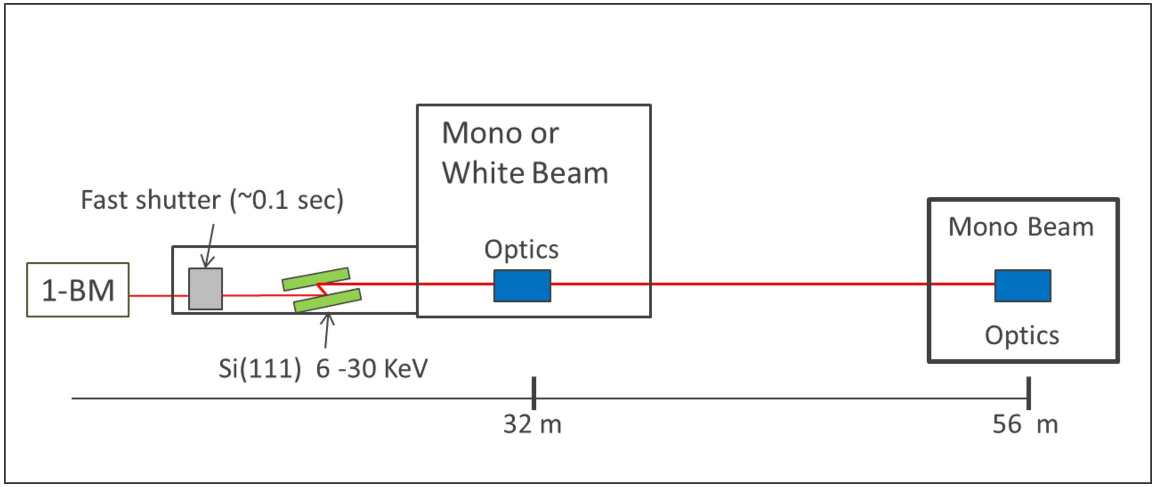
Optics Testing at 1-BM at the APS

Albert Macrander

APS

3-Way Optics Workshop, July 31, 2013

Optics and Detector Testing Beamline: 1-BM



- Strongly recommended in Sept. 2011 DoE review of APS.
- Frequent, brief access on a stable setup needed for developmental efforts: this is difficult to achieve on most other beamlines, which require science-based general user proposals that are often scheduled in one time period over four months.
- Crystal optics testing: topography- both monochromatic and white beam - for APS crystal optics development **and for user community (including industrial users) presently based at NSLS .**
- **IXS analyzer testing: polarization selection, spherical backscattering**
- **Mirror testing:** K-Bs, adaptive.
- At wavelength metrology for all x-ray optics: measurement of surface figures and coherence lengths.
- Zone plate testing: FZPs, MLLs

(Detector testing agenda covered in 3-Way Detector Workshop)

Acknowledgements

Optics Group:

Naresh Kujala
Shashidhara Marathe
Xianrong Huang
Bing Shi
Lashen Assoufid

Optics Mounting:

Deming Shu

IXS polarization selection analyzers:

Clem Burns (Western Michigan)
Joe Pacold (Western Michigan)

IXS analyzers:

Jerry Seidler (Univ. Washington)
Xuan Gao(Univ. Washington)

IXS analyzers:

Ayman Said
Thomas Gog
Diego Casa

Topography users/collaborators:

John Ciraldo (Rubicon Tech.)
Michael Dudley & group(Stonybrook Univ.)
Stan Stoupin & Yuri Shvyd'ko

Grating fabrication for Talbot interferometry:

Derrick Mancini
Michael Wojcik

Adaptive Mirror Tests:

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Richard Egan (Northrop Grumman)
Kevin Ezzo (Northrop Grumman)
Ali Khounsary

Beamline controls:

Kurt Goetze
Joe Sullivan

Beamline reconfiguration:

Mark Erdmann
Scott Wesling
Dan Nocher

XSD:

Mark Beno
Jonathan Lang
Chris Jacobsen
Linda Young

Industrial User Liason:

Jyotsana Lal

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Spherical analyzers and monochromators for resonant inelastic hard X-ray scattering: a compilation of crystals and reflections

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Accepted 16 October 2012

Thomas Gog,* Diego M. Casa, Ayman H. Said, Mary H. Upton, Jungho Kim, Ivan Kuzmenko, XianRong Huang and Ruben Khachatryan†

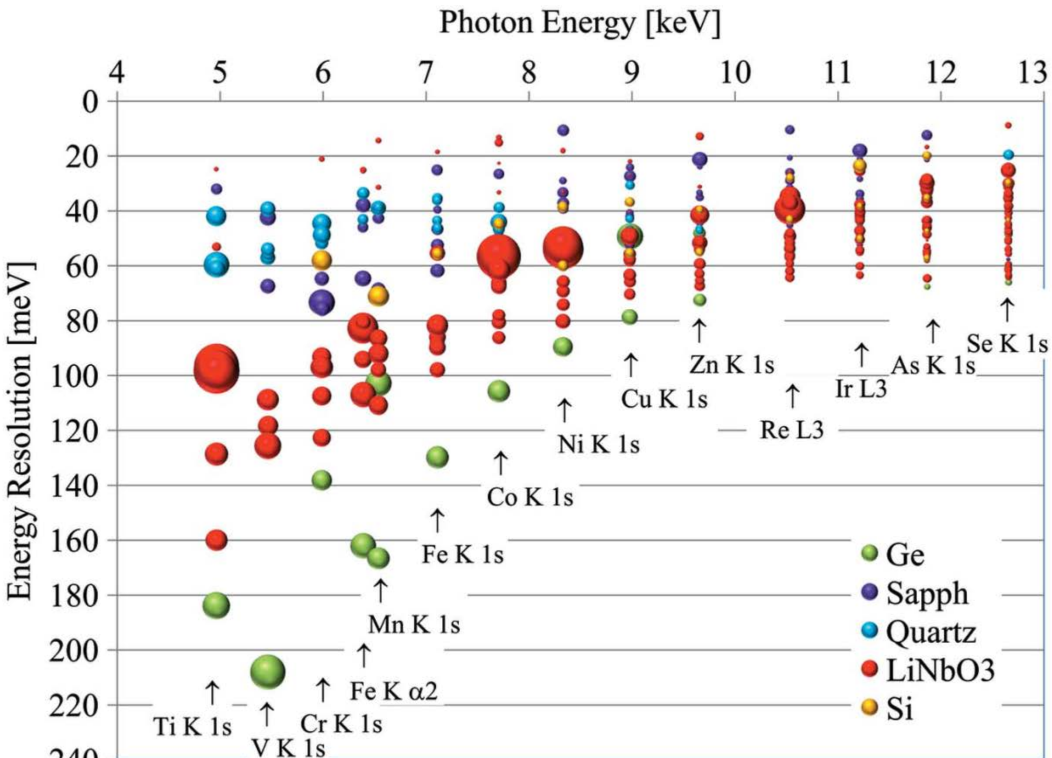
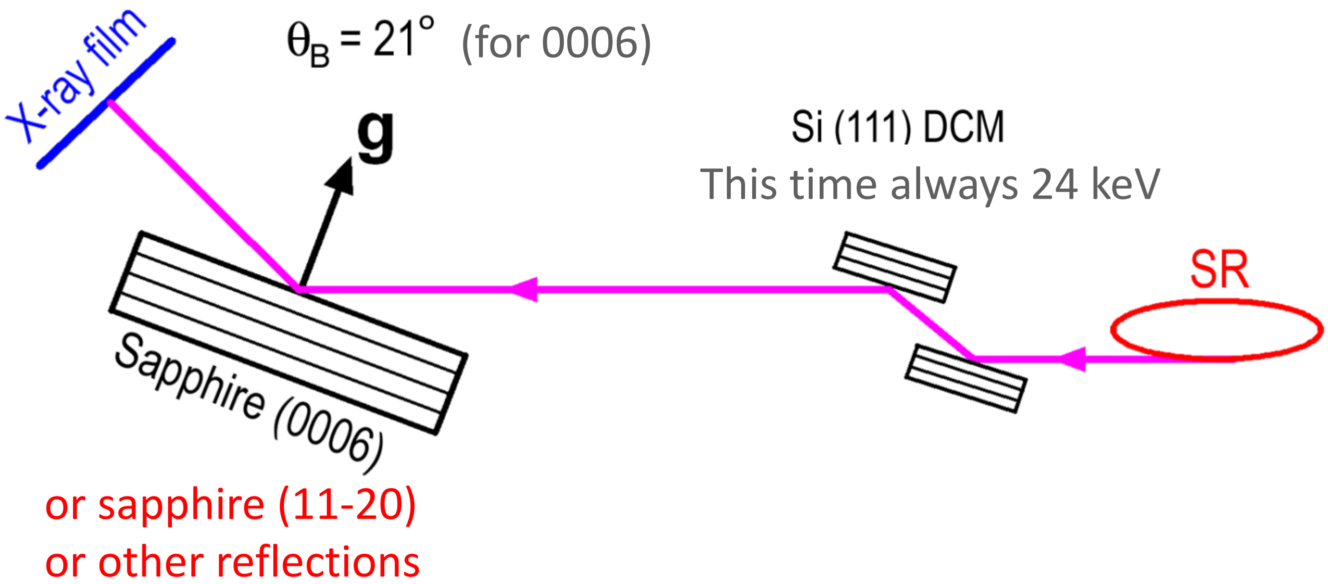


