Optics and Techniques for Diffraction and Contrast Imaging

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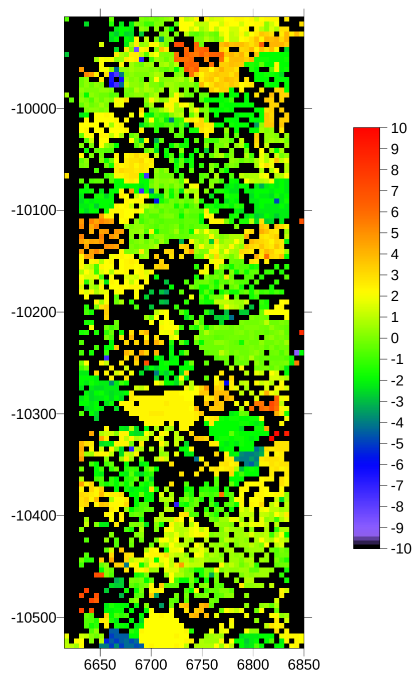

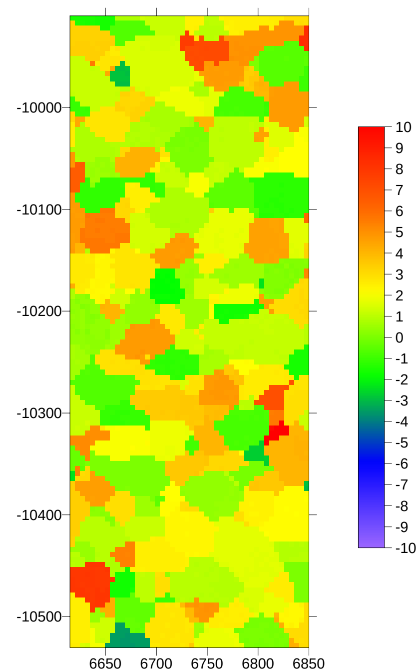

Diffraction mapping emerging area in electron and x-ray microscopy

- EBSD
  - Surface grain structure
  - Grain curvature
  - Phase

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

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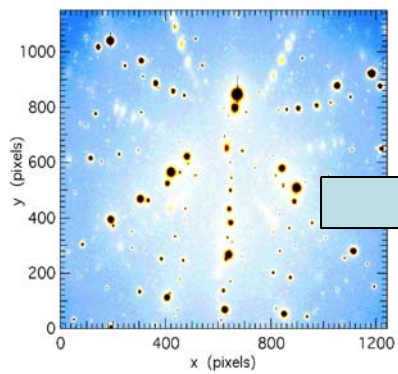
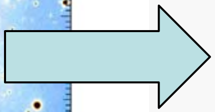
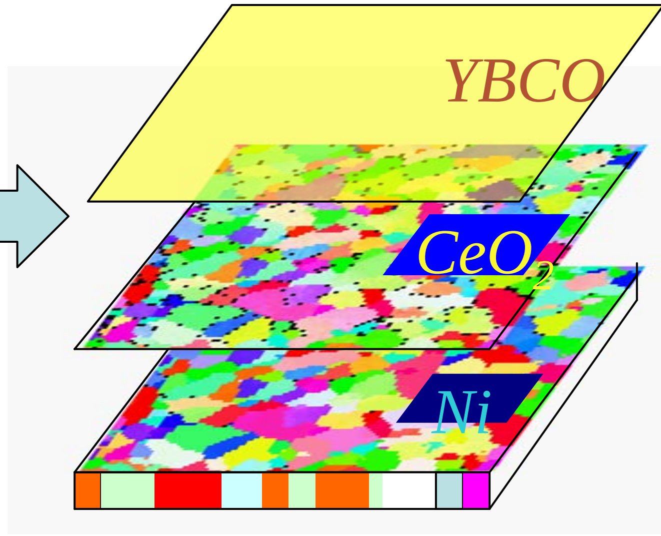
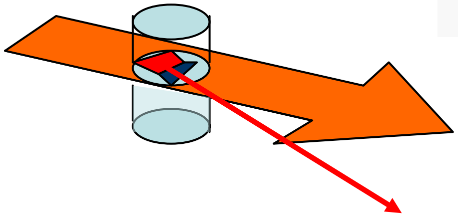
- **Polychromatic X-ray** microdiffraction
  - Phase/texture/strain/
  - deformation







- **4D X-ray microscopy (RISØ)**
  - Time resolved
  - Deep penetration



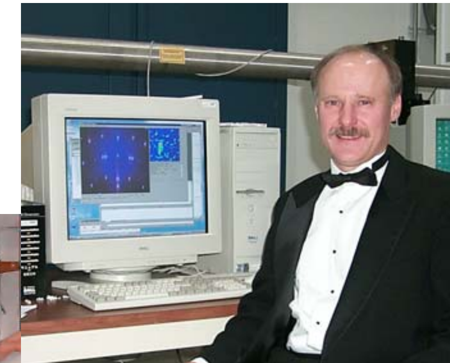
Lots of people involved

- **Ben Larson/ John Budai/Jon Tischler -IPNS polychromatic microdiffraction**

- **Sven Vogel, Camden Hubbard - LANSE tests of focusing optics**

- **Ron Roggie, Judy Pang, Steve Spooner -Chalk *River* tests of focusing with polychromatic microdiffraction)**

- **Chris Tulk, John Parise etc.**



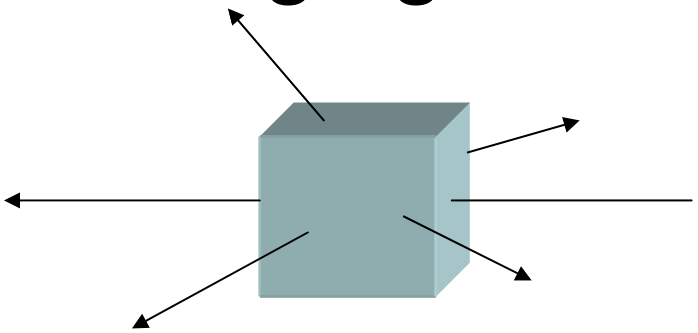


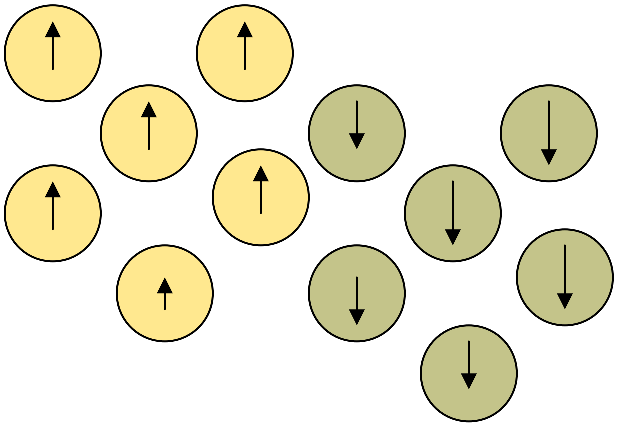





Neutrons unique advantages for diffraction imaging

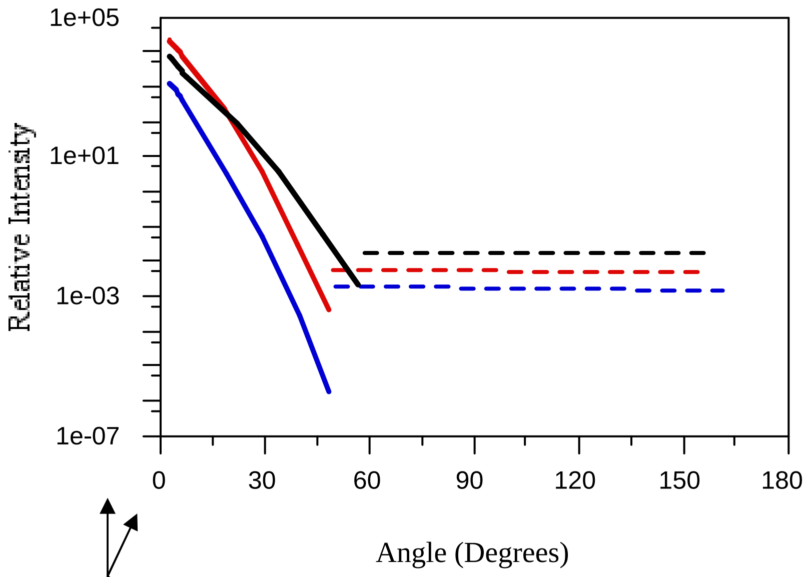
- **Penetrating**
- **Scatter at high Q**
- **Low damage (lowest theoretical limit)**
- **Low Z atoms (precipitates etc).**
- ***<u>Large magnetic cross section</u>***

