Evaluating the performance of a particle counting sensor based on continuous-wave laser-induced incandescence

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Introduction & Background:

We investigate the influencing factors for the performance of an optical particle sensor based on the principle of continuous-wave laser-induced incandescence (cw LII). The sensor’s main target is the determination of the number concentrations for soot particles with a detection limit regarding the particles’ diameter of below 100 nm. In our previous work, we presented a functional compact sensor demonstrator using the focused light of a laser diode for the heating of soot nanoparticles and a silicon photomultiplier for the detection of LII events [1]. With a comparable laboratory setup, the use of such a sensor to reliably determine the soot particle number concentration was shown [2]. For the introduction of the size-dependent count rates, a SMPS was used to measure the mean diameters of the investigated size distributions. In future, this information can be directly deduced from the registered LII signal shapes.

Methodology:

The choice of suitable optical components such as laser source, lenses and mirrors was supported by a systematic study of the associated laser light distribution in the focus and the filter efficiencies regarding the LII transmission and stray laser light suppression. Based on these results, functional demonstrators were built. One critical value to assess the sensor’s performance is the determination of the minimum detectable particle size. By using an indirect method that compares the created particle size distribution to the events registered with the LII sensor, an indication about this figure-of-merit can be derived. We compare the influence of different parameters like the laser power densities, particle velocities, and signal detection methods on the detection limit.

Results & Conclusions:

Through experiments with a variation of the particle distribution generated by a miniCAST soot generator, the indirect method to determine the detection limit helps to understand the cause-effect relationships influencing the sensor performance. The obtained results support further improvements of the sensor setup. The use of near-monodisperse particle distributions allows to improve the accuracy of the determination of the sensor’s detection limit. For the most promising setup, this approach led to a detection limit well below 100 nm. Measurements with various particle sources showed a broad range of derived size distributions. This includes the use of a miniCAST, a kerosene soot point lamp, and a diesel engine. The evaluation of the registered signal peaks reveals a dependency between particle size and signal shape, which opens the possibility to directly correct the monitored count rates.

[1] M. Kammerer, F. Purkl, Poster presented at the 23rd ETH-Conference on Combustion Generated Nanoparticles, Zurich, CH, **2019**.
[2] M. Kammerer, F. Purkl, K. P. Geigle, Presented at the European Aerosol Conference, Aachen (online), **2020**.