The symmetric, broad band double Laue high-energy monochromator at P21.2.

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Introduction

Motivation

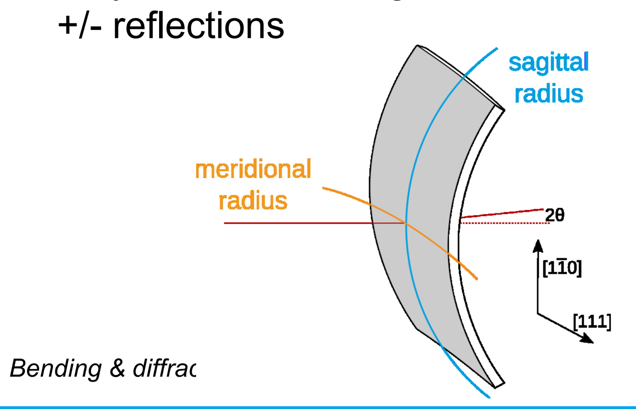
- high energies: 40 - 150 keV
- $\Delta E/E \approx 10^{-3}$ ⇨ $\Delta\theta \approx 50$ µrad
- large source-to-mono distance (100 m)
  - ⇨ large Rowland circle
  - ⇨ small curvature of meridionally bent crystals
  - ⇨ thick crystals required for bandwidth

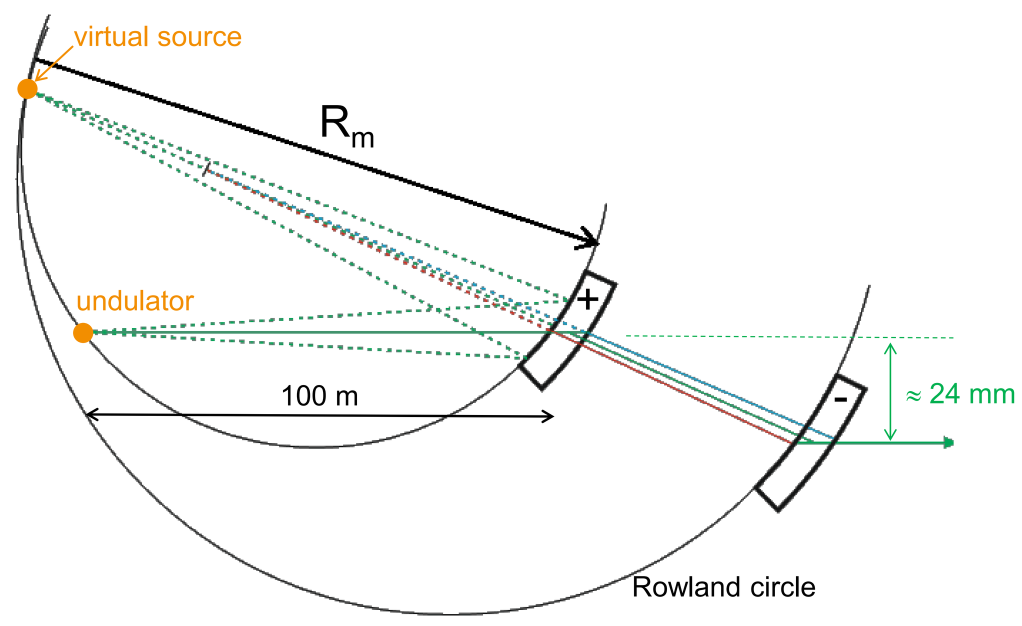
Advantages of sagittal bending

- Symmetric Laue case, perpendicular incidence
- Minimal crystal thickness
  - ⇨ best transmission and minimal heat deposition
- Bending does not couple to glancing angle
- Energy independent Rowland circle

Double Laue Rowland geometry

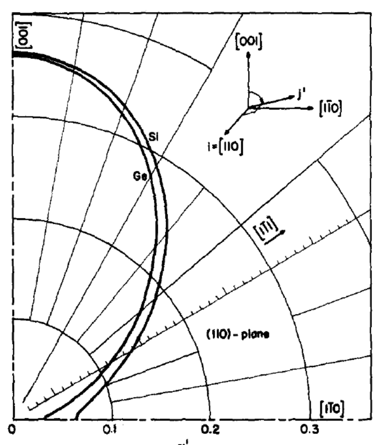
- Horizontal diffraction plane
- Polychromatic divergence cancelled by +/- reflections