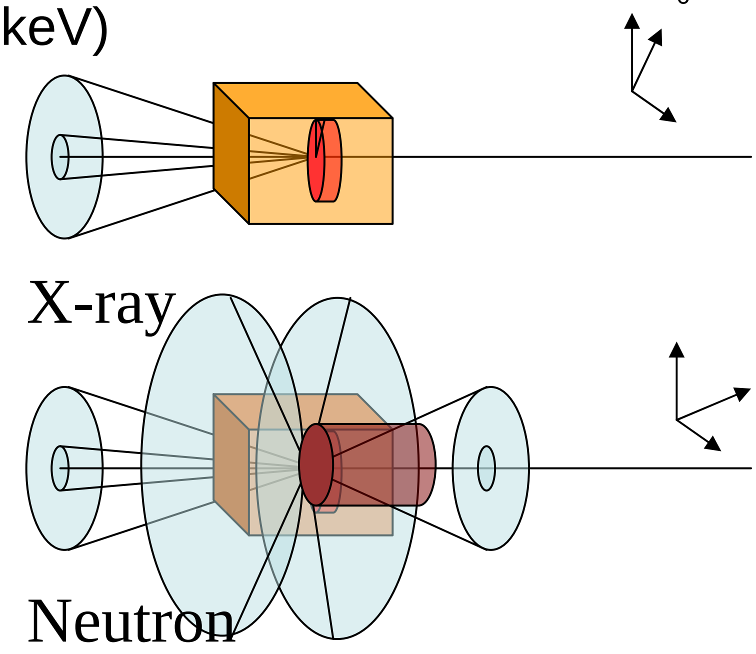




Neutrons probe bulk materials good Q resolution

- 12 orders of magnitude less brilliant than 100 keV x-rays
- But scatter into all directions
- Compliment high spatial resolution of x-rays at low energies (20 keV)





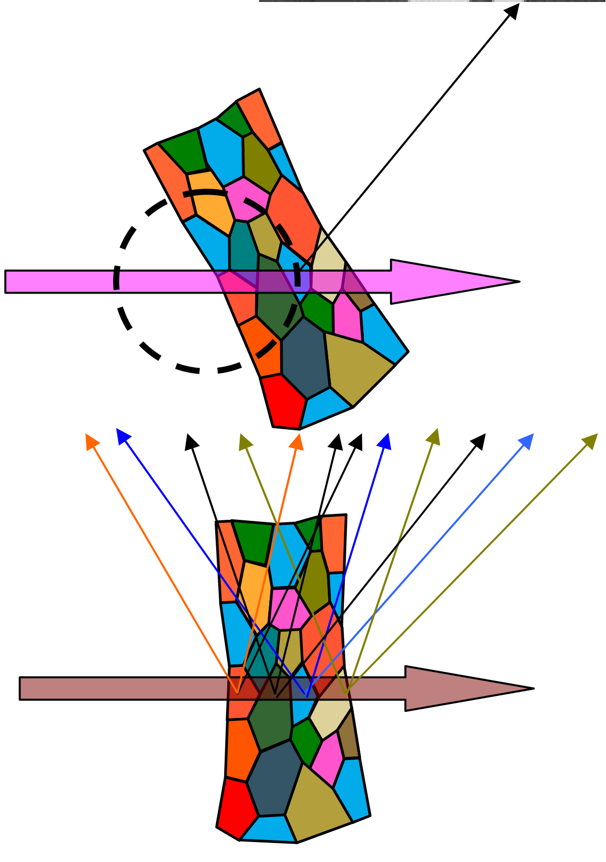
Polychromatic diffraction solves intrinsic problem of microdiffraction

X-rays -Sample does not need to be rotated!

Neutrons- use every neutron!

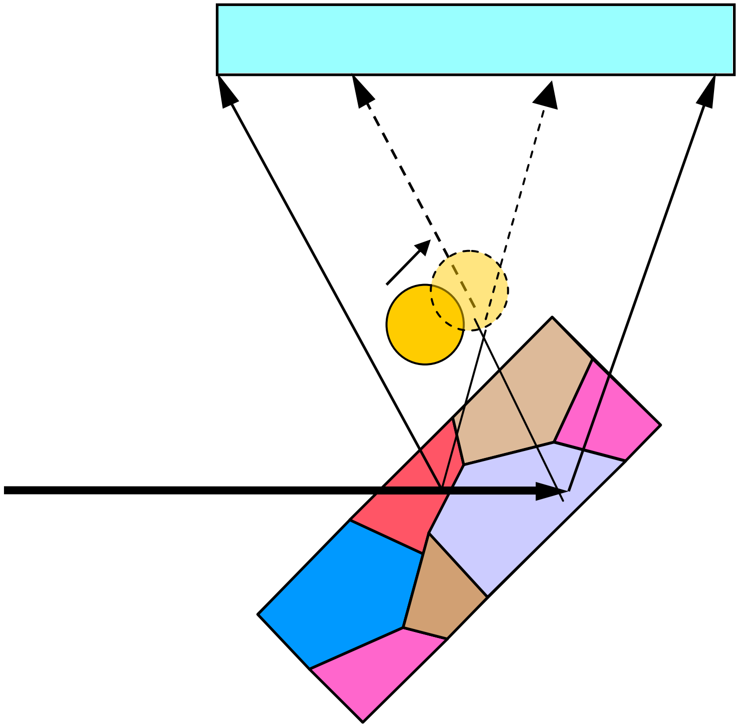
Special software required- Can index polycrystalline samples

3D nondestructive probe of stress/strain/crystal structure!