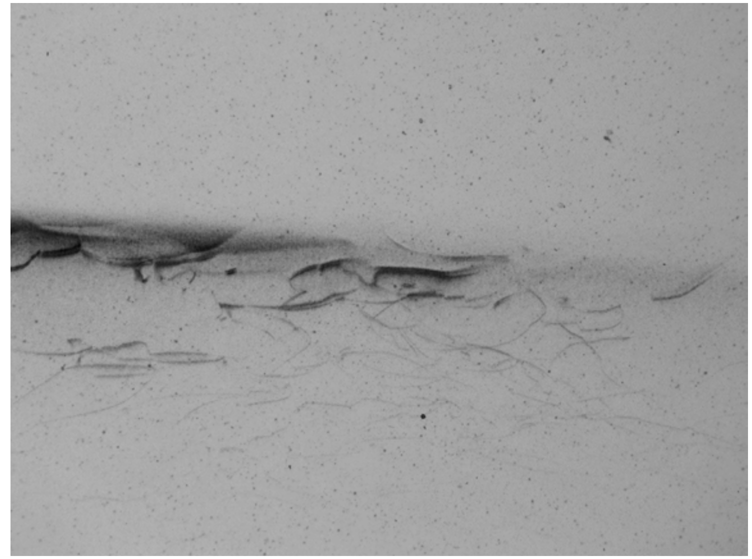
Figure 2
Partial map of the analyzer near-backscattering reflections. For the various relevant energies the intrinsic energy resolution is shown. The area of the markers is proportional to the integrated reflectivity.

Synchrotron monochromatic-beam topography of sapphire crystals
From Rubicon and from Ayman
APS/1-BM, April 08 2013

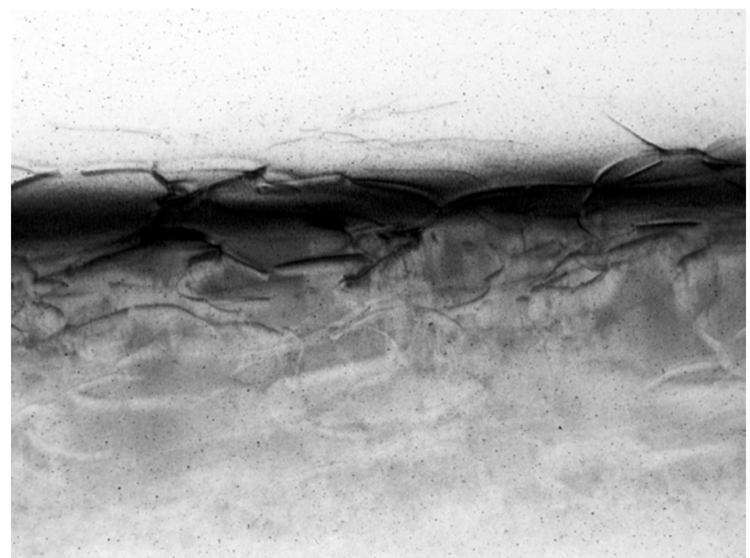


Diffraction geometry

Sapphire from
Rubicon Technology, Inc.
950 Douglas Road
Batavia, IL 60510



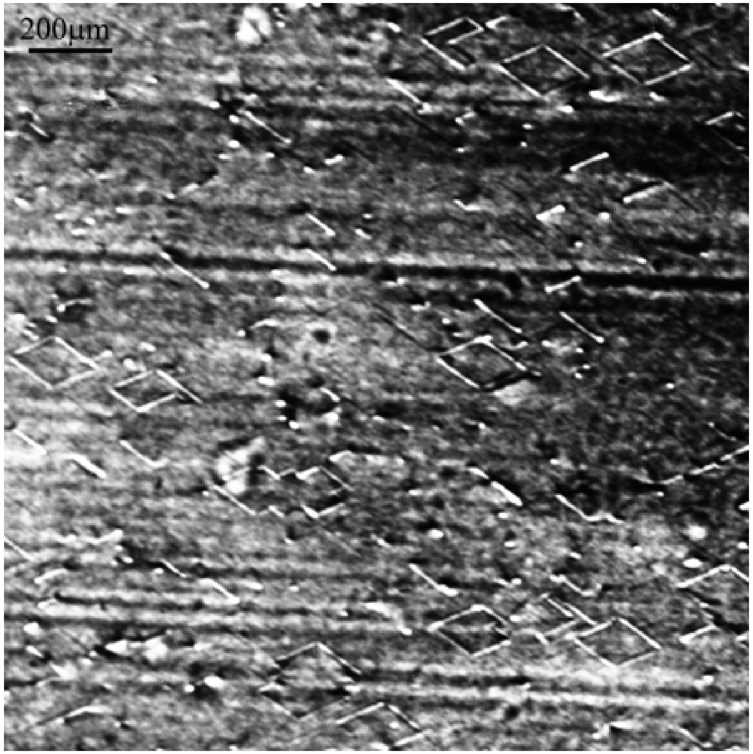
Sample #4 c-plane (2nd sample in the 6-sample box)
Also Very high quality only a few dislocations observed



Sample #4 c-plane (2nd sample in the 6-sample box)
Another topograph was taken on Sample #4, but this times more dislocations observed, indicating dislocation density not homogeneous in this wafer, but overall the quality seems high due to very narrow rocking curve.

