Aerogel QA

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Overview

- Aerogel QA
  - Transparency: High transparency to minimize absorption and scattering of Cherenkov light
    - Assessed through transmittance measurements
  - Refractive Index: Determines Cherenkov radiation threshold
    - A few techniques are being considered
  - Geometric Properties: lateral dimensions and thickness
    - Non-conduct procedure, beyond ruler and touch-probe is needed

- Current Infrastructure
  - Dedicated '*clean*' (~ Class 1000) optical table for measurements
  - Dry box for aerogel storage
  - Plumbing for several gas sources available (if needed)

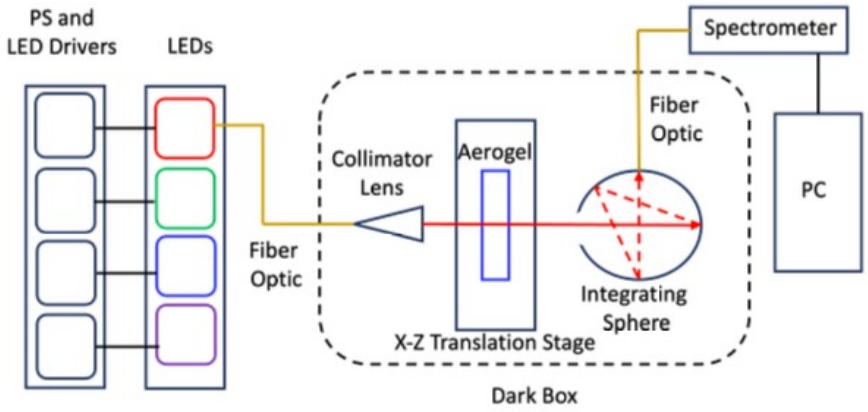
Facilities can be used for any aerogel QA, but project support is needed for personal

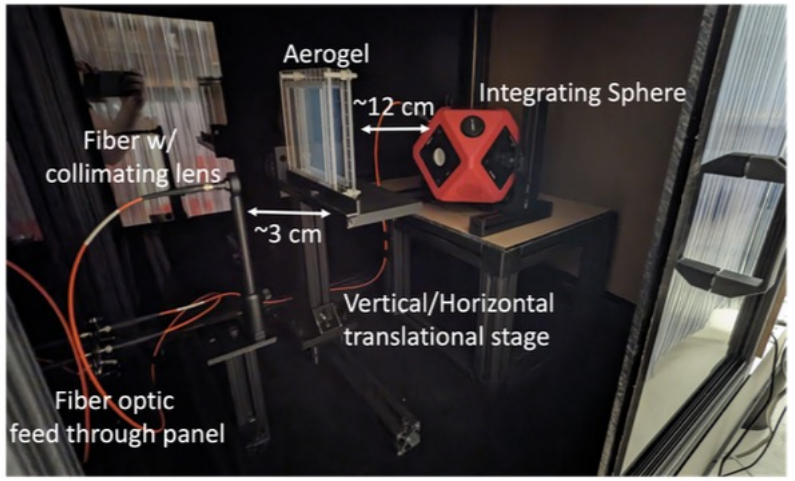
Transmittance

- Several discrete wavelength LEDs are used to measure a wavelength dependent transmittance spectrum
- Results have been validated with monochromator + spectrometer setups (from Aerogel Factory and BNL)
- Aerogel characteristics extracted via fit

