Characterization of $PbWO_4$

By Christian Runyon

The Jefferson Lab

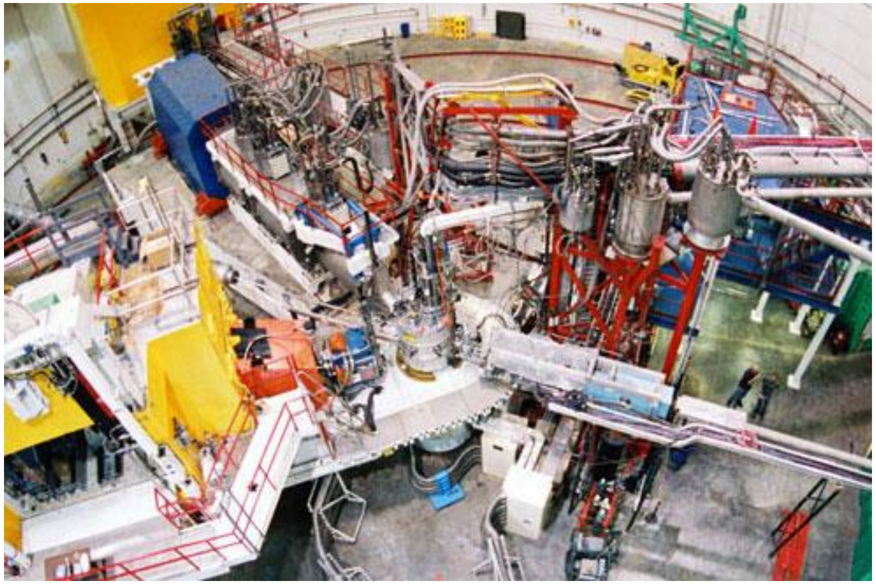
- Houses an electron accelerator with three 'halls' that each carry out their own unique experiments using the accelerated electron.

Accelerator Loop

Halls A, B, and C

Hall C

- Hall C specializes in probing the structure of hadrons
- Currently it does not have equipment which can detect neutral particles.



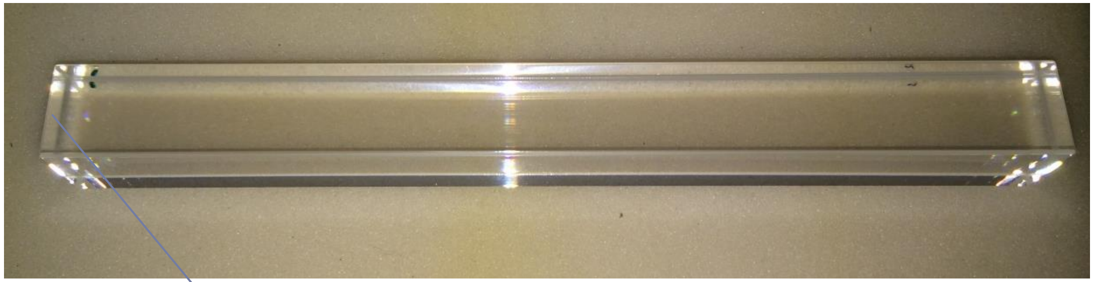
Neutral Particle Spectrometer (NPS)

- Starting in October, construction of the NPS will begin at the JLab.
- It will have two major components: a magnet to bend away charged particles and the detector.
- Detector will be composed of $PbWO_4$ and PbF_2 crystals with PMTs attached to them.

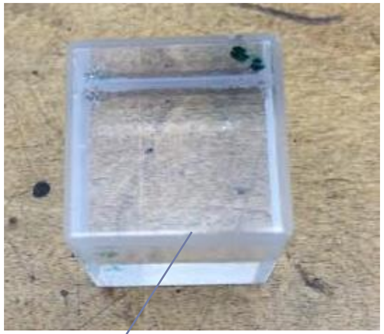
Up to 1116 $PbWO_4$ and 208 PbF_2 crystals

$PbWO_4$

- Lead tungstate is scintillating crystal. This means that, when it is struck by a particle, it releases a flash a light which can then be measured.
- Expensive and only made by a few companies
- Uniformity between the crystals is very important to the accuracy of the detector



2x2x20cm



2x2x2cm

Other notable uses

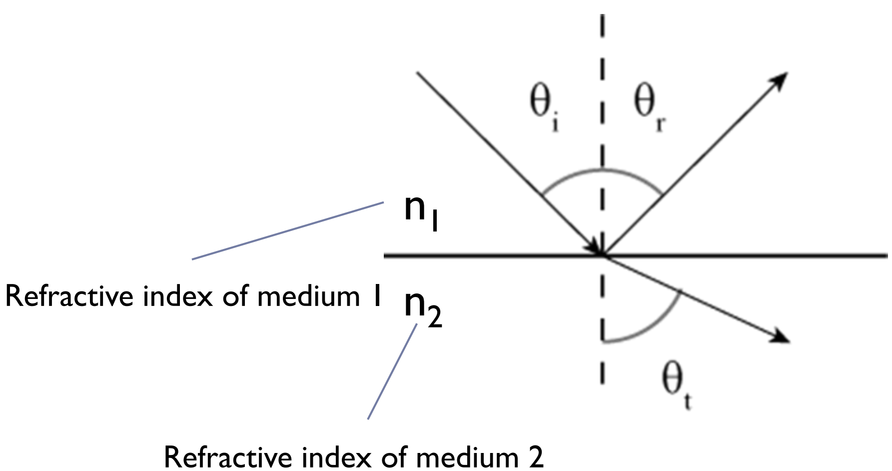
- 70,000 of these crystals were used for part of the CMS detector in the Large Hadron Collider
- The PANDA experiment at GSI in Germany is currently building a barrel calorimeter that consists of 8000 such crystals
- In comparison, the NPS will have 1000

Refractive Index

- The refractive index of a material is defined as the ratio of the speed of light in a vacuum to the speed of light in the material.
- As light changes speed it also bends, this is called the angle of refraction.
- According to literature, our crystal should have a refractive index of around 2.2 at a wavelength of 650nm (the wavelength of our laser)

Refractive Index continued

For light hitting a material at an θ_i from the normal, the angle of the light reflected will be equal to θ_i and the light which enters the material will be refracted at an angle θ_t as described by Snell's law

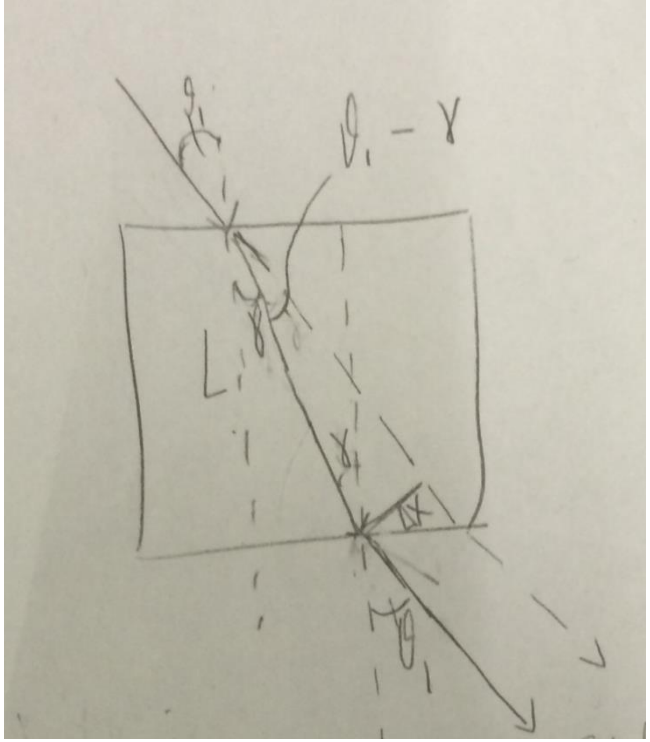


Snell's Law:

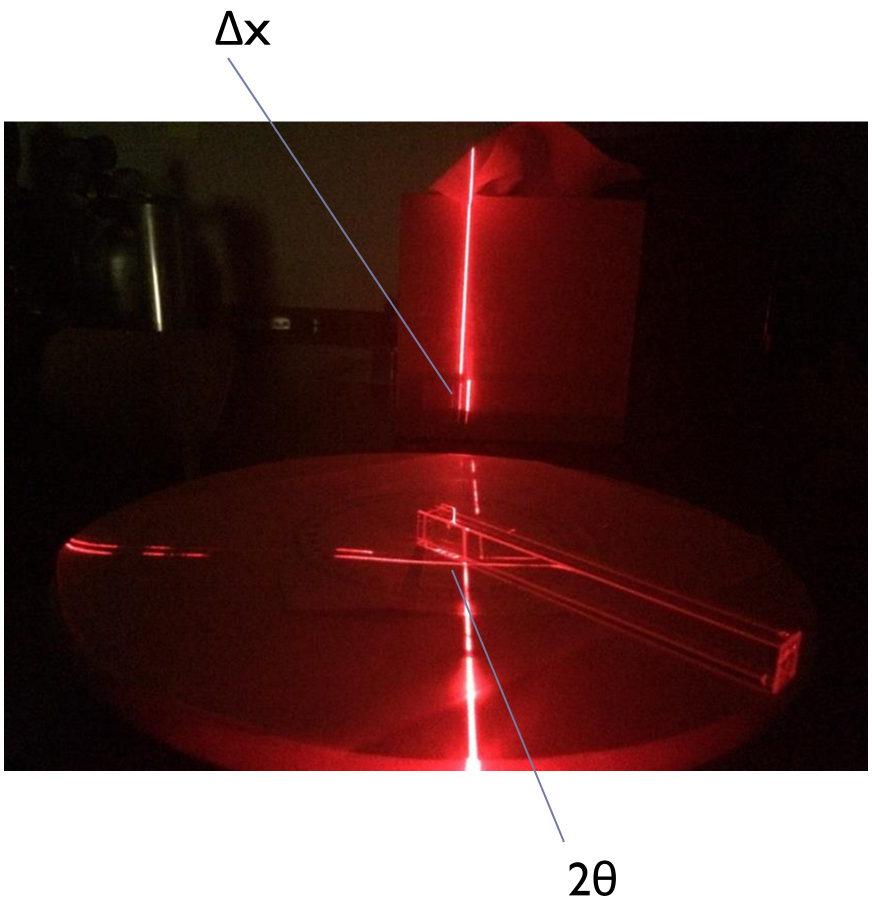
$n_1 \mathrm{Sin}\theta_i = n_2 \mathrm{Sin}\theta_t$

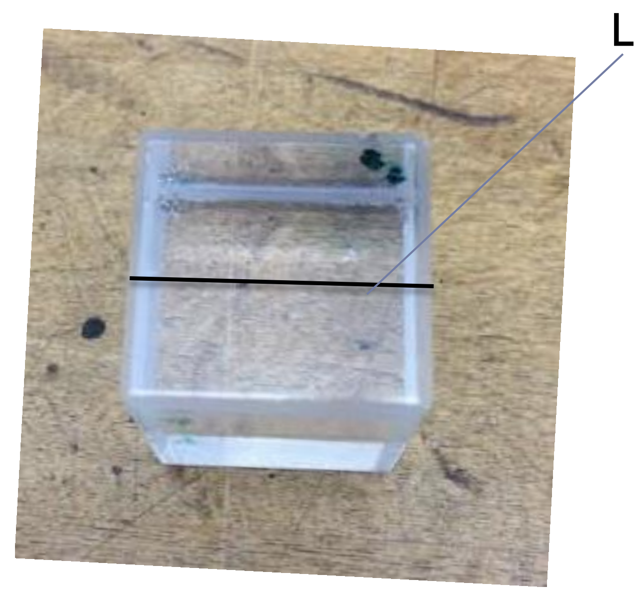
Modified equation for measurements with crystals

- Using geometry and Snell's Law, the refractive index (n) can be solved for as a function of the angle of incidence (θ), width of the crystal (L), and the change in the laser's positions by refraction (Δx)

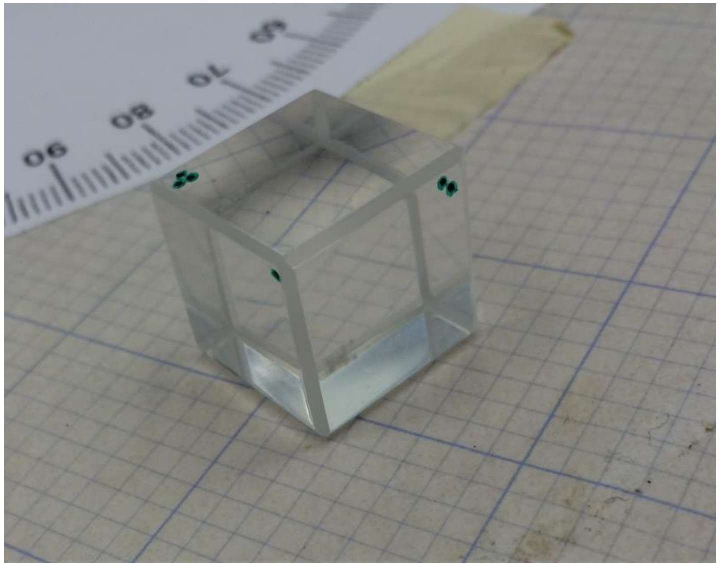


$$n = \sqrt{\left[\frac{\sin 2\theta}{2\left(\sin\theta - \frac{\Delta x}{L}\right)}\right]^2 + \sin^2\theta}$$

