Comparison of calibration methods for in-situ aerosol absorption instruments

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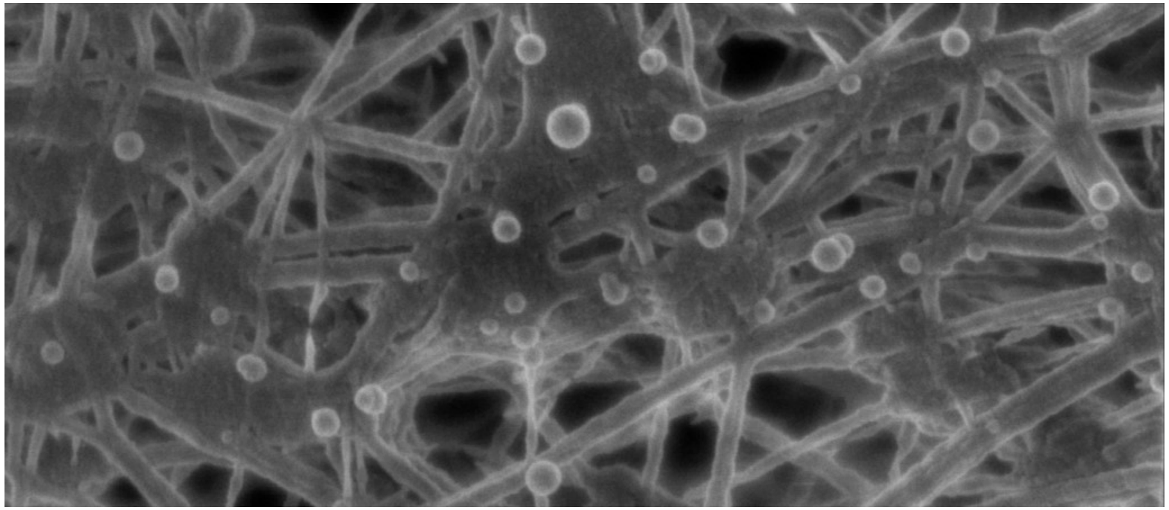


EAC2024

Introduction

Part of the stanBC project:

Standardisation of Black Carbon Aerosol metrics for air quality and climate modelling

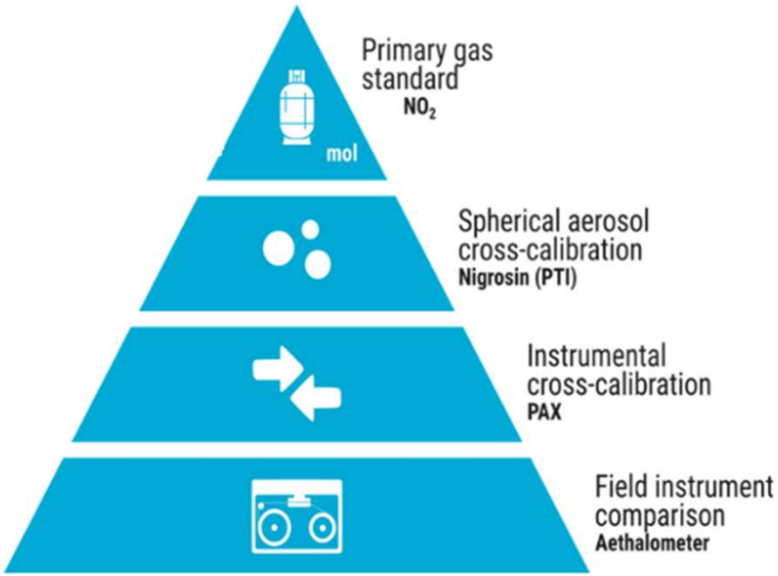
Uncertainty (k=1)

