

# Single Particle Absorption Measurements in the Mid-Infrared by Exploiting Elastic Scattering

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## Report Documentation Page

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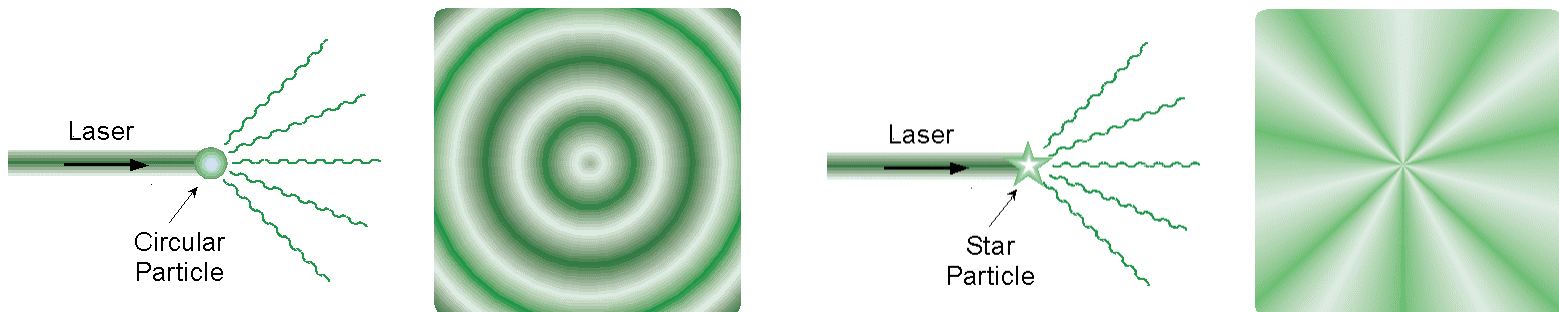
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**Goal:** Measure the infrared absorption and scattering cross-sections for single biological and chemical aerosol particles.

**Use:** Single particle measurements are necessary for detailed modeling and understanding of test results from infrared stand-off detection systems.

**Technique:**

Two-dimensional Angular Optical Scattering (TAOS)

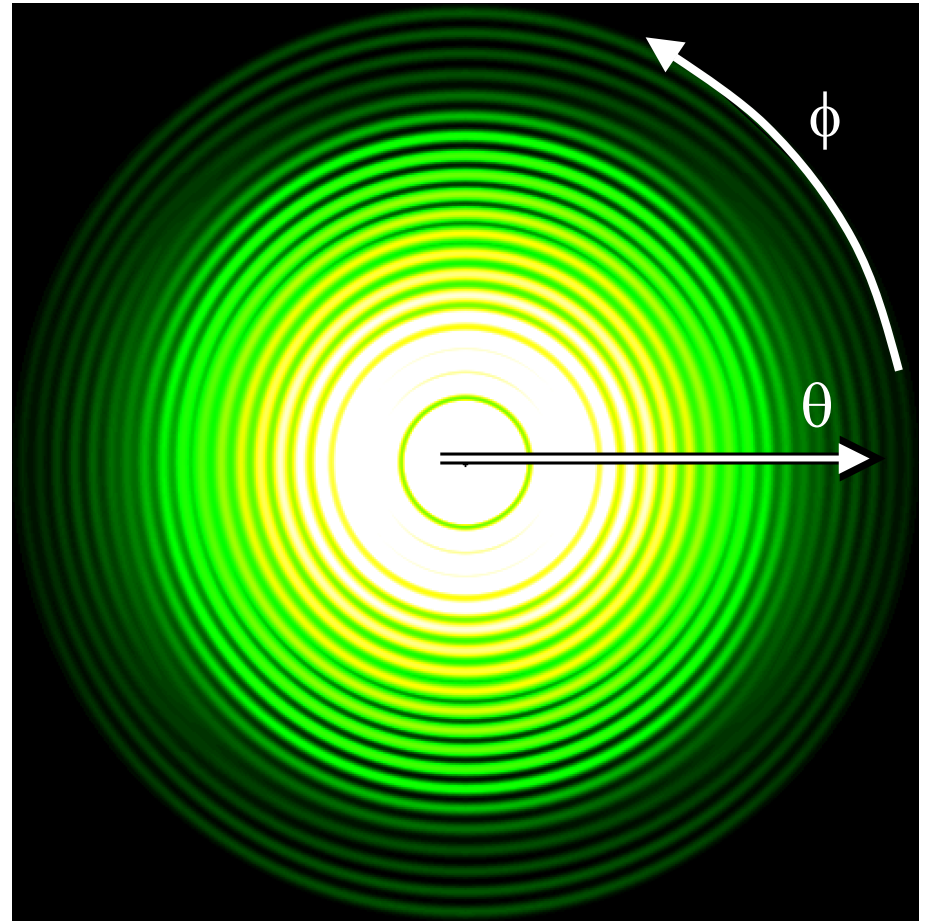
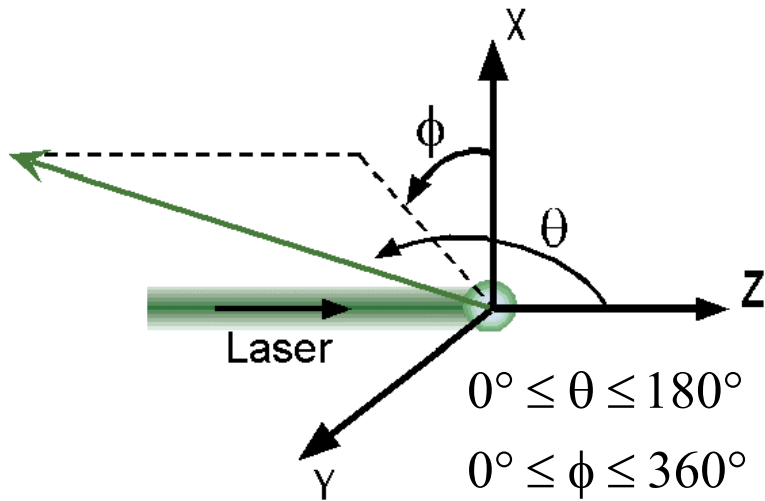


