Non-Specular Reflectance in the Extreme Ultraviolet

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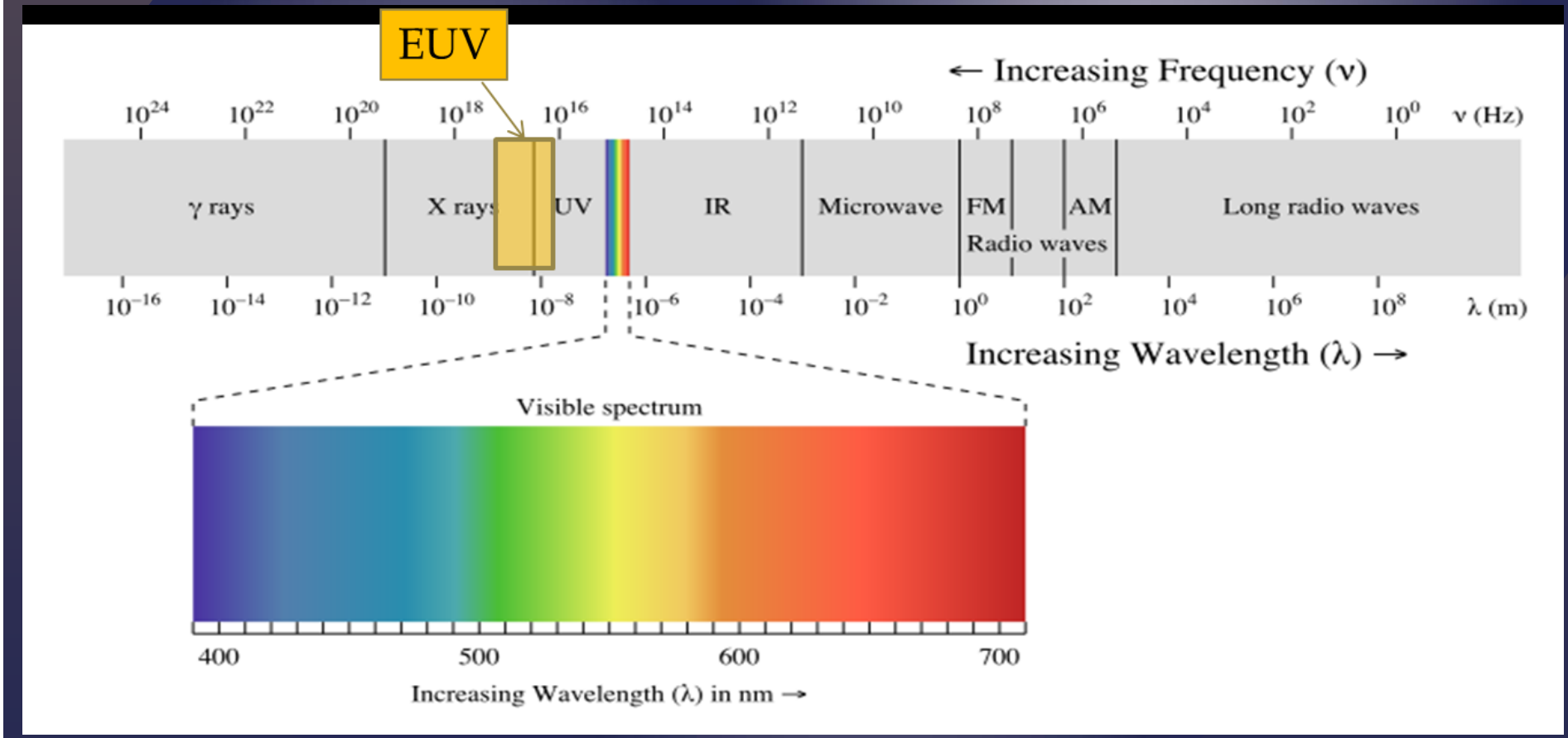
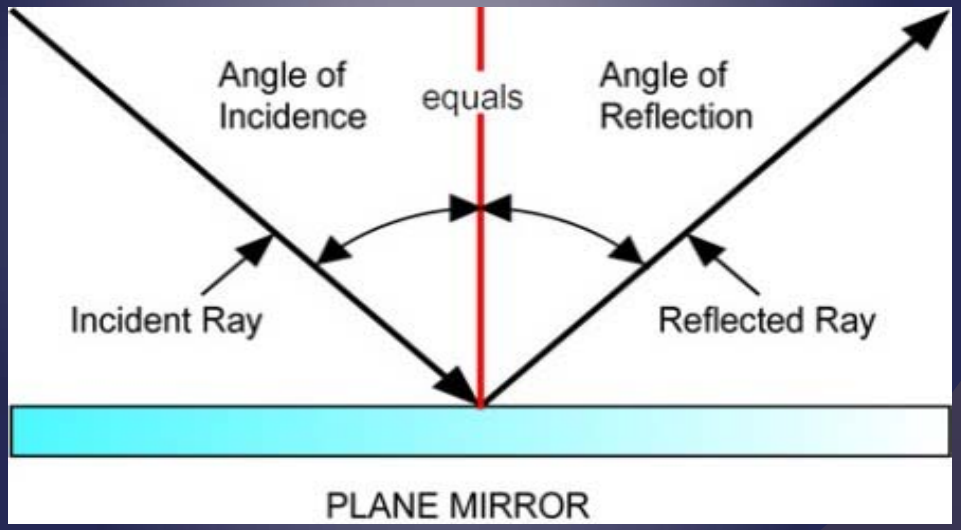
Extreme Ultraviolet (EUV)