Transmittance

$$T_\lambda = \frac{I_{aero} - I_{bkgd}}{I_{ref} - I_{bkgd}}$$

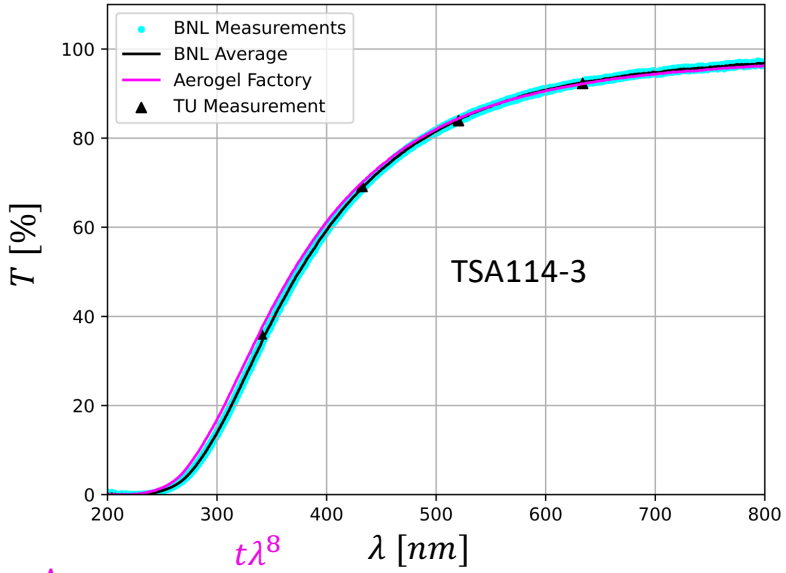




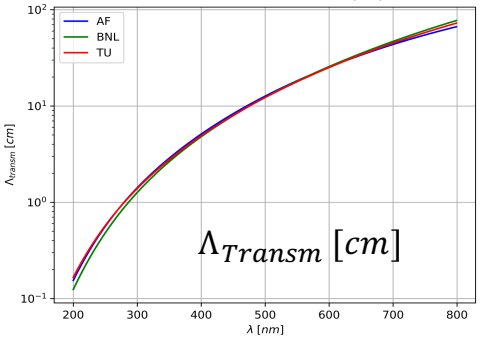
Transmittance: Results

$$T(\lambda) = e^{-\frac{t}{\Lambda_{transm}}} = e^{-t\left(\frac{1}{\Lambda_{abs}} + \frac{1}{\Lambda_{scat}}\right)} = A \cdot e^{-\frac{Bt}{\lambda^8}} \cdot e^{-\frac{Ct}{\lambda^4}}$$

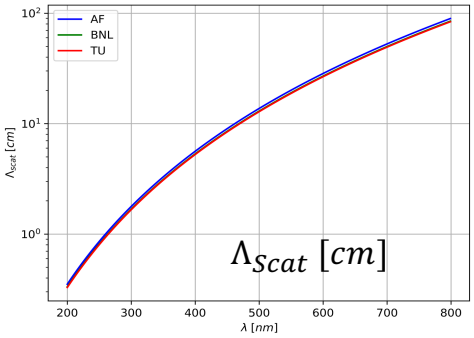
	A	Ct [μm^4]
BNL	99.767 ± 0.090	0.012
AF	99.047 ± 0.062	0.011
TU	99.548 ± 1.606	0.012 ± 0.001



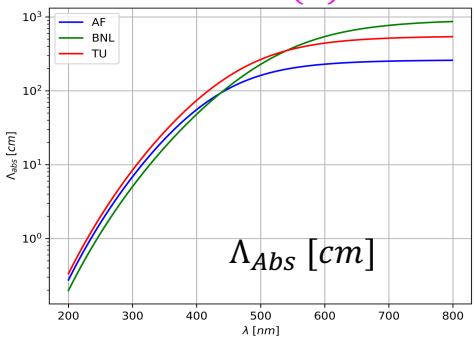
$$\Lambda_{transm} = -\frac{t}{\ln(T)}$$



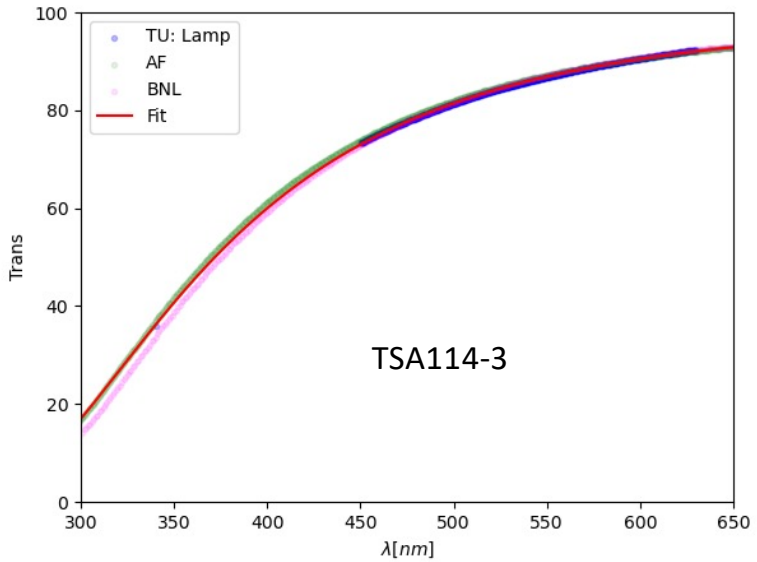
$$\Lambda_{scat} = \frac{\lambda^4}{C}$$