2%

5%

10%

25%



Aerosol absorption traceable to **primary definitions** of SI units

Primary standard methods

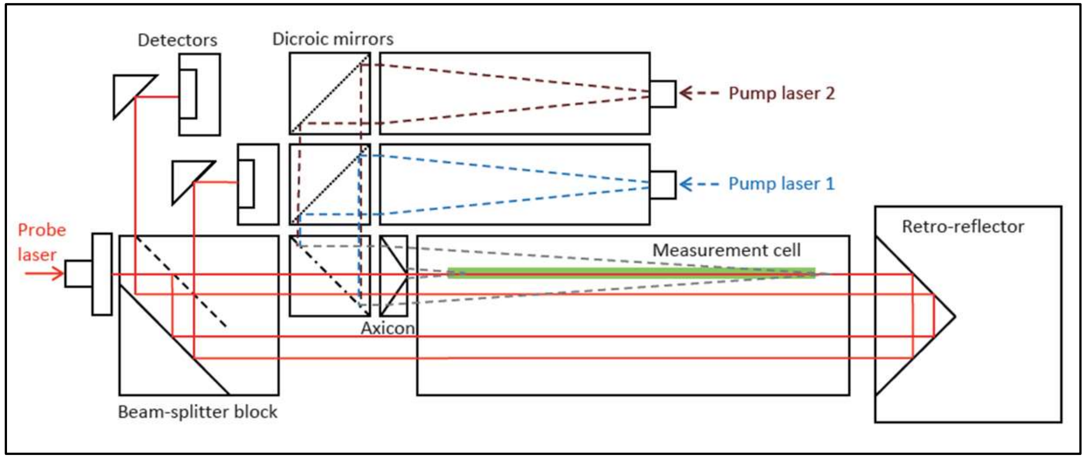
- **Photo-thermal interferometry (PTI)**
- Extinction-minus-scattering (EMS)

Secondary standard: PAX 870 nm

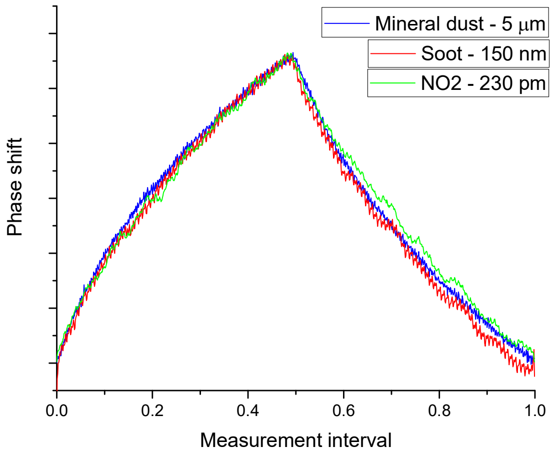
Field instruments: Filter photometers

Photo-thermal aerosol absorption monitor (PTAAM)

- Pump beam focused by **axicon** (patent EP 3492905)
- Simultaneous measurements at **450 and 808 nm**
- **doi.org/10.5194/amt-15-3805-2022**



Photothermal effect for gases and particles



PTAAM response does not depend on particle size

-> calibration can be done with gas

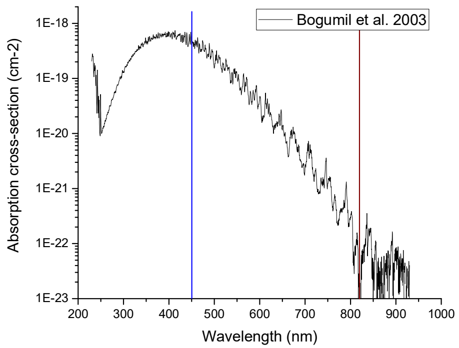
-> instrument can measure absorption from soot to mineral dust particles

Traceable calibration with NO_2

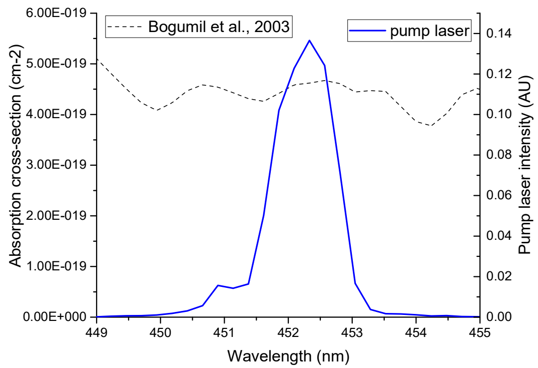
Traceably calibrated NO_2 source:
- POPS permeation generator

