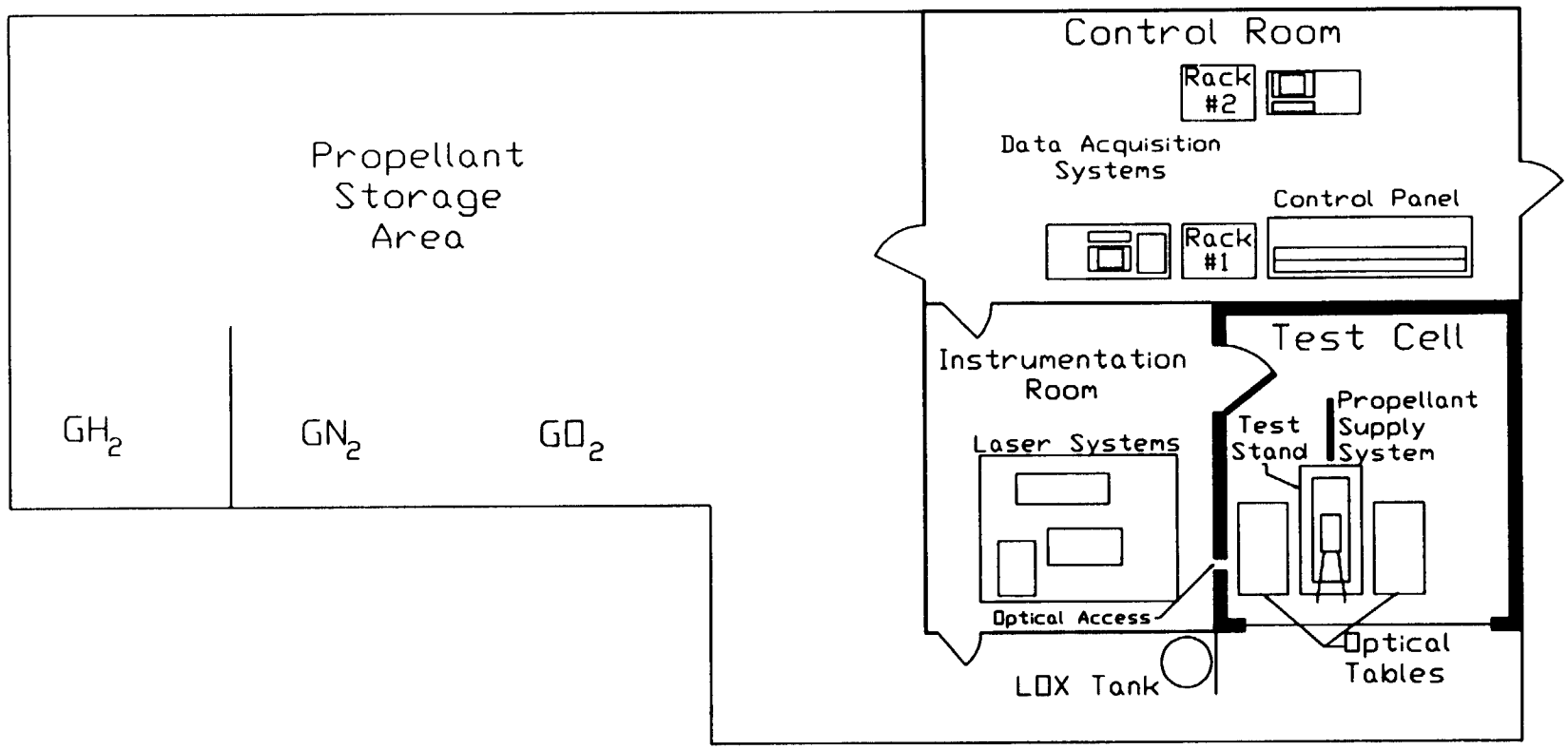
OBJECTIVE

- Apply Laser-Based Diagnostics To Study Flowfield Of Gas/Gas Coaxial Injector
  - Laser Doppler Velocimetry
  - ✓Laser-Induced Fluorescence of OH
  - Laser Light Scattering From Tracer Particles
  - Raman Spectroscopy
- Obtain Data Where Boundary Conditions Are Well Specified And Provide To Rocket Research Community