$$\Lambda_{abs} = \frac{t\lambda^8}{Bt - \lambda^8 \ln(A)}$$



Transmittance: Results



TSA114-3 fit result comparisons

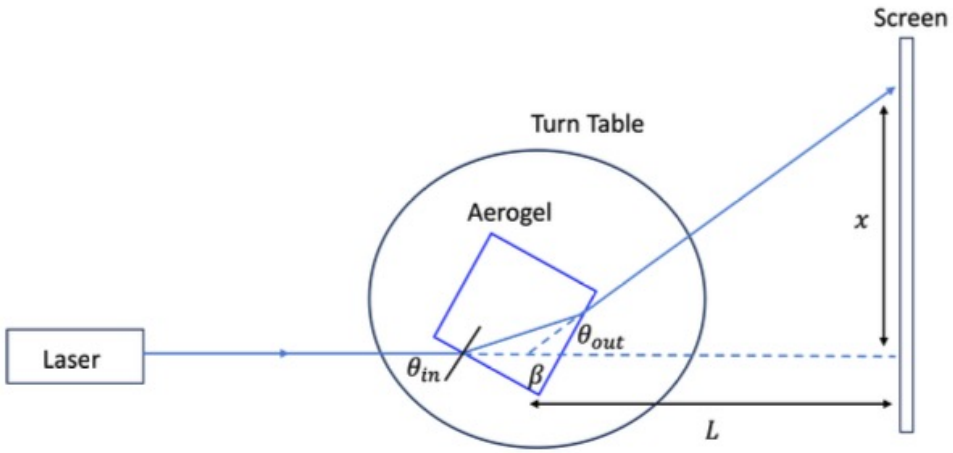
Source	A [%]	C [μm^4]
Aerogel Factory	$99.05 \pm 6\times10^{-2}$	$4.56\times10^{-3} \pm 2.17\times10^{-5}$
BNL	$99.77 \pm 9\times10^{-2}$	$4.82\times10^{-3} \pm 3.37\times10^{-5}$
TU (LED)	99.55 ± 1.60	$4.87\times10^{-3} \pm 5.47\times10^{-4}$
TU (Lamp)	$99.87 \pm 8\times10^{-4}$	$5.10\times10^{-3} \pm 7.66\times10^{-8}$
TU (LED + Lamp)	$99.61 \pm 2\times10^{-4}$	$4.92\times10^{-3} \pm 6.71\times10^{-9}$

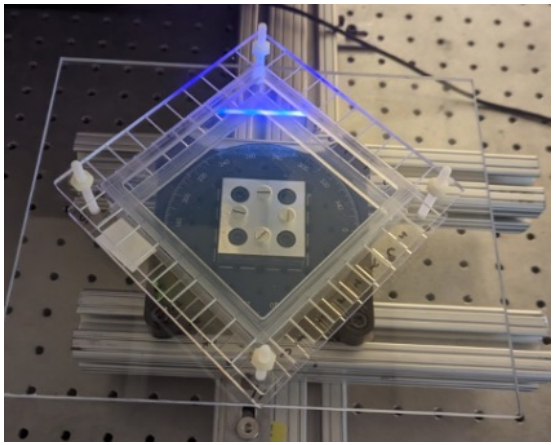
- Ideal to upgrade light source to monochromator
  - Would allow for continuous set of discrete wavelength measurements
  - Leads to more robust fitting (lower uncertainties)
  - Requires project support