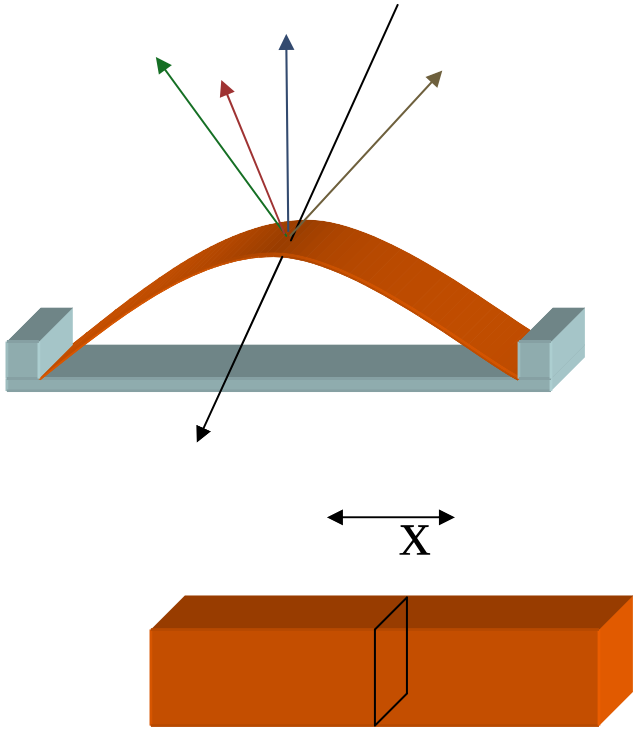


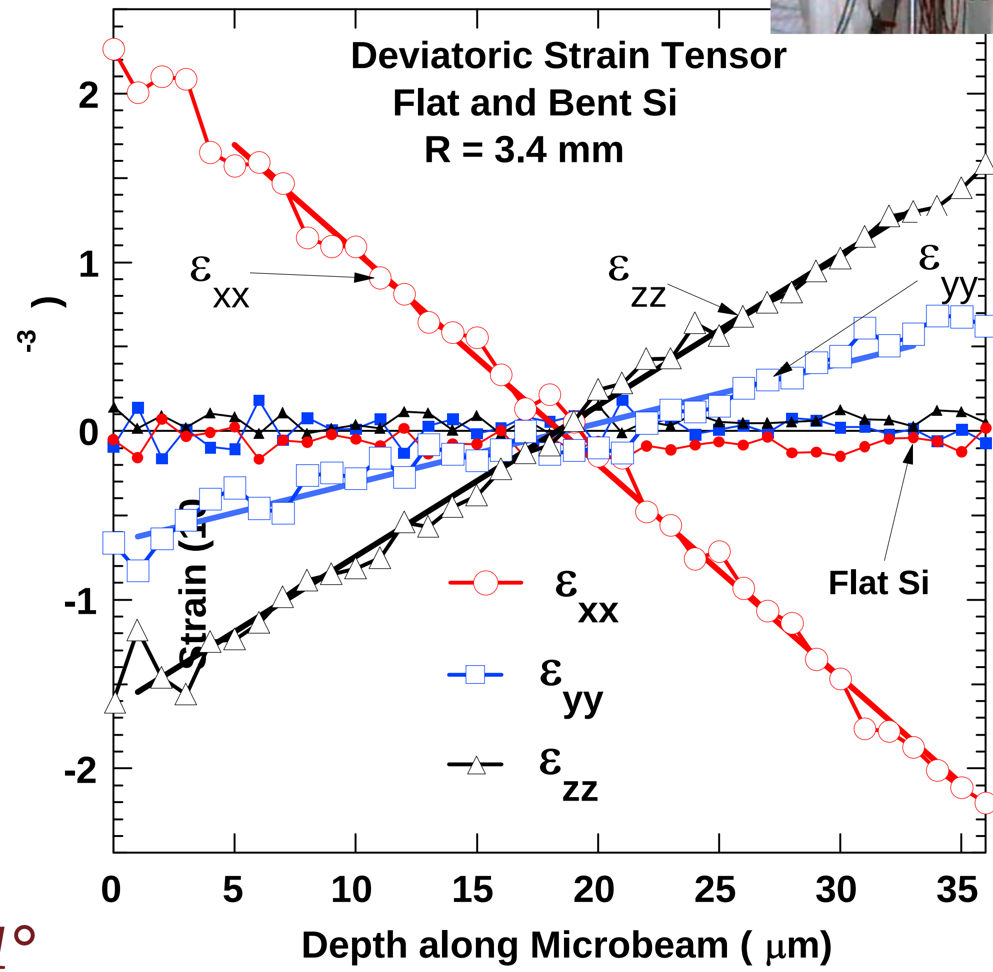
Differential aperture x-ray microscopy yields submicron information in all three directions!

- Simplifies data interpretation
- Submicron Z resolution
- Isolates weak diffraction from strong
- First demonstration by Larson et al. on deformed Cu -



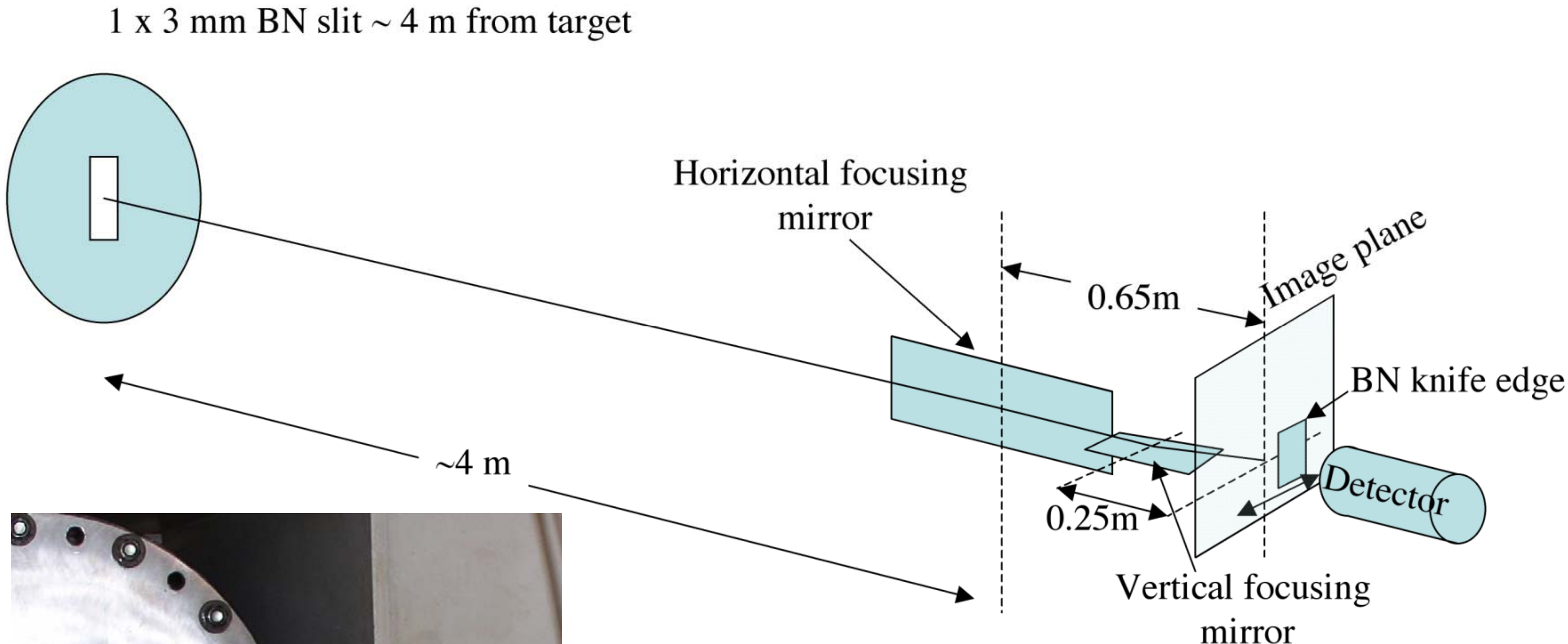
Precision measurements of strain tensor *inside* bent single crystal Si illustrate power of DAXM

