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

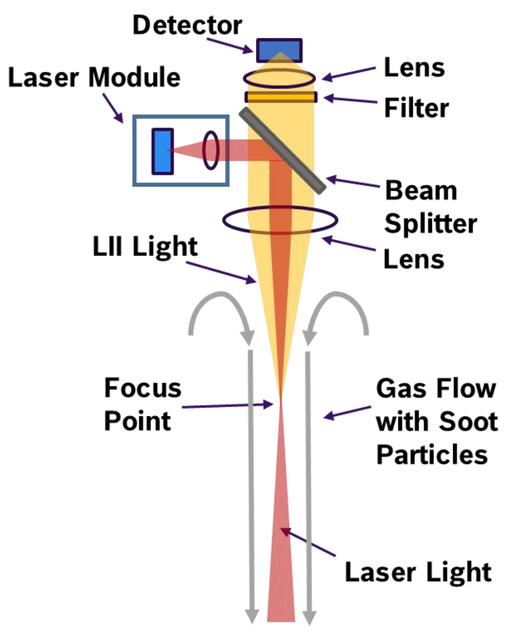
Laser-induced incandescence [1]

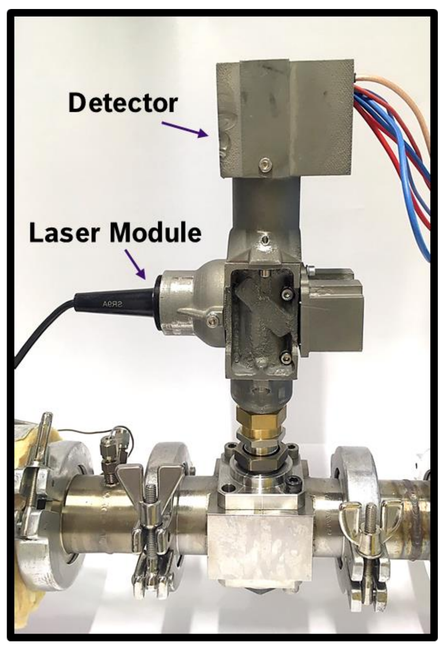
- Heating of nanoparticles to temperatures above $3000\,\mathrm{K}$ due to **absorption of optical energy** emitted by a laser
- Heated particles emit **incandescent light**, which is captured by a detector (e.g. photomultiplier tube)
- Most LII systems rely on bulky (nanosecond) **pulsed, high-powered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

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:

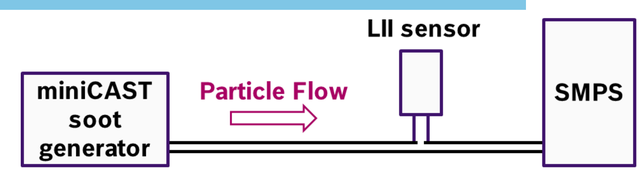
$$\boldsymbol{\lambda = 830\,\mathrm{nm},\ P = 250\,\mathrm{mW}}$$

- Power density in focal spot with $d_{\mathrm{Spot}} \approx 8\,\mu\mathrm{m}$:

$$\boldsymbol{\sim 300\,\mathrm{kW/cm^2}}$$

- Collection of LII signal with a confocal setup using a sensitive **silicon photomultiplier**

Measurement Setup

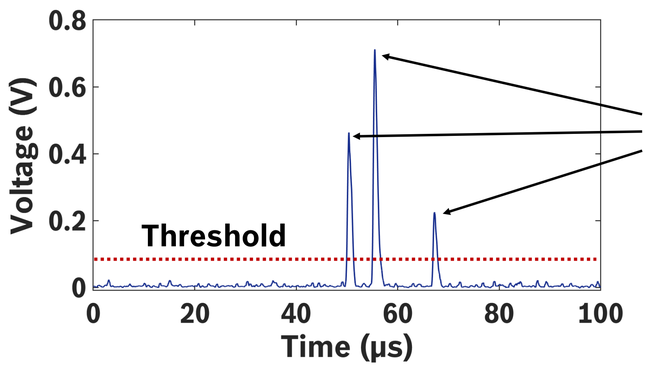


Data analysis

- 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**

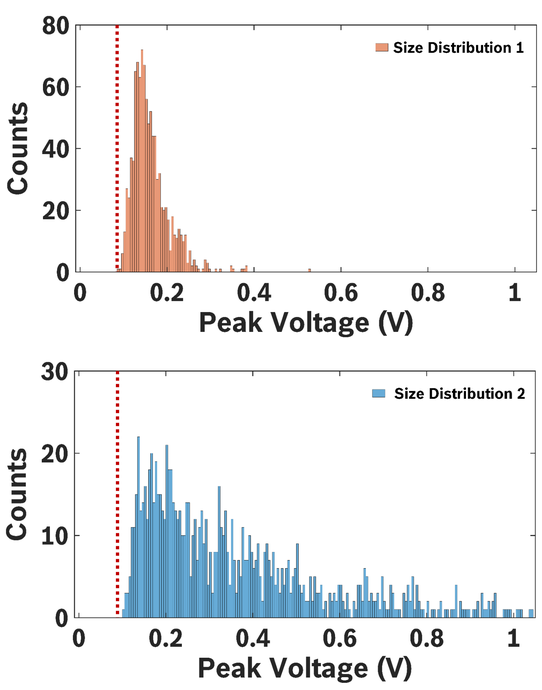
Experimental Results

Exemplary LII signal

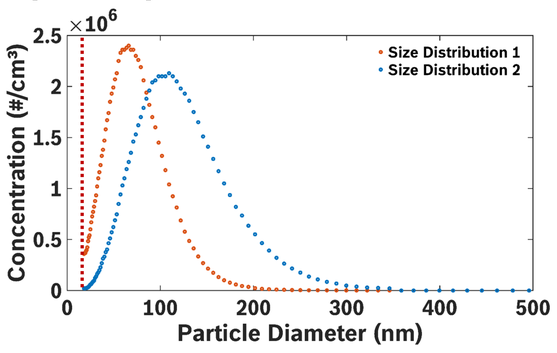


LII signal peaks of **single soot particles**

Histograms of measured LII peaks



Reference measurement (SMPS)



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:
[1] Michelsen H.A. *et al.*: Laser-induced incandescence: Particulate diagnostics for combustion, atmospheric, and industrial applications *Progress in Energy and Combustion Science 51 (2015) 2–48.*

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