Laser induced 2-D In-cylinder soot measurements

Chunbeom Lee · Deokjin Kim

Environmental Components R&D Center, KATECH, 74 Yongjung-Ri, Pungse-Myun, Chonan, Chungnam, Korea
(cblee@katech.re.kr)

Abstract : In-cylinder measurements of soot particle size and number density have been made using PLII and PLIS measurement techniques in a direct injection diesel optic engine. PLII and PLIS measurement with one ICCD camera was done simultaneously, and calibration technique with laminar diffusion jet flame of co-flow burner was used to obtain a quantitative information of soot particles.

Key words : ICCD(Intensified CCD), PLII(Planner Laser Induced Incandescence), PLIS(Planner Laser Induced Scattering), HSDI(High Speed Direct Injection) Diesel Optic Engine, LE(Light Extinction), LS(Laser Scattering), ND(Neutral Density) Filter

Summary

In this study, simultaneous measurement technique of PLII and PLIS signal was performed in combustion chamber
of HSDI optic single diesel engine to evaluate the characteristics of soot particle 2-D distribution.

The engine optic parts were consisted of cylinder linear quartz, piston bowl side quartz, bottom quartz and mirror. The planner laser light was made by the sheet beam generating optics and correction optics and the laser source was Nd-YAG laser of 280mJ/pulse at 532nm.

An ICCD camera(Lavision, NanoStar) and some optical components, such as ND filter and band pass filters (CWL 450nm and FWHM 40nm for PLII, CWL 532nm and FWHM 10nm for PLIS), were used simultaneously to detect the PLII and PLIS images.

Two images were simultaneously recorded in one ICCD camera with image splitter. PLIS signal is more intensive than PLII signal at the same excitation laser condition, so we used ND filter to prevent damage of ICCD and signal saturation.

To measure the soot volume fraction, number density and size quantitatively, data such as volume equivalent diameter obtained from the PLII and PLIS signal was compared with the data by the LE and LS signal of co-flow jet diffusion flame .

It was performed with the same optic system to acquire more precise and reliable calibration constant, thus we could decide optimal excitation laser intensity and image acquisition conditions besides calibration constant from the calibration.

As a calibration test result, there were linear correlations observed between PLII/PLIS and LE/LIS method in a measurement of soot volume fraction, soot size and number density.

Also, PLII & PLIS images were acquired on various conditions such as laser excitation and signal acquisition timing.

The injection strategy was 2-stage injection (BTDC 13°, 0.830mg, BTDC 4°, 11.238mg) and the PLII signals were not generated from the premixed regime but the mixing controlled regime.

We also could understand in-cylinder soot distribution according to the crank angle by calculating the soot number density and soot size from the obtained PLII and PLIS images.

Quantification process from the laser images has a lot of errors and various uncertainties and we have a plan to reduce the uncertainties for the more accurate in-cylinder data.

As a result, we can conclude as follow

1. In-cylinder 2-D soot volume fraction, volume equivalent diameter and number density were obtained quantitatively by using PLII and PLIS method.
2. Calibration results of PLII and PLIS image using laser extinction and scattering method on non-premixed jet flame shows a linear correlation between PLII/PLIS and LE/LS data.
3. The maximum volume fraction of in-cylinder soot shows around 2~3ppm, and the volume equivalent diameter is within the ~200nm

References

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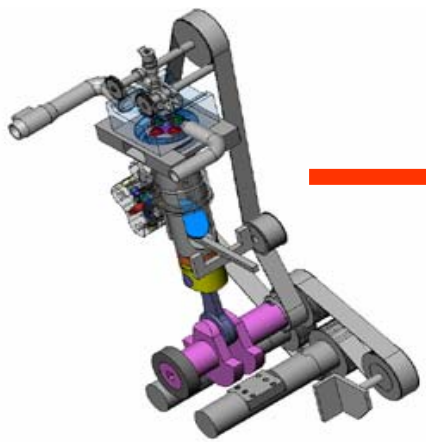
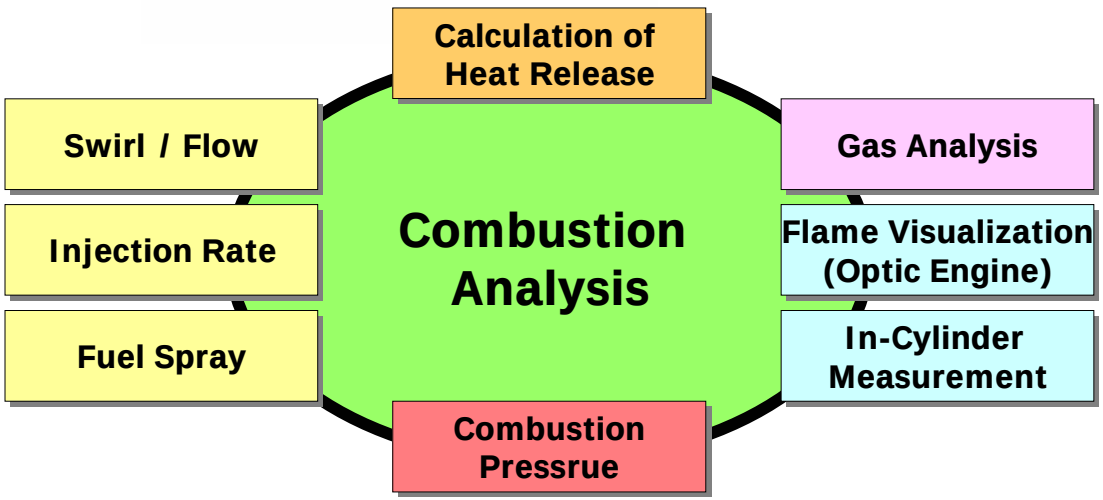
Laser Induced 2-D In-cylinder Soot Measurements

