Laser-induced incandescence (LII) measurements in high vacuum conditions

V. Beyer, D.A. Greenhalgh*
School of Engineering
Cranfield University, Cranfield, UK

We have undertaken a preliminary study of Laser-Induced Incandescence (LII) using carbon black in high vacuum (circa 5×10^{-4} mbar). Our aim was to understand the temperature behaviour of carbon nanoparticles under conditions dominated by radiative cooling. We have found that under these conditions the signal from LII is markedly enhanced (over 2,000 times) and that cooling behaviour can be measured into the 100 µs timescale.

Introduction

LII so far has been studied, modeled and well characterized in many standard conditions: flames, vehicle exhaust conditions, for high pressures and high temperatures domain etc. However the present study describes a novel LII application under high vacuum after the evidence that in 1988 Rohlfing [1] observed carbon clusters enduring LII from ~3900 K to ~2700 K over 42 µs during a study of laser vaporization of graphite. The application of such technique for particulate matter measurements, namely called LII under vacuum, would be solely as an extractive sampling to an external evacuated optical cell.

Theory

The aim prior to the experiment taking place was to deliberately stop conductive heat losses occurring and hence retard the light signal from typical 50 – 200 ns scale to a much longer 40 – 100 µs duration. Thus the main energy loss mechanism should become long-lived blackbody radiative cooling. This approach has the added benefit of significantly increasing the LII signal. Calculated gains in LII signals for a scan duration of 100 us and an input fluence of 0.2 J/cm^2 range are from over 10 000 for a primary particulate radius below 20 nm and ~2000 for a primary particulate radius approaching 100 nm. This preliminary study took place circa 5×10^{-4} mbar, where modeling demonstrated that conductive heat losses are negligible for primary particulates smaller than 10 nm in diameter for temperatures above 2000 K.

Experimental setup

Obtaining a suspension of particulates in a vacuum is clearly a demanding task. One approach is to use a particle beam akin to a molecular beam. This is complex and expensive to implement. Thus to commence this study we choose a simpler approach based on low cost components. Our experiments were conducted in a rotating cylindrical glass bottle. The glass bottle was filled with a few grams of carbon black, evacuated to nearly 10^{-4} mbar and then hermetically sealed. Centrifugal and frictional forces created by the rotation lifts the carbon black aggregates to the top of the bottle, allowing them to drop into the laser beam and initiate LII. The incandescence signals were analyzed using a two-color transient pyrometric system and an intensified camera (see fig.1).

Results and observations

Large carbonaceous aggregates could be isolated and analyzed, these aggregates exhibited a behavior close to a radiative cooling and presented some novel behaviours which may indicated morphology changes to the carbon. Experimental evidence also suggests that light shielding within an aggregate occurs and plays a strong role for the strongly aggregated carbon black.

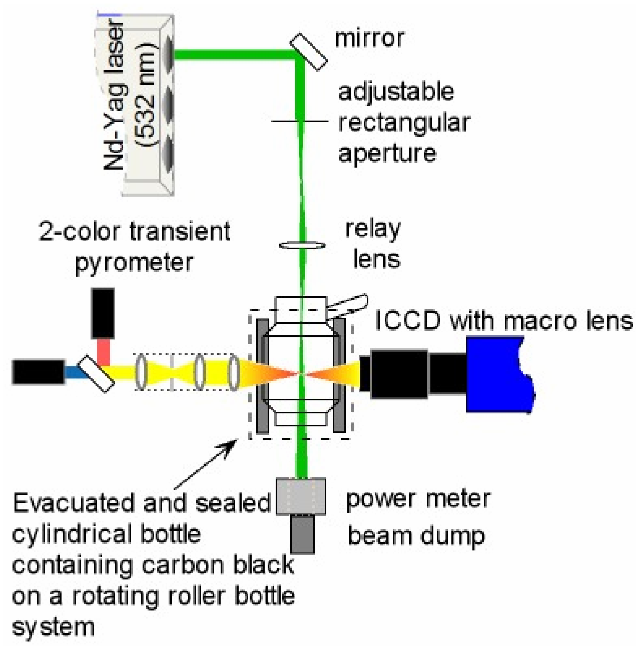

Fig. 1: Experimental setup

References

1 Eric A. Rohlfing, J. Chem. Phys. 89 (10), 15 Nov. 1988, pp. 6103-6112.

Corresponding author: d.a.greenhalgh@cranfield.ac.uk
Proceedings of the International Bunsen Discussion Meeting 2005: Laser-Induced Incandescence, Quantitative interpretation, modelling, application.