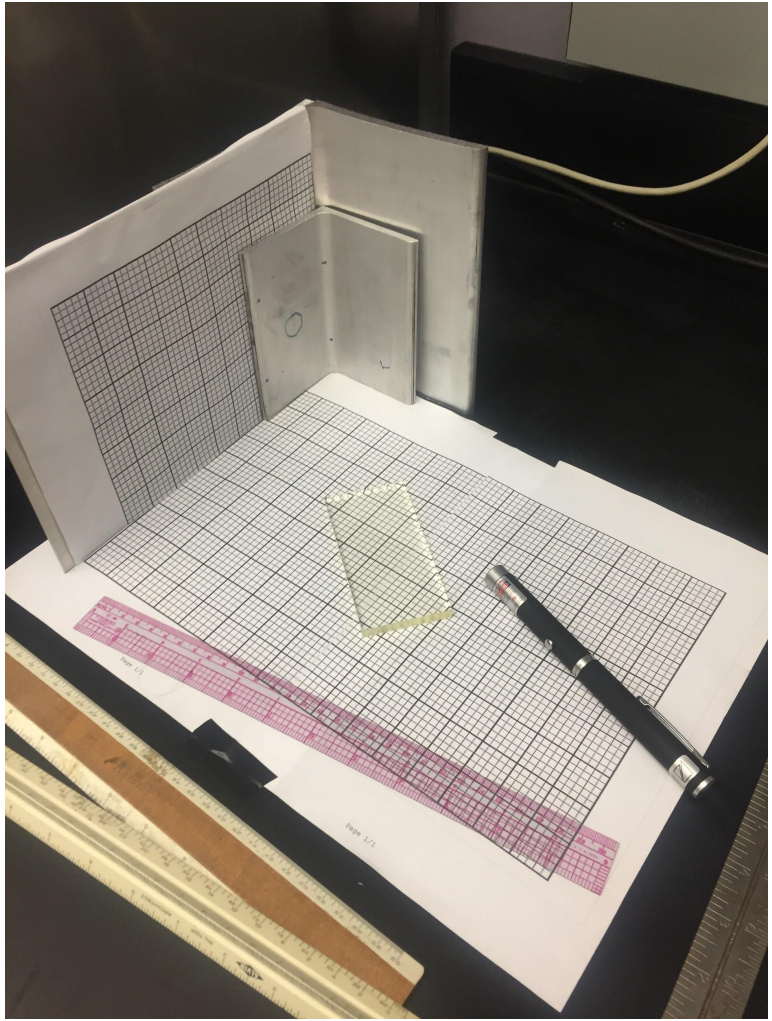
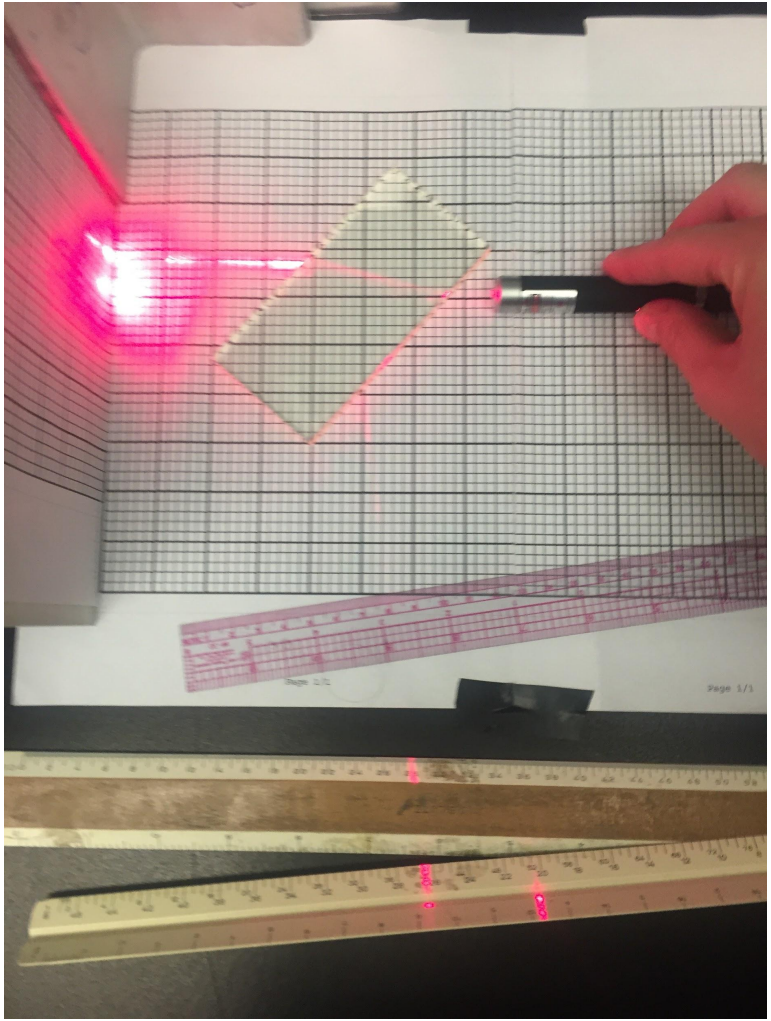
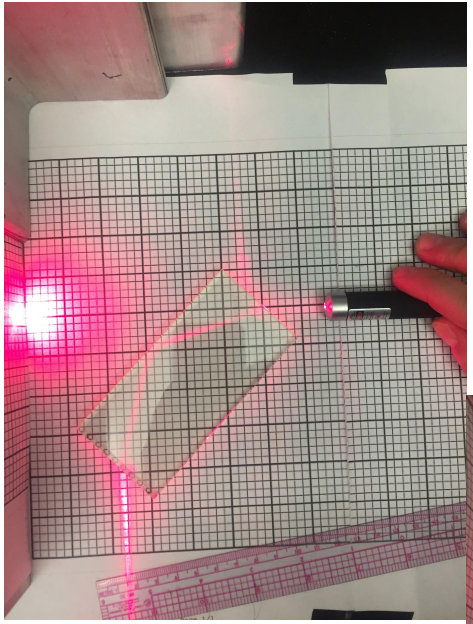
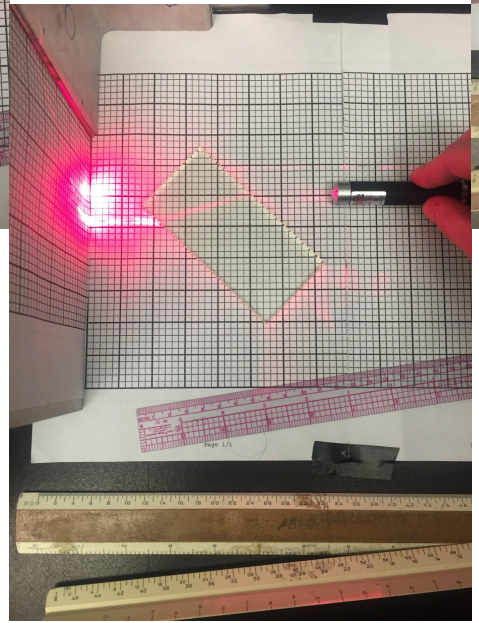
Aerogel Index of Refraction

