Lecture 5:
Aerosol Measurements, Optical Properties Continued

Discussion of Paper:
H_2O_2 Addition to Diesel Engine Exhaust Gas and Its Effect on Particles by Franz et al.

Points to ponder:

What science question are the authors trying to answer?

What techniques were used?

What are the atmospheric implications?

What didn't you understand from reading the article?

Did learn anything by looking it up elsewhere?

Measurements of Scattering and Absorption

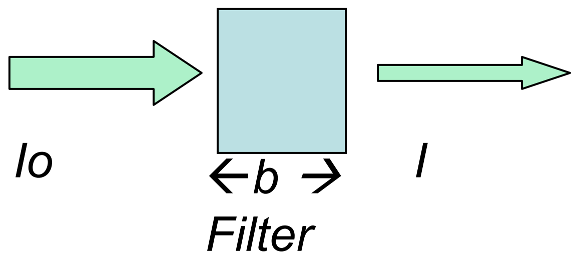
- Point measurements
  1. Scattering coefficients-
  Integrating nephelometers

  2. Absorption coefficient
  Filters
  Aethalometer
  Photoacoustic spectrometry

  3. Extinction coefficient-
  Cavity ring down instruments

(4. Spatial Scattering Parameters-
Small Ice Detector 3 (SID3).
New instrument not covered here…
If curious, see me for more details.)

Measuring Light Absorption by Filter Methods



- The amount of radiation absorbed may be measured by :

Transmittance

- $T = I / I_0$
  % Transmittance, $\%T = 100\ T$
- (I = Intensity of light, Io = initial intensity)

or

Absorbance, $A = \log_{10} I_0 / I$
$A = \log_{10} 1 / T$
$A = \log_{10} 100 / \%T$
$A = 2 - \log_{10} \%T$

The Beer-Lambert Law

- A=ebc

A is absorbance
e is the molar absorbtivity (units of L mol-1 cm-1)
b is the path length of the sample (cm)
c is concentration of absorbers (mol L-1)

Aethalometer (Greek for "To blacken with soot")

"Real-time" filter measurement

Rate of black carbon or other absorber) deposition is proportional to concentration in aerosol

: Hansen et al, 1984, Science of the Total Environment (36, 1984, 191-196)

Calibration:

Quantitative Chemical analysis for black carbon

-Temperature-program analysis of combustion products

Gundel 1984, Sci. of the Total Environmental, 197-202)

Photoacoustic Spectrometer

Advantages

- More accurate in-gas measurements, superior to on-filter methods.
- Improved limit of detection of XX (others 40 nm/m3)