TAOS patterns depend upon particle shape, size, and **complex refractive index**

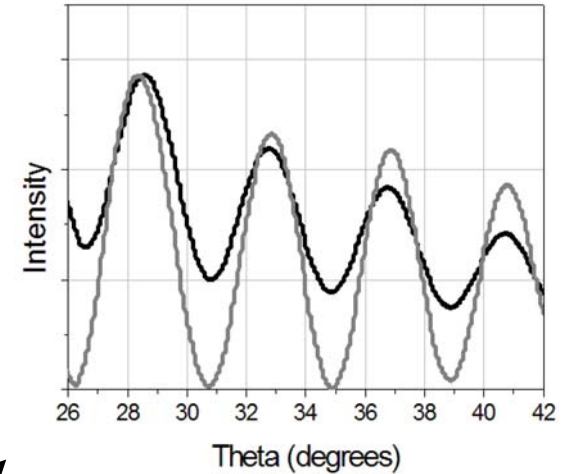
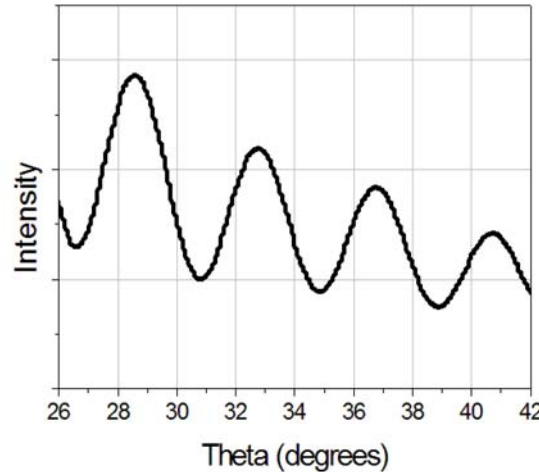
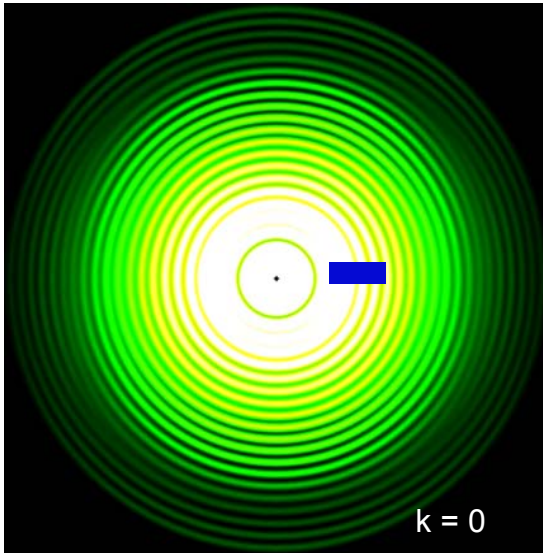
# Coordinates for TAOS patterns

## Scattering Parameters

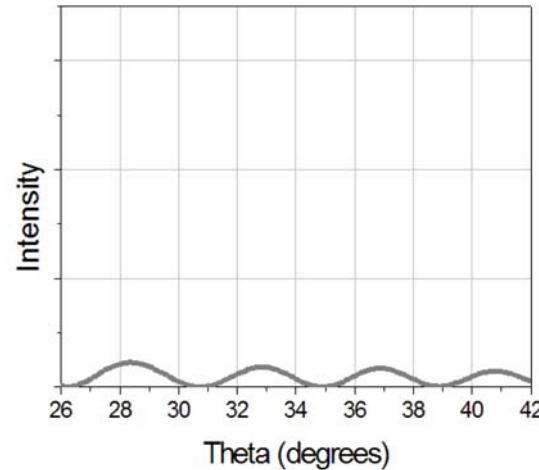
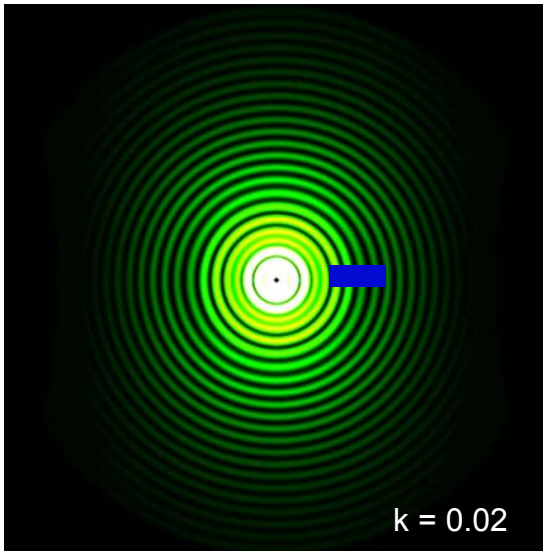
Diameter: 54.2  $\mu\text{m}$   
Refractive Index: 1.342 + i \* 0.00  
Wavelength: 3.41  $\mu\text{m}$   
Size Parameter:  $2\pi*a/\lambda \cong 50$   
Laser Polarization: Vertical