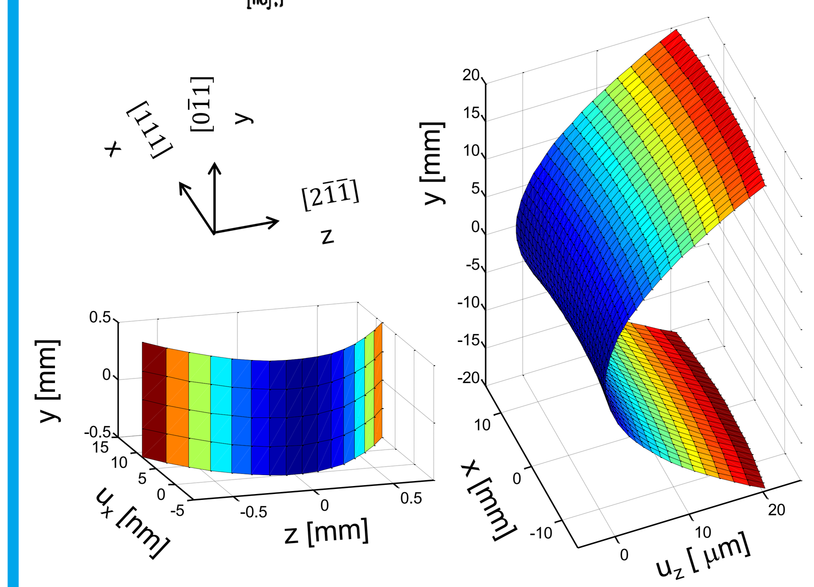


Bending: principles and FEM simulations

Bending of lattice planes due to anisotropy



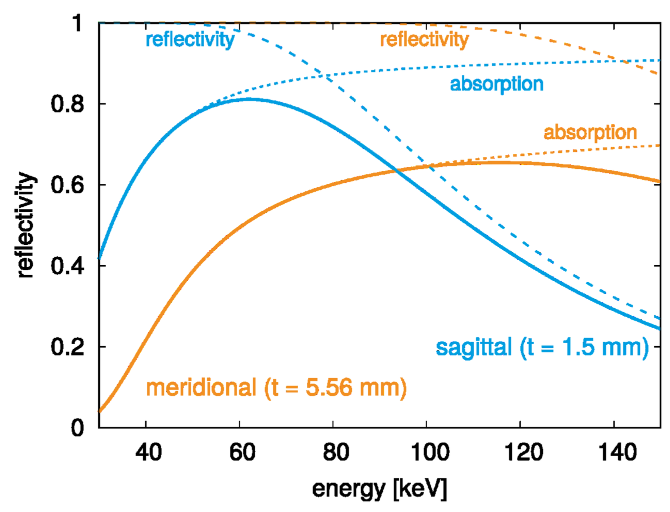
Anisotropy of Poisson's ratio in silicon [Wortman, 1965]



Curvature of lattice planes by simple bending

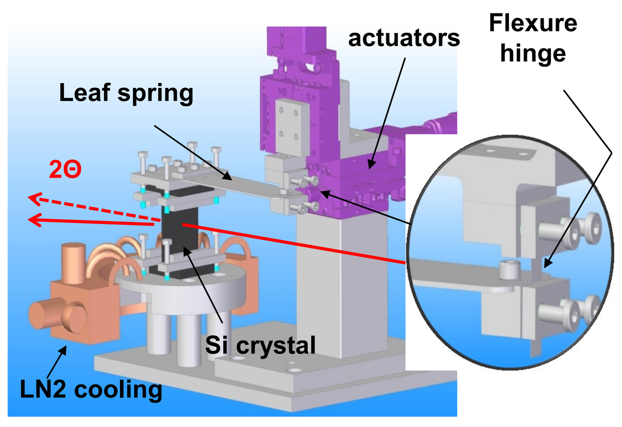
Symmetric Laue case & primary sagittal bending

