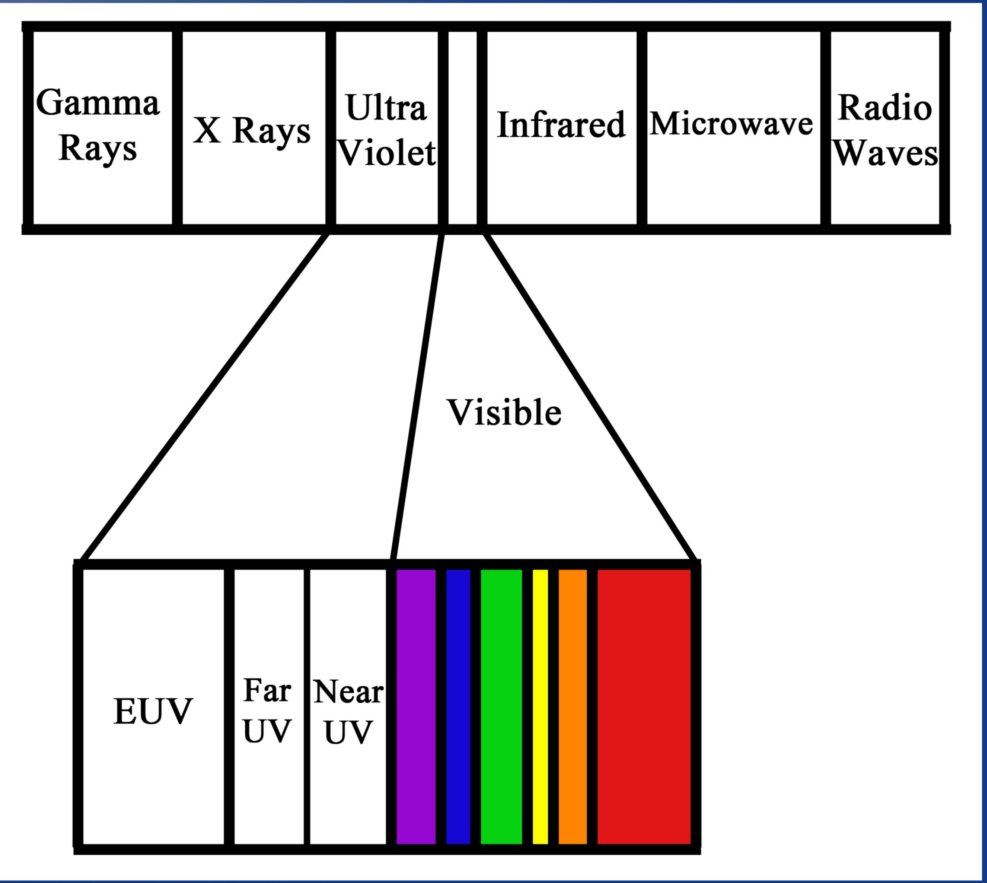
Using EUV Reflection to Understand Thin Film Surfaces

By: Cody Petrie
Brigham Young University
Department of Physics and Astronomy

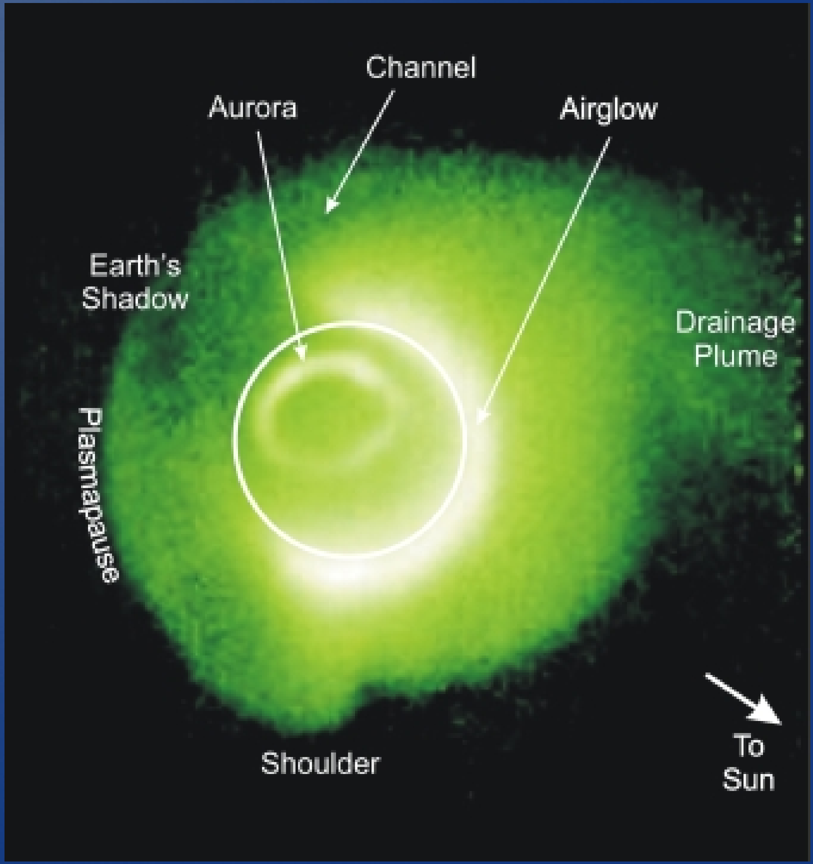
Background

- EUV
  - We use wavelengths of 5nm to 50nm
  - EUV light is very sensitive to absorption in most materials



Background

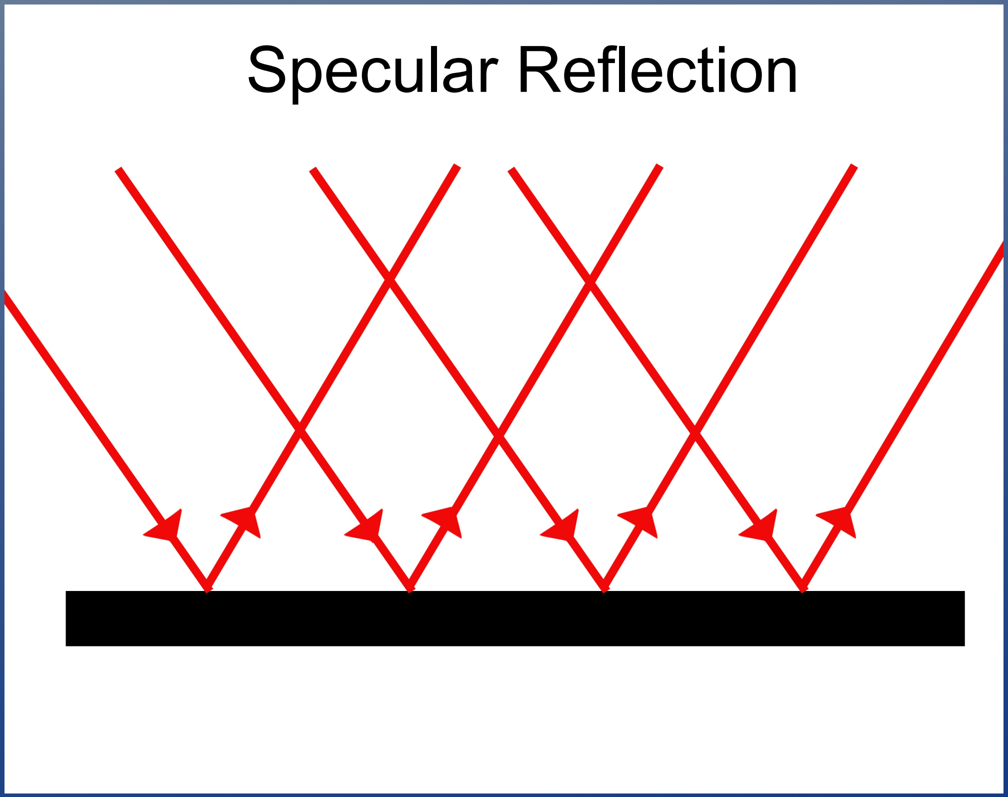
- EUV
  - We use wavelengths of 5nm to 50nm
  - EUV light is very sensitive to absorption in most materials
- Applications
  - Astronomy
  - EUV Lithography
  - Microscopy
  - Etc.

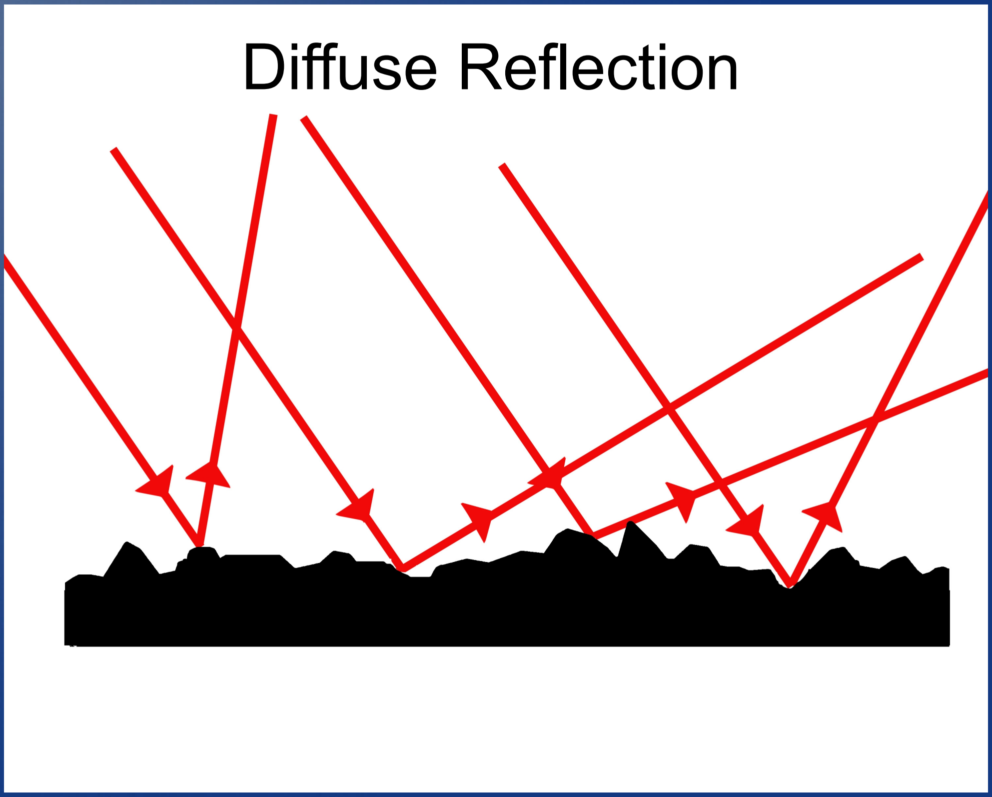


http://euv.lpl.arizona.edu/euv/

Background

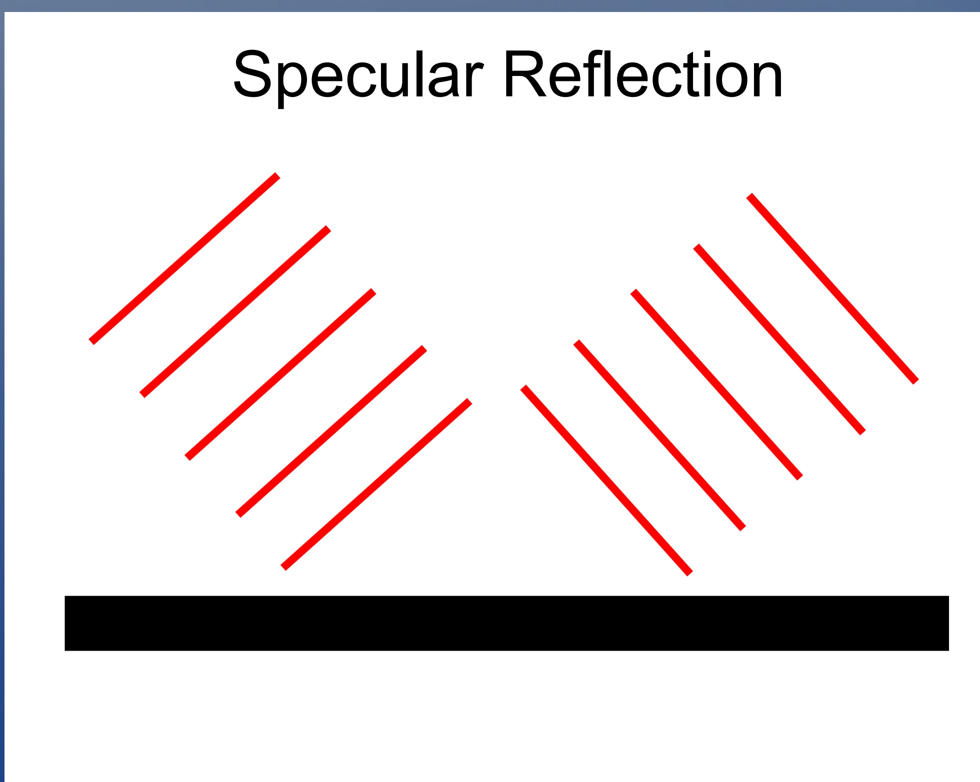
- Diffuse Reflection
  - EUV light is sensitive to deviations in the surface roughness that are comparable to the wavelength of EUV light.