Refractive Index: Minimum Deflection

- Measure minimum deflection (x) of light through corner of aerogel to obtain θ_{out}
- For aerogel tiles assume $\beta = 90^o$
- Most used method referenced in literature

$$n = \frac{\sin\left(\frac{\beta + \theta_{out}}{2}\right)}{\sin\left(\frac{\beta}{2}\right)}$$

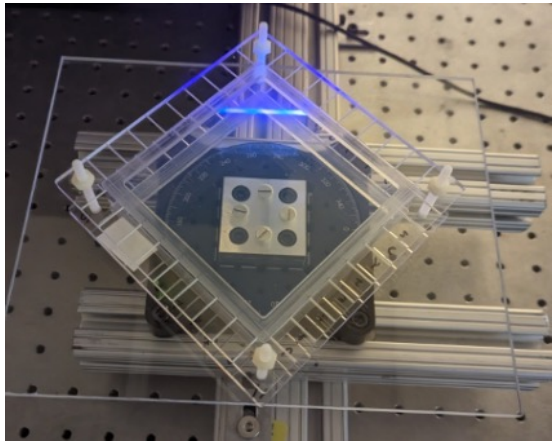




Refractive Index: Minimum Deflection

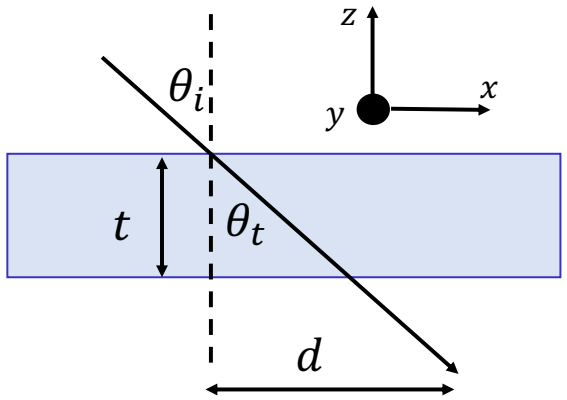
Tile	Temple (TU) $(\lambda = 403\ nm)$	Aerogel Factory (AF) $(\lambda = 405\ nm)$	(TU-AF)/AF [%]
TSA88-1	1.0398 +/- 0.0007	1.0390	0.077
TSA120-1	1.0413 +/- 0.0011	1.0404	0.087
TSA120-2	1.0401 +/- 0.0025	1.0401	0.000
TSA114-3	1.0383 +/- 0.0026	1.0377	0.062

- Potential Issues:
  - Relies on the optical quality of the edges, but production tiles to be cut with water jet. Do they have optical quality edges?
  - Measures refractive index only at the corners, not throughout the tile