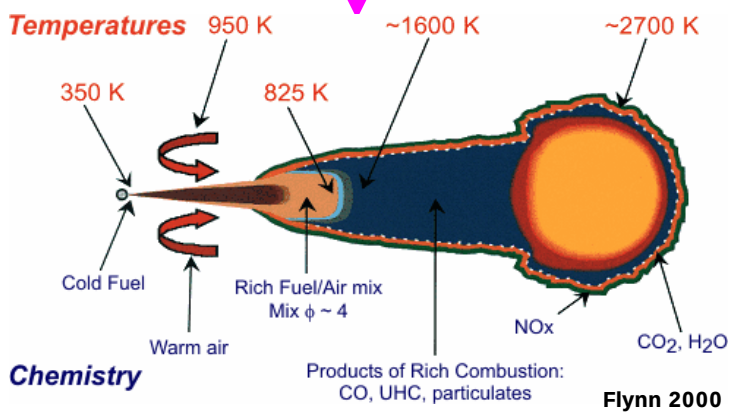
Chunbeom LEE, Dukjin Kim

Korea Automotive Technology Institute (KATECH)
Environmental Parts R&D Center

Research Background



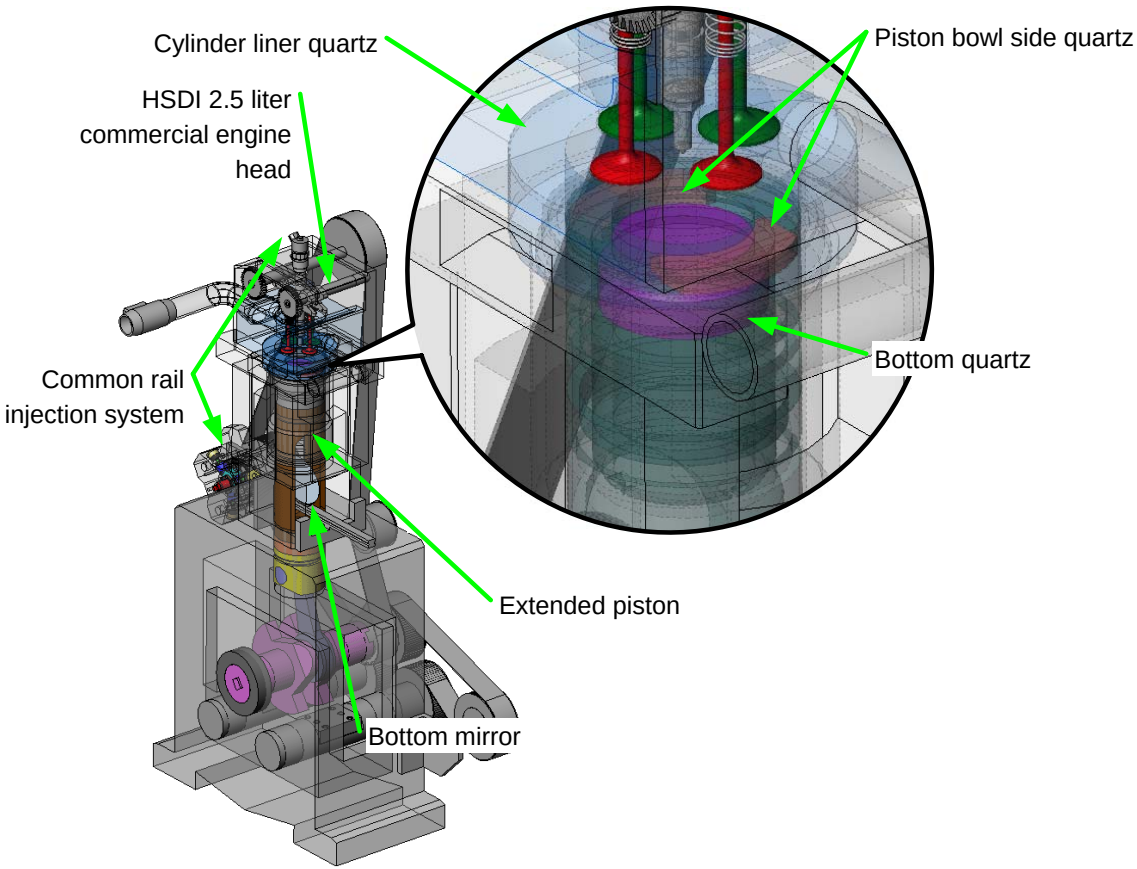




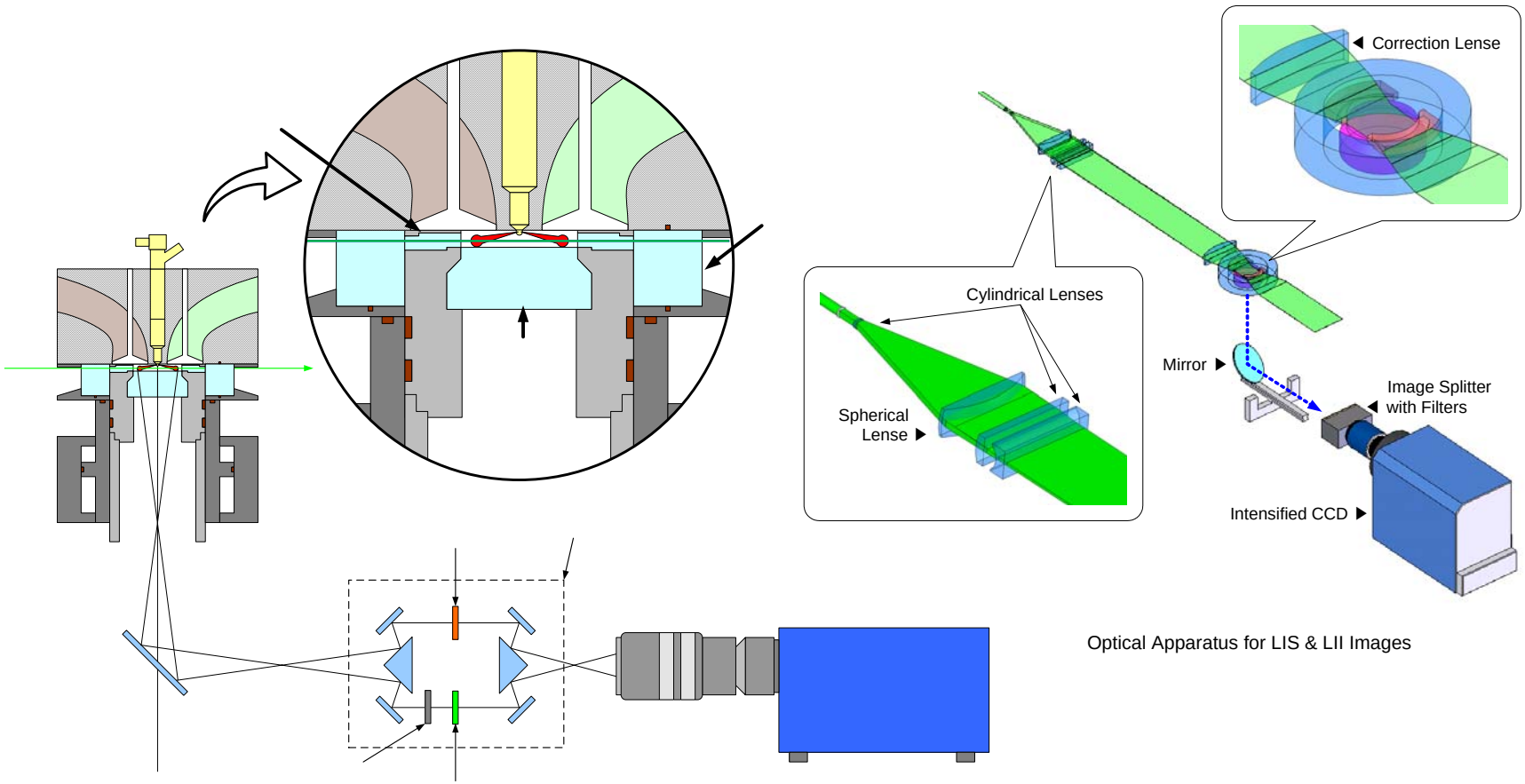
Structure of soot/combustion in Diesel Spray

Experimental apparatus
- Visualization single cylinder engine

Item.	Spec.
Bore× Stroke	91× 96
Stroke volume	624 cc
Fuel Supply System	Bosch 6 hole nozzle common rail injection
Compression ratio	18.30
Max. RPM	2,000 rpm
Max. Pressure	100 bar



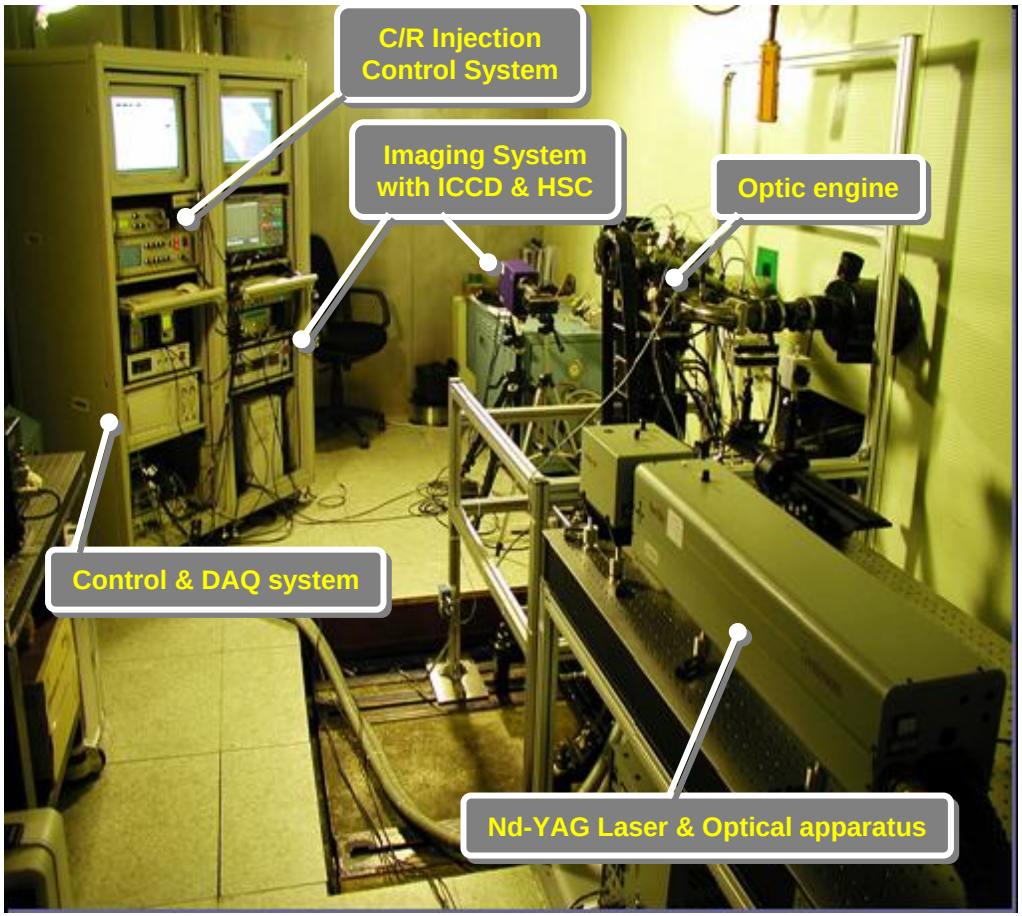
Experimental apparatus
- Optical arrangement for in-cylinder measurement



