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Analysis of Laser Focusing Effect on Quantification of LII Images

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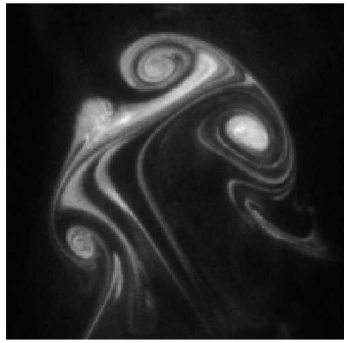
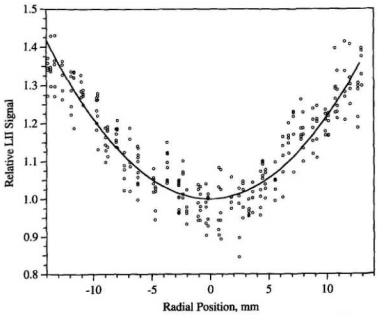
Background and Motivation



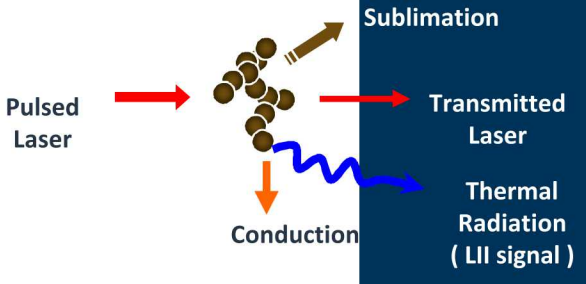
Instantaneous LII image of soot concentration in a turbulent oxy-fuel flame



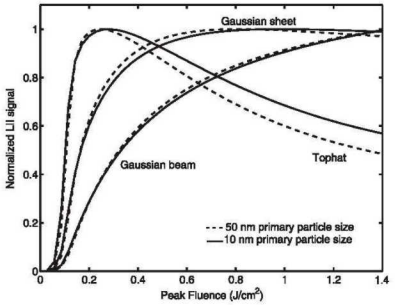
Shaddix and Smyth, *Combust. Flame* 107 (1996) 418–452.

- Laser-induced incandescence (LII) has become the standard for soot concentration measurements, particularly in flames
- One of the advantages of LII is that it is easily performed in a 2-D plane
- To reach the required laser sheet intensity, the laser is usually focused, often with a 1 m focal length lens
- Early work by Shaddix and Smyth (1996) showed that relatively strong focusing (300 mm focal length) of a doubled YAG influenced the LII signal across the image plane

Understanding the Laser Focusing Effect

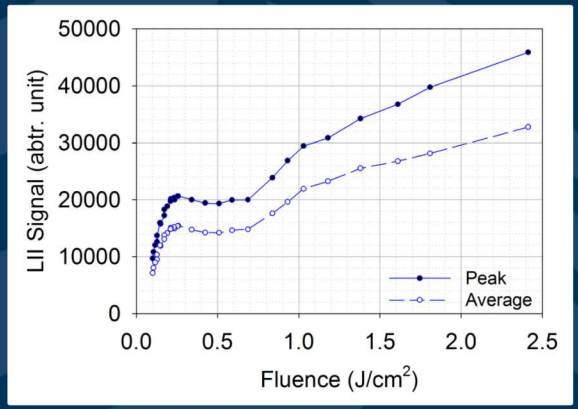


- The laser power dependence of LII is very complex, due to nonlinearity of thermal radiation signal and competing effects of particle heating and carbon loss to sublimation at elevated laser *fluence* levels

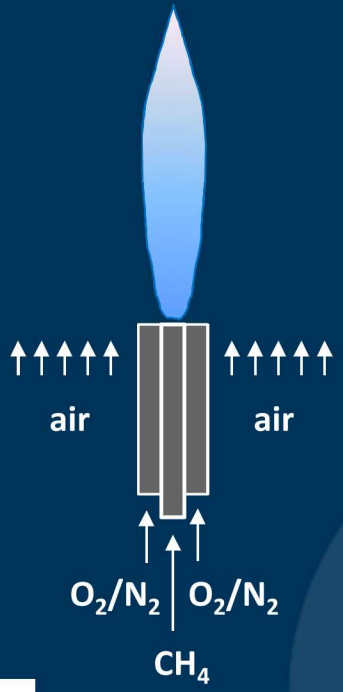


Bladh and Bengtsson, *Appl. Phys. B* 78 (2004) 241–248.