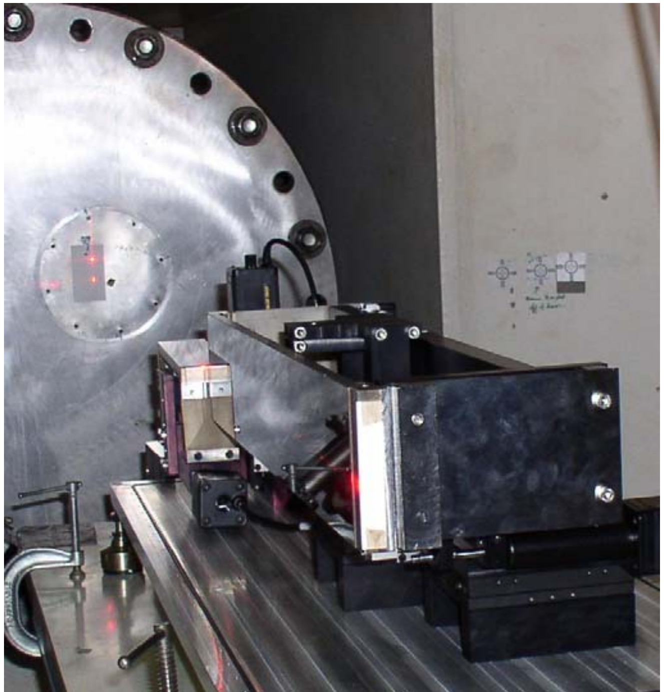




Orientations to 0.001°

Elements for neutron microdiffraction tested





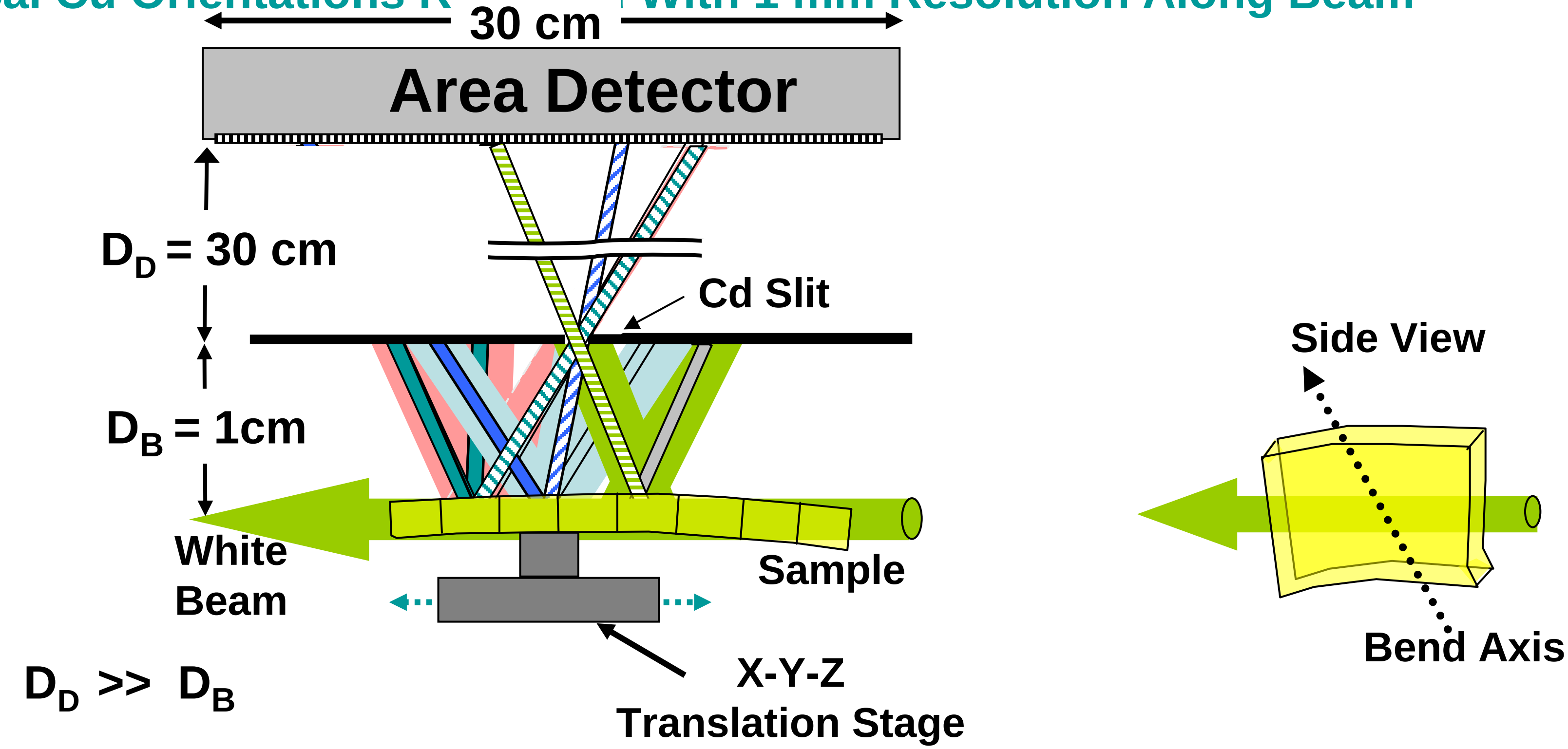
Small polychromatic beams

3D aperture-resolved diffraction

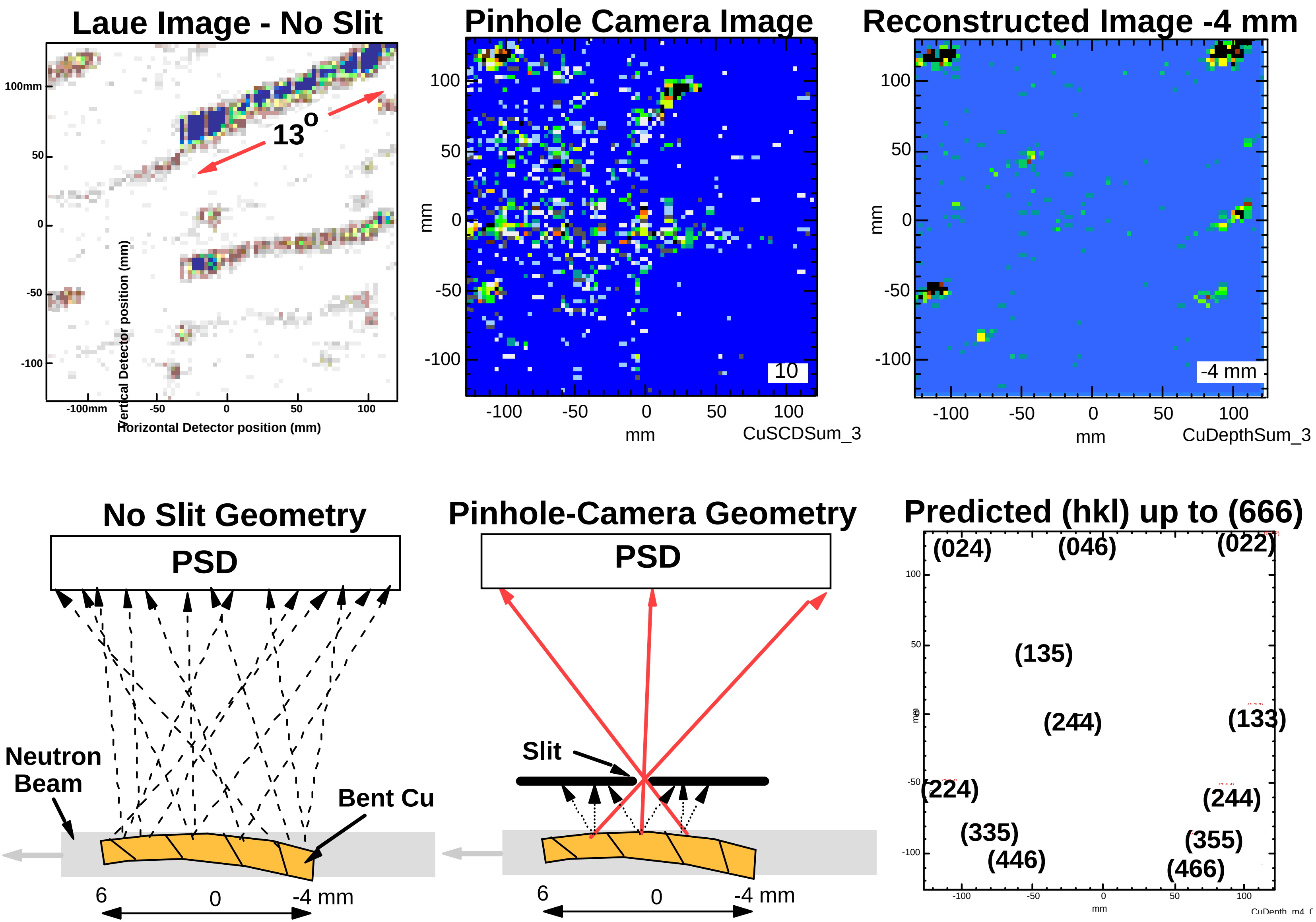
Negligible gravitational dispersion

3D Neutron Structural Microscopy Has Been Demonstrated at IPN

- Measurements Made On IPNS Single Crystal Diffraction (SCD) Beamline
- Cylindrically Bent, <001> Oriented Cu Crystal Plate (2 x 9 x 10 mm^3)
- Slit System Fabricated And Depth-Resolution Analysis Software Developed
- Local Cu Orientations R[illegible] With 1 mm Resolution Along Beam

