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X-ray Diffraction Crystal Calibration and Characterization

Michael J. Haugh, National Security Technologies, LLC (NSTec)
Richard Stewart and Nathan Kugland,
Lawrence Livermore National Laboratory (LLNL)

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Purpose of Presentation

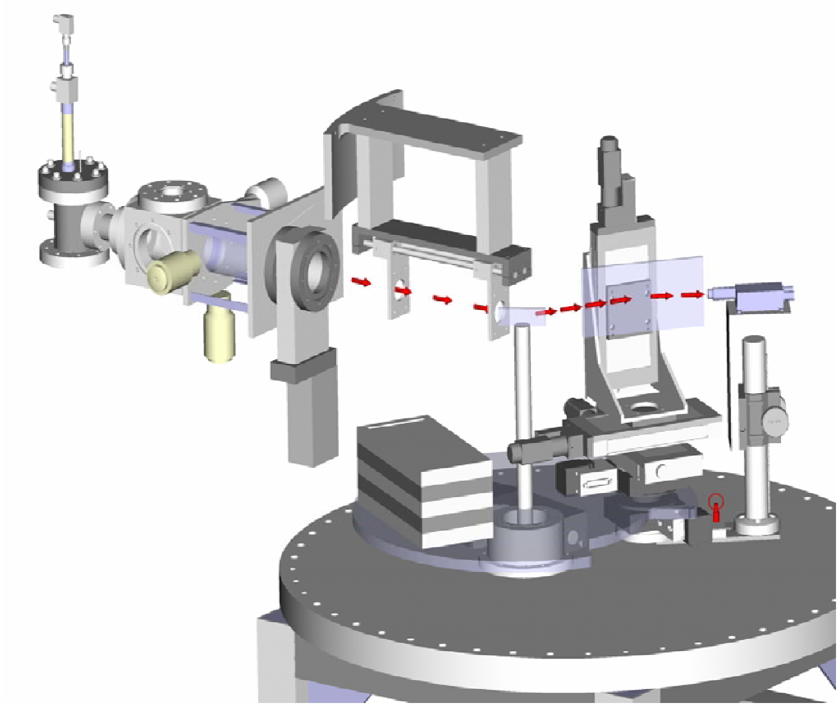
Illustrate the capability of the NSTec goniometer system to characterize the crystal diffraction quality in the 2 to 15 keV energy range. We will discuss the work conducted on two types of crystals:

1. A planar curved thin mica crystal used in a high resolution spectrometer
2. A spherical curved quartz crystal used for imaging a plasma.

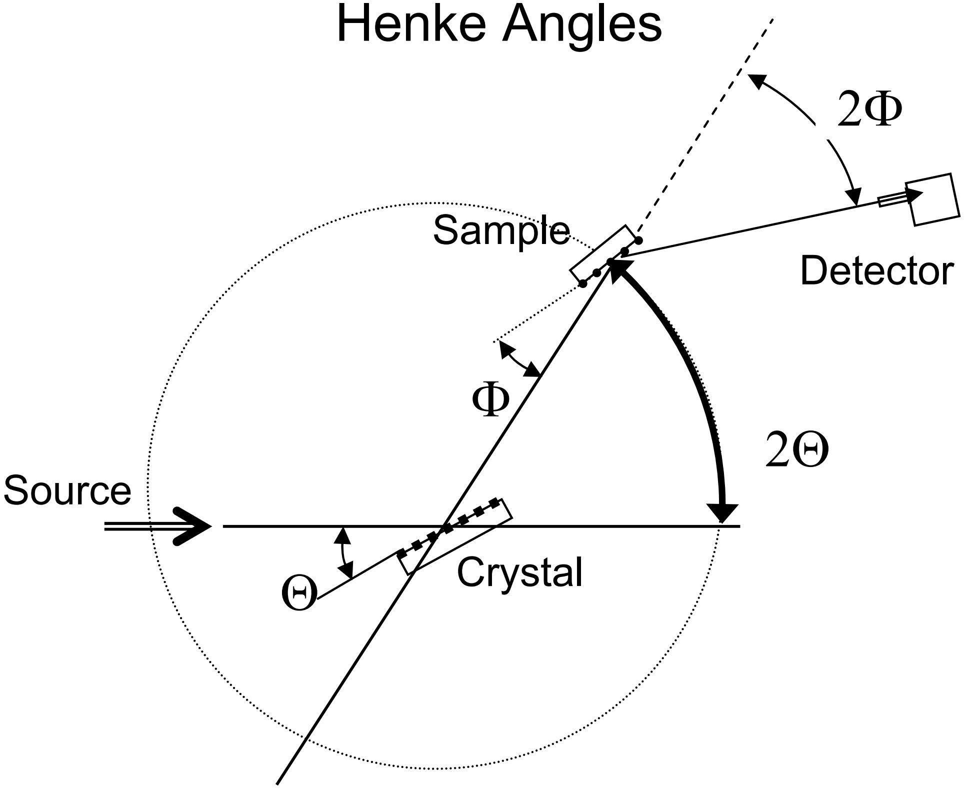
The NSTec Henke X-ray Source and Goniometer for Crystal Measurements

