The Aerodynamic, Dual-Wavelength Optical Spectrometer

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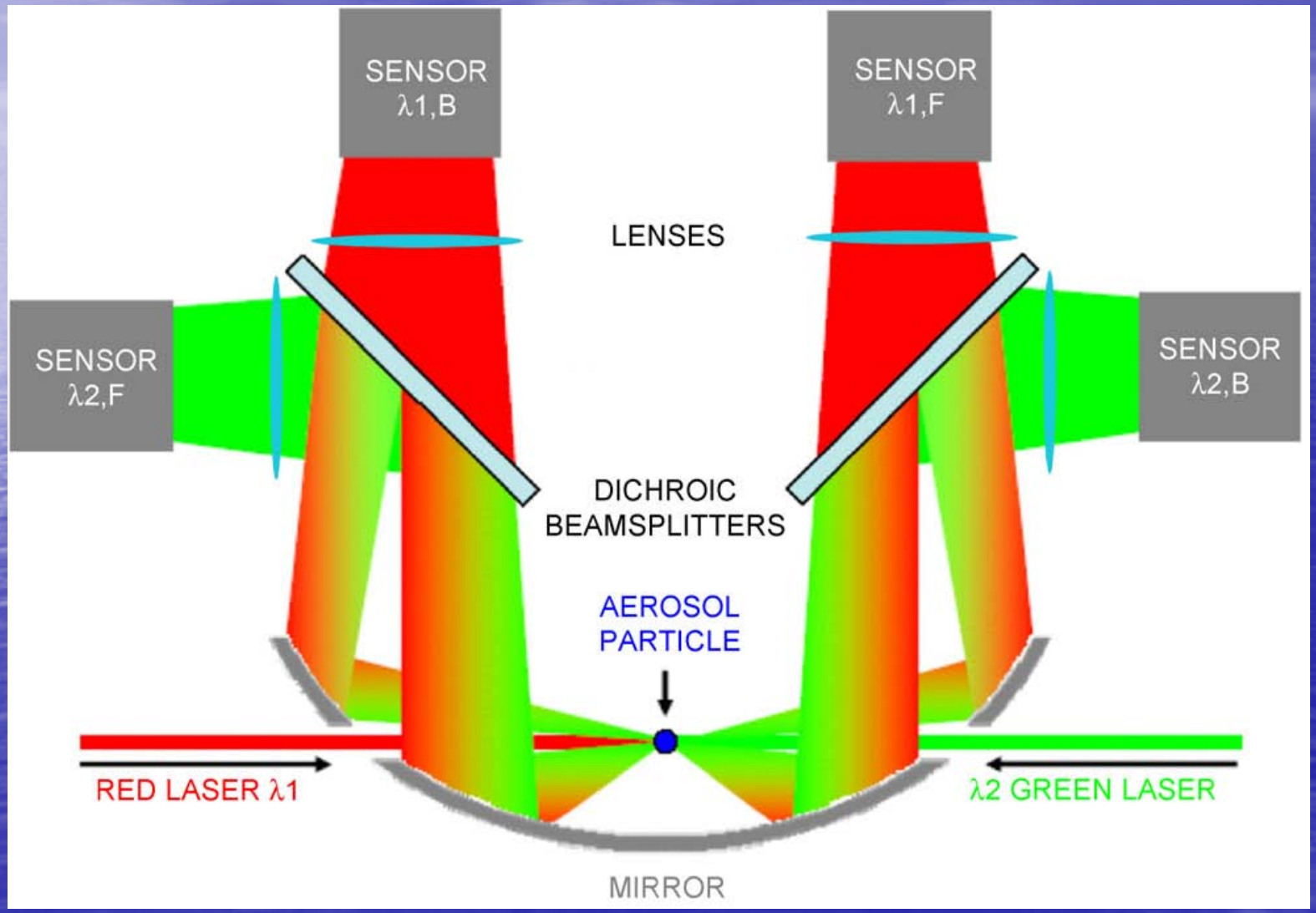
