University of Maryland Baltimore County - UMBC
Phys650 - Special Topics in Experimental Atmospheric Physics
(Spring 2009)

V Martins and MH Tabacniks

http://userpages.umbc.edu/~martins/PHYS650/

CLASS7 – 3/11/2009

Short reports

10:00-10:45 – Discussion of short reports and weekly activities.
10:45-11:00 – Station Manager Report (Adriana)
11:00-12:30 – Single Particle X-Ray Analysis (group a)
12:30-13:30 – Lunch
13:30-15:00 – Single Particle X-Ray Analysis (group b)

LAST CLASS

1. Langley plot for your Sunphotometer

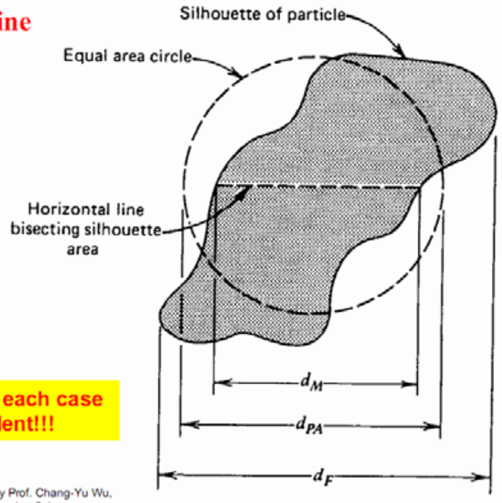
2. Make your own SEM image of
   a) UMBC aerosol sample
   b) A laboratory NaCl aerosol sample

3. Determine the size and mass distribution of 2 given aerosol images:
   - Laboratory generated NaCl sample
   - Ambient aerosol collected on Nuclepore filter (e.g. Smoke from Biomass Burning)

Microscopic Measurement of Particle Size

Q: how do you determine this particle's size?

- Equivalent sizes of Irregular Particles
  - Martin's diameter:
  - Feret's diameter:
  - Projected area diameter:



The particular size to use in each case is highly application dependent!!!

Adapted from ENV 6130 Course on Aerosol Mechanics by Prof. Chang-Yu Wu, University of Florida, Department of Environmental Engineering Sciences

2 minutes of Google

http://www.hanford.gov/dqo/training/lognor.pdf

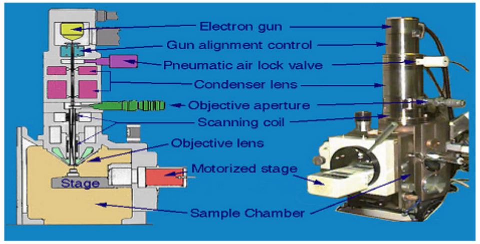
EPA-LogNormalSizeDistributionBCES-3.pdf

http://www.atmos.washington.edu/2008Q4/501/documents/501_Tuesday_Handout.doc

$$\frac{dN}{d\ln(r)} = \frac{N}{\sigma\sqrt{2\pi}} \exp\left\{ -\frac{\left[\ln(r) - \ln(r_{g0})\right]^2}{2\sigma^2} \right\}$$

Introduction SEM:

Scanning Electron Microscope (SEM) is a microscope which uses highly energetic electrons instead of light. These SEM have higher resolution, higher magnification and greater depth of focus in comparision to a general light microscope.



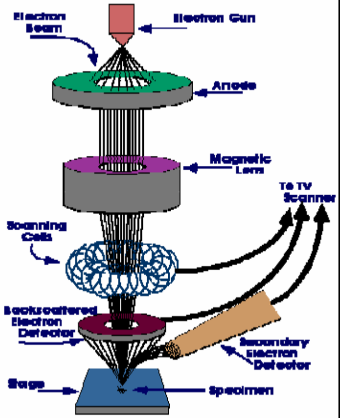
Preparing Sample:

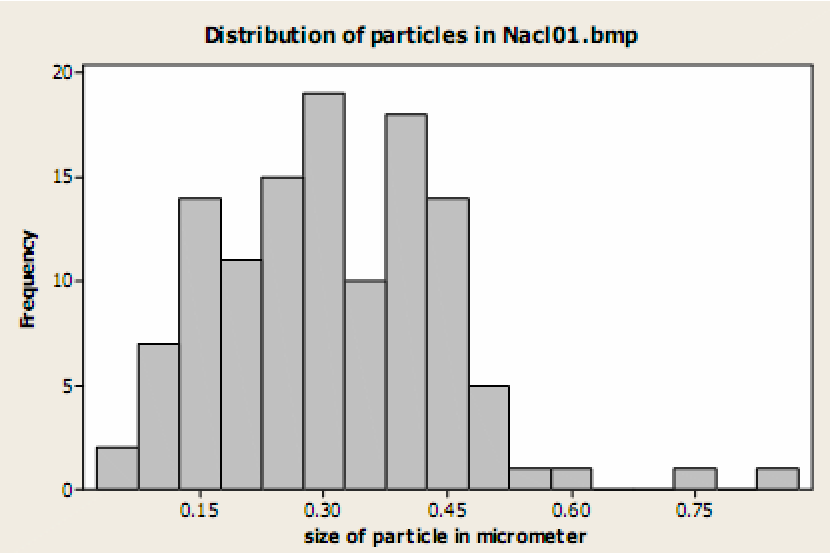
Most of the SEM requires that the sample is electrically conductive. So if we have some non conducting sample, we must cover the sample with thin coat of conducting material like gold or carbon with the help of device called sputter coater. For this first the sample is placed inside the device and vaccum is created and then Argon gas is introduced. Then a high electric field is used which removes electron from its atom and make it ions. These positively charged argon ions are attracted toward the negatively charged gold foil and the gold atoms are knocked out from the gold foil. These gold atoms fall in the surface of the sample resulting a thin coat around the sample. If the vaccum is not created the gas molecules would get in the way of the argon and gold resulting uneven coating.

Working of SEM:

It consists of an electon gun made up of tungsten filament which produces a beam of electrons when heated. The electrons so produced are accelerated by anode, condensed by a condenser lens and focused as a very fine point on the sample by the objective lens. Then the electrons are ejected out of the sample. Detectors collect these secondary electrons and convert them to a signal which produces the image on the screen.

The column and sample inside SEM must be in vacuum. If the filament were surrounded by air, it would quickly burn out, like a light bulb. If the column were full of air, the electrons would collide with the gas molecules and never reach the sample. If gas molecules react with the sample different compounds could form and condense on the sample. This can lower the quality of the image.

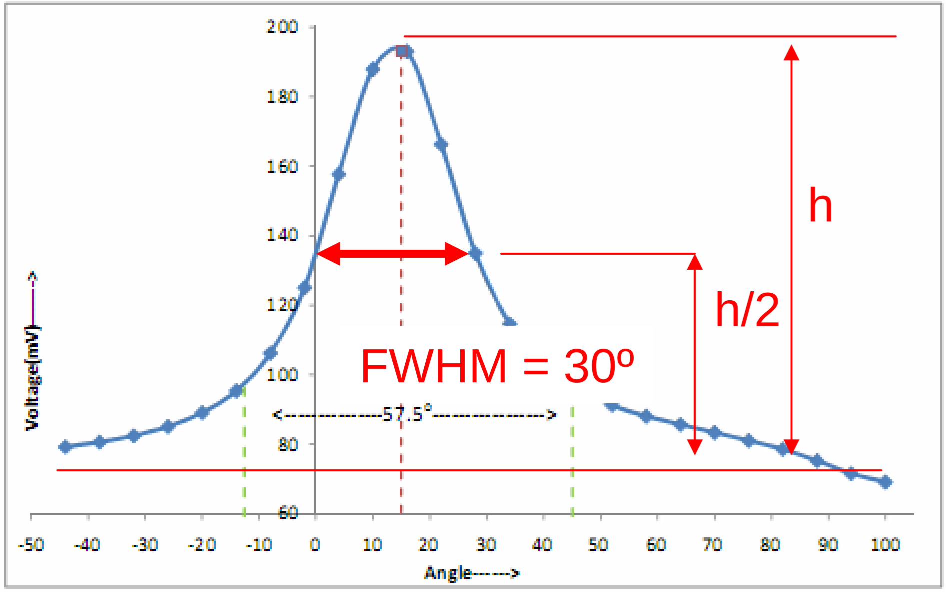




For this I measured the diameter of the particles along their longest side and plotted the histogram as below. This histogram is for the distribution of particles in Nacl01.bmp. The graph shows that most of the particles in Nacl01.bmp are in the range 0.15 to 0.45 micrometer in diameter.

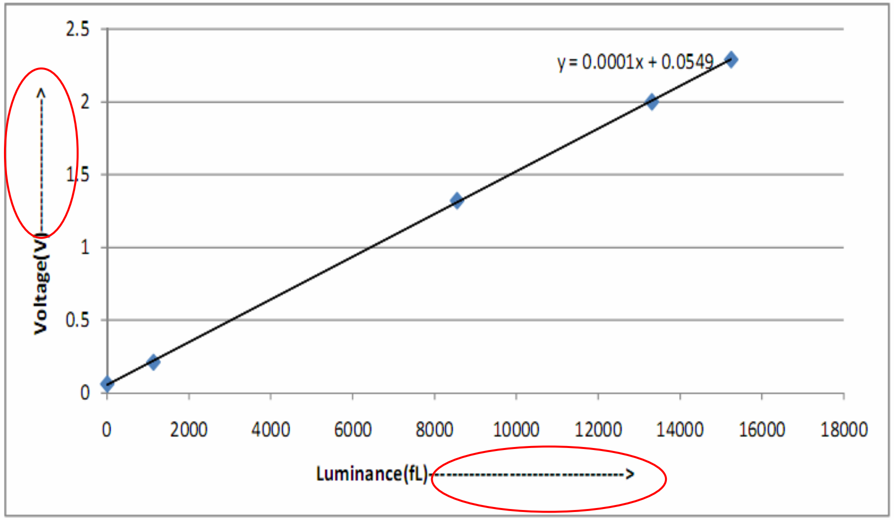
So what?