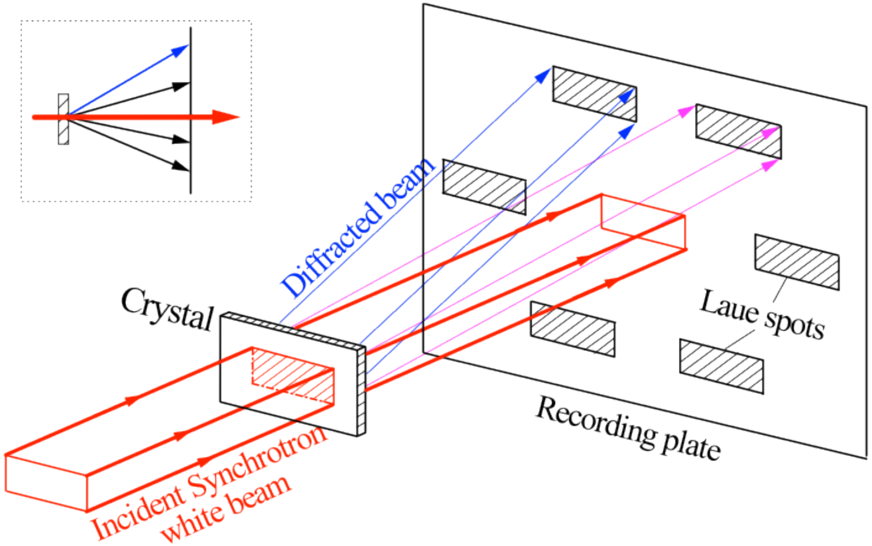
(Courtesy of Ayman Said)

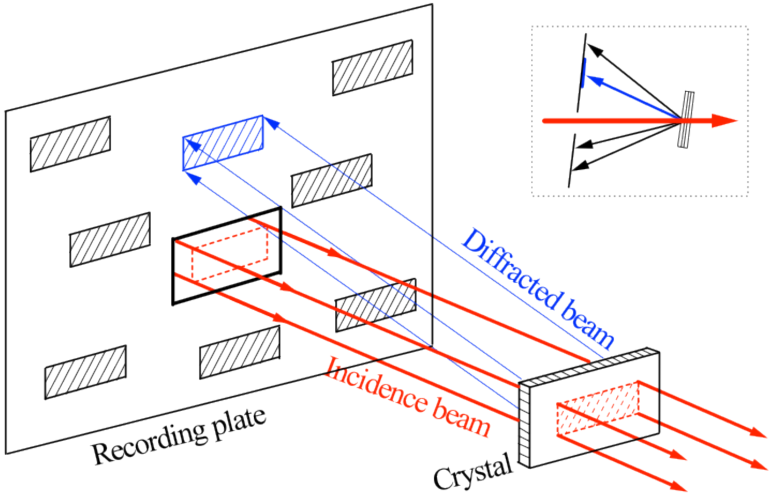
The Dudley group at Stonybrook has been active at NSLS at Brookhaven, which is slated to be shutdown



Mono-beam topograph of epitaxial silicon thin film for solar cell applications, showing network of mismatch dislocations, *by Dudley group (Stony Brook/NSLS) at 1-BM-C*

Synchrotron white-beam topography imaging of single crystals

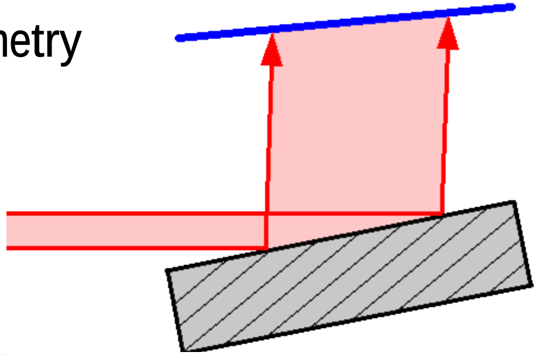




Transmission geometry
Only for thin crystals, < 0.5 mm thick

Back-reflection geometry

Small-incidence Bragg reflection geometry
For large-area imaging (several inches) without scanning

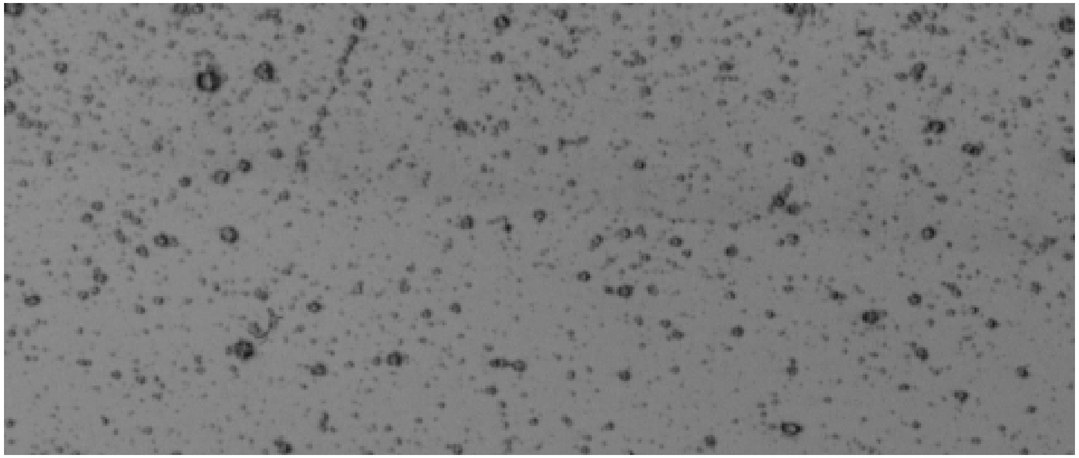


Active industrial user community at NSLS; needs a new home!

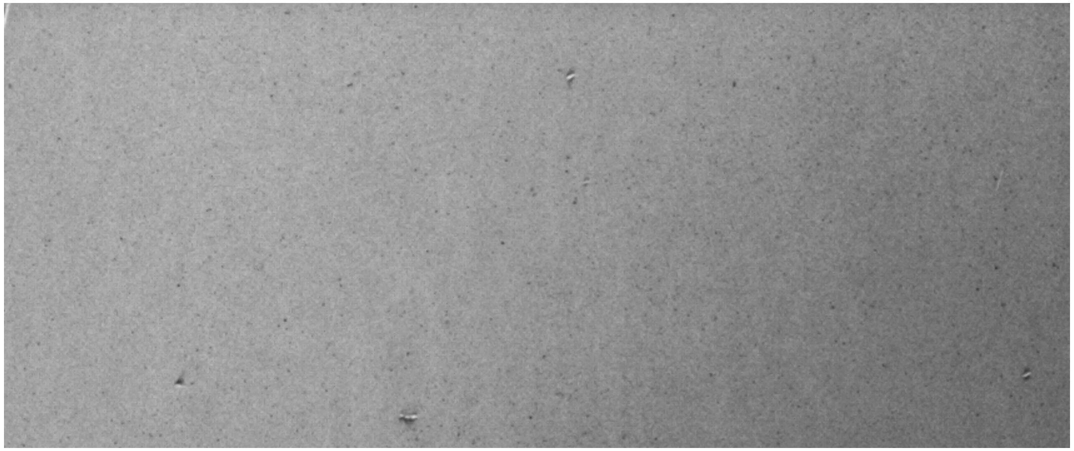
Topographic characterization of crystals

- Characterization of Si & Ge monochromators, analyzers, and various crystal-based optical components
- Characterization of newly fabricated monos, analyzers e.g. RIXS using quartz, $LiNbO_3$, sapphire.
- Diagnostic of crystal optics components used at beamlines
- Developing advanced fabrication & polishing techniques

Routinely required by the Crystal Optics Section of the Optics Group (which delivers ~300 crystals/year)



White-beam topograph showing strains and damages on a polished silicon surface with roughness ~ 1 Å. Manufactured by Crystal Scientific.



Topograph of crystal optic fabricated at APS

Courtesy of Xianrong Huang

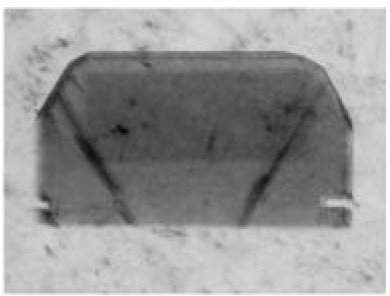
White-beam x-ray topography at 1BM: Diamond crystals

Stanislav Stoupin

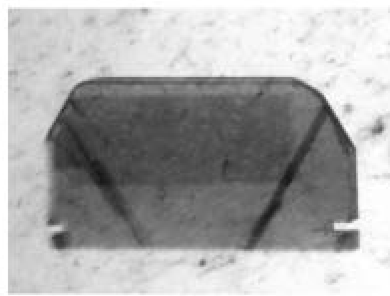
Advanced Photon Source, Argonne National Laboratory

April 2013

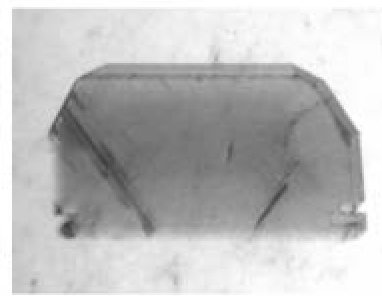
Diamonds from TISNCM in Russia .