- Primary bending around lattice plane normal ⇨ no direct distortion of reflecting lattice planes
- Meridional curvature due to anticlastic coupling
- Strong curvature of lattice planes due to elastic anisotropy of Si:
  - ⇨ Primary bending radius: 8.5 m
  - ⇨ Bending radius of lattice planes: 30 m
  - ⇨ Meridional bending radius: 100 m

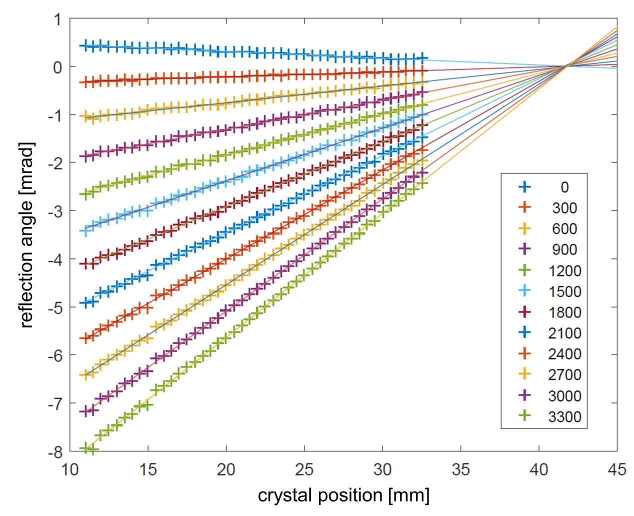


Comparison of reflectivity for sagittal and meridional bending

Bender geometry and characterization

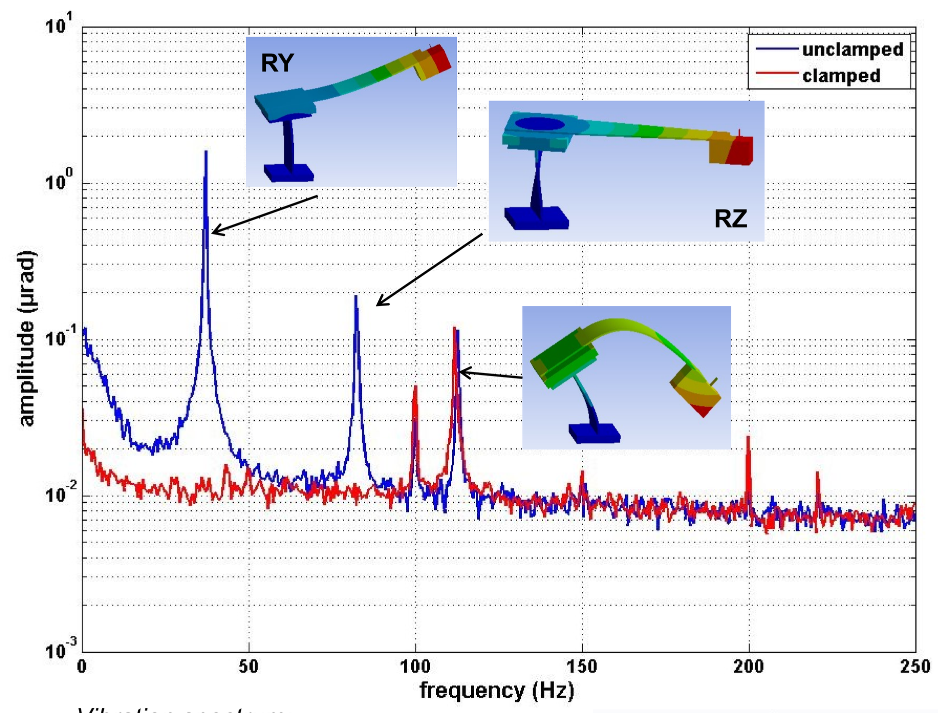


Sketch of crystal bender
Sagittal: force actuator
Twist: position actuator

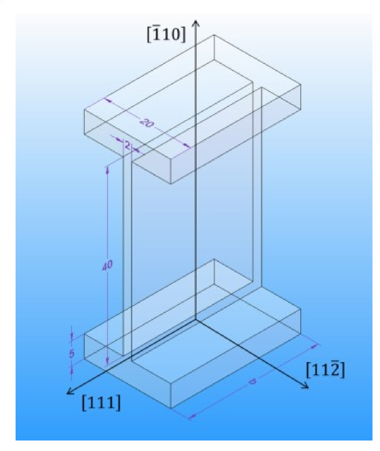