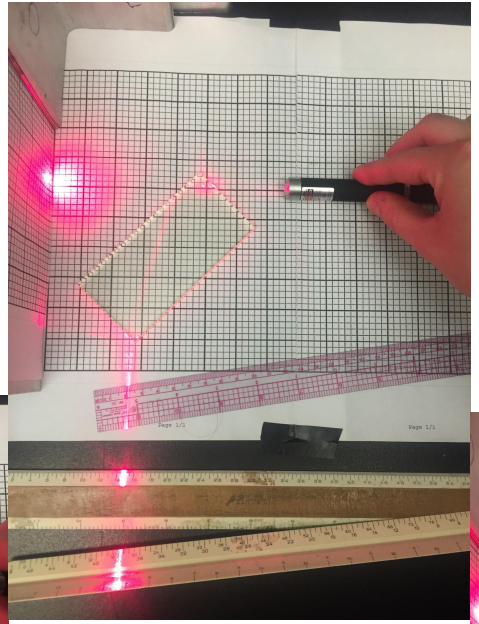
Meeting Updates

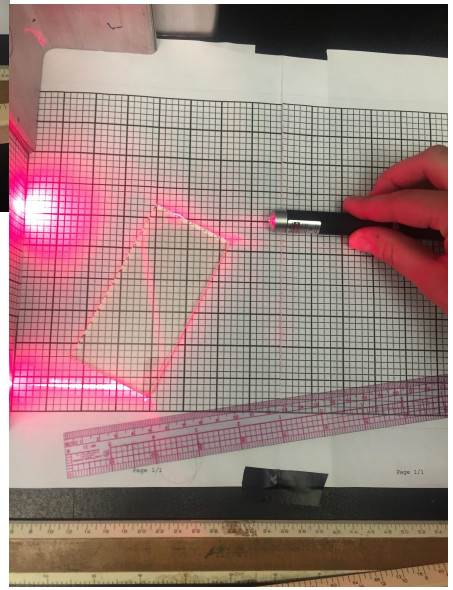




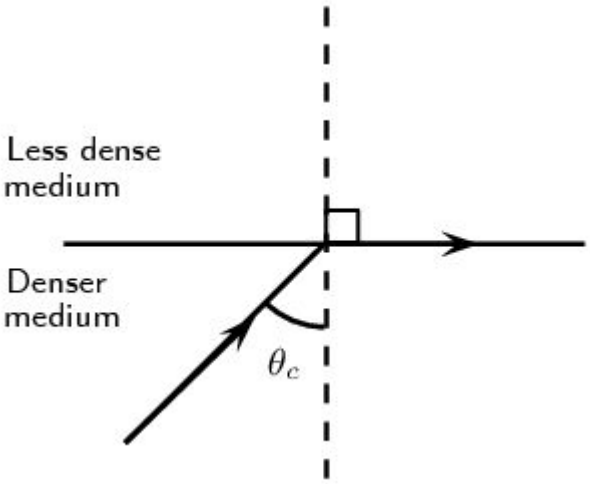


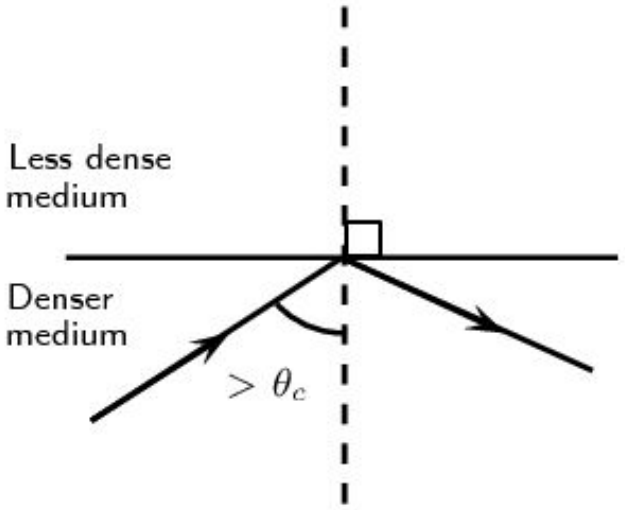






The Critical Angle



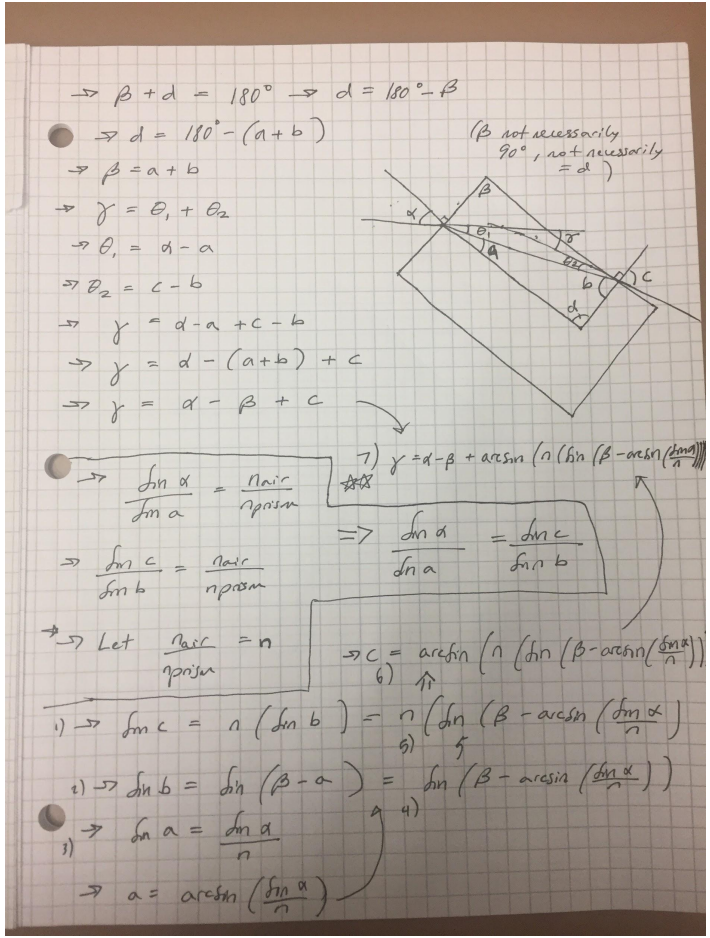


https://www.siyavula.com/read/science/grade-11/geometrical-optics/05-geometrical-optics-07

Index of Refraction (1)

$\gamma = \alpha - \beta + \arcsin(n(\sin(\beta - \arcsin((\sin\alpha)/n))))$

$n = \sqrt{(\sin^2\alpha + \sin^2(\gamma + \alpha))}$



$\rightarrow \alpha = \gamma + c$

$\rightarrow \gamma = \alpha - c$

$\rightarrow \alpha - c + b = \gamma$

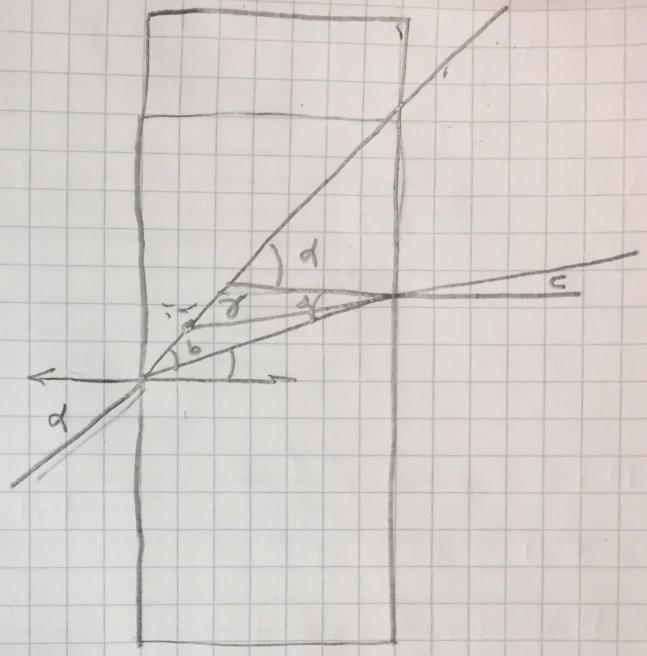
$\rightarrow \gamma = \alpha + b - c$

$\rightarrow \alpha = b + \alpha$

$\rightarrow \dfrac{\sin \alpha}{\sin(\alpha - b)} = n = \dfrac{\sin c}{\sin \alpha}$

