Soot particles detection by LIBS and LII analysis

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Laser-Induced Breakdown spectroscopy (LIBS) is an atomic emission spectroscopy technique that has been used for elemental analysis of solid, gaseous and aerosol samples. The LIBS technique involves a pulsed laser beam focused onto the sample to create a microplasma. The resulting optical breakdown decomposes and excites all species within the plasma volume. The light emission is characterized by a continuum spectrum (Bremsstrahlung) containing discrete atomic emission lines. Both the continuum spectrum and the atomic lines decay with time. In general, the continuum spectrum decay faster than the atomic lines allowing the possibility of detecting atomic lines with a good signal-to-noise ratio by adjusting the delay and the integration time of the detector gate.

In this work the applicability of the LIBS technique to the detection of carbonaceous particulate in a combustion environment is investigated. In particular, a comparison of the carbon atom concentration derived with LIBS and LIImeasurements is performed. Soot particles produced by an ethylene-fueled soot generator are sampled and pumped for LIBS analysis into an optically equipped sample chamber, the outlet of which is then piped in the LII measuring equipment. As for LIBS the IR beam of a Nd:YAG laser was focused to create the plasma and the relative spectral emission was collected onto a fiber bundle coupled to a spectrograph-ICCD unit. As for LII, an home-made portable instrument has been used. The LII signal is detected at two wavelengths (530 nm and 700 nm). A fast digital oscilloscope is used for data acquisition and storage.

Since in LIBS technique the emission line is attributed to a particular atomic element whatever is the initial molecular species containing that element, particular care has to be taken in applying the technique to a combustion environment. In fact, in the case of carbonaceous particles, the elemental analysis does not allow to discriminate the contribution of soot particle and gas-phase species to the carbon atoms measured. The aim of the work is to develop a new methodology to select the contribution of soot particles carbon atoms in the LIBS signal.

In order to discriminate the contribution from soot particles in LIBS signals, a proper choice of the laser operating condition is performed. The laser energy is reduced to a value such that in a pure gas phase environment no breakdown is produced and the LIBS signal is induced by the presence of particles in the probe volume. However, even in these conditions carbon atoms coming from gas species are activated as well. To discriminate the two contributions to the LIBS signal a comparison is carried out between measurements below and above the breakdown threshold. The results confirm that the LIBS technique, applied with the developed procedure, is able to detect soot particles measuring soot concentration in agreement with LII measurements.