Sagittal curvature measured by laser reflection

Vibration spectrum

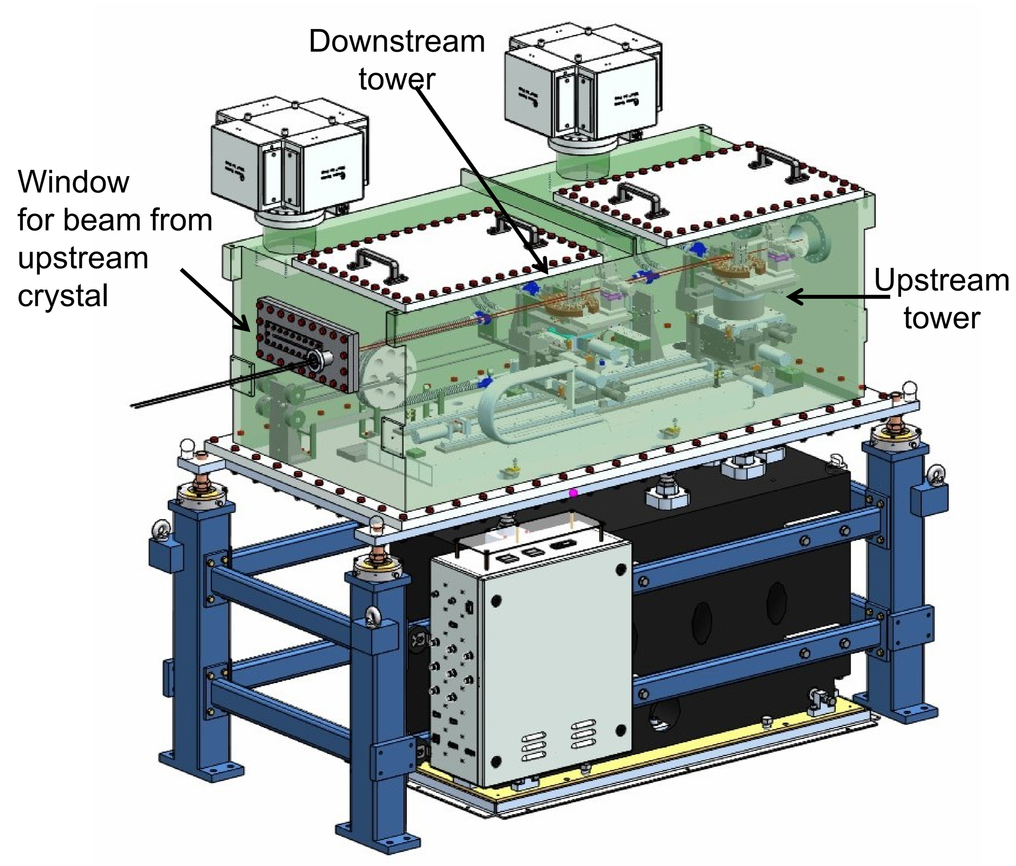


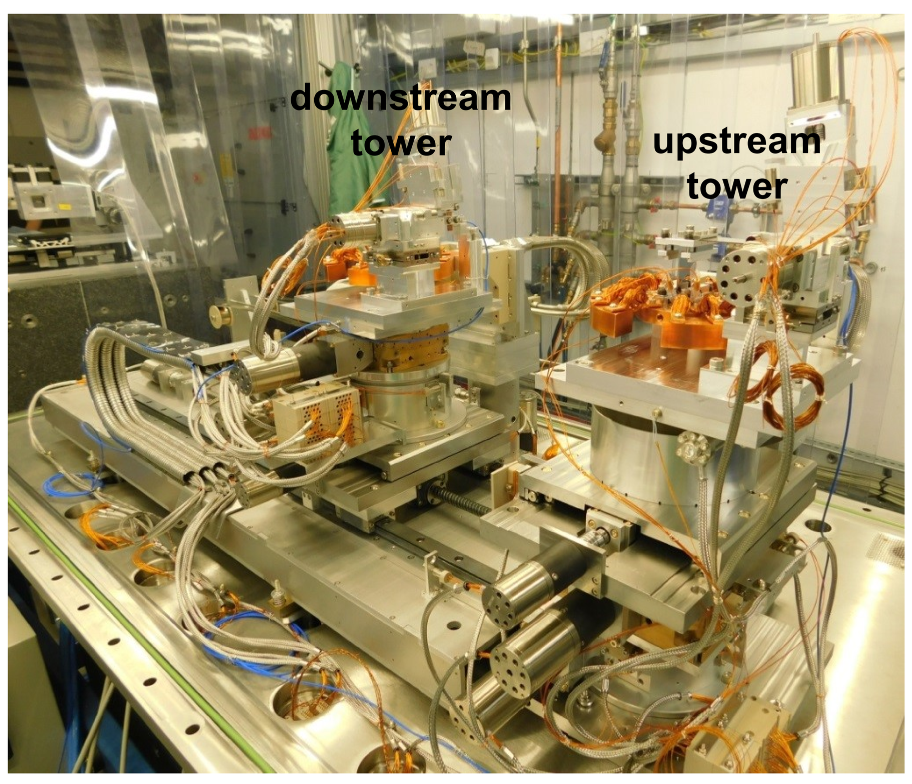
Vibration spectrum: Low frequency modes (RZ, RY) suppressed by clamping



Shape of crystal: Height/width ratio determined by bending radius/rocking curve width (FEM optimized)