$\rightarrow \dfrac{\sin \alpha}{\sin c} = \dfrac{\sin(\alpha - b)}{\sin \alpha} = \dfrac{\sin(b + \alpha - b)}{\sin \alpha} = 1$

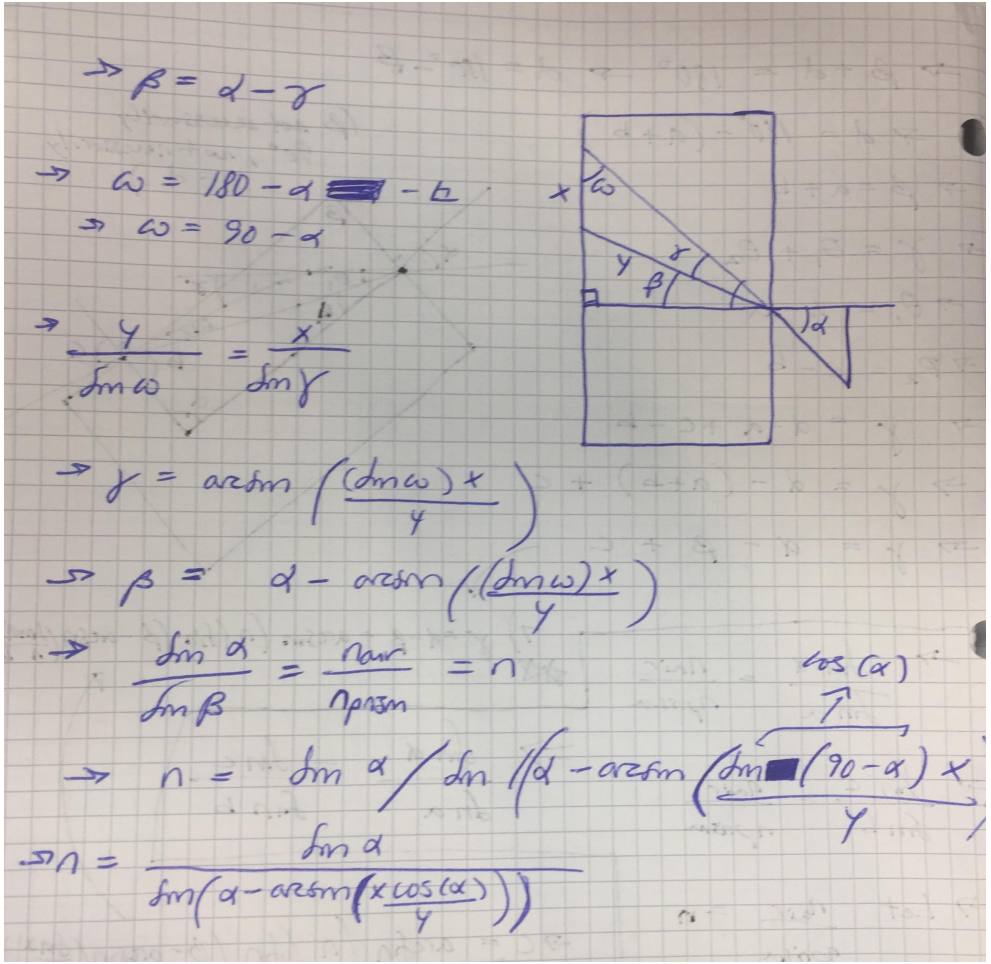
$\rightarrow \alpha = c \quad \because \gamma = 0$



The index cannot be calculated using the first equation when the laser is shone through the body of the prism rather than across the angle

Index of Refraction (2)

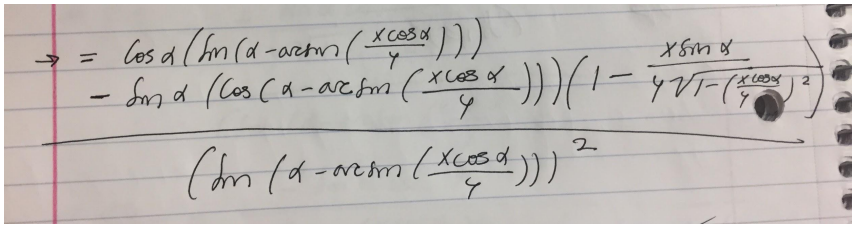
- n = (sin α)/(sin(α - arcsin(x(cosα)/y)))
- n = (sinα)/(sinβ)

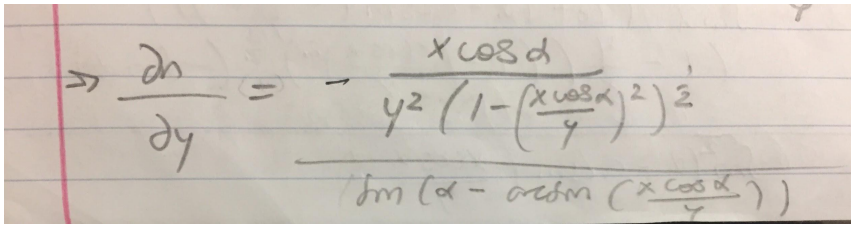


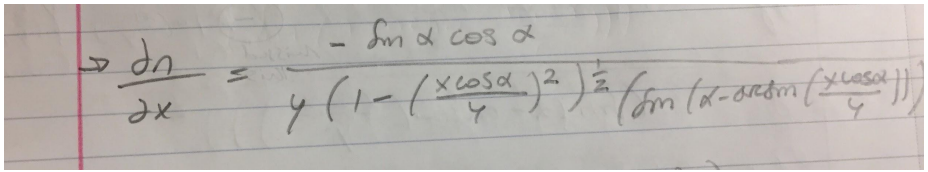
Measurements and Equations (2)

https://docs.google.com/spreadsheets/d/1Txx-vV3wgf3GK_qlBFUmlLhNHIcuCy1psQFxUU7tCow/edit#gid=1868993415

- $n = (\sin\alpha)/(\sin(\alpha - \arcsin(x(\cos\alpha)/y))$
- $n = (\sin\alpha)/(\sin\beta)$
- $\delta n(\alpha,x,y) = \sqrt{((\partial n/\partial\alpha)\delta\alpha)^2 + ((\partial n/\partial x)\delta x)^2 + ((\partial n/\partial y)\delta y)^2}$
- $\partial n/\partial\alpha =$