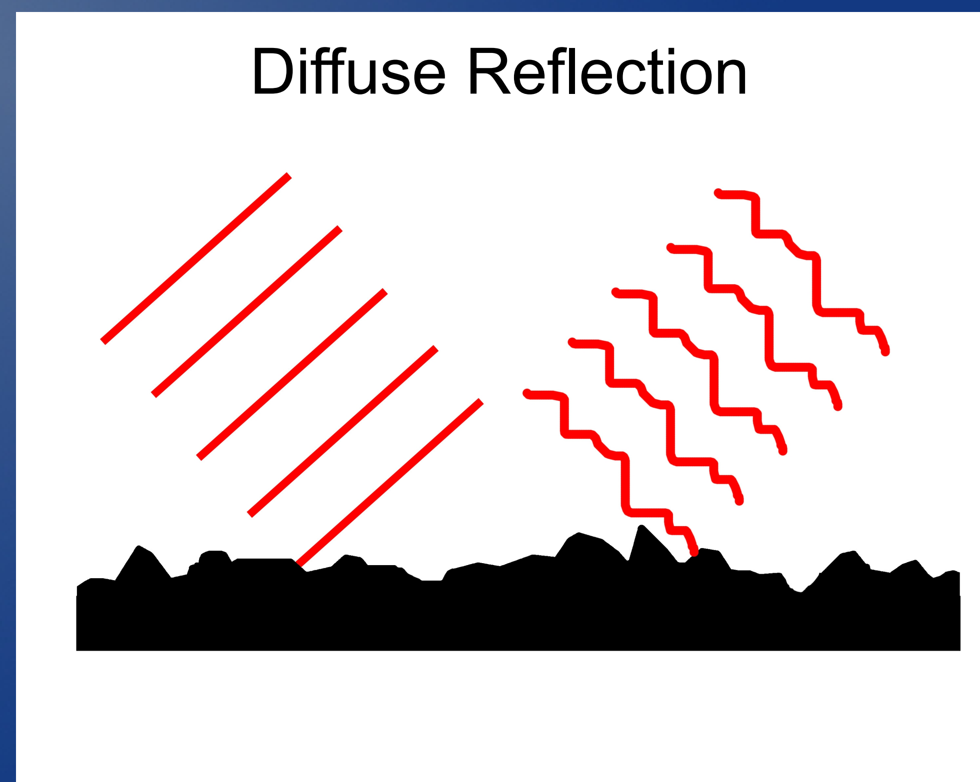




Background

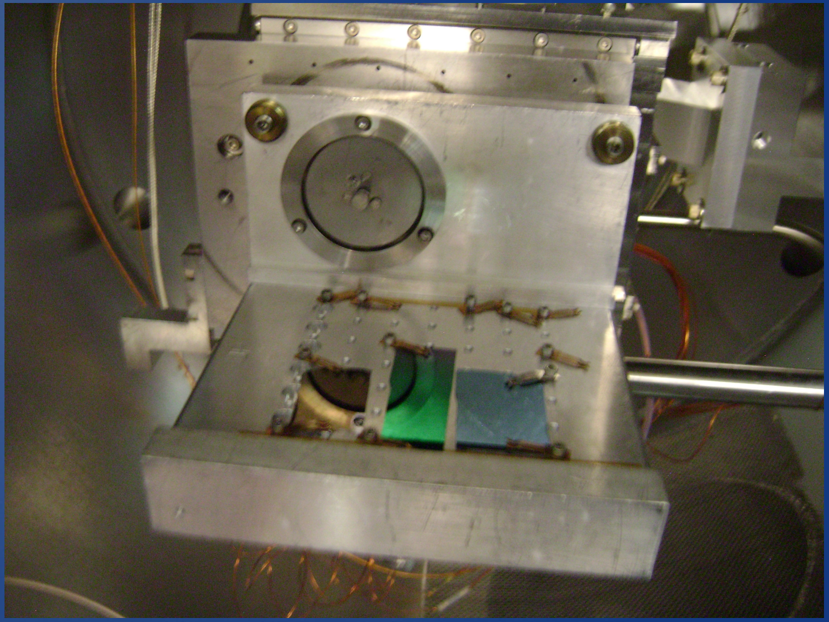
- Diffuse Reflection
  - Plane wave description of diffuse reflection





Goal/Method

- Goal
  - Learn something about thin film surface features.
- Method
  - Calculation/AFM
  - Reflection Measurements