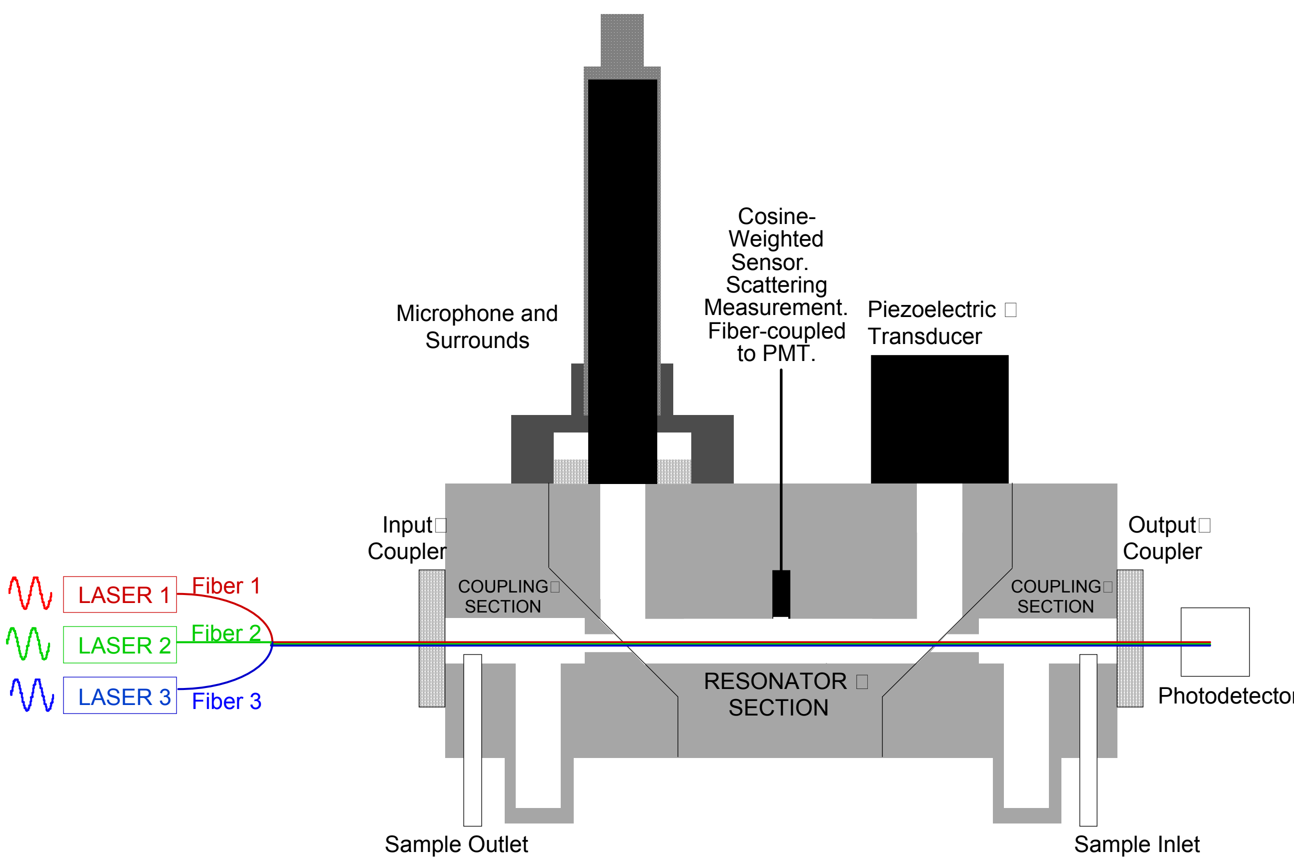
Disadvantages

- Complicated Instrument
- Needs skilled operator.

(Arnott, Atmos. Environment, 33, 1999, 2845-2852)