- Beam arrangement
- Dual goniometer
- Sample translation in 3 directions

Henke Beam Path



Henke Angles



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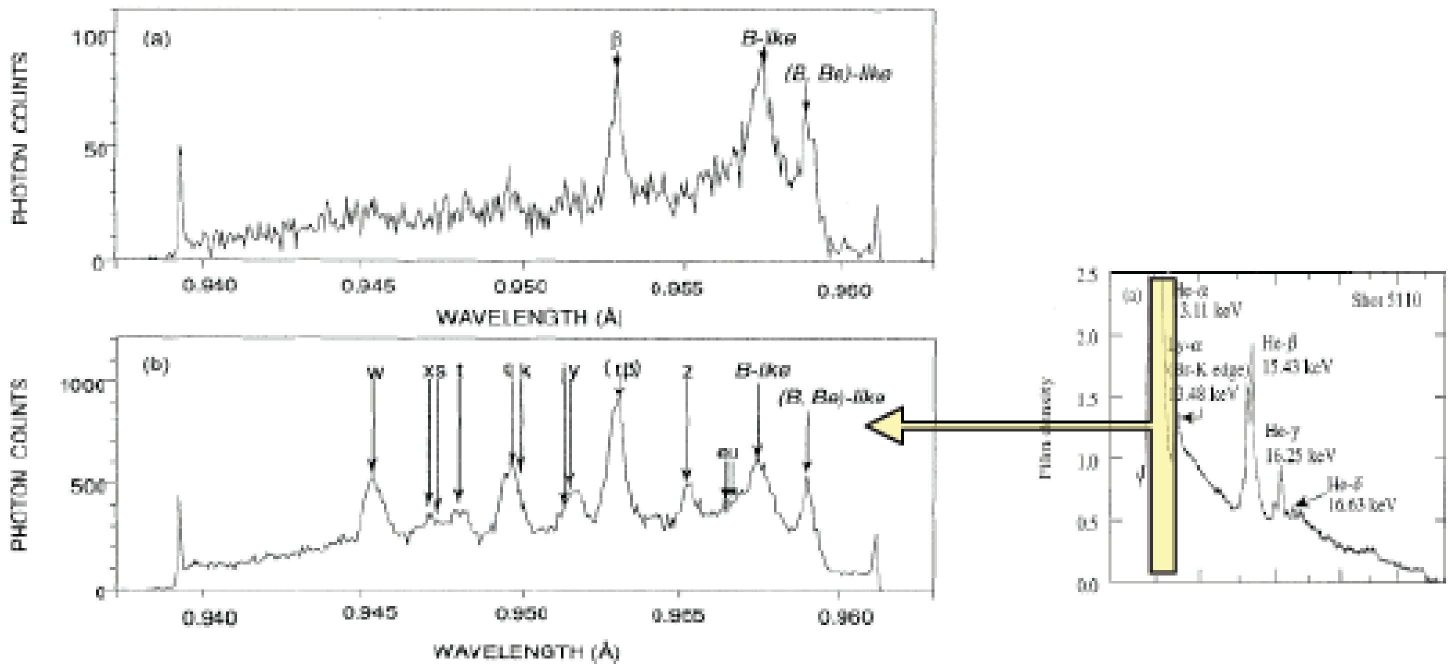
1. Characterizing the Quality of a Curved Mica Crystal

Used for a high resolution spectrometer

Higher resolution spectra might be used to measure charge states, T_e, and T_i by Doppler broadening



TFTR spectrum of krypton helium alpha feature in region of Omega spectrum - Bitter et al PRL 1993

A vertical Johann spectrometer can achieve this kind of resolving power at small Bragg angles required for direct drive experiments.

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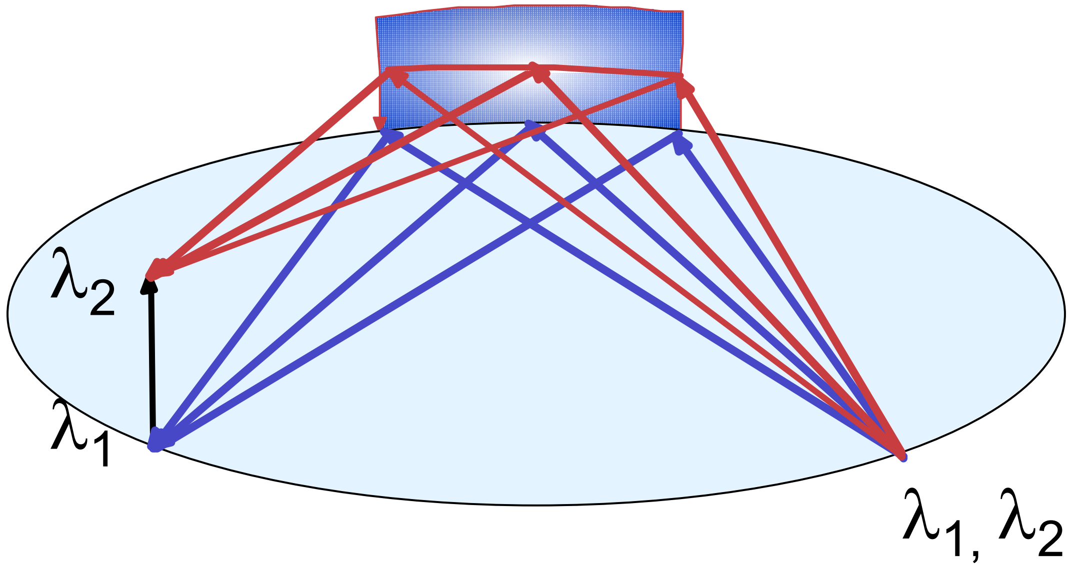
HIRXS – High Resolution X-ray Crystal Spectrometer
Vertical Johann Spectrometer



- For source on the Rowland circle dispersed spectrum lies perpendicular to the normal dispersion plane (Renner et al, RSI 97).
- Dispersion is independent of Bragg Angle $\lambda = \lambda_0 \cos(\phi)$, where $\phi =$ angle of X-ray inclination.
- 5-10x brighter than flat PET crystal, resolving power 10-20x better
- Layout similar to conical spectrometer. Source and crystal must be ±1 mm, camera to 1 cm.

