Modelling laser-induced incandescence of soot and tarballs in the SP2

Fengshan Liu, Tim Sipkens, and Joel C. Corbin

Metrology Research Centre, National Research Council Canada, Ottawa, Canada
joel.corbin@nrc.ca

Depending on the sample, the majority of light absorption in smoke emitted to the atmosphere is due to either soot black carbon or tarballs (TBs). Soot is the primary absorber in smoke from relatively efficient, flaming combustion, while TB is the primary absorber in inefficient combustion such as some wildfires and marine-engine smoke. It is well known that soot particles entering a high-intensity laser beam (e.g. about 1 MW/cm2 of continuous-wave 1064 nm radiation) both scatter light and absorb sufficient light to reach incandescent temperatures, then sublimate. The resultant laser-induced incandescence (LII) signal is proportional to the mass of refractory black carbon (rBC) in the soot particle, while the scattered light is proportional to the overall volume (rBC plus other material) of the particle. It is also well known that detailed modelling of scattering and incandescence requires knowledge of several key physical parameters affecting heat transfer, mass transfer, spectroscopy, and annealing [1]. Here, we extend the substantial body of literature on models of rBC incandescence from pulsed LII experiments to the continuous-wave LII context employed in the commercial Single Particle Soot Photometer (SP2). We apply our model to both soot, also known as black carbon, and tarballs, which are non-volatile, amorphous carbon spheres emitted by wildfire smoke and marine engines [2] and which may anneal in the high-intensity laser [2,3]. We validate this model against real SP2 data. We discuss the assumptions required to reproduce signals from soot, and the constraints on tarball properties that can be obtained from the model. This work provides the basis for the future application of LII for distinguishing tarballs from rBC in real time.

[1] Sipkens et al., Appl. Phys. B., 2022. doi:10.1007/s00340-022-07769-z
[2] J. C. Corbin and M. Gysel-Beer, Atmos. Chem. Phys. 2019, doi:10.5194/acp-19-15673-2019.
[3] Sedlacek et al., Aerosol Sci. Tech. 2018, doi:10.1080/02786826.2018.1531107