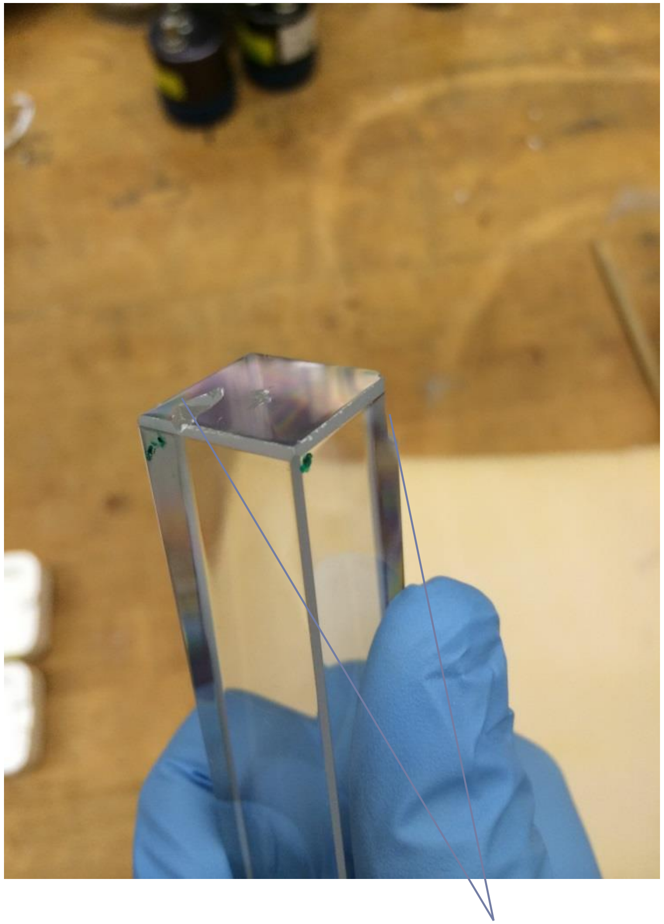

Δx
2θ


L

Keeping track of orientation



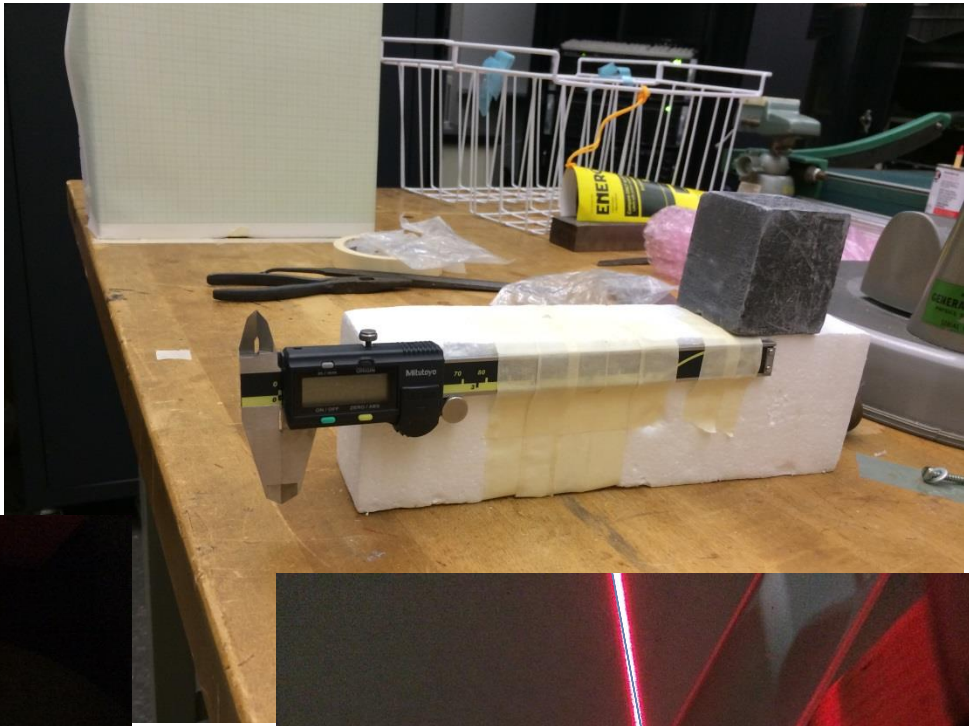
Properties often vary between orientations. I added green dots to the corners to denote the orientation.

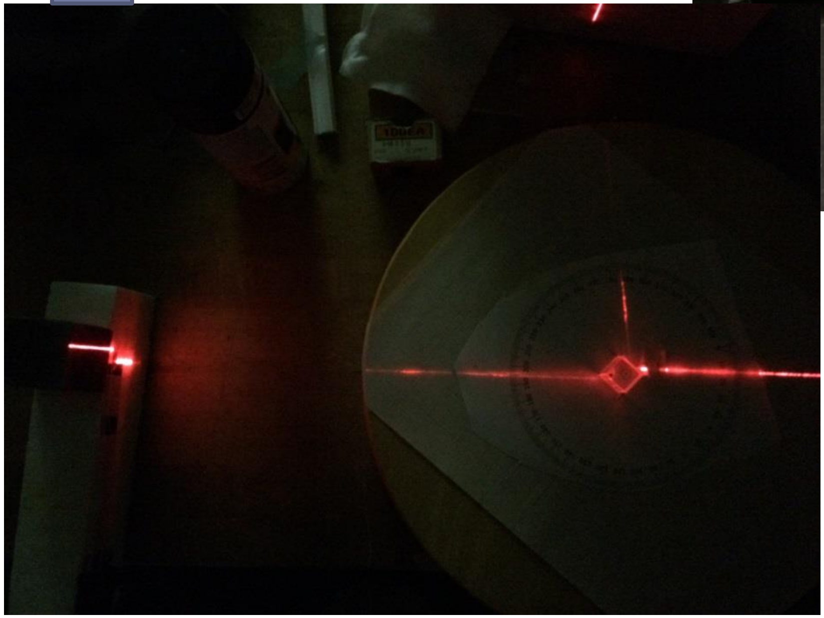


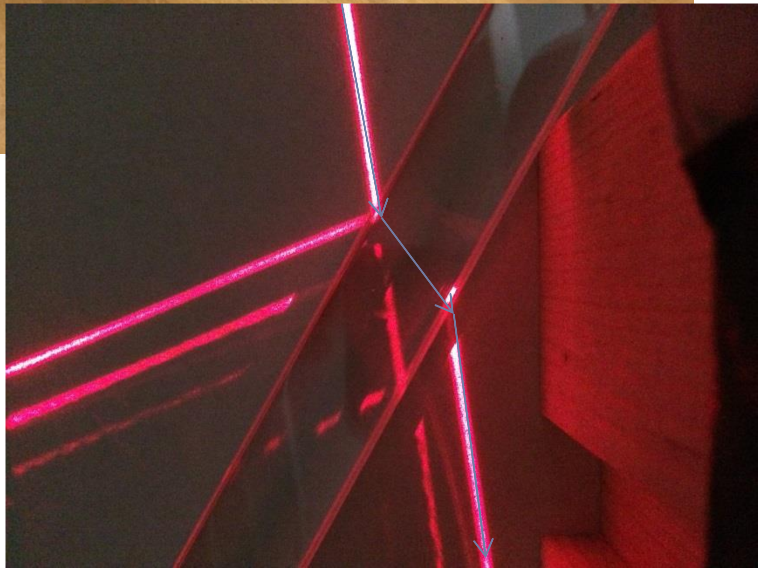
On a side note, the crystal is very fragile. An attempt to remove some optical adhesive caused these chips