H-P Haerri et al 2017 Meas. Sci. Technol. 28 035801

NO_2 absorption cross-section



Laser spectrum



Absorption coefficient

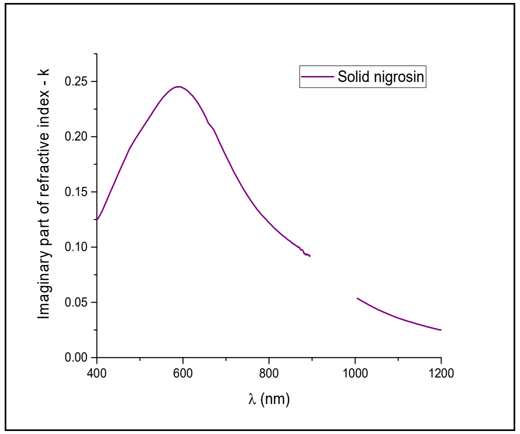
Problems with stability of pre-mixed samples

Traceable calibration with monodisperse nigrosin

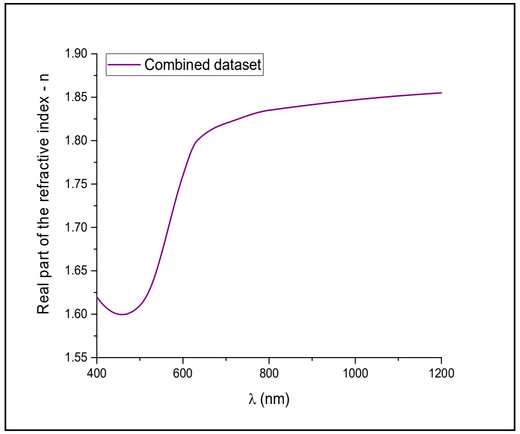
Based on previous studies:
Arnott et al. 2000
Symonds et al., 2013
Bluvstein et al., 2017
Sang-Nourpour and Olfert, 2019