Realization

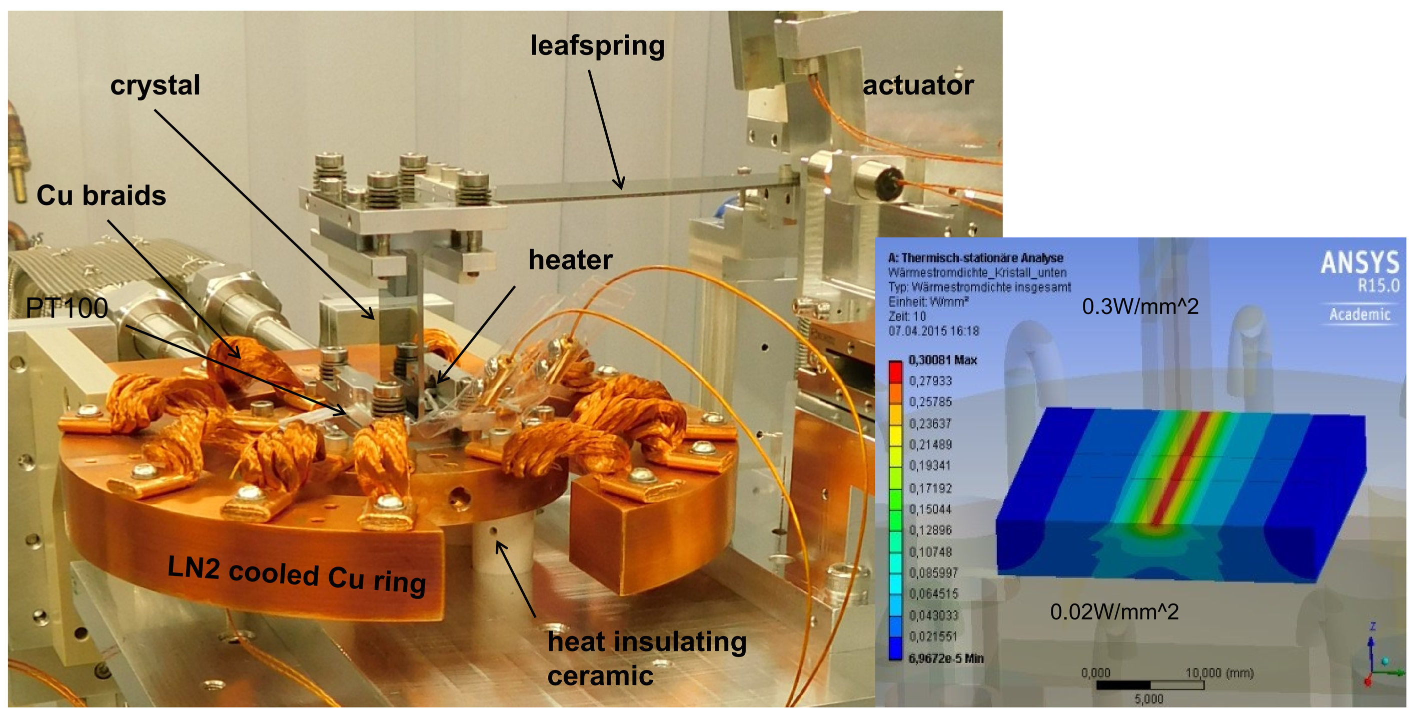




Mechanics, vacuum vessel & cryo-cooling provided by FMB Oxford
Crystal benders designed in-house

Heat flow

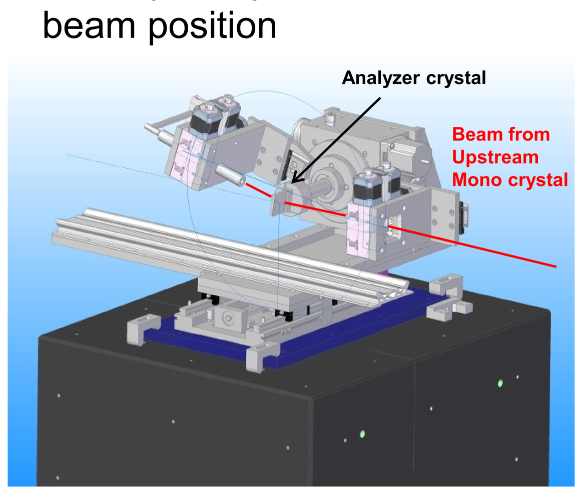
- Indium foil to improve thermal contact between crystal and base plate
- Heat flow density reduced by a factor of 15 across crystal base
- Cooling through flexible copper braids
- Crystal temperature kept constant via PT100 temperature sensor and heater