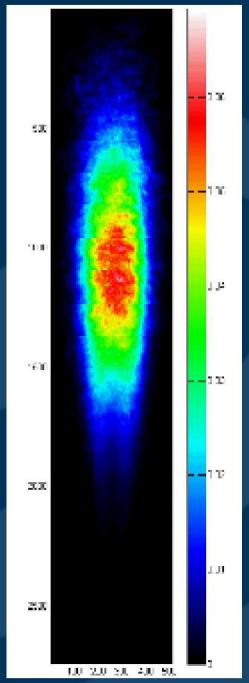
- To reduce sensitivity of LII signals to shot-to-shot laser power variations and to laser absorption across sooty flames, users typically select a laser fluence level that is in a 'plateau' region



Experimental Approach – Perform PLII measurements in laminar and turbulent oxy-fuel jet flames (50% O_2 in N_2)

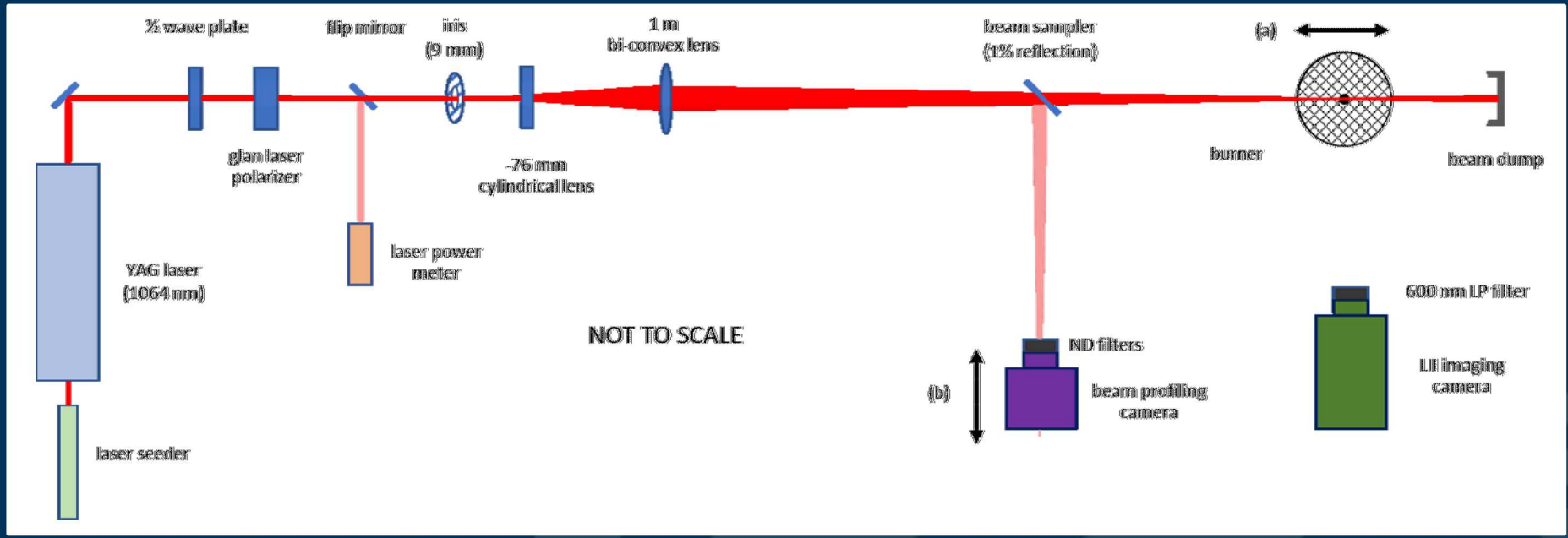


SLR camera image

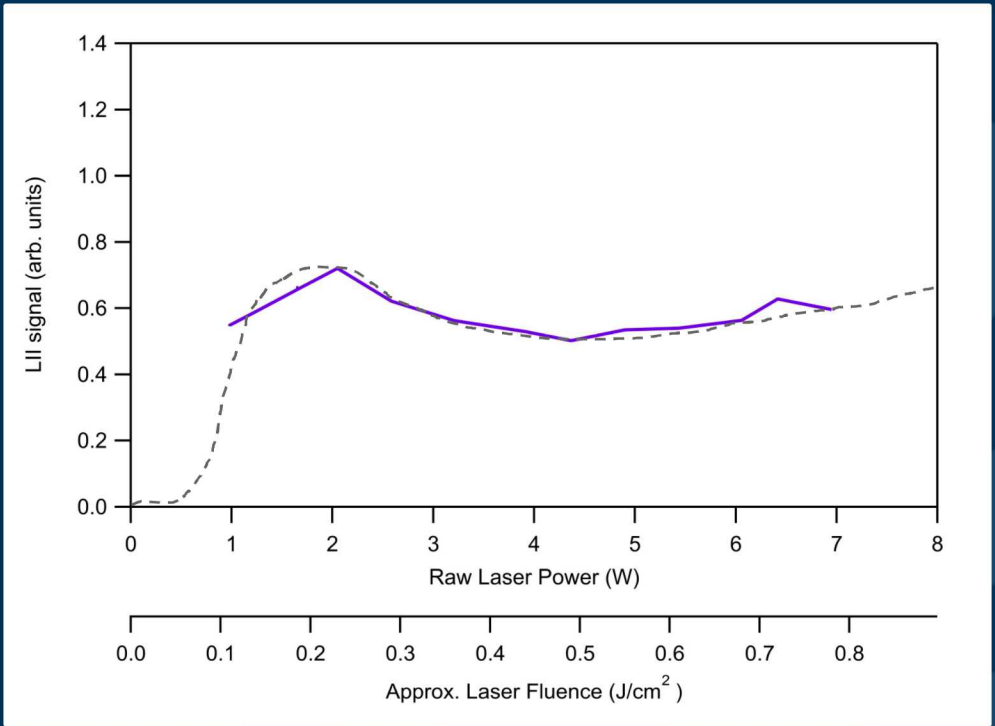


mean soot volume fraction (calibrated, stacked PLII)