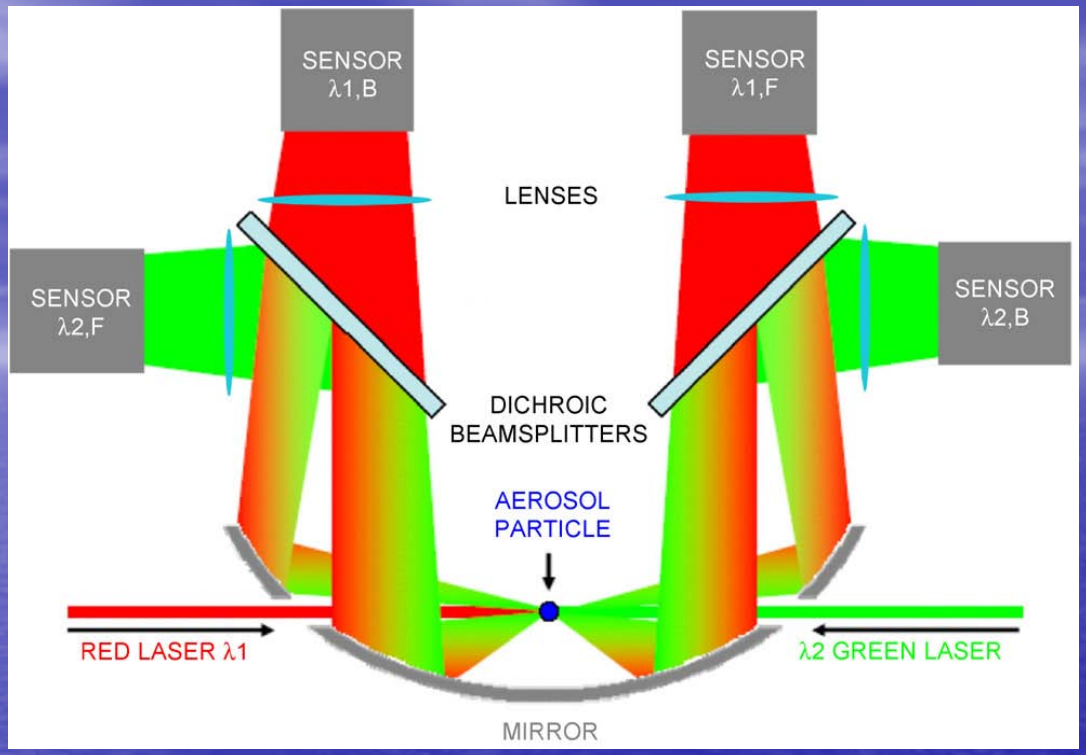
Determination of Real and Imaginary Refractive Indices, Diameter and Density with a Compact Instrument (A-DWOPS)