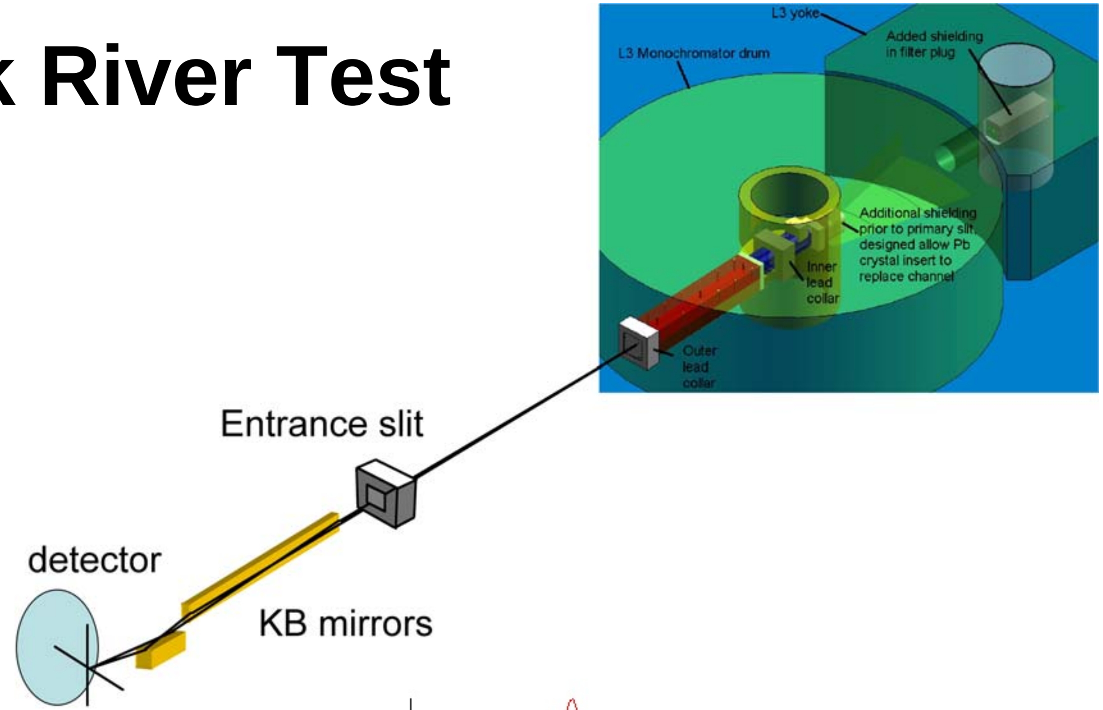


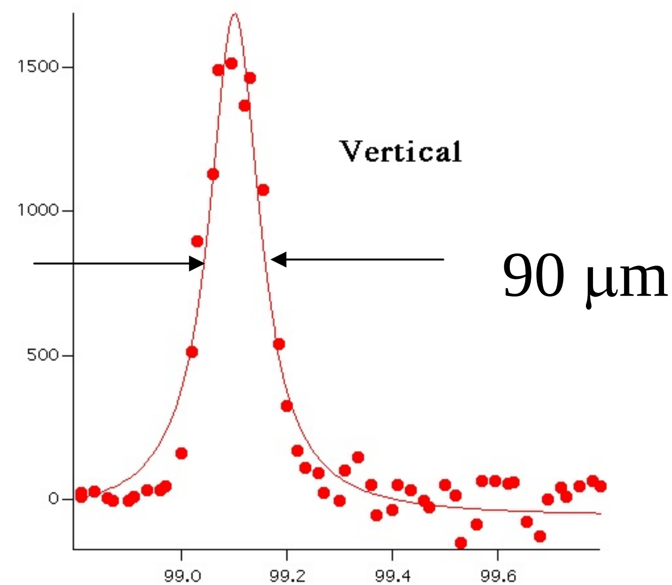
Pinhole-Camera Depth Depth Resolution Process



Integrated Chalk River Test

- **Deflecting mirror in mono tank suppresses background**
- **Upstream slits provide source**
- **Image plate allows microLaue**
- **Focus spot 89 x90 μm**
- **"Gain" measured ~20**
  - **Estimated "actual" ~100-180**
  - **"Theoretical" focused" ~150**
  - **"Theoretical" small beam ~100**

