Influence of temporal laser pulse length and shape on the time resolved Laser Induced Incandescence signal

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Q-switched Nd:YAG lasers are typical choice for LII, with excitation pulse length of 7-10 ns. The question of longer pulse duration was raised in Schulz, Kock et al. (2006) and there is interest in using CW laser for LII (Black, 2010). The preset study is an experimental investigation on the influence of pulse lengths, in the range 50 - 1000 ns, and temporal shapes. The measurements were made 25 mm above a laminar non-premixed ethylene flame, using a Nd:YAG laser with temporal shaping capabilities (Agilite, Continuum). The time resolved LII measurements were made by re-constructing averaged, sequentially delayed, gated (10 or 20 ns) ICCD images in radial profile or spectral modes. Except in spectral mode, the LII signal is recorded with a 10 ns bandpass filter centered at 488 nm and a 532 nm centered notch filter. By using the shaping capabilities of the laser the effect of pulse length has been varied by keeping constant either the pulse fluence or pulse energy.

The main feature that has been observed is shown in figure 1. At the start of the pulse, the LII signal builds up equally for all cases, as a result of particles absorbing energy and heating up. The LII signal for the 50 ns pulse is as expected, decaying at a rate dependent on the primary particle diameter, but when the pulse length is increased, one observes a shouldering of the signal after 50 ns (green curve). This observation is unexpected as for constant pulse length, increasing the fluence, is known to increase the decay rate (i.e. to narrow the LII signal), because of the increase in vaporization rate (Michelsen, Witze et al.). It therefore indicates that the effect of laser fluence expressed in J/cm^2 has a time scale dependency on the LII processes. A further increase in pulse length to 200 ns (red curve) shows not only a further delay in the decay, but also a rebound of the LII signal. The cause of this phenomenon is unclear, as none of the processes known to be involved in the LII theory predicts such an effect. One shortcoming of our set up is that the beam is formed into a sheet, however the spatial resolution is clearly defined by the collection optics and this phenomenon would happen at all pulse lengths if it was due to the interferences from out of focus signals. Figure 2 shows that the signal rebound phenomenon as pulse length increases is also observed at constant fluence, starting for pulses longer than ca. 75 ns. The behaviour was also detected with both a top hat and a quasi-gaussian pulse temporal profile. The spectrally and time resolved LII traces shown in figure 3 seem to exclude the effect of interferences from molecular excitation processes such as late fluorescence, and confirm the efficiency of the filtering scheme chosen in the measurements shown in fig. 1 and 2.

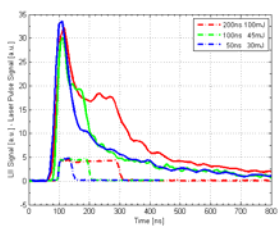

Fig. 1. Red: 200ns/100mJ; Green: 100ns/45mJ; Blue: 50ns/30mJ.

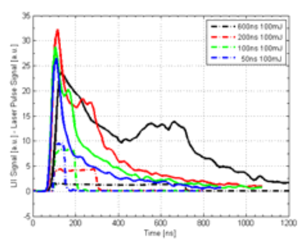

Fig. 2. E: 100mJ. Black: 600ns; Red: 200ns; Green: 100ns; Blue: 50ns.

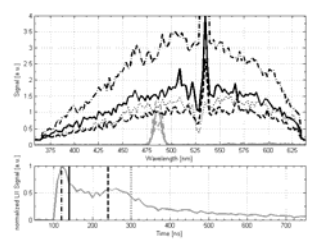

Fig. 3. Time resolved spectra taken at LII time shown in graph below.