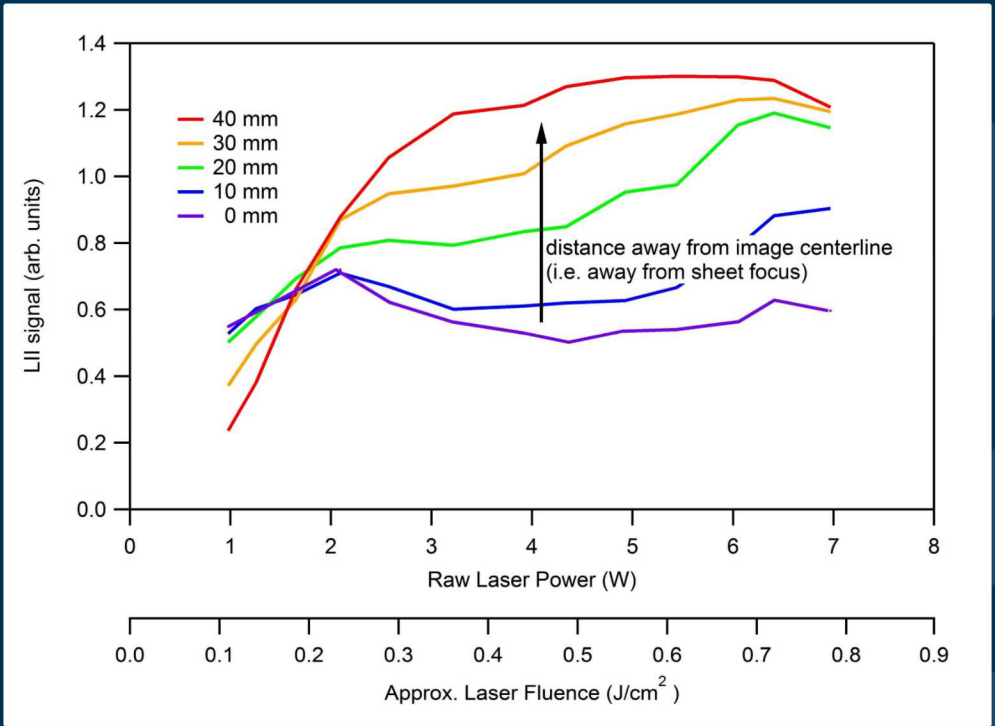
Overhead View of Diagnostic Layout



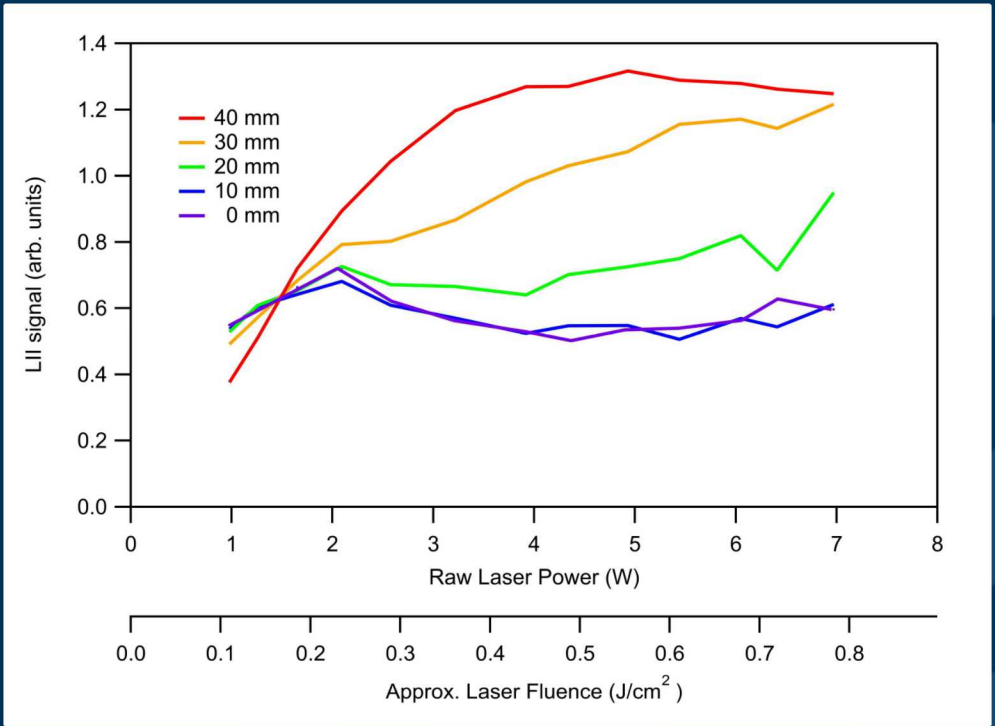
