Imaging your particle beam in 3D: New approaches to beam alignment and beam profiling

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**Motivation**

- Funded aircraft deployment into the tropical upper troposphere/lower stratosphere in 2022
- Need new inlet that (Talk by Dongwook Kim, Jan 21st, 2020 13:00 EST):
  - Works at 75 mbar ambient pressure (currently 250 mbar)
  - Does ideally ~“PM2 (currently PM0.75) for adequate sampling of sulfuric acid distribution
  - Does NOT lose sub-100 nm particles that are abundant in the UT (Williamson et al, 2019)
- Size dependent transmission (ignoring particle bounce) depends:
  - On the “ideal” transmission thru the lens itself ($E_I$)
  - On the aircraft specific plumbing
  - On our ability to direct the lens output into the ionizer ($E_s$)

1. Fast diagnostics that inform about beam shape and position as a function of $D_{va}$
2. An improved alignment tool with diagnostic capability
Currently available tool: Beam Width Probe (BWP)

- At large sizes (for PM1 lens) some resolution limitations (wire size is 0.5 mm)
- Very useful to confirm beam alignment and size dependent variability in focusing
Let’s try to get that size info a lot faster: 2D (SD*X) BWP

- Sample polydisperse calibration aerosol at high concentrations (>1 mg sm⁻³)
- Take one ePToF SD per BWP step (10 s), and set up the timing so wire movement is avoided

Compute:

\[ \text{Att}_{ePToF}(X, D_{va}) = \frac{SD(\text{back}) - SD(X)}{SD(\text{back})} \]

Now take the whole scan of BWP positions and matrix transpose
Rapid lens comparisons across sizes

REMINDER: Minimum Beam width/focus is limited by the BWP wire size
This PM2.5 lens (S/N 61) has a slightly tilted focus, in general focuses slightly worse
So can we measure such deflections in 2D? (e.g. 3D BWP SD*(X,Y) attenuation)?

Luckily when John designed the BWP, he left 6 mm of unused space there..
Preliminary Results (hot off the press): Elliptical beam

“vaporizer up/down”

45 degree angle

“vaporizer left/right”
Refresher: Aligning the aerosol lens in the AMS

- Time consuming, prone to vacuum accidents
- Fairly low spatial resolution
- For aircraft instruments, particularly painful

Iterative process, until both beam widths are about the same
A more user-friendly approach: automated lens stage better than 50 µm resolution
Are we centered (l)? : Combining 1D-BWP and lens scans

So the vaporizer is sitting high. Can we get additional confirmation.
Are we centered (II)? Molecular thermometers!

Cross Section

Standard Vaporizer

NO$_2^+$/NO$^+$ Ratio for nitrate
Ratio DECREASES with $T_{vap}$

Particulate Water/Nitrate
Ratio Increases with $T_{vap}$

So this clearly confirms that the vaporizer is actually NOT aligned with instrument axis
Can we quantify that?
So how much off-center is this vaporizer?

Two independent measurements:
- Skimmer suggests vaporizer +0.12 mm (projected) in the vertical (=>0.32 mm on the vap)
- Molecular thermometer suggest +0.18 mm, nearly vertical (=>0.45 mm on the vap)

Taking the more robust measurement (+0.18 mm) results in a vertical angular deviation of the vaporizer of +2.75 degrees

This mostly within the installation tolerances!
So should you worry about such misalignments?

Normally not, except if you care about:

- **pRONO2 quantification for small particles/with PM2.5 lens**
- **Accurate AMS transmission (CEI) of small particles (especially for PM2.5 lens)**

Also if you modify the inlet flow field of your lens (e.g. for aircraft measurements)
For some more examples, please attend Dongwook’s talk tomorrow
In Summary:

1. 2D Beam Width Probing
   - 45 degree angle

2. 3D Beam Width Probing
   - “vaporizer left/right”

3. Automated Lens Alignment and vaporizer profiling
One not-CE related application: Probing the Hu effect

Hu effect:
non-particulate Cl⁺ and HCl⁺ signals from the vaporizer when sampling nitrate

So can we see this happening on the vaporizer surface?

Chlorine Signal, pre-AChl calibration
Chlorine signal, after “etching” the vaporizer

Perform Achl “RIE Calibration” with the lens position as shown