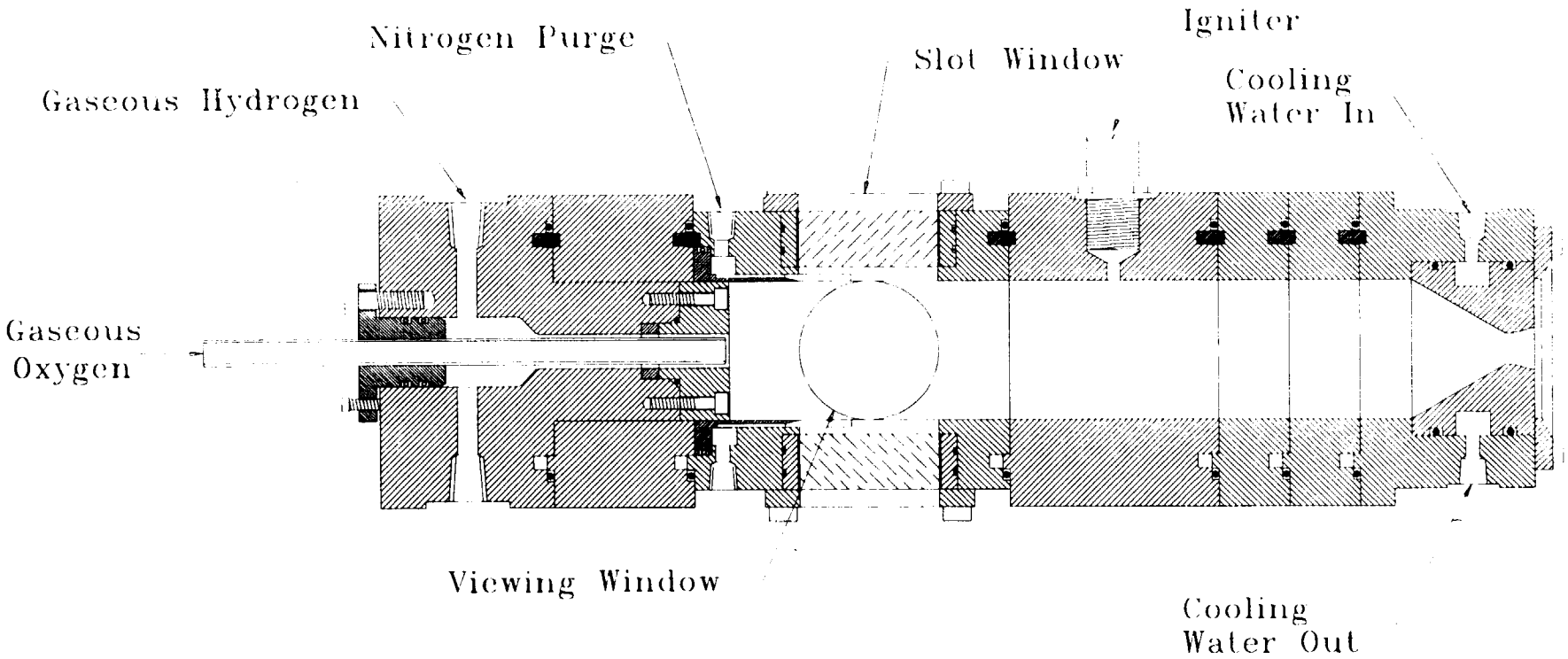
IMPACT

- Gain Insight in Gas/Gas Injector Design
- Obtain Data Base for CFD Code Validation
- Extend Application of Laser Based Diagnostics to High Pressure & Reynold's Number Flows