- DWOPS: Two Wavelengths, Two Angles.
  - A. Nagy, W.W. Szymanski, P. Gál, A. Golczewski, A. Czitrovszky, “Numerical and experimental study of the performance of the dual wavelength optical particle spectrometer” (DWOPS) J. Aerosol Sci.,38 (2007), 467.
- Aerodynamic Particle Sizing
  - Wilson J.C., Liu B.Y.H., "Aerodynamic Particle Size Measurement by Laser-Doppler Velocimetry", *J. Aerosol Sci. 11:139-150*, 1980.

DWOPS


SENSOR
λ1,B
SENSOR
λ1,F
LENSES
SENSOR
λ2,F
SENSOR
λ2,B
DICHROIC
BEAMSPLITTERS
AEROSOL
PARTICLE
RED LASER λ1
λ2 GREEN LASER
MIRROR

DWOPS



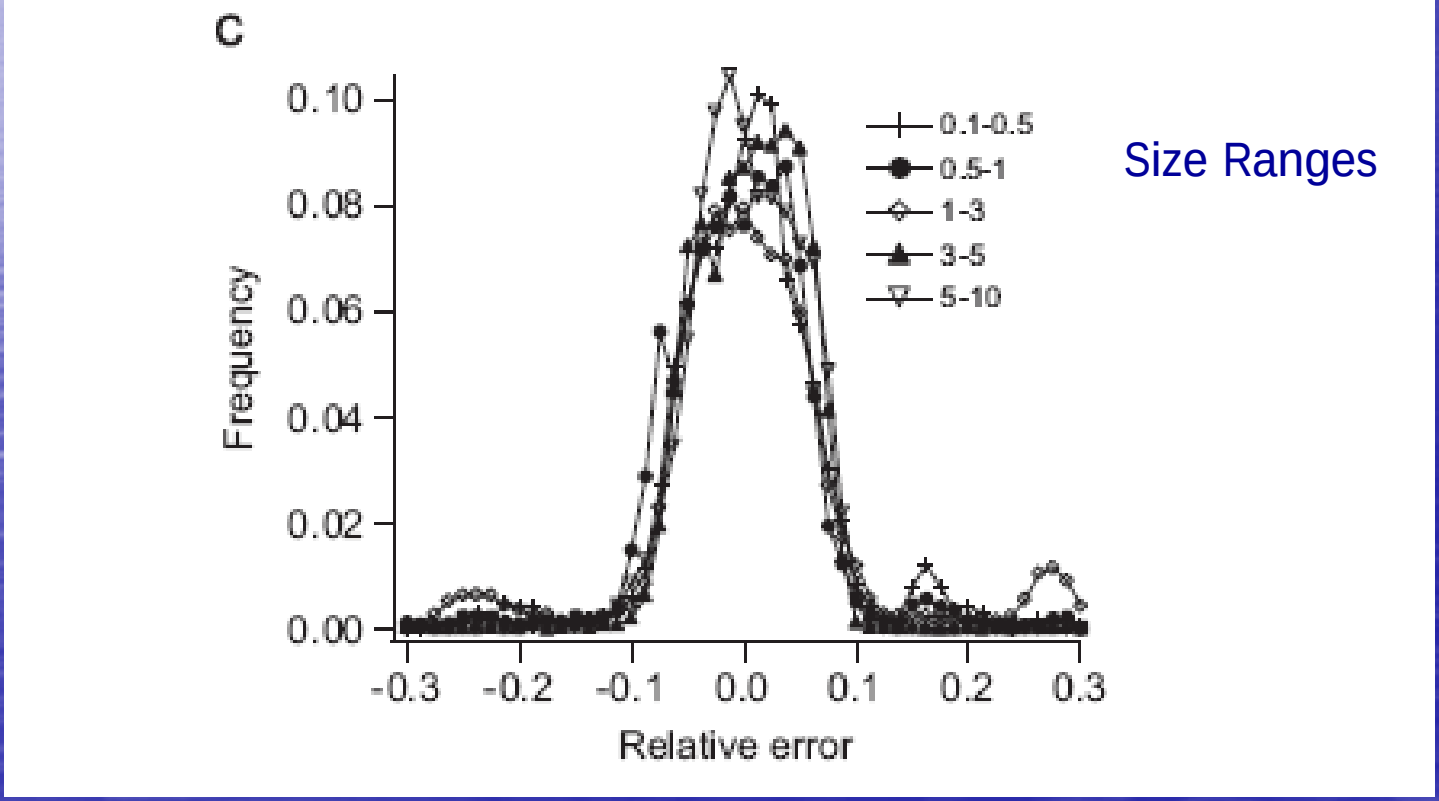
- Angles: 10˚-30˚ and 150˚-170˚ for each beam
- Wavelengths: 685 and 532 nm
- 4 Signals for each particle
- Size:
  - 1. Opto - mechanical assembly: (45x45x15) cm
  - 2. Electronics: (45x25x10) cm
- Total instrument weight: ~15 kg.

Response of the DWOPS for Spherical, Homogeneous Particles

- Numerical Prediction of Performance
  - 0.1 μm <Dp<10 μm
    - 36 logarithmic intervals
  - Real Refractive Index: 1.1 to 2
    - 19 linear intervals
  - Imaginary Refractive Index: 0 to 1
    - 21 linear intervals
- Using the 4 measured signals and a numerical search, find the numerical particle that produces 4 values that are closest to the measured particle's values.
- Upon a match, announce the physical diameter, real and imaginary refractory index.