- Calibration with absorbing particles: monodisperse nigrosin

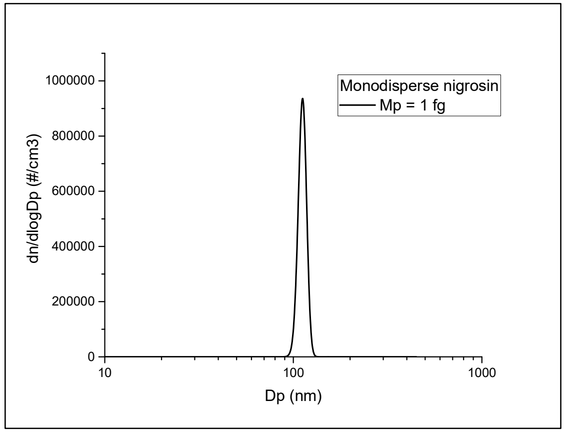
Imaginary part of refractive index



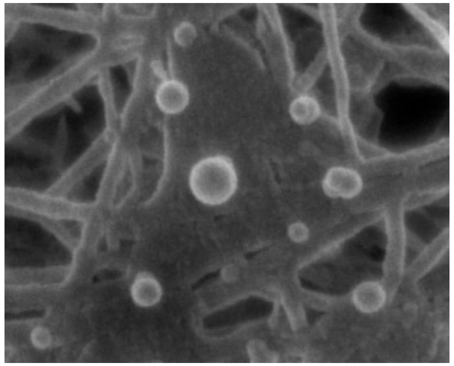
Real part of refractive index



Monodisperse size distribution



Spherical particles



SEM image

Mie theory

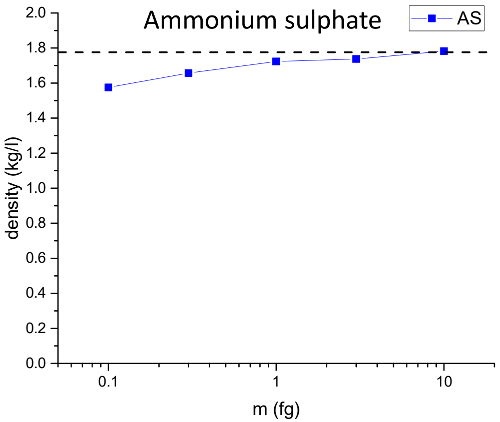
Absorption coefficient

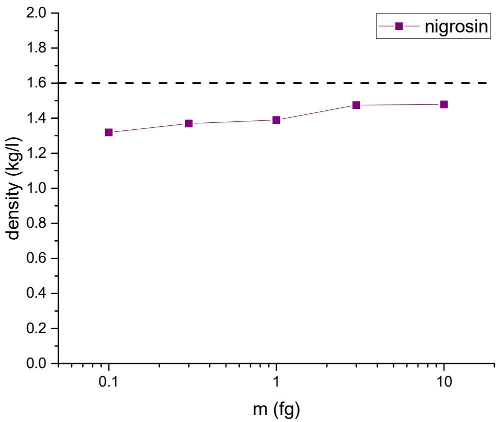
Influence of particle density

CPMA: Centrifugal particle mass analyzer

SMPS: Scanning Mobility Particle Sizer

Nebulizer → Neutralizer → CPMA → SMPS





Validation with 95 nm PSL

-> nominal density: 1.050 g/cm^3

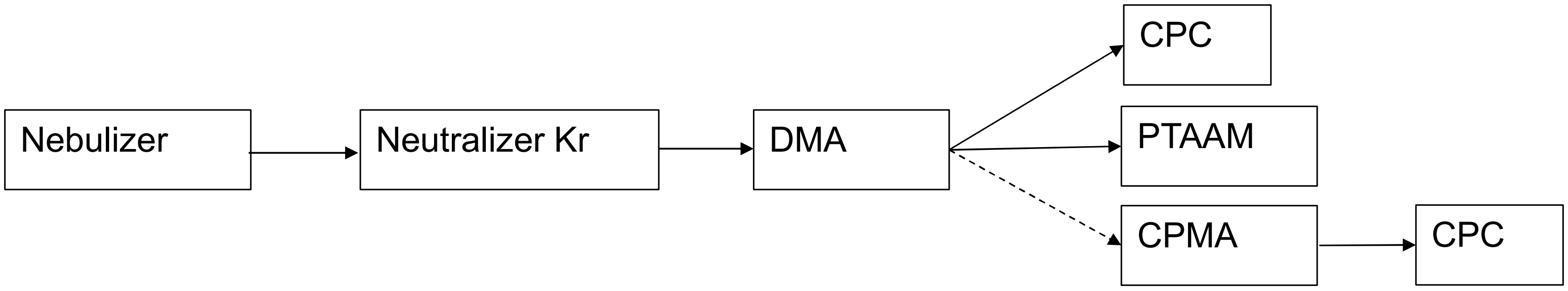
-> measured density: 1.042 g/cm^3

0.8% difference -> instruments OK

For absorption, particle **mass** is a **better** parameter **than** particle **diameter**