CRYOGENIC COMBUSTION LABORATORY



OPTICALLY-ACCESSIBLE ROCKET CHAMBER



TEST CONDITIONS

GH_2 Mass Flow Rate kg/s (lbm/s)	0.010 (0.022)
GO_2 Mass Flow Rate kg/s (lbm/s)	0.042 (0.093)
GO_2/GH_2 Mass Flow Ratio	4.2
Chamber Pressure MPa (psia)	1.31 (191)
Annulus Reynolds Number	6×10^4
Post Reynolds Number	3×10^5

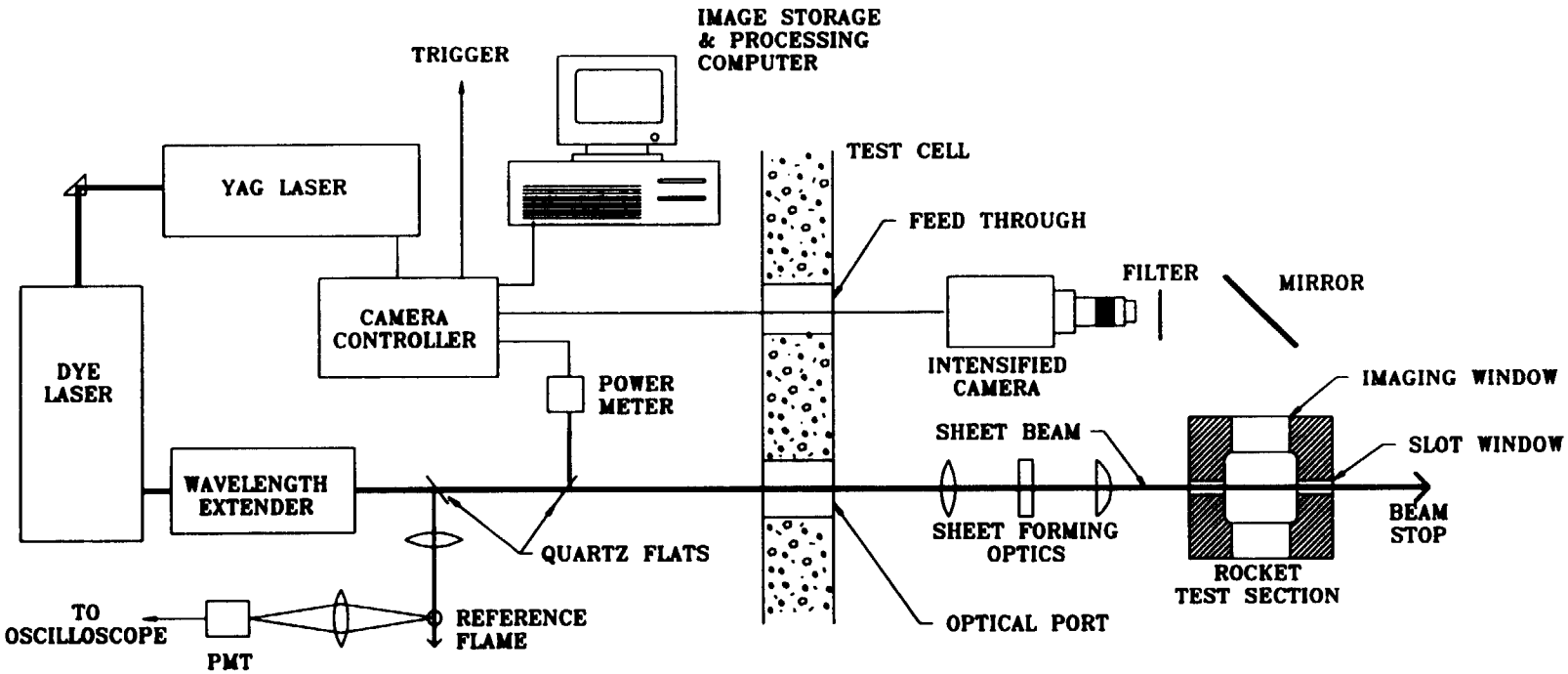
LASER-INDUCED FLUORESCENCE OF OH

- **Hydroxyl-Radicals (OH) Are a Key Intermediate**
- **Relatively Simple Technique**
- **Indicates Reaction Zone Location and Structure**

