Wavelength-dependence of refractive index function of soot particle by two-color laser-induced incandescence

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A new method is proposed to obtain the variation of the refractive index function of soot particles $E(m)$ with wavelength. The method consists to select laser energies at different wavelengths ensuring the equality of the LII signals in the low fluence regime. Such equality is consistent with the fact that the soot particle has reached the same temperature independent on the laser wavelength, e.g. the soot particle has absorbed the same energy. The measurement of the laser energies insuring a perfect concordance of the LII intensities allows the determination of the corresponding variation of *E(m)* with wavelength. The method is applied in a methane diffusion flame by using laser radiation at 532 and 1064 nm.

Introduction

A few papers report on the wavelength-dependence of *E(m)*. It has been shown that results present large discrepancies [1-3]. Particularly accurate knowledge of *E(m)* at 1064 nm is necessary since this wavelength is the most recommended to prevent background fluorescence to be collected with the LII signal. In this work, the recently proposed two-color LII method [4] is extended to derive data on soot optical properties. It is shown that by using two different laser wavelengths (532 and 1064 nm), the ratio of the soot absorption functions $E(m,532)$ / $E(m,1064)$ can be locally determined in any flame. This new method is applied in a methane diffusion flame presenting an axisymmetric soot distribution.

Method

The original method proposed aims to obtain the variation of *E(m)* with wavelength and is based on the LII signal variation with laser excitation wavelength. For the demonstration the two laser wavelengths used in this work were 532 and 1064 nm. But the method can be extended to any couple of wavelengths. The incandescence radiation is collected with the same spectral efficiency independent on the laser wavelength (same $\lambda_{detection}$).

The power absorbed by the particle (radius r_p) is related to the laser irradiance q (Wm^{-2}), and to $E(m,\lambda_{laser})$ according to:

$$H_A = Q_{abs}\,\pi\, r_p^2\, q \quad \text{with} \quad Q_{abs} = 4 \cdot E(m,\lambda_{Laser}) \cdot \frac{2.\pi.r_p}{\lambda_{laser}}$$

where Q_{abs} is the soot absorption efficiency.

Thus, for both selected laser wavelengths we ensure: (1) absence of particle sublimation (2) coincidence of temporal LII signals, (3) same spatial laser energy distribution and (4) the same intensity and volume emission of the two thermal radiations, the ratio of the *E(m)* functions at any laser wavelength is given by the inverse ratio of the laser energies (selected to ensure conditions 2 and 4) times the ratio of the wavelengths.

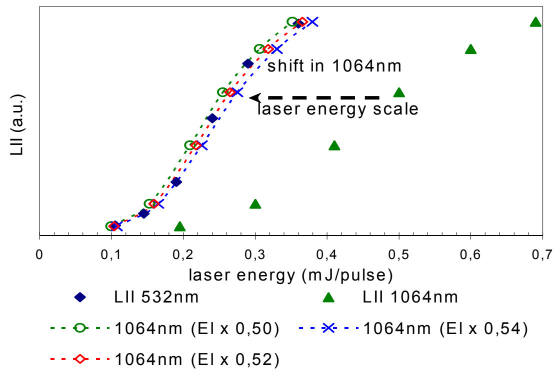

Fig. 1. Determination of the E(m) ratio.

The fluence curves have been thoroughly obtained in the low fluence range. Prompt-LII intensity is plotted in Fig.1 as function of the laser energy/pulse. It can be seen that the fluence curve at 1064 nm perfectly fits that one at 532 nm by reporting it as function of a new abscissa namely (0.52 x $E_{laser}(532)$) (red curve). Thus, LII signals collected successively upon 532 or 1064 nm irradiance are identical for a ratio of the laser energies $E_{laser}(532)$/ $E_{laser}(1064)$ = 0.52 leading to a ratio of $E(m,1064)$/ $E(m,532)$ = 1.04. Without any normalization, LII temporal profiles, measured for any couple of laser energies insuring the equality of the peak LII intensities, were found to be identical.

The method can be applied locally and will be extended to the study of *E(m)* variation in different flames (equivalence ratio, composition…).

References

1 Dalzell, Sarofim; J. Heat Transfert 91, 100 (1969)
2 B.J. Stagg, T.T. Charalampopoulos; Combust. Flame 94, 381 (1993)
3 Zhu, Choi, Mulholland, Gritzo; Int. J. Heat and Mass Transfer, 43, 3299 (2000).
4 Schoemacker-Moreau, Therssen, Mercier, Pauwels, Desgroux,. Appl. Phys. B 78, 485 (2004)

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