Time-resolved laser-induced incandescence (TIRE-LII) coupled with spectral emission measurements for particle sizing in high-pressure diesel combustion environments

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Diesel engine combustion faces increased emission regulation standards worldwide with respect to the amount and size of soot particles escaping through the tailpipe. For efficient reduction of particulate emissions a better understanding of in-cylinder soot formation and destruction mechanisms is desirable. Laser-induced incandescence (LII) [1] is a non-intrusive optical technique for the *in-situ* characterisation of soot, such as mean particle size or spatial distribution of volume fraction. In this technique particulate matter is heated to high temperatures via absorption of a pulsed laser beam with fluence high enough to cause incandescence radiation to be recorded by one- or two-dimensional detectors. In time-resolved (TIRE) LII the soot particle size distribution is deduced from fitting an appropriate model function to the recorded transient signal intensity right after laser heat-up as derived from the particle energy and mass balance equations [2,3]. To accomplish this, in addition to a best knowledge of experimental parameters, i.e., laser fluence, beam profile, detection window, etc., an appropriate physical model for the description of the laser induced particle heating, evaporation and its subsequent cooling is necessary.

The present work describes the optically accessible high pressure Diesel spray combustion chamber at PSI for the simultaneous measurement of TIRE-LII signal traces at two separate detection wavelengths as well as of the spatially and spectrally resolved soot emission using an intensified CCD camera coupled to a spectrometer. Information on the mean soot particle size is evaluated by least squares fitting an appropriate physical model function adapted for the probed high pressure combustion environment [4] with known experimental parameters, such as gas pressure, spatially averaged particle temperature, laser fluence, etc. The submodel assumes a log-normal particle size distribution function and calculates temporal profiles of particle temperature and mean diameter as well as the LII signal intensity for a range of laser intensities representtative for the cross section of a Gaussian spatial beam in the measurement volume.

In the experiments, at initial gas pressures and temperatures (before ignition) between 0.5 and 4 MPa, and 773 K, respectively, and fuel injection pressures of 50 and 100 MPa soot is heated with the fundamental output of a Nd:YAG-laser (1064 nm, 10 ns pulse width) at pulse energies between 20 and 50 mJ. Laser-induced incandescence is collimated, separated by a dichroic beam splitter and focused on 2 photomultiplier tubes equipped with 460 and 630 nm interference filters, respectively. Both detector outputs are digitized on a fast storage oscilloscope (500 MHz bandwidth). Simultaneously, through a second observation window the laser- or flame-induced soot radiation along a vertical line is recorded at the exit plane of a grating spectrometer (focal length 300 mm) using an intensified CCD camera. After calibrating the detection system with a calibration source of known spectral radiance the 2-color LII signal profiles were evaluated for an effective soot particle temperature used as an experimental parameter in the subsequent fitting procedure.

We show that even at the pressures typical for these experiments TIRE-LII signal decays still can be temporally resolved with the present detection systems. Trends of the deduced particle size parameters with external gas and fuel injection pressure, temperature or residence time are discussed. The effects of unknown thermo-physical parameters and of mechanistic assumptions in the LII submodel on the extracted particle size parameters are investigated.

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