A portable optoacoustic sensor for source emission monitoring

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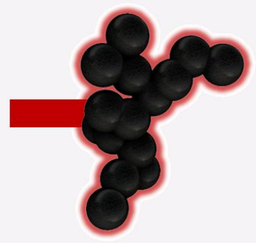
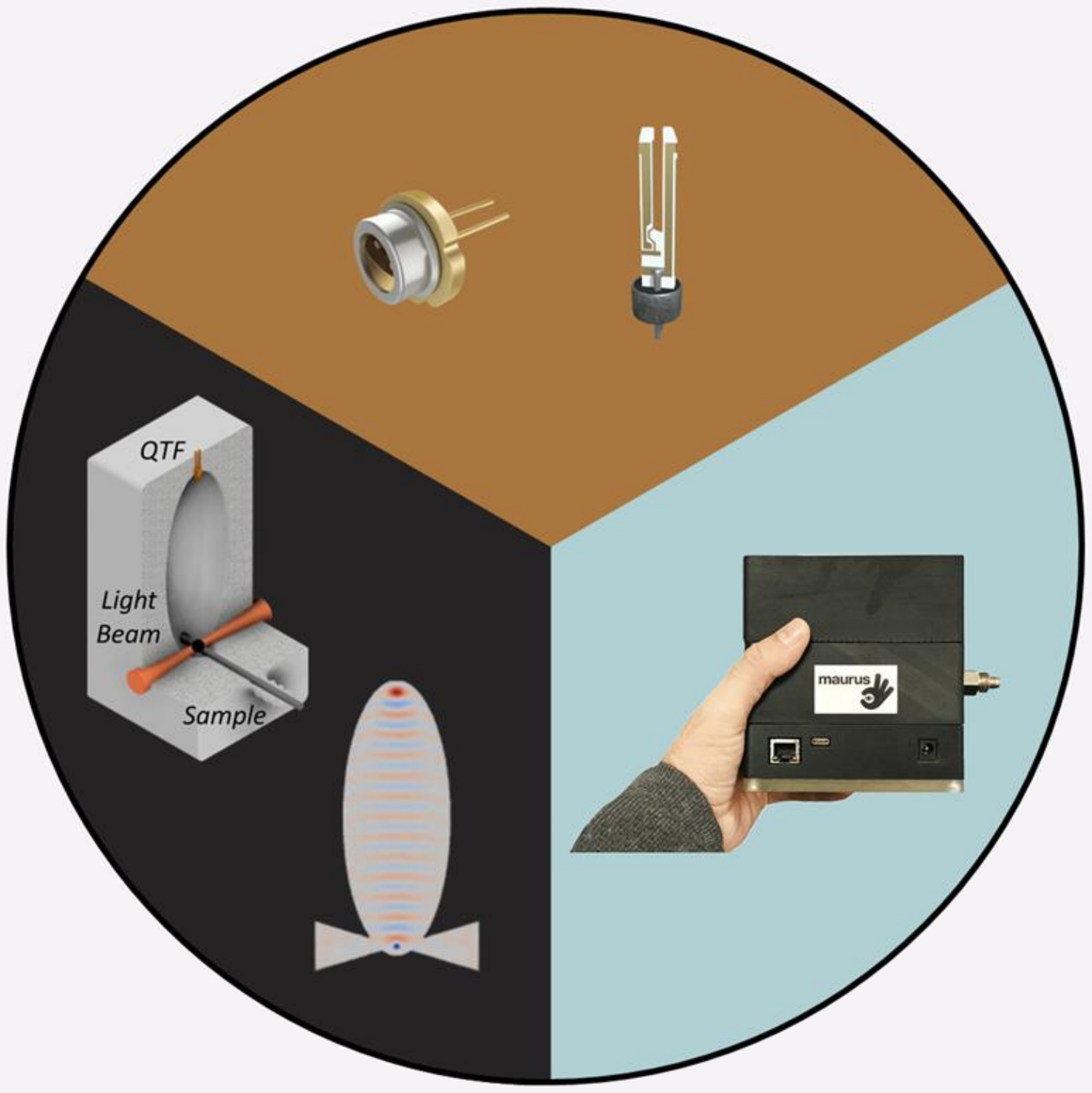
Background

- Black Carbon (BC) is a major pollutant with climatic and health effects
  - Highest absorber of direct sunlight [1]
  - Significant contribution to snow and glacier melting [2]
  - Strong correlation with cardiovascular mortality [3]
- Four main detection methods are used to measure BC
  - Filter smoke number (FS)
  - Optoacoustics (OA)
  - Optothermal (OT)
  - Laser Induced Incandescence (LII)
- OA is the best candidate for continuous and low-cost BC monitoring [4].
- In this work, we present a portable OA sensor [5] that was used to calculate emission factors from BC sources in real world conditions.