LII Power Dependence at Laser Sheet Focus



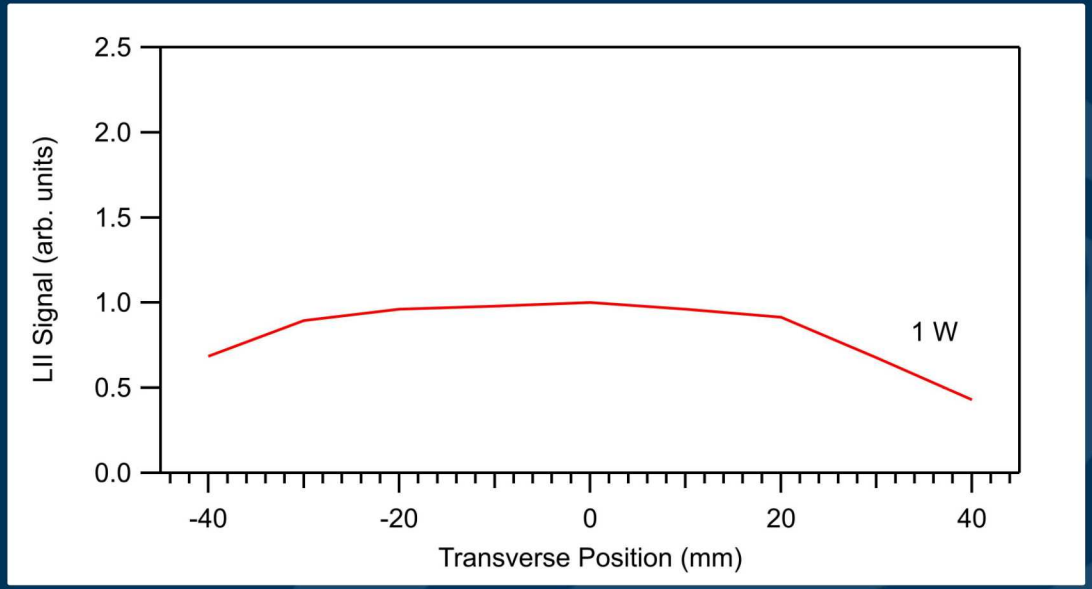
LII Power Dependence Downstream of Laser Sheet Focus