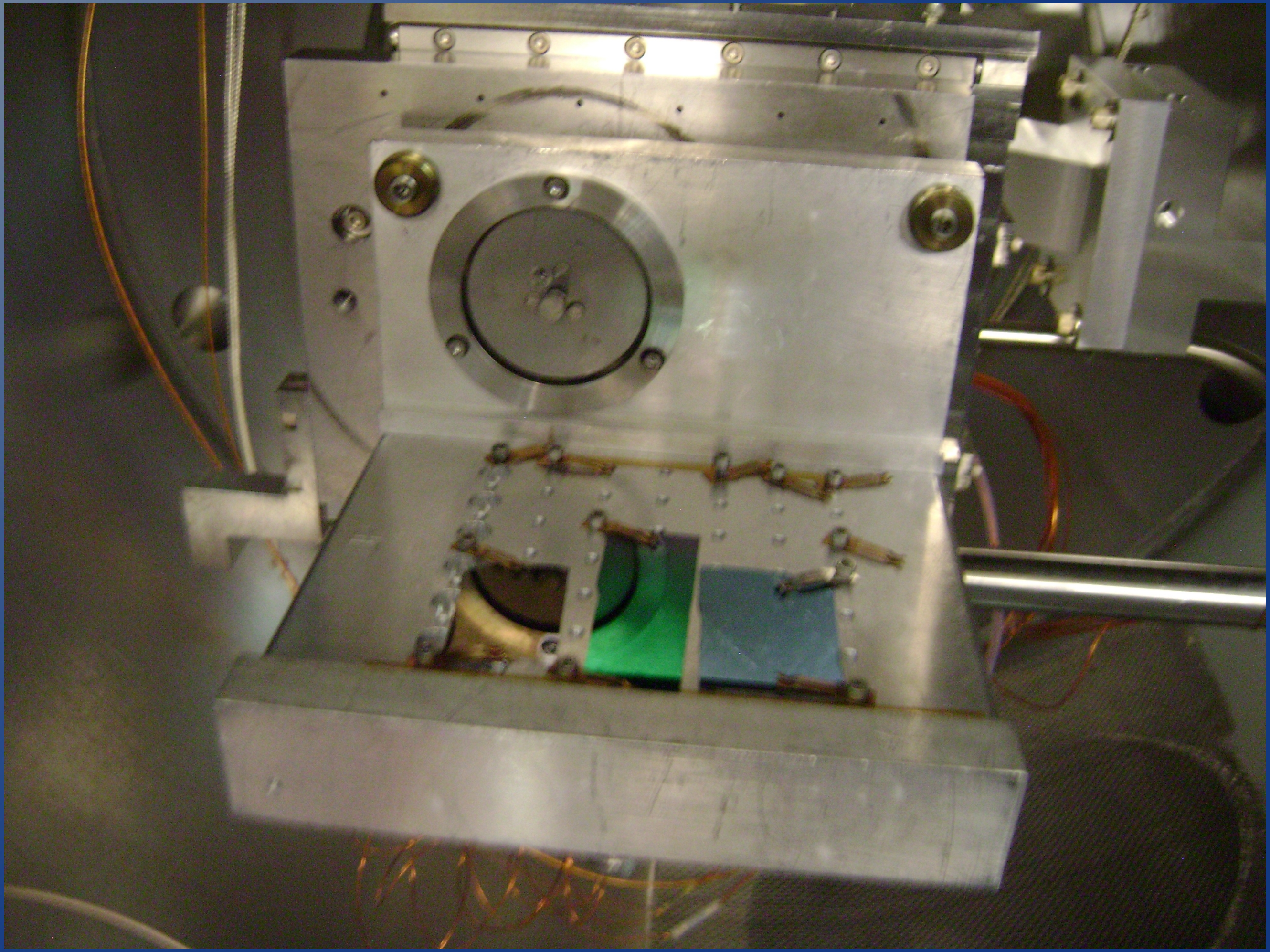


Samples

- Taken on two UO_3 Thin Films

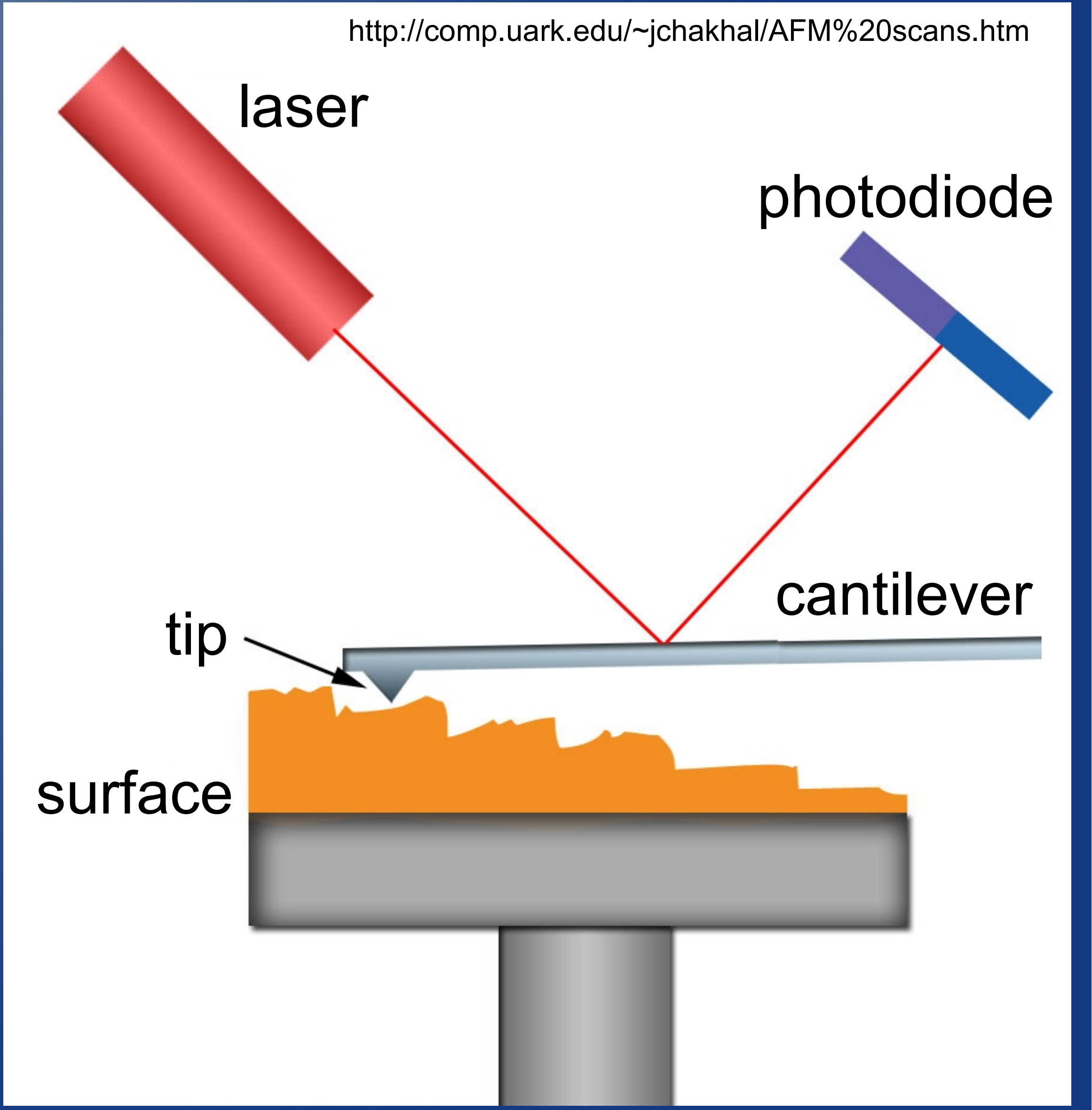
44nm Thick

412nm Thick

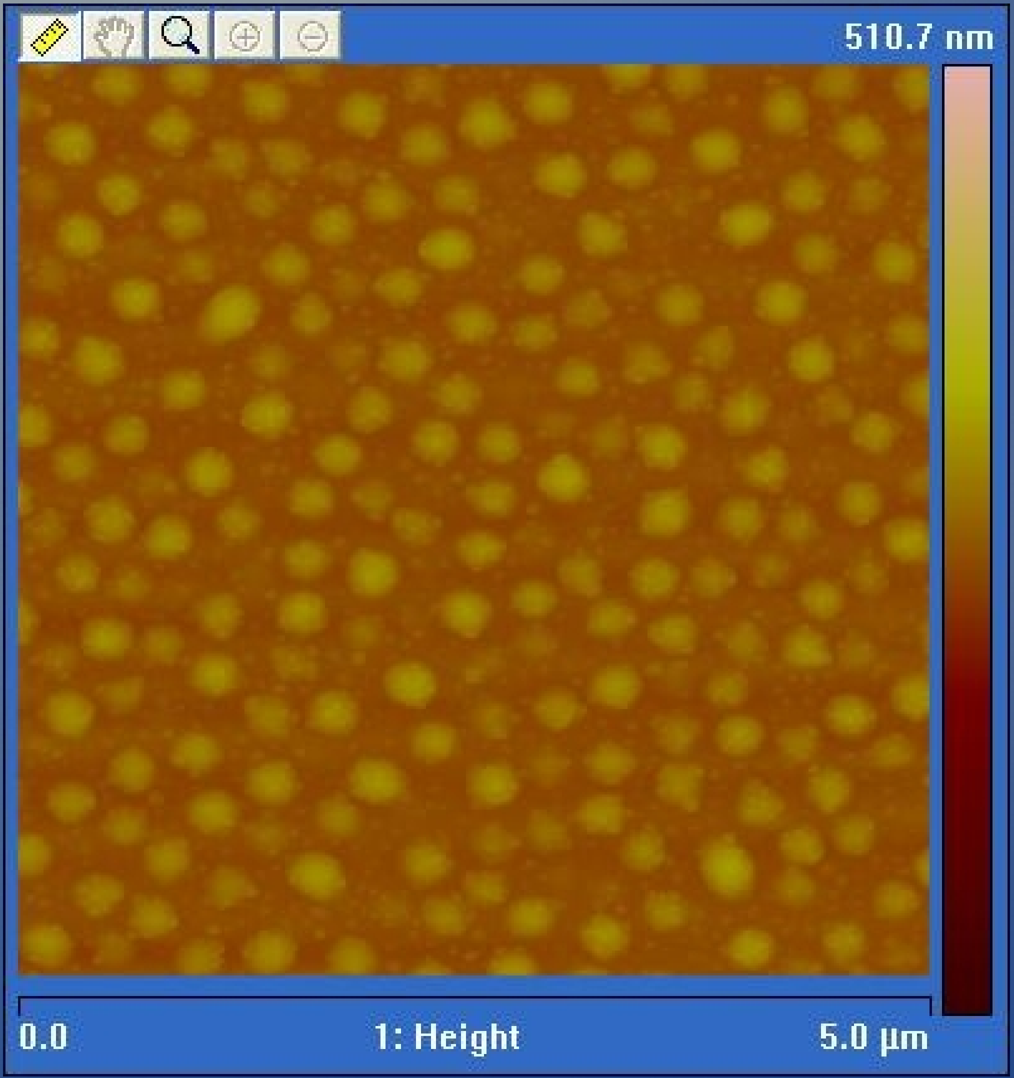


AFM

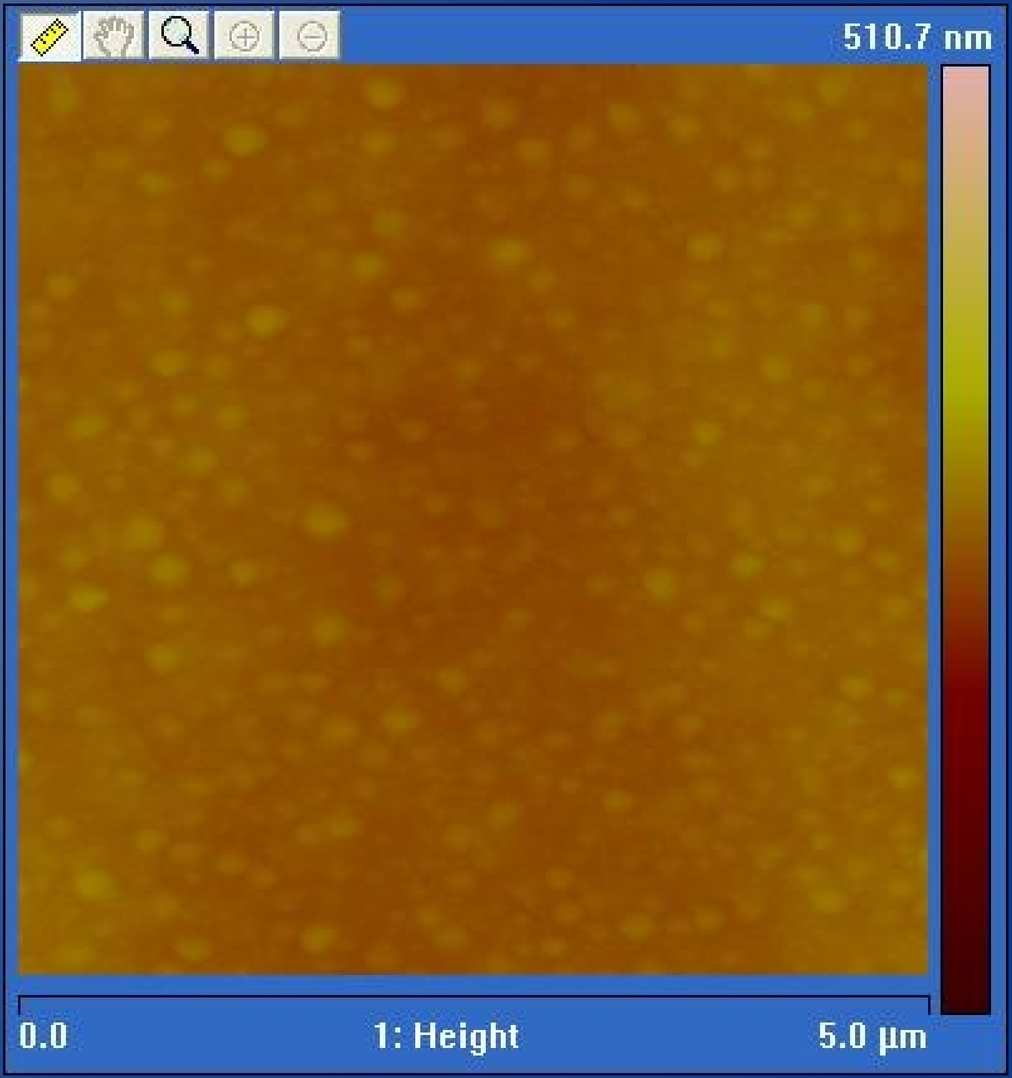
- Tip is bounced across the surface.
- Laser detects movement of the cantilever and height is recorded.



AFM



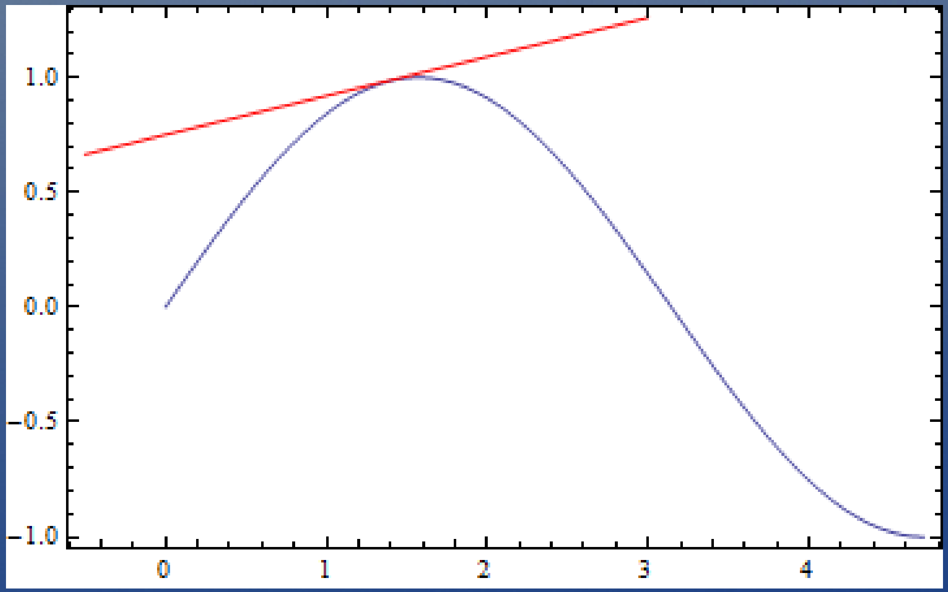
Thickness: 44nm
RMS height: 16.8nm
Ave Spacing: 0.385µm



Thickness: 412nm
RMS height: 9.39nm
Ave Spacing: 5.0µm

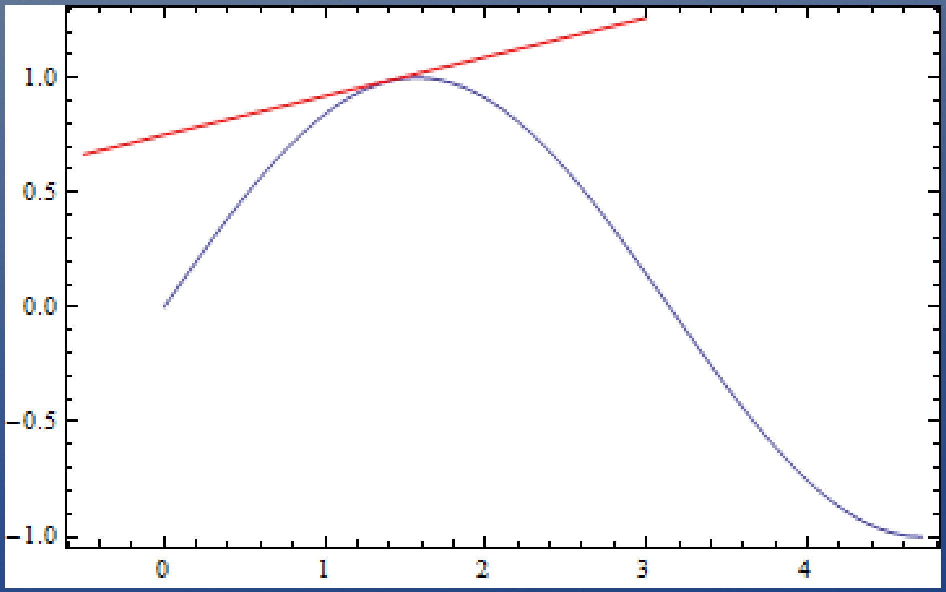
Physical Optics Calculation

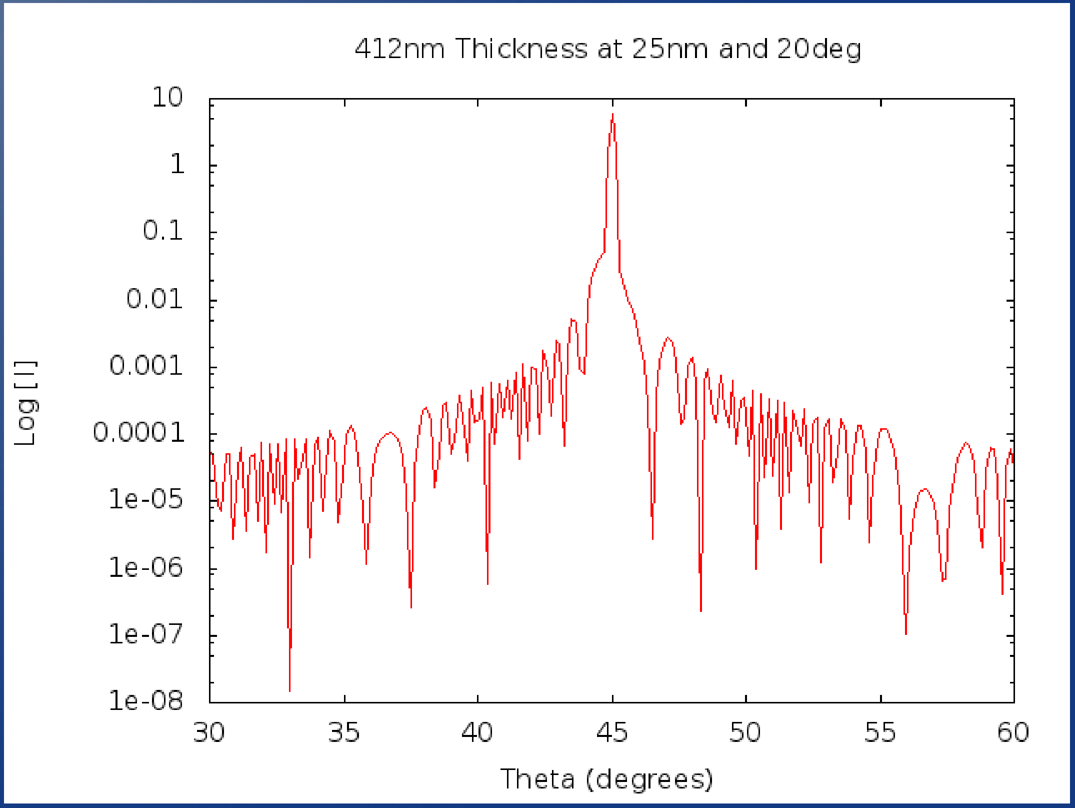
- Kirchhoff approximation



Physical Optics Calculation

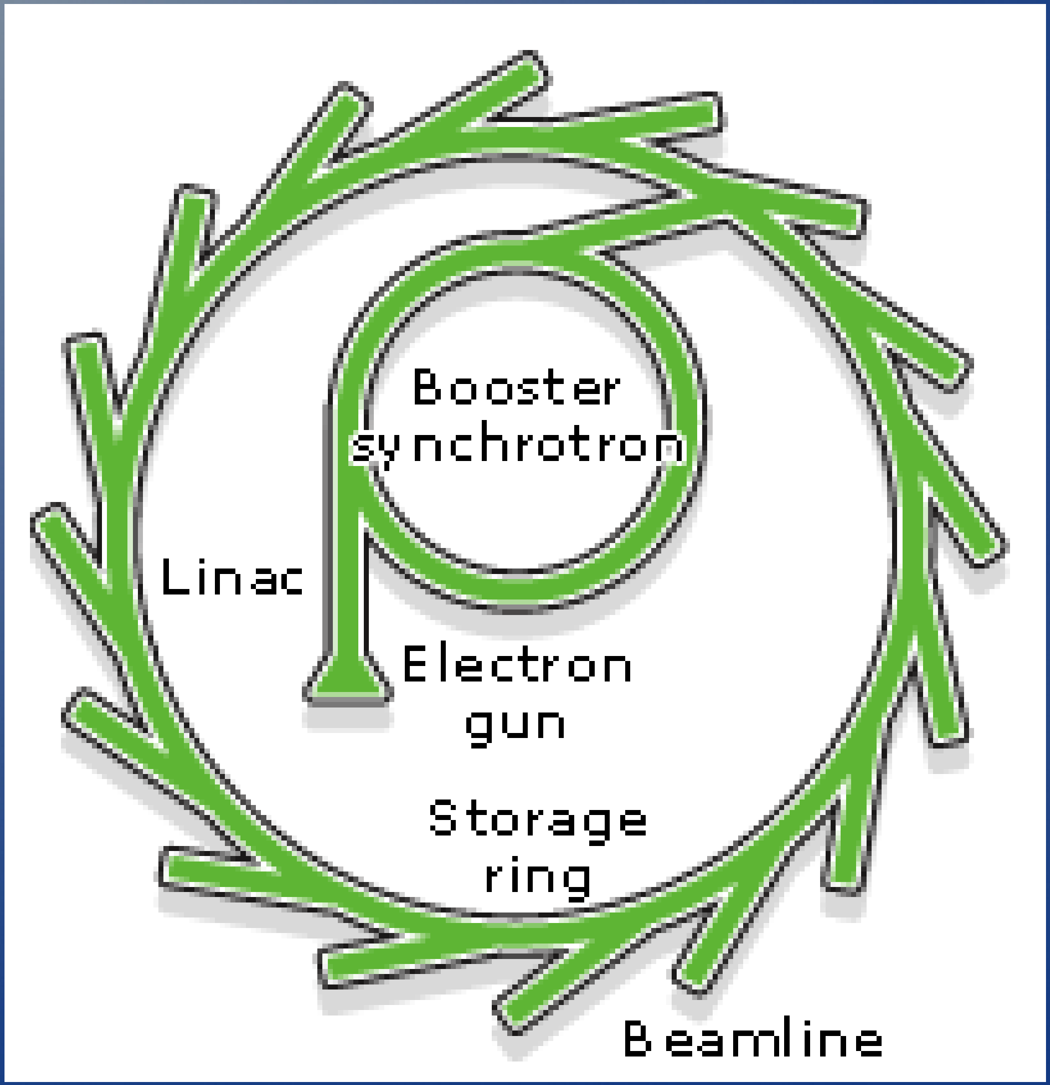
- Kirchhoff approximation
- Use Maxwell's equations to calculate the current induced by incident light
- Calculate radiation in the far field