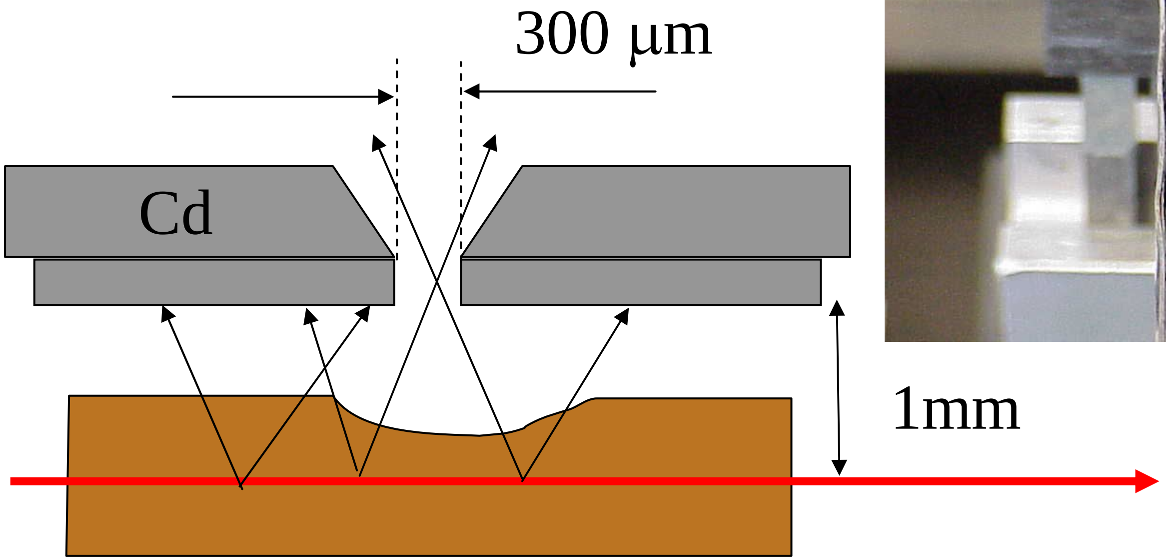


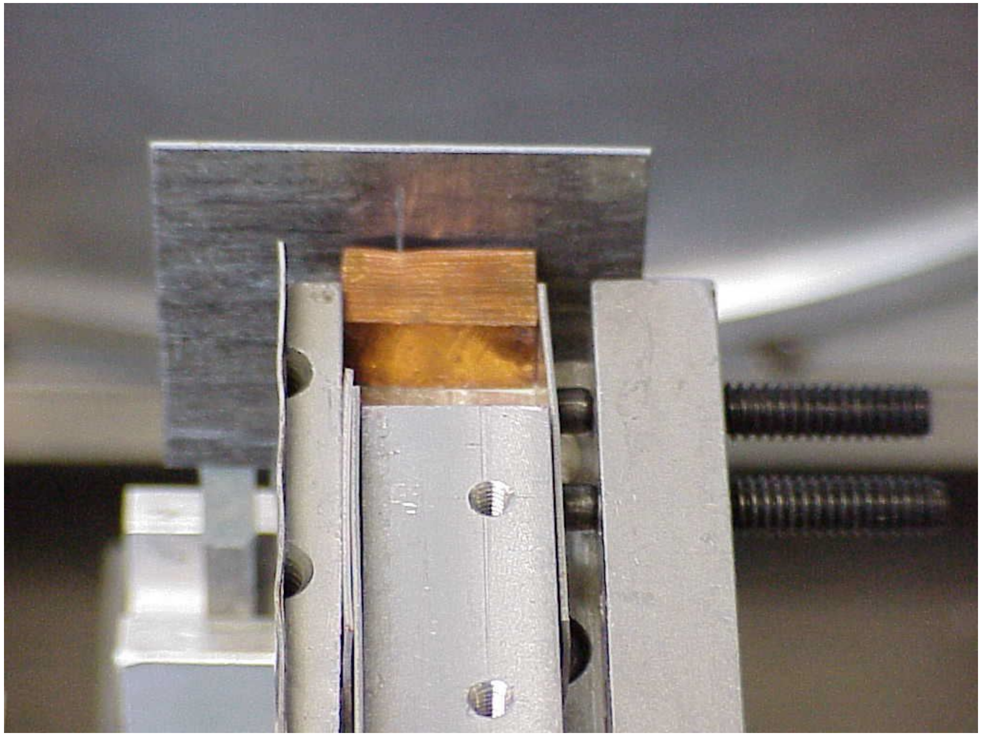


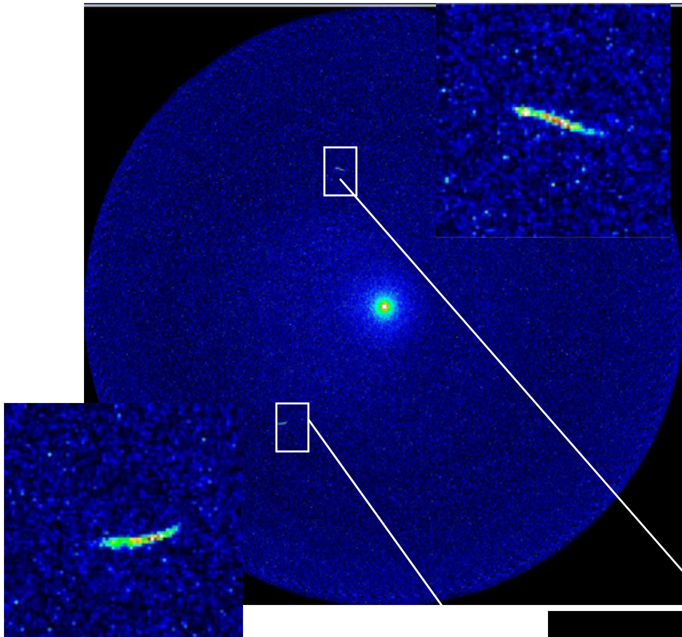
Near theoretical performance

Deformed Cu sample measured with much higher spatial resolution

- 200 x smaller area
- 3 x smaller slit



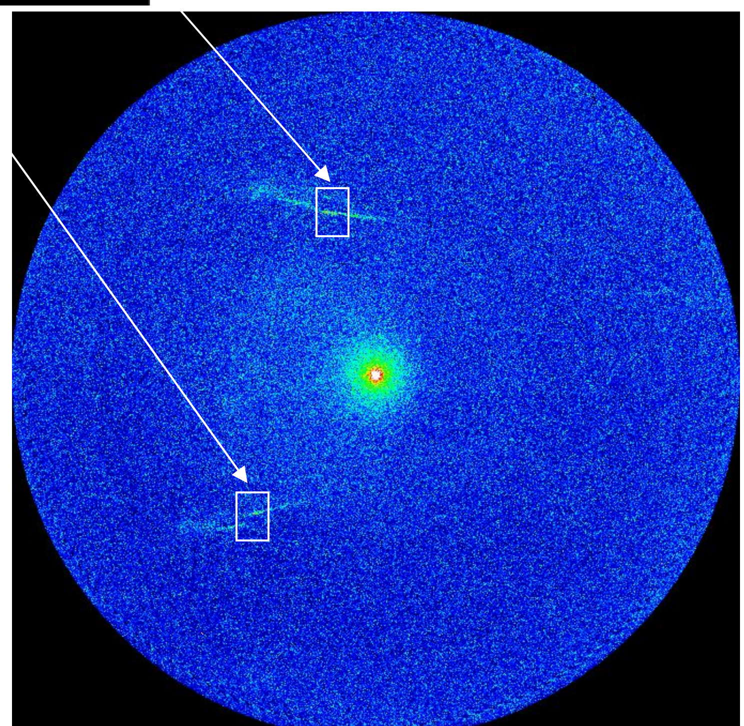


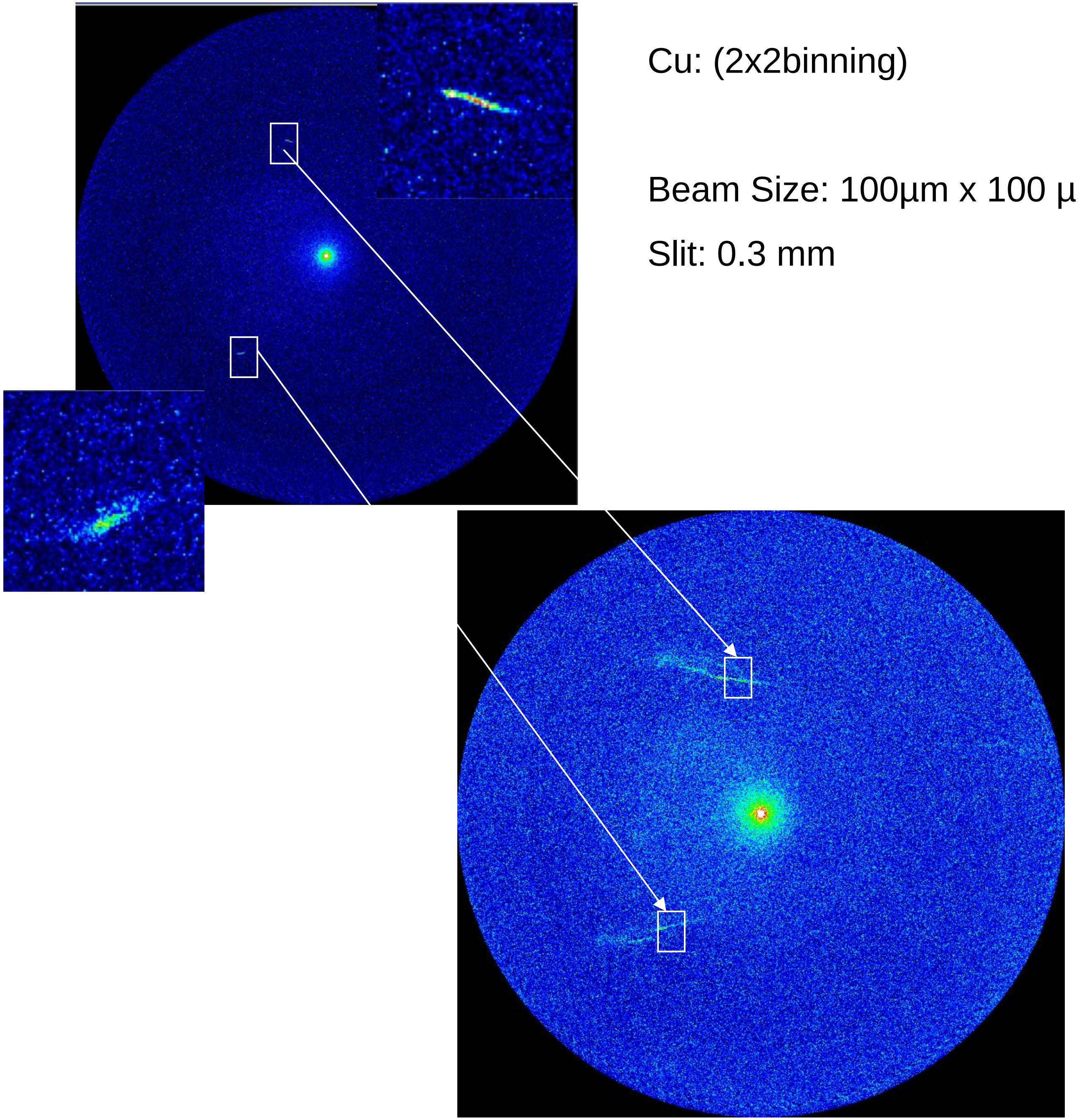


Cu: (2x2binning)

Beam Size: 100µm x 100 µm

Slit: 0.3 mm





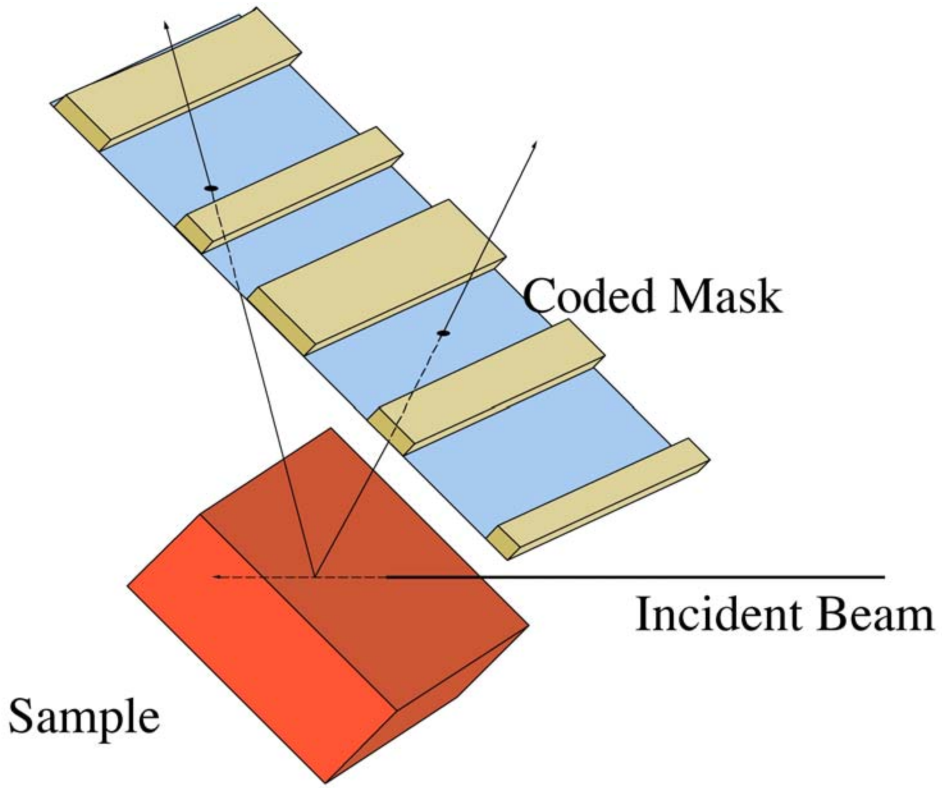
Cu: (2x2binning)

Beam Size: 100µm x 100 µm

Slit: 0.3 mm

Coded aperture methods can further accelerate experiments

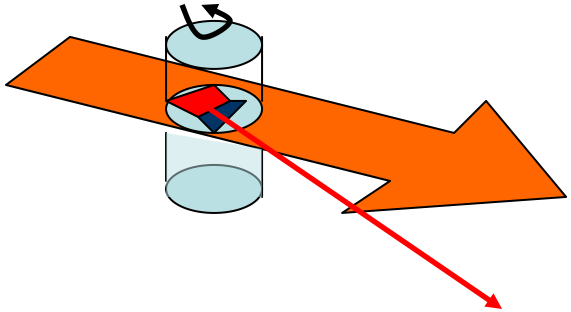
- **Additional factor of 10 possible!**
- **3D information along line minutes**
- **25 μm?**
  - **3 x faster with nested mirrors**
  - **10 x faster with SNS/HFIR**
  - **10 x with coded**



Optimized system 5 x faster than test system with 4 x better spatial resolution in all 3 dimensions!