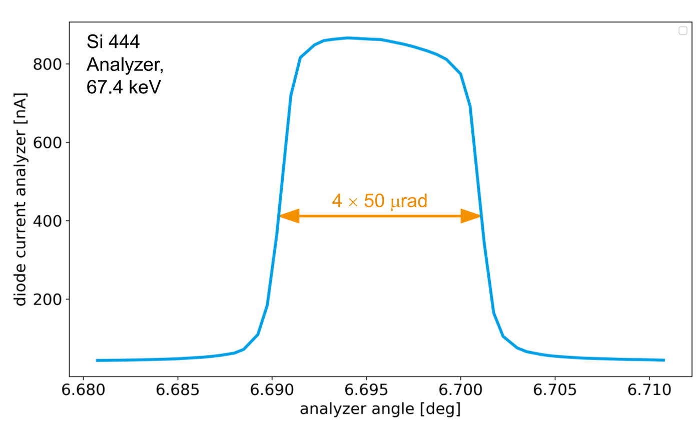


Experimental characterization

Analysis of diffracted beam by upstream crystal analyzer

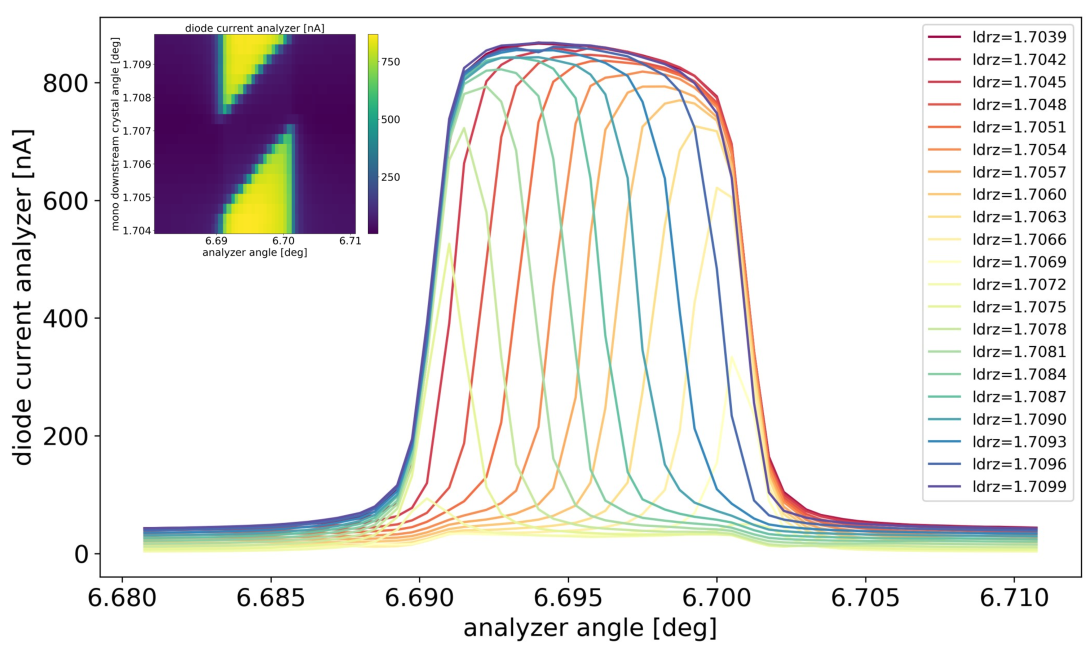
- Flat Laue crystal
- Vertical diffraction plane
- Alignment of crystal bending and twist by analysis of peak shift vs. beam position





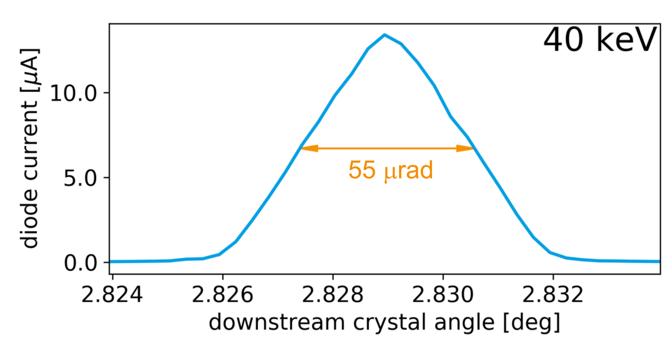
Reflectivity curve of upstream mono crystal

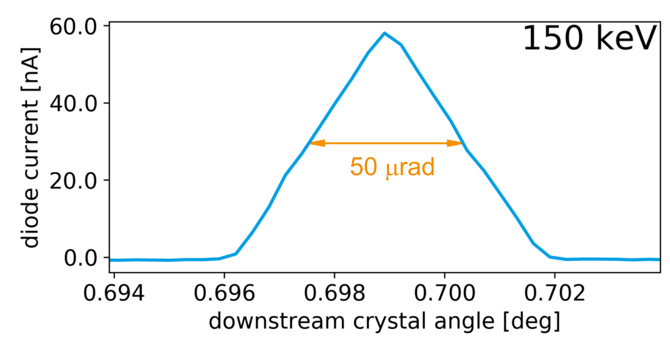
- Rocking curves agree with theoretical prediction
- No beam position vibration due to cryogenic cooling
- Vertical beam motion while scanning energy: 200 microns at the sample position (50 m downstream)



Analyzer scans while rocking mono downstream crystal: Energies constituting total bandwidth are linearly spread across crystal thickness

Rocking curves





Triangular shape expected from convolution of rectangular box shapes

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