-> CPMA is needed to determine/select particle mass

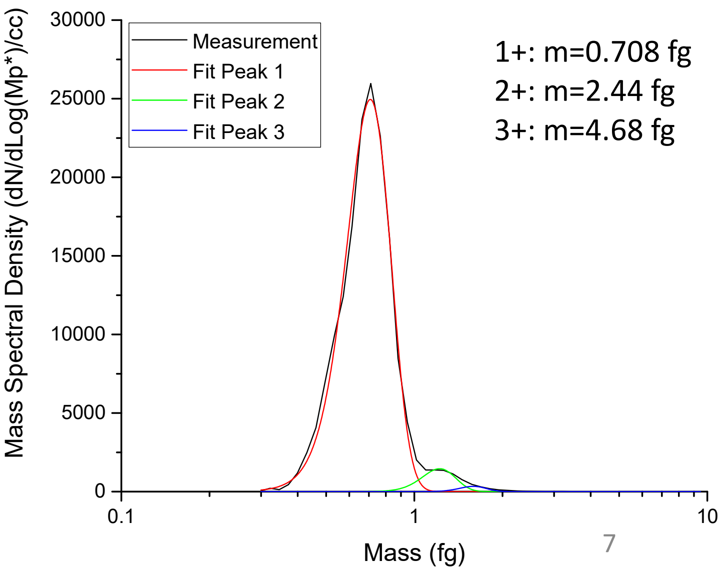
Generation of monodisperse nigrosin particles: DMA



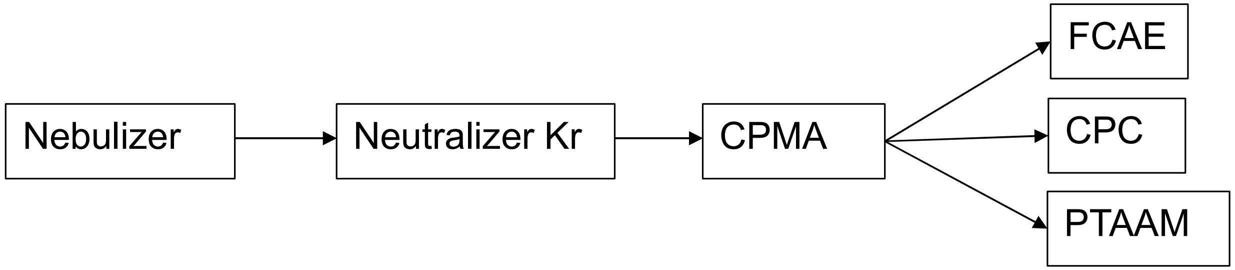
DMA transmits **multiply charged particles**

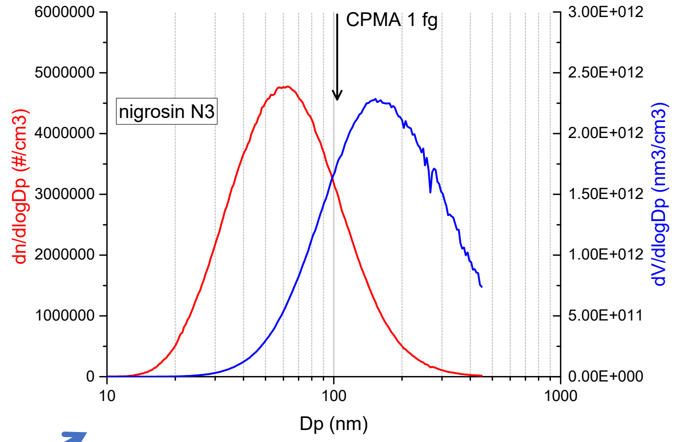
-> correction needed

- Mass spectral density was measured with CPMA+CPC
- The increase of absorption due to multiply charged particles is **13-28%**
- Correction brings additional uncertainty