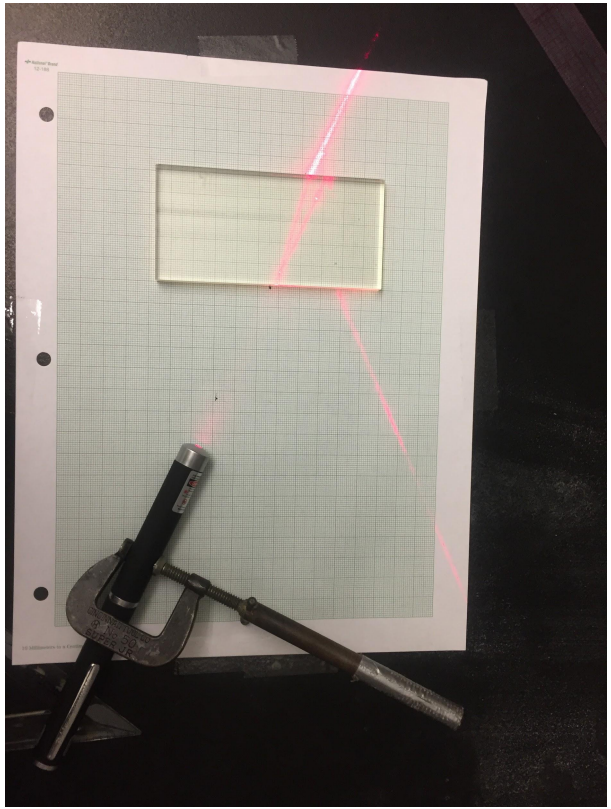


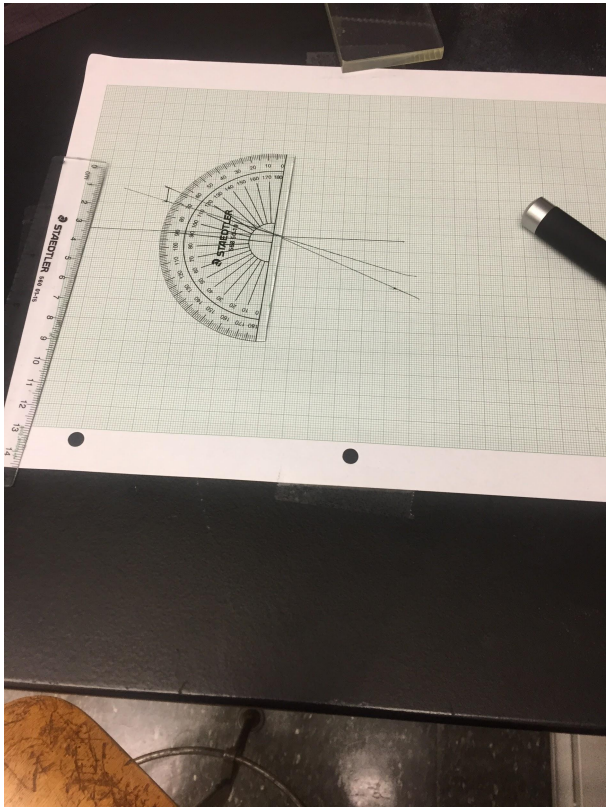


Original Measurement Approach

- Measuring while the laser was on
- Using original graph paper as reference
- Taking whole laser width as systematic error with additional random error
- Taking each measurement of 4 values as a set
- Problems:
  - Beam lifted up and put down to be able to see angles - eventually propped it up instead
  - Laser wouldn’t stay on
  - Prism and laser easily inadvertently moved
  - Protractor placed on top of prism - additional error from perspective
  - Small protractor, beam covers multiple degrees
  - Beam refracted through transparent ruler and protractor
  - Estimated error of +/- .2 for n

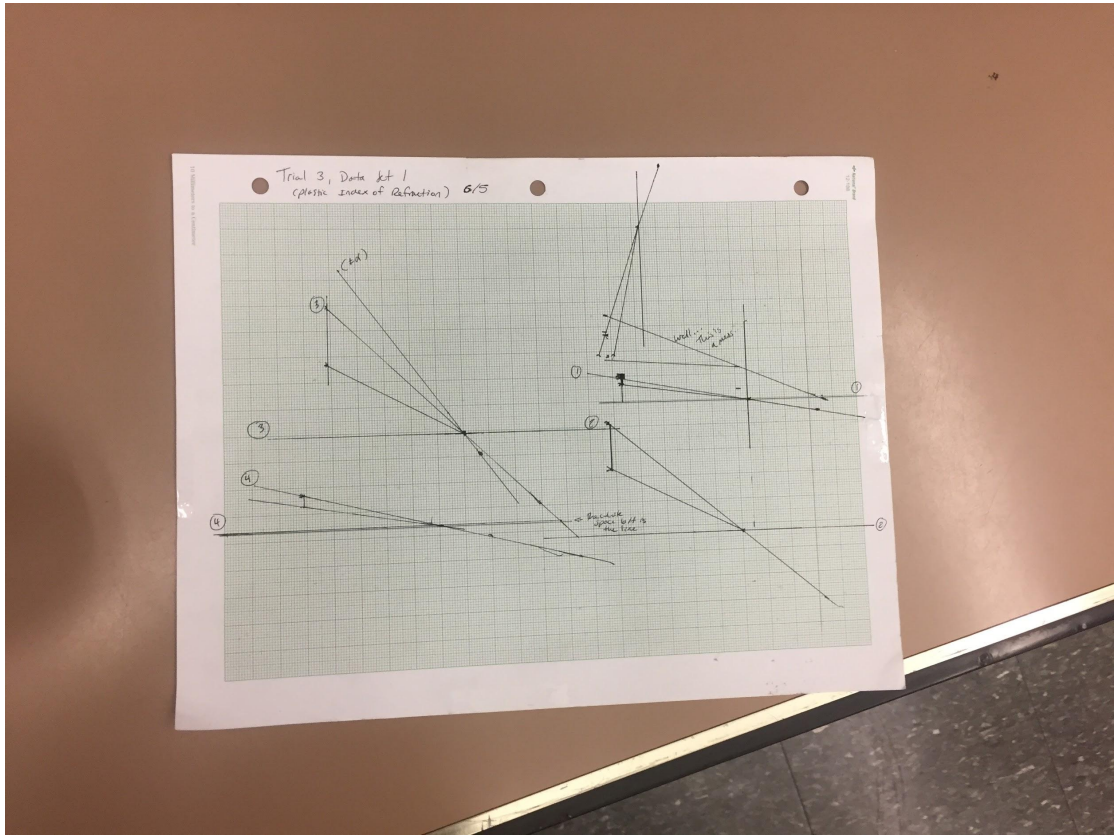
New Approach





New Approach

- Marking the location of the beam and measuring afterwards
- Using more precise graph paper
- Estimating the position of the edge of the laser beam (set 1) and then the center of the laser beam (set 2) as the point of measurement
- Taking each measured value independently
- Problems:
  - Protractor
  - Lines and points contribute to possible systematic error
  - Still error of .06+ for n
  - Data doesn't agree -> error underestimated