LASER-INDUCED FLUORESCENCE OF OH

- Excite (1,0) Band of OH
- Collect Fluorescence from (1,1) and (0,0) Band
- Two-Dimensional Images
  - Laser Beam Formed into Sheet
  - Laser Tuned to $Q_1(9)$ and $Q_2(8)$ Lines at 283.92 nm
- One-Dimensional Images
  - Laser Beam Focused
  - Laser Tuned to $P_2(8)$ Line at 285.98 nm or to $S_{21}(8)$ Line at 278.83 nm

LASER-INDUCED FLUORESCENCE
Experimental Setup

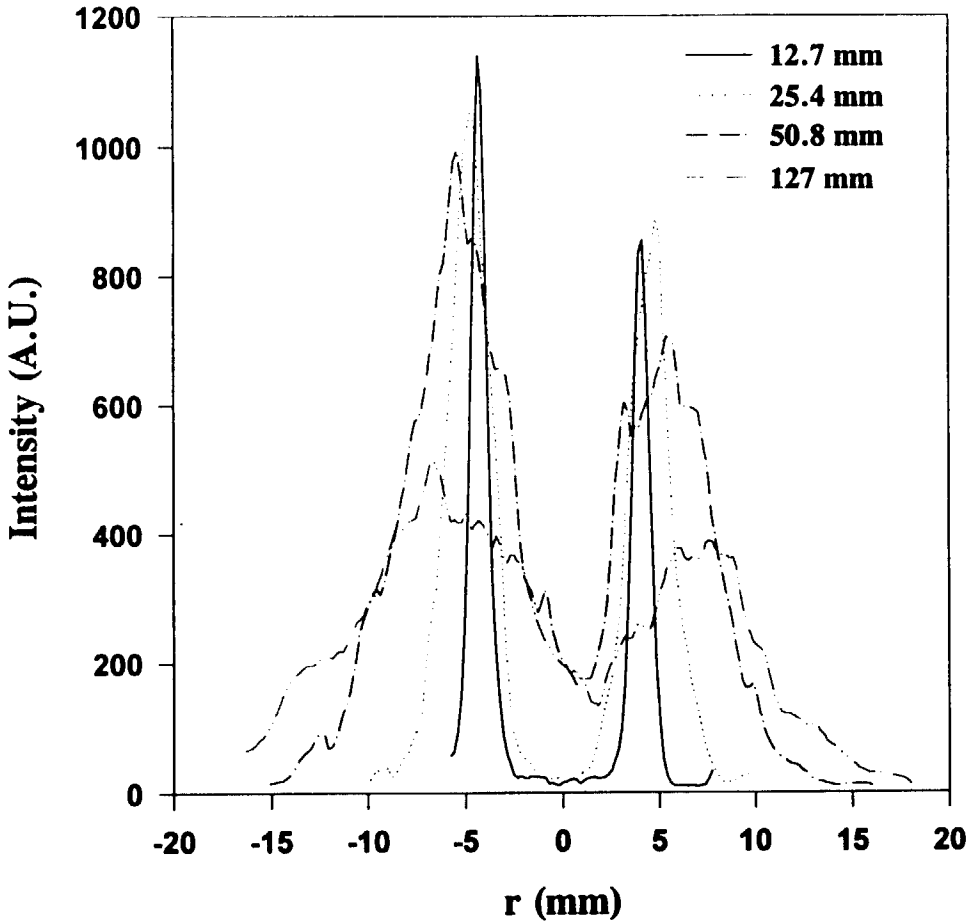


LASER INDUCED FLUORESCENCE

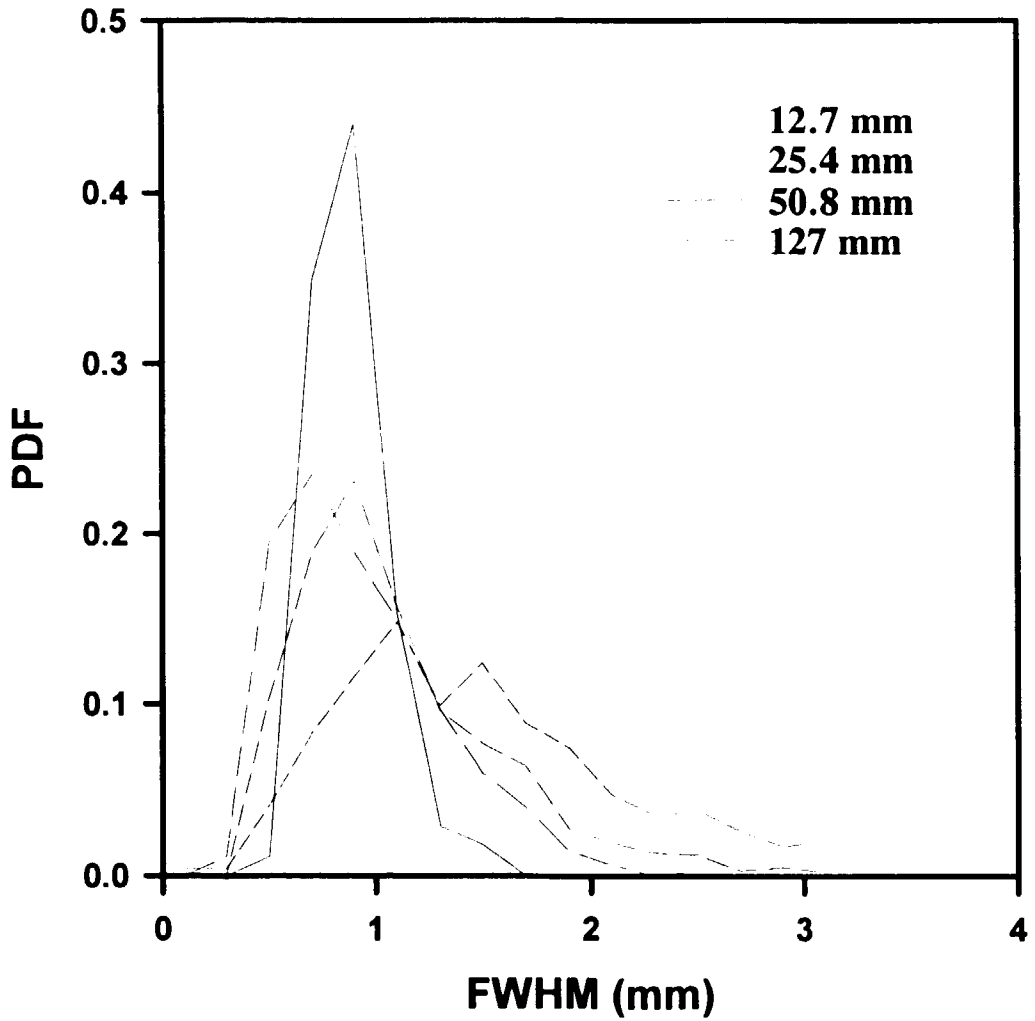
Fluorescence of Hydroxyl-Radicals

Instantaneous [illegible] Average of 70 Frames

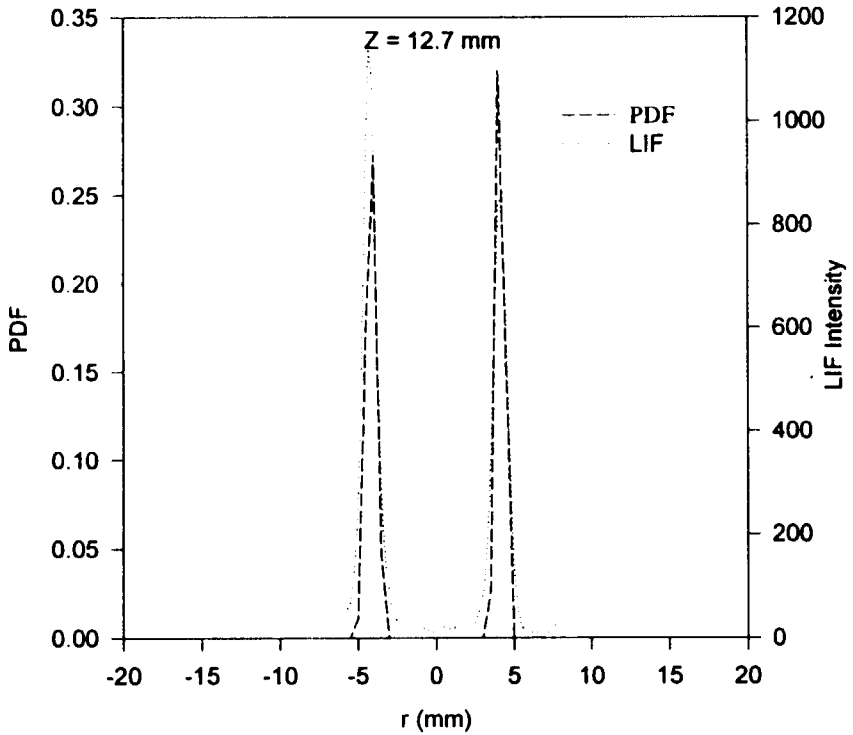
AVERAGE LIF PROFILES

