Relationship between LII Signal and Soot Volume Fraction – Effect of Primary Particle Diameter Polydispersity

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LII has been increasingly applied to measure the concentration and size of nano-particles, such as combustion generated soot in flames, in-cylinder, and engine exhaust, black carbon in the atmosphere, and other synthesized nano-particles. The basis of LII concentration measurement is the assumption that the LII signal is proportional to the particle volume fraction, while the principle of LII particle sizing is the particle size dependence of heat conduction cooling after the laser pulse. In this work, the discussion is focused on measurement of volume fraction of combustion generated soot using LII.

Two approaches have been developed to conduct quantitative LII measurements of the soot concentration. The conventional method detects the LII signal at one wavelength in the visible and seeks a calibration constant using a known source of particle concentration, i.e., $S_{LII} = C \times f_v$. The second one is the more recently developed two-color LII or auto-compensating LII. In this method, absolute LII intensities are detected at two wavelengths in the visible spectrum to infer the soot temperature based on the pyrometry principle. This method does not require a known particle source to arrive at a calibration constant. However, it requires the knowledge of both relative and absolute values of E(m) at the two detection wavelengths, which represents the main uncertainty of the two-color LII method. The calibration constant C in the conventional LII method in general is not constant under conditions other than those of the calibration. Since soot temperature is determined in the two-color LII method, the two-color LII method can be viewed as a special version of the conventional LII method in which the calibration constant is obtain *in situ*.

It is shown numerically that for a polydisperse primary soot particles the soot temperature derived in two-color LII is biased towards the temperature of those larger and hotter particles. As smaller particles cool faster than larger ones, smaller particles gradually ‘disappear’, leading to a decrease soot volume fraction determined by the two-color LII. Based on numerically results, the relationship between LII signal and soot volume fraction can be summarized as:

(1) It is linear in the two-color LII during and shortly after the laser pulse in the low-fluence regime
(2) It is linear in the two-color LII only briefly around the peak of the laser pulse in the high-fluence regime
(3) It is in general non-linear in the conventional LII method