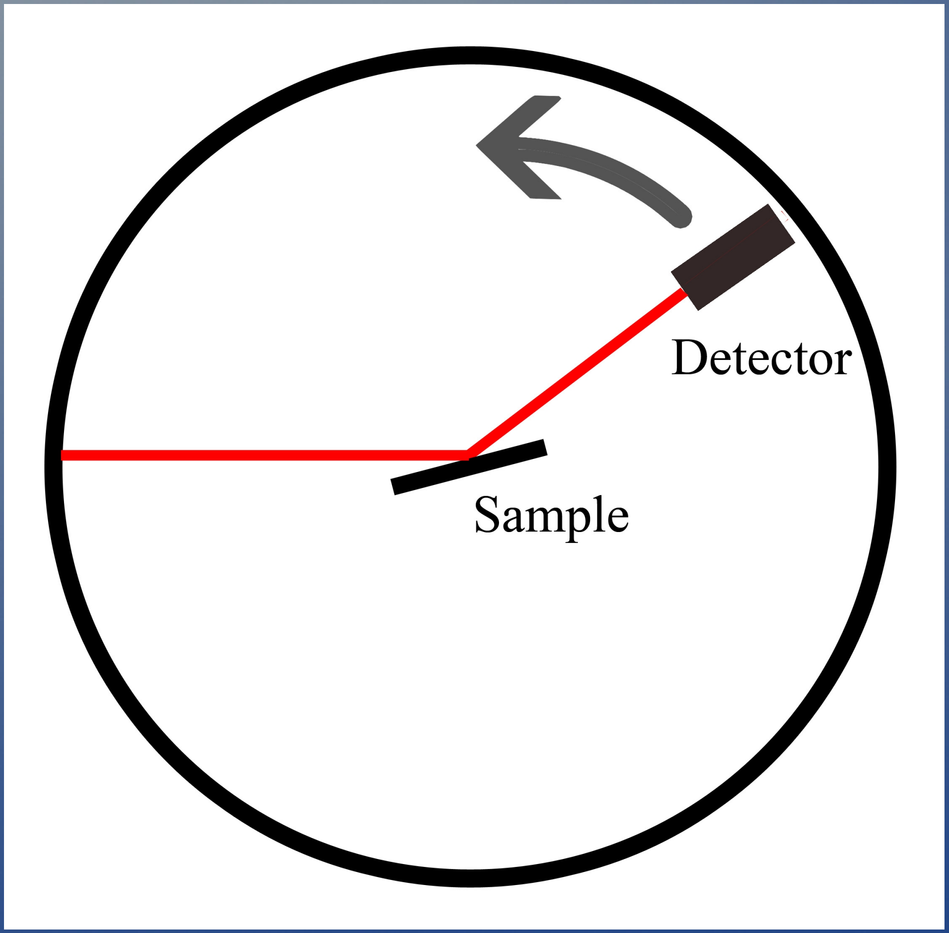


Reflection at The ALS

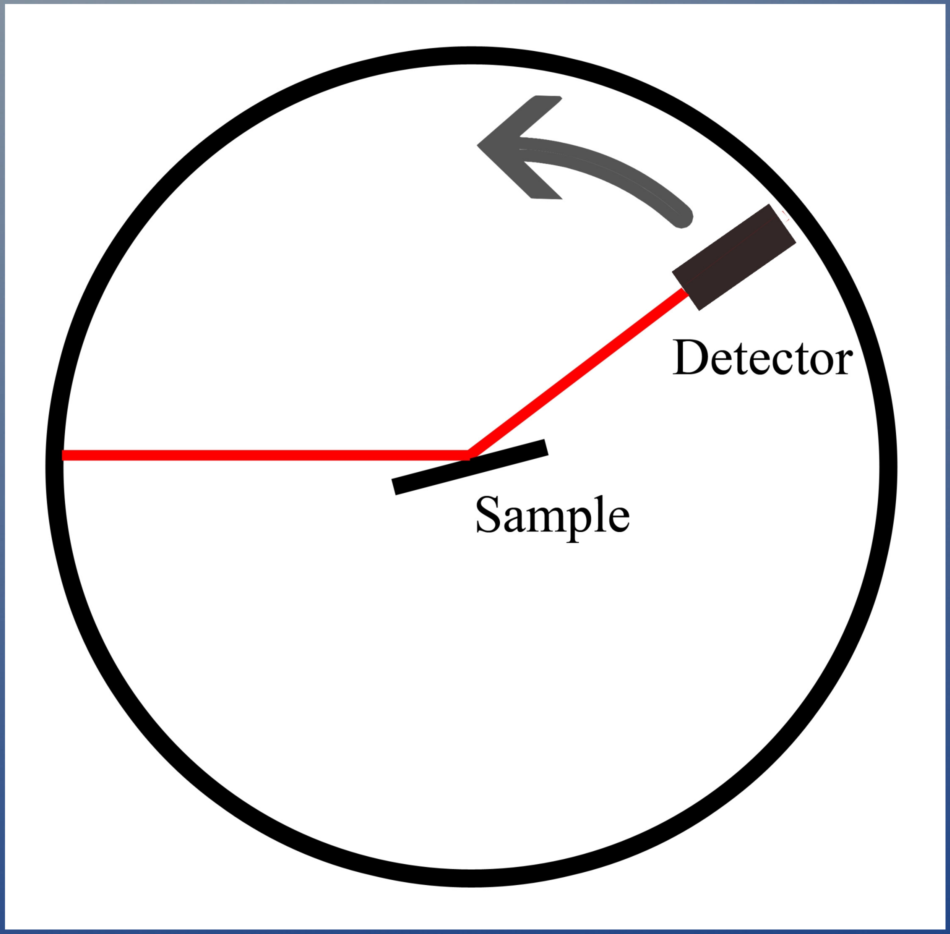
- Synchrotron Radiation

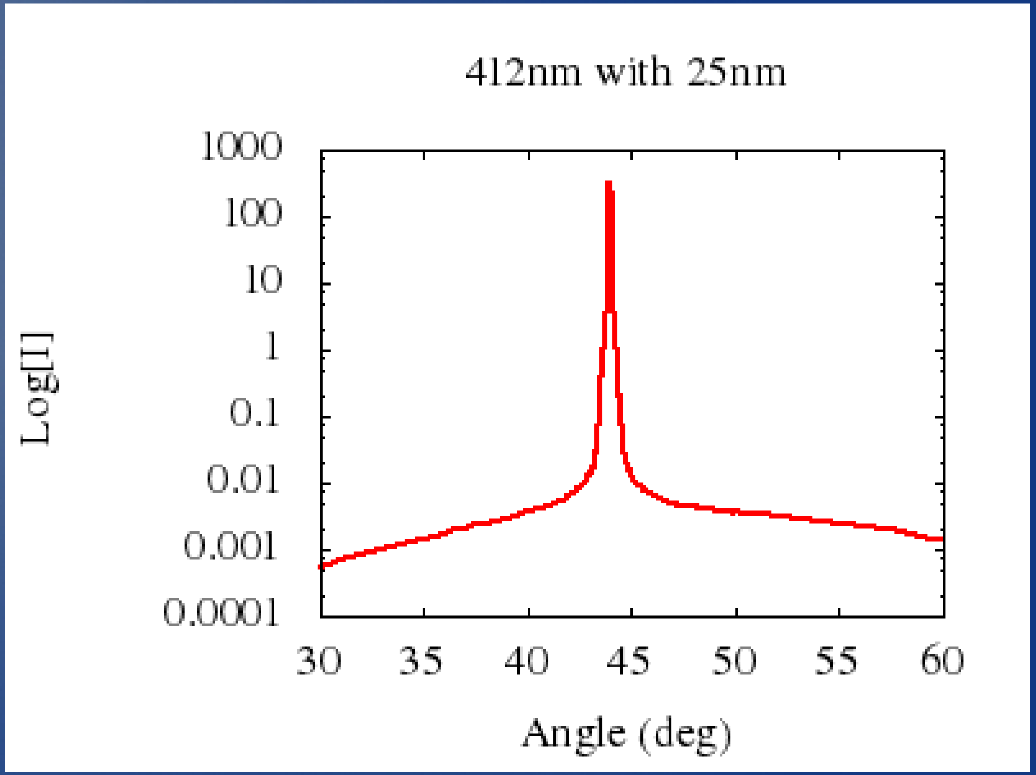


ALS Reflectometer

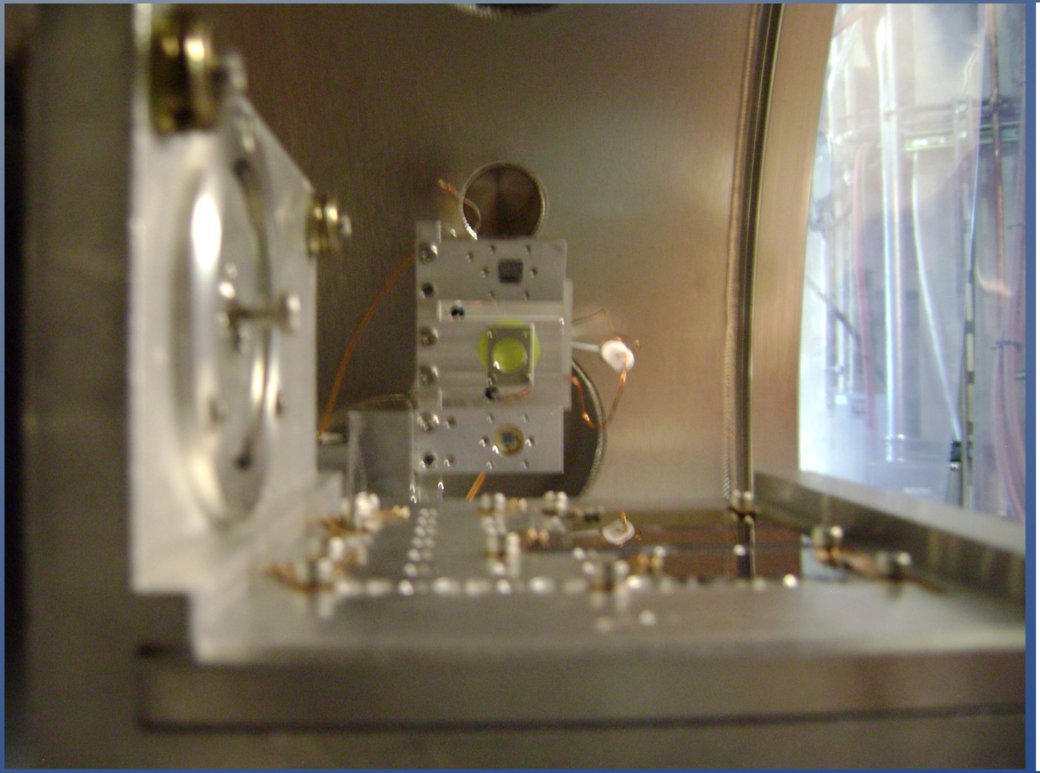


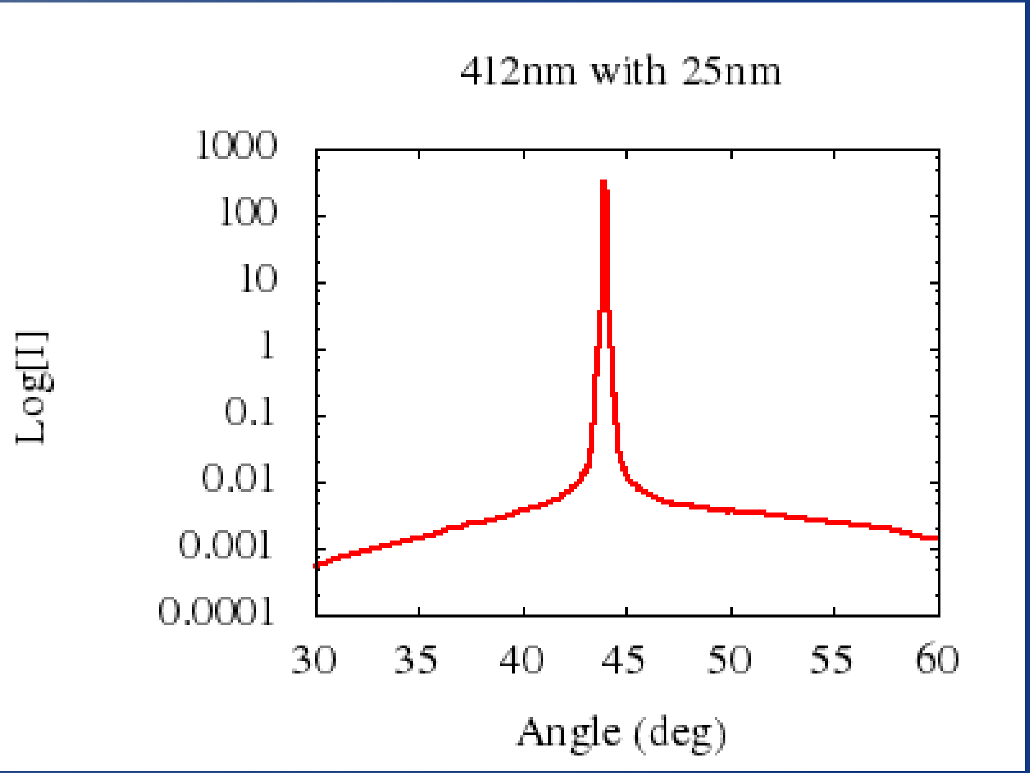
ALS Reflectometer





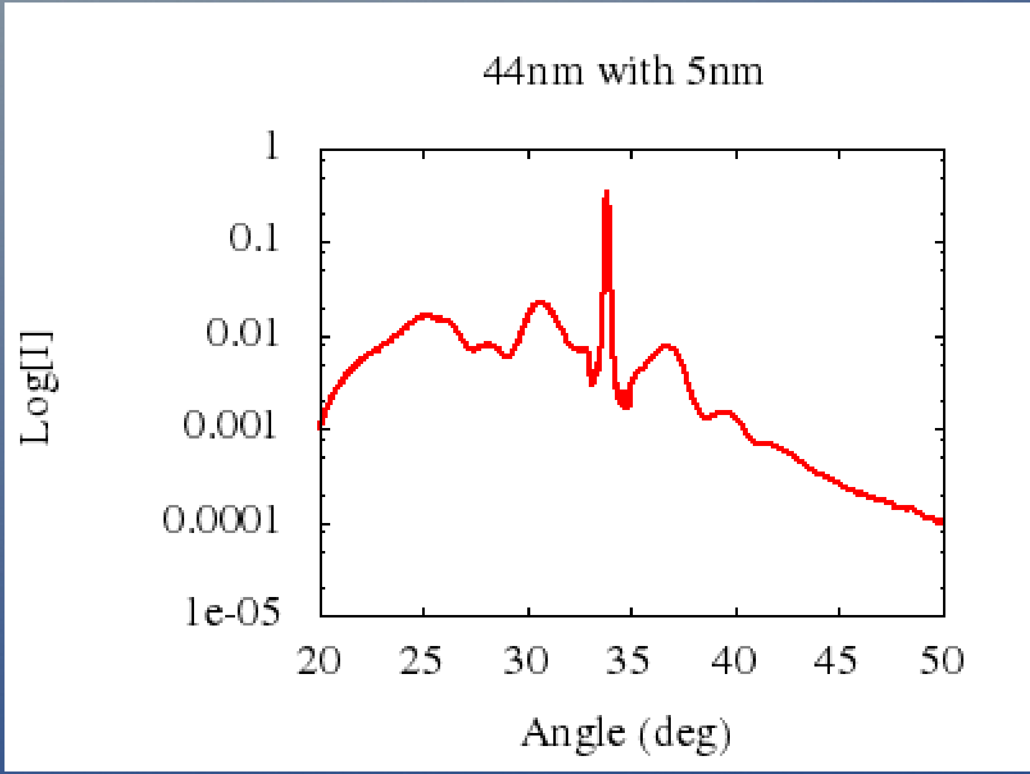
ALS Reflectometer

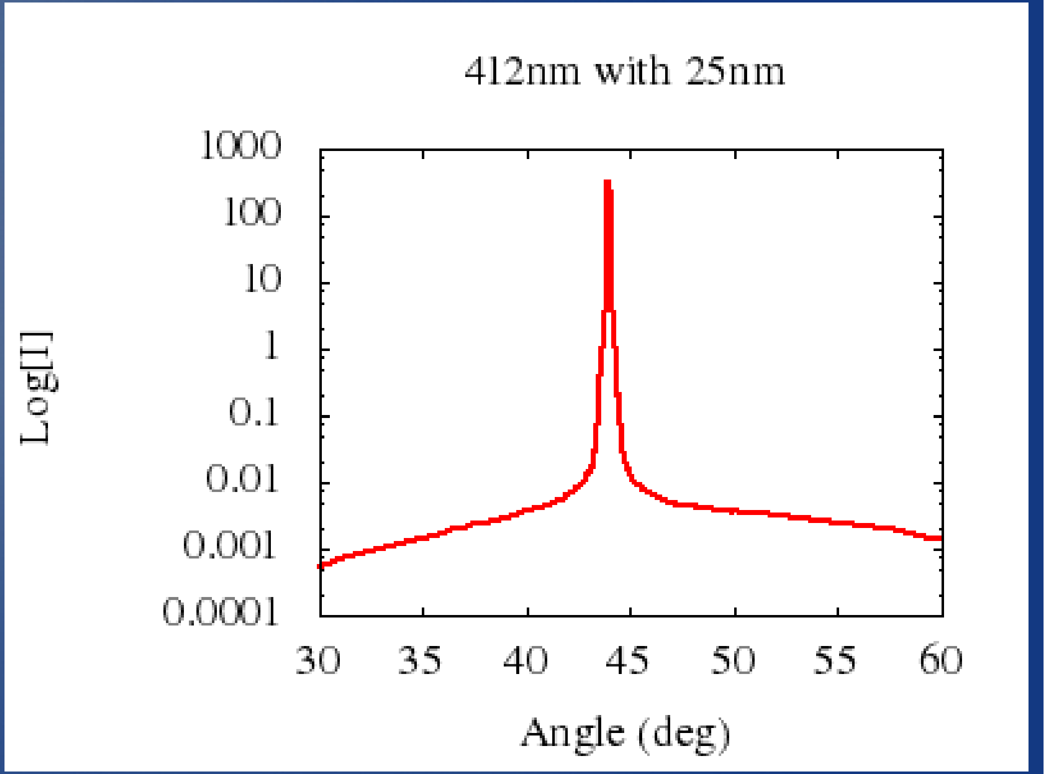




1. Channeltron