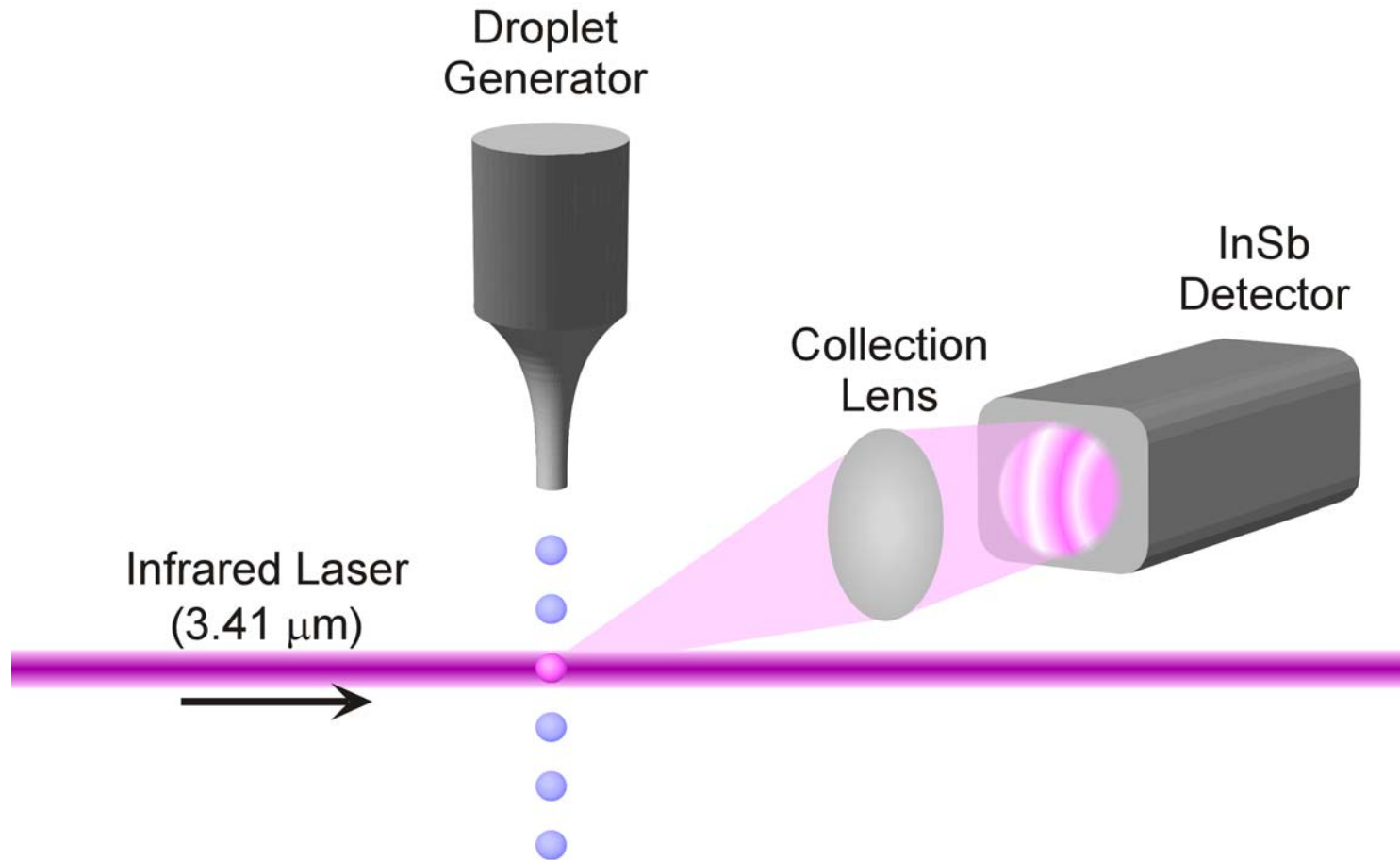
# Extrapolate absorption cross-sections of spherical particles by comparison with Mie theory



Changes in absorption leads to changes in the scattering profile beyond just a scale factor.



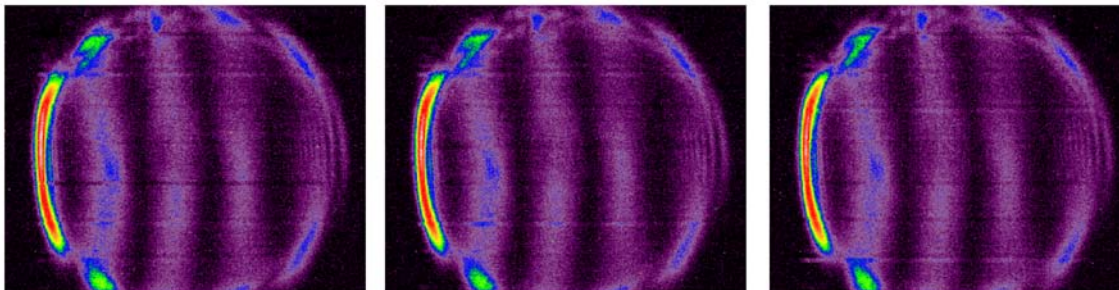
# Experimental set-up to collect TAOS patterns of droplets



