Gas-phase temperature imaging in sooting flames by multi-line NO-LIF thermometry

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Two-dimensional gas-phase temperature fields were measured in sooting atmospheric pressure and elevated pressure flames with multi-line NO-LIF thermometry. The data is then used as input for modeling particle sizes with temporally resolved LII measurements at high pressure. We also compare flame temperature values derived by pyrometry measurements with the gas-phase temperatures measured in a stabilized McKenna flat flame and find some differences in the lower part of the flame.

Introduction

The gas-phase temperature in flames is of high interest because it governs chemical reaction kinetics and influences the LII signal decay rate significantly [1].

Multi-line NO-LIF thermometry

In contrast to conventional two-color LIF thermometry for gas-temperature the multi-line technique yields absolute temperatures without calibration [2] and the technique can be applied even in systems with strong scattering and fluorescence background. The technique is based on the measurement of LIF (Laser Induced Fluorescence) excitation spectra of nitric oxide (NO). Some thousand ppm of NO are added to the fresh gas as a fluorescent tracer. The laser is tuned over a part of the NO absorption spectra while individual images are taken with an intensified CCD camera for each excitation wavelength. From the resulting stack of pictures (each with the laser tuned to the next wavelength) LIF excitation spectra can be extracted for each pixel. Simulated spectra are then fit to the experimental data using LIFSim (www.lifsim.com). Free parameters are absolute temperature, broad-band background as baseline and signal intensity.

A tunable KrF*-excimer laser (248 nm) is frequency-shifted to 225 nm in an 8-bar H_2 Raman cell. The laser beam is formed to a 40 × 0.5 mm^2 light sheet which illuminates a vertical plane in the region of interest. The NO molecules are excited in the A-X(0,0) band and the LIF-signal is recorded with an intensified CCD-camera. Elastically scattered light is suppressed by Schott UG5 filters. An additional reflection band pass filter separates the 230 – 255 nm range for detection to suppress fluorescence from soot precursor molecules.

High pressure flat flame burner

The gas phase temperature could be determined in an elevated pressure ethylene flat flame with an equivalence ratio ϕ = 2.1. For 1 bar we find 1644 ±30 K, for 2 bar 1710 ±20 K and at 5 bar we measured 1850 ±100 K in the middle of the flame 10 mm above the burner matrix. An excitation spectrum and the fit is shown in Fig. 1. The data is used as input for modeling particle sizes with LII.

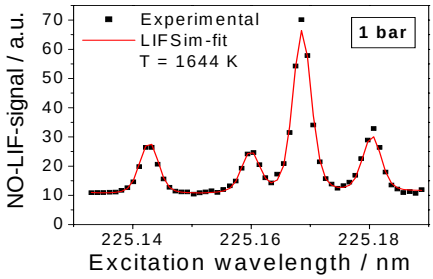

Fig. 1: NO-LIF excitation spectrum at 1 bar in a sooting ethylene/air flame at ϕ = 2.1

Soot particle versus gas-phase temperature

The multi-line NO-LIF technique has been used to obtain temperature fields (Fig. 2) of sooting atmospheric pressure flat flames on a McKenna burner stabilized by a metal plate. Soot particle temperatures derived by pyrometry [3] showed deviation from the gas-phase temperature in the lower flame zone.

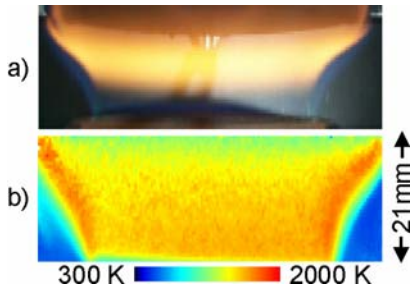

Fig. 2: a) Photograph and b) gas-phase temperature field of a sooting flame stabilized on a McKenna burner

References

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