Optical Apparatus for LIS & LII Images

Laser Diagnostics System for Engine Combustion

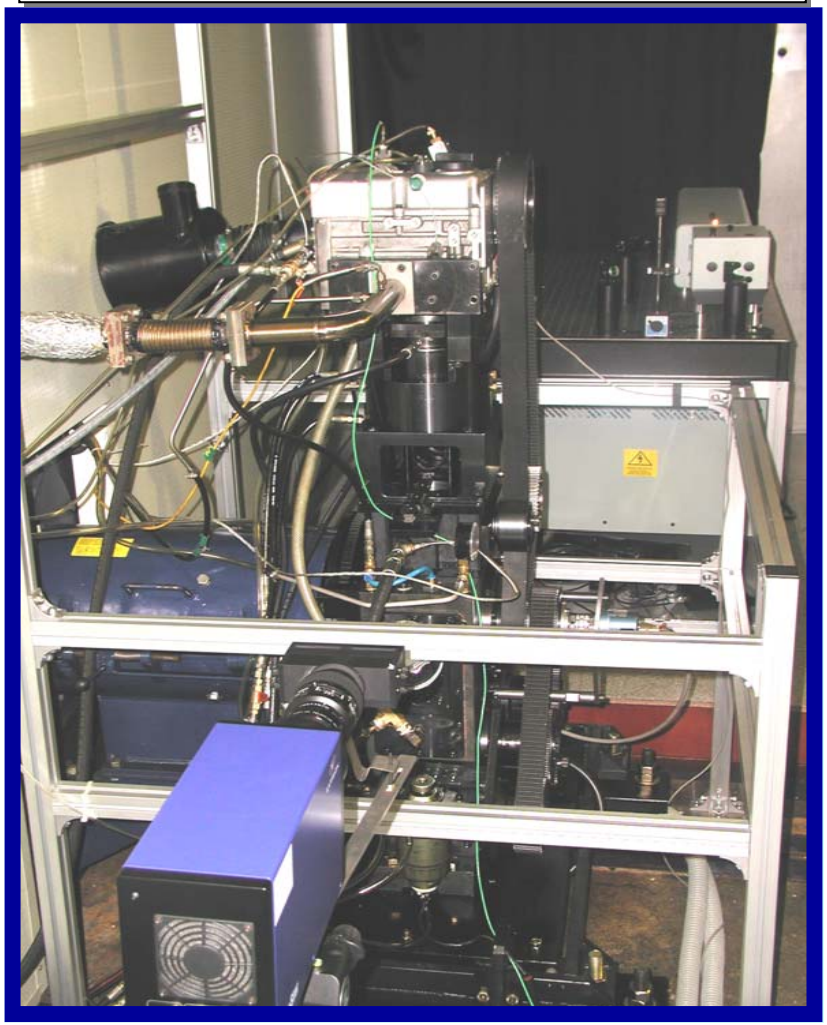
Optical Engine Test System



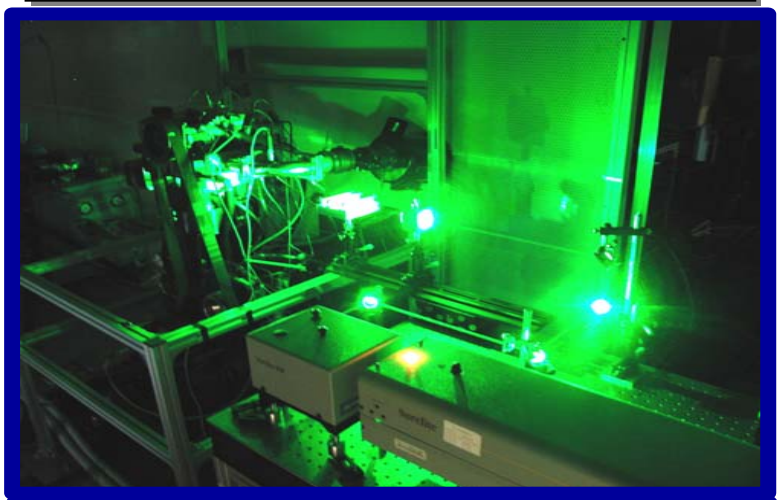
- Control and DAQ system
- ICCD/HSC Imaging system

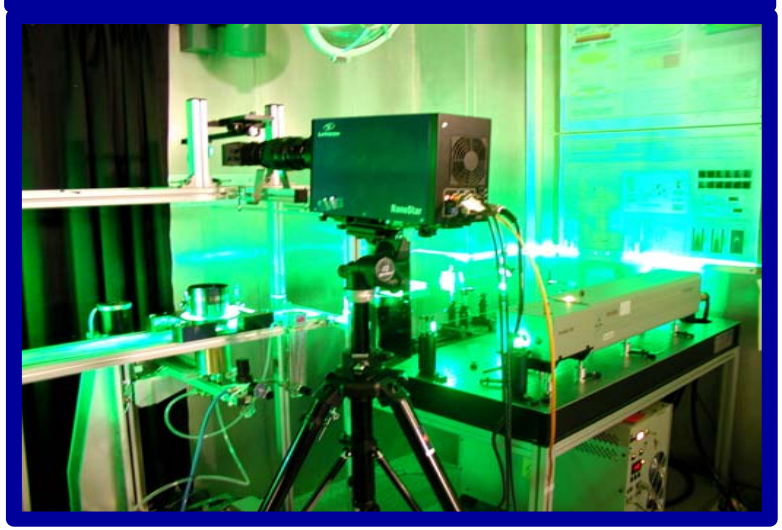
Situation of Laser Diagnostics (Engine and Calibration Test)