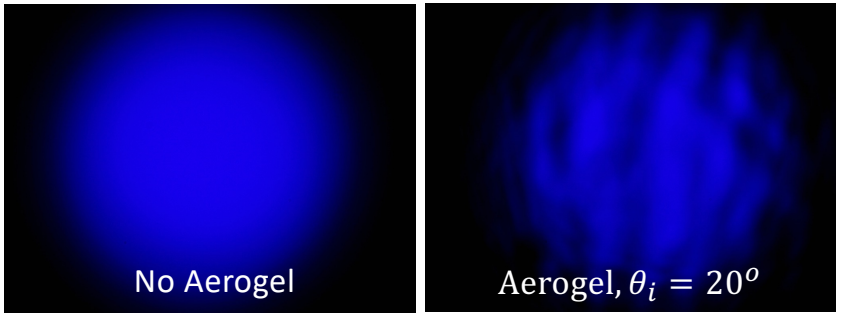
Refractive Index: Lateral Displacement

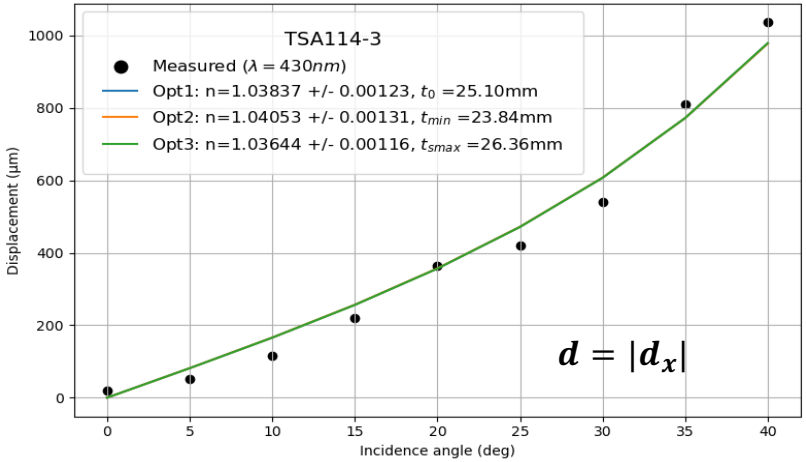
- Measure lateral displacement (d) as a function of incident angle



$$\sin(\theta_t) = \frac{\sin(\theta_i)}{n_{aerogel}} \qquad d = t(\tan(\theta_i) - \tan(\theta_t))$$

$\lambda = 430nm$

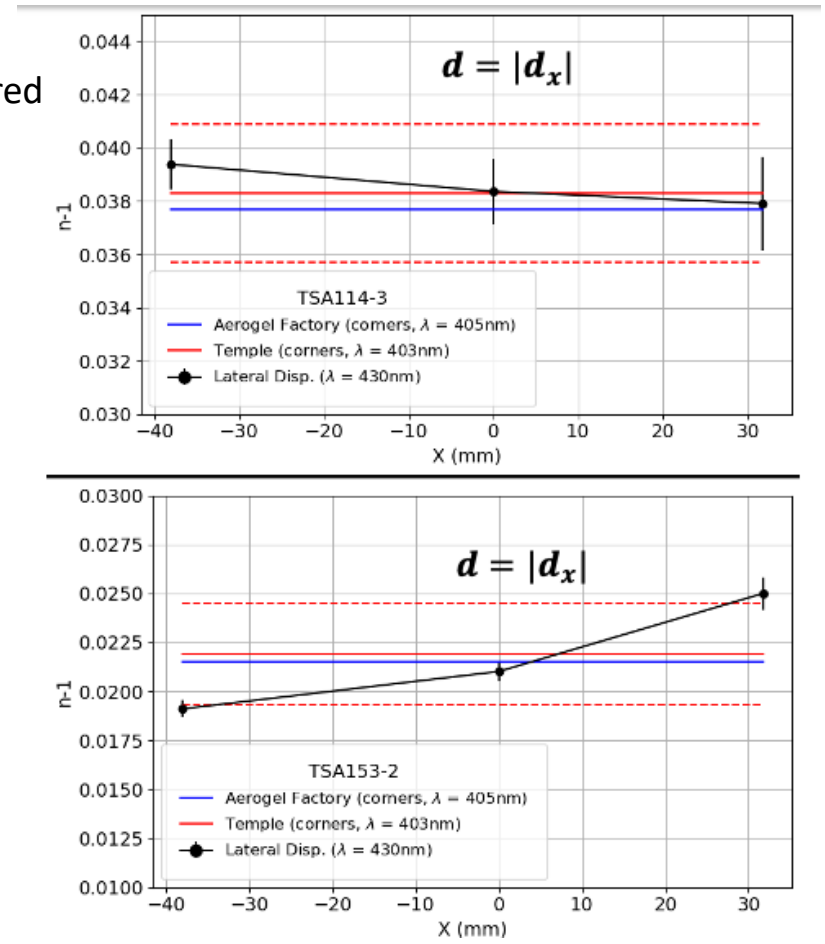




- Displacements fit with three different thicknesses:
  - Nominal thickness and +/- 5% of nominal thickness