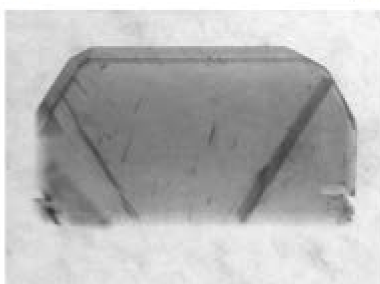
(a) $1\bar{1}1$



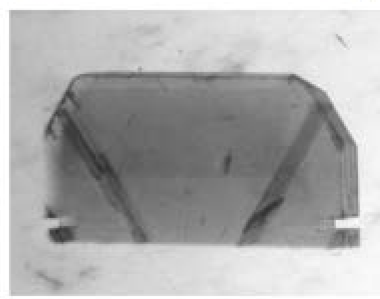
(b) $\bar{1}11$



(c) $\bar{2}24$

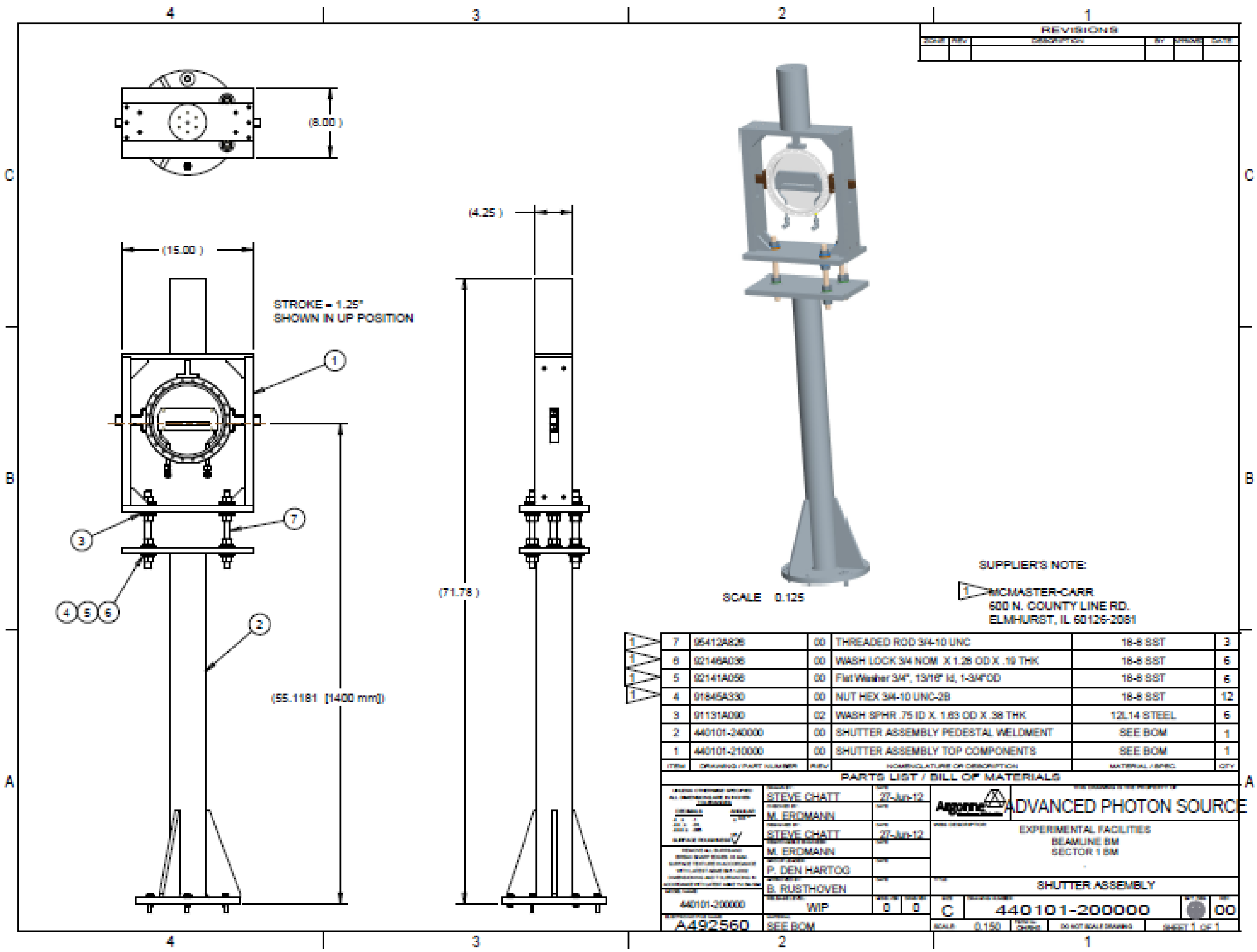


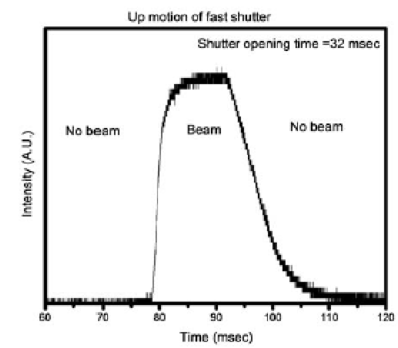
(d) $2\bar{2}4$



(e) $\bar{3}53$

“A fast white-beam shutter for hard x-ray topography at beamline 1-BM of the Advanced Photon Source”, Naresh Kujala, Mark Erdmann, Kurt Goetze, Joseph Sullivan, Xianrong Huang, and Albert Macrander, J. of Physics: Conference Series, SRI2013 , submitted.





32 msec demonstrated

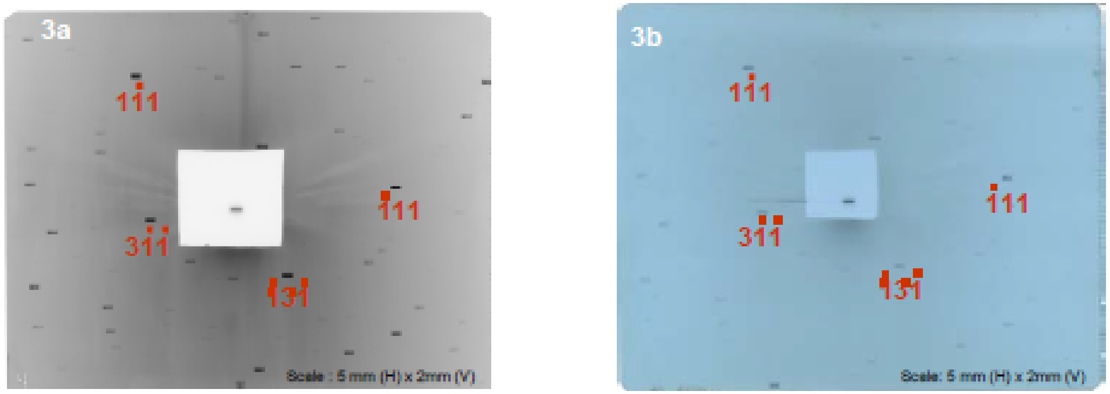


Figure 3: White-beam transmission Laue patterns of a (111) type IIa diamond crystal recorded on 8 inch x 11 inch X-ray film; each diffraction spot is a topograph of the crystal (see Fig. 4). 3a: Laue pattern taken with the personal safety shutter (PSS) with opening time of ~1 seconds, where many diffraction spots are too dark due to over exposure. 3b: Laue pattern taken with the white-beam fast shutter with opening time of 32 milli-seconds (accurately controllable from 30 milli-seconds to a few seconds).