# Collected TAOS patterns of droplets

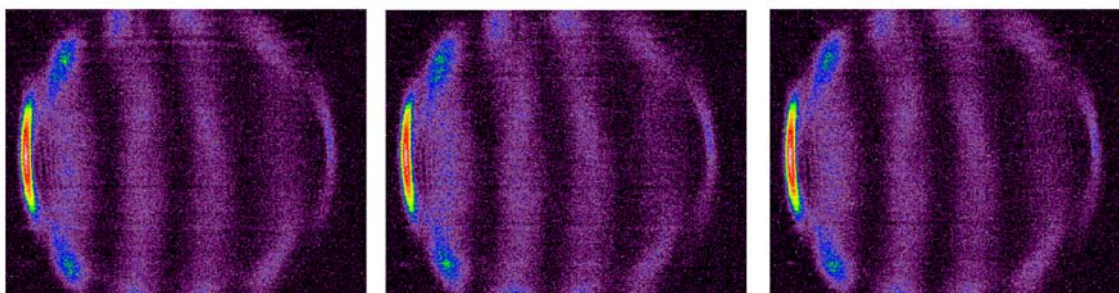
$\text{H}_2\text{O}$

Droplet Diameter:  $57.4 \mu\text{m}$   
Refractive Index:  $1.405 + i 0.018$



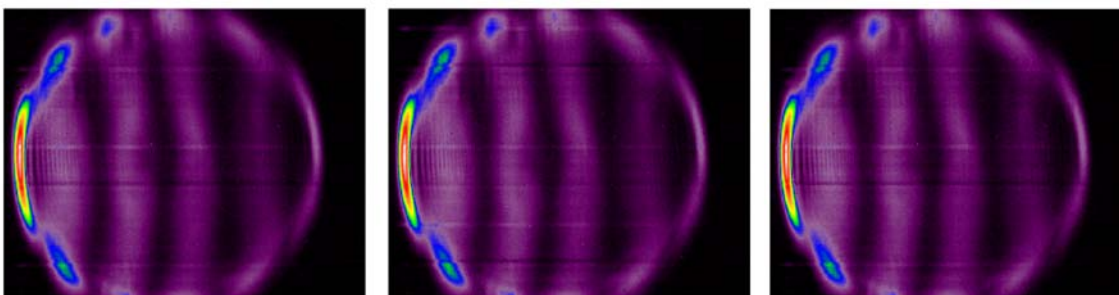
50%  $\text{H}_2\text{O}$  - 50%  $\text{D}_2\text{O}$

Droplet Diameter:  $54.2 \mu\text{m}$   
Refractive Index:  $1.342 + i 0.010$



$\text{D}_2\text{O}$

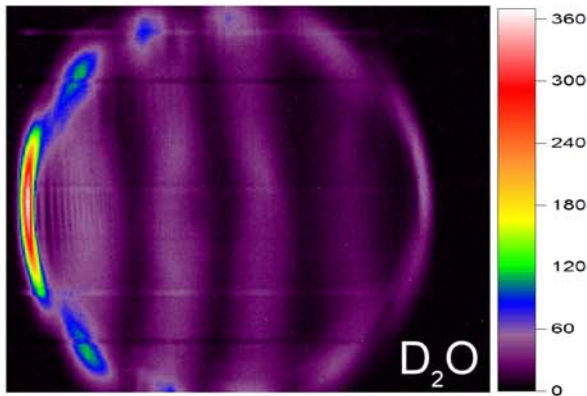
Droplet Diameter:  $55.2 \mu\text{m}$   
Refractive Index:  $1.279 + i 0.002$



