Continuous Wave LII in an Atmospheric Pressure Kerosene Flame

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Fibre and diode lasers with sufficient power to heat soot particles to incandescent temperatures are readily available at lower cost than the nanosecond pulsed lasers traditionally used in LII. There are less stringent safety restrictions on the use of CW lasers and they can be delivered with excellent beam quality through standard optical fibres, making them more suitable for LII in practical environments. Using the collimated beam from a diode laser at 803 nm in the power range 5 – 30 W, LII was easily observable in a highly sooting kerosene flame (F_v ~10^{-5}). However, the laser causes major changes in the combustion, increasing soot burn out rates and transferring heat to other regions of the flame.

In contrast to short pulse LII, soot particles experience laser heating and cooling by heat transfer at rates comparable with their reaction rate. Their residence time in the beam and other processes such as photophoresis and optical trapping also have to be considered. Hence, modeling is much more complicated than for short pulse LII, and the processes are not well understood.

Figure 1: LII in a quasi-2-D kerosene lamp flame with 28 W 1 mm diameter cw laser beam photographed through a BG3 filter

Visible emission spectra were collected using a traversable fibre optic probe from a magnified projected image of the flame shown in Figure 1. There is a good match between predicted emission spectra based on the blackbody curve and observed spectra from the flame in the wavelength range 590 – 790 nm. From these spectra estimated soot temperature in the absence of the laser is 2150 K, rising to 2600 K in the region of a 28.5 W laser beam. Temperature rise is linear in laser power. Local soot temperature is increased both above and below the beam when the laser is present. Above the laser beam, light emitted at 700 nm decreases quadratically with distance from the height of the centre of the laser beam to the edge of the visible flame, although the soot particle surface temperature remains at ~2350 K in this upper part of the flame. The intensity of light emitted at 700 nm at the centre of the laser beam at varying laser power is in good agreement with a prediction based on blackbody radiation. This indicates that the mechanism of increased light emission is particle heating (LII) and not creation of additional soot by laser stimulated reactions in the flame.

Although cw LII is at a very early stage of development, the potential for combustion diagnostics – soot concentration, temperature, velocity by flow tagging, etc. – is obvious. The observations described here should provide a basis for future investigation of the processes involved.