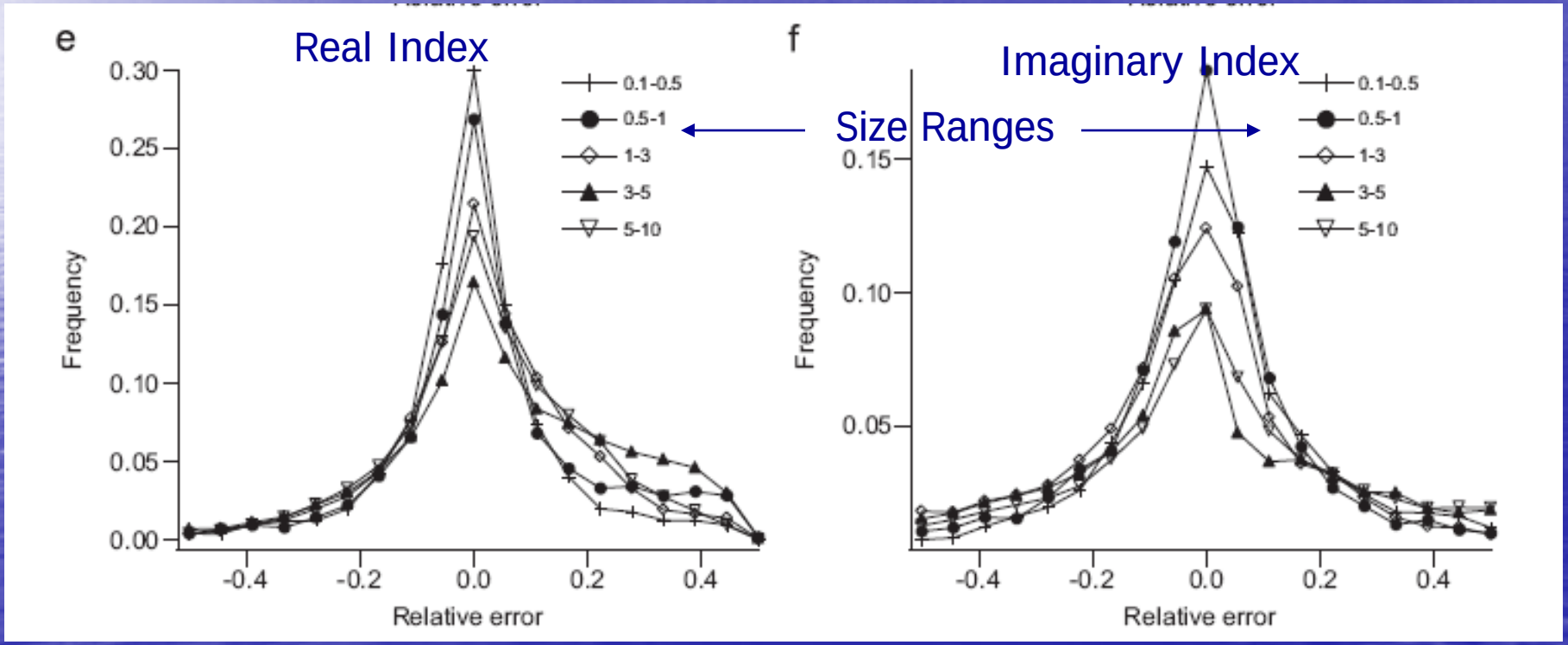
Results of Numerical Experiments

- Signals plus noise and retrieval of Diameter (most particles sized to better than 10% for most sizes):



Results of Numerical Experiments

- Signals plus noise and retrieval of Indicies of Refraction (10,000 particles):



DWOPS Numerical Experiment Results

- Retrieved particle sizes are typically within 10% of the challenge value
- Retrieved Indices are typically within 20% of the challenge value

Lab Measurements

Material	DMA Dia.	DWOPS Dp	DWOPS Real	DWOPS Imag
DHES 1.45+0.0i	0.589	0.588 ± 0.01	1.55 ± 0.20	0.04 ± 0.04
DHES 1.45+0.0i	0.846	0.834 ± 0.03	1.46 ± 0.02	0 ± 0.04
PSL 1.59+0.0i	1.00	0.949 ± 0.01	1.60 ± 0.02	0 ± 0.04
Ink (SM745) 1.70+0.32i	0.845	0.811 ± 0.08	1.61 ± 0.20	0.32 ± 0.2