The measurements

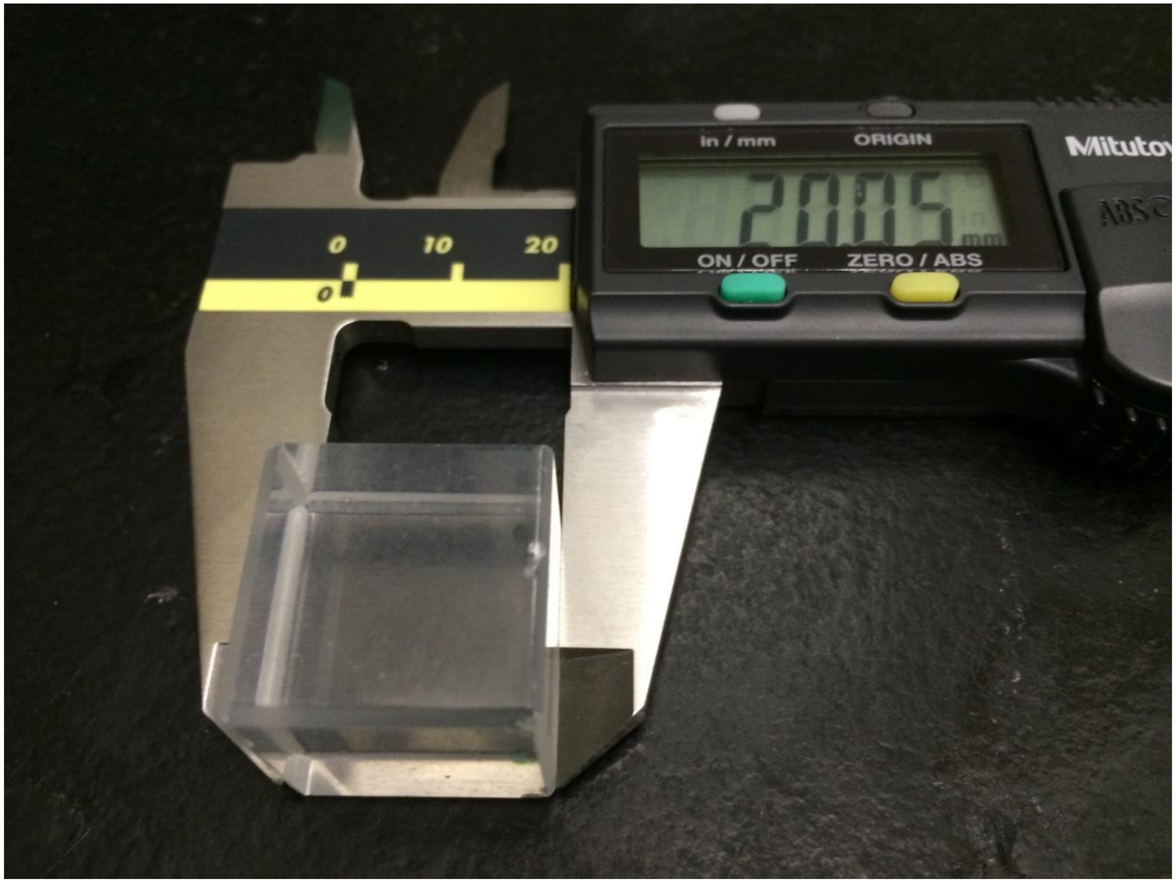
CUA







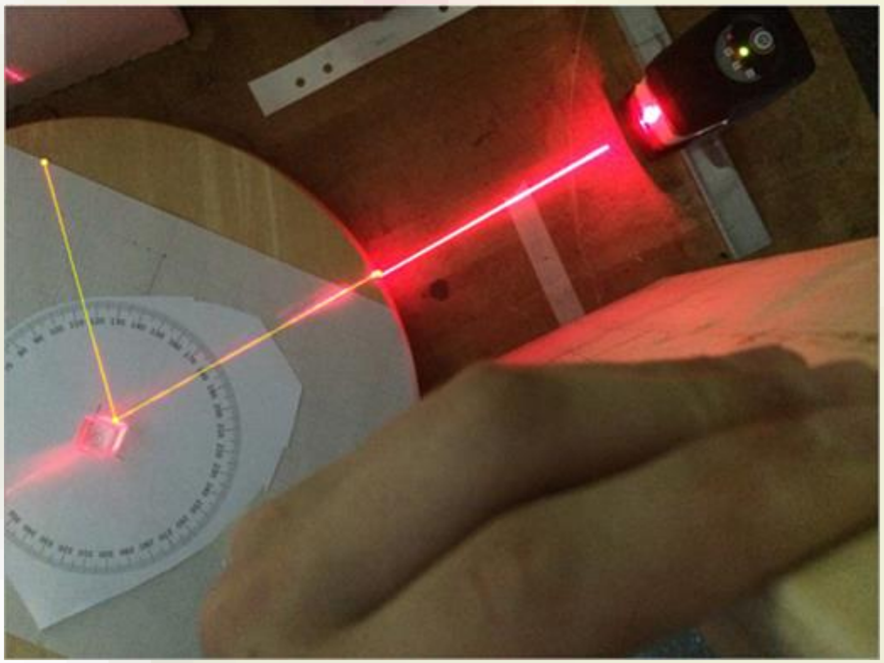
Measuring the width (L)

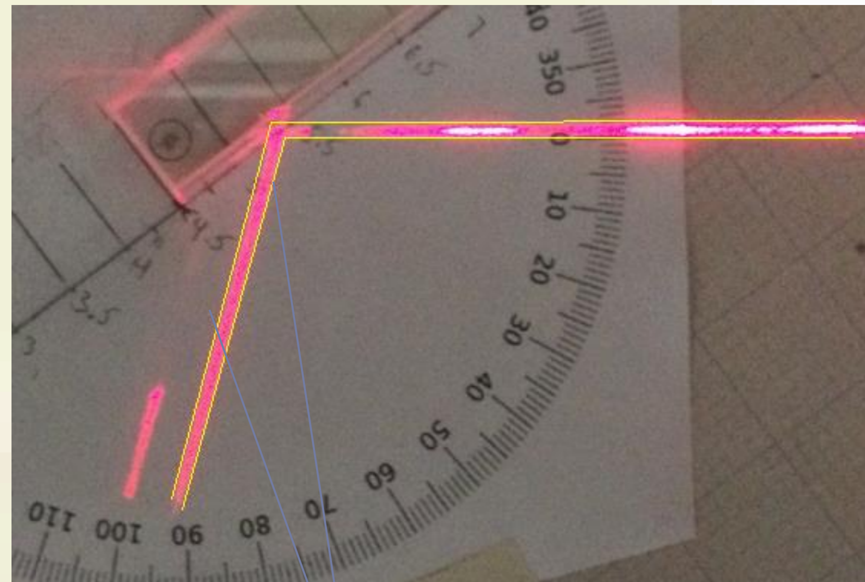


The uncertainty is ± .05mm

Measuring the angle (θ)

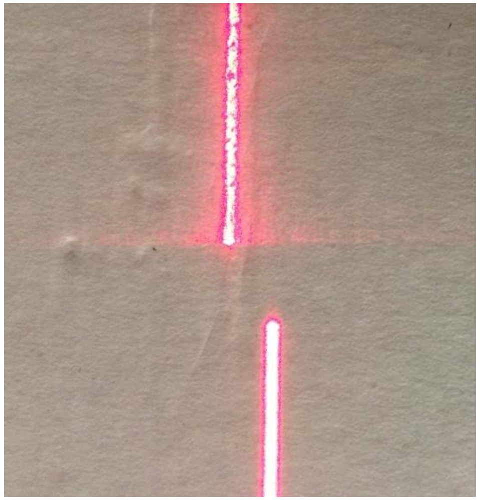
- Using digimizer, an image analyzer software