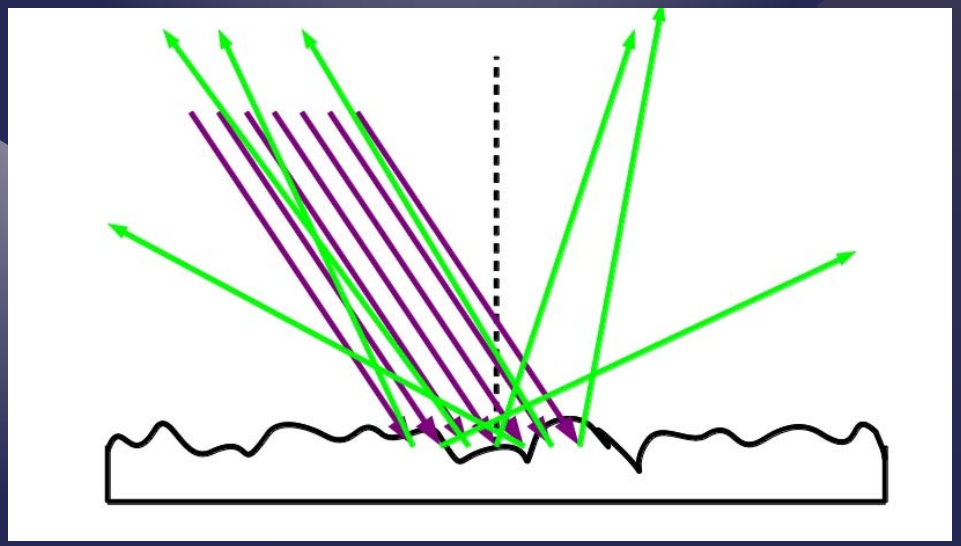
3 nm – 120 nm



Non-Specular Reflection

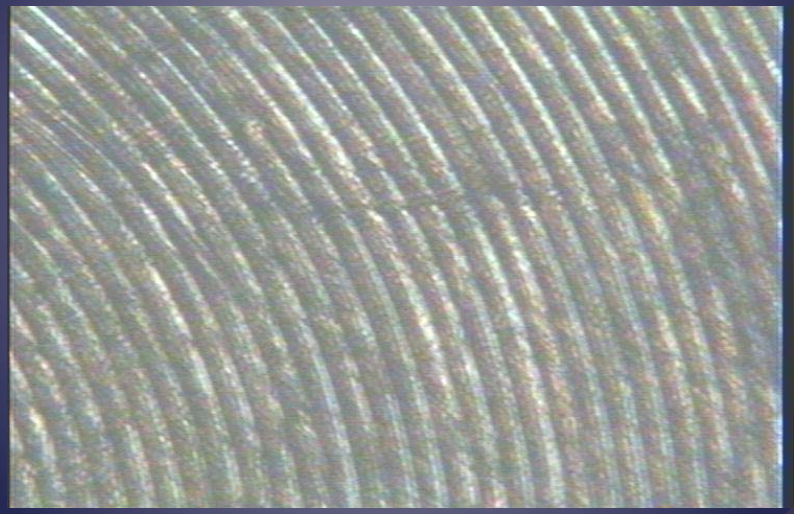
- Characterizing surface roughness
  - Non-specular reflection in the EUV
- Applications in the EUV
  - Lithography
  - Space based Astronomy
  - Medical imaging

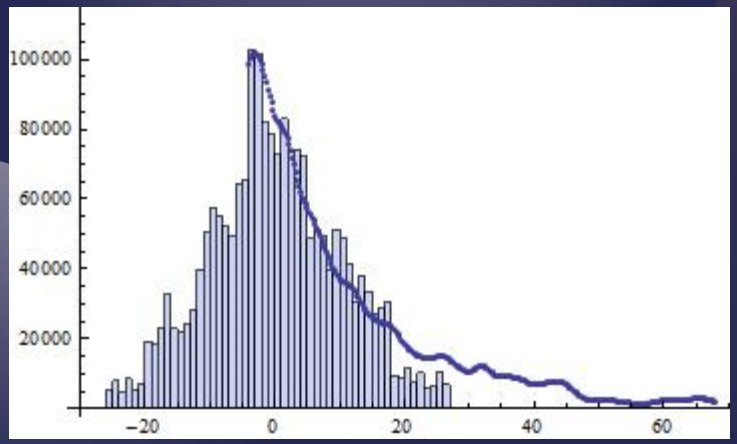




Overview

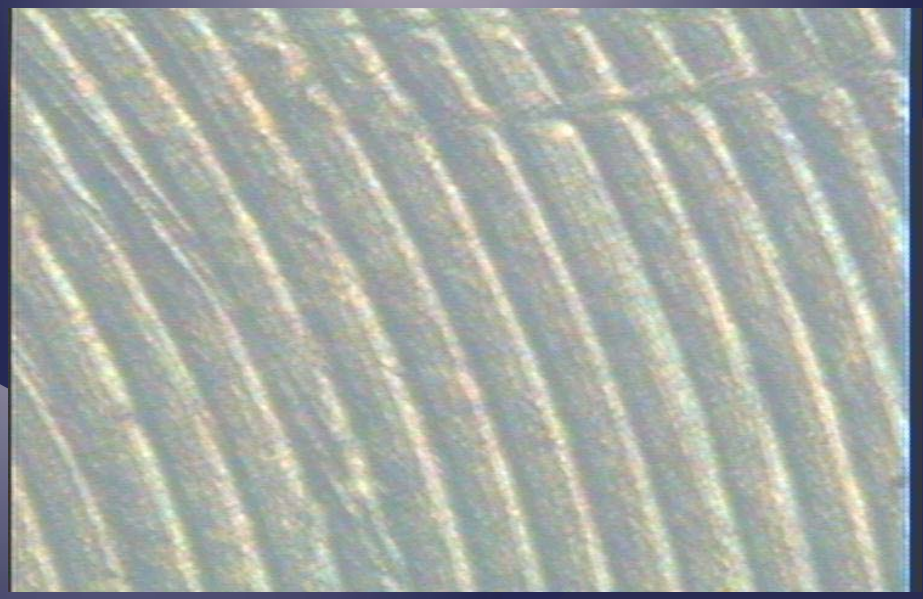
- Chrome samples
- Equipment/Procedure
- Analysis of reflection data
- Proof of principle
- Further work