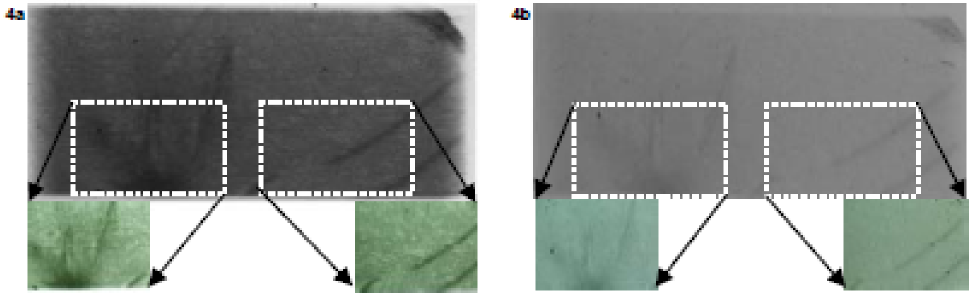
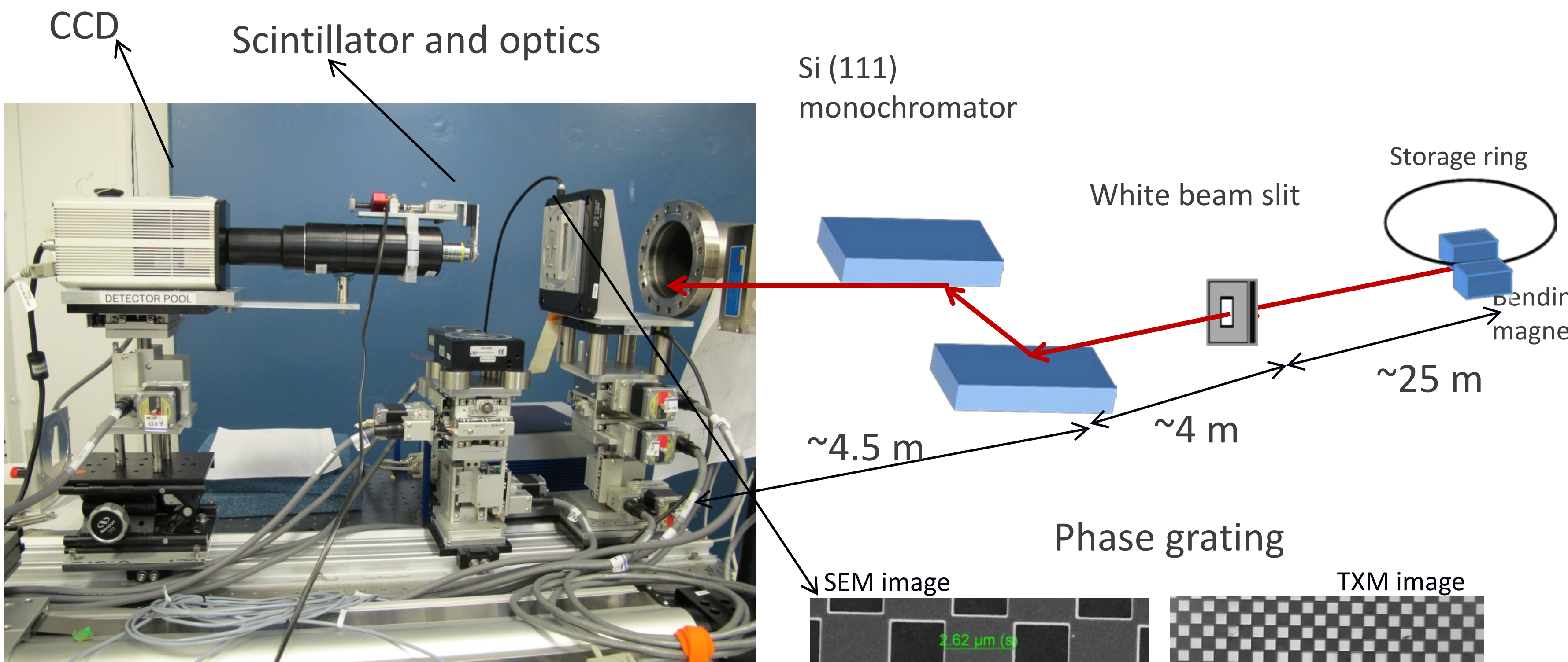


Figure 4: Topographs of the type IIa diamond crystal magnified from Fig. 3; 4a: $\bar{1}11$ reflection topograph taken with the PSS with opening time of ~1 second. 4b: $\bar{1}11$ reflection topograph with the fast shutter with opening time 32 milli-seconds, showing finer and weaker contrast features.

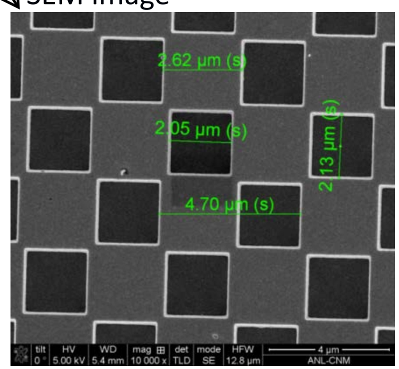
Optics and beam wavefront characterization at 1-BM



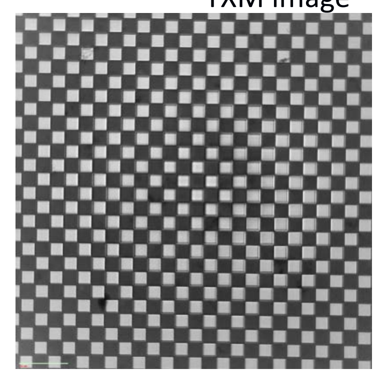
Schematic diagram of the single grating interferometry setup

Phase grating

SEM image



TXM image

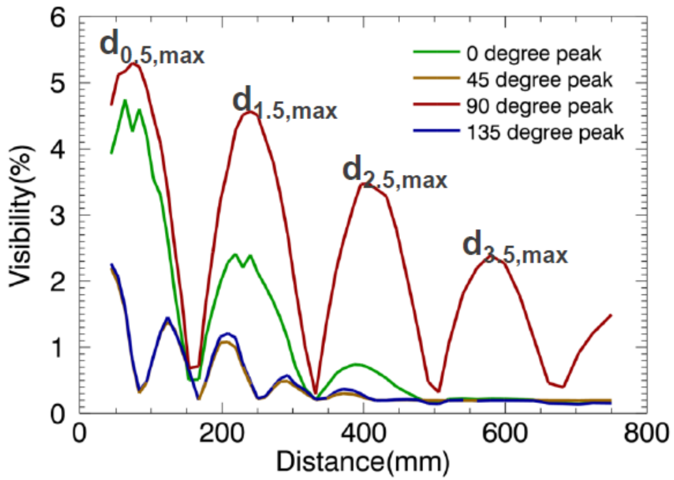


18 keV, π/2 phase grating fabricated by electroplating Au into a polymer mold with a 4.8-µm pitch on Silicon nitride membrane.