PLII/PLIS Measurement with Optic Engine



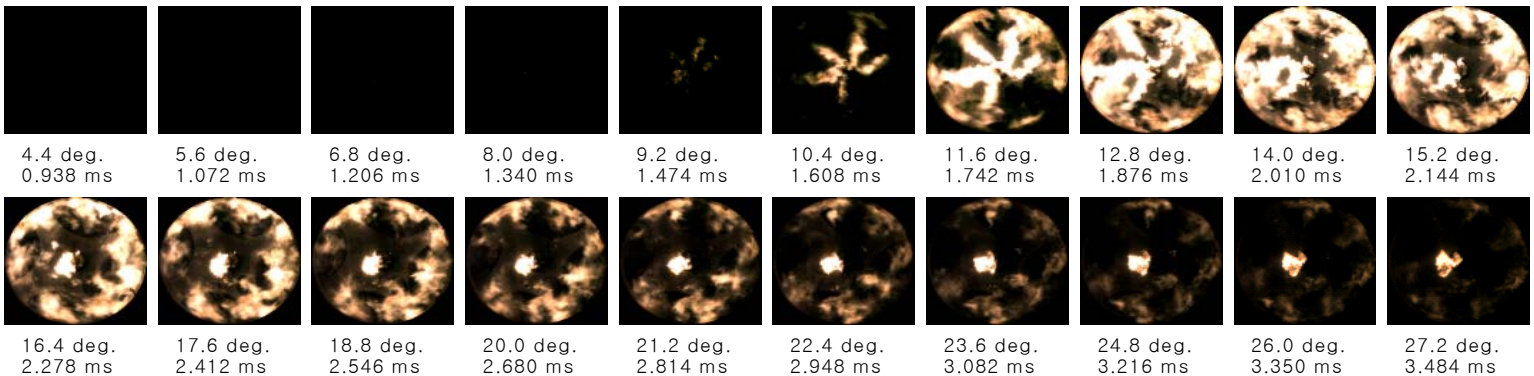
Engine Optic Calibration and Pre-test



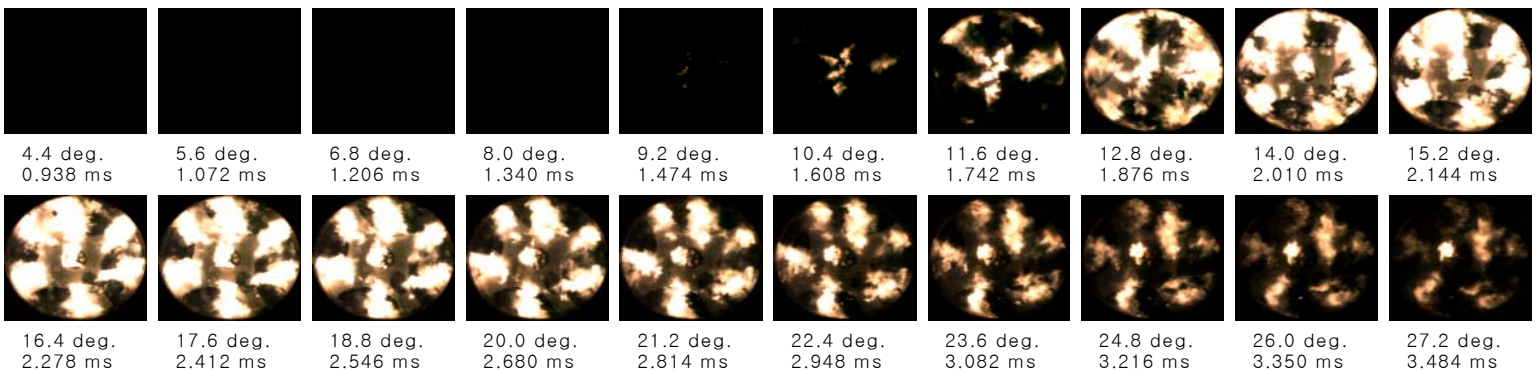


Flame Visualization - 600bar, 21.9mg/st

Swirl Ratio = 2.4



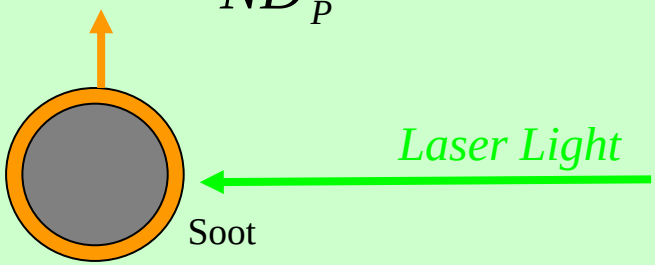
Swirl Ratio = 1.8



Principle of LII and LIS

LII signal (T < 4500°K)

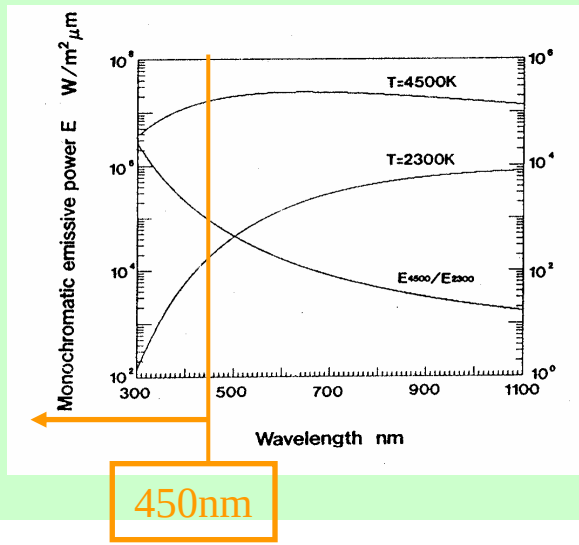
$\sim ND_P^{3+0.154\lambda}$



Temp. rising time : 8-10ns

Signal Duration : ~ several μs

Emission(T=4500°K) > Emission(T=2300°K)

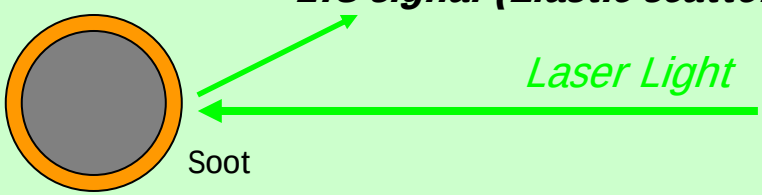


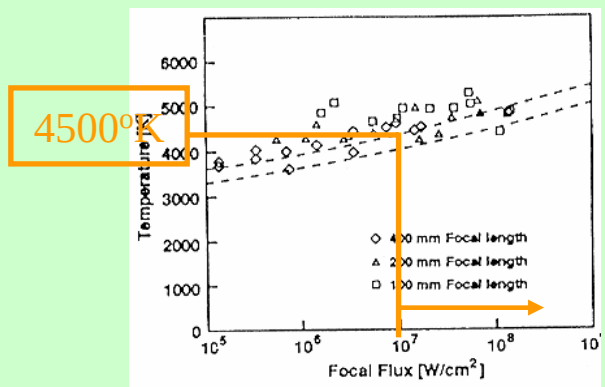
LIS signal (T < 4500°K)