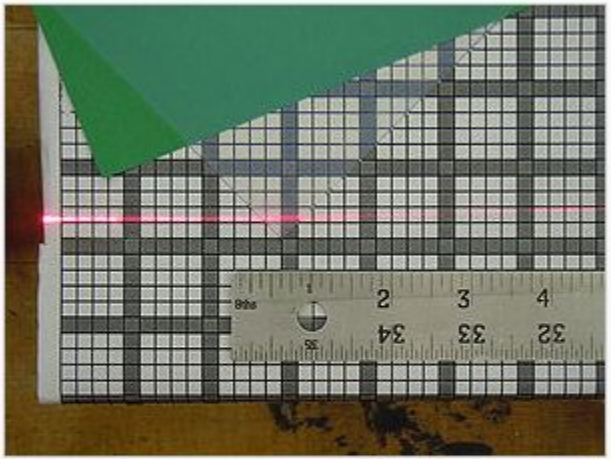
https://docs.google.com/spreadsheets/d/1Txx-vV3wgf3GK_qlBFUmlLhNHIcuCy1psQFxUU7tCow/edit#gid=1346628582 - Spreadsheet

Possible Image Analysis Software

- ImageJ - Free Image Analysis Software https://imagej.nih.gov/ij/features.html
- “Measure area, mean, standard deviation. Measure lengths and angles. Use real world measurement units such as millimeters. Generate histograms and profile plots”
- Fiji - ImageJ Package http://fiji.sc/
- Same measurement features as ImageJ -Tested this week
- Digimizer - not free https://www.digimizer.com/features.php
- ‘Define unit of measurement, measure distances and lengths of line segments or path, measure angles, locate middle of line segment, measurements on perpendicular lines, fit line’
- Adobe Photoshop - https://helpx.adobe.com/photoshop/using/measurement.html
- “Using the Photoshop Measurement feature you can measure any area defined with the Ruler tool or with a selection tool, including irregular areas selected with the Lasso, Quick Select, or Magic Wand tools. You can also compute the height, width, area, and perimeter, or track measurements of one image or multiple images”

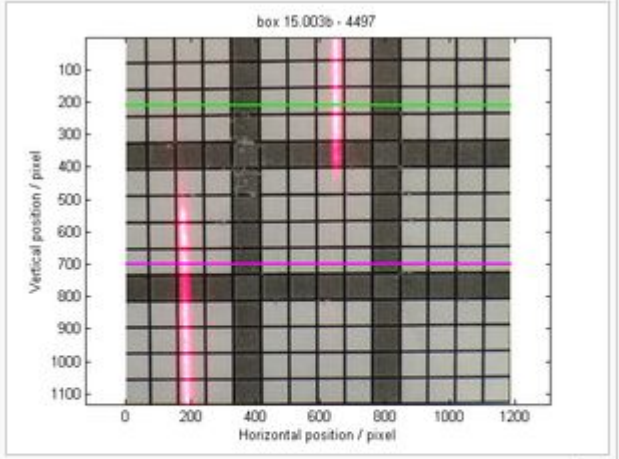
2013 Project

Copying set up from 2013 (Images from http://www.vsl.cua.edu/cua_phy/index.php/MainPage:Nuclear:KaonDetector:AerogelCharacteristics)



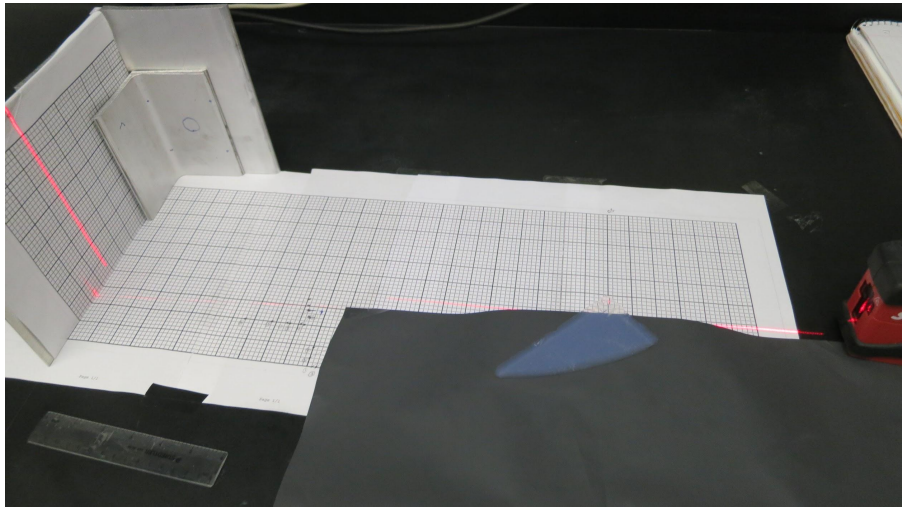
2) Part of the laser sheet pass through the aerogel tile, being deflected by its refractive index. The other part pass on the top of the tile, going direct to the reference paper target.

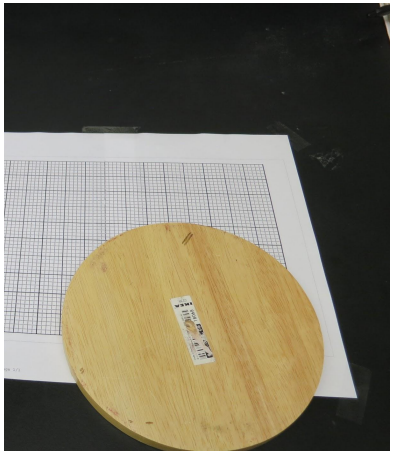
1) Experimental setup for the measurement of the aerogel refractive index. A laser sheet is refracted by the tile and hit a target paper. The deviation of the laser can be measured for the calculation of the refractive index.

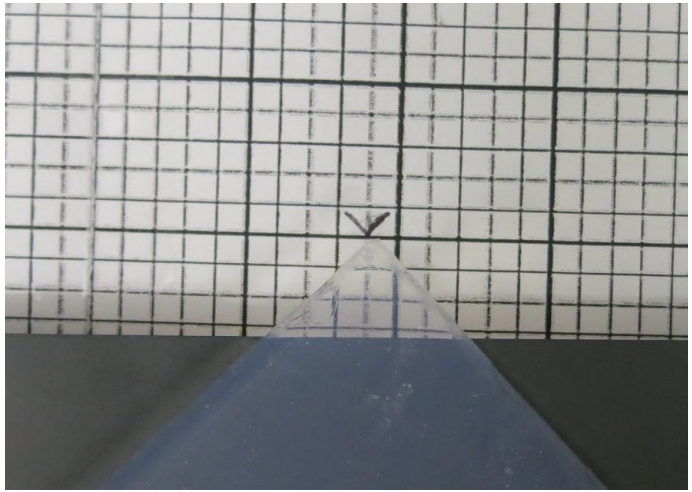


3) Picture of the reference paper with the direct (top) and refracted (bottom) laser beam. Two lines are selected for the pixel intensity analysis, looking for the peaks identification.

