A compact and mobile optical particle counting sensor based on continuous wave laser-induced incandescence

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Motivation

Development of an optical particle sensor based on continuous wave laser-induced incandescence (CW-LII)
- Investigation of nanoparticle properties, including number concentration & particle diameter
- Mobile use through a compact sensor setup for an application in varying measurement environments

Working Principle

Laser-induced incandescence [1]
- Heating of nanoparticles to temperatures above 3000 K due to absorption of optical energy emitted by a laser
- Heated particles emit incandescent light, which is captured by a detector (e.g. photomultiplier tube)
- Most LII systems rely on bulky (nanosecond) pulsed, high-powered Nd:YAG lasers with a typical continuous wave equivalent optical output power of 100 W

Our approach
- Use of a continuous wave laser diode
- Focusing of laser light to reach sufficiently high optical power densities
- Extraction of the particle number concentration from the amount of detected LII peaks with knowledge about the laser beam properties & fluidic particle behavior

Recent sensor setup
- Continuous wave laser diode in the near-infrared spectral region: 
  \[ \lambda = 830 \text{ nm}, P = 250 \text{ mW} \]
- Power density in focal spot with \( d_{\text{Spot}} \approx 8 \mu\text{m} \):
  \[ \approx 300 \text{ kW/cm}^2 \]
- Collection of LII signal with a confocal setup using a sensitive silicon photomultiplier

Measurement Setup

Data analysis
- Filtering and smoothing of detected voltage signal
- \( d^3 \)-dependency of emitted LII signal gives indication for primary particle sizes
- Signal pulse width gives indication about particle speed

Experimental Results

Exemplary LII signal
- LII signal peaks of single soot particles

Histograms of measured LII peaks
- Comparison of measured LII signal peaks with SMPS data suggests the possibility of particle sizing.

Conclusion

- Functionality of compact CW-LII sensor concept successfully shown
- First comparison of signal peak distribution to reference measurements shows possibility of particle sizing

Further work
- Determination of detection limit
- Improved data analysis
- Verification of LII models

Reference:

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