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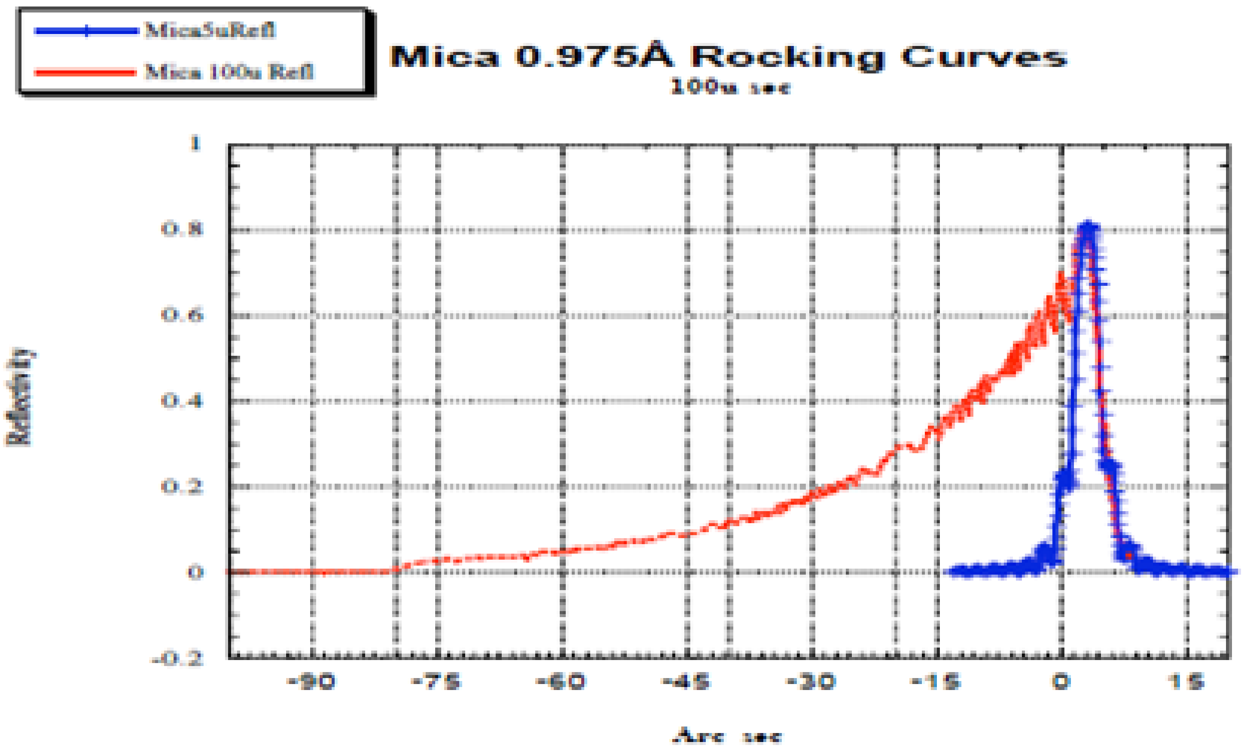
High energy diffraction from bent mica crystals is significantly broadened even at 1.6 m curvature



- Calculated with Takagi - Taupin equation

Thinned crystals (~ 5-10 microns) needed to control diffraction width

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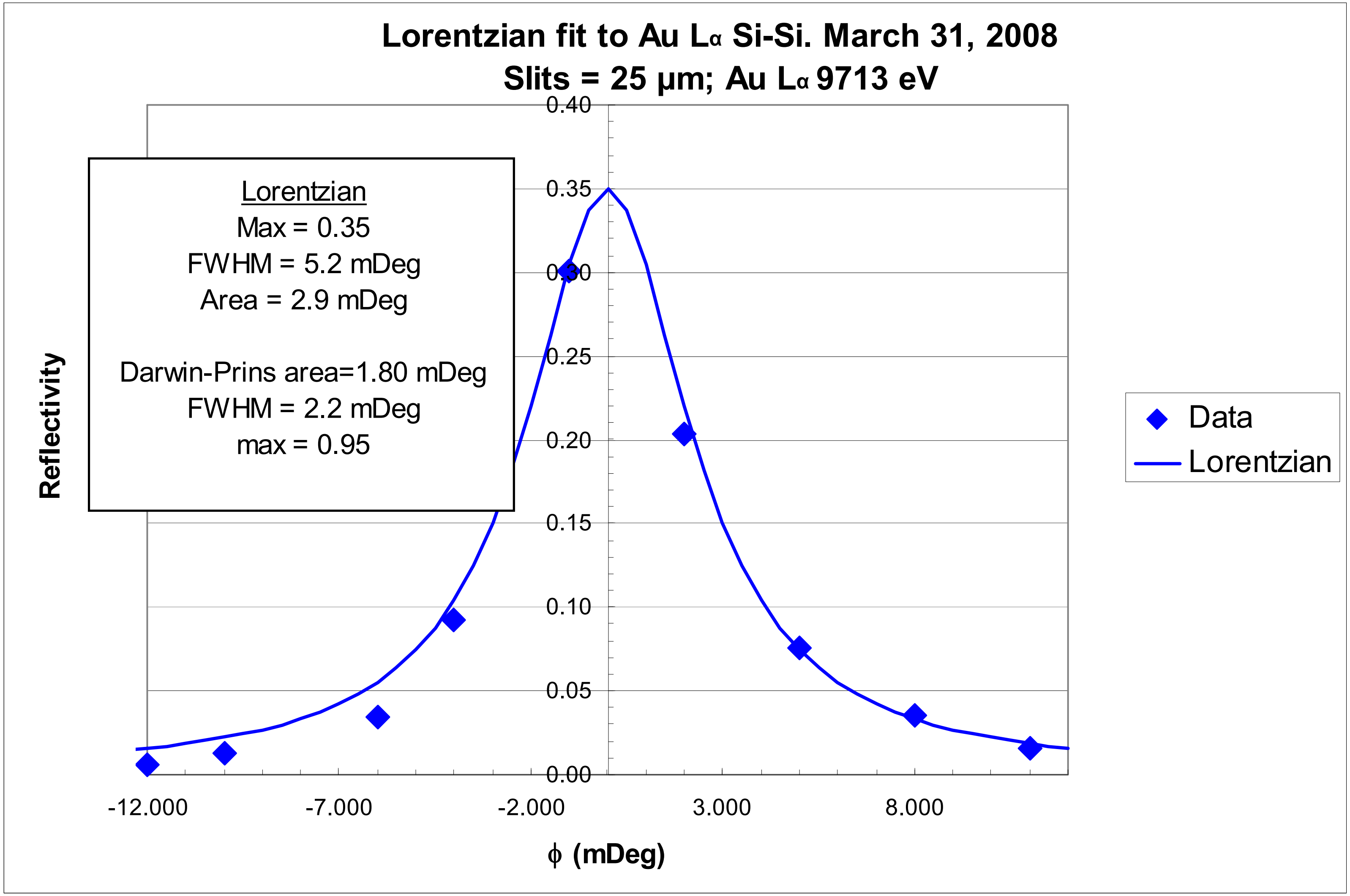
Mica Characterization Procedure

