NEXT Optics Procurement Experience

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BROOKHAVEN NATIONAL LABORATORY
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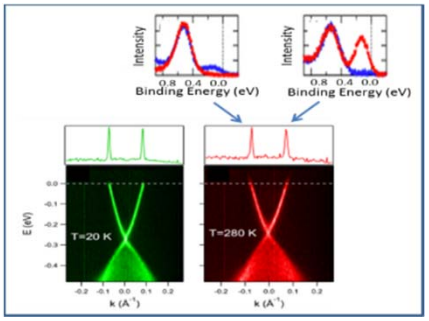
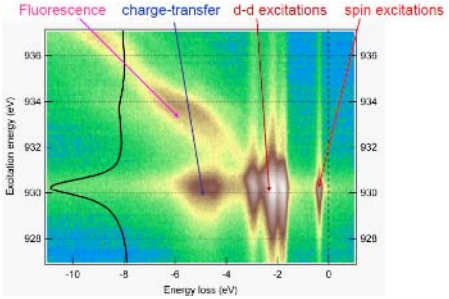
Outline

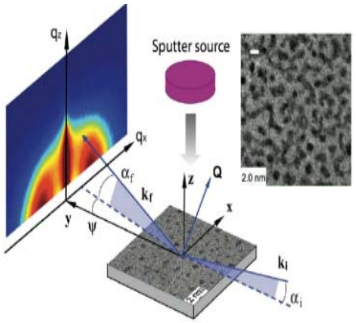
- NEXT Beamline Overview
- NEXT Beamline Optics Procurement Experience
  - ISS, ISR, ESM, SMI, SIX
- Summary of NEXT optics procurement experience
- Further Analysis

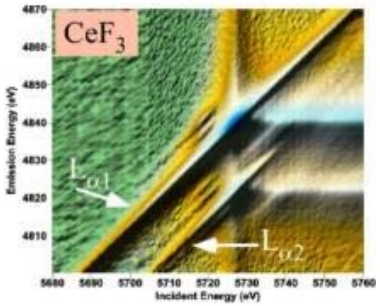
NSLS-II Experimental Tools (NEXT) Beamlines

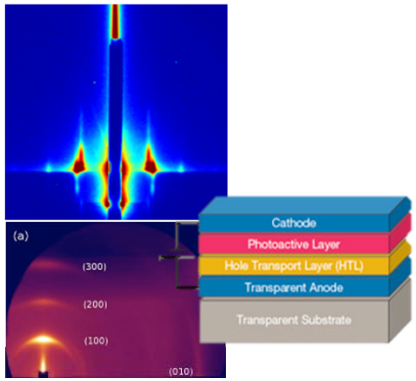
Beamline		Energy Range (keV)	Source
ISS	Inner Shell Spectroscopy	4.9–36	DW100
ISR	Integrated In-Situ & Resonant X-Ray Studies	2.4–23	IVU23
SMI	Soft Matter Interfaces	2.05–24	IVU23
ESM	Electron Spectro-Microscopy	0.015–1.5	EPU57, EPU105
SIX	Soft Inelastic X-ray Scattering	0.165–2.3	EPU57

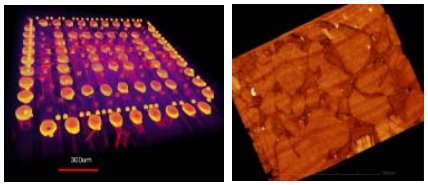












ISS Beamline Optics

Mirror Name	#	Figure	Dimensions (Optical Area)	Material, coating	Mirror orientation *	Specified figure error (RMS)	Delivery time after award (contract / actual)	Cost (direct)
High heat load mirror	1	Plane	1400 x 140 mm^2	Si, directly-cooled, with Rh, Si, & Pt stripes	0	≤ 1.5 µrad (tang.) ≤ 5 µrad (sag.)	14 mos. / 23 mos.	$175k
Vertical collimating Mirror	1	Tang. cylinder, with radius13.4 km	1400 x 120 mm^2	Si, indirectly-cooled (Ga bath), with Rh & Pt stripes	180	≤ 1.5 µrad (tang.) ≤ 3 µrad (sag.)	20 mos. / 17 mos.	part of $900k system
Toroidal focusing mirror	2	Toroidal: Tang. radius variable 4-50 km, optimized at 28 km Sag. Radius 91mm	1400 x 60 mm^2	Si, coatings: Rh (1), Pt (1)	0	≤ 3 µrad (tang.) ≤ 20 µrad (sag.)	18 mos. / 18 mos.	part of $640k system
Higher harmonic rejection mirror	3	Plane	500 x 70 mm^2	Si, coatings: Rh (1), Si (1), Pt (1)	180	≤ 3 µrad 3Å roughness	3 mos. / 3 mos.	part of $300k system

* 0 = upward, 90 & 270 = sideward, 180 = downward

Issues

- High heat load mirror: no issues other than delivery time
- Vertical collimating mirror: system delivery time shown in table; optic fabrication time was shorter
- Toroidal focusing mirror: one mirror delivered on time, 2nd was 4 months later
- Higher harmonic rejection mirror: no issues