NaCl01



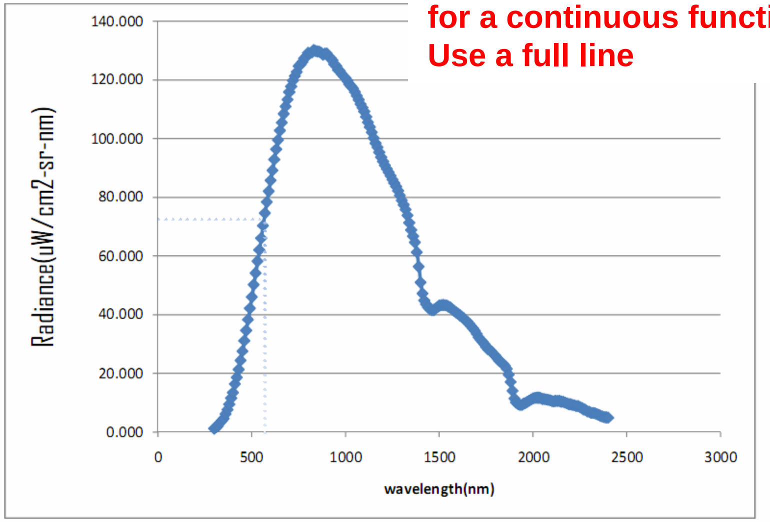
Wrong

To calibrate the sun photo meter the field of view of its LED has to be determined. To find the field of view of our LED, we put our LED in front of monochromatic light source. To make the light parallel we place a convex lens between light source and our sun photometer. With the center of the light on the

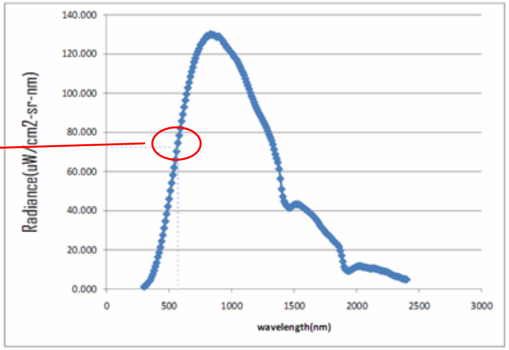


wrong

Do not plot data points for a continuous function
Use a full line

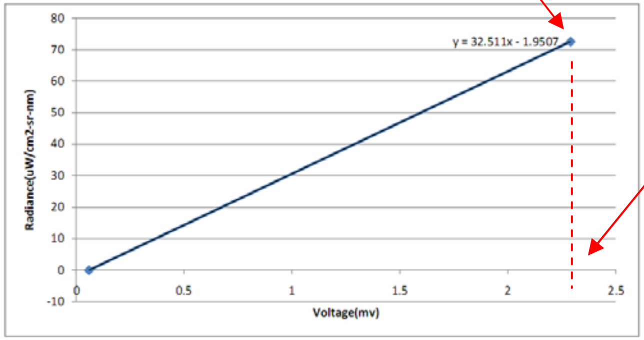


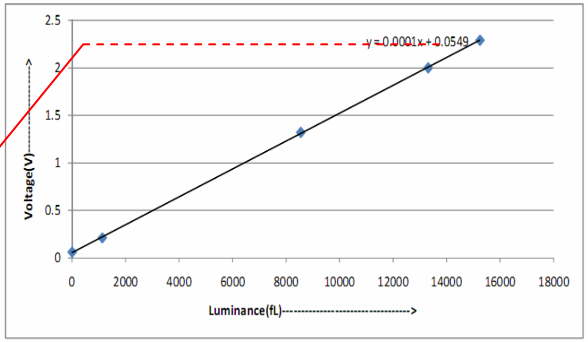
peak wave length of the LED as 566nm



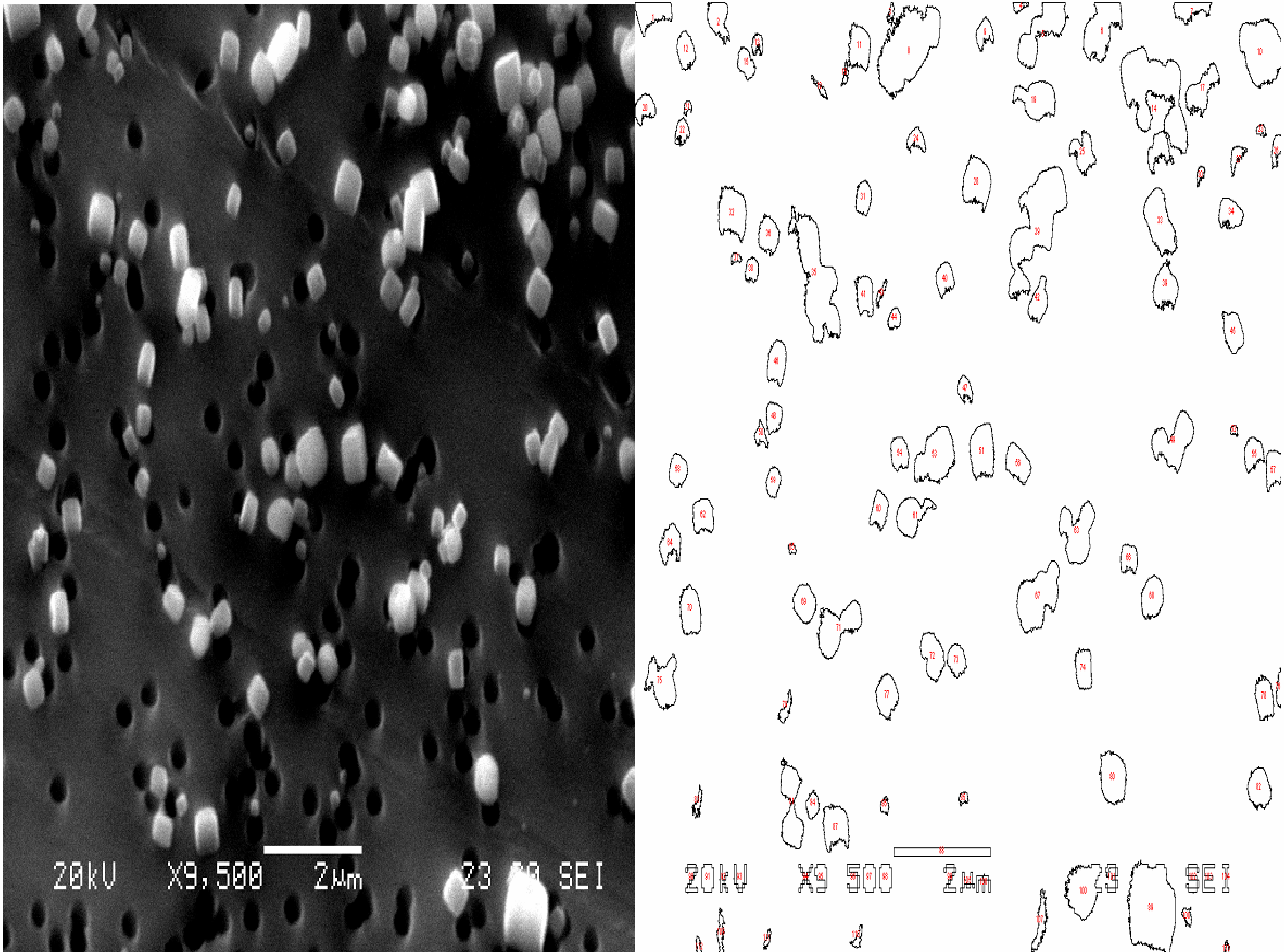
From the graph it is seen that radiance corresponding to the 566nm wave length is 72.5uW/cm2-sr-nm

wrong





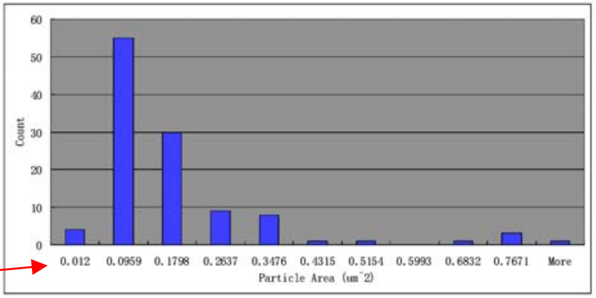
Thus the number of photons per second is found to be $2.064X10^{14}$ (when all lamps are on)


20kV
X9,500
2μm
SEI

1.2 Summary of NACL01.BMP

Slice	Count	Total Area (μm^2)	Average Size (μm^2)	Area Fraction	Mean
NACL01.BMP	113	14.969	0.132	11.2	255

From this summary table, we can see that there are approximately 113 salt particles totally in this sample. And the average particle area is 0.132 μm^2 .But the Imagej mistakenly treats the bottom text line "20KV x9,500 …" as particles. In addition, it also sees a group of overlapping particles, for example, count number 14, as one big particle rather than a few of particles. Furthermore, it couldn't tell the filter holes, in the same size magnitude of particles like the ones in the left bottom, from the particles. In a word, this is just a rough particle analysis.



Scale !!