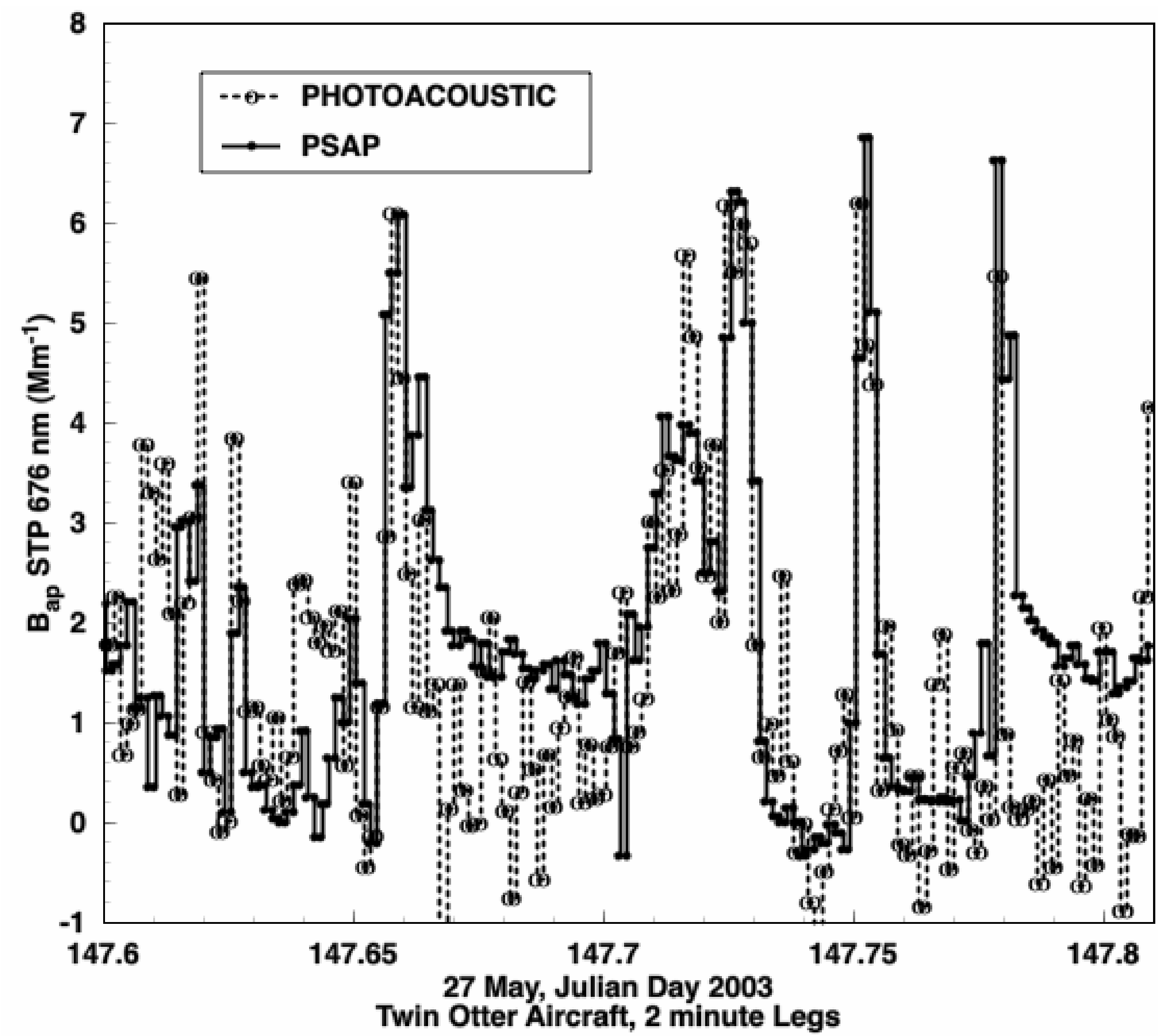
Photoacoustic Spectrometer

- **Schematic of 3 wavelength Photoacoustic instrument with scattering sensor (Arnott, DRI 2005)**