LII Power Dependence Upstream of Laser Sheet Focus



Implications for LII Signal Quantification Across Images



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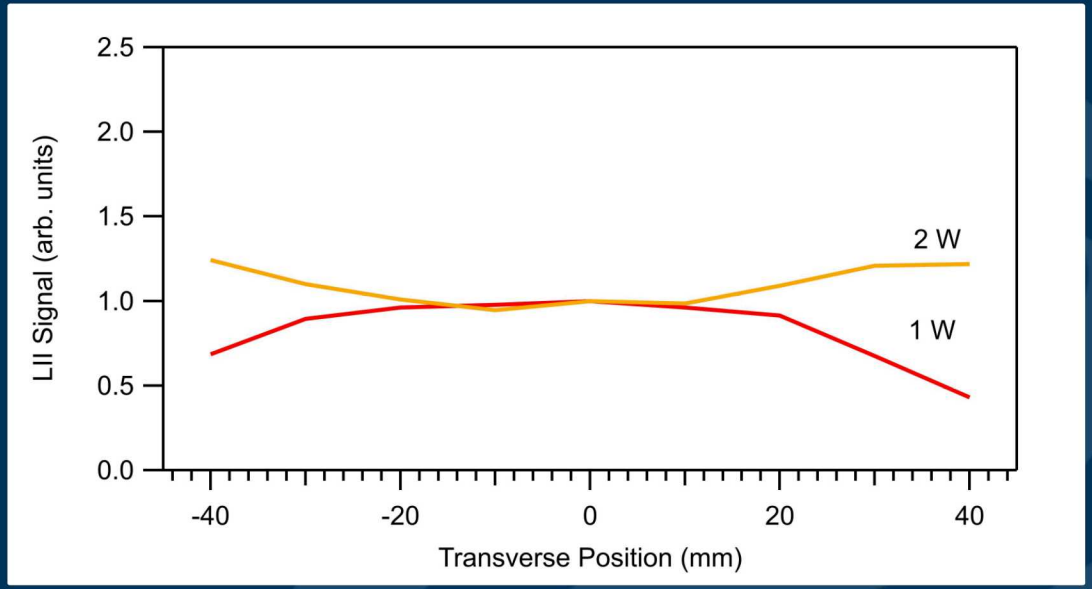

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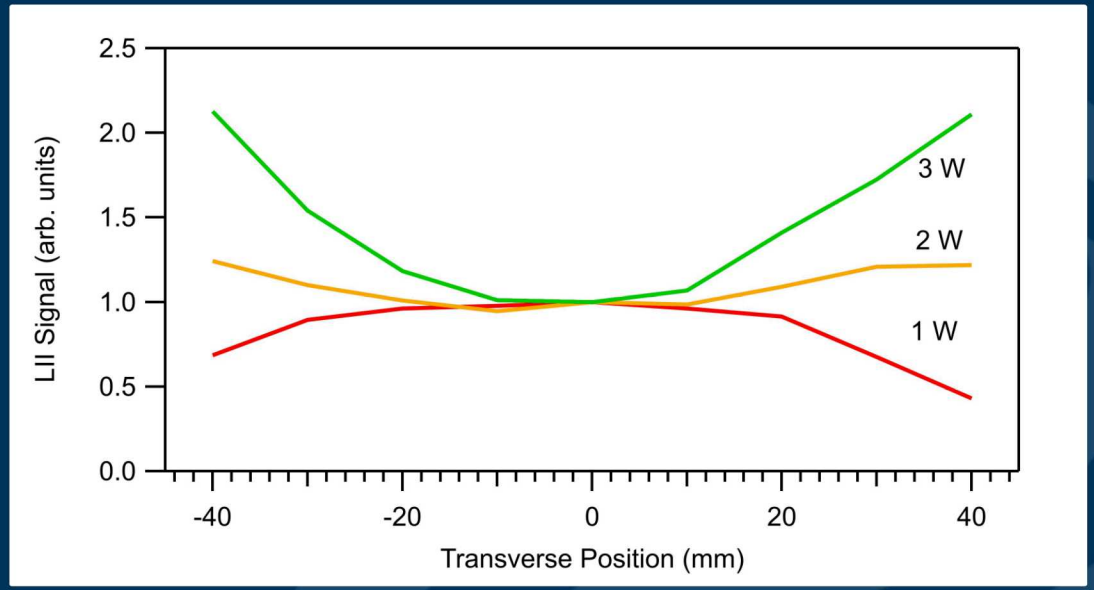