Velocimetric Determination of Aerodynamic Diameter: Schematic From Wilson and Liu (1980)

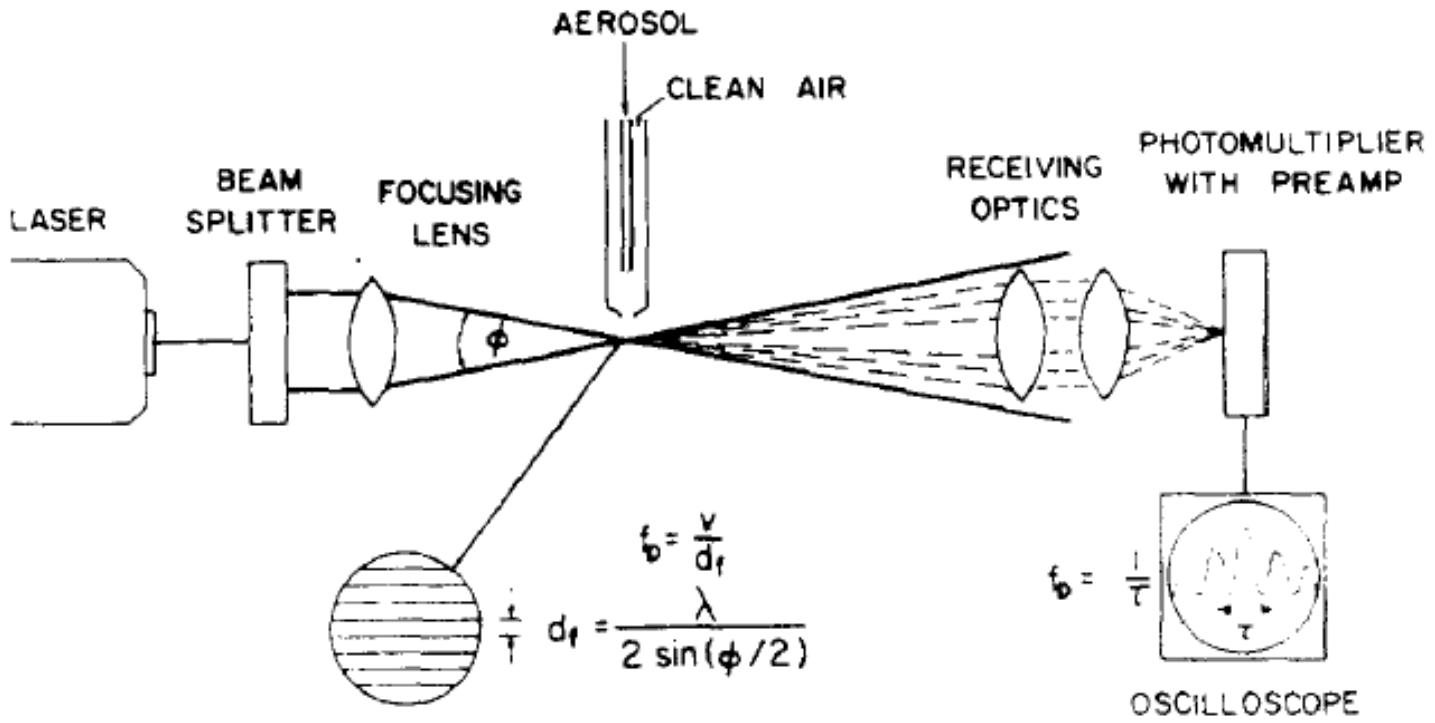