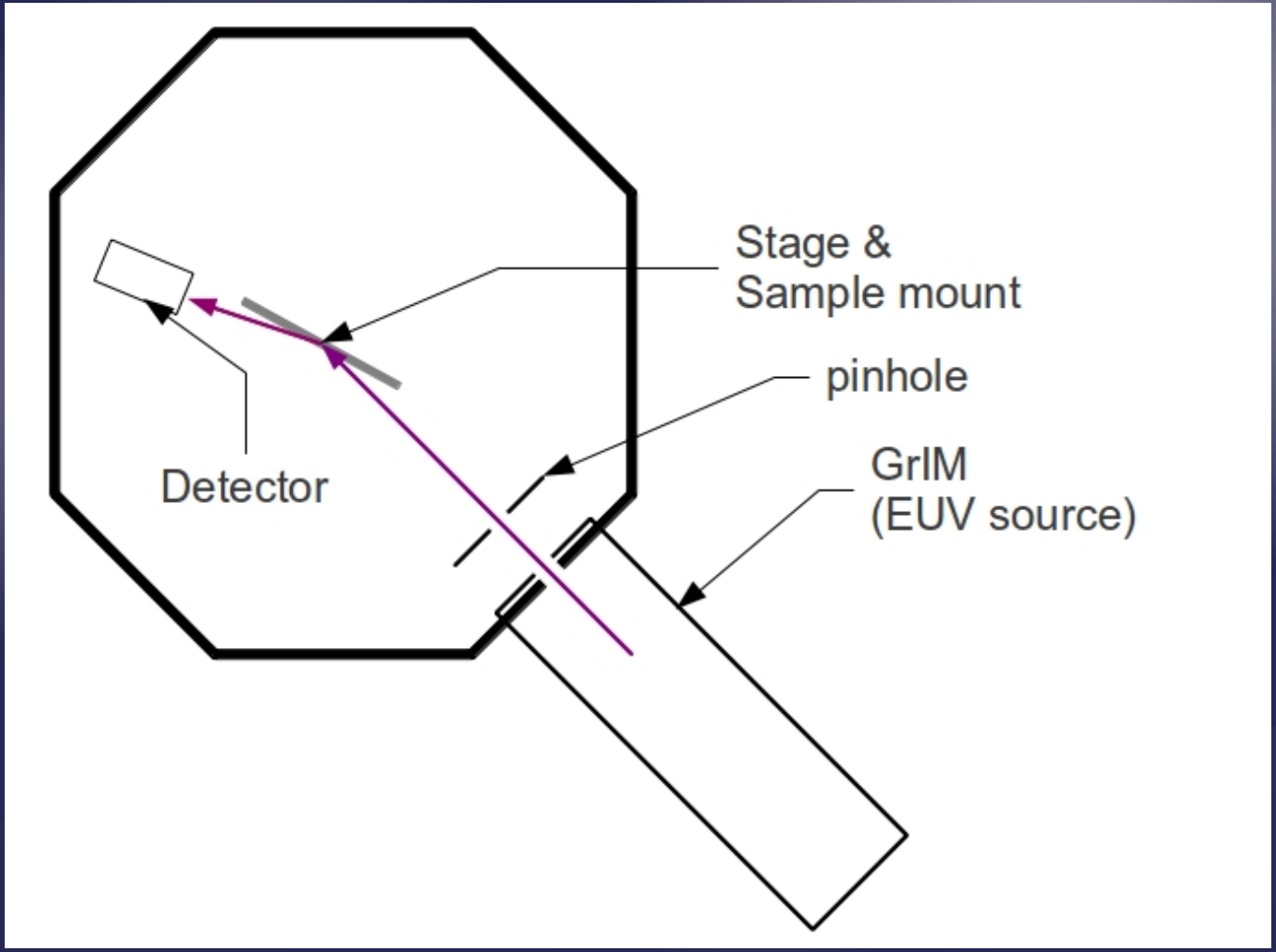
Chrome Samples

- Lawrence Livermore National Laboratory
  - Equipment sensitive in the EUV
  - Reduce non-specular reflection