2. Photodiode

Reflection Results

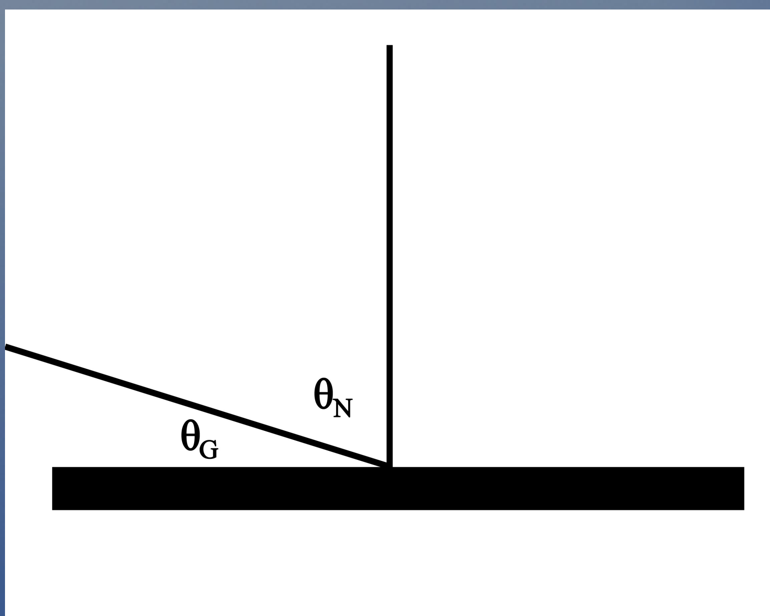


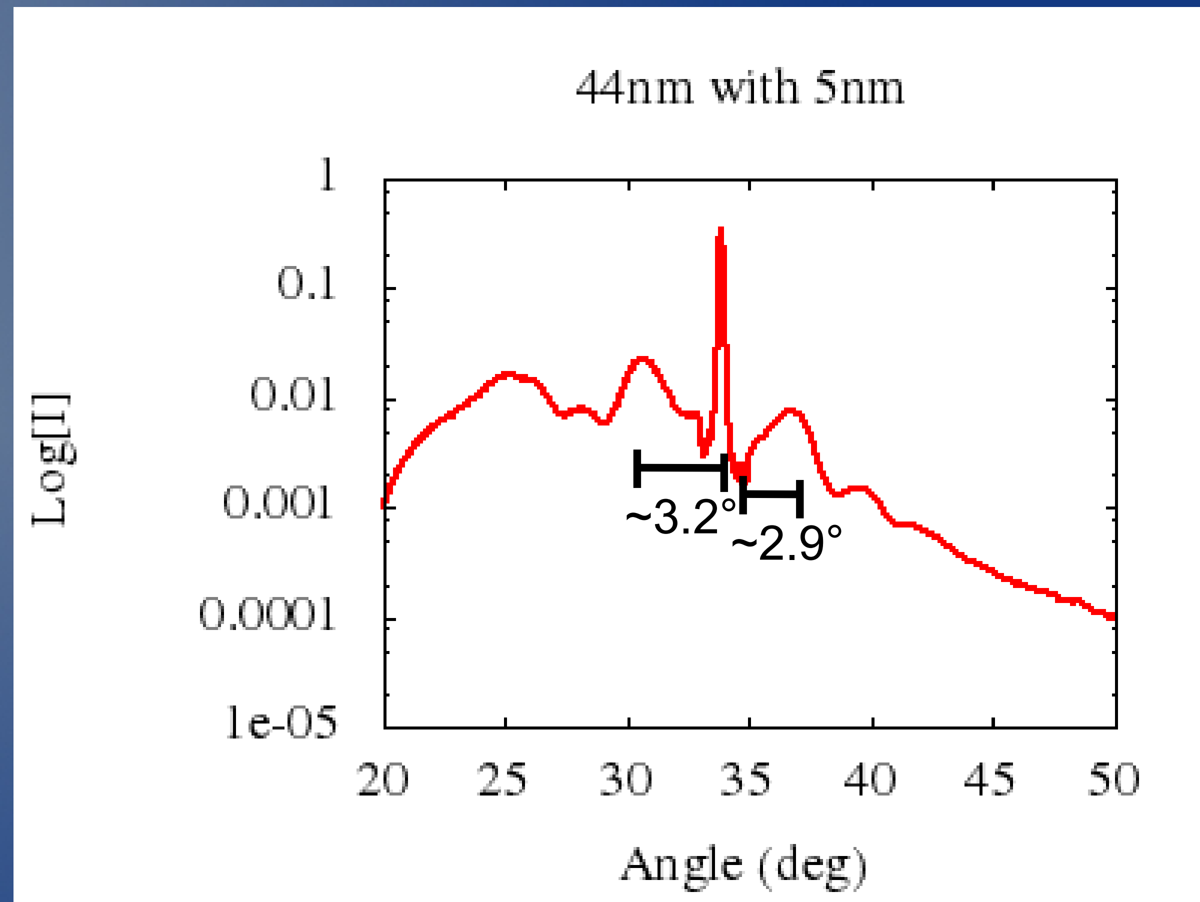


Diffraction Grating?

- Grating Equation

$$d\left(\sin\left(\theta_i\right)+\sin\left(\theta_m\right)\right)=m\lambda$$





$$d\left(\sin\left(75.0^\circ\right)+\sin\left(-71.955^\circ\right)\right)=(1)*5\text{nm}$$

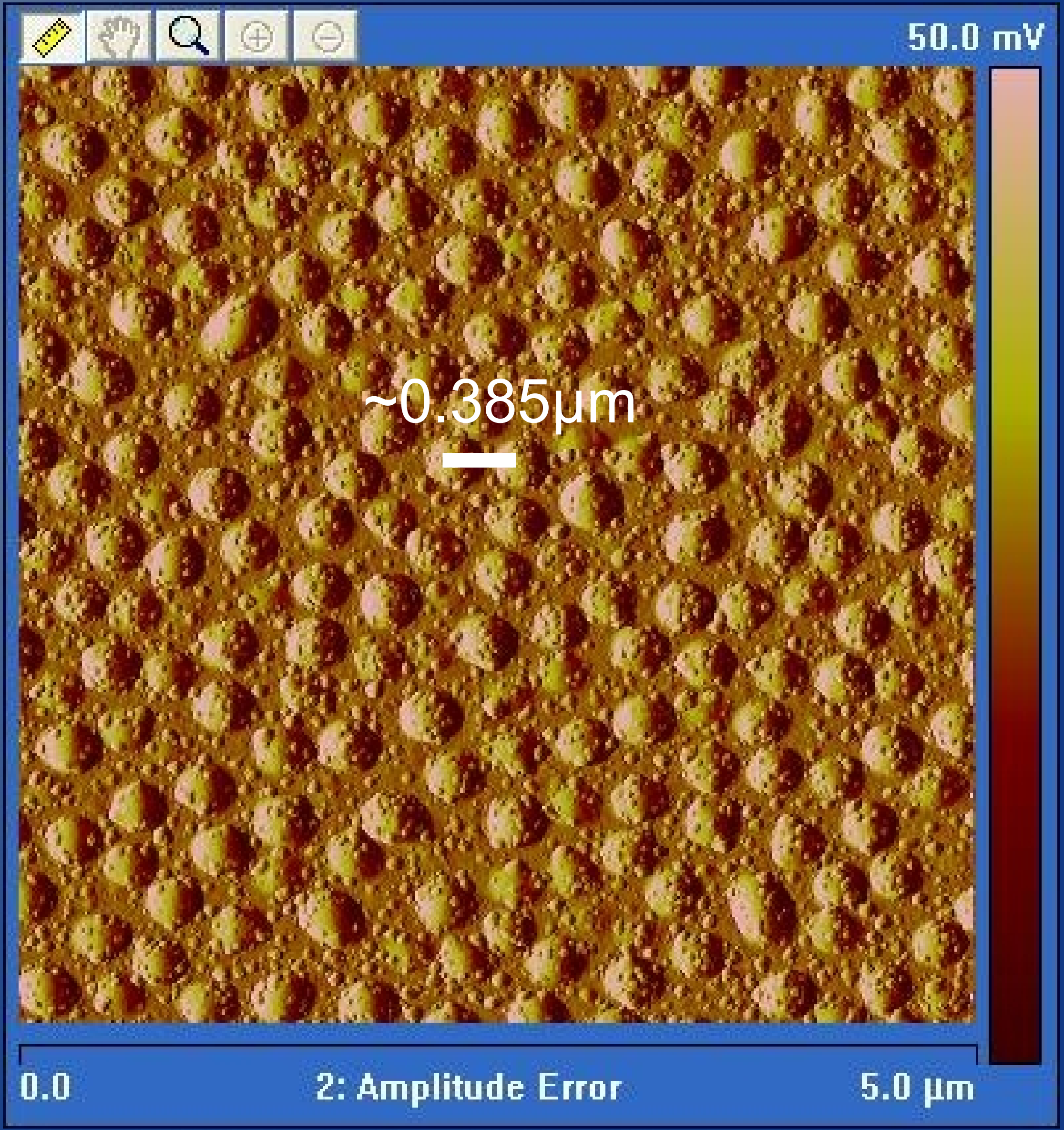
$$d=0.331\,\mu m$$

Diffraction Grating?