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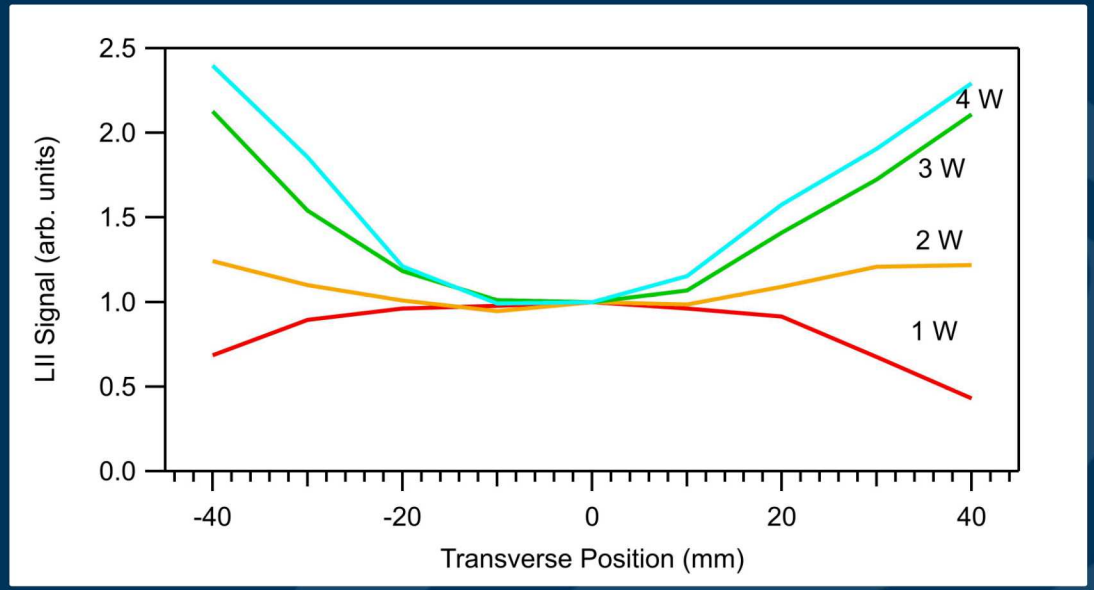

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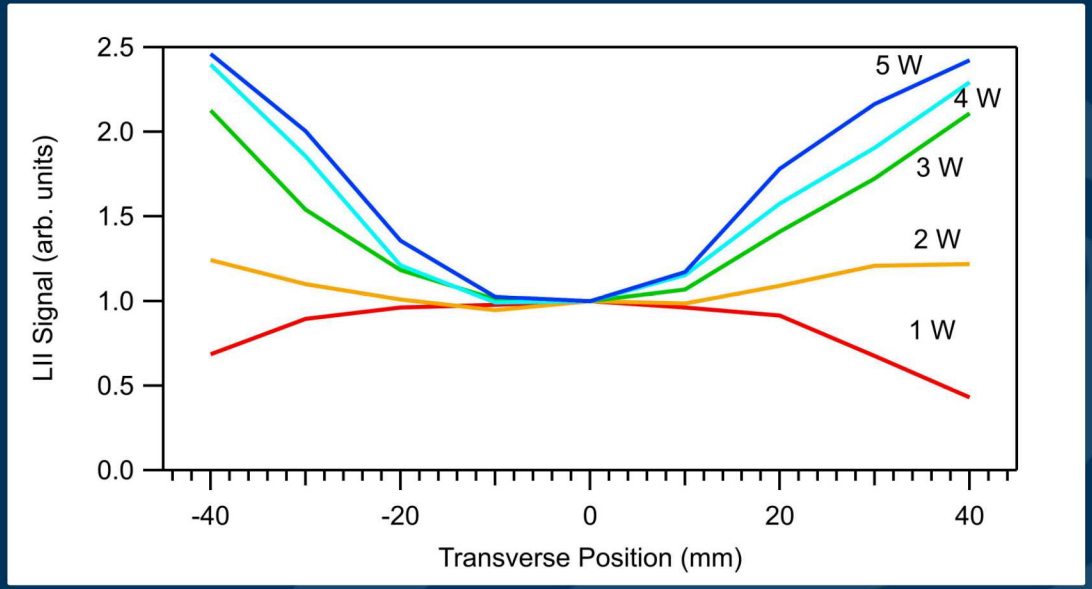