$\sim ND_P^6$

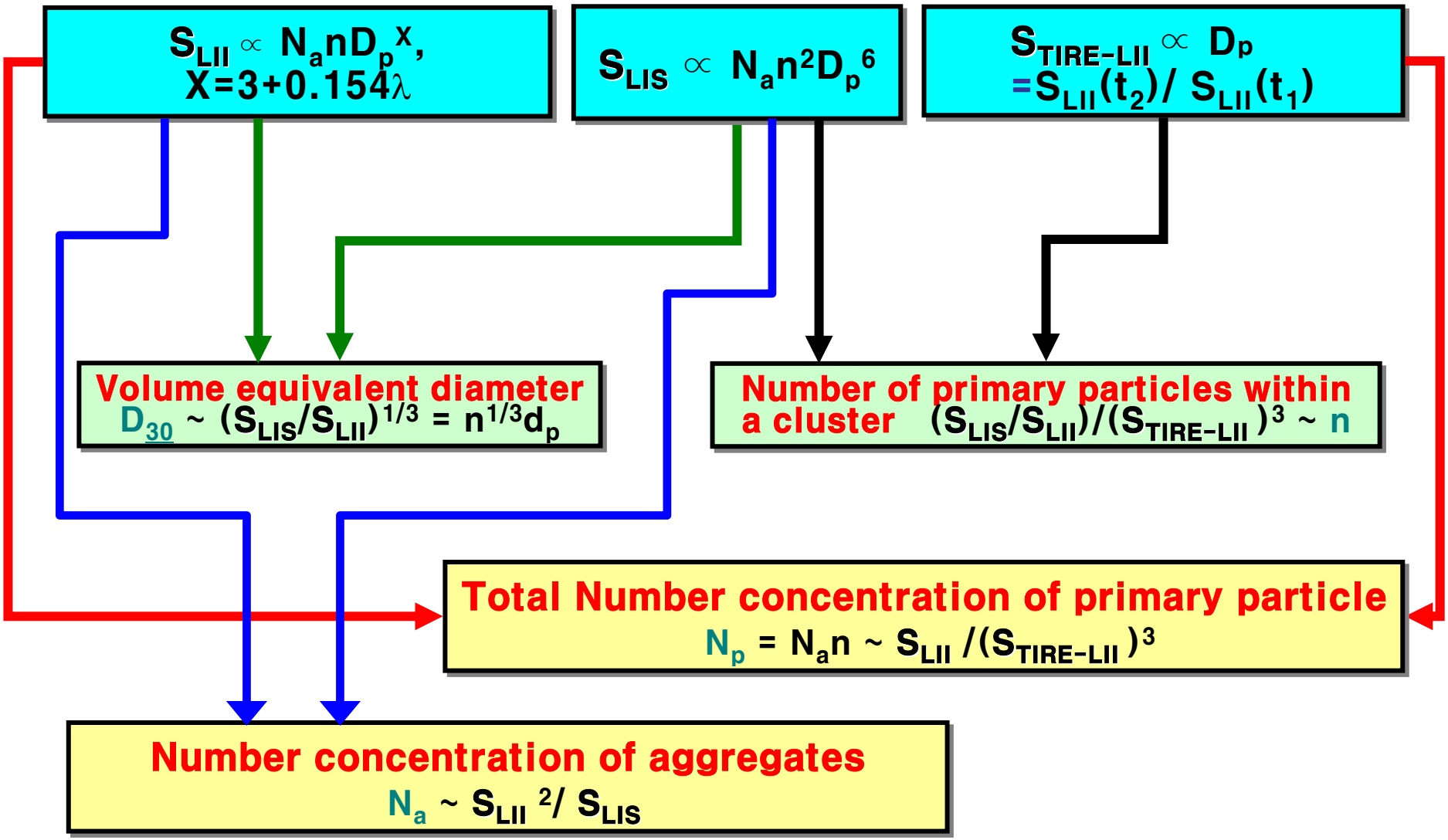
✓Signal Duration : ~O(10)ns

LIS signal (Elastic scattering)