# Comparison between experiment and Mie theory

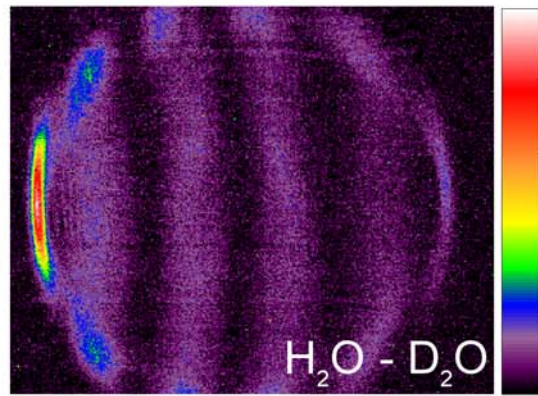
$D_2O$

Droplet Diameter: 55.2  $\mu m$   
Refractive Index: 1.279 + i 0.002



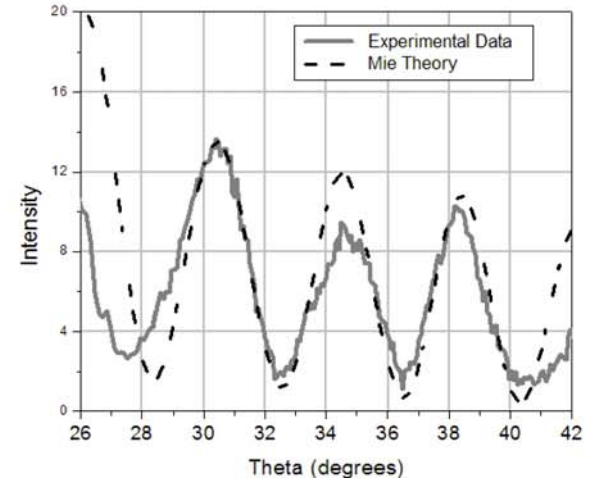
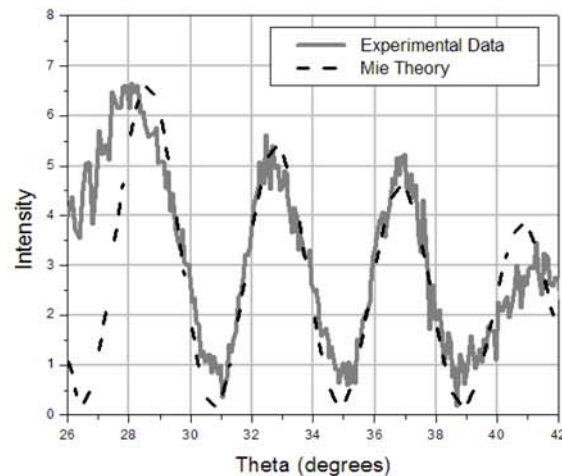
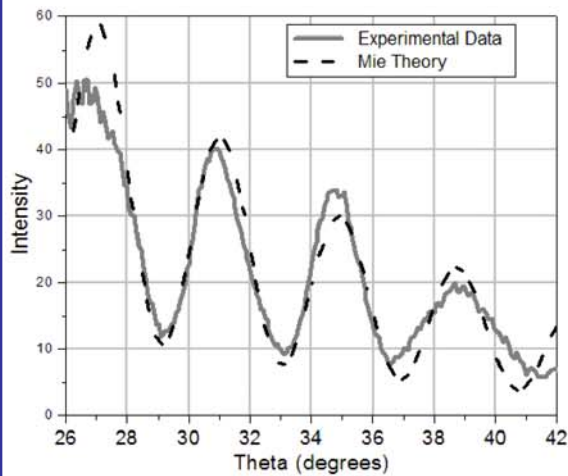
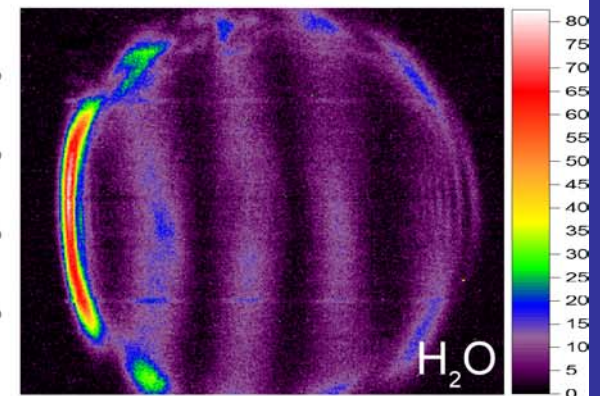
50%  $H_2O$  - 50%  $D_2O$

Droplet Diameter: 54.2  $\mu m$   
Refractive Index: 1.342 + i 0.010



$H_2O$

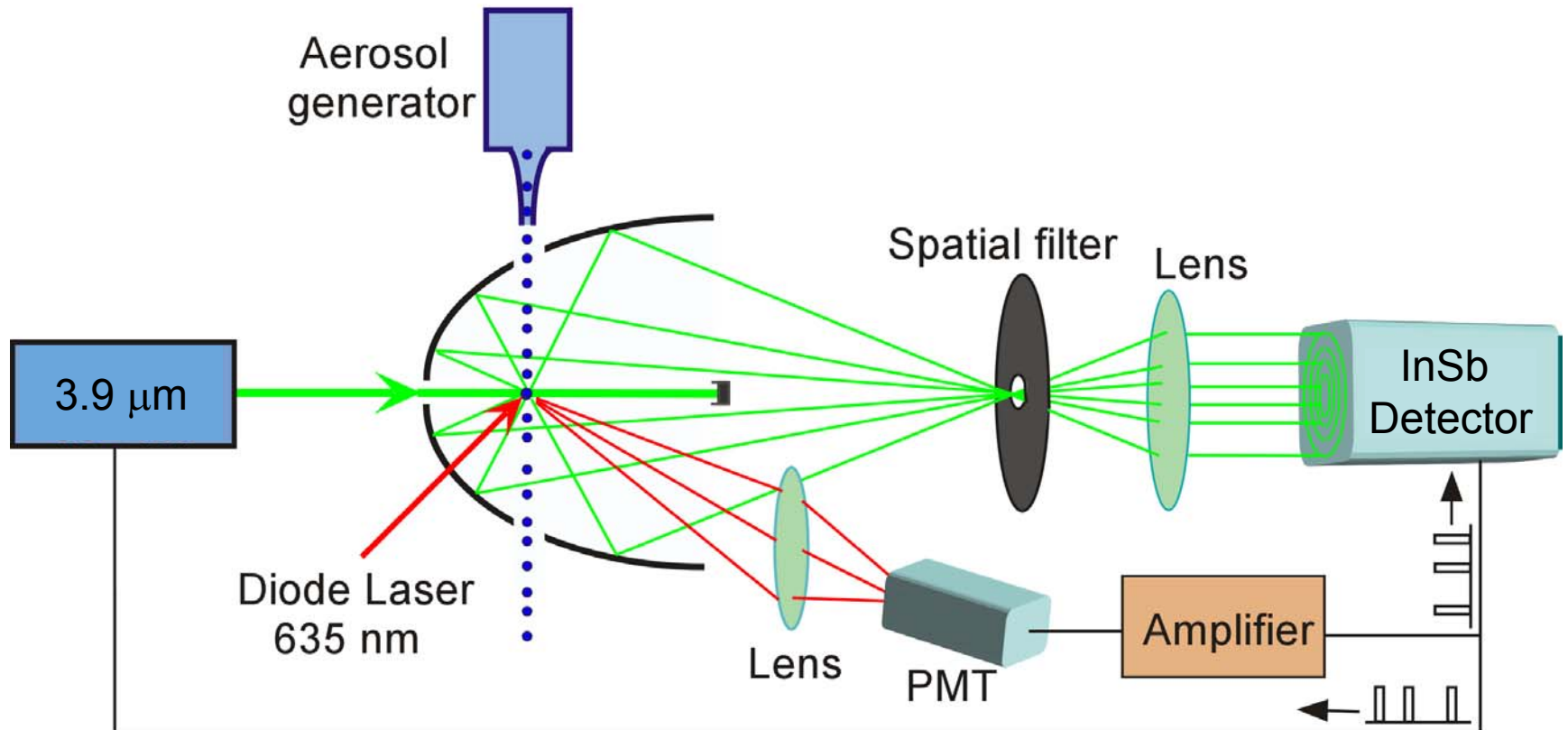
Droplet Diameter: 57.4  $\mu m$   
Refractive Index: 1.405 + i 0.018