Sensor design



Resonator free design

- A Quartz Tuning Fork (QTF) is used for sound detection due to its low-cost and large Q factor
- A low-cost and high energy laser diode is used for optical excitation of BC
- An ellipsoid chamber is used to:
  - ✓ achieve good acoustic properties by refocusing sound instead of relying on a resonator
  - ✓ avoid contamination of sensitive components (QTF and Optics)
- A passive flow setup leads to long-term and low-maintenance operation
- Custom electronics are used to miniaturize the system and reduce cost
- The sensor's dimensions are: 11.5 x 11 x 10 cm and 1.2 kg

Compact system

Results

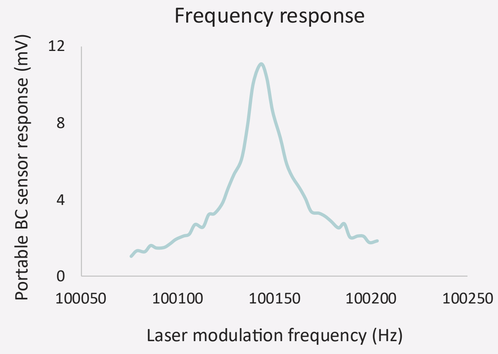
Lab evaluation

The sensor was evaluated in the lab using

- an Aerosol Particle Generator (AVL)
- a Micro Soot sensor (AVL MSS) as reference

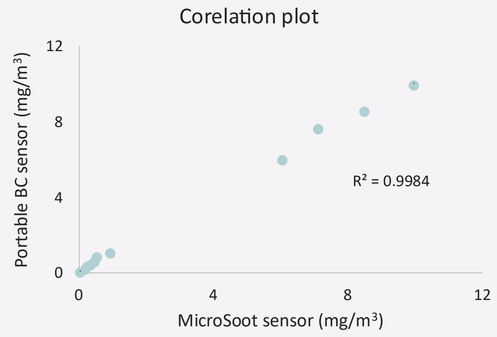
The sensor shows very selective frequency response due to the sensitive QTF

- Resonance frequency: 100143 Hz
- Q factor: ~3500



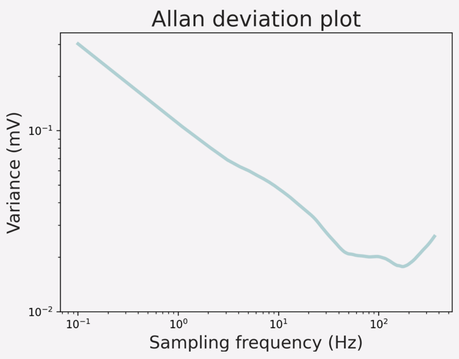
A comparison with the Micro Soot Sensor shows excellent correlation

- R2 above 0.99
- LOD: ~5 µg/m^3 @ 1 s averaging

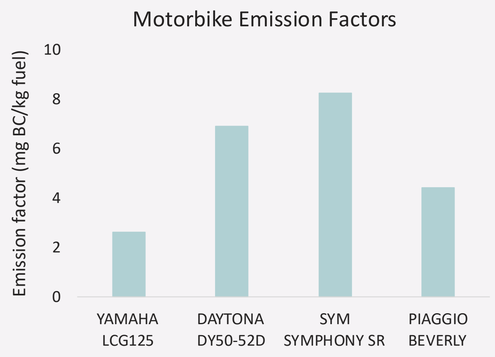


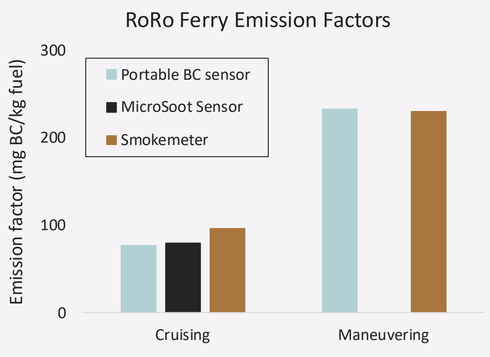
An Allan deviation is used to estimate the LOD for longer averaging times

- Optimum performance for ~ 2 minutes
- Lowest LOD: ~ 1 µg/m^3



Real world implementations





Conclusions

- The portable BC sensor can accurately measure BC particles in good agreement with commercial instruments using the same technology.
- The components and sensor design allow for a compact, low-cost system.
- The portable sensor was used to measure BC sources and estimate emissions factors that are in good agreement with literature values.

Commercialization

- Maurus Oy has been established as a spin-off of the Aristotle University of Thessaloniki to commercialize the technology.
- *Stay tuned: https://maurus.fi/*

Acknowledgments

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References

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