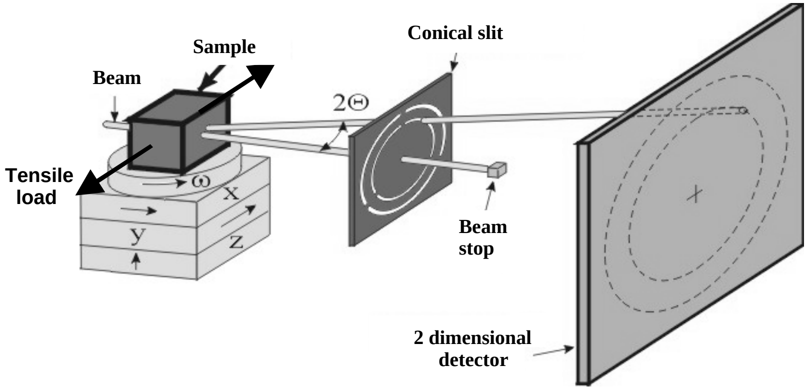
4D Microscope offers advantages for neutrons

- Singly focused monobeam illuminates numerous grains
  - Bragg condition satisfied by single rotation



- Grain outline determined
  - Ray tracing
  - conical slit
  - Back-projection tomography

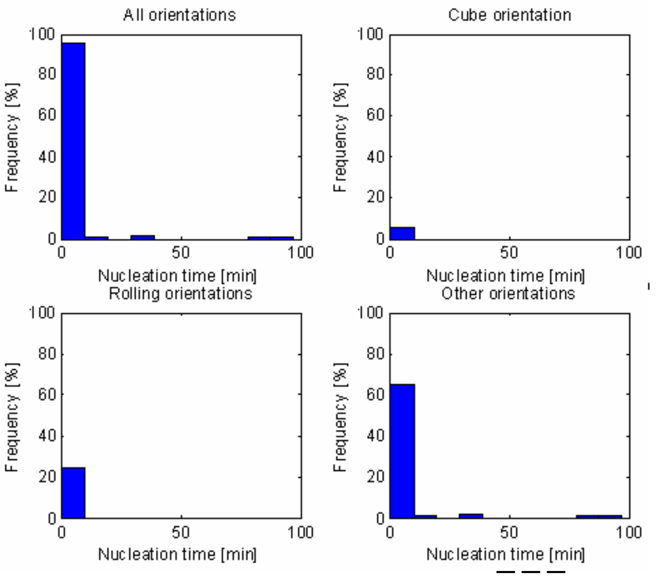
- E>50 keV allows deep measurements



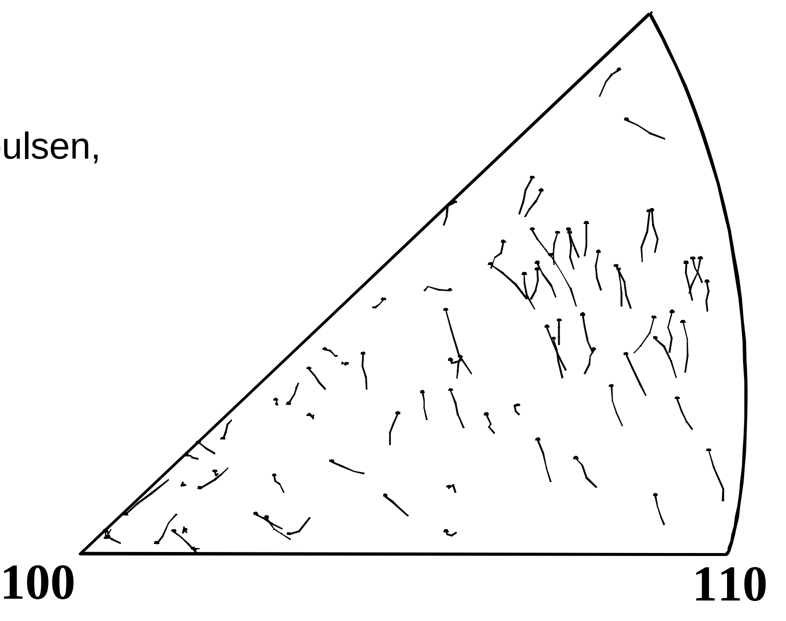
FAST!!

Particularly important for dynamics

- Recrystallization growth individual grains-deep
  - E. M. Lauridsen, D. Juul Jensen, U. Lienert and H.F. Poulsen (2000). *Scripta Mater.*, ***43***, *561-566*

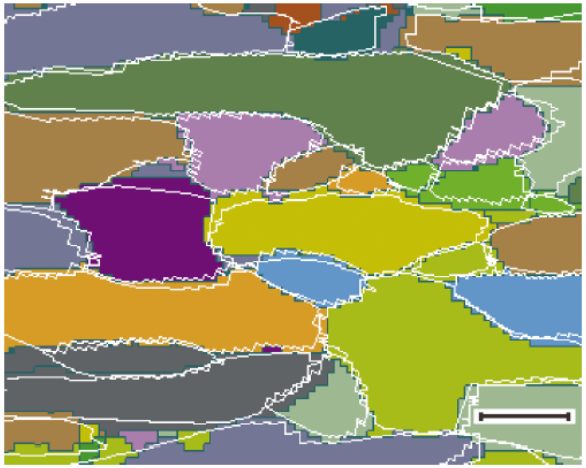


- Rotations/texture evolution individual grains during deformation
  - Tests deformation models
  - L. Margulies, G. Winther and H.F. Poulsen, Science **291**, 2392-2394 (2001).



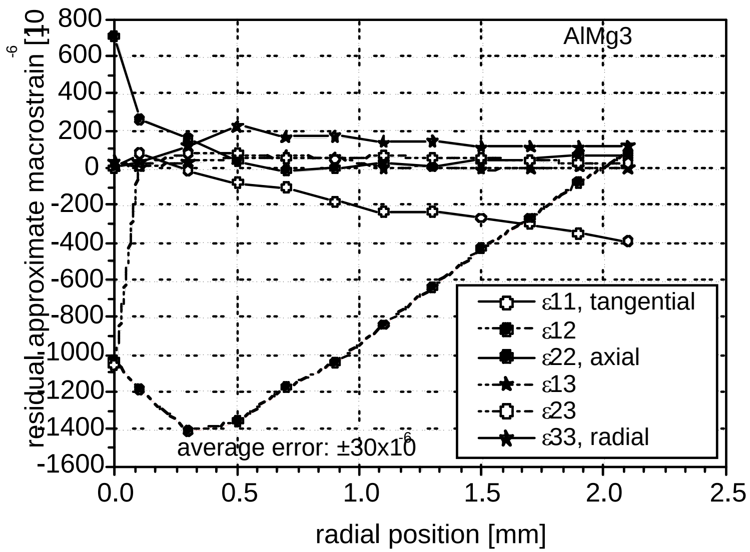
3DXRD Microscope provides additional powerful capabilities

- Grain boundary mapping in coarse grained materials- 5μm
  - Poulsen et al. J. Appl. Cryst. 34 751-756 (2001)