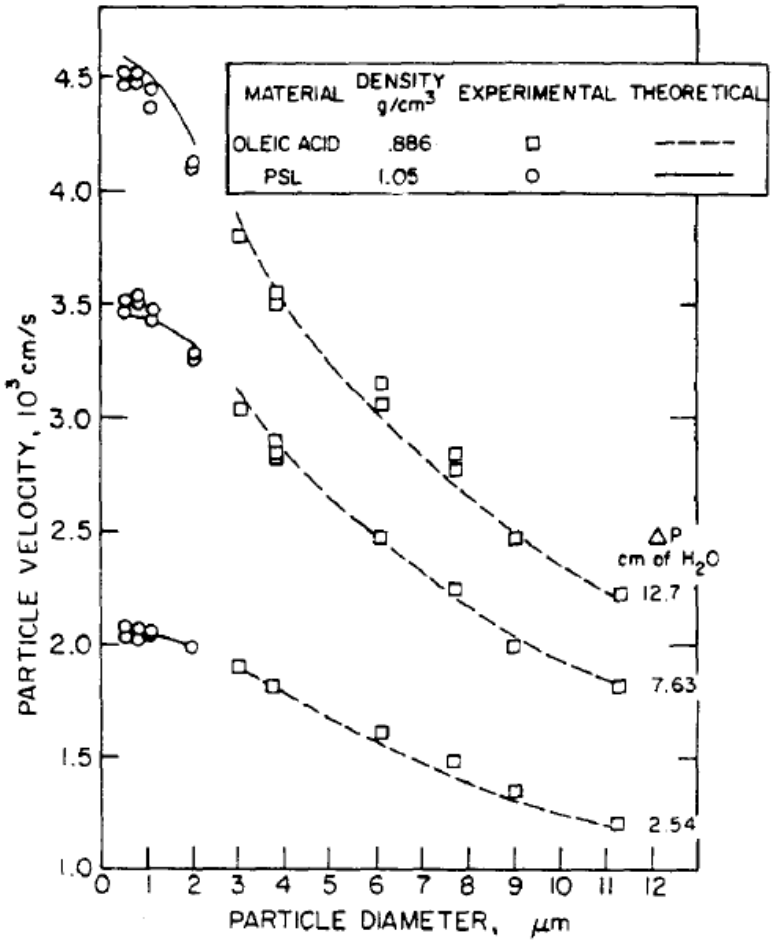
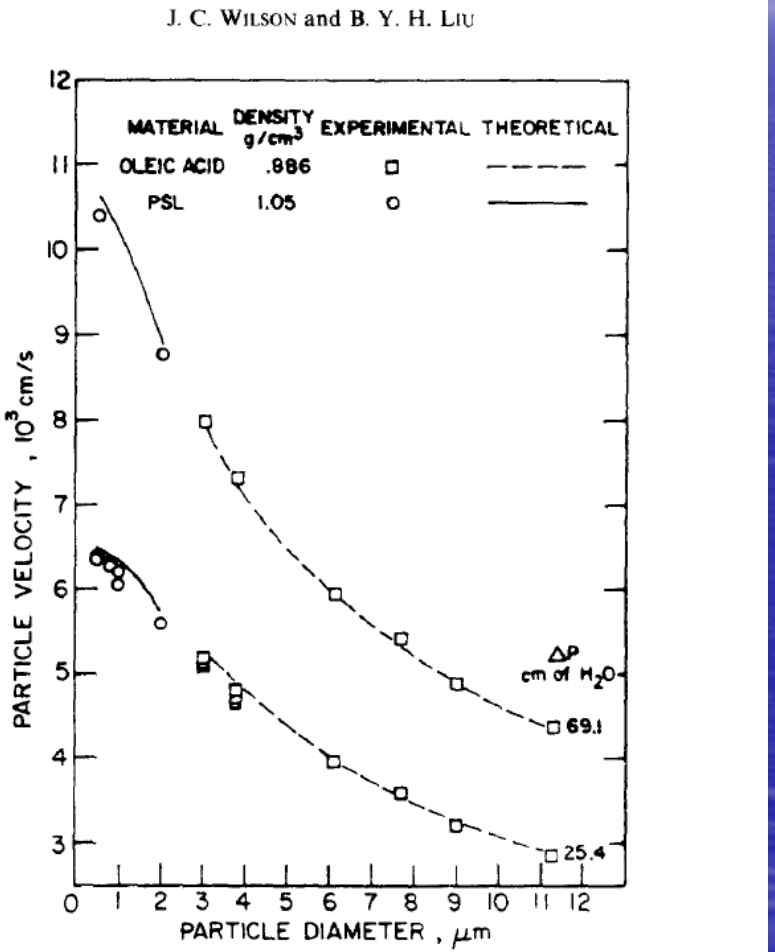


Fig. 2. Schematic of the LDV system.