1. Purchase many crystals from the best producers.
2. Preliminary optical evaluation:
   - Haidinger fringes,
   - Fizeau fringes
3. Evaluate further the best crystals as flats using the NSTec goniometer system.
4. Measure the best of those as curved crystals; mount thick on curved surface, then cleave.
5. NSTec measurement capability??
6. Evaluate using diffraction grade Si crystals.

Reflectivity Curve for Si-Si Double Crystal Measurement



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Integrated Reflectivity

- Literature states that the integrated reflectivity is independent of instrument parameters.
  - Evans and Leigh, *Space Science Instrumentation*, **2**,1976
  - Evans, Leigh and Lewis, *X-ray Spectrometry*, **6**, 1977
- Use integrated reflectivity to compare mica crystals quality of X-ray diffraction.
- Use the Au $L_{\beta 1}$ spectral line, 11442.3 eV

Typical Results

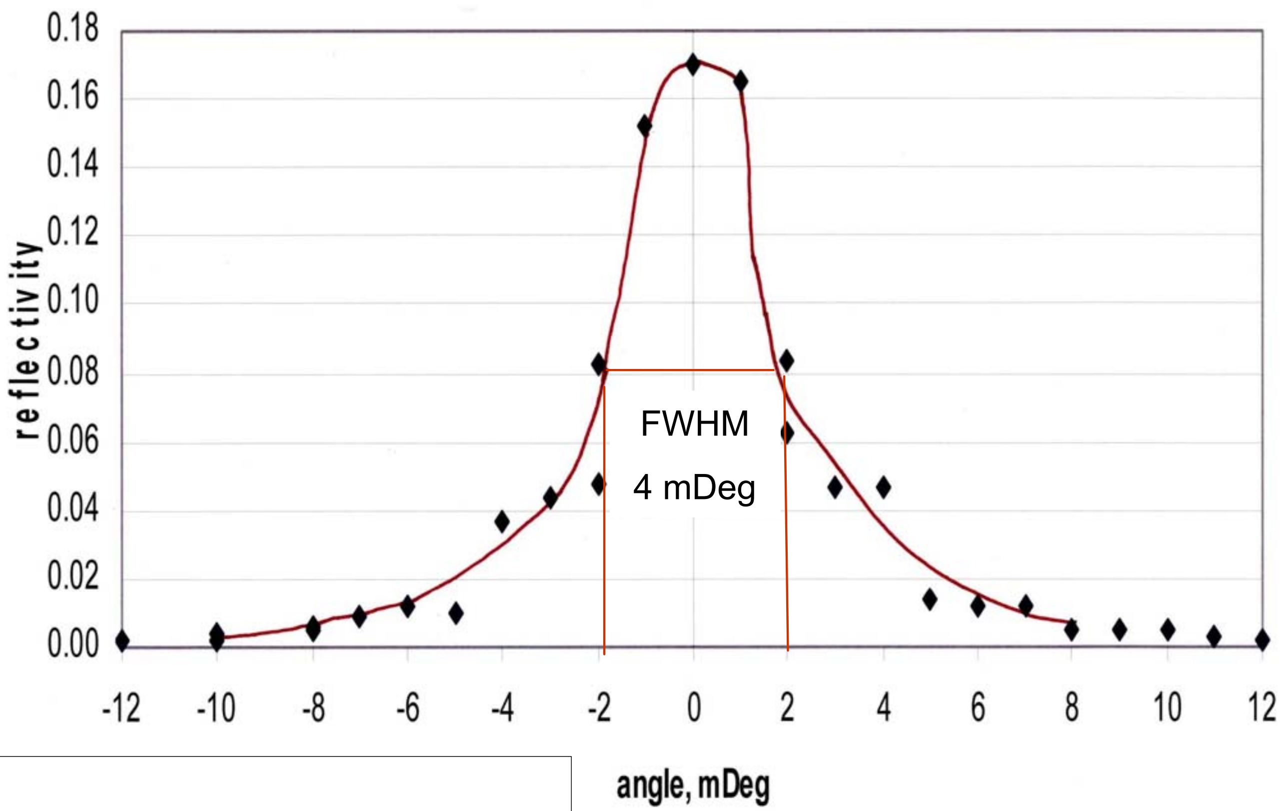
For the first number of crystals

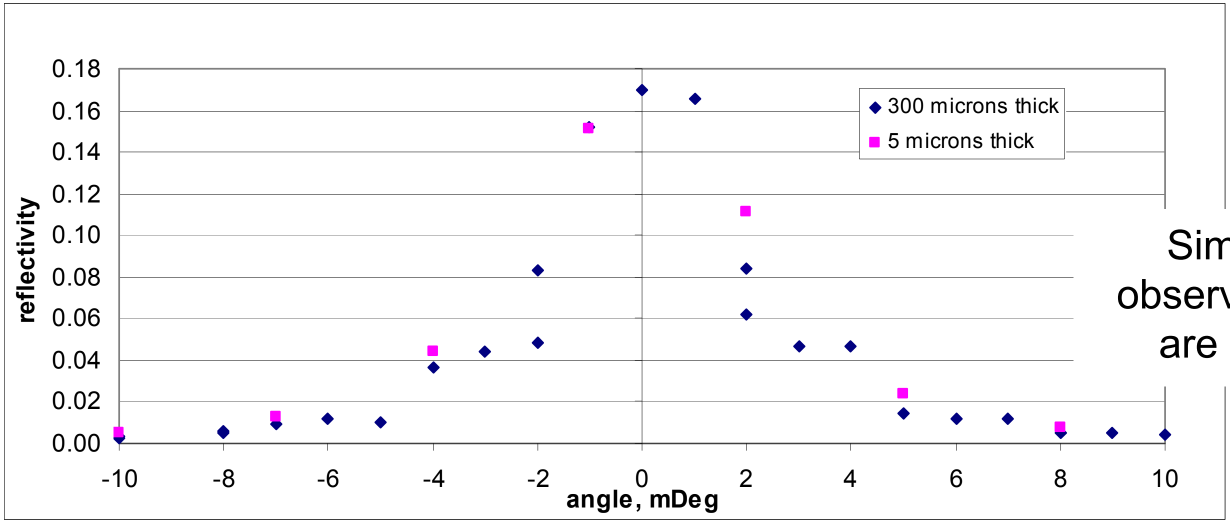
- $9.5 \leq$ FWHM, mDeg ≤ 36
- $0.03 \leq R_p \leq 0.10$
- $0.74 \leq R_c \leq 1.7$

The reflectivity curve is very narrow.

Mica NSC#2,
300 microns thick
For Au $L_{\beta 1}$, 11442eV

Integrated Reflectivity, Rc	0.86
Peak Reflectivity, R_p	0.93
FWHM, mDeg	0.71





Similar results are observed when crystals are 5 microns thick

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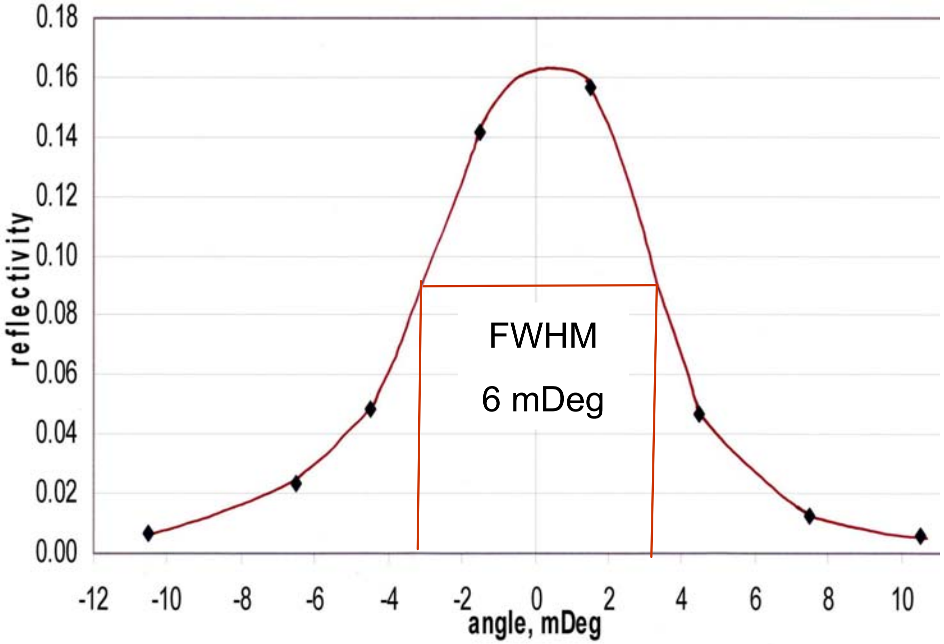
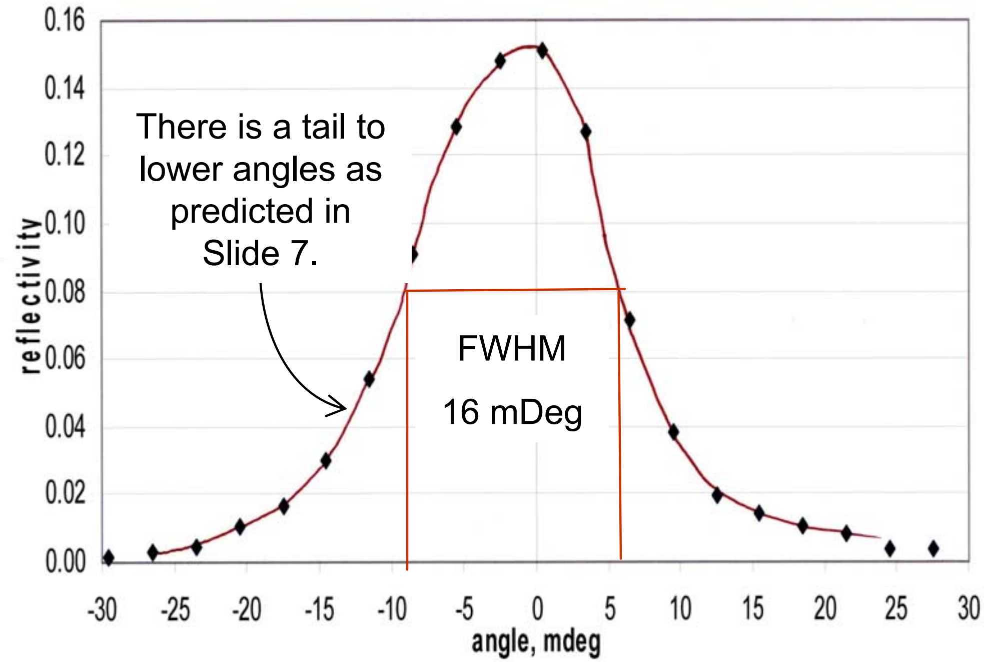
Crystal Comparisons