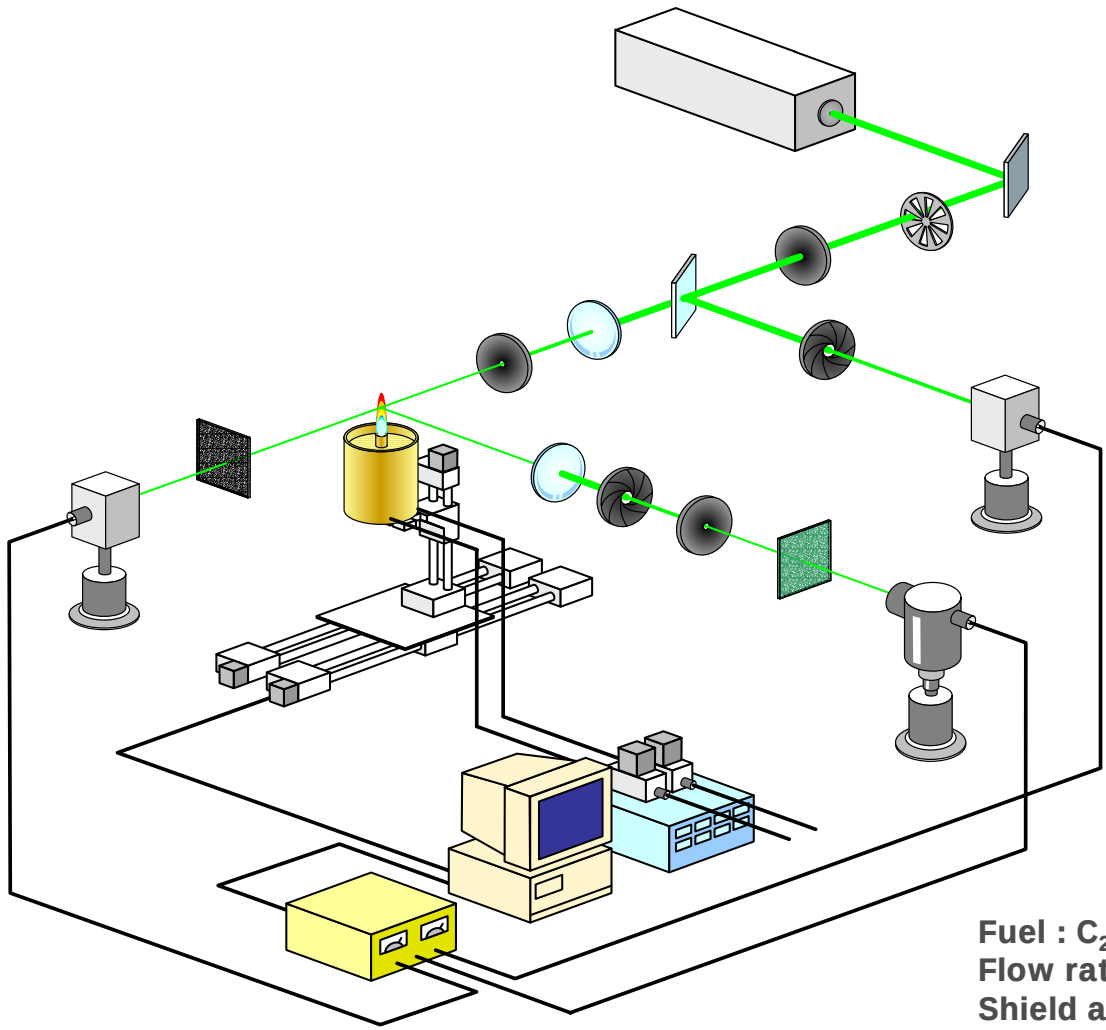




Laser Diagnostics Procedure

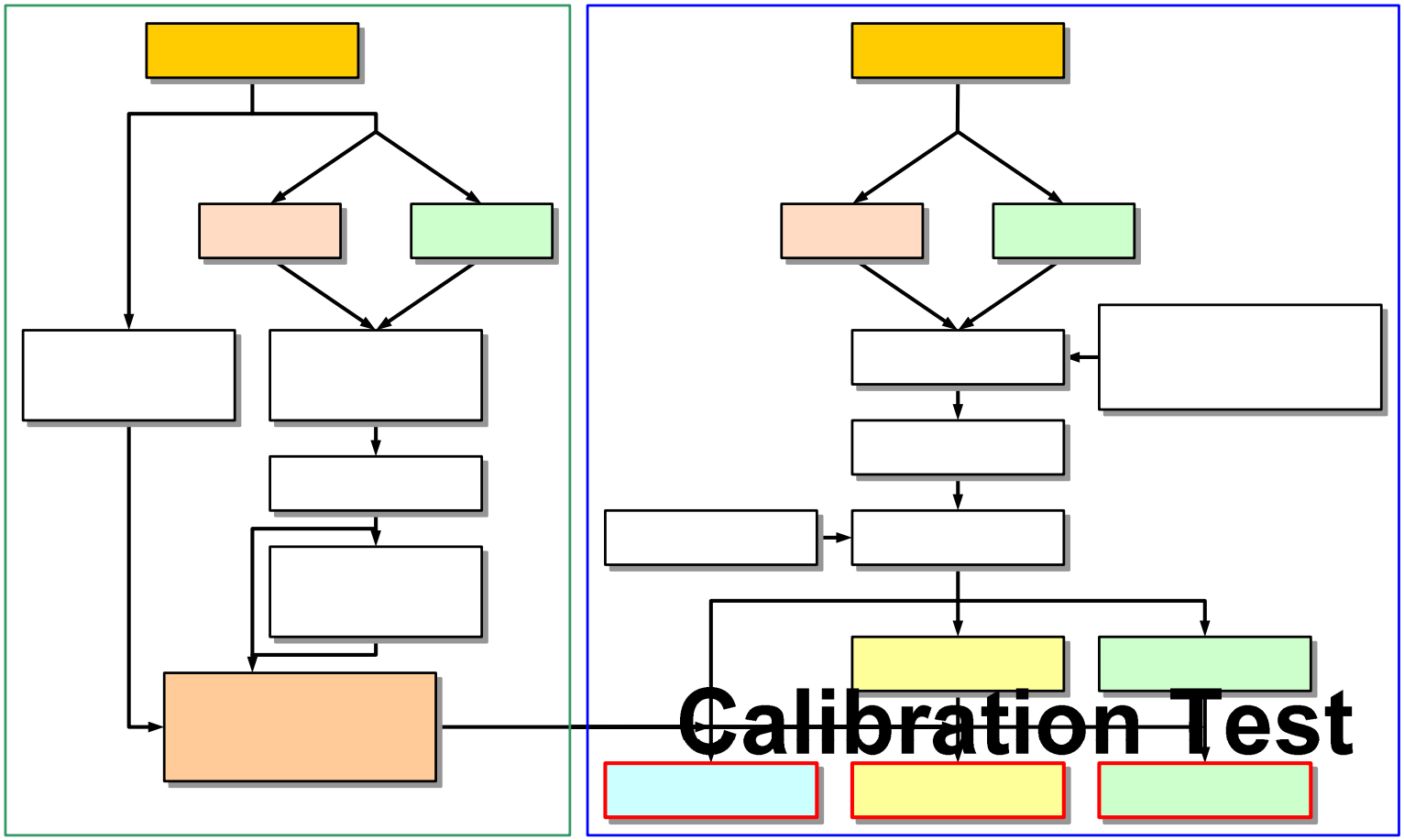


Experimental apparatus
- Laser light extinction and scattering method



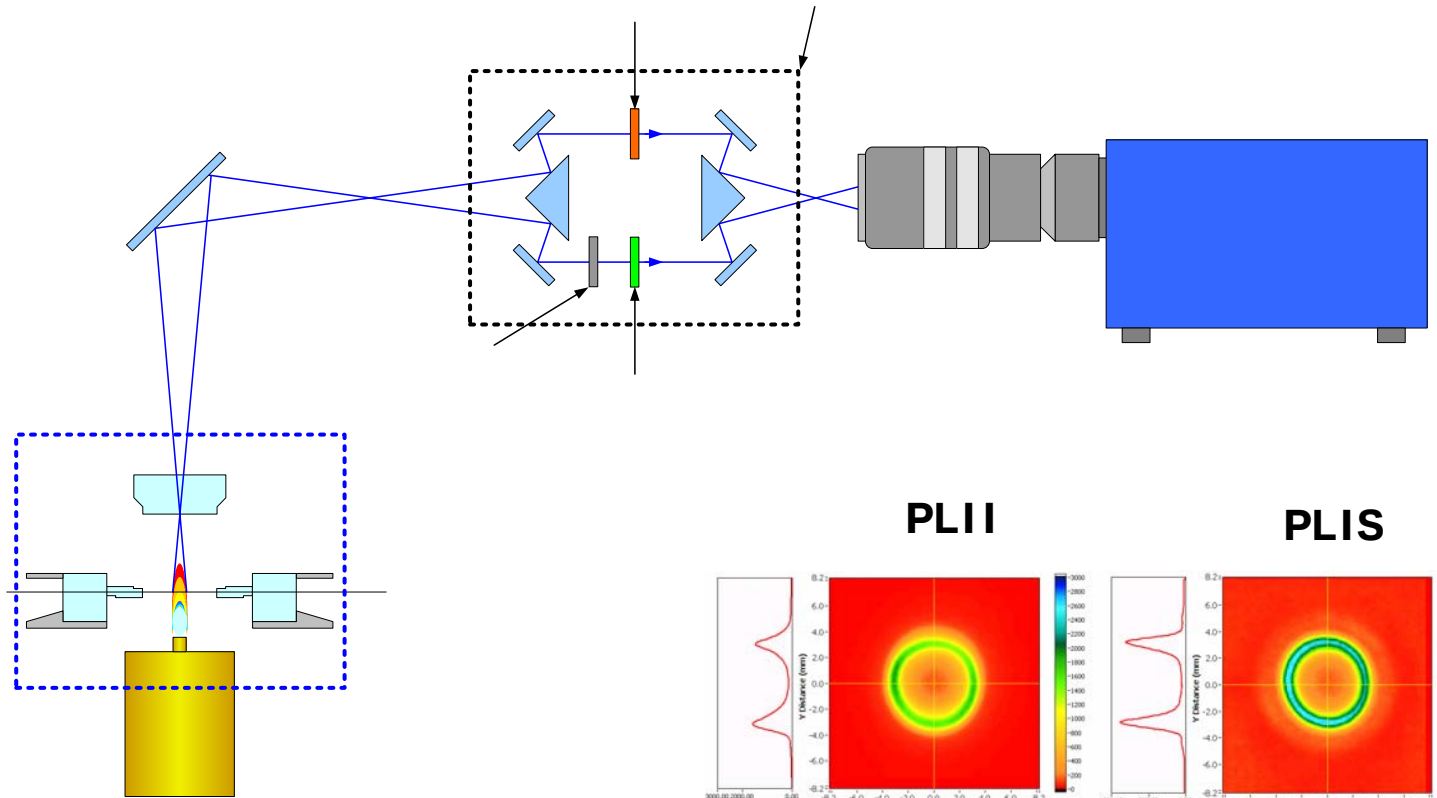
Fuel : C_2H_4
Flow rate : 180 scc/m
Shield air flow rate : 60 sl/m

Calibration and calculation procedure of E/G Image



Ethylene Diffusi
Flame

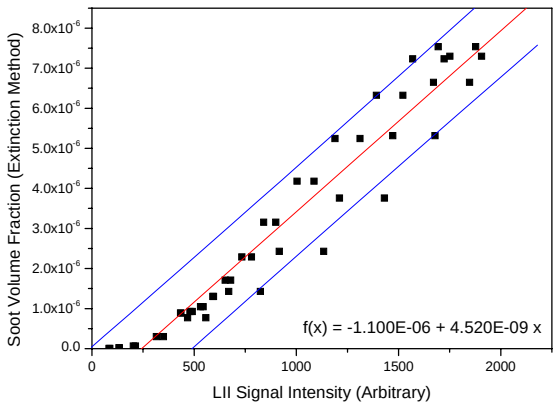
Experimental apparatus
- for 2-D Calibration system with co-flow burner