# Current work

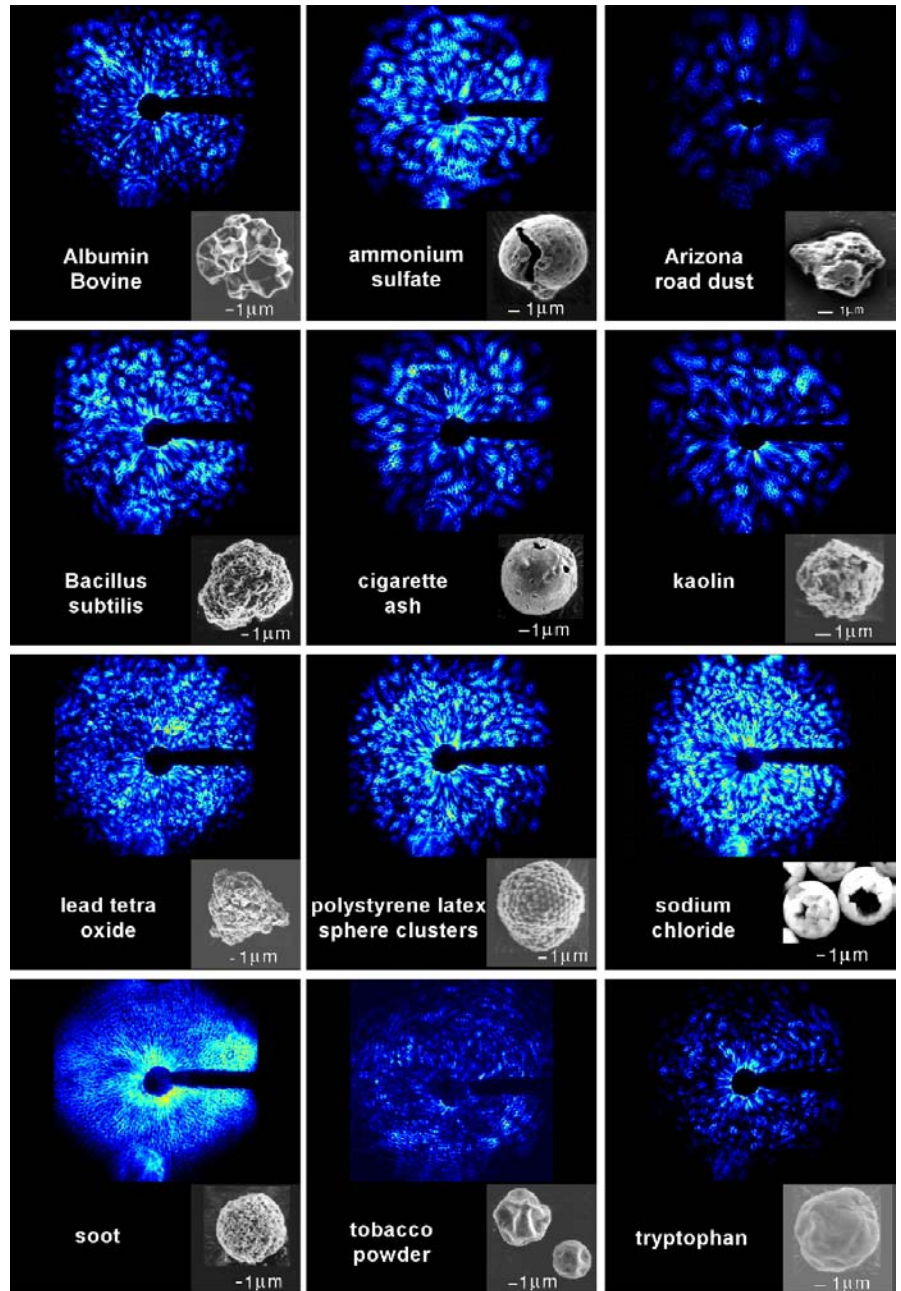
*Collaboration with MIT Lincoln Lab*

*(Anish Goyal, Tom Jeys, and Antonio Sanchez)*



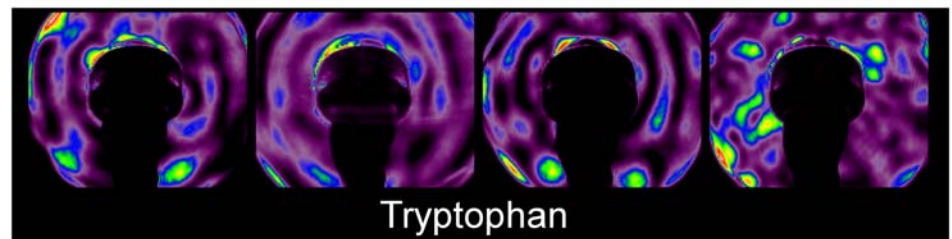
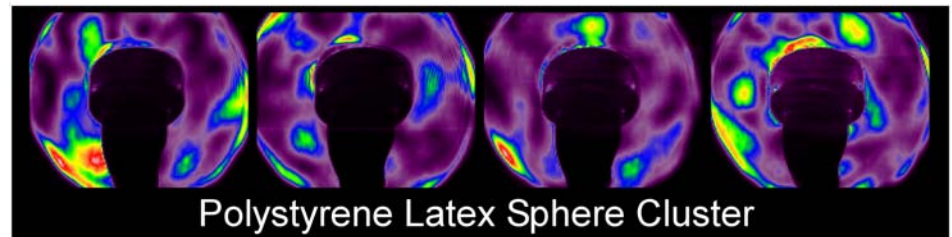
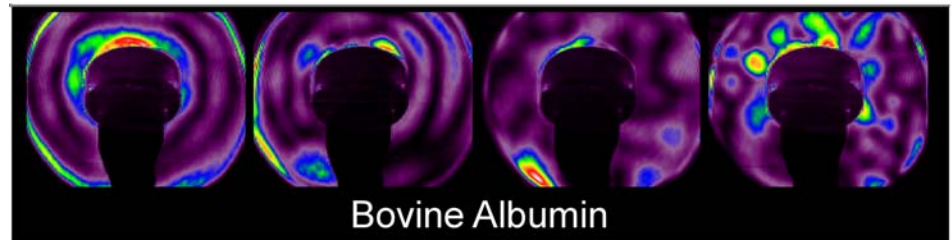
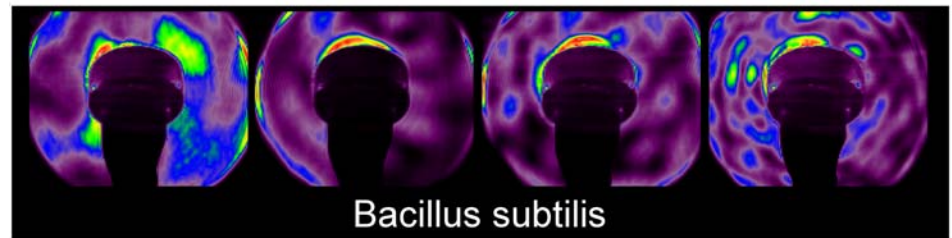
**Large Angle Two-dimensional Angular Optical Scattering**

LA TAOS patterns collected  
in the **visible** of clusters  
( $\lambda = 532 \text{ nm}$ )



