Laser-induced incandescence and multi-line NO LIF thermometry for soot diagnostics at high pressures

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Laser-induced incandescence (LII) is investigated in laminar premixed flat ethylene/air flames at pressures up to 5 bar in a recently constructed high-pressure burner. Time-resolved LII signals were compared with a numerical model considering the influence of pressure on the LII signal decay. Peak particle temperatures after laser heat up were measured by the detection of the LII signal at two wavelengths. Laser-induced emission spectra enabled to check for interfering signals. Gas-phase temperatures were required to compare the LII signal decay with the model and were measured using multi-line NO-LIF thermometry.

Introduction

Laser-induced incandescence (LII) has proven to be a powerful tool for soot diagnostics. It has been used successfully for measuring volume fractions of soot in flames and exhaust gases and particle sizes have been deduced from the temporal behavior of the LII signal. While applications in high-pressure environments (namely IC engines) are frequently performed, systematic investigations of LII at elevated pressures have only been performed in [1]. Important for understanding and interpreting LII signals is the temperature information of both soot particles and the surrounding gas.

Experimental

We set up a high-pressure burner with a premixed, laminar sooting ethylene/air flame. For stabilization the central sooting flame was surrounded by a premixed, non-sooting methane/air flame. Optical access was provided by four quartz windows. The flame at 1, 2 and 5 bar is shown in figure 1.

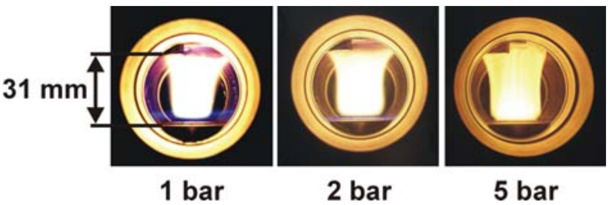

Fig. 1 . Premixed ethylene-air flame with an equivalence ratio of ϕ = 2.1 at 1, 2 and 5 bar.

LII signals were generated by a Nd:YAG laser at 1064 nm at elevated pressure up to 5 bar with wavelength, excitation-energy-density- and time-resolved detection. Time-resolved LII signals were detected at two different wavelengths with fast photomultipliers in order to obtain the peak particle temperature after laser heat up. The optical system was calibrated by a black body radiator.

Gas temperatures were measured using multi-line NO thermometry. Therefore, the sooting flame was seeded with some hundred ppm NO. The NO molecules were excited in the A-X(0,0) band by a tunable narrowband KrF*-excimer laser (248 nm) which was frequency-shifted to 225 nm in a 10-bar hydrogen Raman cell. The LIF-signal was recorded with an intensified CCD-camera. Gas temperatures were deduced by fitting simulated NO-LIF spectra to the experimental excitation spectra using the LIFSim program [2].

TR-LII measurements provide systematic information about the pressure influence on the LII technique. Excitation with different laser-energy densities gives information about soot evaporation as well as subsequent particle cooling at different pressures. Current numerical models simulating LII signals were compared with experimental data. To obtain particle sizes using the signal decay curve it is important to use the correct heat transfer model as the heat transfer mechanisms change with increasing pressure.

References

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