Generation of monodisperse nigrosin particles: CPMA

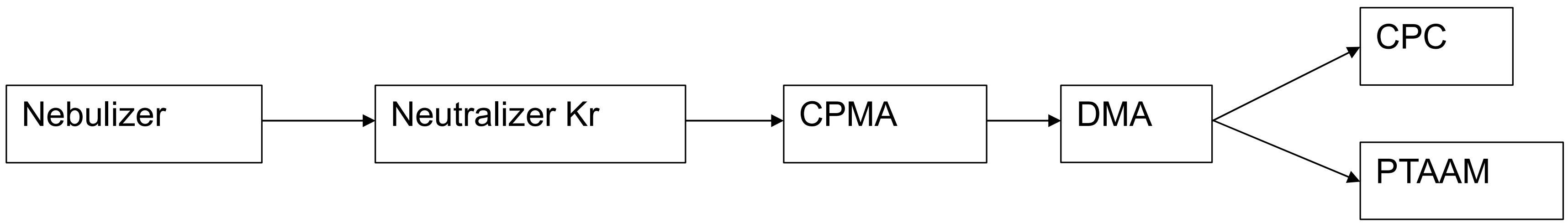




- Particle charge is measured with a Faraday-Cup Aerosol Electrometer (FCAE)
  - Doubly charged particles have double mass -> no correction needed
- CPMA transmits small **neutral particles.** Their contribution can be reduced by:
  - selecting particles on the left side of the particle volume distribution
  - Using high rotational speed – high value of the resolution parameter R_m

Rm	CPC (#/cm³)	FCAE (#/cm³)
3	85889	20942
15	4362	3432

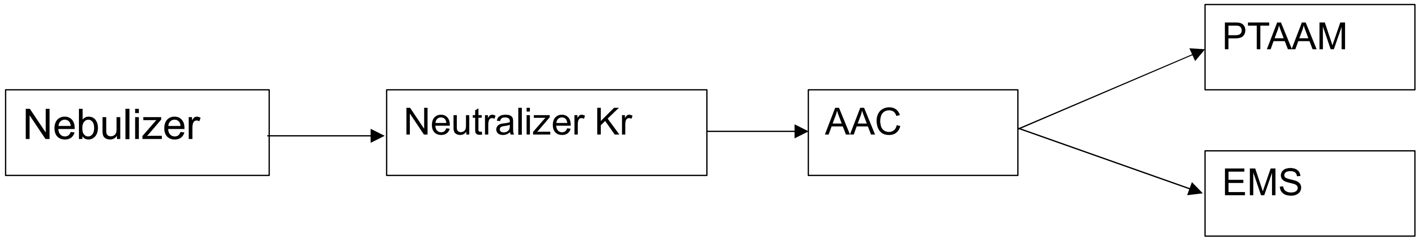
Generation of monodisperse nigrosin particles: CPMA + DMA



- CPMA and DMA are set to transmit particles with fixed mass and mobility diameter
  - Multiply charged particles are not transmitted
  - Small neutral particles are blocked by the DMA

-> No correction needed for neutral or multiply charged particles

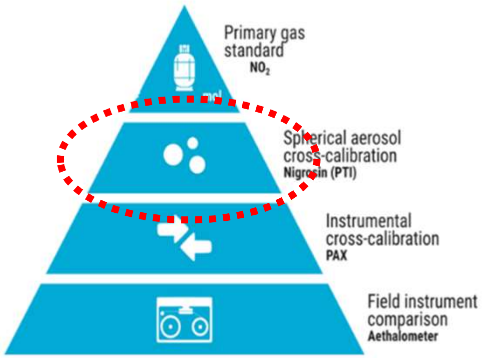
Comparison of primary standards PTAAM & EMS



Nigrosin particles: Da=200 nm

EMS = Extinction minus scattering
- 3X CAPS PMEX
- Aurora 4000 nephelometer

Conclusions



- Traceable calibration of primary absorption standard PTAAM (stanBC project)
- In situ absorption instruments can be calibrated with low uncertainty (<5% @ k=1)
  - using absorbing gas NO_2 or monodisperse nigrosin particles
- Density of nigrosin particles is smaller than the nominal value of 1.6 g/cm^3
  - CPMA is needed in all configurations to measure particle mass
- Different schemes for monodisperse particle selection were compared
  - DMA needs multiple-charge correction
  - CPMA prone to transmission of neutral particles
  - A tandem setup CPMA + DMA is proposed
- Absorption of nigrosin particles measured by EMS compares well with PTAAM

Acknowledgements

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