Curved Mica Crystal #7 NSC
3 microns thick



Curved Mica Crystal AXIM
300 microns thick



MICA SUMMARY

- This equipment can characterize crystal diffraction quality.
- The integrated reflectivity is not sufficient for characterizing diffraction quality.
- Thin (approximately 5 μm) curved mica crystals can achieve the diffraction quality of flat mica crystals.
- Thick (approximately 300 μm) curved mica crystals increase the reflectivity curve width by a factor of 3 or more.

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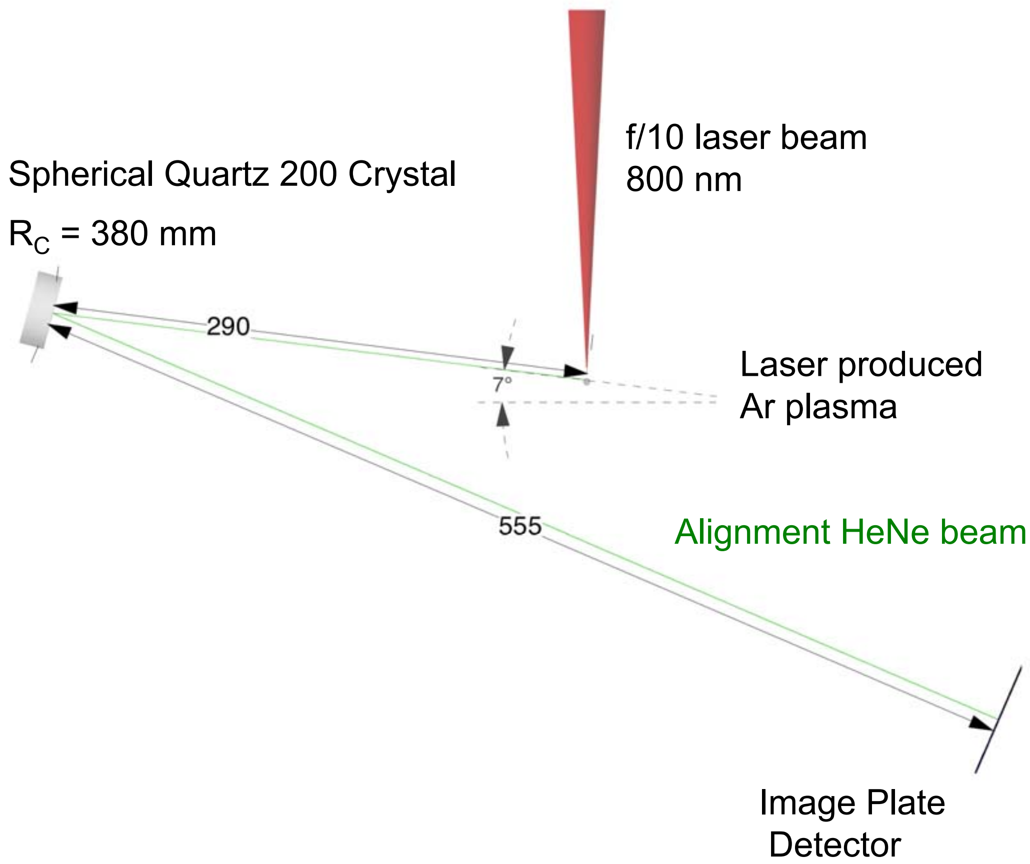
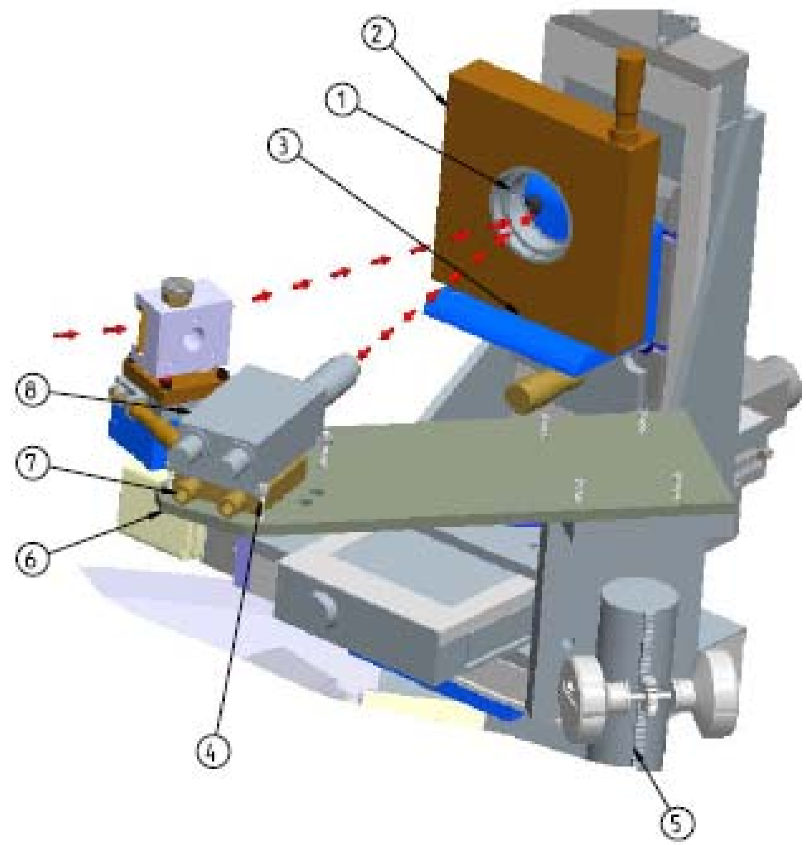
2. Characterizing the Quality of Spherically Curved Quartz Crystal