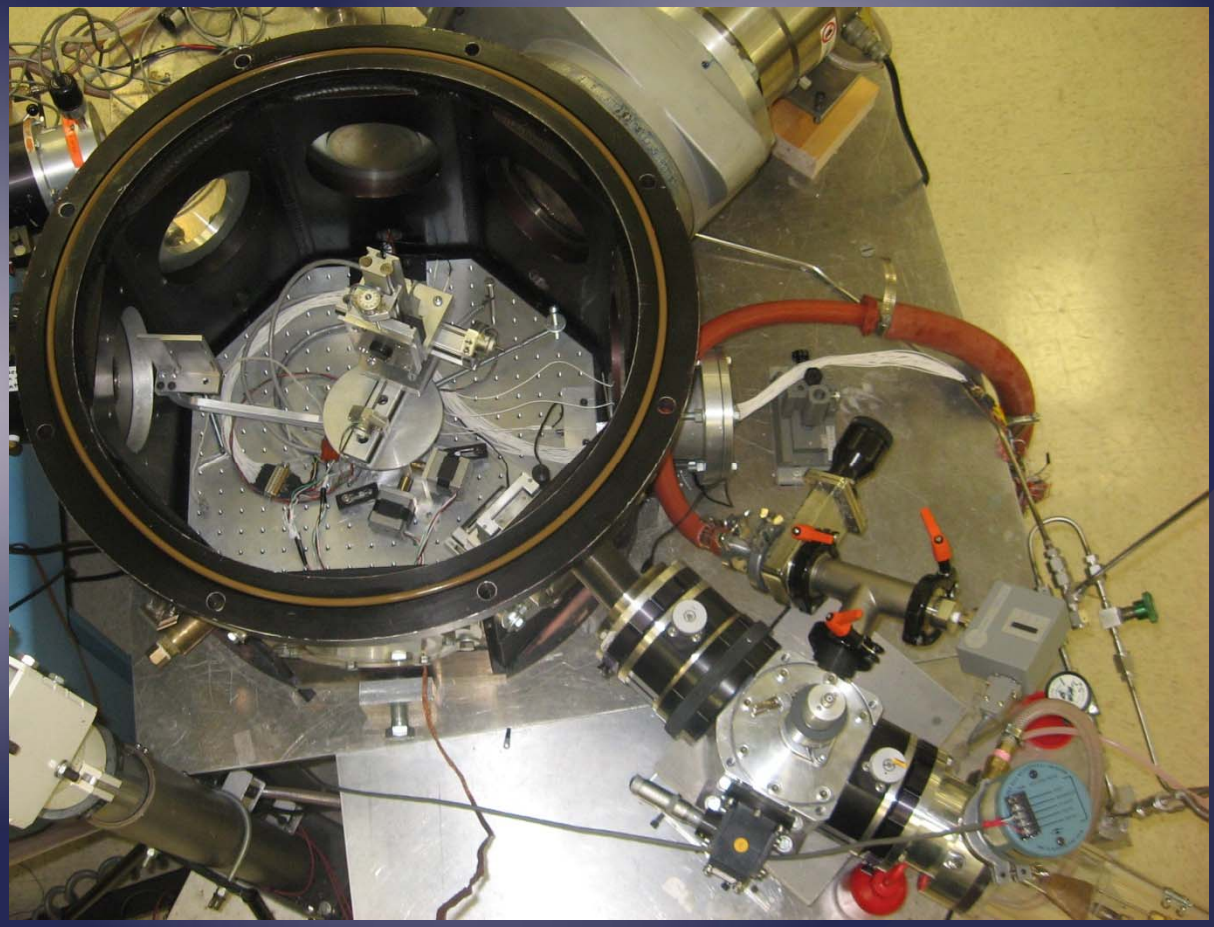
Groove width: ~18 ± 1 μm

Equipment/Procedure



Measurements

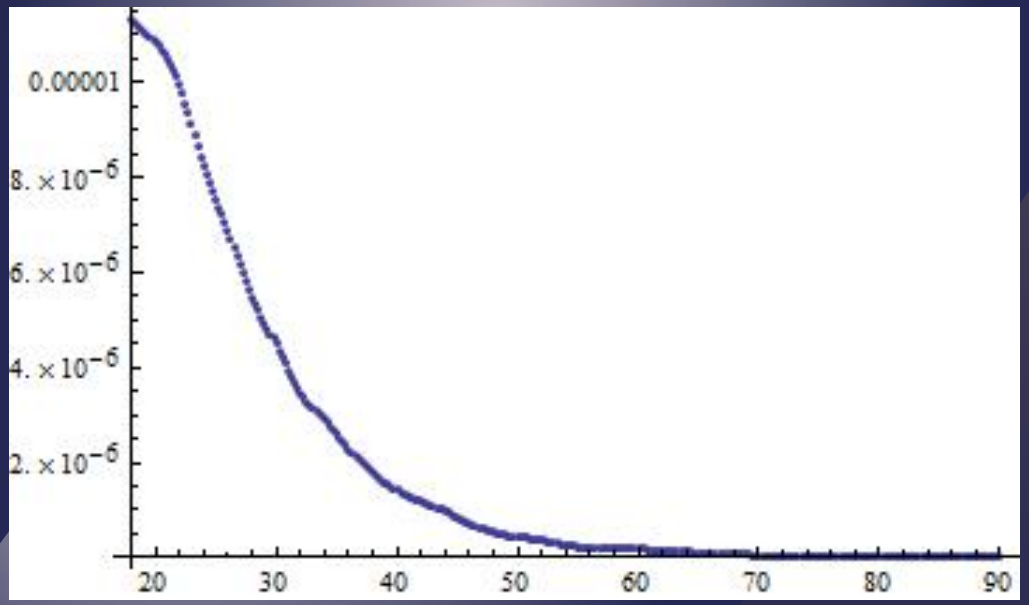
- Dark Counts
- Background
- Beam Profile
- Reflectance



Analysis

Things we accounted for:

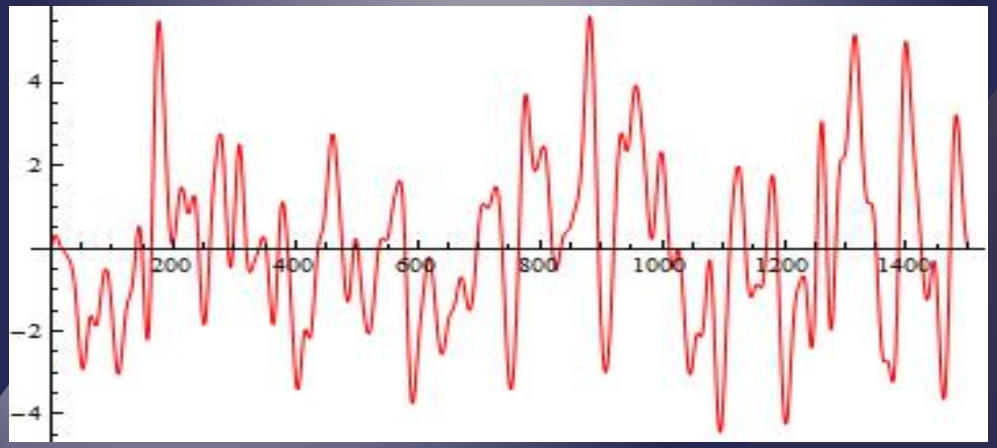
- Dark Counts from detector
- Background noise
- Our measurements are a convolution of the original beam with:
  - Detector hole (a circular aperture)
  - Smearing off sample
- Normalize with incident beam



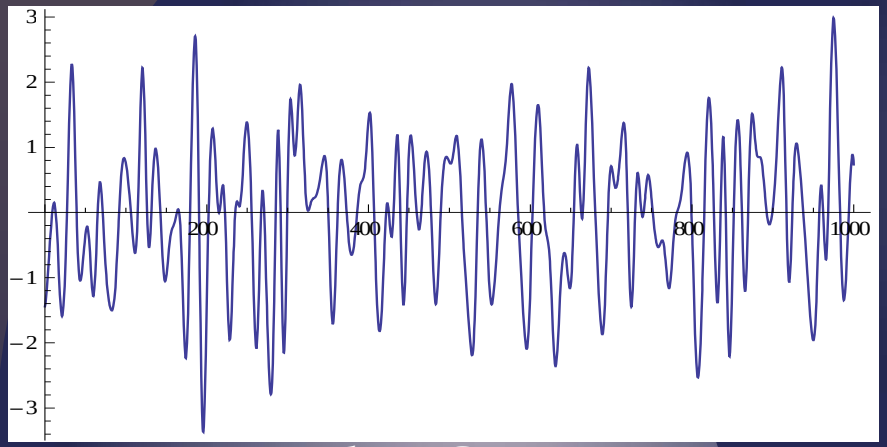
Can we understand surface features based on reflection data?

Proof of Principle:

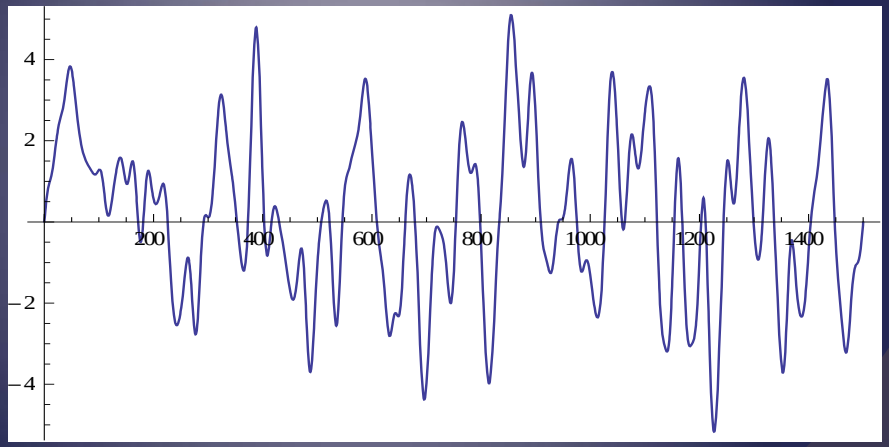
- Modeling surfaces
- Vary surface parameters
- Match to reflection data