- Single crystal refinement for polycrystals

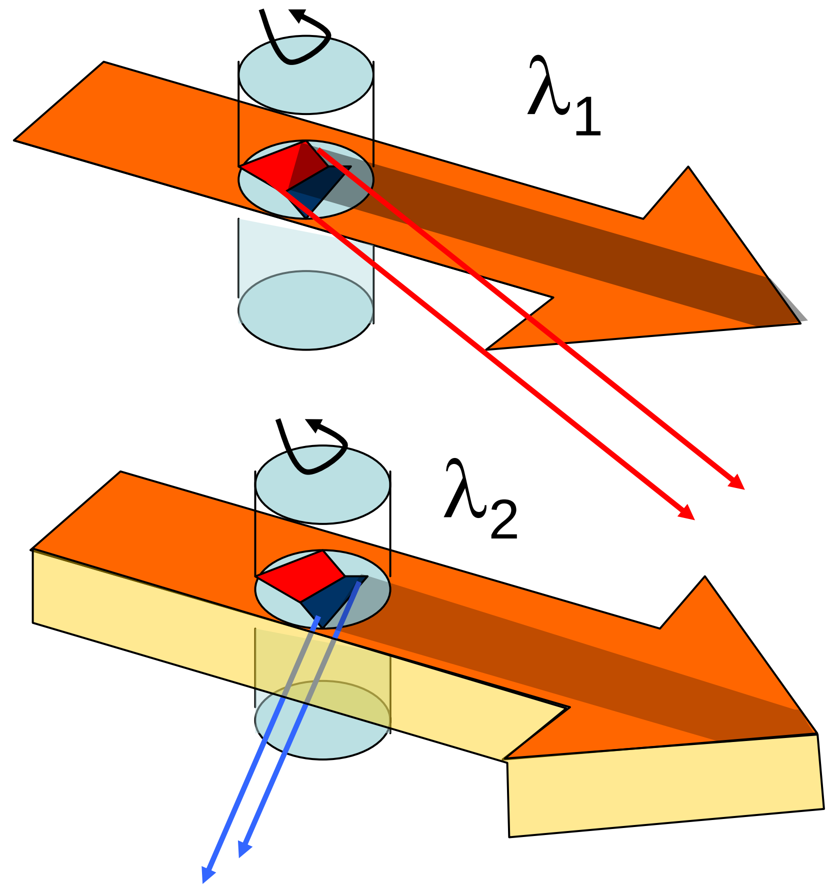
- Macro/microstrain

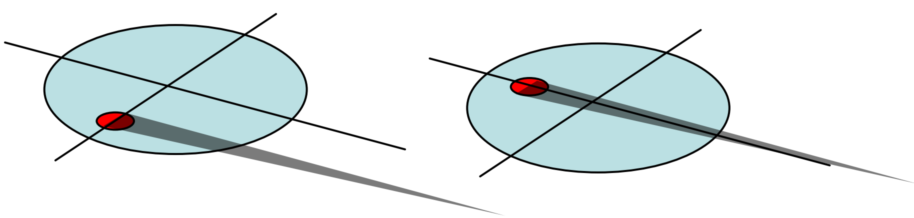


Strain tensor elements in torsion sample

Pulsed neutrons offer major advantages

- Simultaneous multiple λ's combines polychromatic with 4D
- Best S/N
- Large diffraction contrast for direct beam

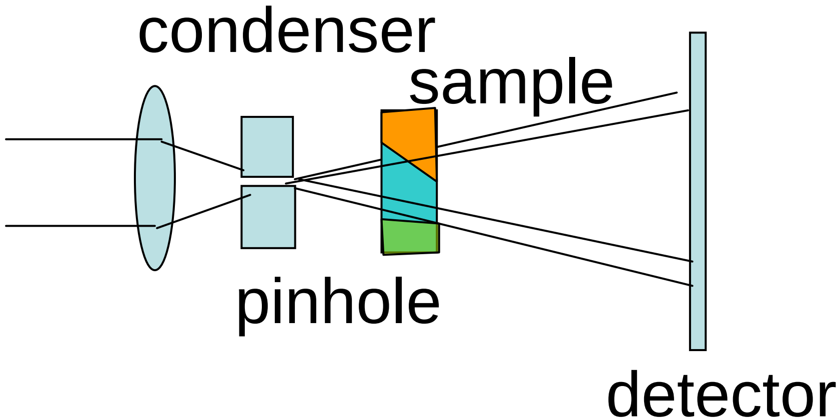




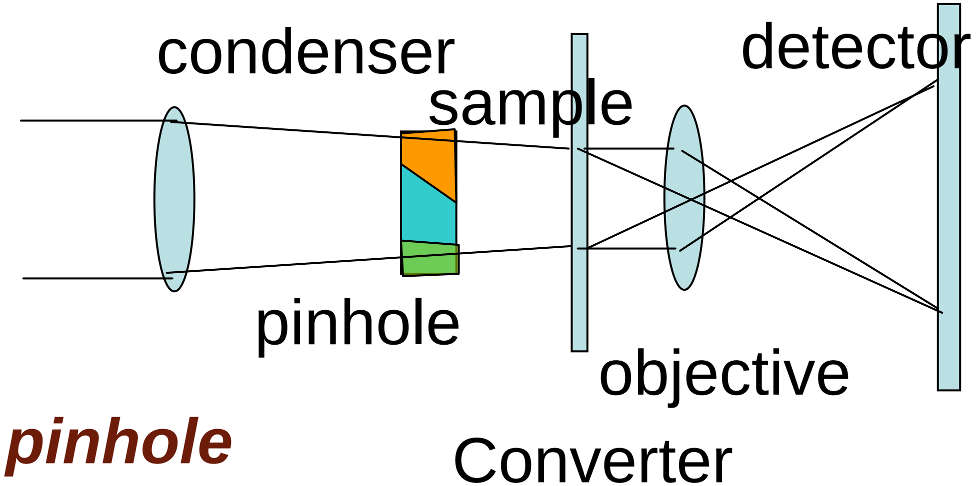
Two images defines source point- detector is the key!

Two approaches

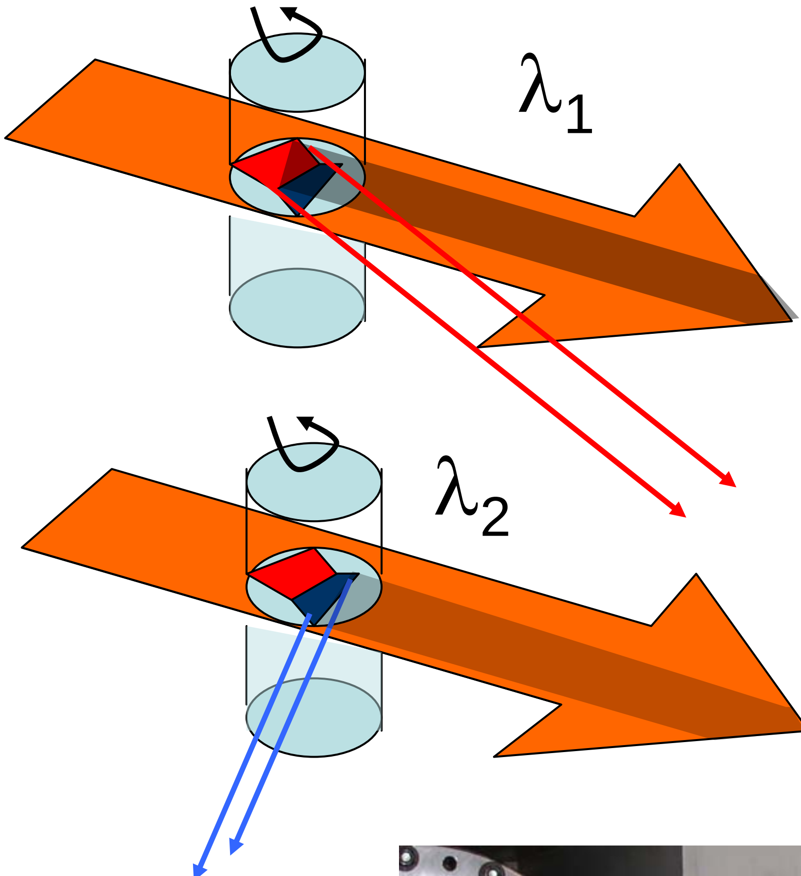
- Projection imaging
  - Simpler optics
  - Collimation a problem

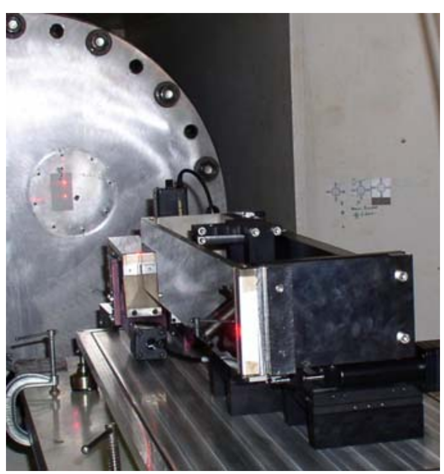


- Magnified imaging
  - Already in use
  - Needs timing!



Can possibly use multiple pinhole methods to increase signal!





Neutrons very precious, not a single one to spare

But ask the average person- they really couldnÕt care

Imaging essential- with crystallography

We visualize distorted grains-see what we need to see

CHORUS

Neutron optics- they increase the density

In a volume -resolved three dimensionally

Resolve Šdefine- identify- the way that crystals grow

To guide and investigate- how much theorists know.

Scanning probes essential-they focus on one grain

But Imaging much faster- with major temporal gains

Combining many wavelengths - rotate the sample too

Will let us see inside samples-give science a new clue

CHORUS

New neutron detectors can change what we can do

Imaging position- with neutron wavelength too

And with this new development Š it clear as you can se

Imaging contrast -through crystallography