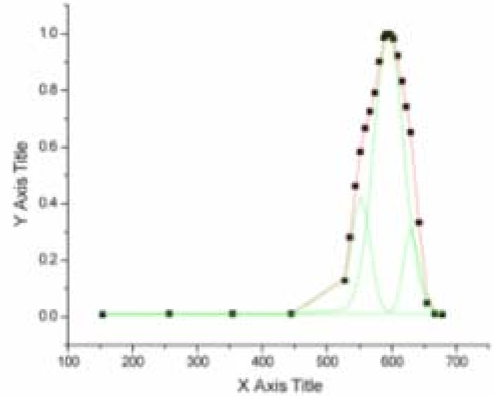
A 3 gaussian fit to the LED emission curve

a)

[3/10/2009 15:00 "/Graph1" (2454900)]
Data: Data1_B
Model: Gauss

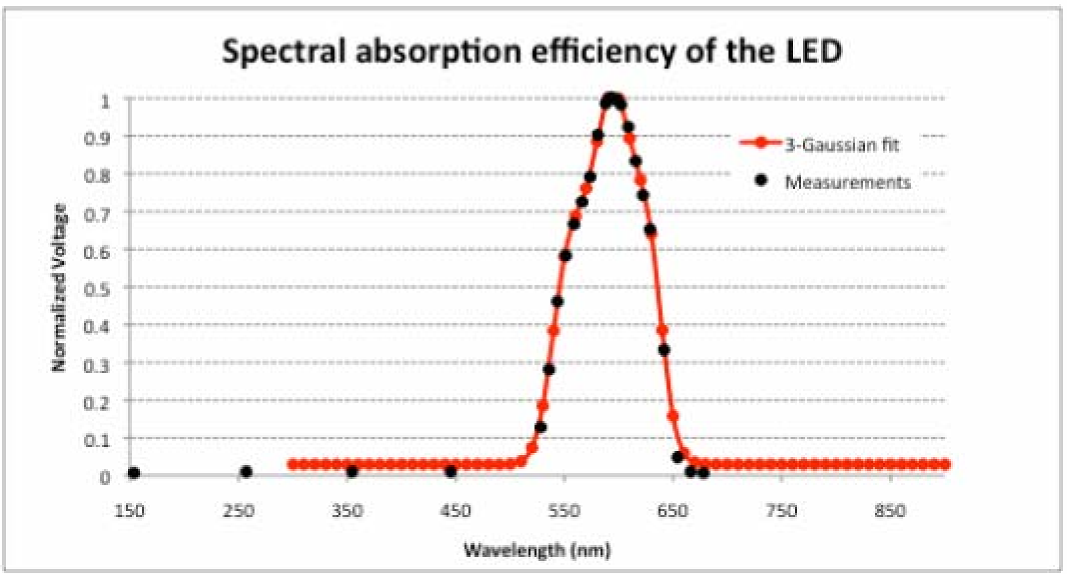
Chi^2/DoF	R^2
0.00016	0.99923

Parameter	Value	Error
y0	0.01	0
xc1	595	0
w1	46.19869	4.25754
A1	57.6926	5.63789
xc2	551.68296	1.35304
w2	29.33028	1.72468
A2	15.26261	2.87294
xc3	630	0
w3	23.51033	2.17487
A3	9.01868	2.77811



y=y0 + (A/(w*sqrt(PI/2)))*exp(-2*((x-xc)/w)^2)

b)



Two figures and a simple text explain in detail the FOV measurements

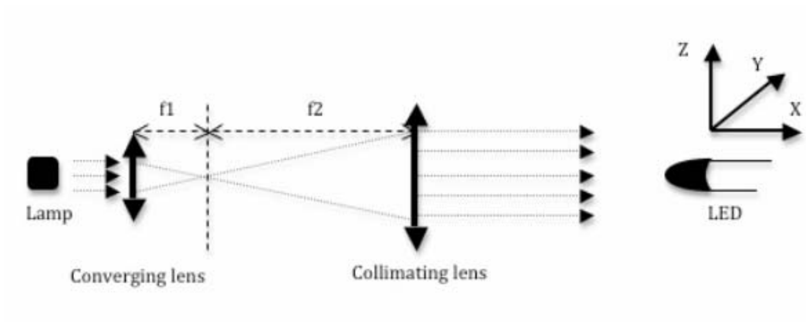


Figure 2: Experimental set up to measure the LED's Field of view

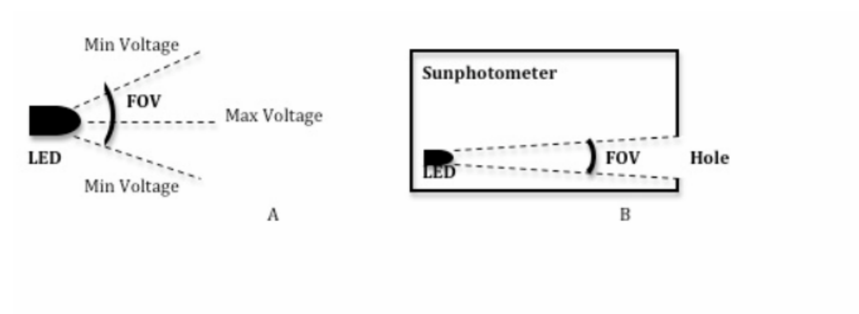


Figure 3: Measurement of the LED (A) without the collimator and inside the box (B).

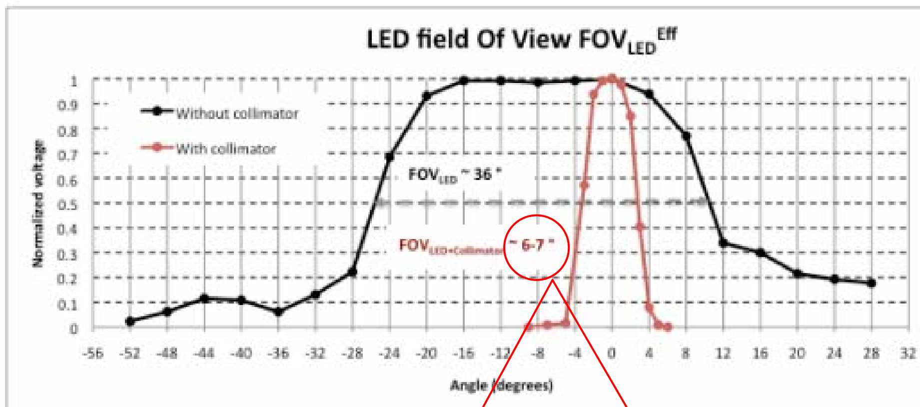


Figure 4: Normalized (to the maximum) voltage of the LED, function of the angle with (red) or without (black) the collimator

If the LED was considered as a point, the FOV of the LED with the collimator would be equal to 2 x $\tan^{-1}$ (radius of the hole/2 x distance LED-hole) ~ 4 ° But the LED is in reality a finite point with a radius of ~2.3 mm.

Let's call Ω_{LED} , the solid angle of the LED (in sr) with
$\Omega_{LED} = 2\pi(1-\cos(\theta))$.

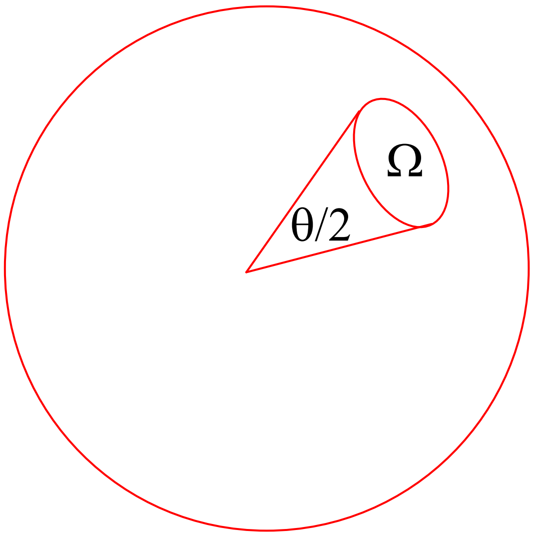
We also need to define the "Efficient LED solid angle",

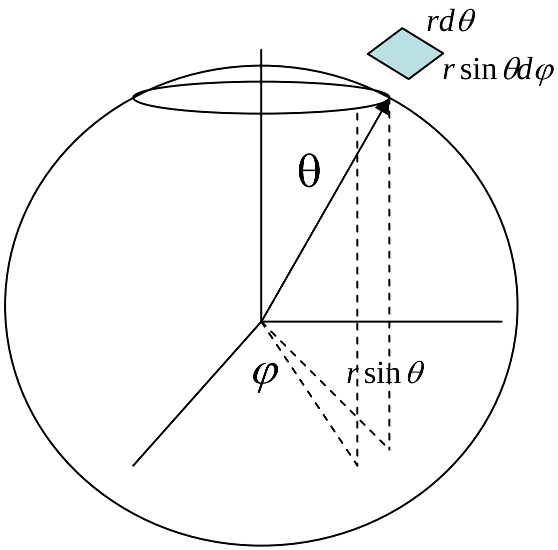
$$\Omega_{LED}^{Eff} = \int_{d\theta} FOV_{LED}^{Eff} \times 2\pi(1-\cos(\theta))d\theta$$

with FOV_{LED}^{Eff} as the red curve on figure 4.