- Grating Equation

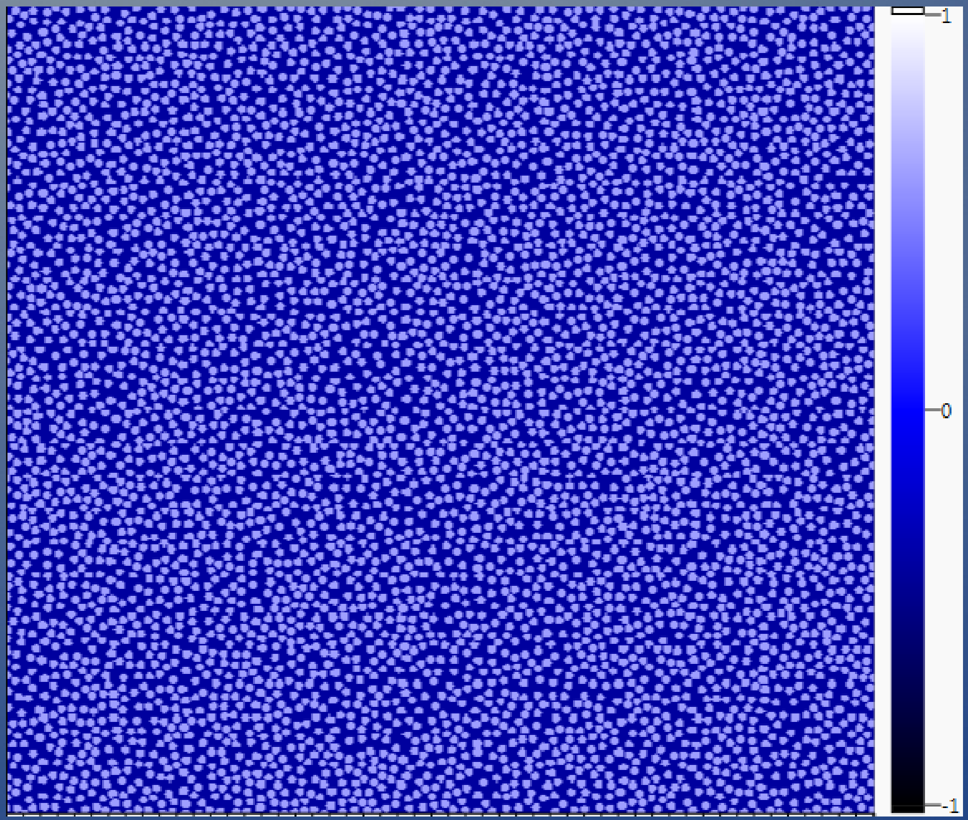
$$d\left(\sin\left(\theta_i\right)+\sin\left(\theta_m\right)\right)=m\lambda$$