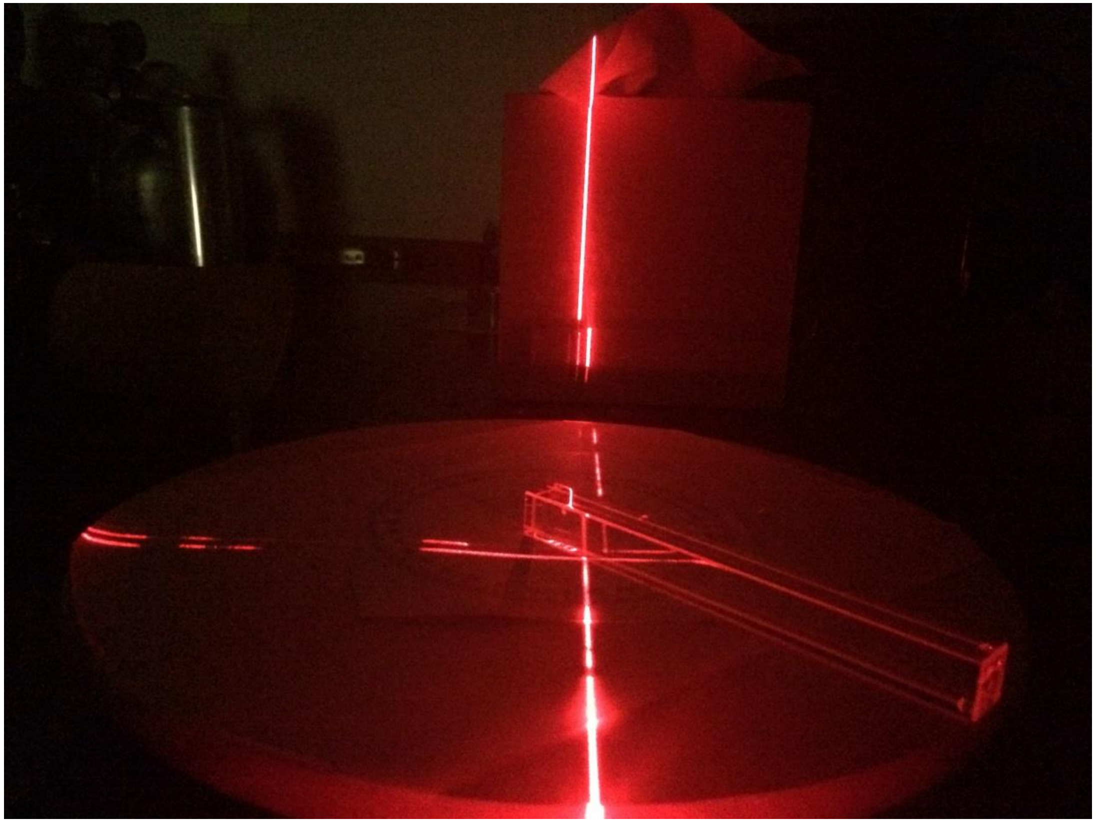




Measuring from both sides on the laser reveals the uncertainty of about ± .5°

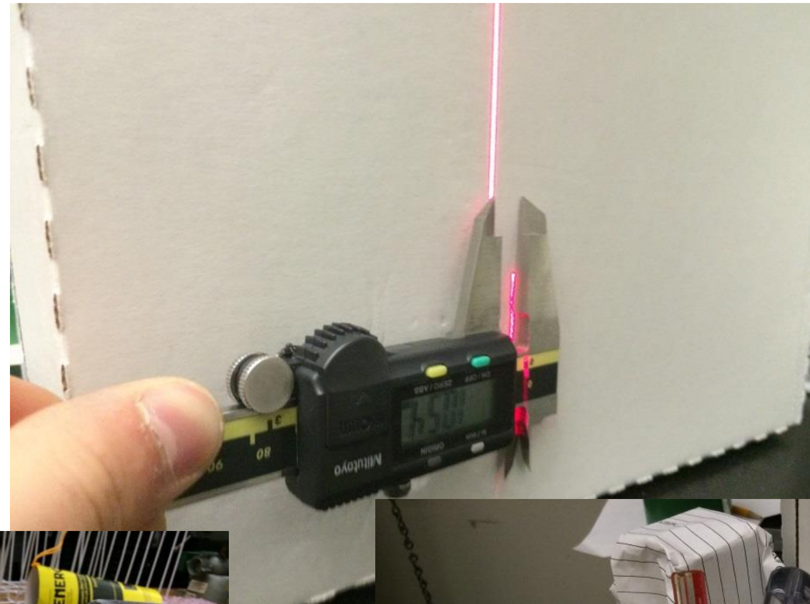
Measuring the change in the laser (Δx)



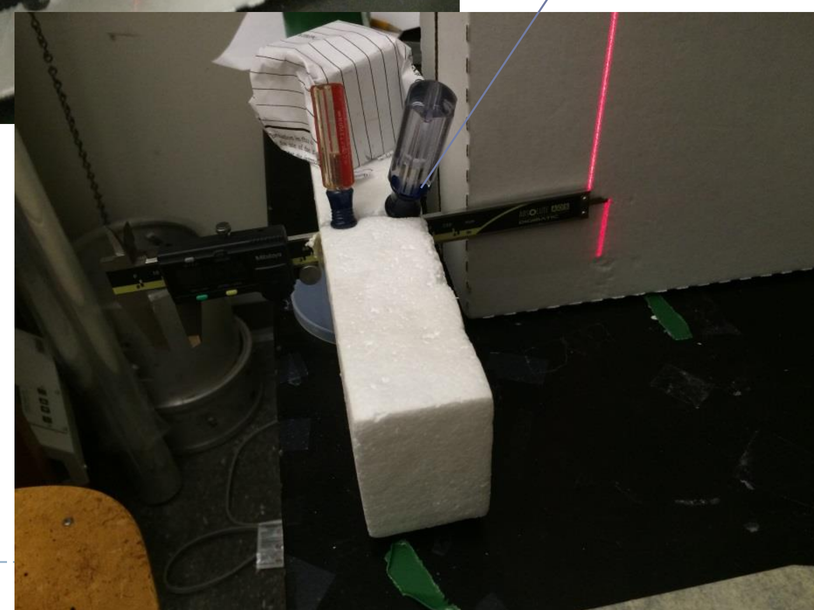


Measuring the change in the laser (Δx)

- Tried several methods
- Used calipers to reduce uncertainty

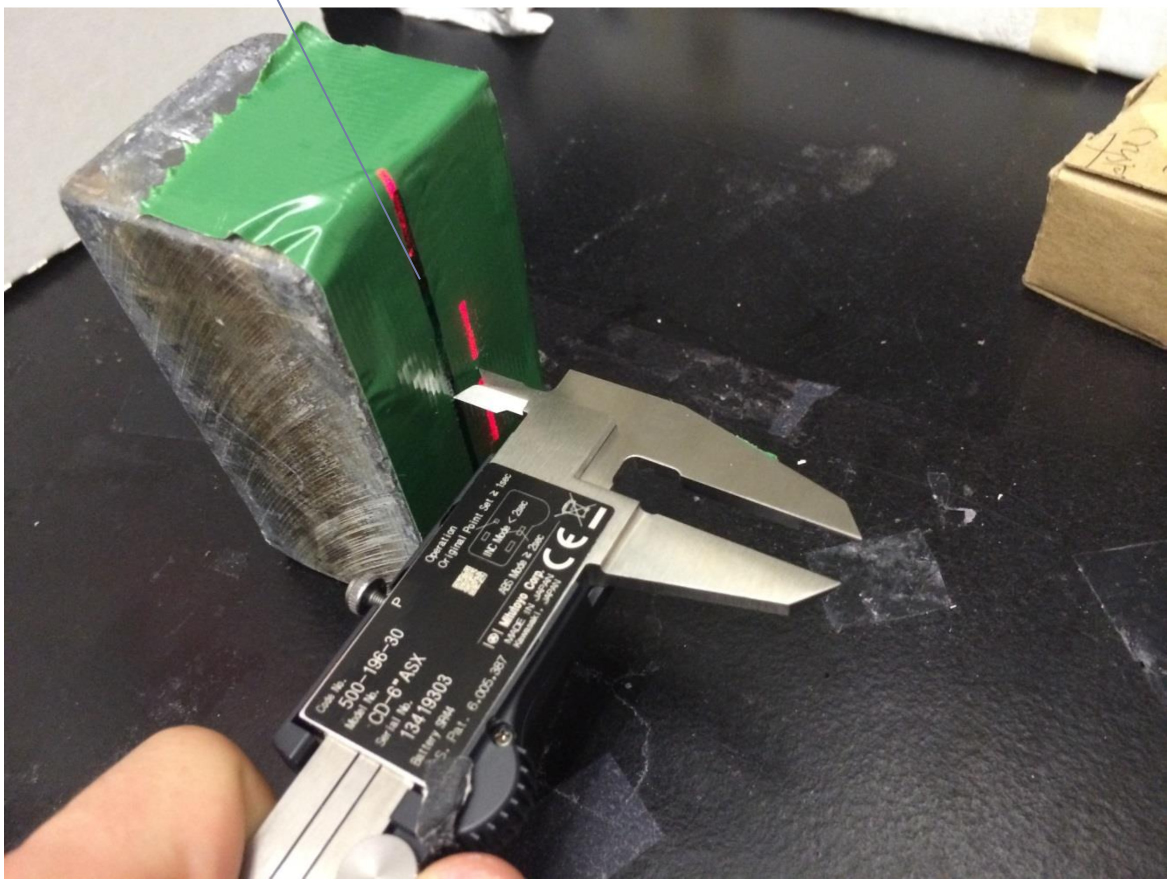


What a great idea!