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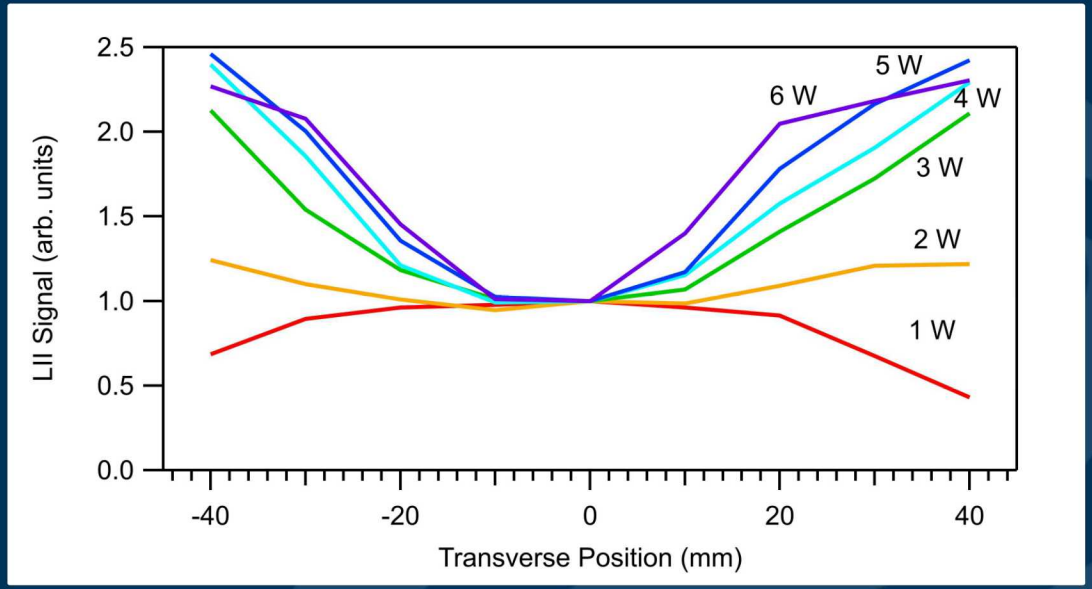
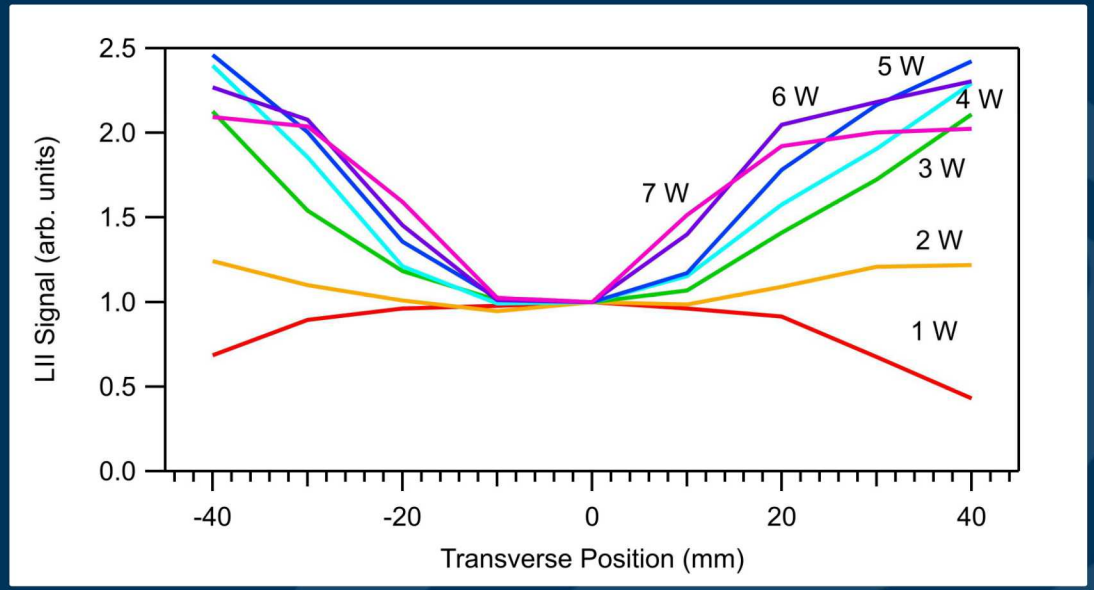
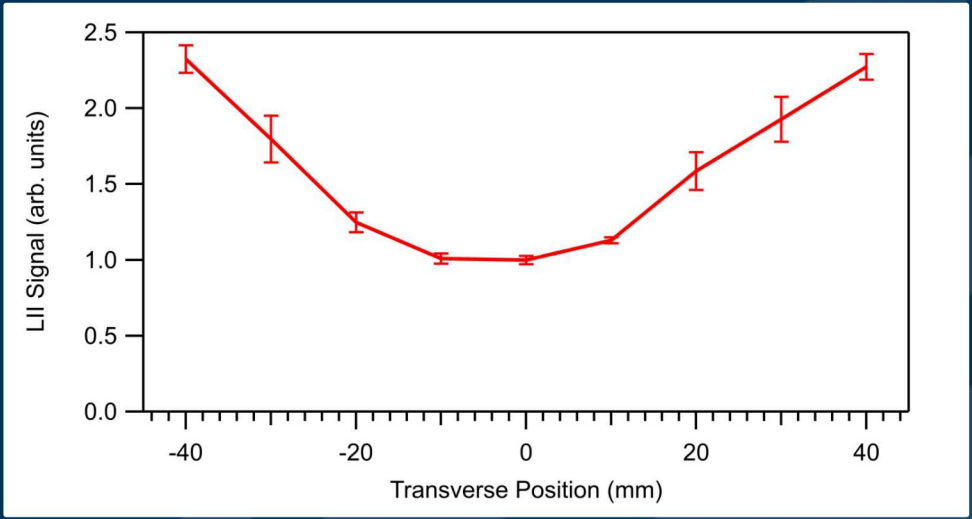