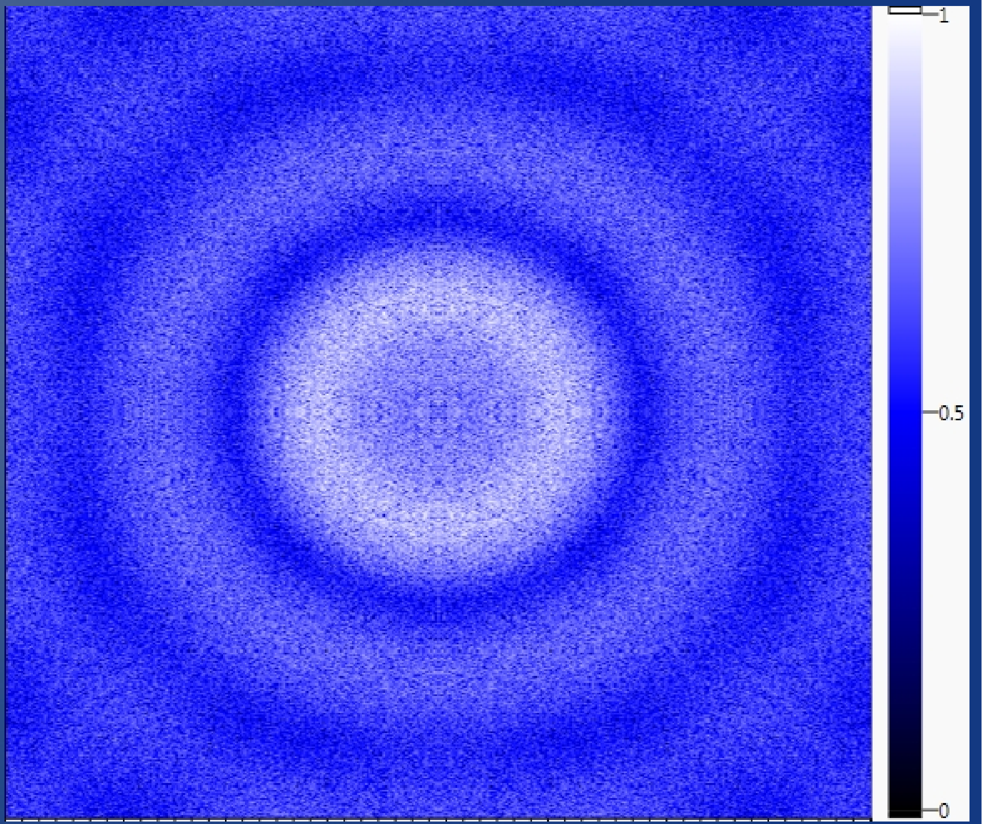
$$d=0.331\,\mu m$$



Bumps On Surface

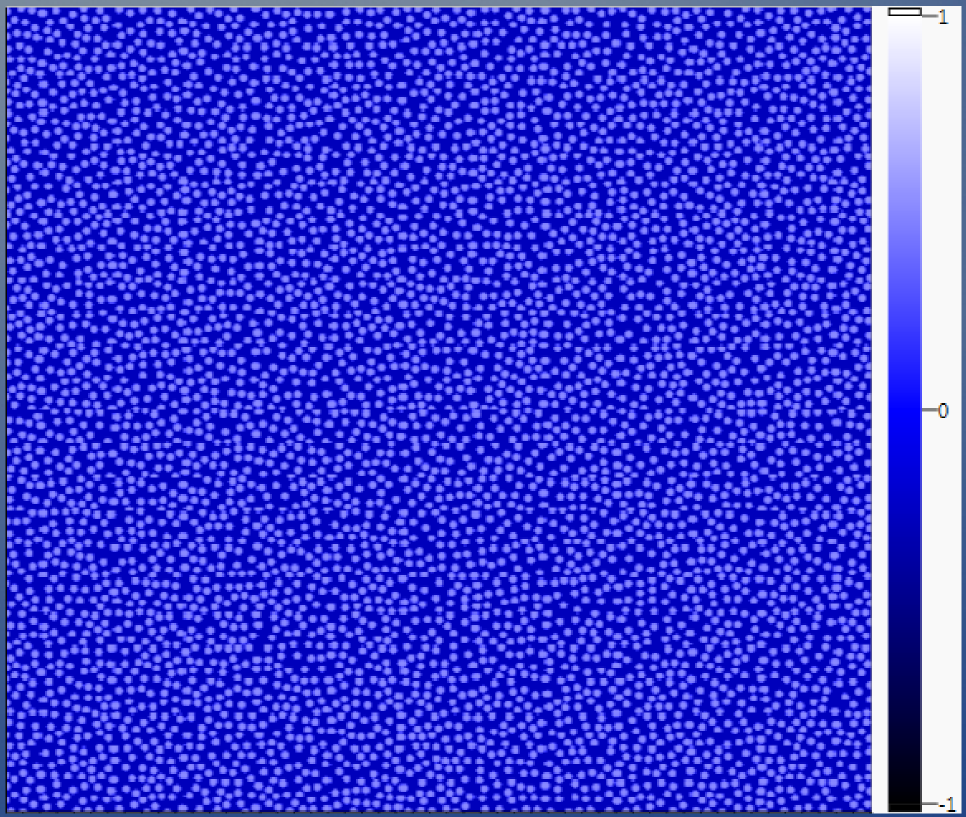
Circles

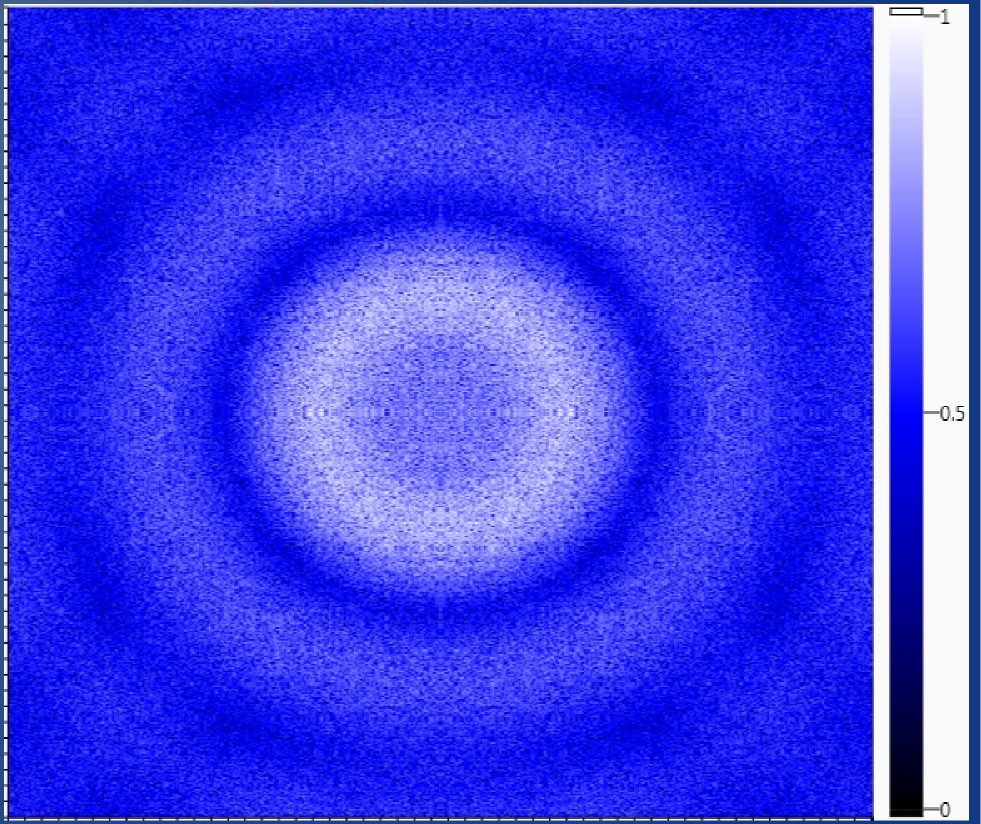




Bumps On Surface

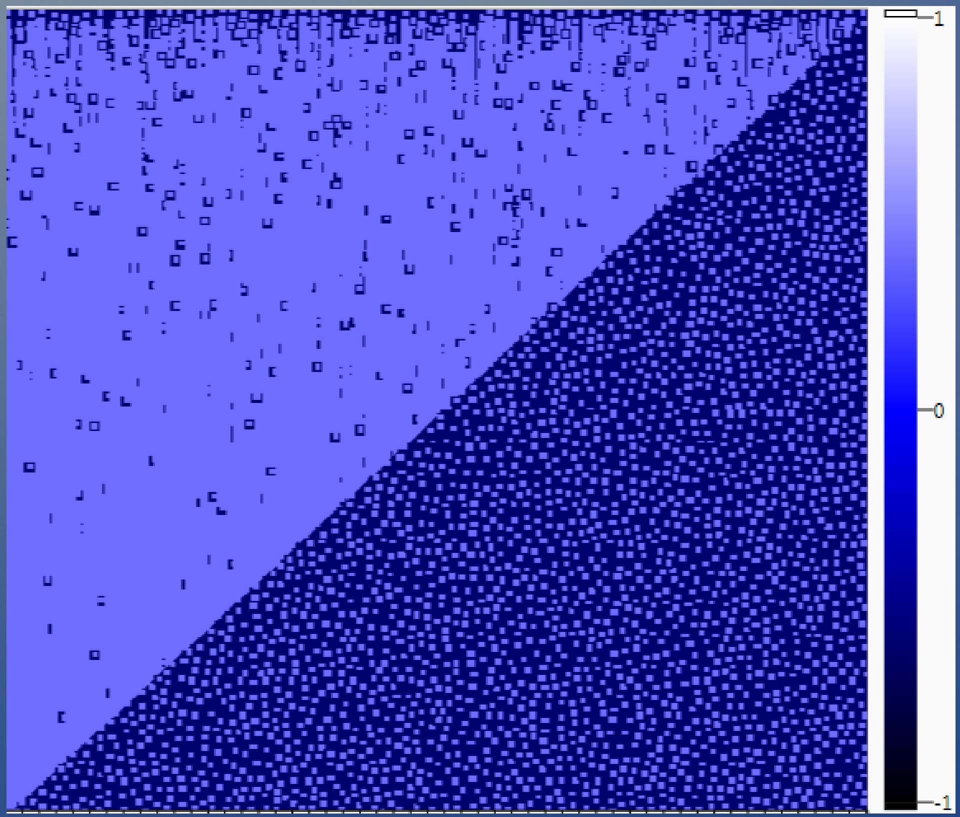
Hemispheres

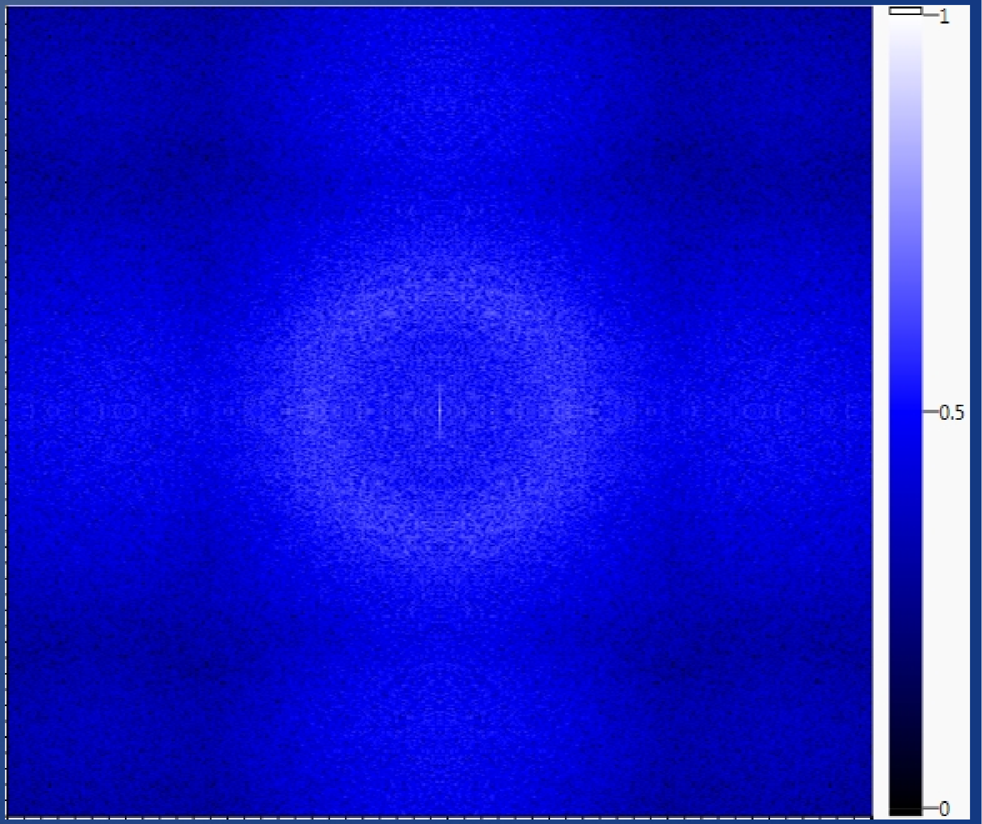




Bumps On Surface

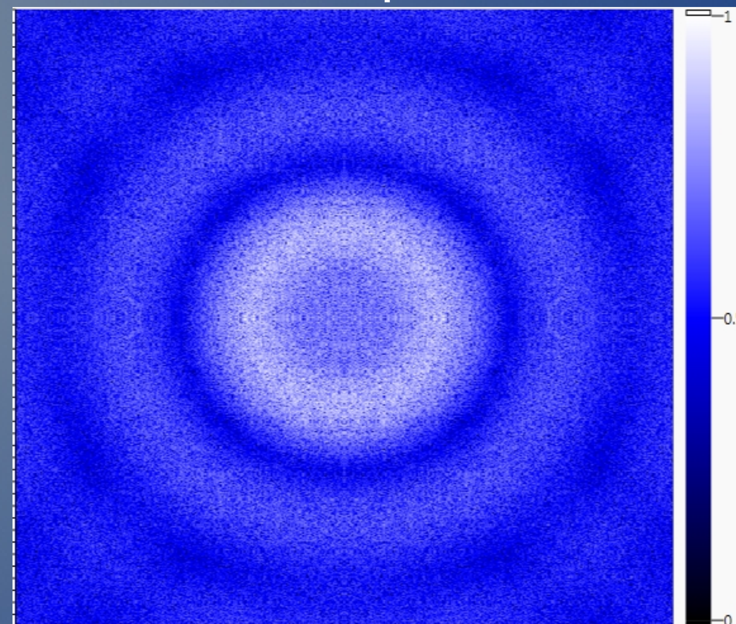
Square





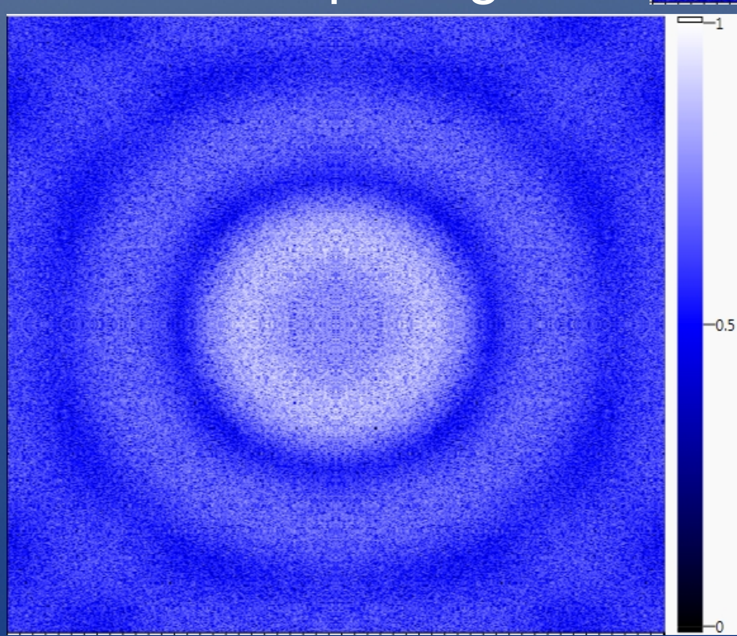
Bumps On Surface

Hemisphere

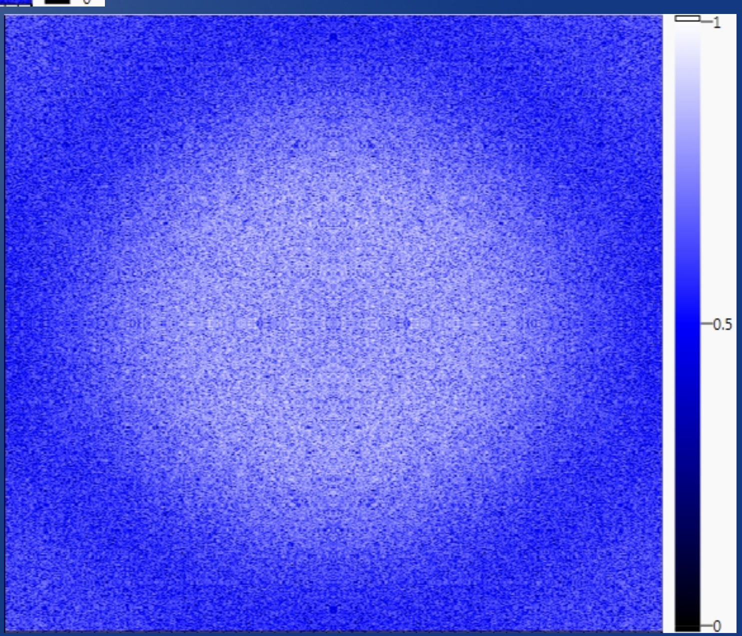


Normal

Half Spacing



Half Radius



Circular Aperture

$$I(\theta) = I_0\left(\frac{2J_1(kasin(\theta))}{kasin(\theta)}\right)^2$$

Circular Aperture

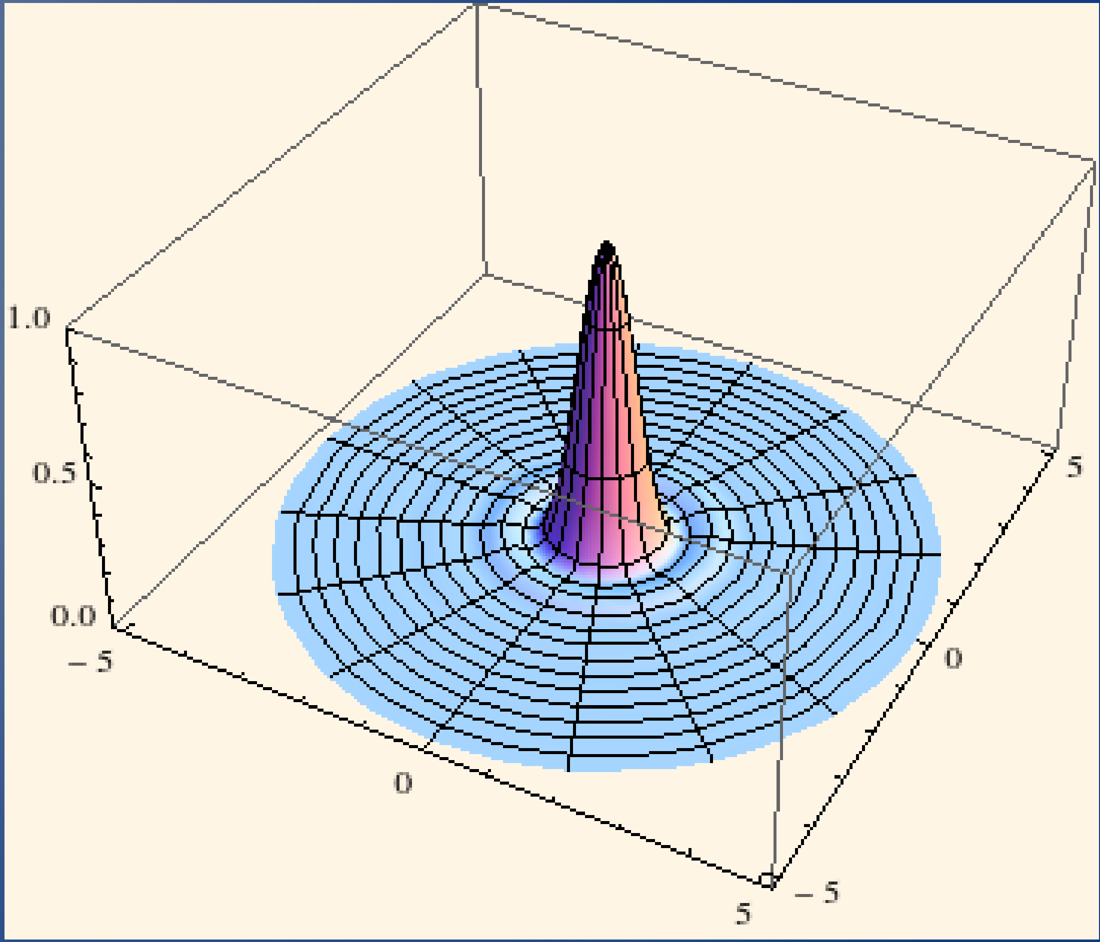
$$I(\theta) = I_0\left(\frac{2J_1(kasin(\theta))}{kasin(\theta)}\right)^2$$

J_1 is the Bessel function

a is the radius of circle

$a = 153.5\text{nm}$

$$k = \frac{2\pi}{\lambda} = 1.257\text{nm}^{-1}$$



Diffraction for a circular aperture

Circular Aperture

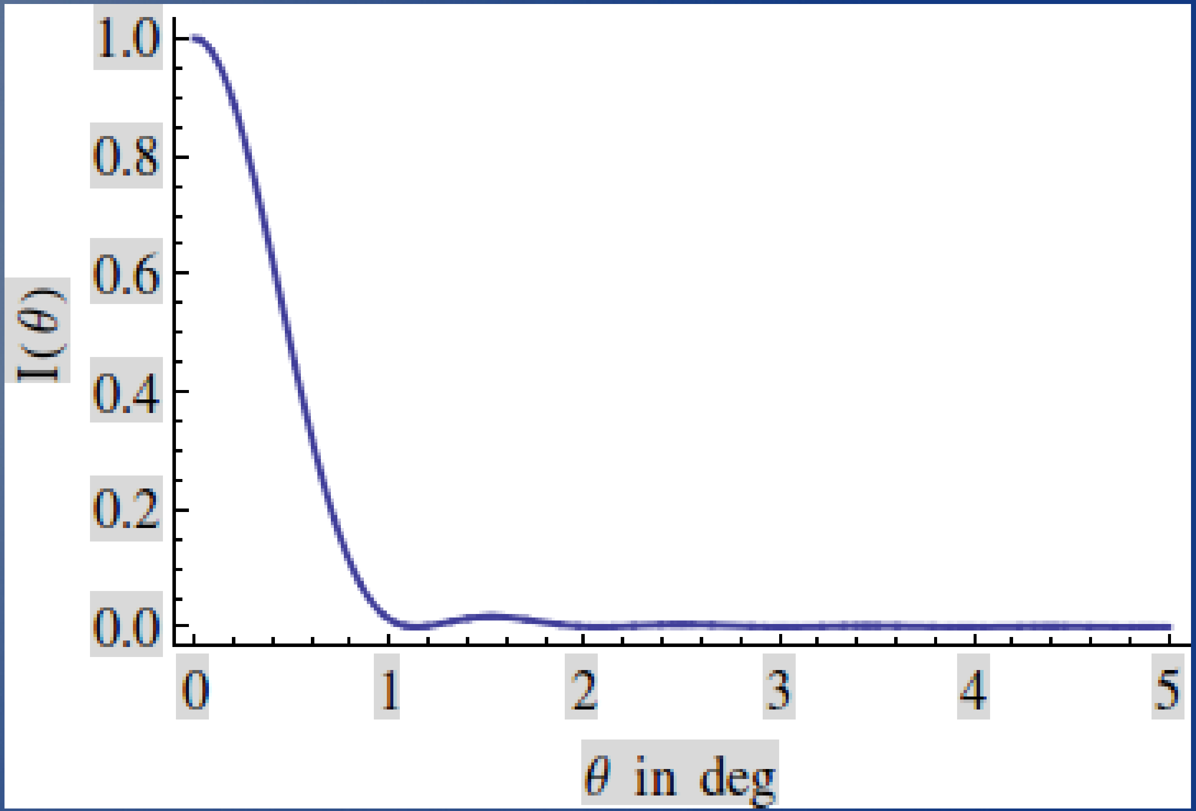
$$I(\theta)=I_0\left(\frac{2J_1(ka\sin(\theta))}{ka\sin(\theta)}\right)^2$$