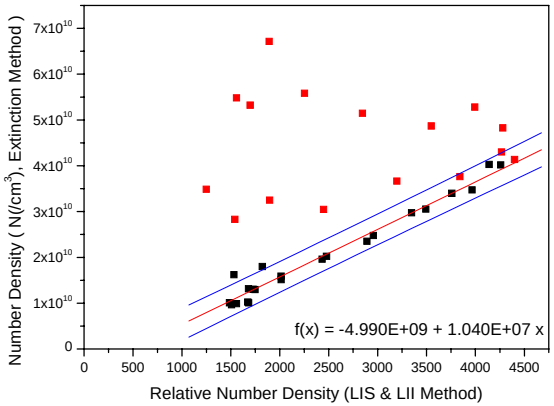


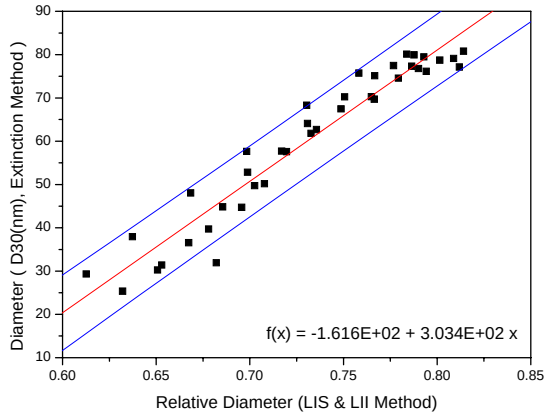
PLII

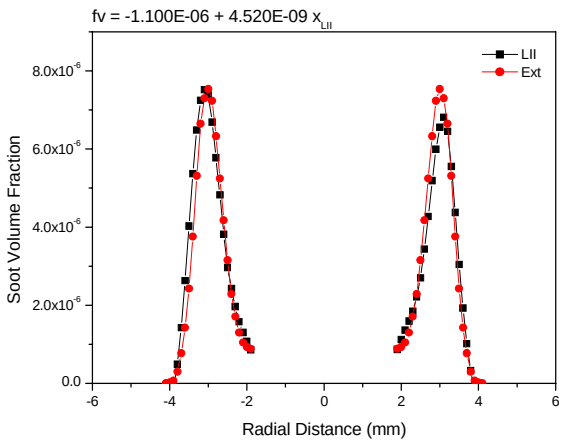
PLIS

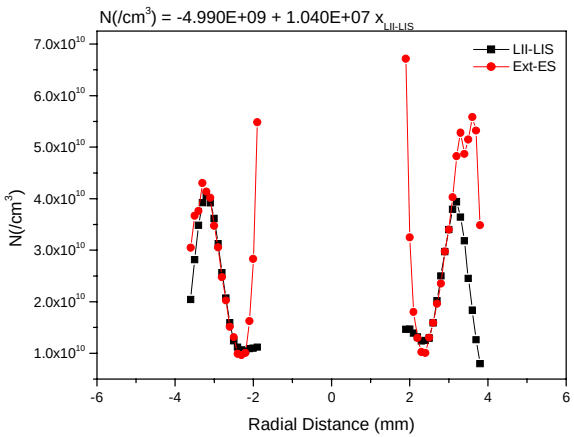
Calibration of PLII and PLIS Data

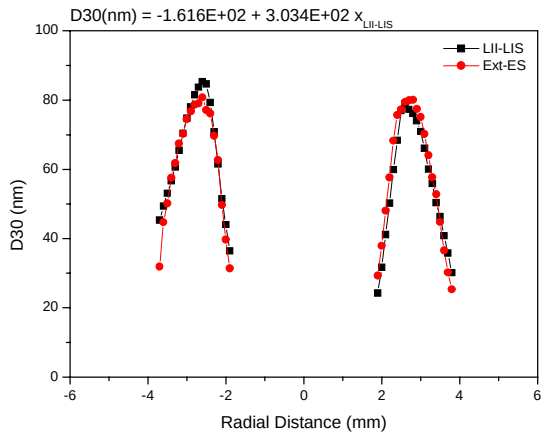






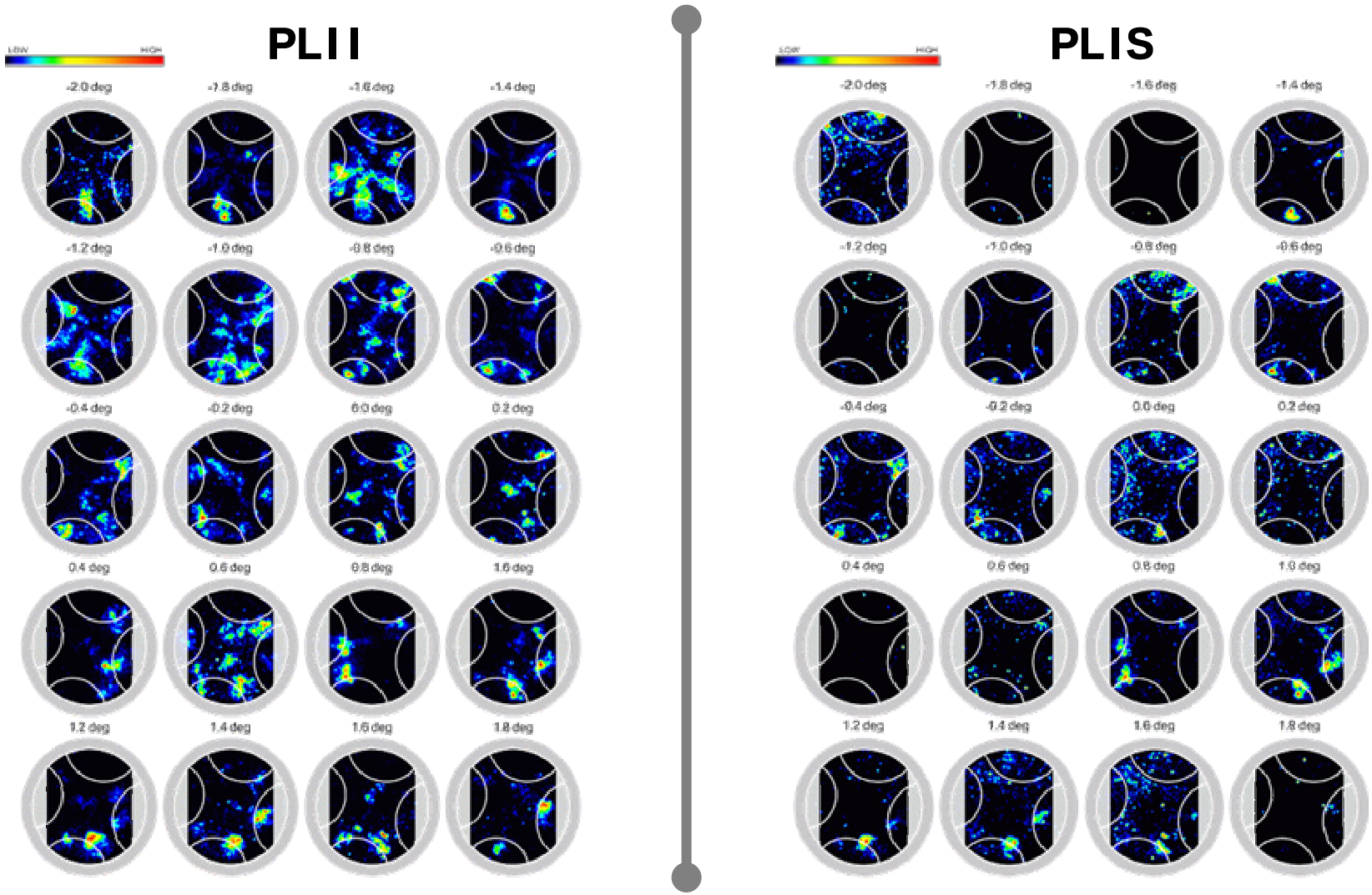




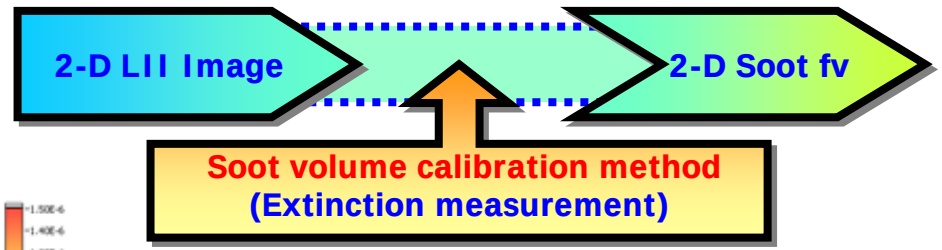


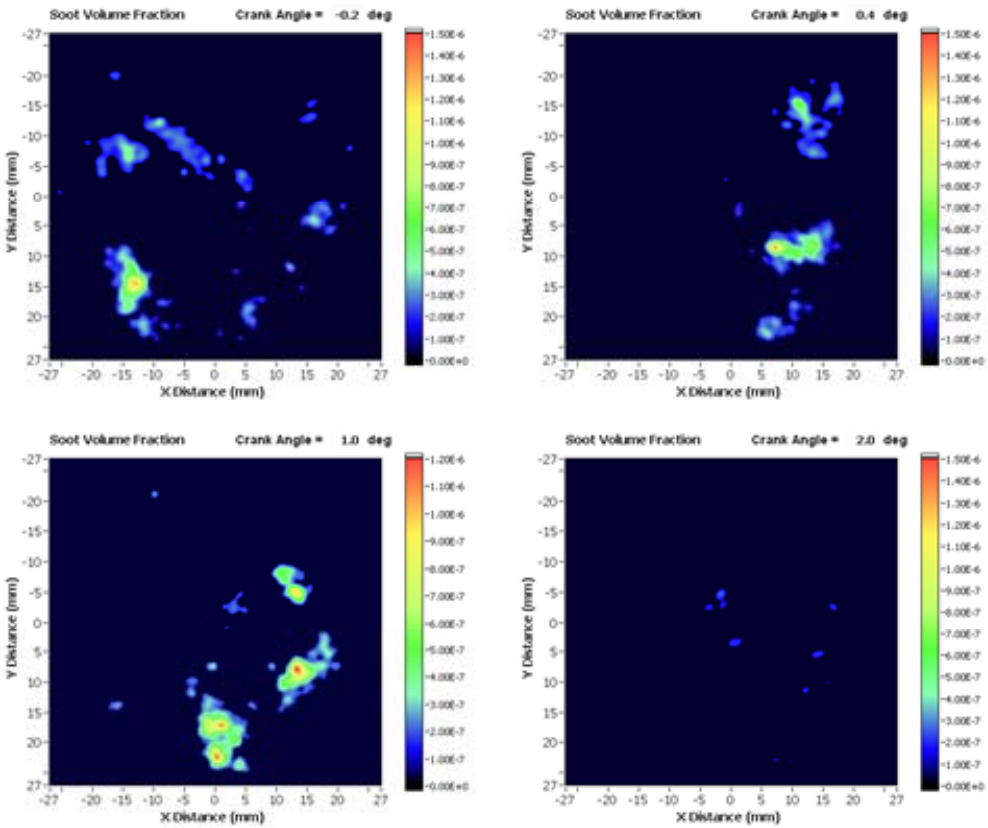
(a) Soot volume fraction (b) Soot number density (/cm³) (b) Volume Equival. Dia.(nm, D30)