Aerogel Setup

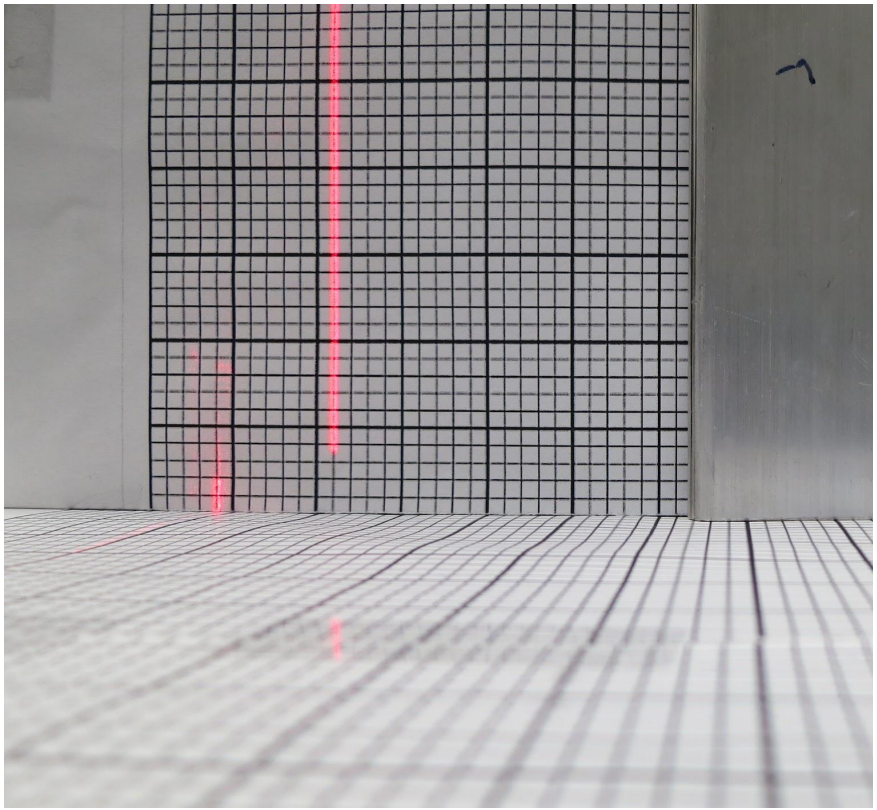


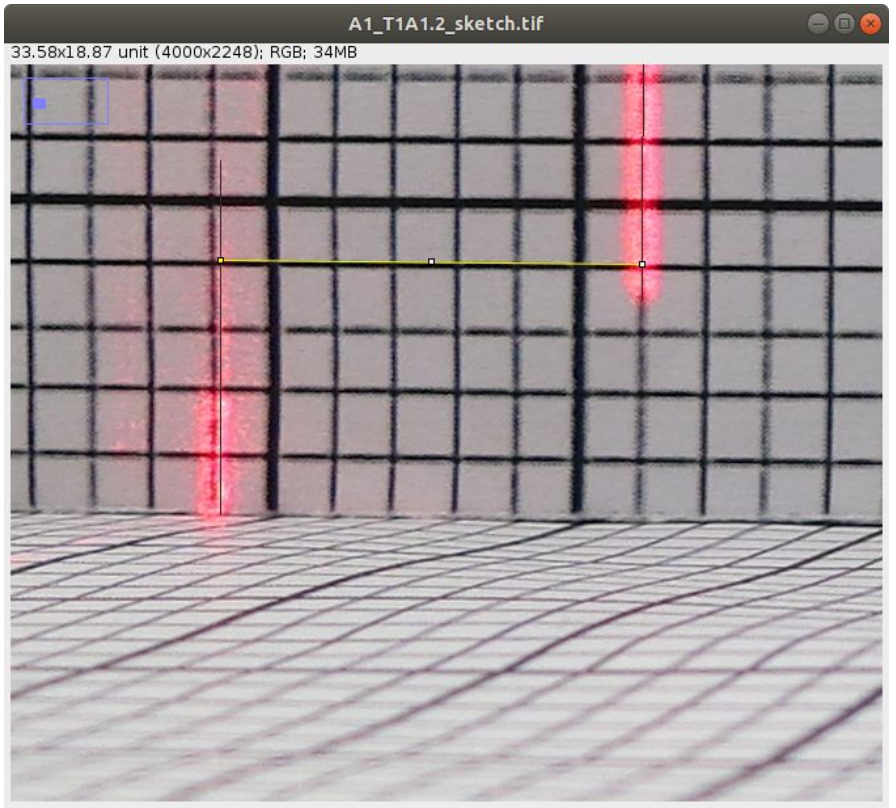




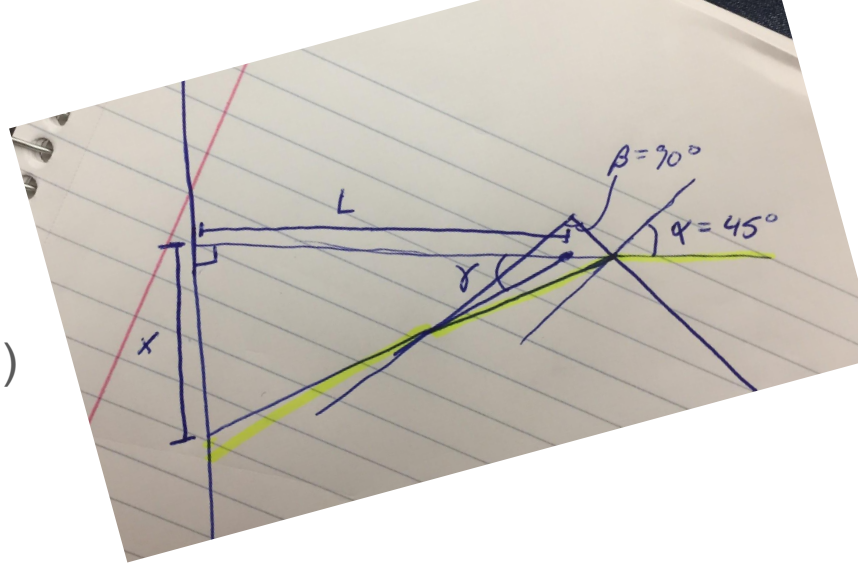
- Removes variables of angle and distance from target
- New variable - distance inside aerogel
- Measure distances on the target using pictures and distance from target by hand