J_1 is the Bessel function

a is the radius of circle

$$a=153.5\text{nm}$$

$$k=\frac{2\pi}{\lambda}=1.257\text{nm}^{-1}$$



Diffraction for a circular aperture

Circular Aperture

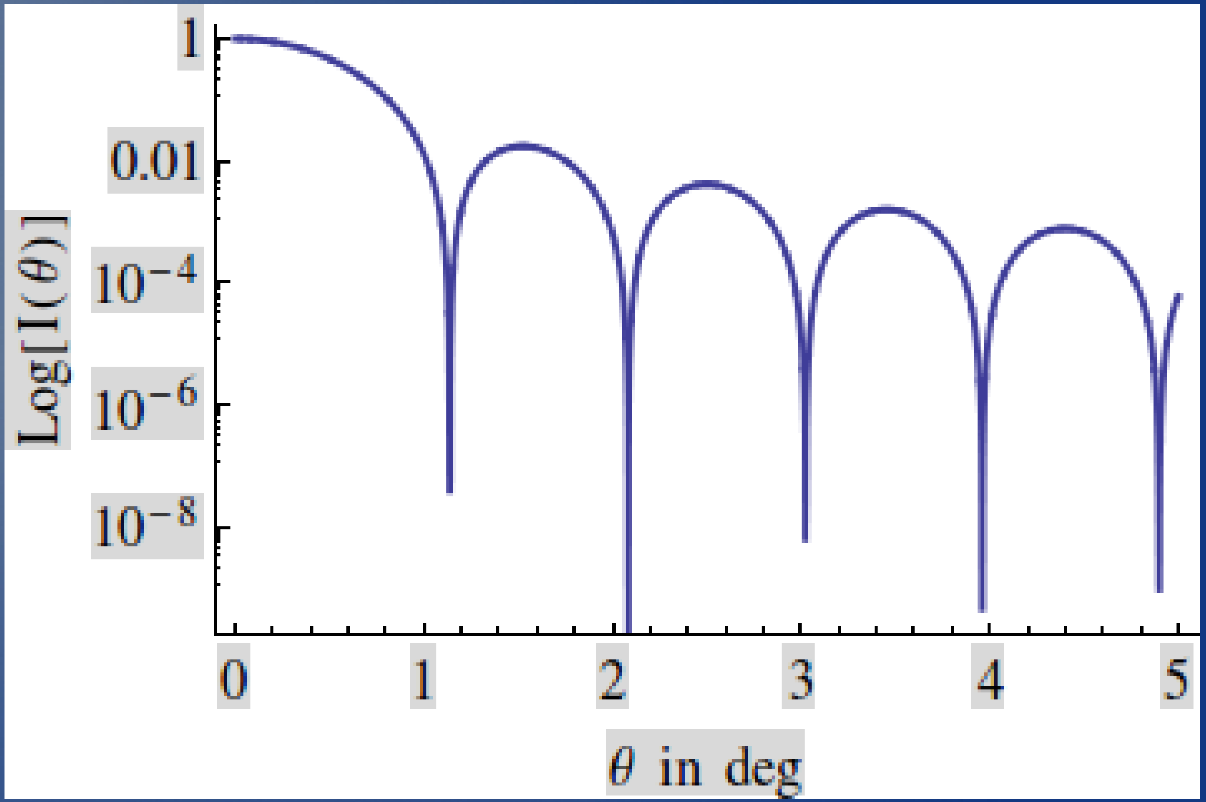
$$I(\theta) = I_0\left(\frac{2J_1(ka\sin(\theta))}{ka\sin(\theta)}\right)^2$$

J_1 is the Bessel function

a is the radius of circle

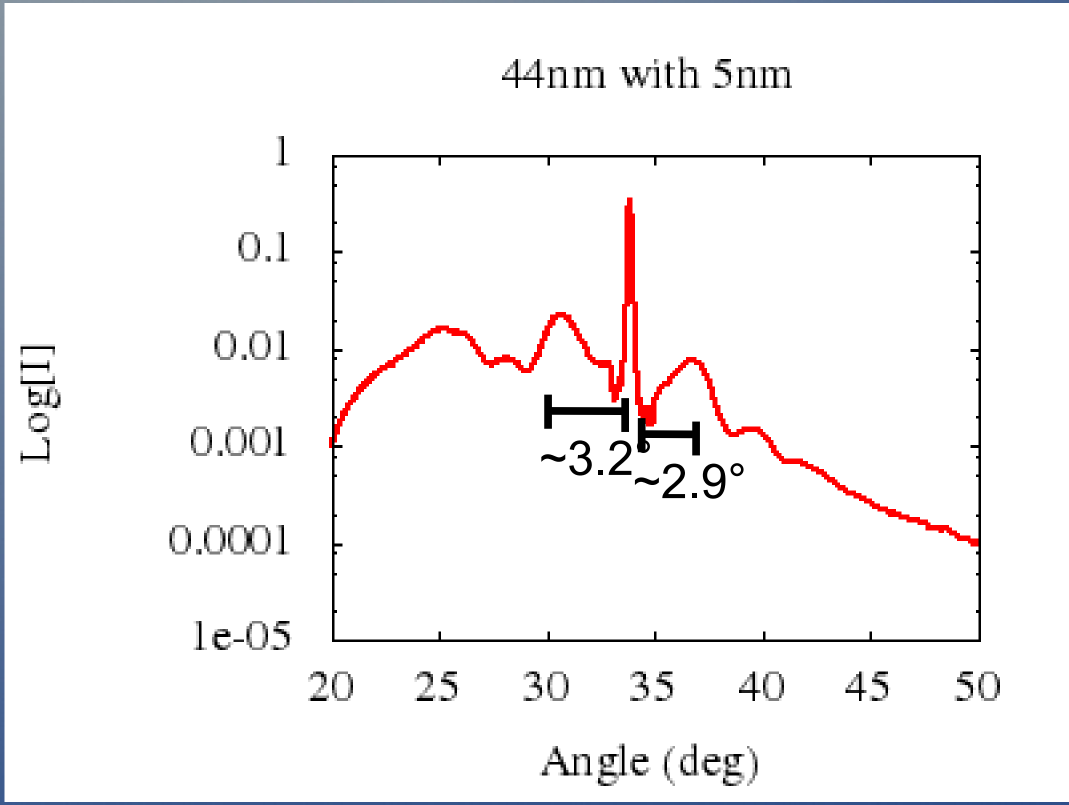
$a = 153.5\text{nm}$

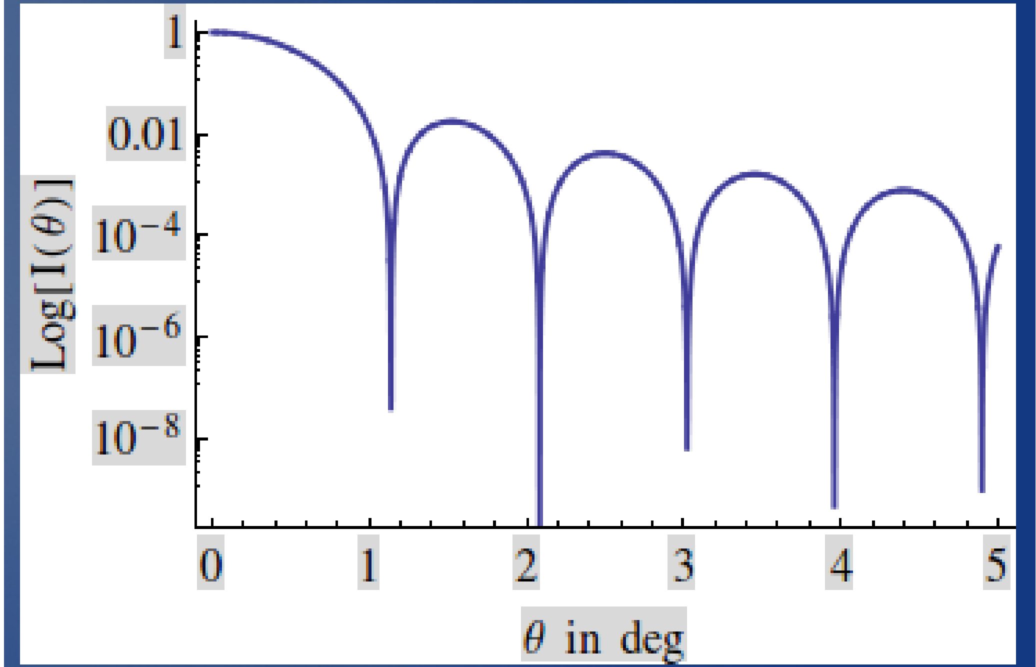
$$k = \frac{2\pi}{\lambda} = 1.257\text{nm}^{-1}$$



Diffraction for a circular aperture

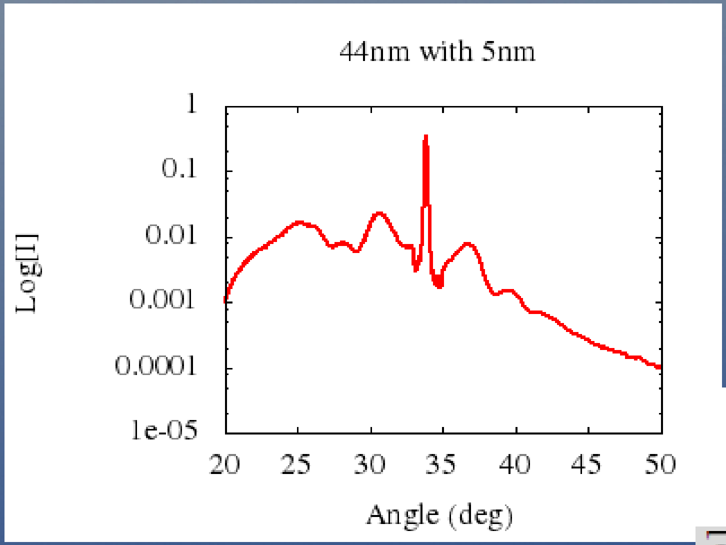
Circular Aperture?

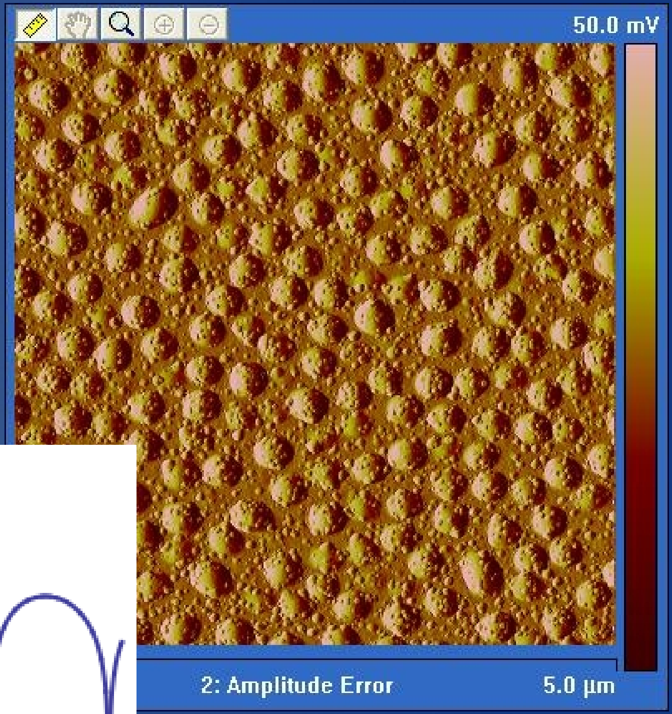


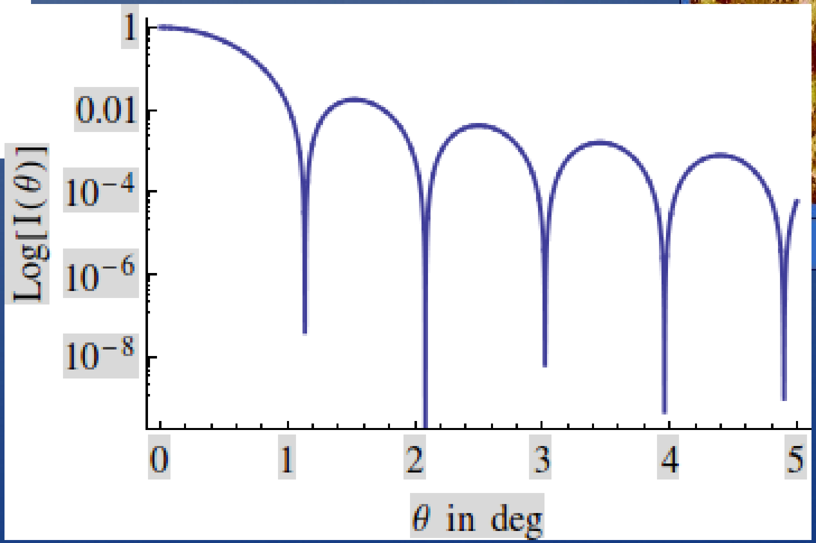


Conclusion

- From these results we conclude that reflection measurements have the potential to tell us new things about our thin film samples.







Acknowledgements

- R. Steven Turley
- David Allred
- John Ellsworth
- Holly Stewart
- Stephen Harman
- Lexi Bach
- NSF
- Advanced Light Source at Berkley
- Brigham Young University