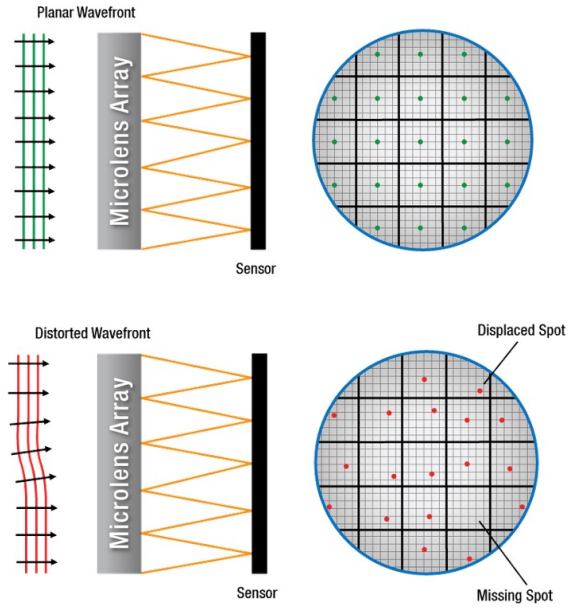
Refractive Index: Lateral Displacement

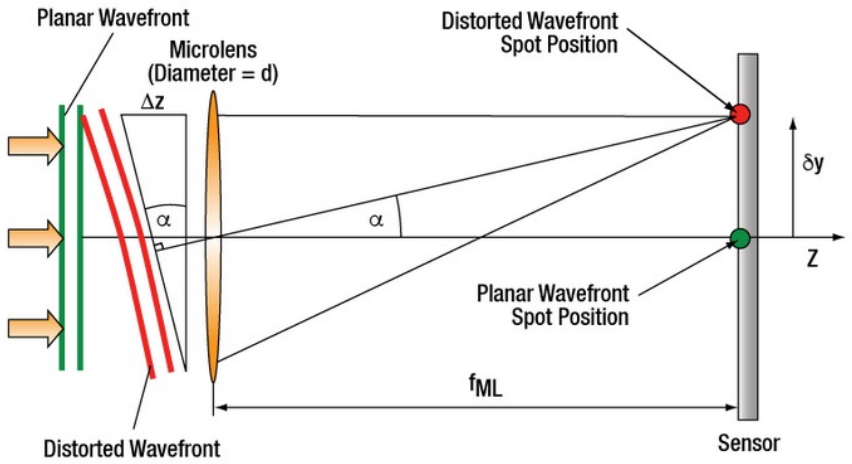
- ❑ Lateral displacement measurements agree with n measured via light deflected through the tile corners.
  - Assumes fixed nominal thickness
  - 3 local spots measured on aerogel tile
- ❑ Pros:
  - Not reliant on optical quality edges
  - Allows mapping of refractive index (local measurements)
- ❑ Cons:
  - Correlation between refractive index and thickness



