PM$_1$ and PM$_{2.5}$ lens in AMS ground/aircraft applications: Insights from laboratory characterizations

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For more info on aerosol intercomparisons, see Hongyu’s slides presented on 20 JAN 2021 10:00 EST

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Introduction

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Guo et al., 2020

ATom 1-4 Stratosphere
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Objective is to generate monodisperse small particles (< 300 nm) w/o double charges.
- Evaporated oleic acids are condensed by quenching flow forming monomodal aerosols
- Tip: select larger size than the peak diameter to avoid doubly charged particles!
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- Zhang et al., 2004 determined low end TE during new particle formation event in Pittsburgh which shows higher TE.
- Our results are consistent with or slightly better than Zhang et al., 2004
- Oleic acid RIE = 3.5
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PM$_{2.5}$ Lens Transmission Efficiency

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- Differences in setting: (1) Ambient pressure in Boulder is ~ 150 Torr lower (2) aircraft plumbing (3) Xu et al. used capture vaporizer and we used standard vaporizer.
- By adjusting the lens position, we could get even better transmission small particles.

For more info on lens stage, see Pedro’s slides presented on 20 JAN 2021 11:00 EST
@ low altitude

Pressure-controlled inlet (PCI) for aircraft platforms

- In aircraft platform, the ambient pressure keeps changing.
- PCI pump maintain constant pressure in the PCI chamber to keep the same AMS flow rate and lens pressure (Bahreini et al., 2008)
- Current version uses larger top/bottom C.O. (350/220 um) and expansion volume after PCI
- Current system can cover the typical DC-8 flight range (up to 13 km, Guo et al., 2020)
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Transmission Efficiency of PM$_{2.5}$ + PCI system

![Graph showing transmission efficiency vs. vacuum aerodynamic diameter. The graph includes two lines: one for PM1 lens (red dashed) and one for PM2.5 lens (black dotted).]
Transmission Efficiency of PM$_{2.5}$ + PCI system

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- Fluid dynamic model captures some noisy feature of $E_L$.
- Large particle transmission is mostly limited by impaction loss followed by recirculation in the expansion volume due to higher lens pressure used for PM$_{2.5}$ lens.
- Better design of expansion volume for PM$_{2.5}$ lens may improve $E_L$ in the high end.
Performance of Current PCI + PM$_{2.5}$ Lens System

- PCI setup with larger second C.O. (350 um), at ~15 km altitude, we achieved better transmission curve than PM1 lens.
- This be improved further redesigning PCI and expansion volume.
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![Graph showing transmission efficiency and aerosol volume distribution.](image)
Performance of Current PCI + PM$_{2.5}$ Lens System

- PCI setup with larger second C.O. (350 um), at ~15 km altitude, we achieved better transmission curve than PM1 lens.
- This be improved further redesigning PCI and expansion volume.
Can generate monodisperse aerosols (30-300 nm) without doubly charged particles.

Observed better $E_L$ of PM$_1$ lens than Liu in both low and high ends.

$E_L$ of PM$_{2.5}$ lens may be better for small particle sampling than previously thought.

PM2.5 lens transmission is mainly limited by expansion volume.

Current PCI with large C.O.2 can achieve better $E_L$ than PM1 lens at ~15 km alt.
Backup slides
Basic Setup

Three AMS measurements:
- Evaporation transient of single particles provides
  a) particles/cc
  b) Signal/particle (sensitivity cal)
  c) Size of particles from time correlated measurements
Only works for large, volatile particles (>350 nm)
- Bulk (averaged) time correlated measurements provides size
- Bulk (averaged) total signal measurements provides mass

- Use all three AMS measurements for large particles
- Can only use only bulk size/mass for smaller particle
- Both AMS and DMA calibrated with PSLs
- Still use AMS measurement of size in case of evaporative losses (don’t happen in the lab with current setup)
- To prevent CPC saturation we use simple diluter for small particles (so we can measure up to $2e6$/cc at e.g. 20 nm with a std TSI CPC)
- Small particle TE decrease mainly due to the dispersion after the nozzle at the end of the aerodynamic lens
- The dispersion (beam width) was measured by 1-D and 2-D beam width probe (BWP) technique
- 2D BWP: ePToF & polydisperse aerosols
- The actual beam width may be smaller than shown above considering the width of BWP (0.5 mm).
- IPL was designed to operate at ~ 3.8 Torr lens pressure
- But when airplane ascend beyond PCI’s limit, lens pressure starts to decrease
- Fortunately, ~ 33% lower lens pressure (green) shows better TE in low end and similar TE at high end
- ~ 33% higher lens pressure (magenta) shows much worse performance in the low end.
- With 350/220, standard lens P can be maintained up to 9.75 km
- Need lower PCI pressure (larger bottom C.O.) for operation in higher altitude
- Large particle TE degrades at lower PCI pressure so not suitable for TI3GER
- Thus trying PCI + PM2.5 lens
- Unlike PM1 lens, IPL focuses ~200 nm particle the most resulting in more broader sampling of aerosols.
- IPL lose both small and large particles due to dispersion at the nozzle at the end of the lens.
- Addition of the PCI shifts the beam focusing toward left which explains slightly better TE at low end.
IPL+PCI: PCI pressure dependance of TE

Ambient pressure
~ 137 Torr @ 12.5 km
~ 83.6 Torr @ 15.24 km

**In order to operate PCI without change of the lens pressure, PCI pressure needs to be lower than ambient pressure**

- 350/350 C.O. set up can tolerate ~ 72 Torr line pressure (~ 15 km alt.) with PM1 lens performance
- Even at higher alt. (thus lower lens pressure than 3.8 Torr), TE may stay similar but need further tests.
- We will test even larger bottom orifice (400 um).
Technological Innovation into Iodine and GV Environmental Research (TI3GER) campaign: upto ~ 16 km