Used for imaging a section of a plasma and identifying individual spectral lines.

Experimental Imaging Arrangement



Experimental Arrangement for Characterizing the Crystal



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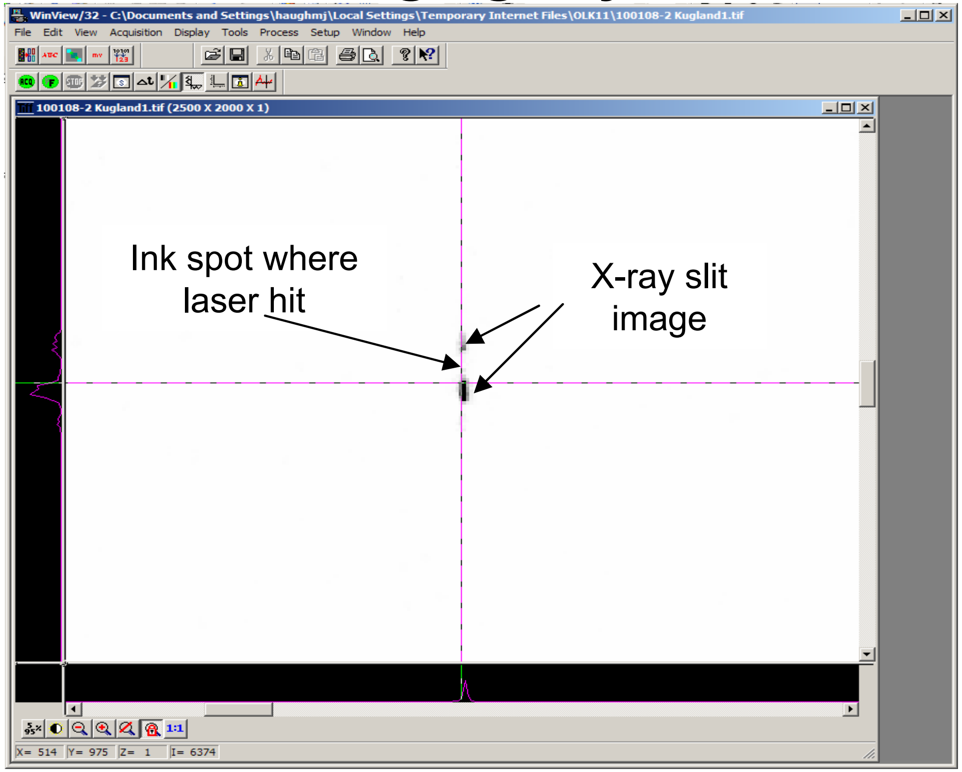
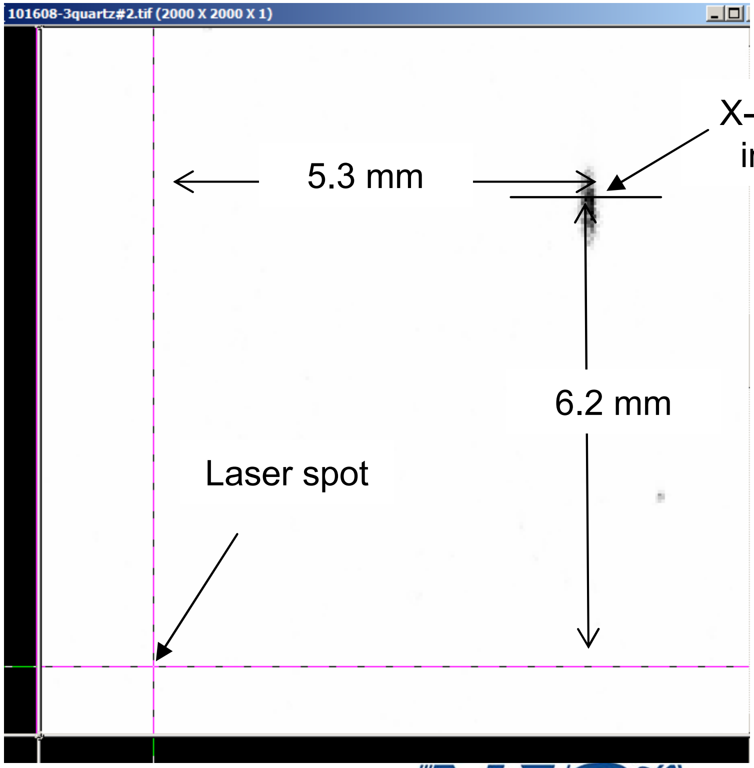
Imaging Crystal Calibration