Aerogel Set up and Image Analysis





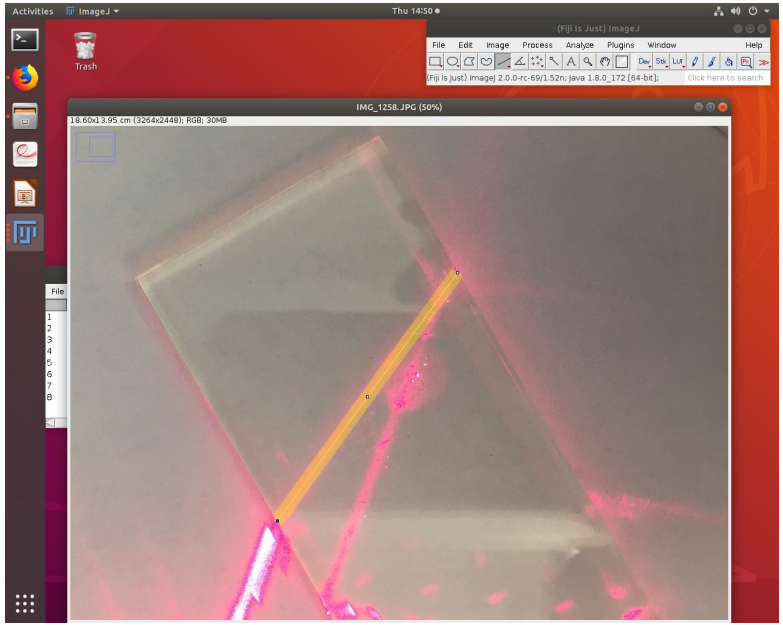
Calculations

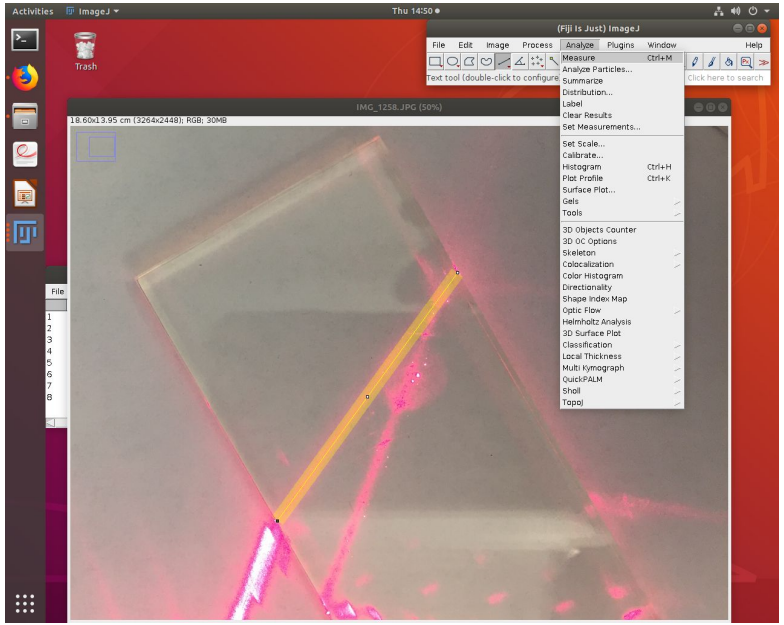


Equations (1): n = 1.029 +/- .001

- $\gamma = \alpha - \beta + \arcsin(n(\sin(\beta - \arcsin((\sin\alpha)/n))))$
- $n = \sqrt{(\sin^2\alpha + \sin^2(\gamma + \alpha))}$
  - - assumes β is a right angle
- $\delta n(\alpha,\gamma) = \sqrt{((\partial n/\partial\alpha)\delta\alpha)^2 + ((\partial n/\partial\gamma)\delta\gamma)^2}$
- $\partial n/\partial\alpha = (\cos(\gamma - \alpha)\sin(\gamma - \alpha) + \sin(\alpha)\cos(\alpha))/(\sqrt{\cos^2(\gamma - \alpha) + \sin^2(\alpha)})$
- $\partial n/\partial\gamma = (-\cos(\gamma - \alpha)\sin(\gamma - \alpha)/(\sqrt{\cos^2(\gamma - \alpha) + \sin^2(\alpha)})$
- https://docs.google.com/spreadsheets/d/1RAnGFBmL_D1iQxKTcW4Yfsl09JV-1IP1-hGFo8ZTCdM/edit#gid=0

ImageJ


Activities
ImageJ
Thu 14:50
Trash
(Fiji Is Just) ImageJ
File Edit Image Process Analyze Plugins Window Help
IMG_1258.JPG (50%)
18.60x13.95 cm (3264x2448); RGB; 30MB


Activities
ImageJ
Thu 14:50
Trash
(Fiji Is Just) ImageJ
File Edit Image Process Analyze Plugins Window Help
Measure Ctrl+M
Analyze Particles...
Summarize
Distribution...
Label
Clear Results
Set Measurements...
Set Scale...
Calibrate...
Histogram Ctrl+H
Plot Profile Ctrl+K
Surface Plot...
Gels
Tools
3D Objects Counter
3D OC Options
Skeleton
Colocalization
Color Histogram
Directionality
Shape Index Map
Optic Flow
Helmholtz Analysis
3D Surface Plot
Classification
Local Thickness
Multi Kymograph
QuickPALM
Sholl
Topoj
IMG_1258.JPG (50%)
18.60x13.95 cm (3264x2448); RGB; 30MB

ImageJ

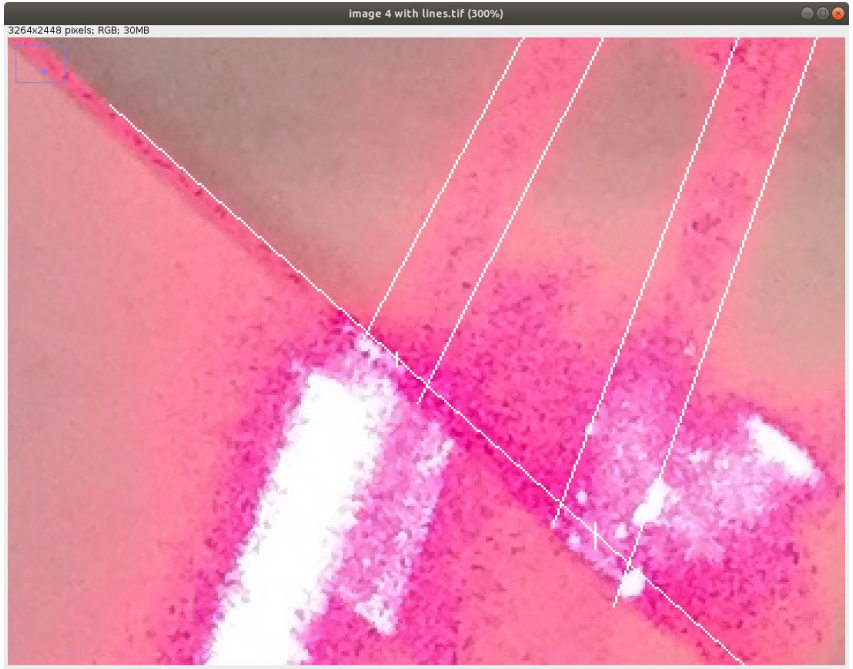
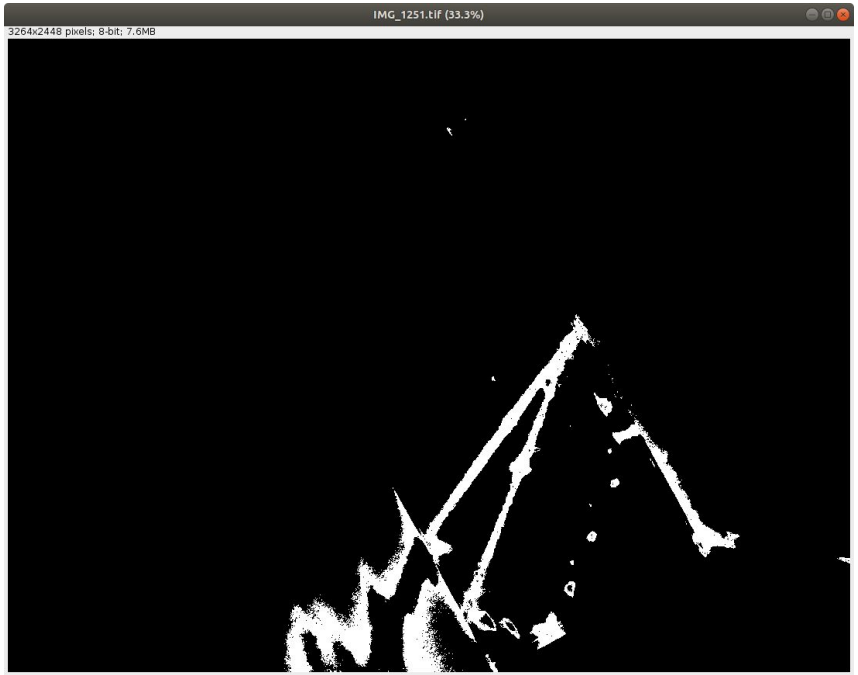
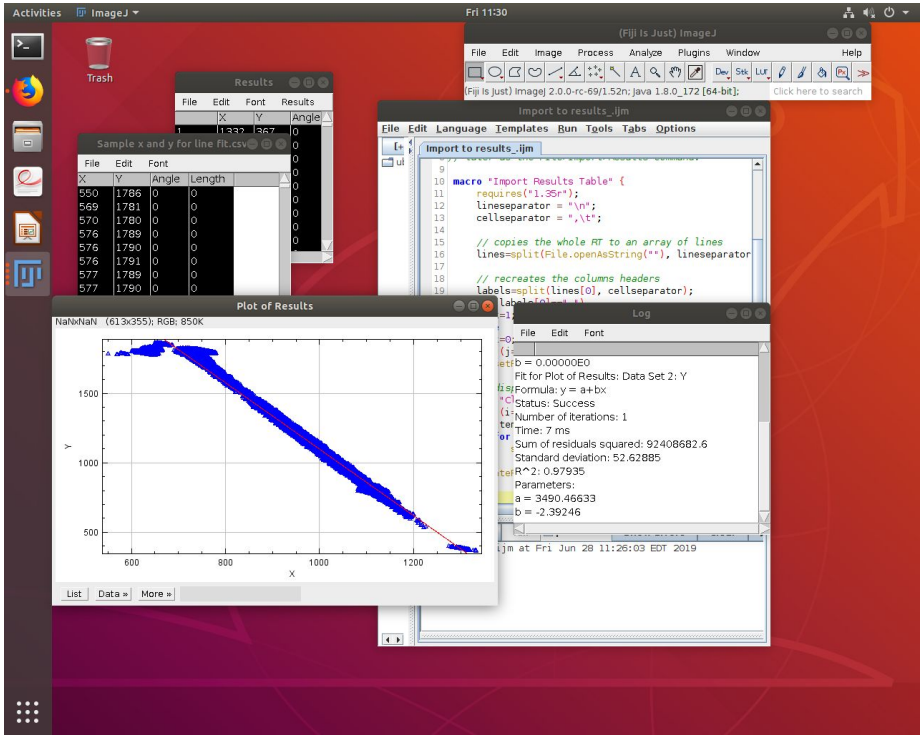


