In-situ characterization of soot formation based on the temporal analysis of laser induced incandescence and scattering signals

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Soot emitted from various combustion systems and fires into the atmosphere have been considered as the second largest contributor to global warming just after CO2 (Bond, Doherty et al. 2013) and found harmful to human health. This second point can be explained by their nano-size and large specific area (Brown, Wilson et al. 2001) favoring the transfer of toxic compounds as PAH (Lighty, Veranth et al. 2000) to the organism. For these reasons and for a better understanding of soot formation and growth during combustion processes, it is important to develop techniques able to follow the growth of soot particles and their chemical composition. This hard task is rarely achieved by in situ optical techniques. Furthermore, a single optical technique can not inform us about all parameters of soot. Therefore it is important to couple techniques to properly characterize these nanoparticles. LII is a powerful laser based technique that allows obtaining information on the soot volume fraction and more indirectly on the primary particle size, respectively through the amplitude and the time related to the LII signal decrease. Generally, LII measurements are performed with an infrared laser source in order to avoid the contamination of the signal by fluorescence and detected with a lower wavelength. Static light scattering (SLS) is another optical technique, able to inform us about the particle size because this signal is proportional to the aggregates concentration and to the square number of primary particles per aggregate. SLS being an elastic phenomenon, visible wavelengths are generally used as excitation source. (Reimann, Kuhlmann et al. 2009; Snelling, Link et al. 2011; Olofsson, Simonsson et al. 2015) have already shown that the coupling of these techniques could bring new information on properties of soot aggregates.

In this study, a coupling of LII and SLS with only one laser source (ND:YAG doubled at 532 nm) and one detection system (photomultiplier tube) with an interference filter centered at 442 nm is proposed to study the soot formation along the centerline of an ethylene diffusion flame and some ethylene/air partially premixed flames. SLS signal being more than ten thousand times stronger than the LII signal, a part of the SLS signal remains detectable in spite of the interference filter and a temporal extraction of LII and SLS signals becomes possible. This extraction is validated by comparing the obtained results with true LII (at 1064 nm) and true SLS (Detected at 532 nm). The first advantage of this approach is that SLS/LII signals are obtained simultaneously with exactly same conditions. Secondly, by using a polarizer in front of the detection, we can also study the depolarization ratio of SLS signal ($\rho = I_{vh}/I_{vv}$) that is connected to the primary particle size and to the scattering function F(m) (Bescond, Yon et al. 2013). This technique can also be applied to soot (miniCAST) reinjected into a non-sooting flame in order to observe evolution of their properties during the oxidation phase.

In this study, SLS, LII and depolarization are determined at different heights above the burner, using diffusion and premixed ethylene flames.

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