- Compare laser reflection to X-ray reflection using an image plate.
- Imaging the slit, 1000 microns by 200 microns
- Radius of curvature 400 mm; quartz 200; X-ray energy 2.8 keV using Ag L_α spectral line
- Not tested as imager; close to focal plane but not necessarily exact

Quartz Imaging Crystal #1



Quartz Imaging Crystal #2



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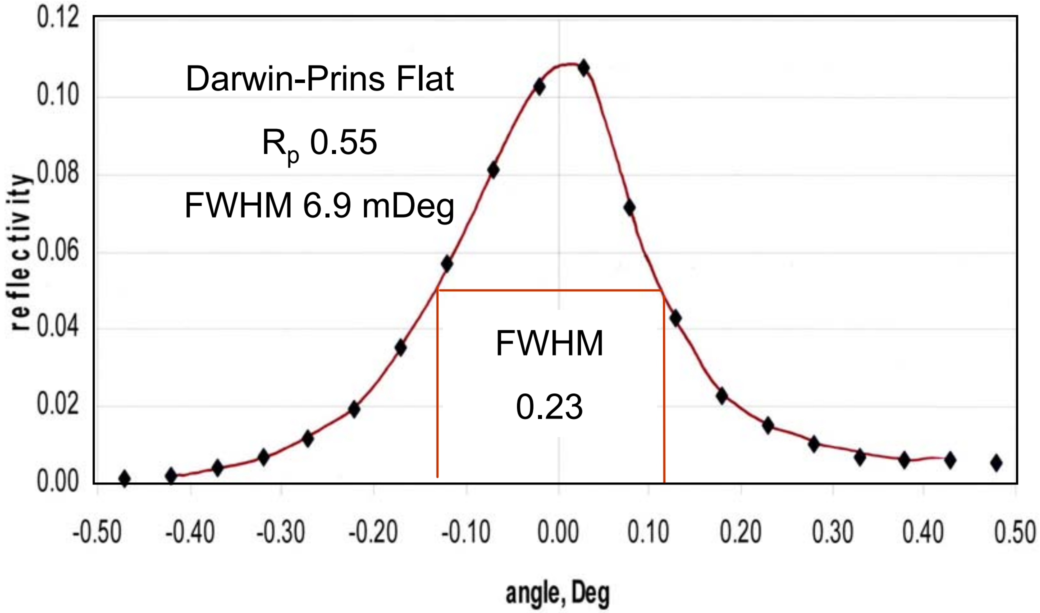
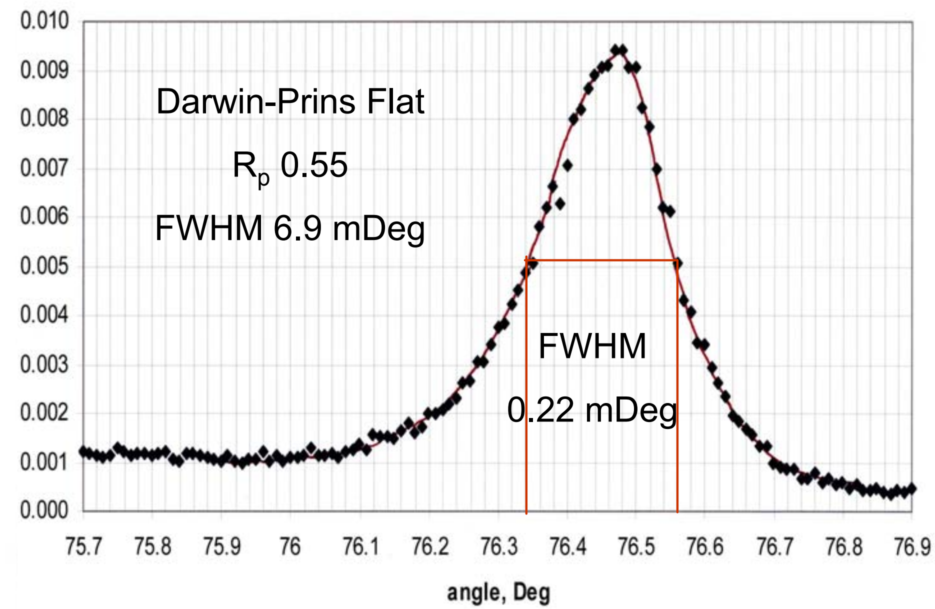
Rocking Curves of Quartz Imaging Crystals

Crystal #1



Crystal #2



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Summary

- We can identify crystal diffraction quality up to 15 keV.
- We can characterize the quality of spherical imaging crystals.
- We continuously improve procedures and hardware for ease and speed of calibration.