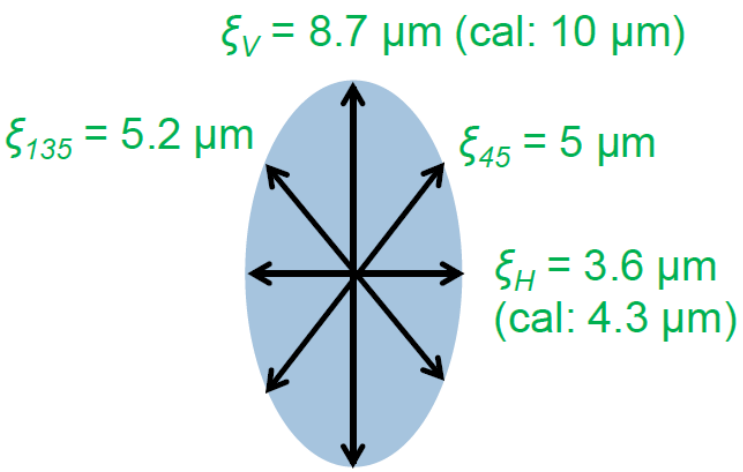
Courtesy of Shashidhara Marathe

Coherence length measurements with a 2-D grating at beamline 1-BM at the APS

- Measurement of the coherence of the Beam wavefront reflected from a Si(111) double crystal monochromator



Measured Coherence length(ξ)				
Peak	0 ° (H)	90 ° (V)	45	135
ξ(μm)	3.6	8.7	5	5.2



Coherence area of the wavefront as seen from down stream at the grating position

Shashidhara Marathe, Talbot Interferometry Workshop, Gaithersburg, MD, June 17, 2013.

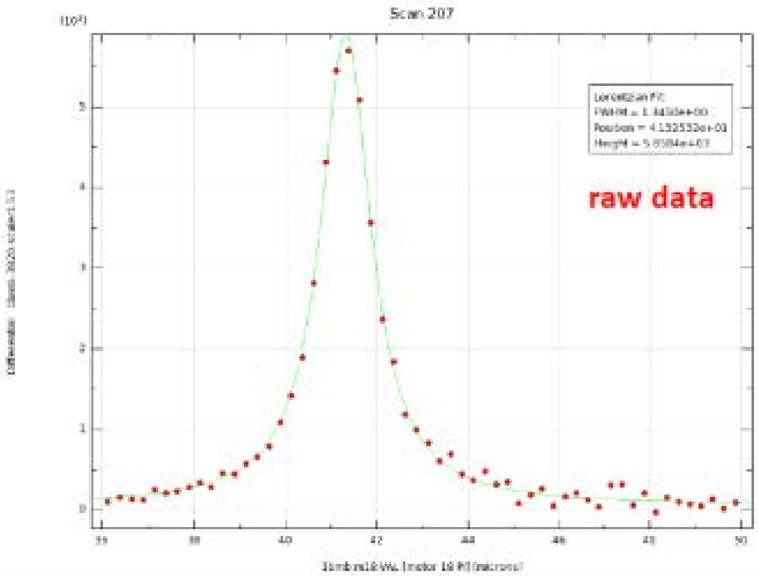
Test Results of a Prototype K-B Mirror Assembly for 8-BM

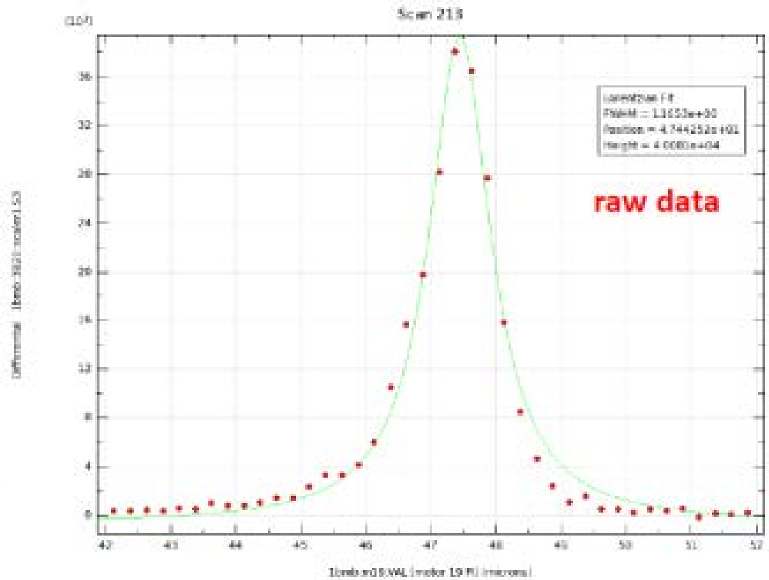
XSD/OPT Group , March 4, 2013

- Elliptical mirrors fabricated by profile coating
  - Spec. : 1 µm x 1 µm focus
  - Vertical focusing mirror (VFM): 70 mm, Horizontal focusing mirror (HFM): 60 mm
  - Substrates: Si, Coating material: Pt
- Mounting assembly design by D. Shu
- Tests carried out at 1-BM using 18 keV x-rays

- Demagnification of ~124
- Vertical source size =110 µm
- Geometrical focus ~ 0.89 µm
- Diffracted-limited size <200 nm

Measured 2-D focus size (raw data):
~1.2 µm (H) x 1.3 µm (V) (Spec. : 1 µm x 1 µm)



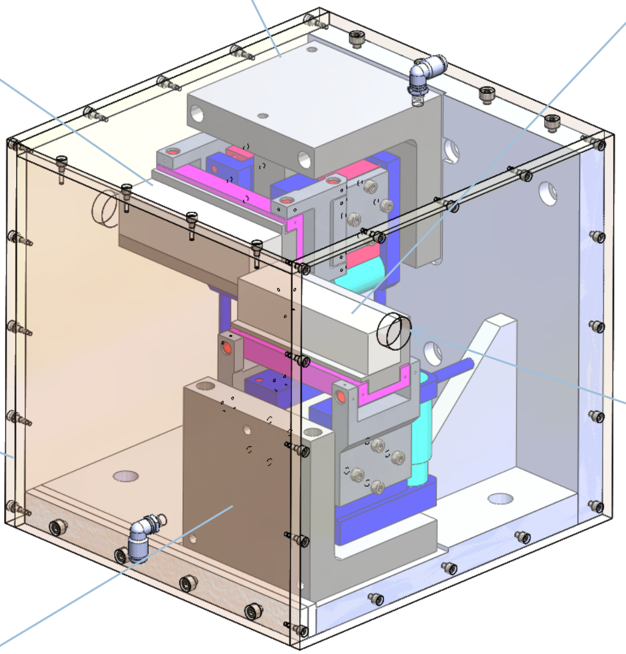


"Testing of elliptical Kirkpatrick-Baez mirrors focusing optics for hard X-rays at the beamline 1-BM of Advanced Photon Source", Naresh G Kujala, Shashidhara Marathe, Deming Shu, Bing Shi, Jun Qian, Lydia Finney, Chris Jacobsen, Albert T Macrander, and Lahsen Assoufid*, in preparation.

Optical parameters of the K-B mirrors

Parameters	Vertical focusing mirror (M1)	Horizontal focusing mirror (M2)
Mirror length	80 mm	60 mm
Focal length	250 mm	155 mm
Mirror angle	3 mrad	3 mrad
Fabrication	Deposition	Deposition
Surface coating	Pt	Pt
Demagnification (1-BM/8-BM)	136/214.6	220/349
Beam acceptance	240 µm	180 µm

Y9-64 K-B mirror mount for 1-BM test



Deming Shu

Shu, D., Harder, R., Almer, J., Kujala, N., Kearney, S., Anton, J., Liu, W., Lai, B., Maser, J., Finney, L., Shi, B., Qian, J., Marathe, S., Macrander, A., Tischler, J., Vogt, S., and Assoufid, L. (2013) *Proc SPIE*, in preparation.

1D parabolic x-ray mirrors fabricated at the APS for UHRIX project: performance tests at 1BM

S. Stoupin, Yu. Shvyd'ko, B. Shi, L. Assoufid, D. Shu, N. Kujala, S. Marathe, A. Macrander
Advanced Photon Source, Argonne National Laboratory, Illinois, USA

TABLE I: Mirror design and measured parameters: F^n - nominal focal distance, Δy^n - nominal vertical acceptance, $\Delta\theta^n$ - nominal angular acceptance, θ_0^n - nominal center angle of incidence, θ_0^m - optimal center angle of incidence (measured) and Δy^o - optimal focal spot size (measured as FWHM of the beam profile in vertical direction).