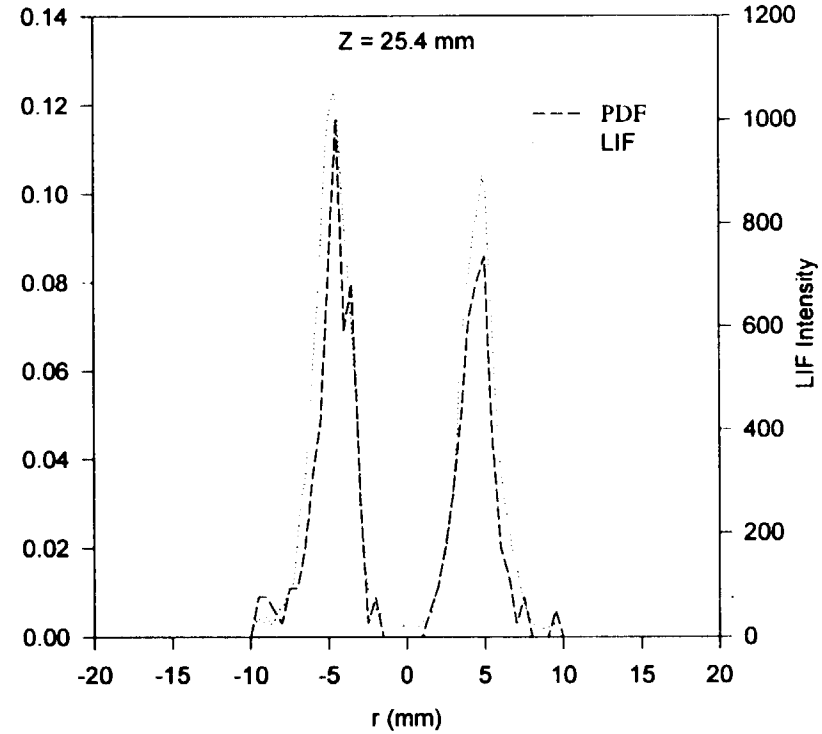


PEAK WIDTH PDFs



PEAK POSITION PDFs & LIF PROFILES





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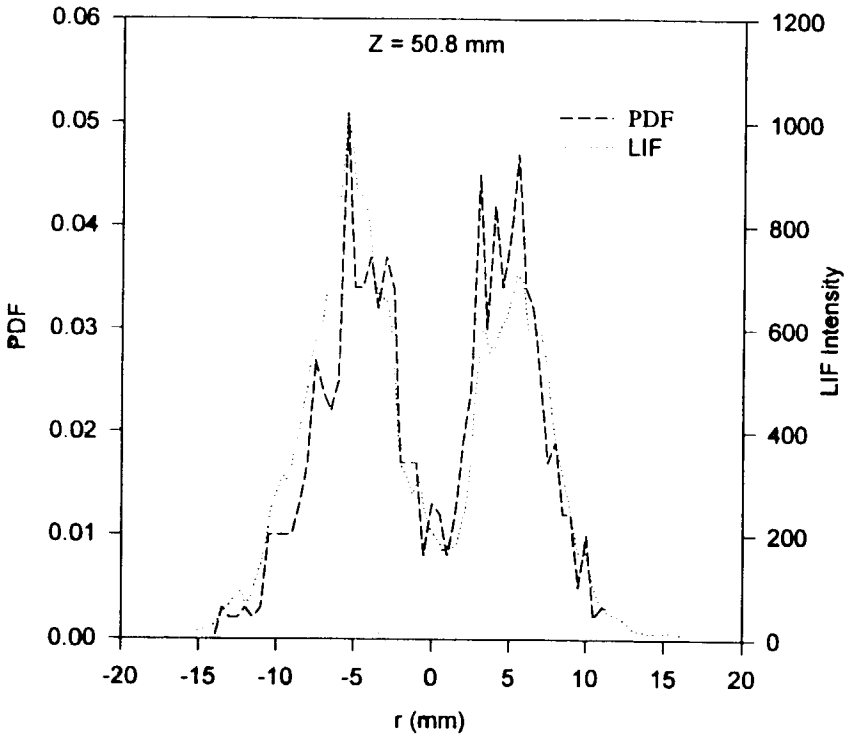

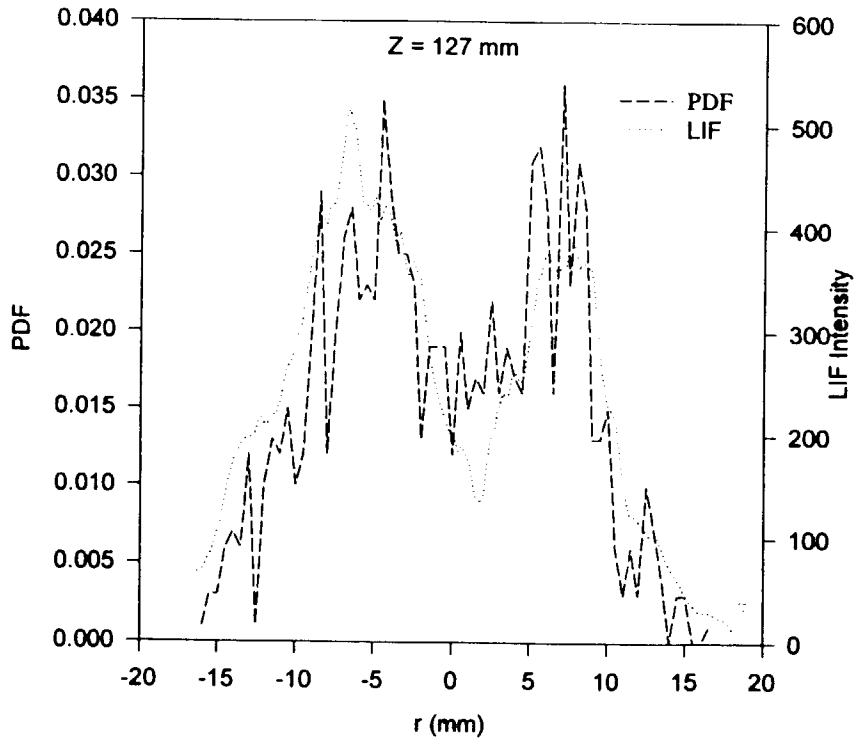

SUMMARY/CONCLUSIONS

- Gas/Gas Shear Coaxial Injector Exhibits Poor Mixing Characteristics
- Reaction Zone has Characteristics of Thin Wrinkled Laminar Flame Front
  - Reacting Flowfield Dominated by Large Scale Turbulence
- Data Available To Rocket Research Community
  - Average LIF Profiles Useful for General Profile Shape and Location Comparisons
  - Velocity and Light Scattering Data Also Available