Modeling Surfaces



Random Gaussian



Filtered

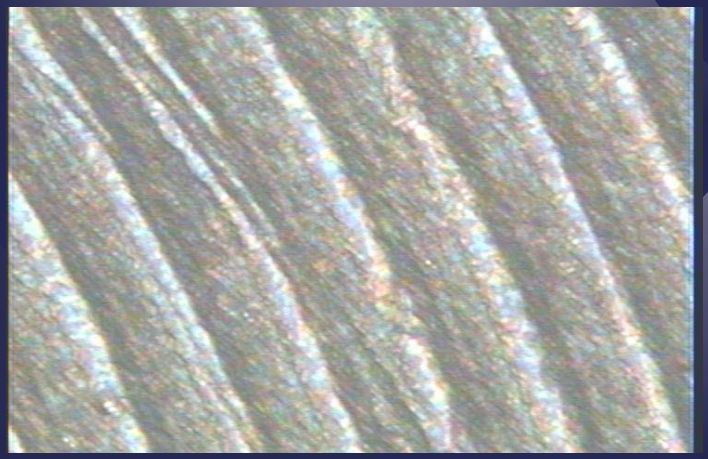
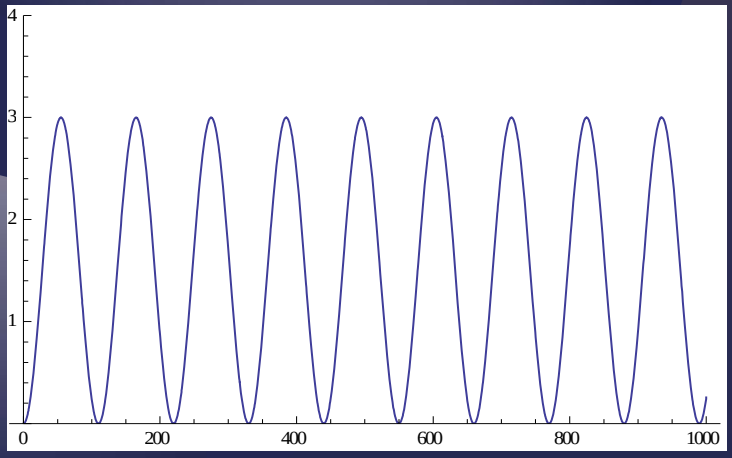


Image shows periodic features

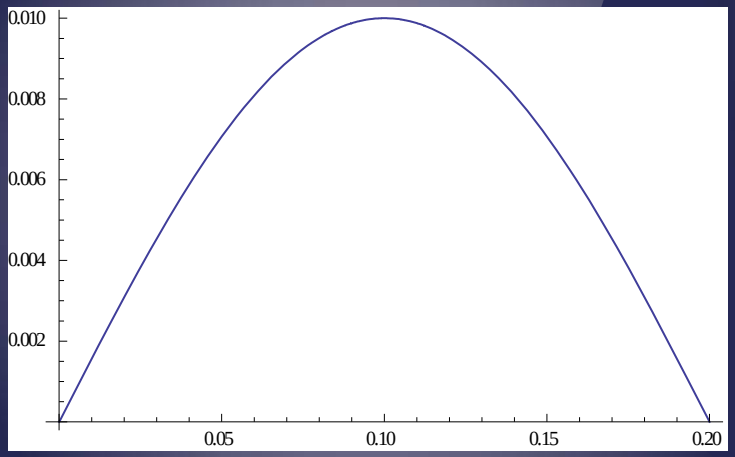


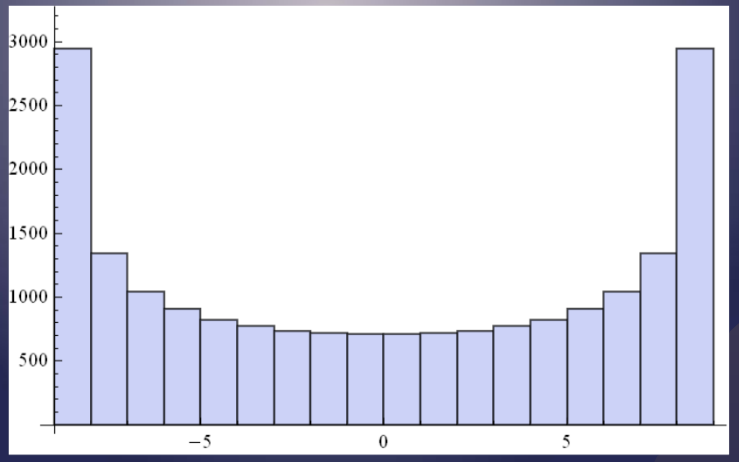
Sin^2

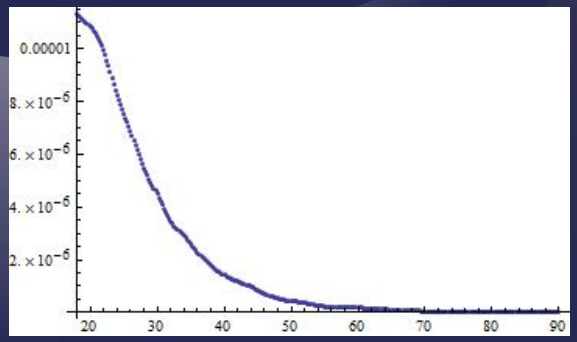
Periodic Surface

Geometric optics to calculate reflection

Sine function:





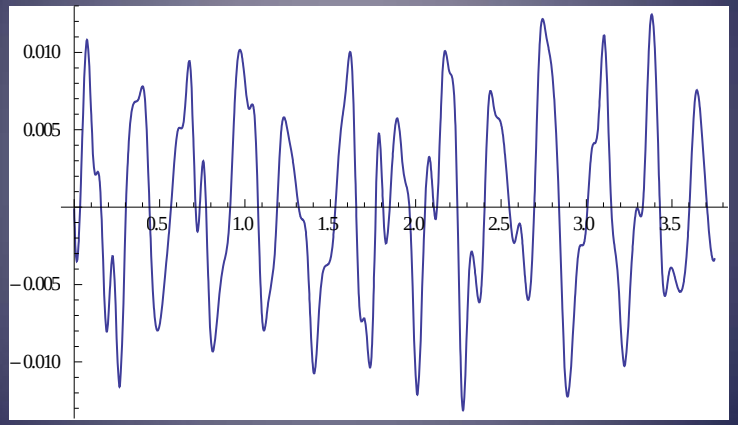


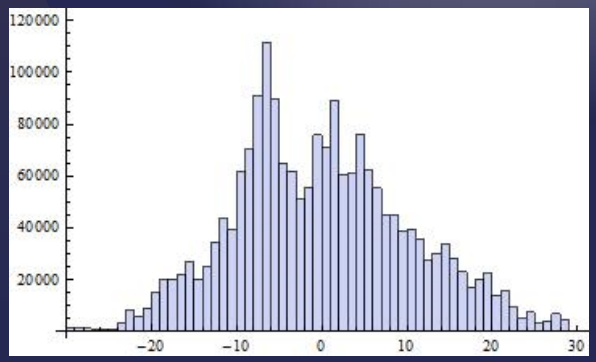
Does not match reflection data

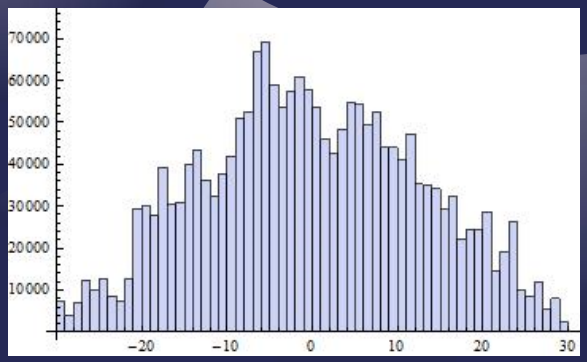
Varying Parameters

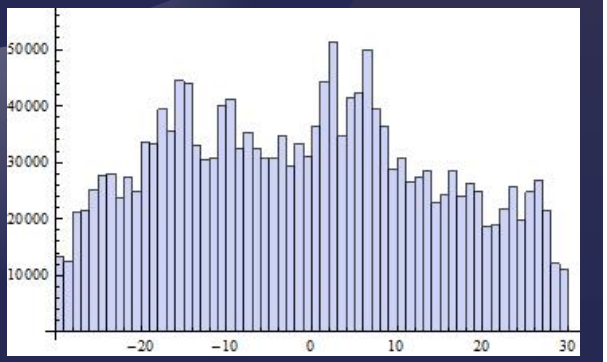
Parameters of Sin^2:

- Period
- Height of bump
- Height of noise
- Length of surface

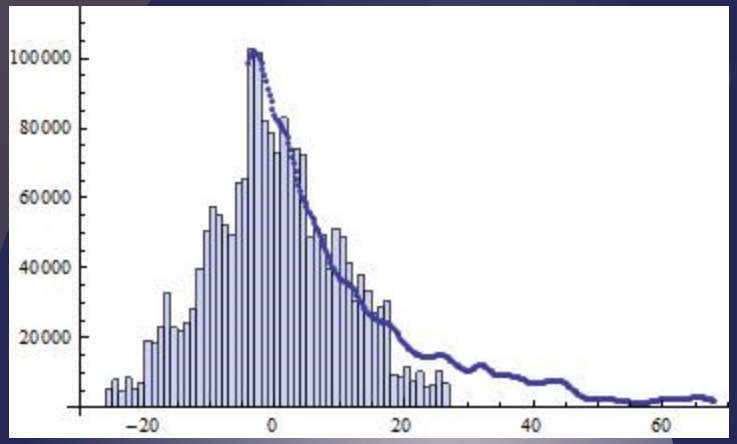




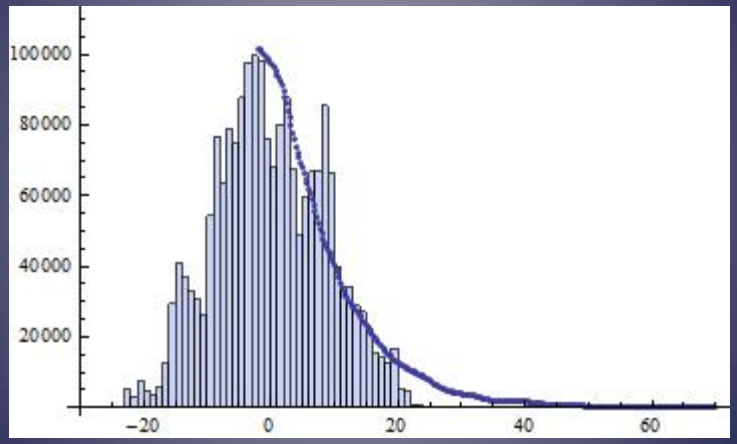




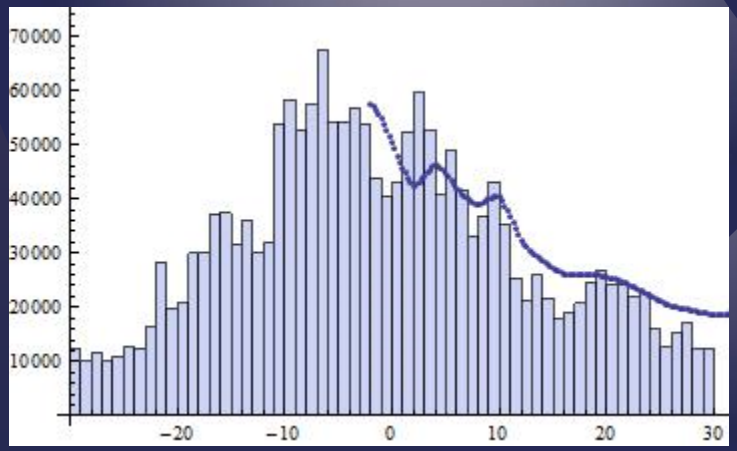
Matching Reflection Data



25.6 nm at 10°



30.4 nm at 10°



30.4 nm at 20°

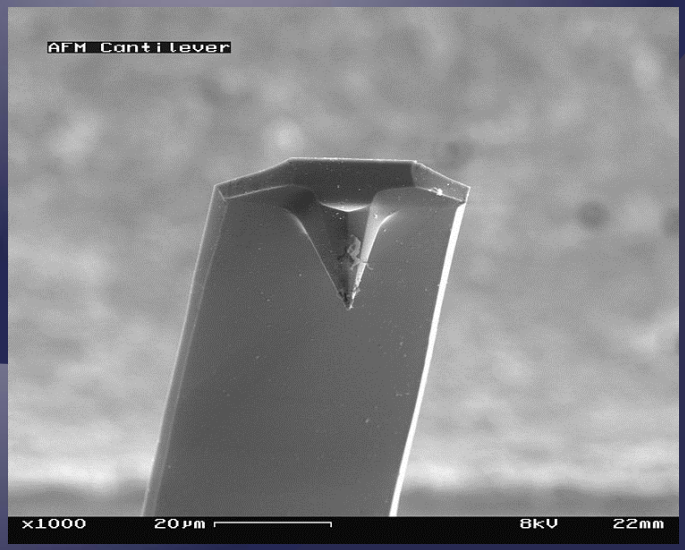
Non-specular reflection can be used to characterize surface roughness

Conclusion

- Measuring non-specular reflectance
- We can learn about surface features

Further Work:

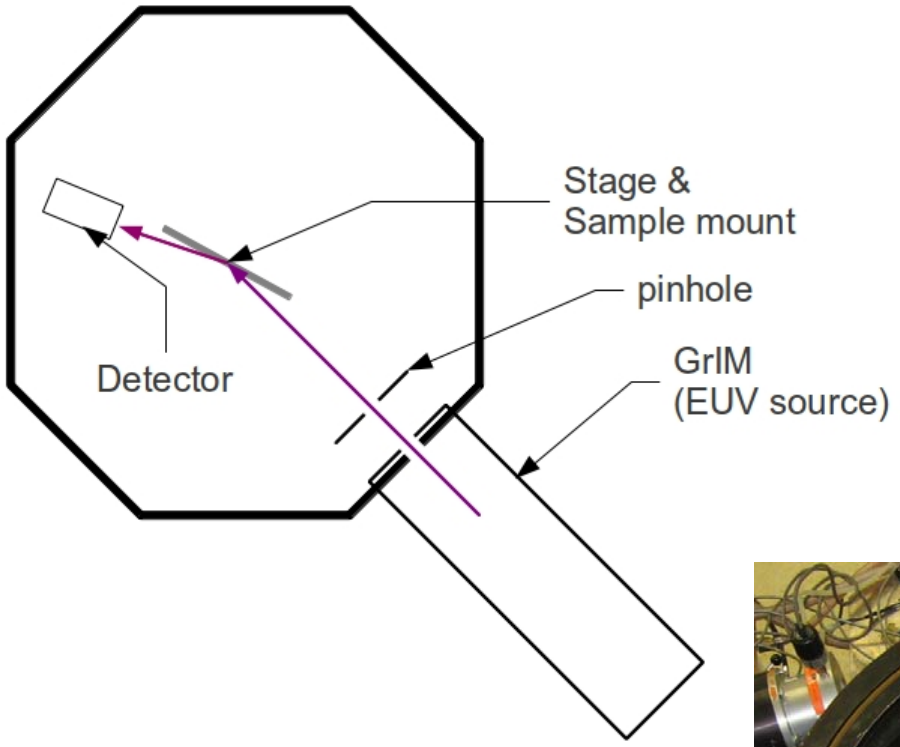
- Reflection data on a variety of samples
- Compare with more complex models
- Compare with atomic force microscopy