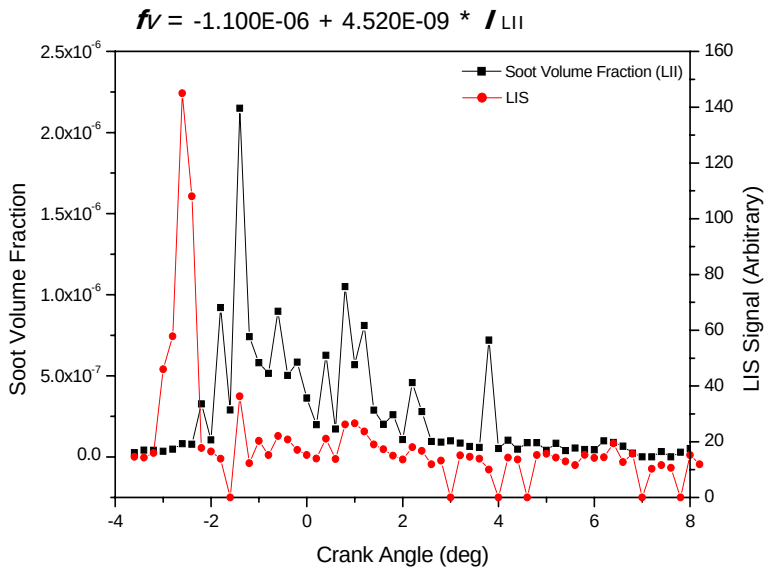
PLII and PLIS Images



soot volume fraction from PLII images

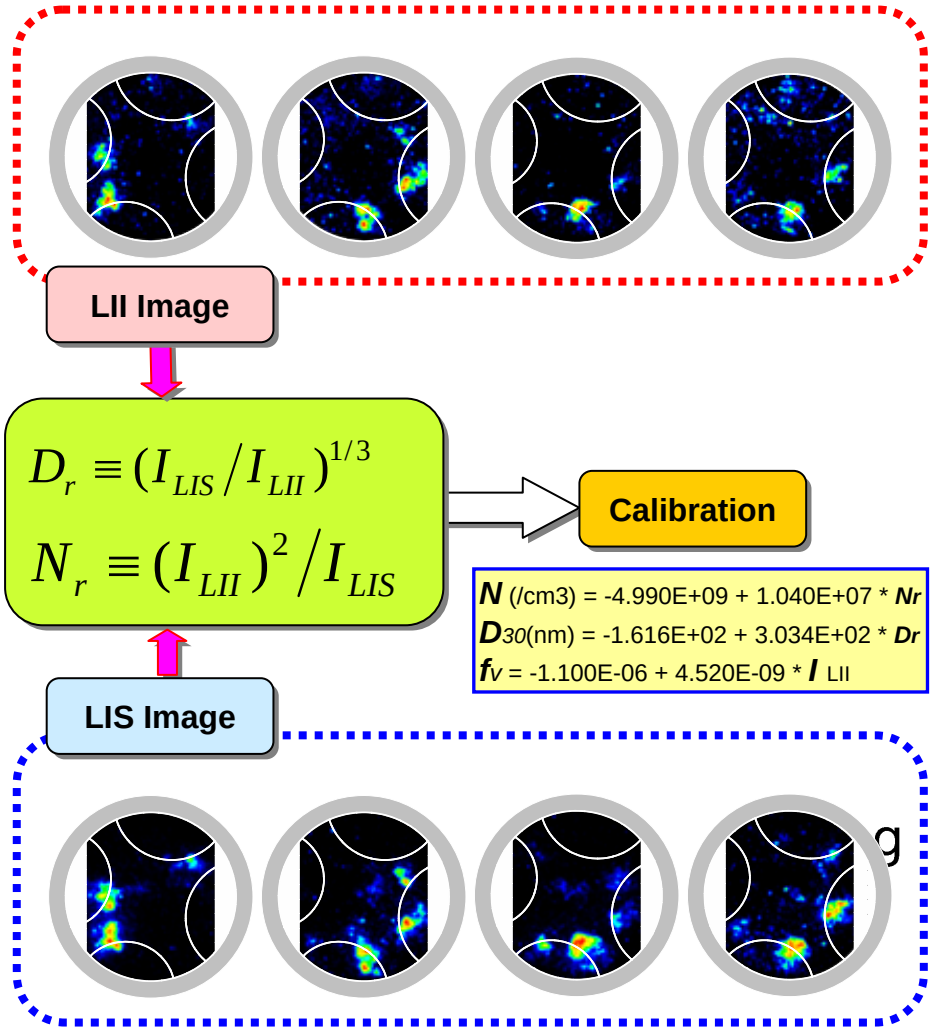




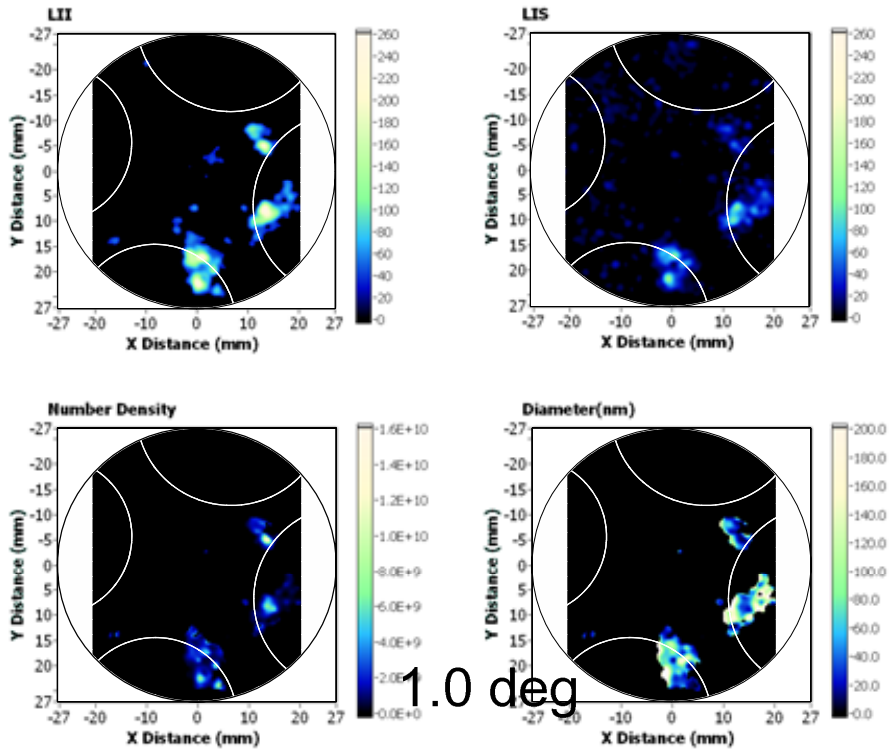


Engine Speed : 600rpm
Rail Pressure : 600bar
1st Injection : 0.83mg/st, BTDC 13deg
2nd Injection : 11.38mg/st BTDC 4deg

Soot Number Density and Volume Equivalent Diameter-PLII & PLIS



LII & LIS images of Engine : number density, D30



1.0 deg

Summary

- In-cylinder 2-D soot volume fraction, volume equivalent diameter and number density were obtained quantitatively by using PLII and PLIS method.

- Calibration results of PLII and PLIS image using laser extinction and scattering method on non-premixed jet flame shows a linear correlation between PLII/PLIS and LE/LS data.

- The maximum volume fraction of in-cylinder soot shows around 2~3 ppm, and the volume equivalent diameter is within the ~200nm

Acknowledgement

- **Korean MOCIE (Ministry of Commerce, Industry and Energy)**
- **Korea Engine Tec.**

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