Mirror #	F^n (mm)	Δy^n (mm)	$\Delta\theta^n$ (mrad)	θ_0^n (mrad)	θ_0^o (mrad)	Δy^o FWHM (μm)	mirror function in UHRIX
1	1000	0.37	0.35	4.9	4.3	14.3	detector mirror

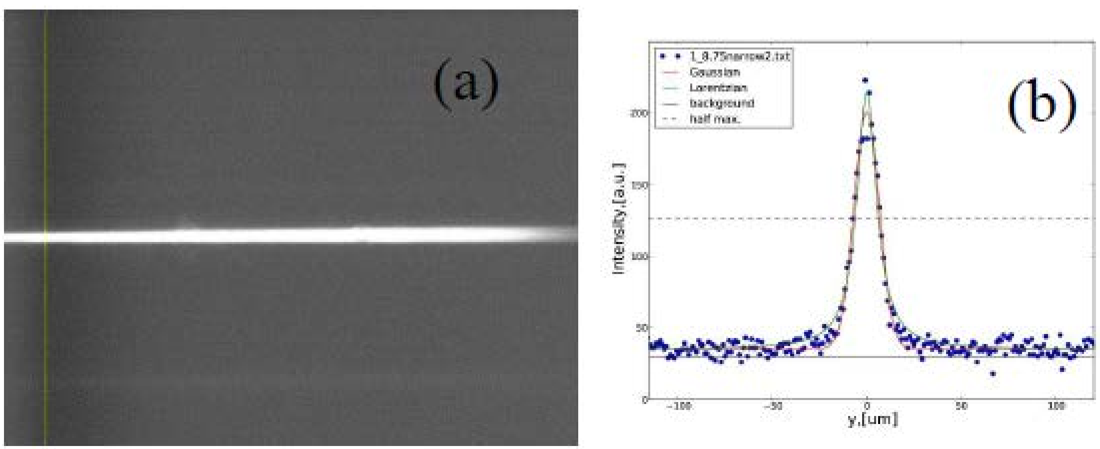


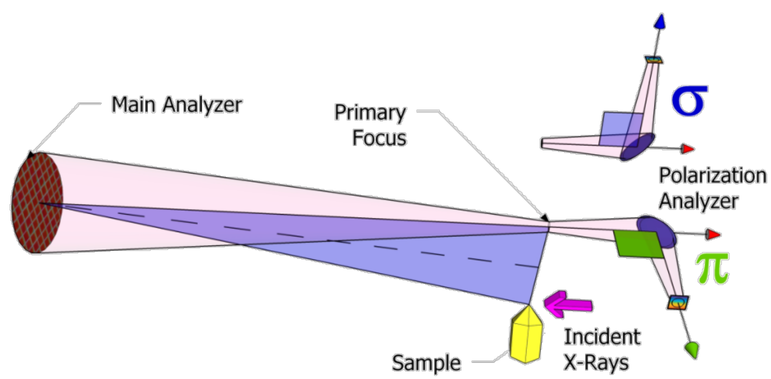
FIG. 2: (a) Focal plane image (at nominal focal distance F^n) for mirror # 1 set at the optimal angle of incidence $\theta_0^o = 4.3$ mrad. (b) Beam profile (14.3 μm FWHM) measured along the yellow vertical line in (a) fit with Gaussian (15.7 μm FWHM) and Lorentzian (12.7 μm FWHM) functions.

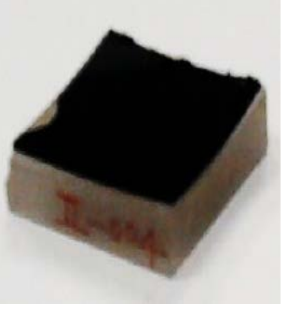
Polarization Analysis for Resonant Inelastic X-ray (RIXS) Scattering

Xuan Gao (WMU), Clem Burns (WMU), Diego Casa (APS), Naresh Kujala (APS), Al Macrander (APS)

Goal: Create an analyzer to measure polarization of the scattered x-ray in RIXS

- Make analyzer for iridates - Ir L3 edge
- Analyzer is toroidally bent high quality Si (4 4 4)
- Polarization analysis provides symmetry information about electronic excitations
- Allows studies of magnetic excitations
- Reduces elastic background

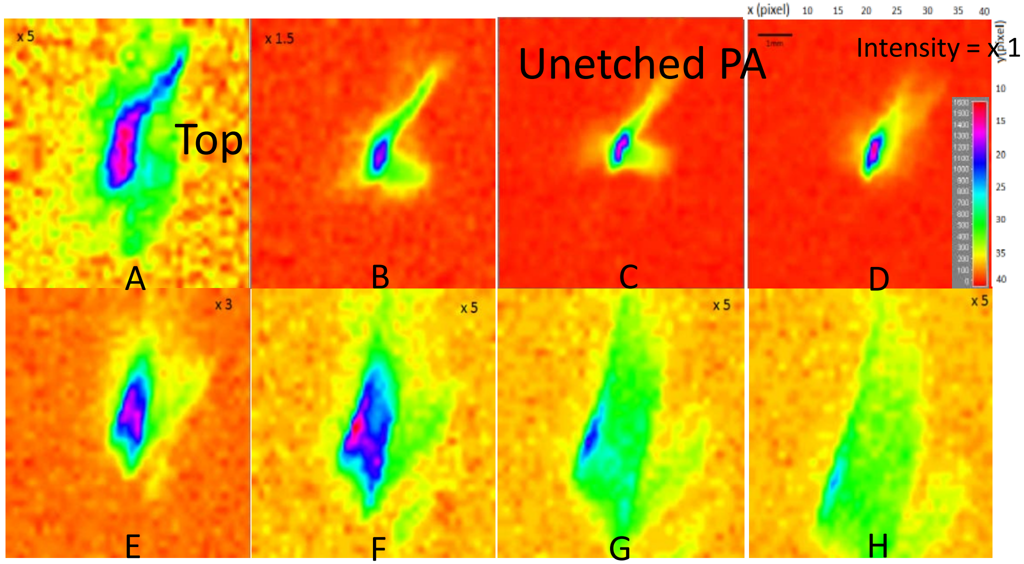




General Scheme – Scattered x-rays from sample are energy analyzed by the main analyzer and than polarization analyzed by the polarization analyzer to measure the two polarization components. Signal is then focused unto a strip detector.

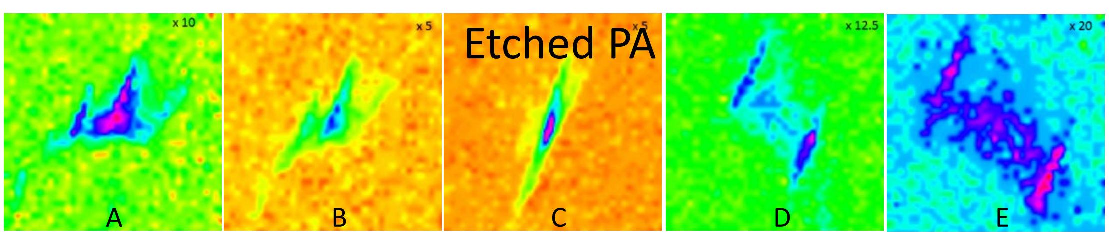
Characterization of Polarization Analyzer Focus at 1 BM

- Incident beam from Si mono hits plastic source creating spherical wave which impinges on the polarization analyzer
- Incident energy 11.215 keV (Ir L3 edge); Beam 1x1 mm^2; focus at 5 cm
- We study the reflected beam at several distances around the focus



Above - Unetched Si: Images on the detector at different distances. A=-5cm, B= -3cm, C=-2cm, D=0cm (focus), E=3cm, F=5cm, G=8cm, H=10cm