After integration, we obtain:
$\mathbf{\Omega^{Eff}_{LED} = 0.92\ sr}$

Note: This value represents ~1% of the whole sphere (4 π sr)





$$ds = rd\theta . r\sin\theta d\varphi$$

$$\Omega = \iint \frac{ds}{r^2} = \int_0^{2\pi} d\varphi \int_0^{\theta} d\theta \sin\theta$$

$$\Omega = 2\pi \int_0^{\theta} d\theta \sin\theta = 2\pi[-\cos\theta]_0^{\theta} = 2\pi(1-\cos\theta)$$

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$$\Omega_{LED}^{Eff} = \int_{d\theta} FOV_{LED}^{Eff} \times 2\pi(1-\cos(\theta))d\theta$$

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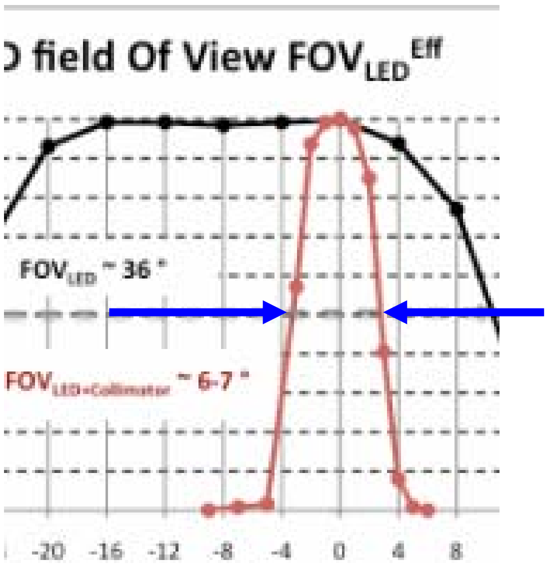


$$\left(\frac{\theta}{2}\right)_{FWHM} = \frac{3.2-(-3.5)}{2} = 3.4^0 = \frac{\pi 3.4}{180} = 0.059rd$$

$$\Omega_{FWHM} = 0.0110\ sr$$

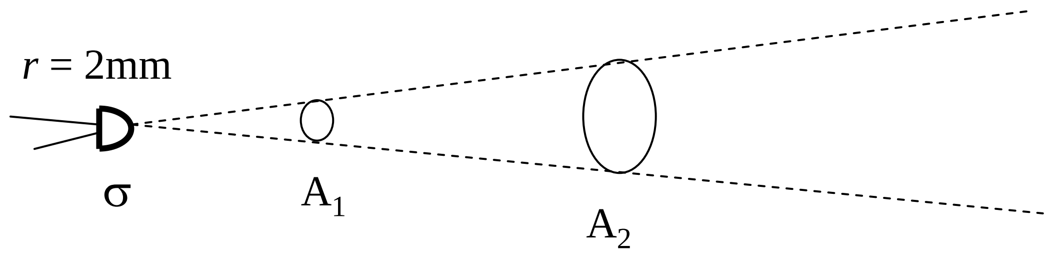
$$\frac{\Omega}{4\pi} = \frac{0.0110}{4\pi} = 0.00088$$

Finally, we define the LED cross section, σ_{LED}, as the cross section of the collimator hole of the sunphotometer with $r_{hole} = 2.32$ mm:

$\sigma_{LED} = 4\,\pi \times r_{hole}^{\;2}$

=> $\boldsymbol{\sigma_{LED} = 0.68\ cm^2}$

CROSS SECTION



$$\sigma = \pi r^2 = 0.12\,cm^2$$

The measurements are displayed on figure 6 below.

Sphere			Sunphotometer
Radiance (590-600 nm)	Volts	Lamps	Volts
88.11	164.07	4: ITHS300-ITS150-ITHS75-ETHS150	1.34
1.30	55.27	3: ITS150-ITHS75-ETHS150	1.30
1.23	31.27	2: ITHS75-ETHS150	1.23
10.48	19.52	1: ETHS150	0.99
0.00	0.00	0	0.00

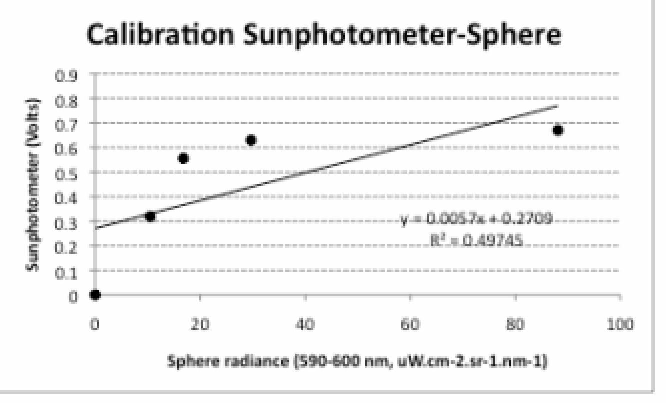


Figure 6: Calibration of the sunphotometer with the sphere by turning down the lamps once at a time

there is something wrong. We have only 2 intensity calibrations for the sphere and other plots V x radiance came out straight lines

5. Number of photons absorbed by the LED per seconds

Let's start with the spectral radiance calibration of the sphere, R_{Sphere} [micro $W.cm^{-2}.sr^{-1}.nm^{-1}$] as given by the "Sphere Optics" manual (figure 7 below).

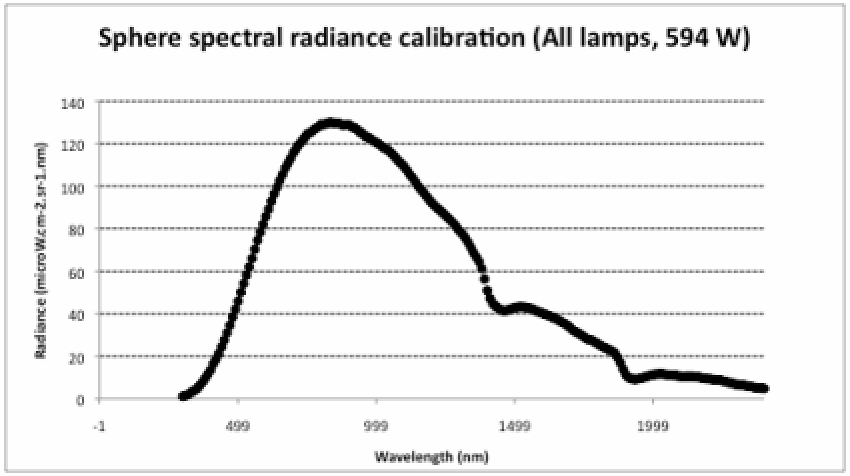


Figure 7: spectral radiance calibration of the sphere with all 4 lamps activated

Below are four steps to compute the number of photons absorbed by the sunphotometer per second:

1. Computing the LED spectral Emittance, E_{LED}, by multiplying the spectral radiance of the sphere, R_{Sphere} and the efficient solid angle, Ω_{LED}^{Eff}:

$$E_{LED}(\lambda) = R_{sphere}(\lambda) \times \Omega_{LED}^{Eff}$$ in [micro W.cm^{-2}.nm]

$$\boxed{\Omega_{FWHM} = 0.0110\, sr}$$

2. Computing the LED spectral power, $P_{LED,\lambda}$ by multiplying E_{LED} and the LED cross section, σ_{LED}:

$$P_{LED,\lambda} = E_{LED}(\lambda) \times \sigma_{LED}$$ in [micro W.nm]

$$\boxed{\sigma_{LED} = 0.12\ cm^2}$$

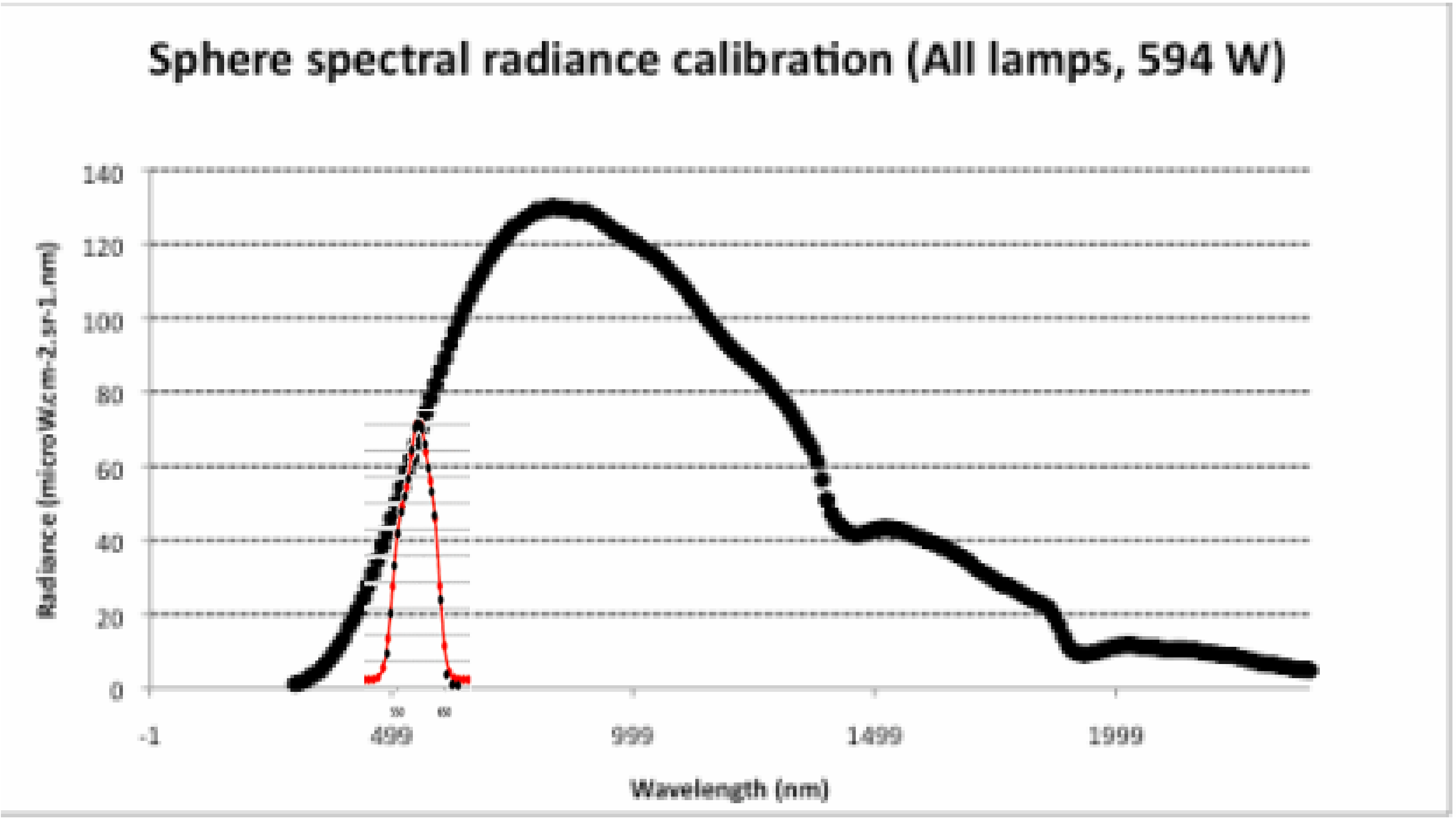
3. "1 Watt" is "1 Joule per second" and "1 Joule" is the number of photons times the Energy. Finally, since the energy is hν, "1 Watt" equals "Number of photons x hc/λ".
Let's compute the Number of photons per second per wavelength, $N_{LED,\lambda}$:

$$N_{LED,\lambda} = P_{LED,\lambda} \times \frac{\lambda}{hc}$$ in [nm.s^{-1}]

with h = 6.62606896.10^{-34} J.s^{-1}

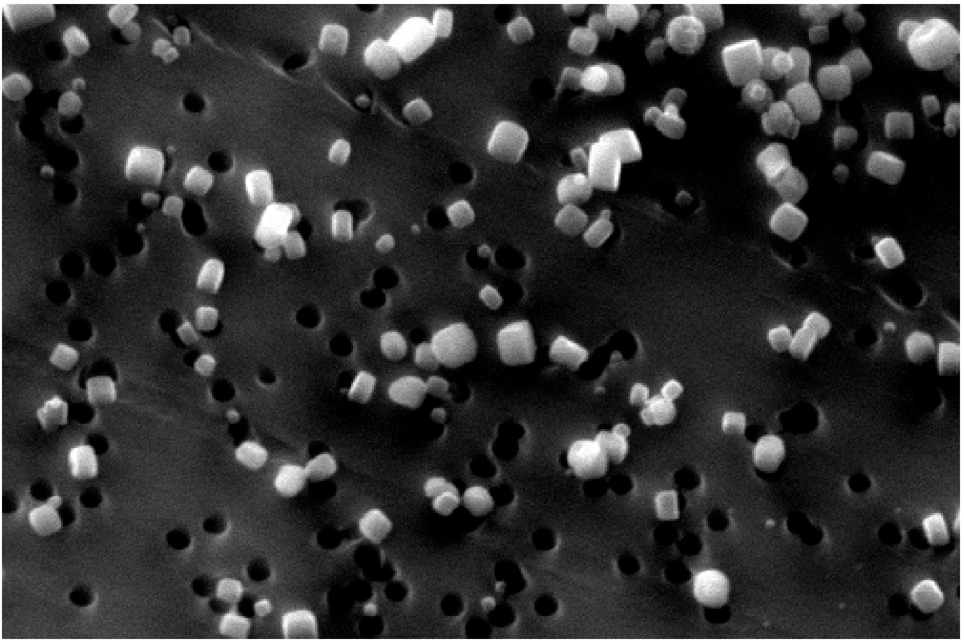
4. Finally, we can multiply the number of photons per second per wavelength by the normalized spectral efficiency of the LED, $SE_{LED,\lambda}$ (see section 1) and integrate the product on each wavelength:

$$N_{LED,\lambda} = \int_{\lambda} N_{LED,\lambda} \times SE_{LED,\lambda} d\lambda$$ [s^{-1}]



$$N_{LED,\lambda} = \int_{\lambda} N_{LED,\lambda} \times SE_{LED,\lambda} d\lambda \qquad [s^{-1}]$$

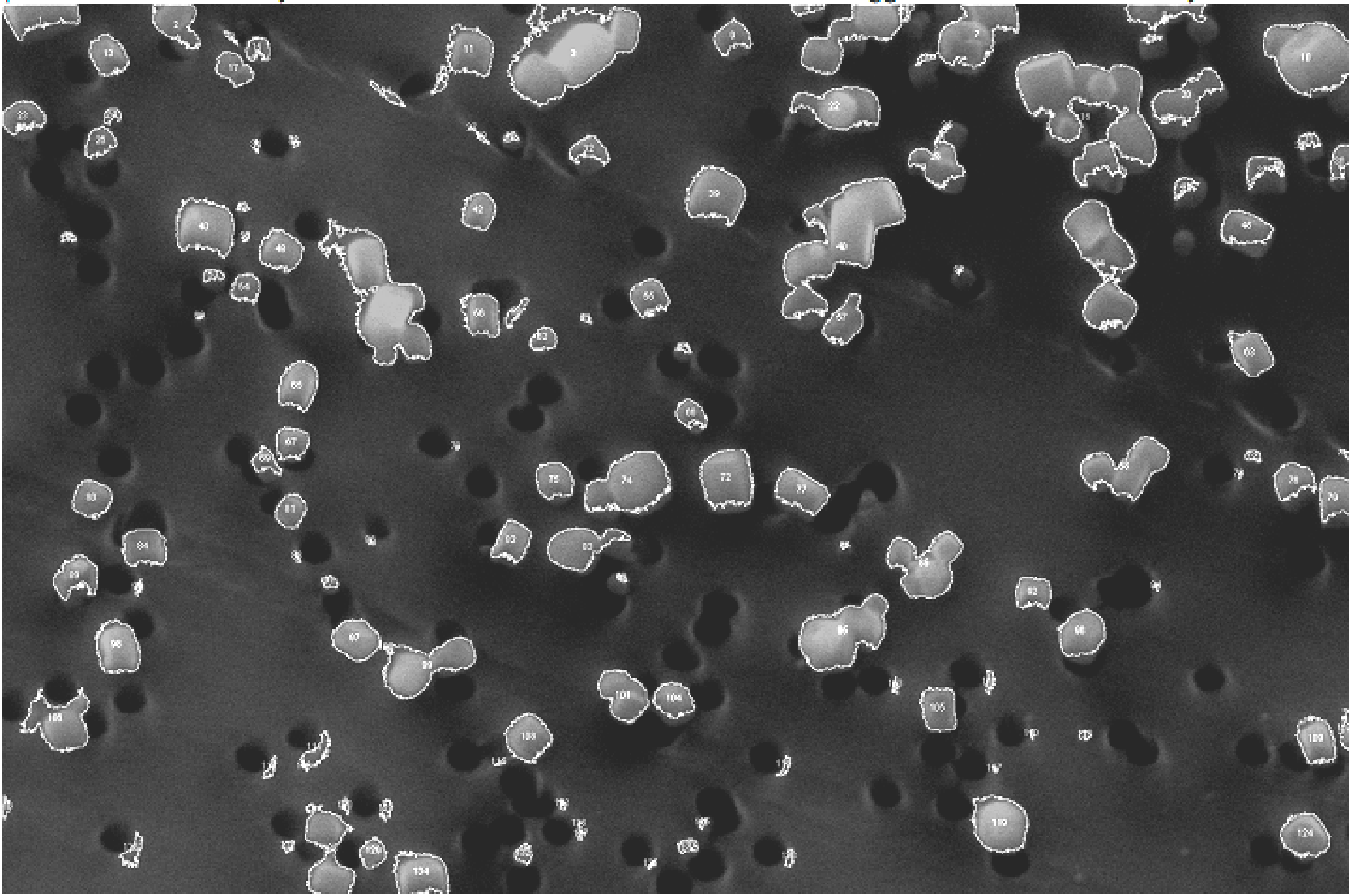
We must convolute the LED absorption and the sphere radiance



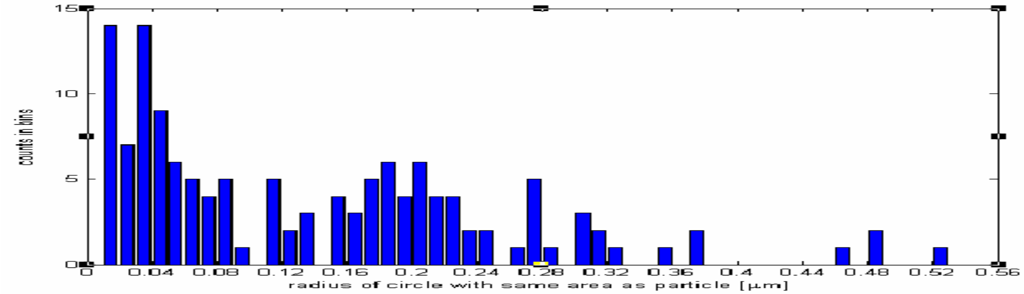
I used ImageJ to process this image.

I measured the length of the scale bar at the bottom of the image in pixels and used this number to set the units in ImageJ, so from that time all the size measurements were displayed in µm by the ImageJ software.