LA TAOS patterns collected  
in the **mid-IR** of clusters  
( $\lambda = 3.9 \mu\text{m}$ )

Variability within a data set is due to multiple factors: cluster size, shape, and orientation, and optical alignment distortions.

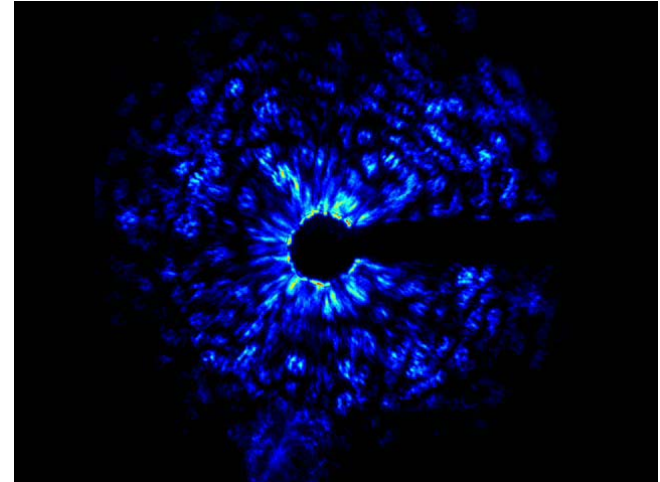


# LA TAOS in the visible and mid-infrared

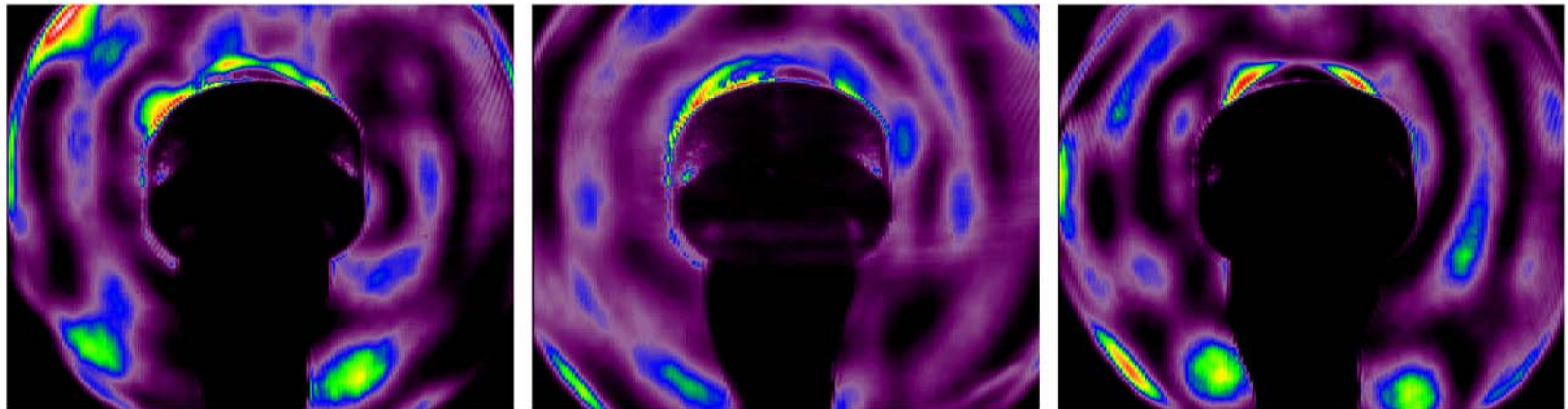
By increasing the wavelength,  
the LA TAOS technique  
becomes more sensitive to  
larger structure sizes.