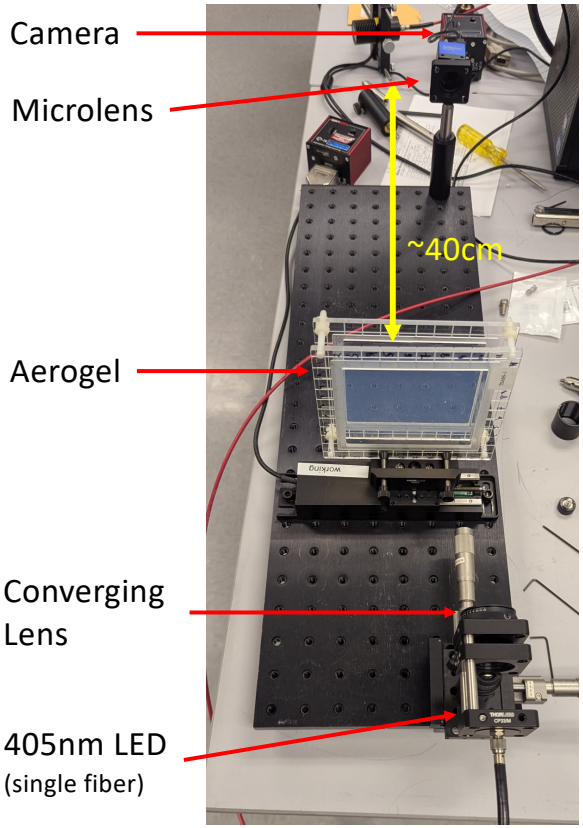
Refractive Index: Microlens

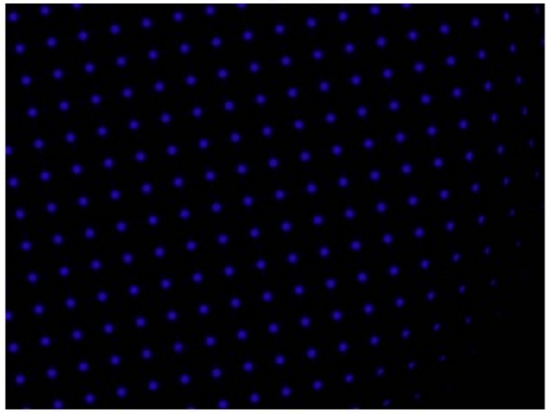
- Use microlens to assess light wave-front distortions/changes
- Efforts are being made to analyze distortions of entire microlens grid
- How to relate lattice changes to refractive index?

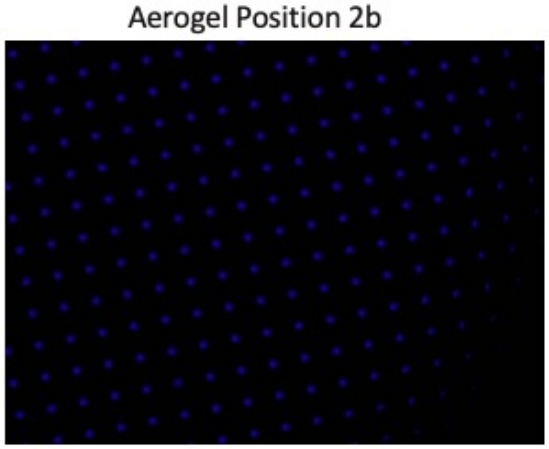


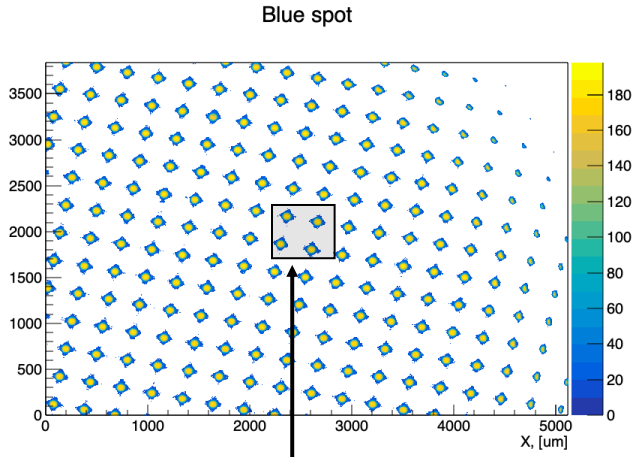


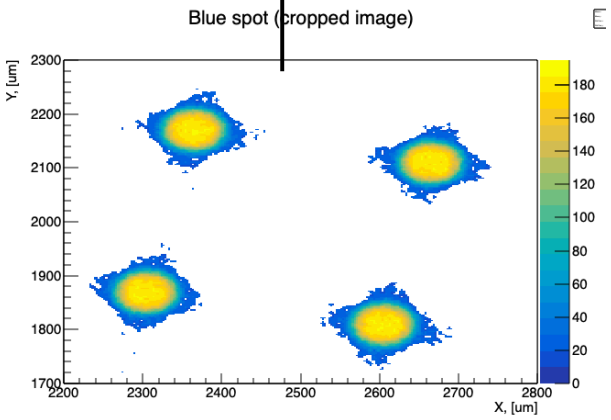
Microlens Concept











Open Questions

- **How to measure the absolute refractive index (n)?**
  - Ability to measure local refractive index → allows for aerogel n-map
  - Independent thickness measurement is needed to remove refractive index and thickness correlation.
- **How to measure aerogel thickness (t)?**
  - Touch probe → risks damaging aerogel
  - Measure optical path difference → Depends on thickness and refractive index, but can combine with lateral displacement method(?)
- **Other methods related to t and n**
  - X-ray CT depends on density and thickness: $I = I_0 \exp(-\mu\rho t)$
  - Optical coherence tomography (OCT) (ala HELIX Collab. RICH 2025)
  - Ellipsometry: measures polarization change upon reflection. Typically used on thin films ($<\approx 10\ \mu m$)