Temperature measurements for LII evaluation in non-premixed flames – comparison between emission spectroscopy and CARS

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The purpose of this work is to evaluate the accuracy of temperature measurements using emission spectroscopy in a parabolic flight set-up. The acquired time resolved temperature information is then used for particle sizing by TIRE-LII. For comparison, additional temperature measurements have been performed using coherent anti-Stokes Raman scattering (CARS).

Introduction

To study soot formation under microgravity conditions, TIRE-LII experiments have been performed during parabolic flight campaigns to simultaneously measure soot volume concentration as well as primary particle sizes in laminar non-premixed flames. As the temperature of the surrounding gas phase is an input parameter for primary particle size determination, it was necessary to measure this quantity at the same time. Thus, soot emission spectroscopy was chosen, as it is a robust measurement technique and rather simple to implement in an parabolic flight set-up. The applicability of this set-up was tested in the laboratory in comparison to CARS temperature measurements.

Experimental set-up

To evaluate the measurement procedure, data were taken in the same flame used in previous parabolic flight campaigns. The burner consists of two co-annular tubes (2.2 mm inner diameter, 30 mm outer diameter) for fuel and co-flow. The used gas flows (fuel: 75 scm^3/min ethylene, co-flow: 10 sl/min synthetic air) resulted in a non-premixed flame with a luminous flame length of 31 mm, and spectra were taken at several downstream positions from the burner exit.

Radial projections of light emitted by flame soot at a certain axial position is focused into the entrance slit of a spectrometer and detected by a CCD camera for wavelengths between 430 and 640 nm. Afterwards, the data were corrected for self-absorption using soot volume fraction data obtained by LII measurements, and an onion peeling algorithm for tomographic reconstruction is applied to obtain emission spectra at certain radial positions in the flame out of the projected data. Planck curves were fitted to the corrected spectra to get temperature profiles at certain axial flame position.

For accurate temperature determination coherent anti-Stokes Raman scattering with non-resonant background suppression was applied. C_2-interferences [1] were avoided by shifting the signal wavelength to an interference-free spectral region using a dual-pump CARS approach.

Results

Temperatures measured by emission spectroscopy and CARS show a rather good agreement at most of the examined downstream positions of the flame. For most flame heights the deviation between both techniques is smaller than 100 K. Thus, this method is suitable for temperature measurements in large part of the flame area. Unfortunately, it gives no reliable results in regions with very low soot concentration, especially at lower axial flame positions. Here, the use of a more sensitive camera could possibly lead to further improvements.

Acknowledgements

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[1] F. Beyrau, T. Seeger, A. Malarski and A. Leipertz, J. Raman Spectrosc., 34, 946–951 (2003).

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