SEM of Tryptophan

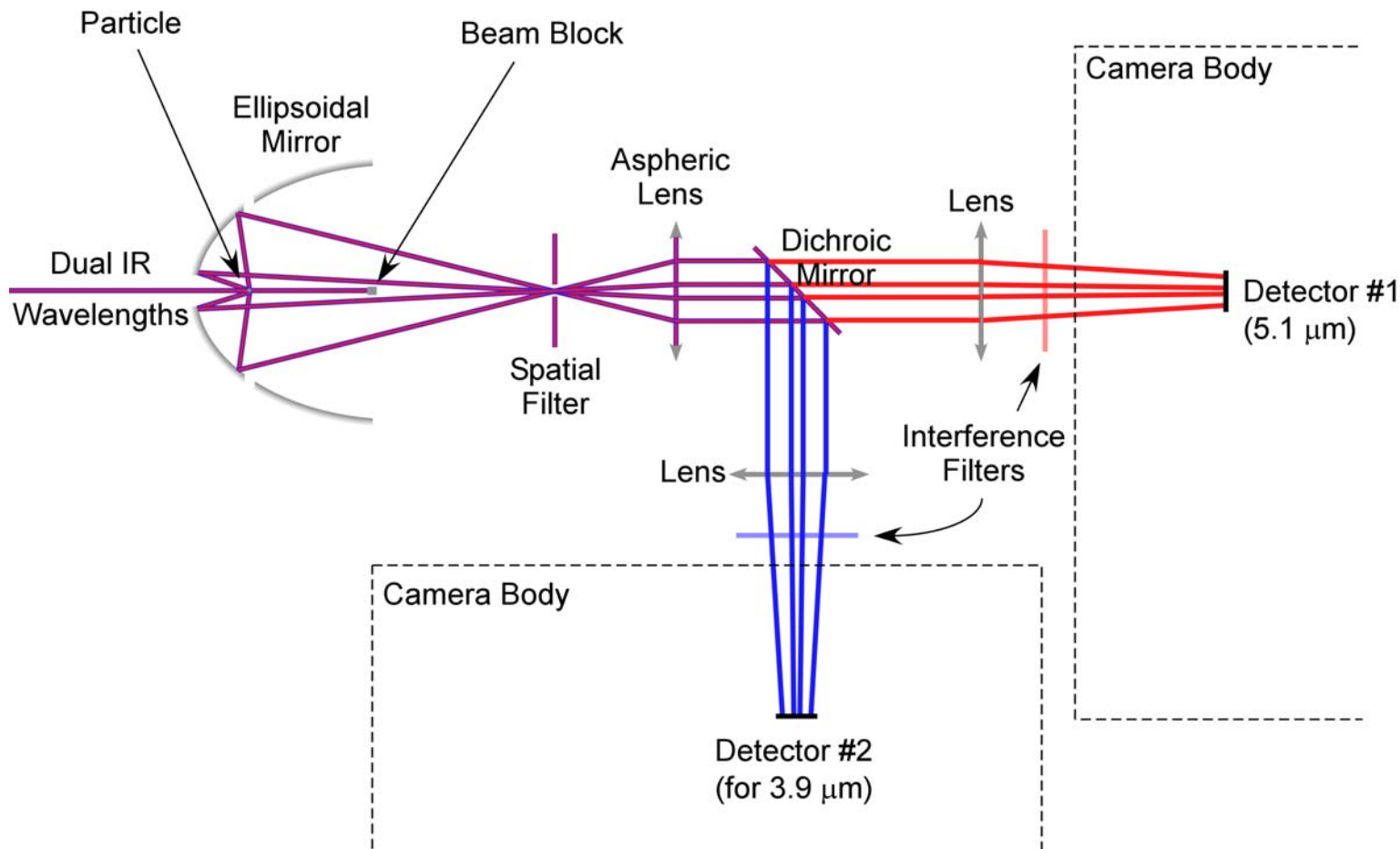


Visible LA TAOS pattern of Tryptophan  
at  $\lambda = 532 \text{ nm}$



Mid-IR LA TAOS patterns of Tryptophan at  $\lambda = 3.9 \mu\text{m}$

# Future Plans: Capture Dual Wavelength LA TAOS



Use two mid-infrared wavelengths to simultaneously illuminate an aerosol, then compare the LA TAOS patterns to ascertain if there is absorption at either wavelength.

## Summary of Work

- Detected TAOS patterns of single 50  $\mu\text{m}$  droplets composed of  $\text{H}_2\text{O}$ ,  $\text{D}_2\text{O}$ , and  $\text{H}_2\text{O}/\text{D}_2\text{O}$  mixture.
- Able to achieve decent visible match with results derived from Mie theory.
- Unable to implement a minimization routine to find absorption because of aberration in the collection optics as well an inability to determine absolute angle reference.
- Collected LA TAOS patterns of Arizona Road Dust, BG, Bovine Albumin, PSL sphere cluster, and Tryptophan