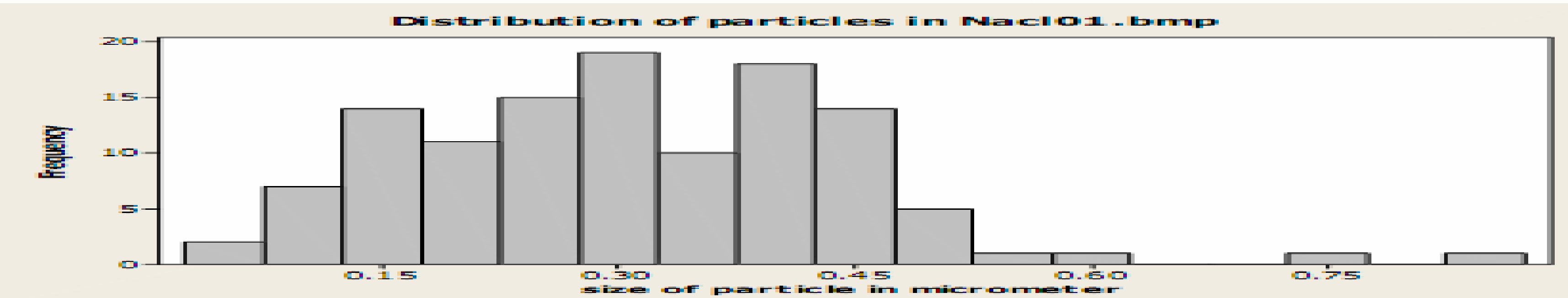
I cropped the bottom with the text and applied a threshold operation of 92 or higher to 0 and lower to 255. The results was:



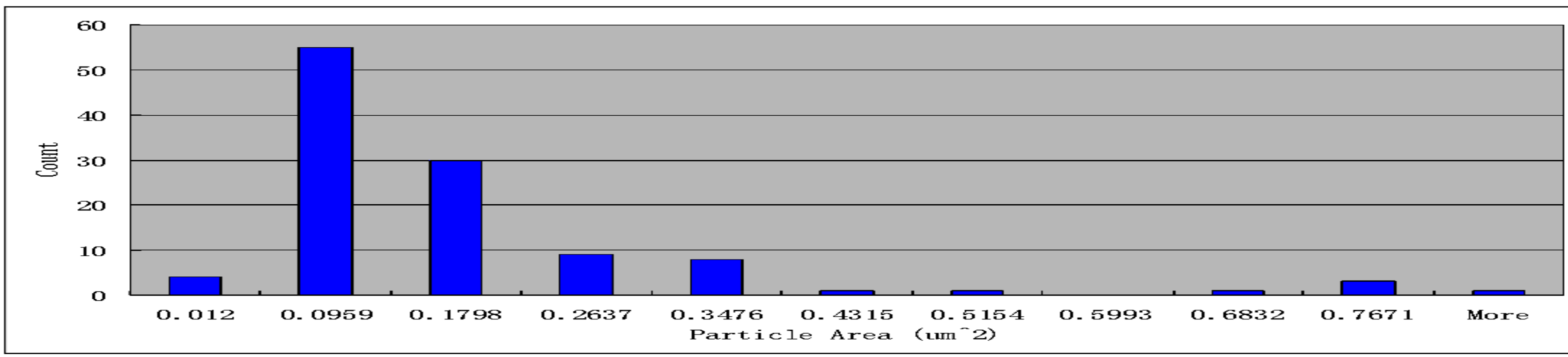
Then I used the command in the analyze menu to detect particles (closed edges) and this gave me a list of particles, numbered (in red in the image below) and with their locations. This is called the mask.



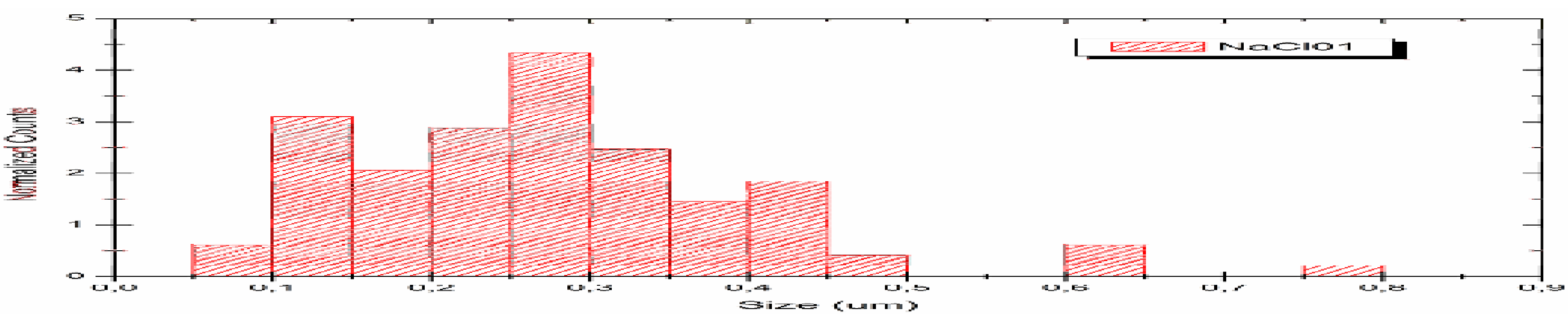
counts in bins
0
5
10
15
0
0.04
0.08
0.12
0.16
0.2
0.24
0.28
0.32
0.36
0.4
0.44
0.48
0.52
0.56
radius of circle with same area as particle [µm]



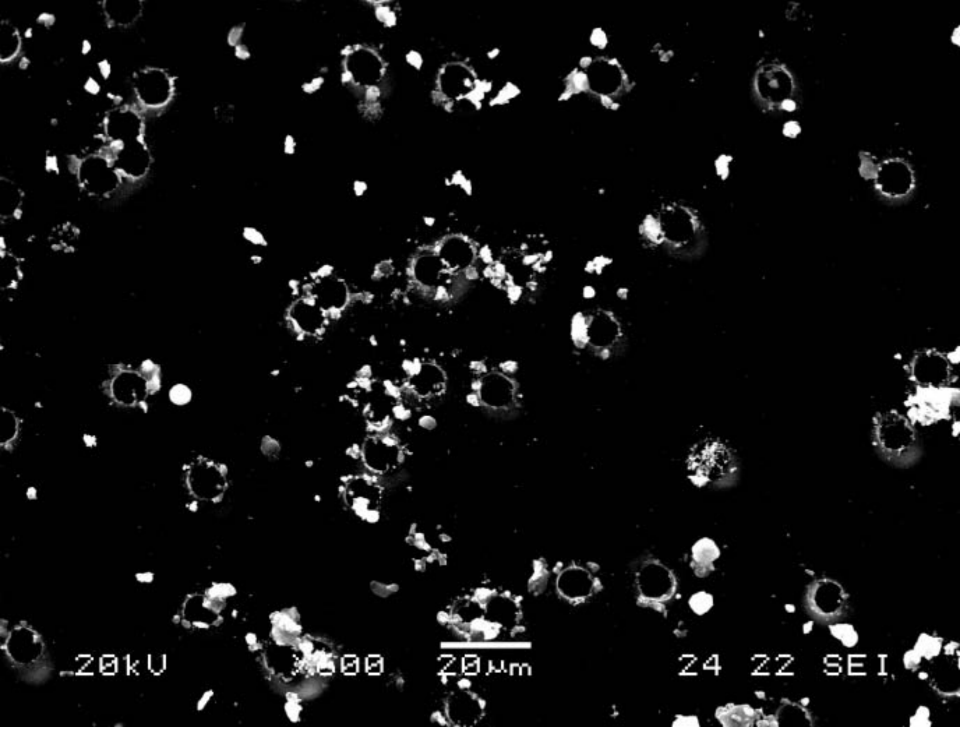
Distribution of particles in Nacl01.bmp
Frequency
0
5
10
15
20
0.15
0.30
0.45
0.60
0.75
size of particle in micrometer



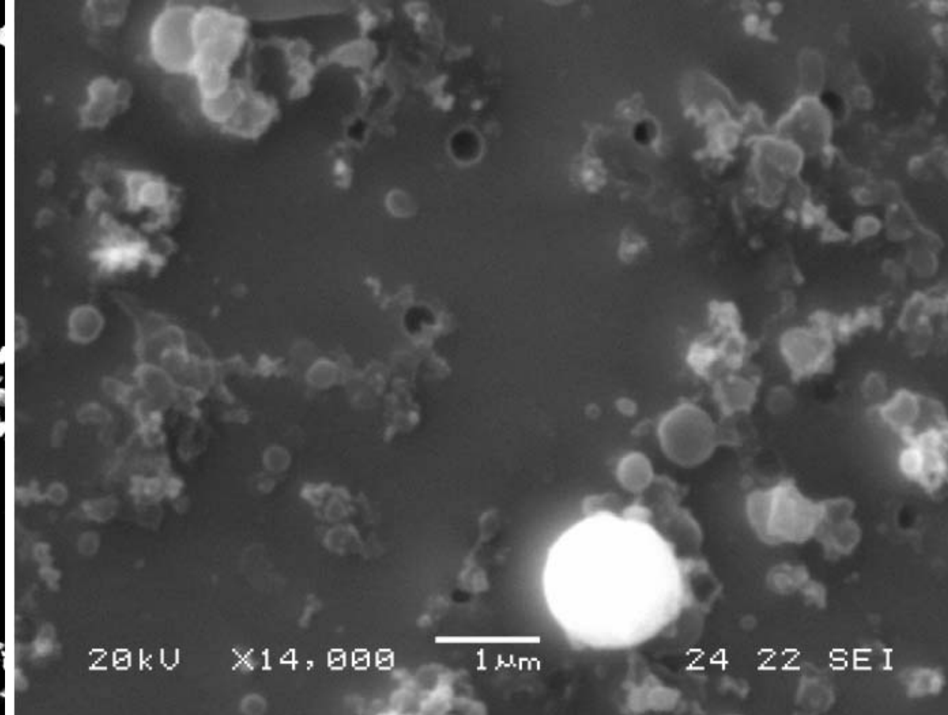
Count
0
10
20
30
40
50
60
0.012
0.0959
0.1798
0.2637
0.3476
0.4315
0.5154
0.5993
0.6832
0.7671
More
Particle Area (um^2)



Normalized Counts
0
1
2
3
4
5
NaCl01
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Size (um)



