Influence of pulsed laser heating on the optical properties of soot

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Influence of Pulsed Laser Heating on the Optical Properties of Soot

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Laser-induced incandescence (LII) is frequently described as an optical, non-intrusive diagnostic. However, it is well known that excitation at too high laser fluences is responsible for particle surface sublimation. This process is not well described by current LII models. In addition, several soot parameters introduced into LII modeling have to be approximated by those measured or extrapolated for graphite. The presented research focuses on monitoring changes of soot properties while LII excitation is applied.

Introduction

A cornerstone of the theory of laser induced incandescence applied to soot aerosols is that the soot is not affected by rapid laser heating. However, it has been demonstrated in the literature that intense laser irradiance typical of 'high' or 'plateau regime' LII leads to significant modification of the internal structure of soot particles [Vander Wal] and even the formation of new particles from vaporized material [Michelsen]. For moderate laser fluences typical of auto-compensating LII (AC-LII) [Snelling], morphological changes are not observable via high resolution transmission electron microscopy (HR-TEM) [Michelsen]; however, it is still conceivable that the rapid heating of soot aggregates to temperatures in the range of 3000 to 4000 K can influence the internal crystalline structure of soot as well as materials adsorbed on the surface and thus the optical properties of the soot may change as a consequence of the laser heating. Variation of the optical properties of the soot on time scales relevant to LII measurement would have impacts on the interpretation of signal which must be accounted for.

Experimental

In the present work, we monitor the extinction coefficient of a soot aerosol with time while simultaneously heating the aerosol with a laser pulse typical of LII. Measurements are made of the extinction coefficient at wavelengths of 405 and 830 nm and for a range of IR laser fluences. The cw attenuation laser monitors the central homogeneous portion of the pulsed IR laser beam when both concentrically travelling along a soot containing pipe. The incandescent emission from the soot is also monitored at wavelengths of 450, 557, and 750 nm close to the pipe exit to correlate the attenuation information to time-resolved soot temperatures.

Results

The variation of the extinction coefficient during and after laser heating is interpreted in terms of elastic and plastic variation of the soot refractive index absorption function, desorption and dissipation of adsorbed species, and sublimation. For low fluences signal changes are found to linearly correlate to changes of soot temperature. This behavior is expected when assuming a temperature dependent density or particle diameter (Fig. 1). In contrast, high LII laser fluences the particle density decrease, thus increase of attenuation is accompanied by diameter reduction due to surface sublimation. Implications of the performed experiments for LII measurement interpretation are discussed.

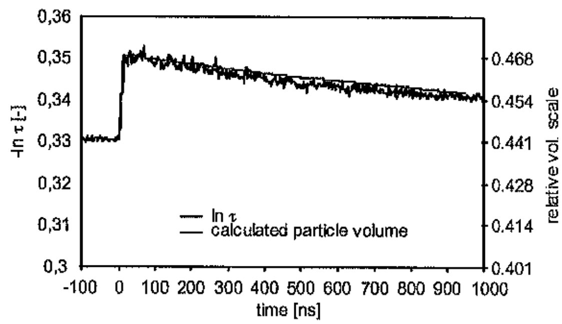

Fig. 1: Comparison of the attenuation at 830 nm measured during the LII process and relative volume based on LII modeling [4] for a reasonable particle size of 30 nm. The 1064 nm LII laser pulse at low fluence generates a change in attenuation starting from time zero.

References

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