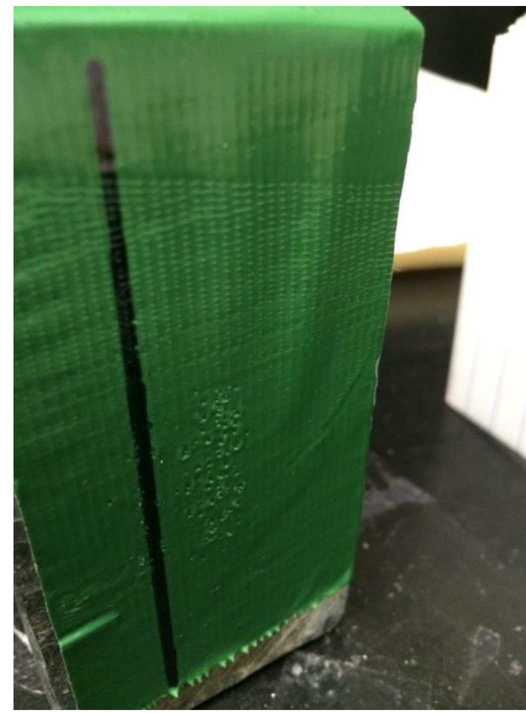


Chosen method

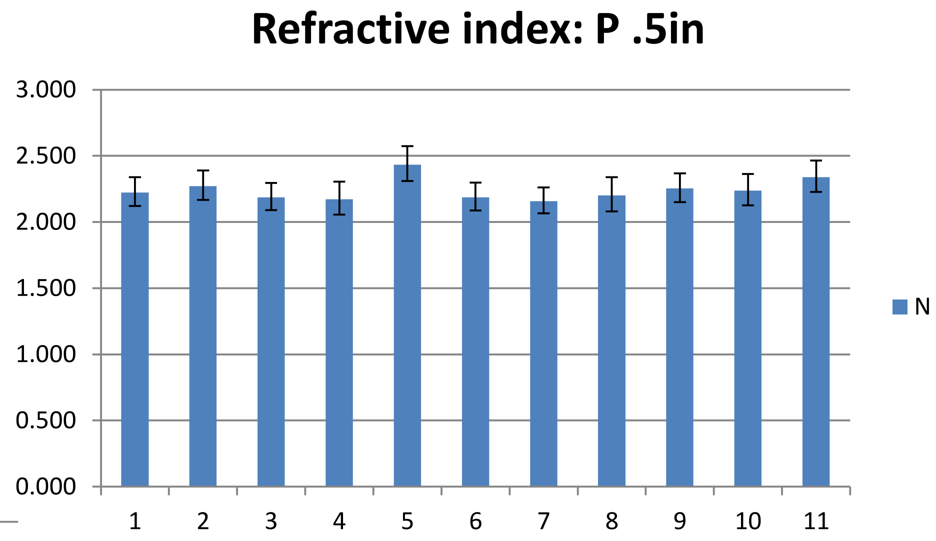
Perpendicular to ground



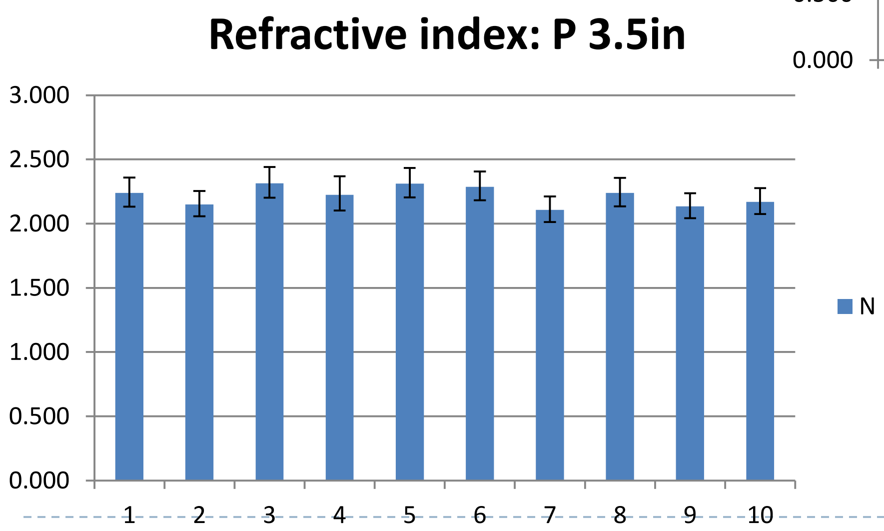
The uncertainty for this measurement was ± .3mm



Orientation 1 Positon 0.5in and 3.5in Index of Refraction: consistent with literature



Refractive Index based on mean and error P3.5in: 2.22 ± .13



Refractive Index based on mean and error P.5in: 2.22 ± .14

Transmittance

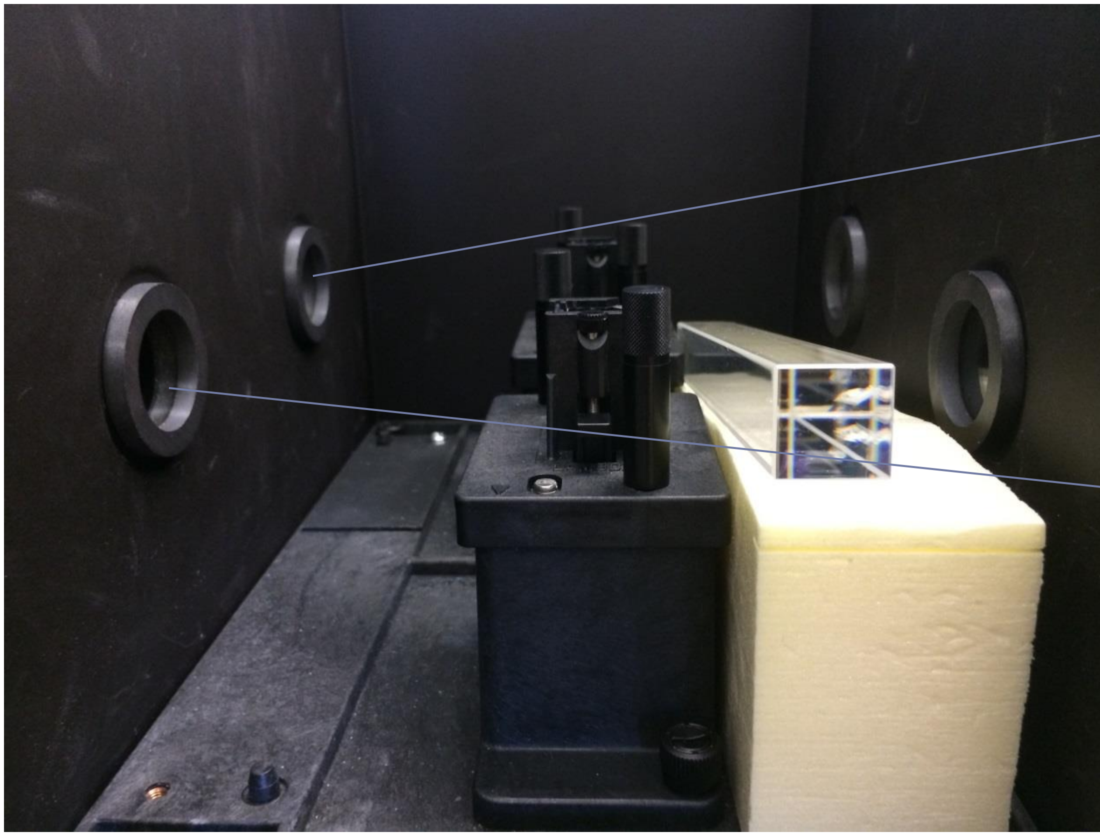
- Defined as the ratio of the light energy falling on a body to that transmitted through it
- For light at 420nm, a quality $PbWO_4$ crystal should have ~60% transmittance
- Can also double check refractive index using a simple case of Fresnel's equations:

$$R = \left(\frac{n_t - n_i}{n_t + n_i} \right)^2$$

R is the amount reflected.
Transmittance = 1-R

The n's are the two different refractive indices of the mediums

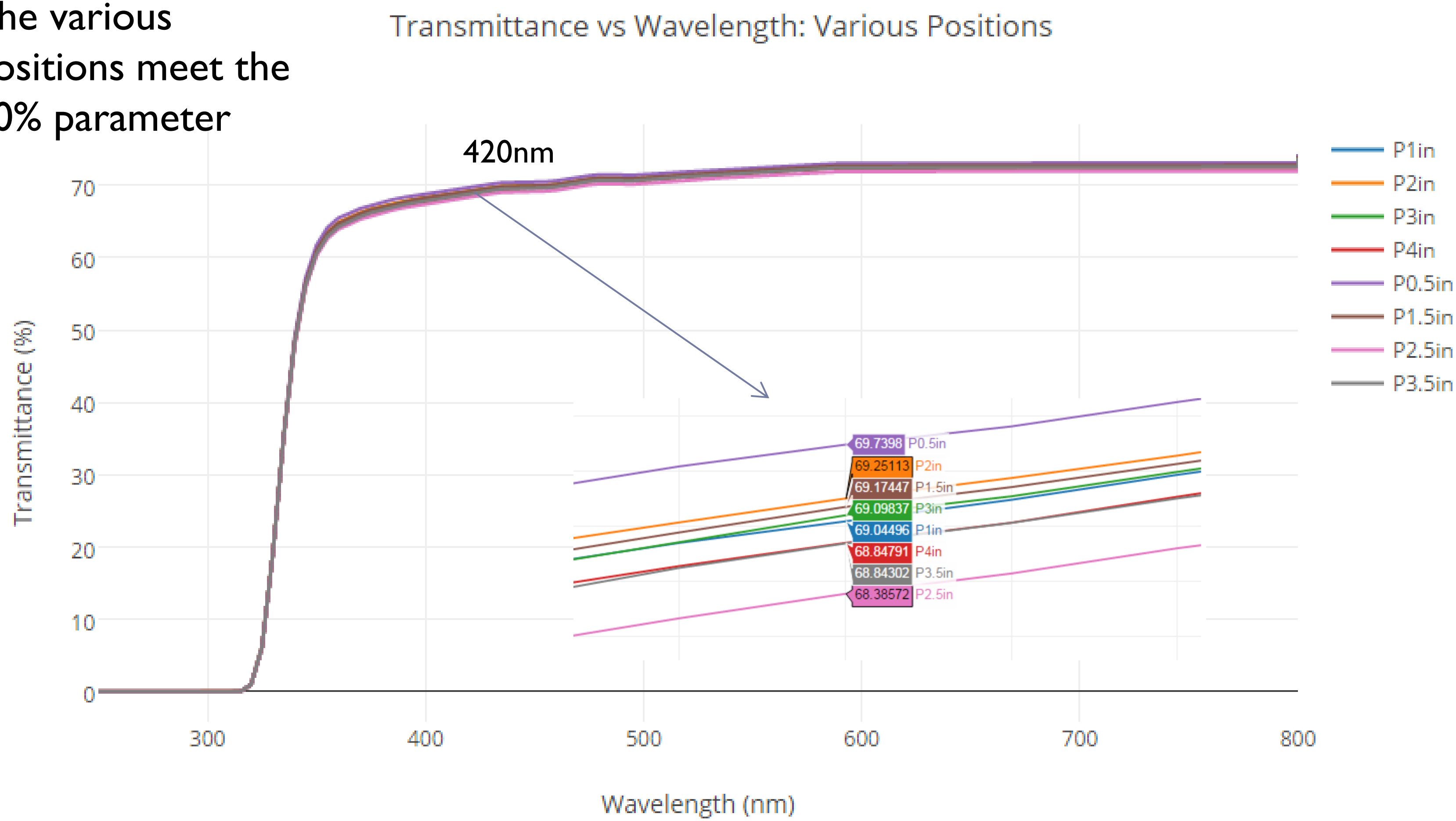
Photo spectrometer: PerkinElmer Lambda 750 UV/VIS/NIR



Thank you VSL for letting me use this machine!