MXA63C

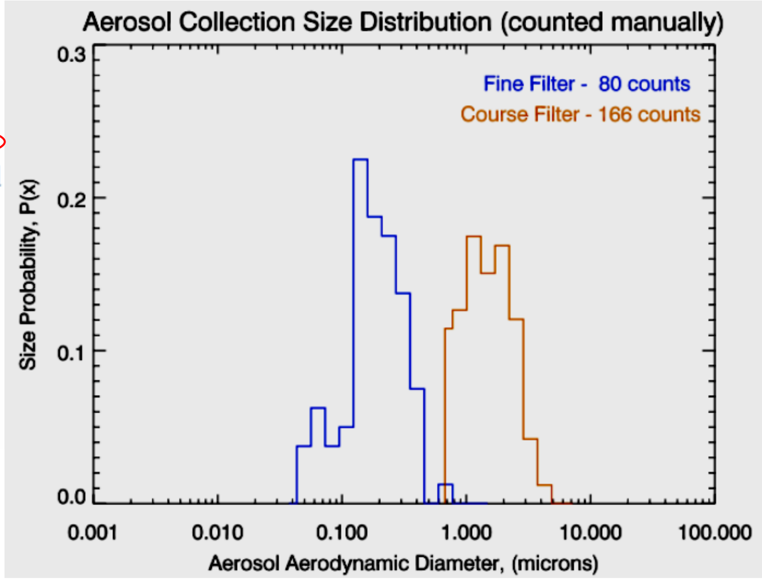


MXA63F

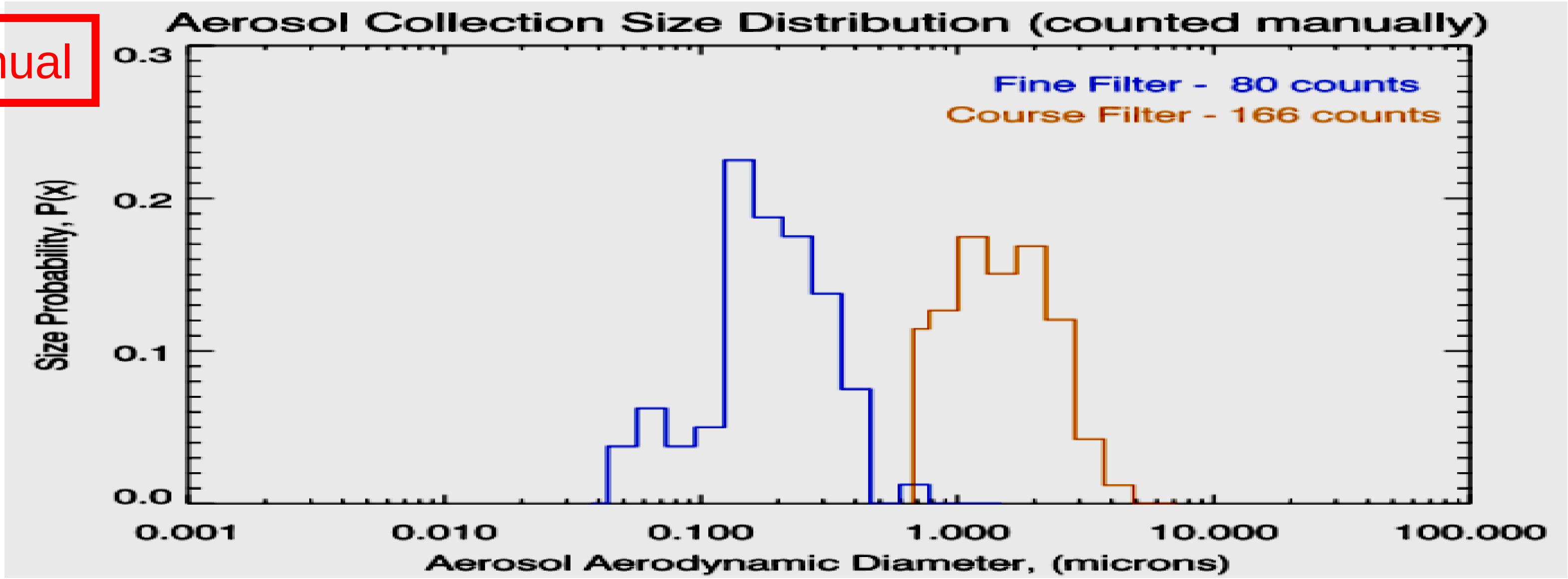
The area of an aerosol was then found by outlining it using the ImageJ program, which computed the area of the outlined aerosol. The use of a digital pen tablet expedited this process. A metric for the aerosol size was found by assuming that all of the aerosols held a sphere-like shape, The diameter of these spherical aerosols, called the aerodynamic diameter, were found from:

$$d_{AD} = 2\frac{\sqrt{a}}{\pi}$$

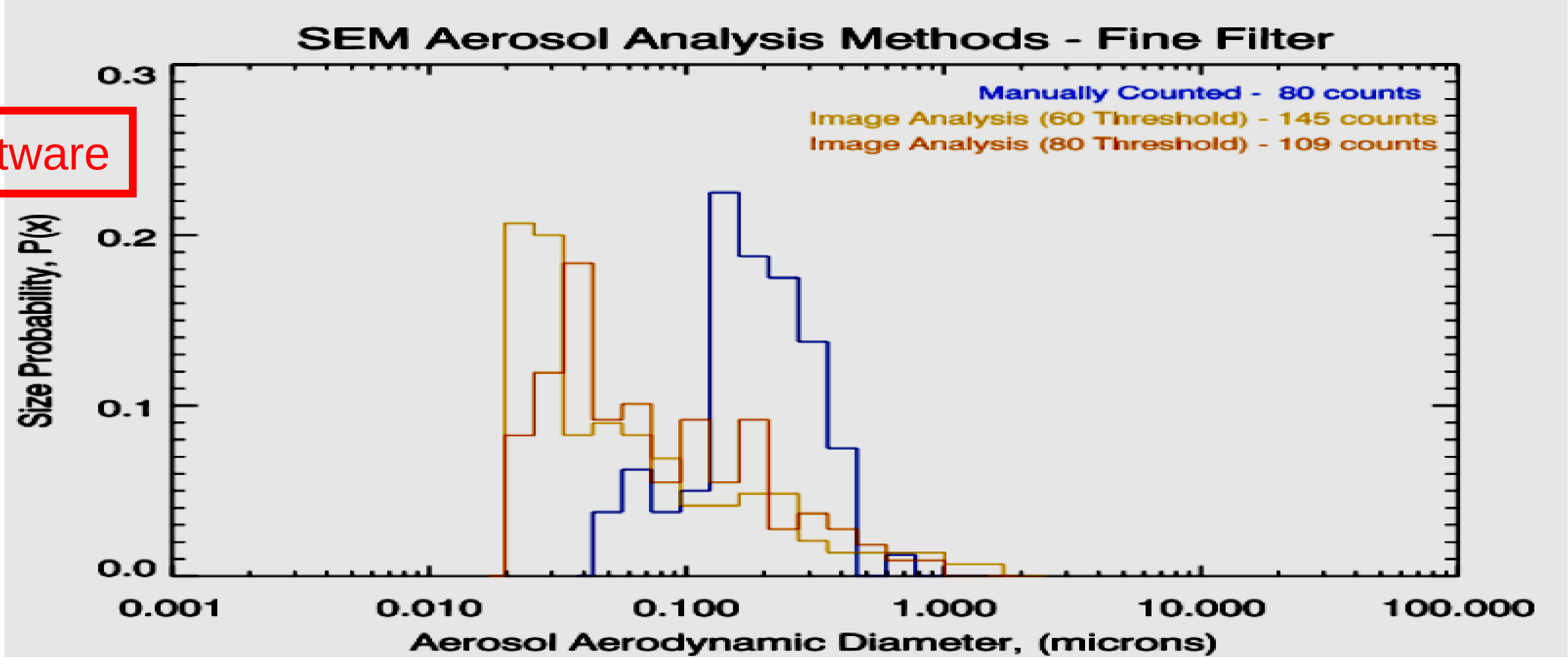
where d_{AD} is the aerodynamic diameter and a is the measured area of an aerosol. This



