Peak soot temperature in laser-induced incandescence measurements

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In order to better understand the processes involved in Laser-Induced Incandescence (LII) technique and consequently to develop a theoretical modeling of the physical and chemical processes involved in nanosecond heating of soot particles, many experimental efforts are still required. In this work, results concerning the value of the maximum soot temperature as obtained at the peak of laser-induced incandescence signal are presented. To this purpose, a two-color LII technique has been applied, together with a calibrated lamp used as the reference source. A value close to 4000 K was obtained in flames of different fuels and for many soot conditions (growth, agglomeration and oxidation).

Introduction

The development of non-intrusive optical techniques is of primary importance to understand soot formation mechanisms in combustion systems. Laser-induced incandescence technique (LII) is a promising tool that allows temporally and spatially resolved characterization of soot in terms of soot volume fraction and particle size. Although many works on LII are reported in literature, both on theoretical modeling and on the experimental approach, efforts are still required for an accurate description of this process. Several discrepancies and uncertainties still prevent a straightforward interpretation of the phenomena involved. Soot refractive index, maximum soot temperature, LII signal dependence on laser irradiance are just a few meaningful points of concern. In this work results are presented about the maximum temperature detected at the incandescence peak. This has been performed on different flames and covering all sooty regions in each flame. Basically, the maximum soot temperature is always found to be close to 4000 K, that is the commonly accepted value for soot vaporization.

Experimental and results

A two-color LII experimental set-up was implemented. A portion of the beam of a Nd:YAG laser (1064 nm) is selected by means of a diaphragm and imaged above the burner mouth by a lens (160 mm). In this way a quite uniform and sharp edged beam cross-section is obtained and checked by a webcam. The temporal behavior of LII signal at two wavelengths (450 and 600 nm) is revealed by a monochromator coupled with a photomultiplier and a fast digital oscilloscope. The most suitable procedure to determine the peak LII signal was determined through a statistical analysis of the signal integrated over different gate widths around the peak. The dependence of the peak LII signals at the two wavelengths, and, consequently, of the temperature, on the laser fluence was also investigated. Temperature linearly increases with the laser fluence up to a threshold value (about 250 – 300 mJ/cm^2). With the beam cross-section used, above this value, it remains quite constant with only a slight decrease for laser fluences beyond 600 mJ/cm^2, where vaporization takes place. LII measurements have been performed at about 300 mJ/cm^2, above the threshold level and where vaporization is minimized. Comparison of LII signals with the light intensities from a calibrated tungsten ribbon lamp allowed to determine the LII peak temperature and soot volume fraction by applying well-known two-color emission relationships. Different flames and different soot stages (from inception to oxidation) have been investigated. Fig. 1 shows an example of soot volume fraction and peak temperature axial profiles for diffusion flames fueled with ethylene and methane. As it can be seen, whatever is the soot load and sooty region in each flame, peak temperature is always close to 4000 K. Similar results have been obtained in radial profiles as well.

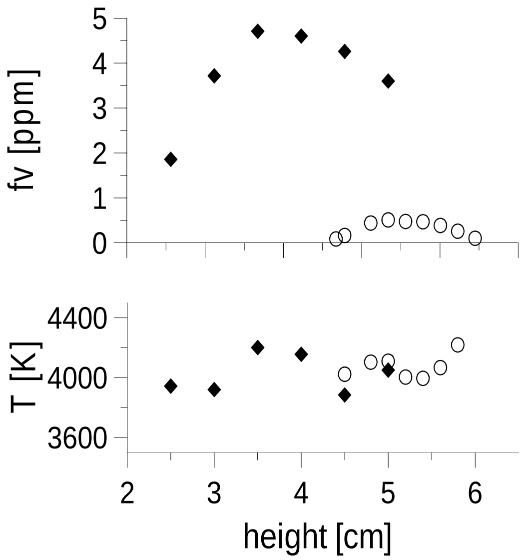

Fig. 1: T and f_v axial profile in C_2H_4 (closed diamonds) and CH_4 (open circles) diffusion flames

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Proceedings of the International Bunsen Discussion Meeting 2005: Laser-induced Incandescence, Quantitative interpretation, modelling, application