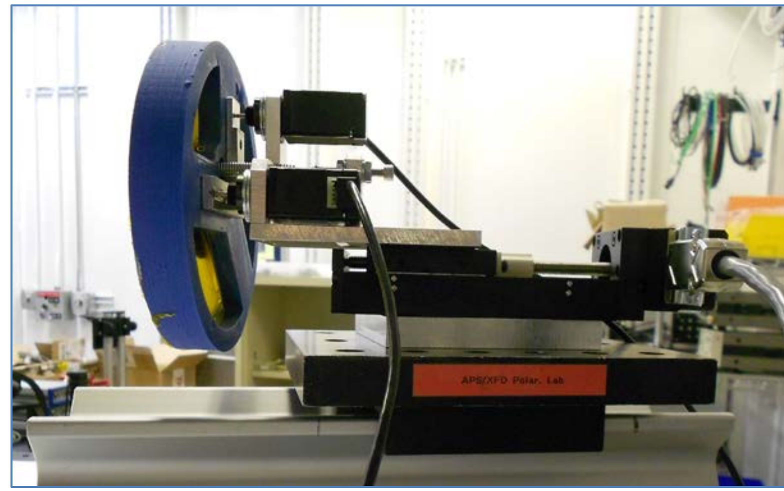
Below - Etched Si: Images on the detector at different distances. A=-3cm, B= -2cm, C=0 cm (focus), D=5cm, E=8cm



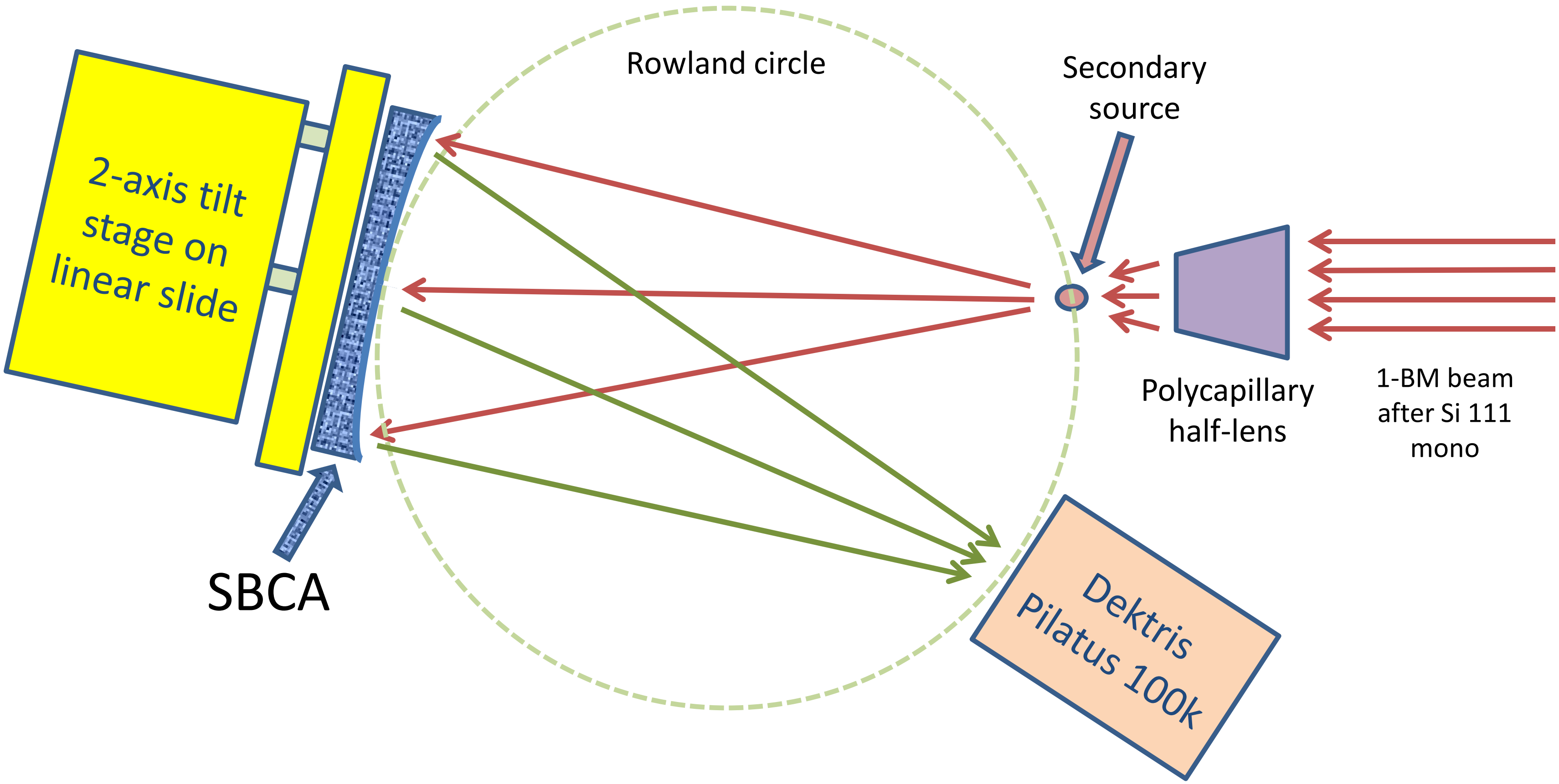
First test-run 7/2013 of SBCA characterization endstation at 1-BM

UW: Joe Pacold, Ramon Sharma, Nichole Barry, Marshall Styczinski, Jerry Seidler
APS: Naresh Kujala, Al Macrander

- Goal: establish versatile high-throughput test station for SBCA characterization, especially in support of large-scale fabrication efforts for multi-SBCA systems
- First results:
  - Easy tune-up using ‘table-cloth’ guides
  - Straightforward transitions between point-focusing and off-circle operation
  - Somewhat count-rate limited when using fluorescence from constrained (un-focused) beam on metal foil target
  - Useful characterization of errors in first-generation of UW-fabricated SBCA



Next Step: 2013-3 Optical layout for 1-BM high-throughput SBCA-testing platform



- A 6-mm diameter polycapillary half-lens will make a ~50-micron secondary source with **>10^{10} monochromatized photons/sec** diverging in a ~10 degree cone.
- Fast pre-alignment by translating the secondary source downstream, off-circle, to use a dispersive configuration. This will quickly establish chi and correct any gross errors in theta.
- **Goal**: high-throughput testing, 1 hour per SBCA to characterize energy resolution (point-to-point focus) and to map bend characteristics across the surface of the optic.

Optics and Detector test beamlines worldwide

This is a representative list, rather than a complete one

- Diamond Light Source, Oxfordshire, UK: bend B-16 "Test beamline" http://www.diamond.ac.uk/Home/Beamlines/B16.html
- ESRF, Grenoble, France: bend BM05 "Instrumentation Facility" http://www.esrf.eu/UsersAndScience/Experiments/Imaging/BM05
- Swiss Light Source, Villigen, Switzerland: bend X05DA "Optics Test Beamline" http://www.psi.ch/sls/optics/optics
- Petra III Extension, Hamburg, Germany: P21.5 "Education, Training and Testing End Station" http://petra3-extension.desy.de/e84814/e86697/
- BESSY II, Berlin, Germany: PTB-Laboratory with nine experimental stations including characterization of optical components http://www.ptb.de/mls/aufgaben/bessylab.html
- SSRL, Stanford, USA: bend 2-2 "White light station" http://www-ssrl.slac.stanford.edu/beamlines/bl2-2/
- ALS, Berkeley, USA: bend 5.3.1 "Instrumentation development" http://www-als.lbl.gov/index.php/beamlines/beamlines-directory/104-531.html
- NSLS, Upton, USA: bend U3C "Livermore metrology" http://beamlines.ps.bnl.gov/beamline.aspx?blid=U3C

Thank you for your attention