Effect of Laser Pulse Duration on Laser-Induced Incandescence of Soot

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The phenomenon of laser-induced incandescence (LII) has been utilized to develop versatile diagnostic techniques for measurements of combustion-generated soot concentration and primary particle size in many combustion applications. Many aspects in the implementation of LII have been investigated, such as the excitation laser wavelength and spatial profile, signal detection timing (prompt or delayed) and temporal width, and signal detection wavelengths. One potentially important parameter in LII practice that has received little attention in the LII community is the laser pulse duration. This is perhaps due to the fact that almost all the LII experiments conducted in the last two decades employed Q-switched, flashlamp pumped Nd:YAG lasers as the light source, which all provide a similar pulse duration in a narrow range between 5 and 10 ns FWHM. Few LII experiments were conducted using a much long laser pulse (microsecond) or much a shorter one (picoseconds). Picosecond laser pulses were shown theoretically to provide advantages over nanosecond ones in the determination of primary particle size distribution using low-fluence LII in flames at elevated pressures.

In this study the effect of laser pulse duration on the temperature histories of primary soot particle of different sizes was numerically investigated in both low- and high-fluence regimes under conditions of a typical atmospheric pressure laminar diffusion flame. The laser pulse durations considered in this study vary from 100 ps to 6 ns FWHM. Such laser pulse durations correspond to those of a typical Ti:Sapphire pulsed laser operated at 780 nm. Such laser is capable of generating laser pulses with duration from picoseconds to nanoseconds, depending on if the regenerative amplifier is seeded by the femtosecond oscillator.

Numerical results show that at a fixed laser fluence in the low-fluence regime with decreasing the laser pulse duration the effect of heat conduction on the peak soot temperature is suppressed. Under the conditions considered here heat conduction lowers the peak soot temperature of a 30 nm soot particle by about 70 K when the laser pulse is 6 ns FWHM. As the laser pulse duration decreases, the differences in the peak temperatures reached by particles of different sizes become smaller, due to the effective separation of the volumetric heating process and the surface dependent heat conduction cooling. In high-fluence regime, the peak soot temperature increases more significantly with decreasing the laser pulse duration. There seem no advantages using a shorter laser pulse than the commonly employed 6 ns FWHM one in the high-fluence regime.

In summary, a shorter laser pulse offers advantages over the typical 5 to 10 ns duration one in some low-fluence LII applications where it is desirable to suppress the effect of heat conduction, such as particle size determination in high pressures and evaluation of E(m). However, it does not seem to offer advantages in high-fluence regime.