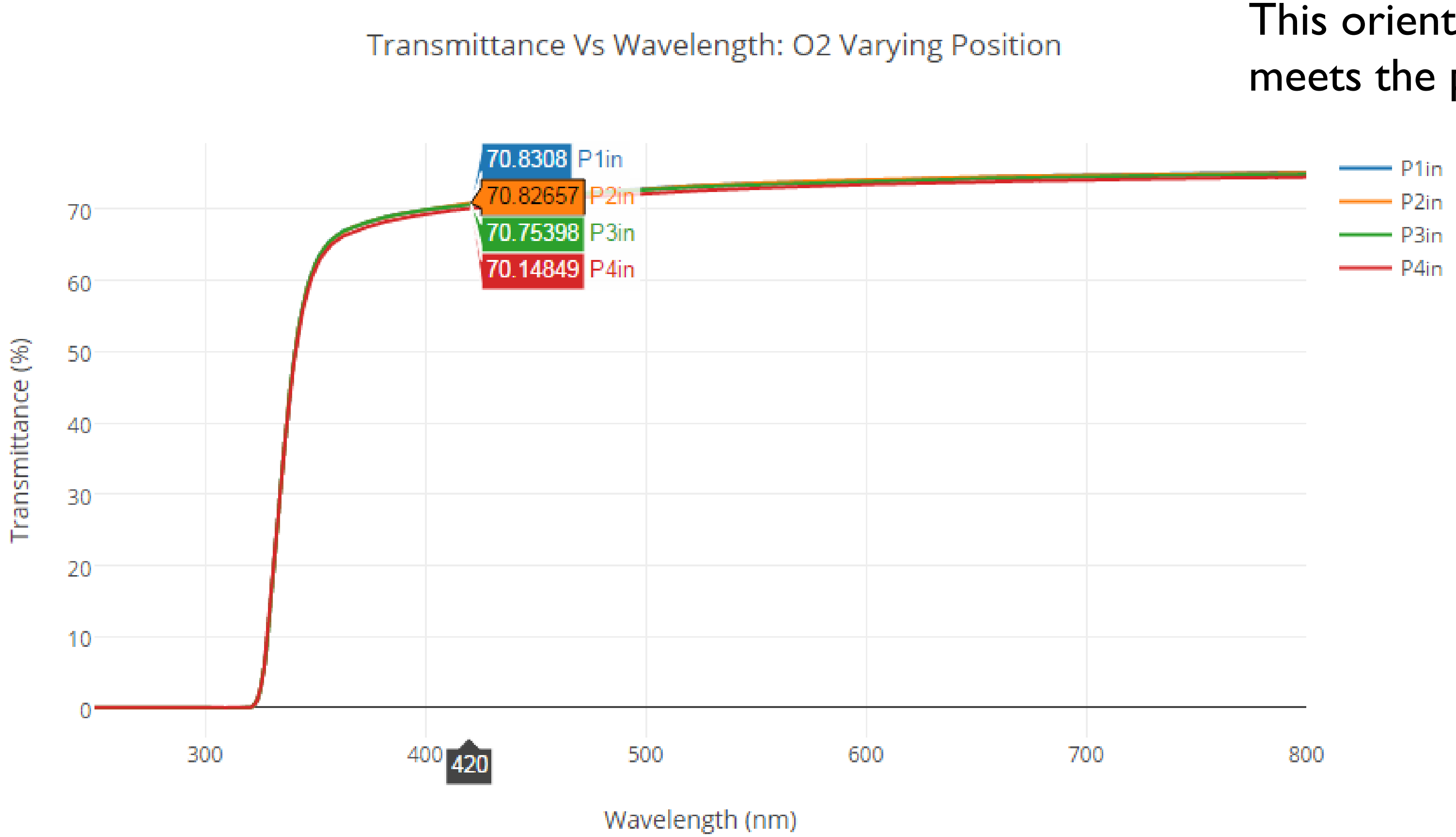
Transmittance: Orientation 1

The various positions meet the 60% parameter



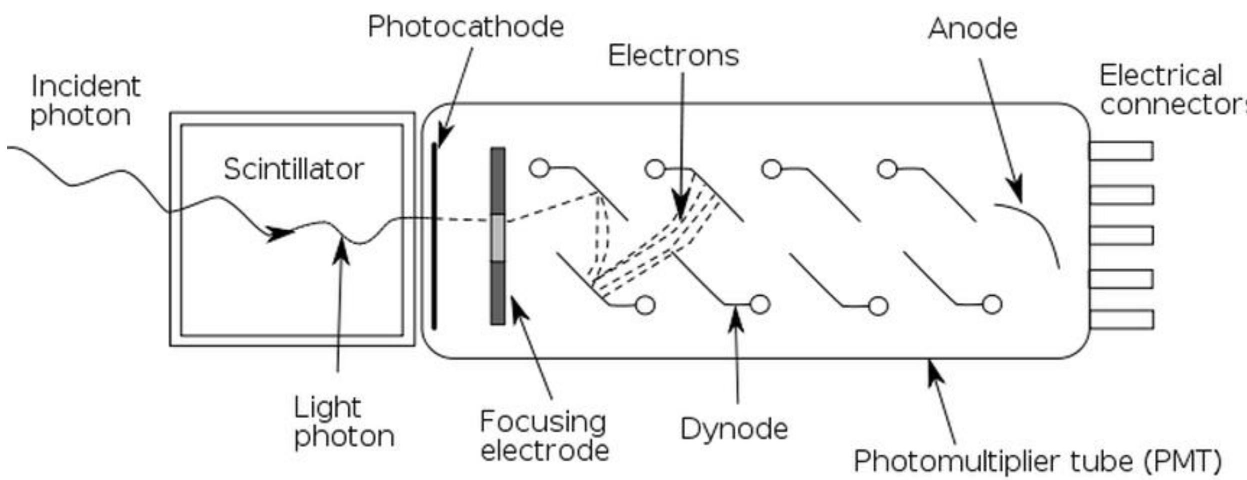
Transmittance: Orientation 2

This orientation also meets the parameters

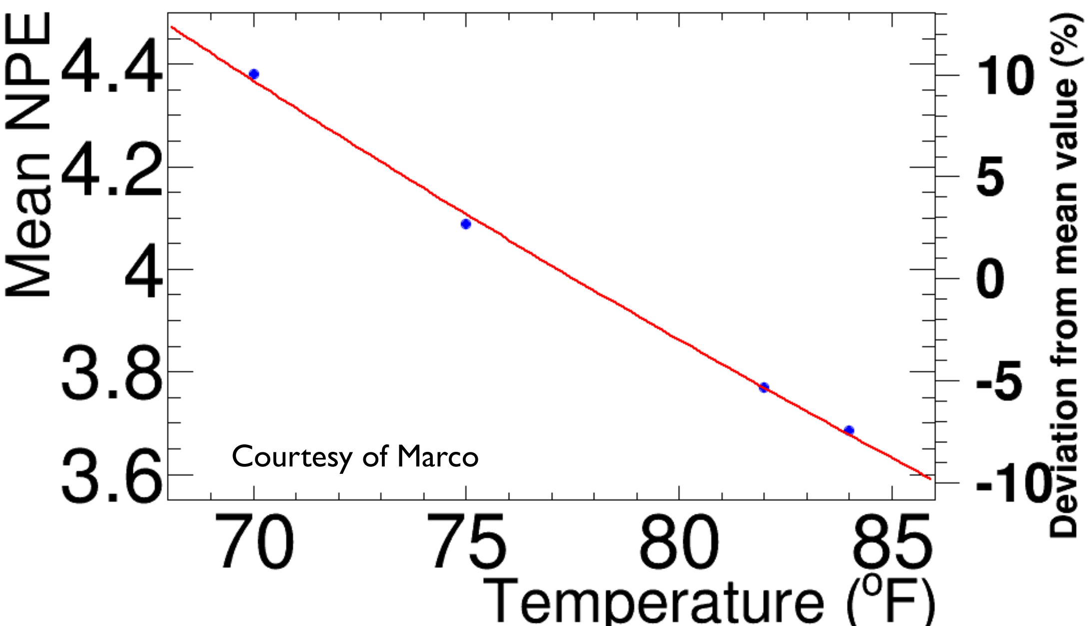


Light Yield

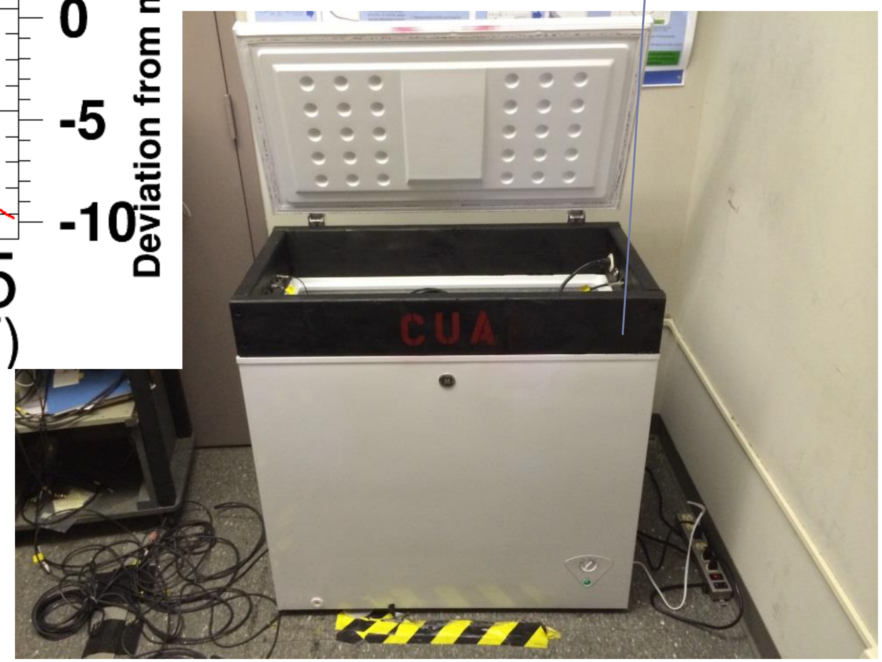
- Light yield is measured in the number of photo-electrons emitted per amount of energy
- We are measuring light yield using a Photo Multiplier Tube (PMT). PMTs use high voltage and the photo-electric effect to allow for the detection of individual photons



Temperature control:



Wooden frame added so that wires can easily reach the inside



Measuring Light Yield

$PbWO_4$

PMT

Radioactive source

Iron to control radiation

Trigger PMT

Upcoming Research

- In the coming weeks I intend to explore the light yield of $PbWO_4$.
- Further, I wish to explore if there is a correlation between position on the crystal and its characteristics
- Also, I will collect data on more crystals so that I can compare data between them

Acknowledgements:

- Dr. Horn
- Marco Carmignotto
- VSL for letting me use equipment