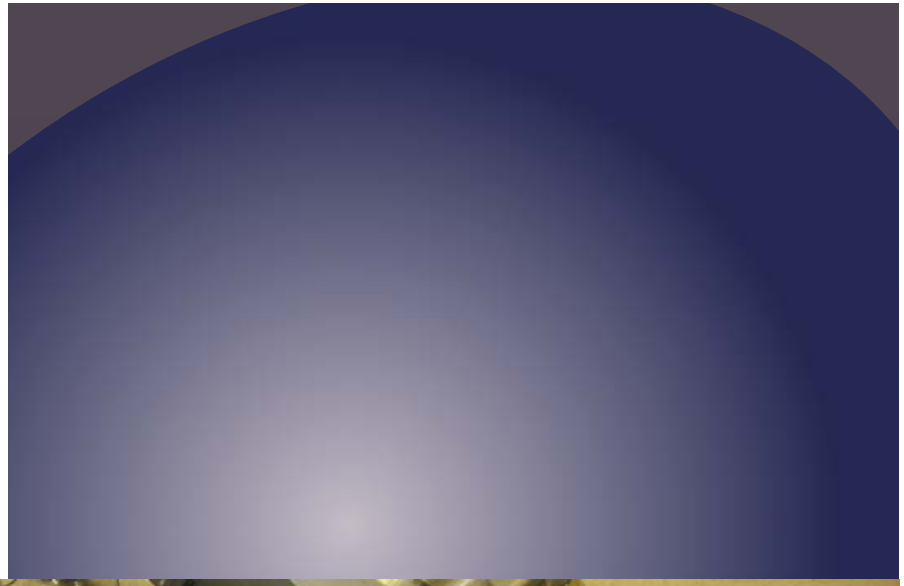


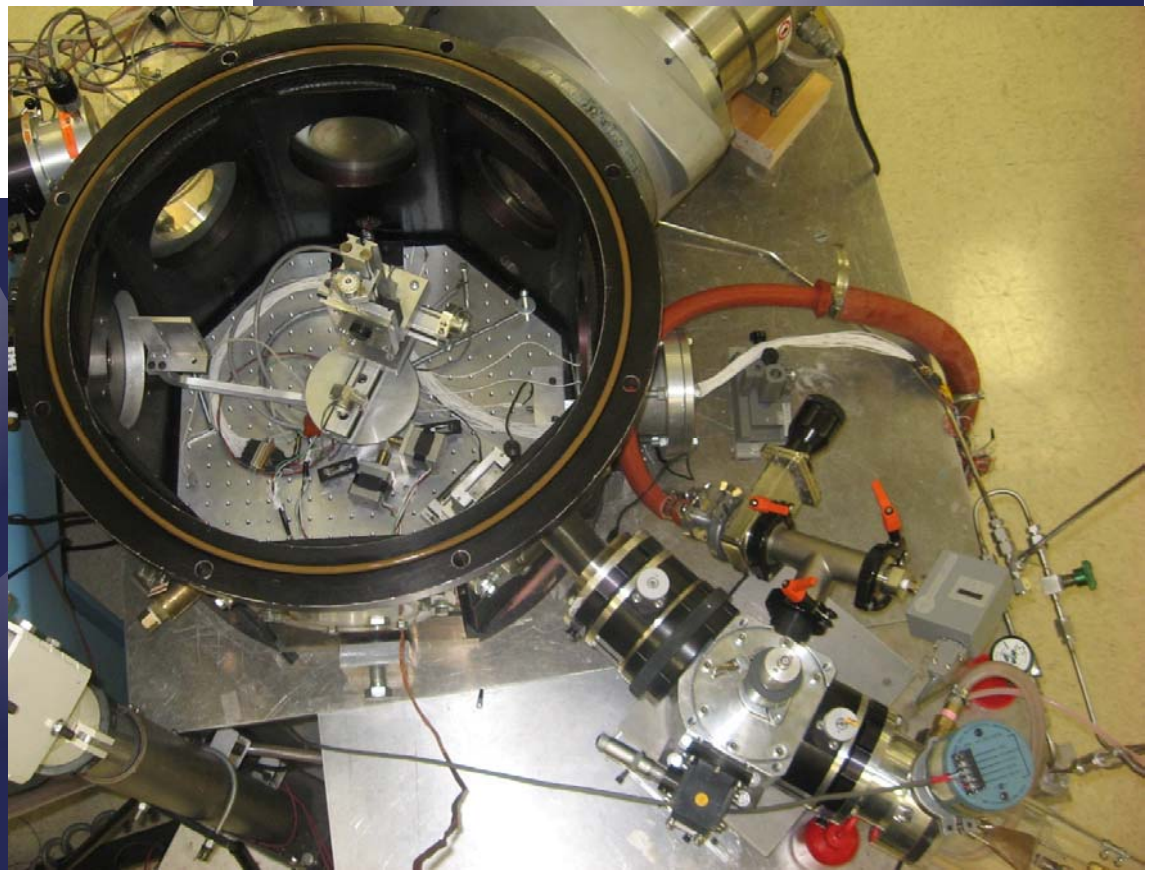
Wikipedia

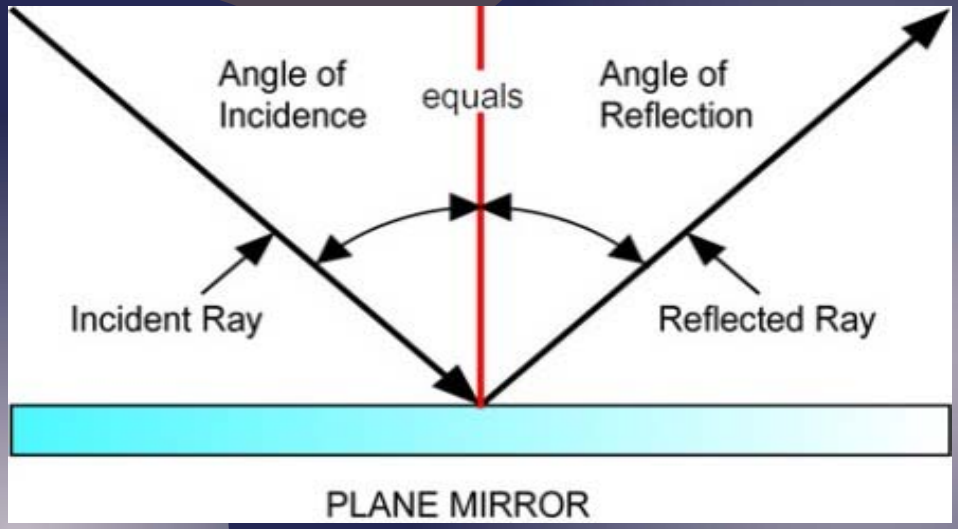
Acknowledgements

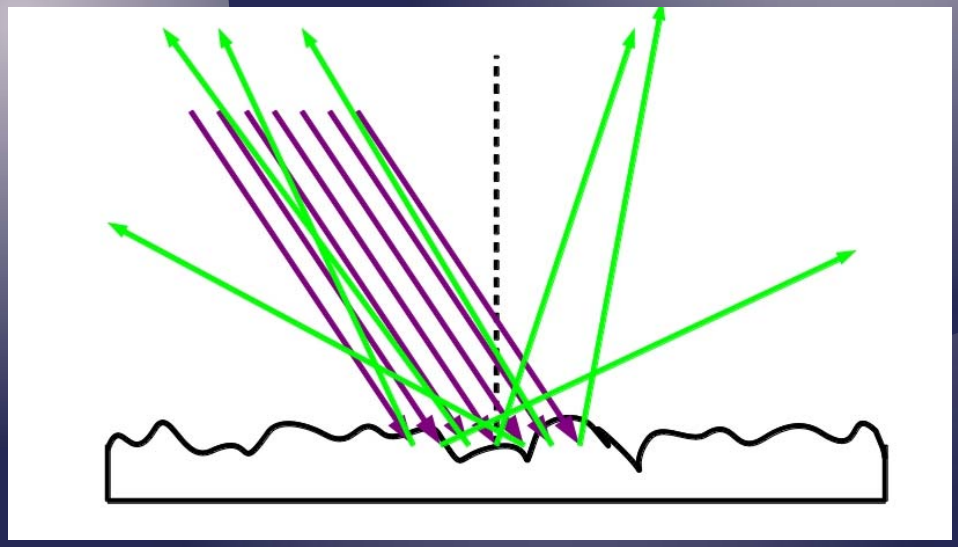
- Dr. R. Steven Turley
- John Ellsworth
- Brigham Young University Physics Department
- Lawrence Livermore National Laboratory

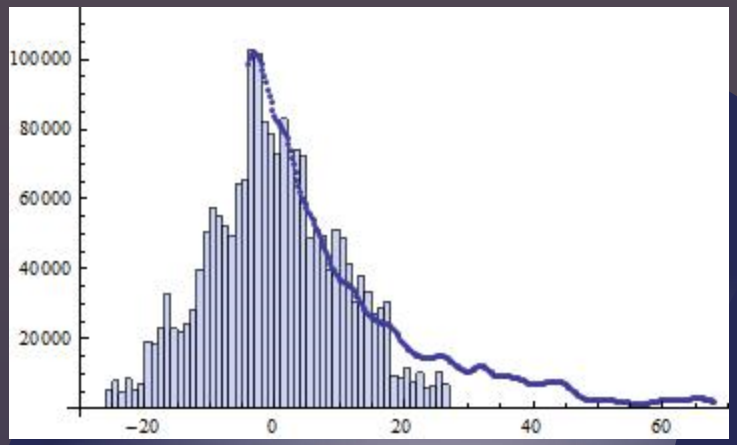

Stage &
Sample mount
pinhole
Detector
GrIM
(EUV source)






Angle of Incidence
equals
Angle of Reflection
Incident Ray
Reflected Ray
PLANE MIRROR





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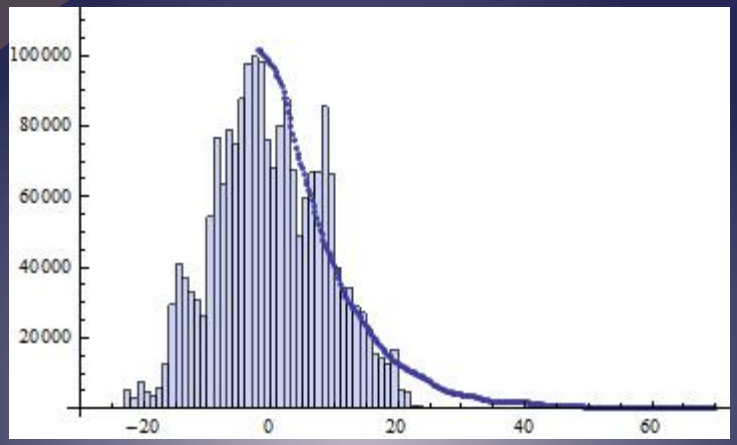
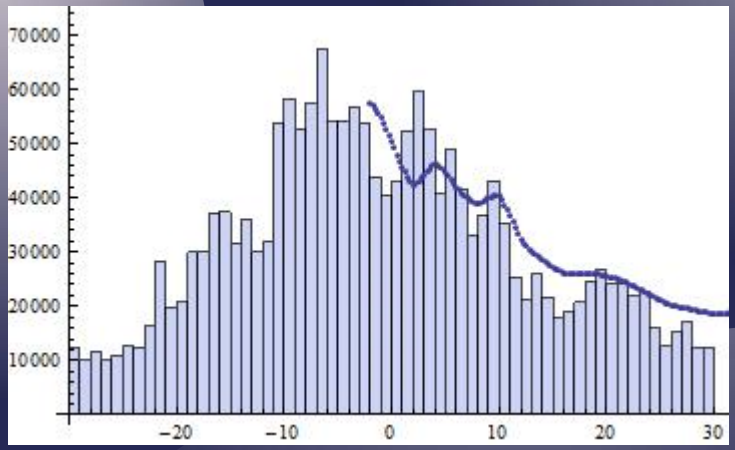


30.4 nm at 10°



30.4 nm at 20°