Implications for LII Signal Quantification Across Images



Recommendations

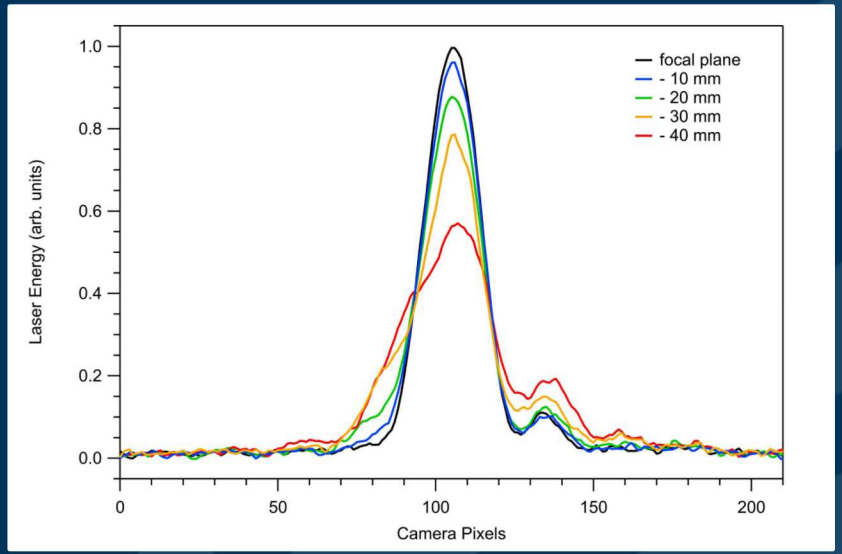
- For lightly sooting flames and consistent laser shot-to-shot power, choose relatively weak laser fluence – minimal transverse LII signal variation
- In other cases, use moderate laser power, wherein transverse correction has consistent shape and slowly varying magnitude



Average LII signal variation for laser power between 3-5 W

Ongoing Analysis

- The measured laser sheet energy approaching and receding from the focus is being analyzed to help explain the relative impact of central beam ‘bleaching’ and beam wing contributions to the measured LII power dependence



Mid-height Cross-Sections of Laser Sheet Energy

In Summary

- The ‘focusing effect’ on LII signal intensity during planar imaging has been investigated for a typical, modern LII implementation strategy
- Significant signal enhancement is seen off-focus for a Gaussian laser sheet at intermediate LII excitation intensities (a factor of 1.5x at 20 mm from image center and factor of 2.5x at 40 mm from image center)
- At low LII excitation intensities, a particular fluence exists at which the LII sensitivity is fairly constant across a wide image
- When intermediate LII excitation intensities are required, a signal correction is required for quantitative LII imaging

Acknowledgment

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Questions?