Image 4 with lines.tif (300%)
3264x2448 pixels; RGB; 30MB


Image 1 with lines.tif (200%)
18.64x13.98 cm (3264x2448); RGB; 30MB

ImageJ


IMG_1251.tif (33.3%)
3264x2448 pixels; 8-bit; 7.6MB

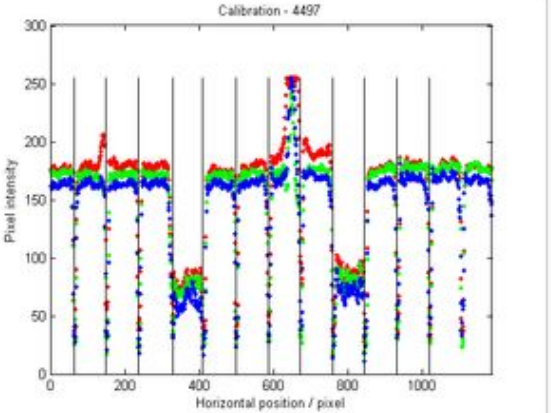

Activities
ImageJ
Fri 11:30
Trash
(Fiji Is Just) ImageJ
File Edit Image Process Analyze Plugins Window Help
Results
File Edit Font Results
Sample x and y for line fit.csv
File Edit Font
X Y Angle Length
550 1786 0 0
569 1781 0 0
570 1780 0 0
576 1789 0 0
576 1790 0 0
576 1791 0 0
577 1789 0 0
577 1790 0 0
import to results_ijm
File Edit Language Templates Run Tools Tabs Options
Import to results_ijm
macro "Import Results Table" {
requires("1.35r");
lineseparator = "\n";
cellseparator = ",\t";
// copies the whole RT to an array of lines
lines=split(File.openAsString(""), lineseparator
// recreates the columns headers
labels=split(lines[0], cellseparator);
Plot of Results
NaNxNaN (613x355); RGB; 850K
1500
1000
500
600
800
1000
1200
X
Y
List
Data »
More »
Log
File Edit Font
b = 0.00000E0
Fit for Plot of Results: Data Set 2: Y
Formula: y = a+bx
Status: Success
Number of iterations: 1
Time: 7 ms
Sum of residuals squared: 92408682.6
Standard deviation: 52.62885
R^2: 0.97935
Parameters:
a = 3490.46633
b = -2.39246
ijm at Fri Jun 28 11:26:03 EDT 2019

Mathematica

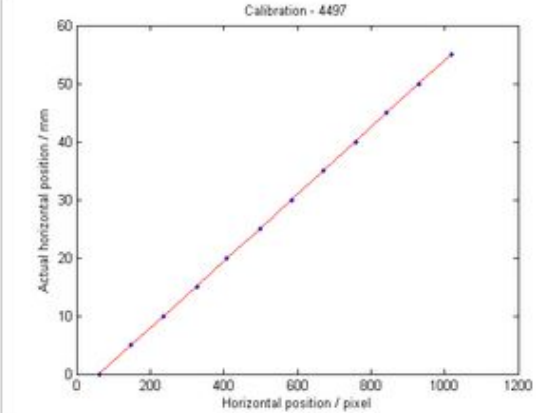
- Working with Nick to come up with image analysis program
- Many of the same tools as imagej
  - Thresholding, edge tracing, Hough and Radon Transform
- Image info (matrix)
- Began with measuring distances of lasers inside plastic prism
  - He suggested a program where someone would select the corners of an image and the laser beams and then the angle and distance would be automatically measured
  - Do we need a streamlined process?

2013 Project

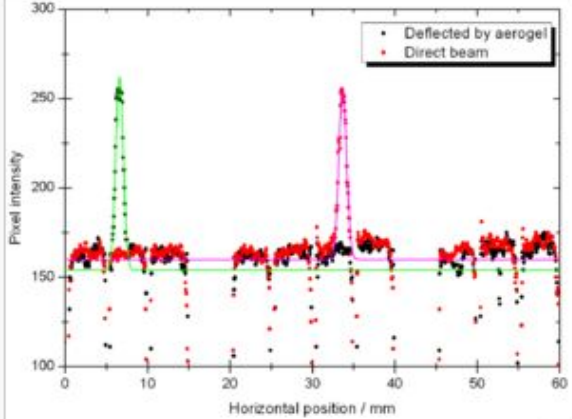
(Images from http://www.vsl.cua.edu/cua_phy/index.php/MainPage:Nuclear:KaonDetector:AerogelCharacteristics)



4) Calibration process example: a MatLAB code identifies the grid lines of the target paper.



5) Knowing the grid size of the previous image, the relation pixel to millimeter can be calibrated along the desired line.



6) After the calibration of the two lines (directed and refracted beams), the peaks position can be fitted for the analysis of the refracted beam deflection due to the aerogel.