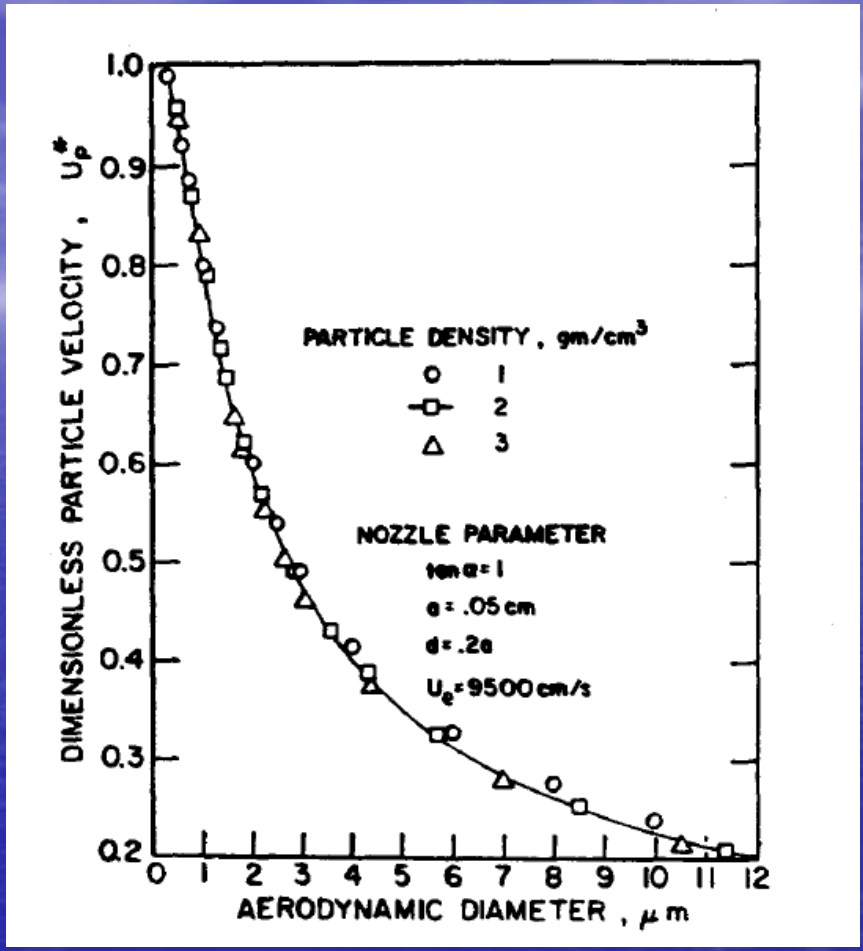
Experimental and Theoretical Test





Effect of Density and Increasing Velocity

- Reducing pressure will permit measuring submicron particles accurately
  - 50 mb, 1 mm nozzle, 4 scc/s
  - Reduces molecular (Rayleigh) scattering



Particle Density

- Physical Size from the DWOPS
- Aerodynamic Diameter from the Velocimetric Measurement
- Calculate particle density

Atmospheric Particles

Aerosol Type	Density, g/cm^3	Real Refractive Index	Imaginary Refractive Index
Organic Carbon	1.4	1.46	0.0
Elemental Carbon	1.9	1.93	0.66
Sulfate	1.77 – 1.84	1.47 – 1.54	0.0

Dick, W. D., Ziemann, P. J., & McMurry, P. H. (2007). Multiangle light-scattering measurements of refractive index of submicron atmospheric particles. *Aerosol Science and Technology*, 41, 549-569 (2007)..

Atmospheric Particles

- Expderiments show that coated particles with irregular cores scatter similarly to spherically symmetrically coated particles. Need to look at the DWOPS to coated particles
- Irregular particles constitute about 20% of the atmospheric aerosol and will be characterized in some way or another with the A-DWOPS.
  - TBD. How many angles to you need to usefully characterize the phase function?
  - I want to compare it with the Cavity Ring Down etc.