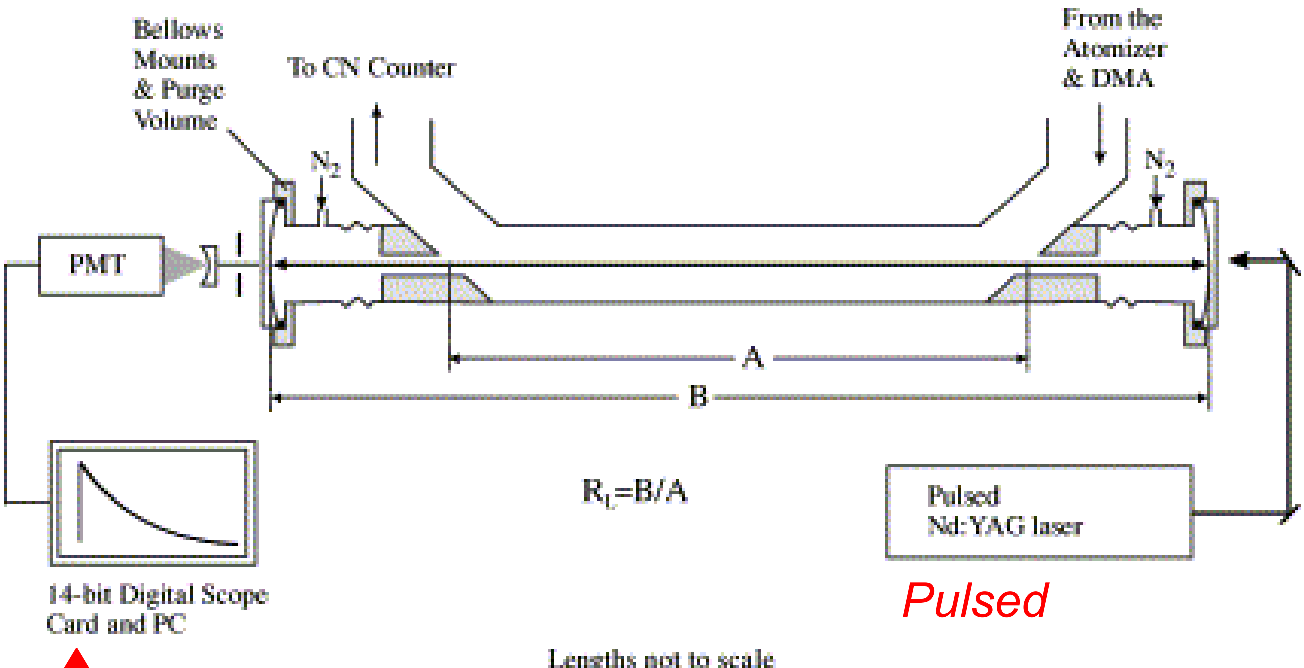


Results for Photoacousitc Spectrometer ~agrees with filter-based measurement

Sheridan and Arnott, 2005



Optical extinction measurements - Cavity Ring Down Spectroscopy (CRDS)



Pulsed

Pulse   Signal Decays

Pettersson et al, J. Aerosol Sci. 2004, 995-1001

CRDS Measurement of Extinction

$$\alpha = \frac{R_L}{c}\left(\frac{1}{\tau} - \frac{1}{\tau_o}\right)$$

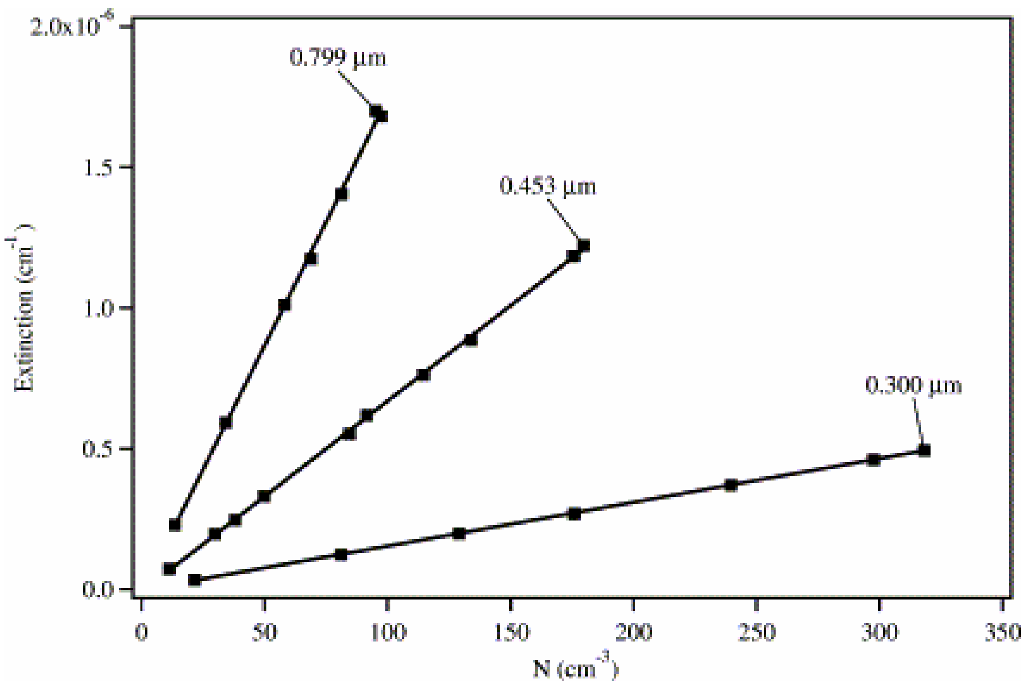
Where α is sample extinction
Rl is ratio of total cavity length to the length occupied by aerosol
T is measured ringdown time
T0 is ring down time with aerosols removed
C = speed of light

CRDS detection limit:

$$\alpha_{min} = \frac{R_L}{c}\frac{\sqrt{2}s(\tau_0)}{\tau_0^2\sqrt{RT}},$$

- where *s*(τ0) is the minimum detectable change in the ring down time for one laser shot, *R* is the repetition rate and *T* is sampling time. For the current system, τ0 is about 75 μs at 532 nm and *s*(τ0) is approximately 0.6 μs, resulting in an instrumental limit of about 1.7×10−9 cm−1 for a one second average.
- → Great! Highly sensitive

