An experimental setup to study soot sublimation as typically occurring in high fluence LII

Klaus Peter Geigle, Gregor Gebel, Markus Köhler

Institute of Combustion Technology, German Aerospace Centre (DLR), Pfaffenwaldring 38-40, Stuttgart, Germany, klauspeter.geigle@dlr.de

Particle sizing with LII requires modeling of the temporal behavior of the laser-induced emission. While most models are well validated in the low fluence regime, agreement for high fluences is identified to be insufficient, specifically when comparing different models for the short time window of soot sublimation (see Fig. 15 in [1]).

As a consequence, particle sizes are typically deduced in a low fluence time-resolved LII experiment, with the temporal fit window starting after sublimation is assumed negligible. This approach becomes inconvenient with increasing pressure when the decay rates decrease significantly towards the duration of the exciting laser pulse. Modeling of the full LII profile is then desirable requiring best possible modeling of all sub-processes involved.

Sublimation of the soot surface due to a rapid temperature increase causes a rapid vapor expansion of approximately 3-4 orders of magnitude within few nanoseconds. This correlates with the assumption of a supersonic expansion once vaporization becomes effective (see eq. 70 in [2]) and the related audible sound. To confirm this assumption, attempts can be made to detect and characterize the resulting blast wave. An example is identified in [3] where the expansion causes beam steering of a monitor laser beam passing a pulsed laser heated soot volume.

Our experiment makes use of an experimental setup used to study plasma ignition of sprays [4,5]. A green laser pulse is focused into a premixed sooting flame and the resulting effect is monitored with a Schlieren setup involving an intensified CCD camera for detection. Because the expansion of the created wave produces a very weak gradient in our current setup, we had to use very high laser fluences, clearly beyond typical LII applications. However, the expansion occurring at LII employing “high fluences” is expected to follow a similar behavior as that detected for fluences close to plasma generation in flames. The wave expansion in the flame is somewhat faster than speed of sound at the respective flame temperatures while extrapolation to the wave origin is not possible at the required accuracy.

Based on this first approach we present ideas to optimize the experimental setup for future experiments then suited to validate the assumptions currently employed in calculating the sublimation term in LII models.

[1] H.A. Michelsen et al., Appl. Phys. B **87**, 503-521 (2007).
[2] H.A. Michelsen, J. Chem. Phys. **118**, 7012-7045 (2003).
[3] K.A. Thomson et al., Proc. Combustion Institute Canadian Section 2011 Conference, Paper CICS11-39, Manitoba, Canada, 2011.
[4] G.C. Gebel et al., Proc. Fifth European Combustion Meeting, Paper 061, Cardiff, 2011.
[5] G.C. Gebel et al., Proc. ASME Turbo Expo 2012, Paper GT2012-68963, Copenhagen, Denmark, 2012.

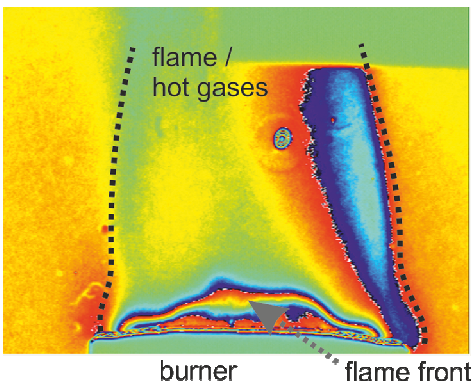

Fig. 1: Exemplary picture from time series visualizing an expansion wave generated by a high fluence laser pulse, detection delayed by 1.25 µs.