Manual



Software



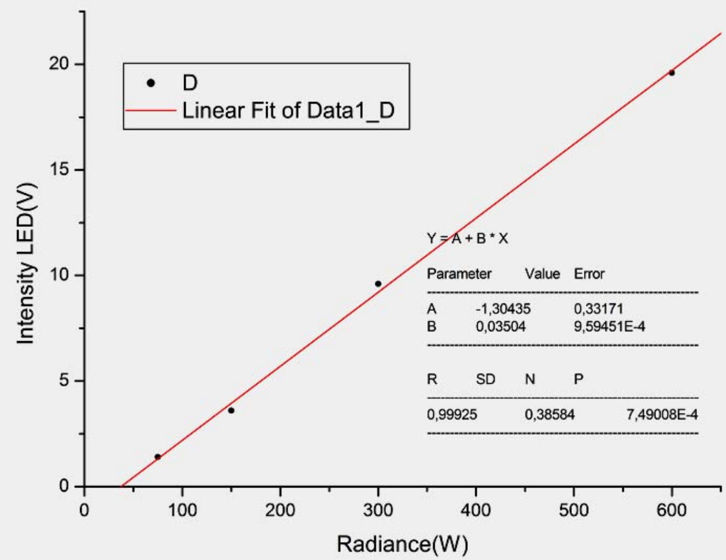


Fig.4 *Linear fit of the absorption LED in function to Sphere Optic Radiance.*

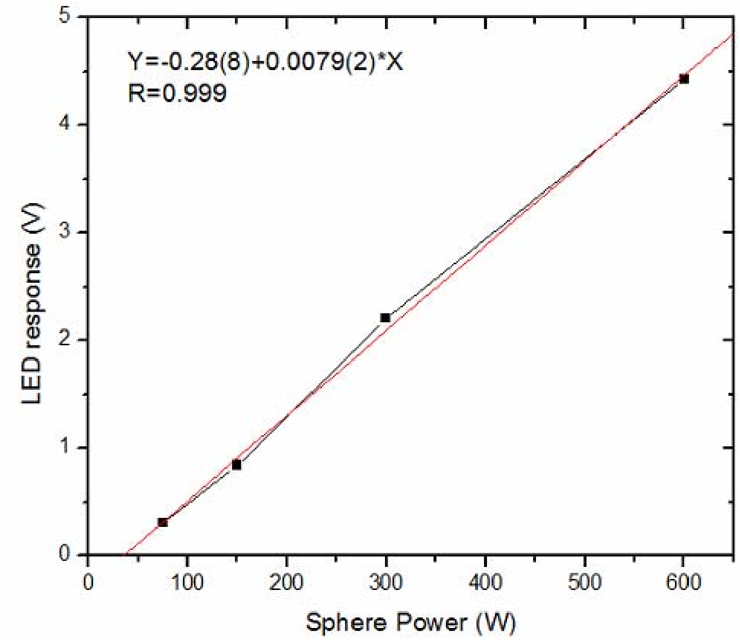
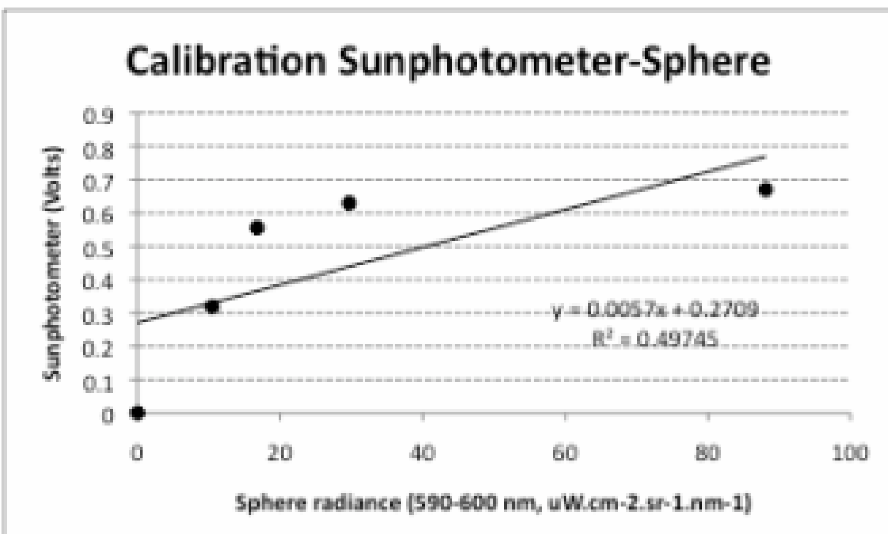
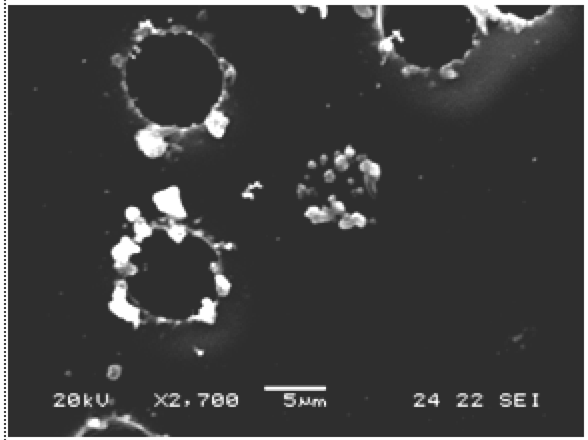


Fig 2 – Linear fit in the calibration dataset using an integrating sphere. (Dark current correction was applied).

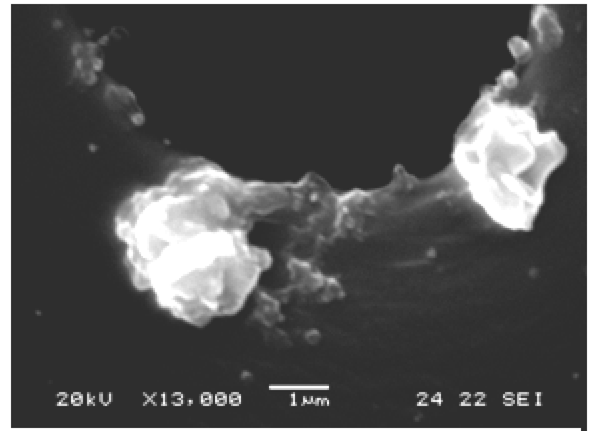


Coarse·Filter·Pictures:¶

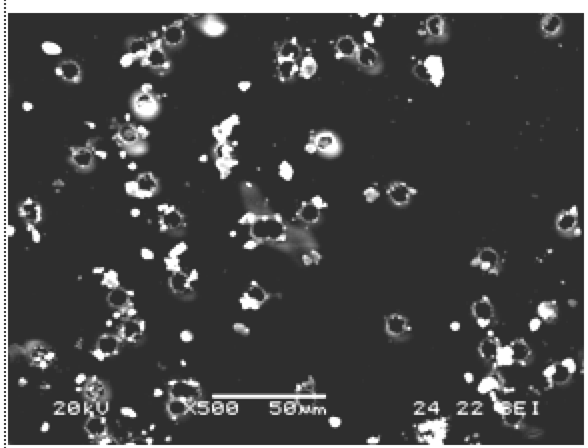
Page Break



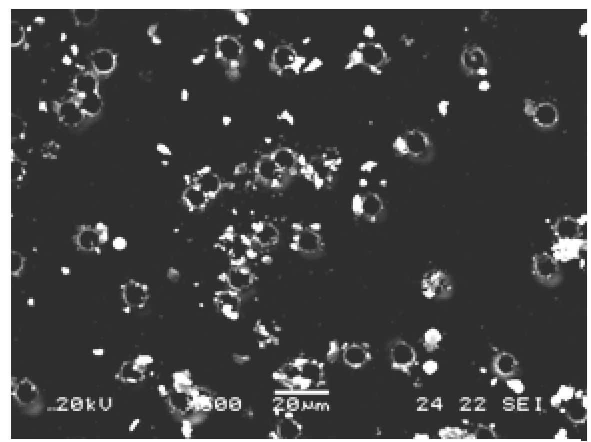
Figure·1:·MXA-63C·Image·1¶



Figure·2:·MXA-63C·Image·2¶

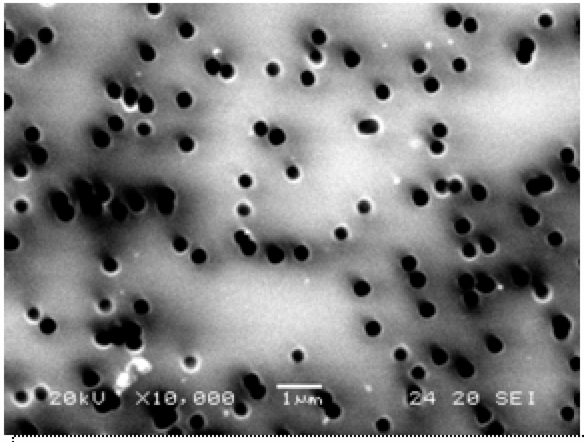


Figure·3:·MXA-63C·Image·6¶

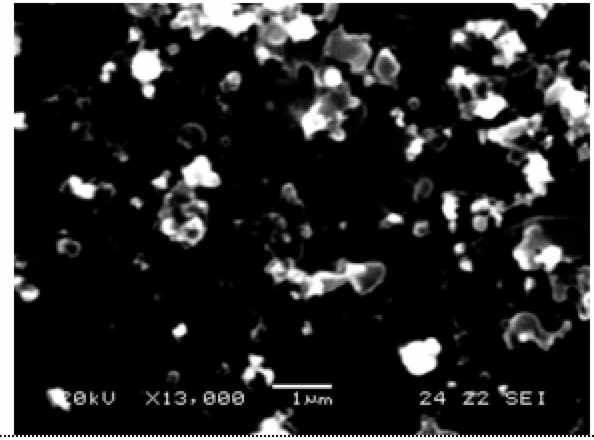


Figure·4:·MXA-63C·Image·4¶

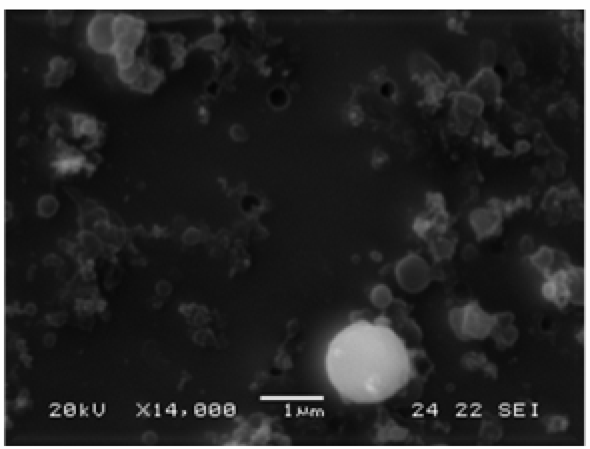
Fine·Filter·Pictures:¶



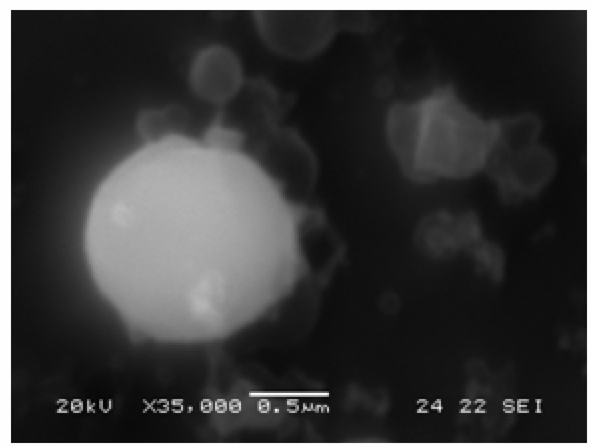
Figure·5:·MXA-63F·Image·1¶



Figure·6:·MXA-63F·Image·2¶



Figure·7:·MXA-63F·Image·1¶



Figure·8:·MXA-63F·Image·1¶