Extinction varies with wavelength of light



Extinction efficiency and particle size (at constant wavelength, 532 nm)

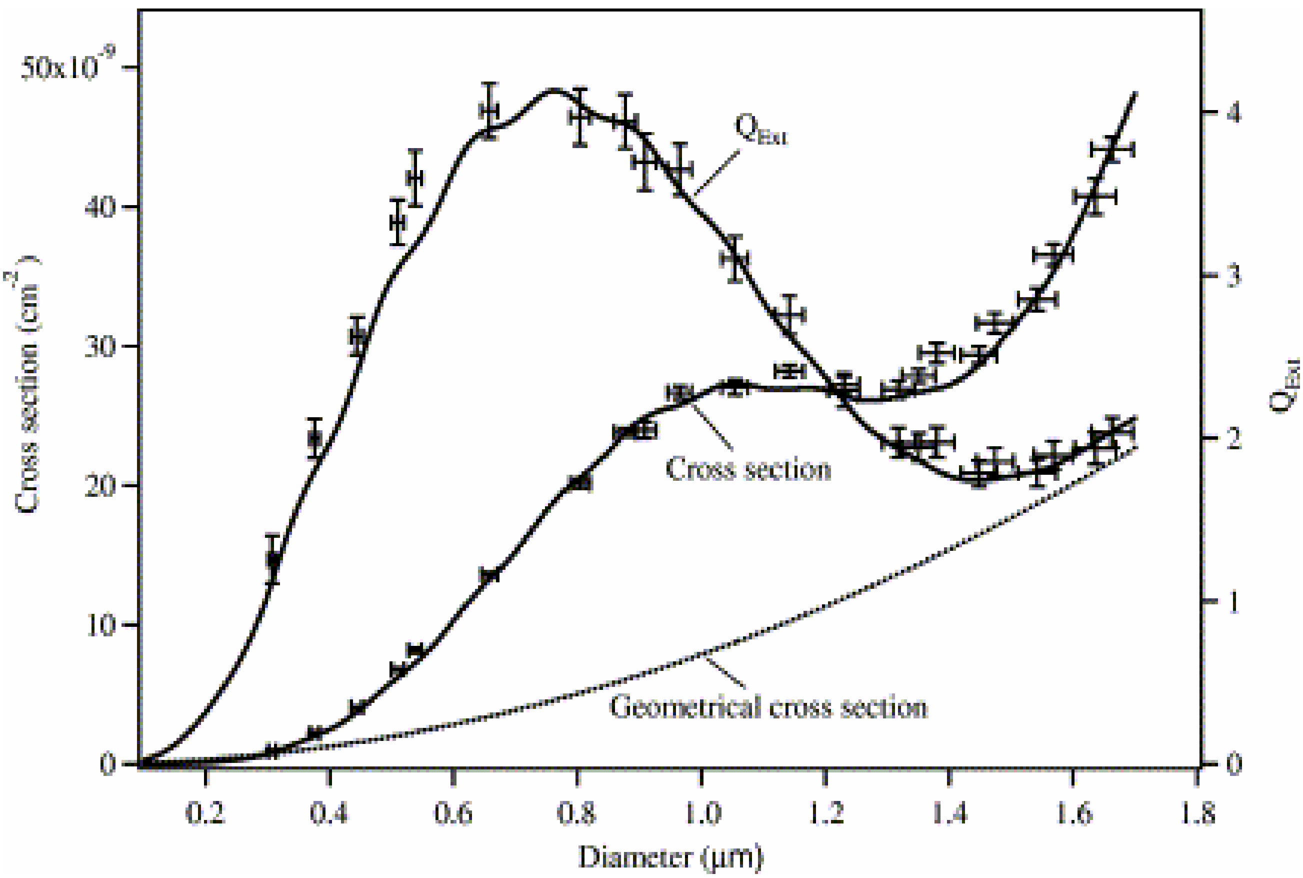


Fig. 3. Extinction efficiency *QExt* and extinction cross section of DOS particles as a function of size. The results are corrected for doubly charge particles. The solid curves are the fits to the experimental values using Mie theory with refractive index as the only free parameter. The fitted refractive index is 1.455.