Note: ISS has had considerable issues related to Si crystals, not described here

ISR Beamline Optics

Mirror Name	#	Figure	Dimensions (Optical Area)	Material, coating	Mirror orientation *	Specified figure error (RMS)	Delivery time after award (contract / actual)	Cost (direct)
HFM	1	Spherical, with radius range ~10-14 km	800 x 20 mm^2	Si, side-cooled, with Pd stripe	90	≤ 0.4 µrad slope error	19 mos. / 21 mos.	part of $2.2M system
VFM	1	Spherical, with radius range ~7-13 km	600 x 20 mm^2	Si, with Pd stripe	0	≤ 0.3 µrad slope error	19 mos. / 21 mos.	part of $2.2M system
DHRM	2	Plane	252 x 20 mm^2 474 x 20 mm^2	Si	90, 270	≤ 0.25 µrad slope error	16 mos. / 15 mos.	part of $1.2M system
KB	1	Pair of elliptical cylinders	300 x ~10 mm^2 (3 mm/stripe)	Si with Pt and Rh stripes	0, 90	≤ 0.3 µrad slope error	16 mos. / 19 mos.	part of $1.2M system

* 0 = upward, 90 & 270 = sideward, 180 = downward

Issues

- HFM actual figure error 0.6 µrad, with side-cooling water lines attached
  - Earlier problems with tangential radius range (bender-related) have been remedied
- VFM: no issues
- DHRM: no issues
- KB: no issues with mirrors; benders have issues with controls and stability

SMI Beamline Optics

Mirror Name	#	Figure	Dimensions (Optical Area)	Material, coating	Mirror orientation *	Specified figure error (RMS)	Delivery time after award (contract / actual)	Cost (direct)
HFM	1	Spherical with 16-element bimorph piezos for tang. figure correction; radius range 5.8 – 11.7 km, pre-polished to 7.4 km	500 x 30 mm^2	Si with Pt, Rh, Si, B4C stripes	90	≤ 0.8 µrad at 0V 3Å roughness	19 mos. / 19 mos.	part of $1.8M system
VFM	1	Spherical with 16-element bimorph piezos for tang. figure correction; radius range 2 – 9 km, pre-polished to 4.5 km	400 x 30 mm^2	Si with Pt, Rh, Si, B4C stripes	0	≤ 0.3 µrad at 0V 3Å roughness	19 mos. / 19 mos.	part of $1.8M system
Vertical Deflecting Mirror	1	Plane	400 x 30 mm^2	Si with Pt, Rh, Si, B4C stripes	180	≤ 0.3 µrad 3Å roughness	19 mos. / 19 mos.	part of $1.8M system

* 0 = upward, 90 & 270 = sideward, 180 = downward

Issues

- HFM: measured actual figure error at 0V was 0.5 µrad, but PV height error was 50nm vs. 15nm specified; figure met specification with bi-morph piezo correction
- VFM: measured actual figure error at 0V was 0.5 µrad, not meeting specification; figure met specification with bi-morph piezo correction
  - Mirror figure error at FAT did not meet specification and was rejected. Re-polished mirror figure met specification, and the 2 mos. of re-polishing fit within the optical component package delivery time (19 mos.)
- VDM: measured actual figure error was 0.1 µrad, easily meeting specification

ESM Beamline Optics

Mirror Name	#	Figure	Dimensions (Optical Area)	Material, coating	Mirror orientation *	Specified figure error (RMS)	Delivery time after award (contract / actual)	Cost (direct)
M1 Horiz. deflection mirror (BL)	1	Plane	535 x 16 mm^2	Si, directly-cooled, Au	90	≤ 0.25 µrad (tang.) ≤ 0.5 µrad (sag.)	13 mos. / 17 mos.	$93k
M2 Vert. deflecting mirror (BL)	1	Plane	515 x 22 mm^2	Si, directly-cooled, Au	0	≤ 0.25 µrad (tang.) ≤ 0.5 µrad (sag.)	13 mos. / 17 mos.	$90k
M3 Horiz. focusing mirror (BL)	2	Elliptical cylinder	600 x 15 mm^2	Si, Au	90, 270	≤ 0.5 µrad (tang.) ≤ 1.0 µrad (sag.)	7 mos. / 11 mos.	part of $900k system
M4 Refocusing mirror (BL)	1	Ellipsoid	600 x 15 mm^2	Si, Au	90	≤ 0.5 µrad (tang.) ≤ 5 µrad (sag.)	14 mos. / 30 mos.	part of $525k system
KB mirrors	2	Elliptical cylinder	335 x 15 mm^2 (h), 215 x 10 mm^2 (v)	Si, Au	270, 0	≤ (0.1, 0.5) µrad (tang./sag.) ≤ (0.2, 1.0) µrad (tang./sag.)	16 mos. / 16 mos.	part of $680k system
Grating substrates (Package 1)	2	Plane	180 x 30 mm^2	Si, Au	180	≤ 0.1 µrad (tang.) ≤ 0.5 µrad (sag.)	11 mos. / 11 mos.	$59k for 2
Grating substrates (Package 2)	6	Plane	155 x 30 mm^2	Si, Au	180	≤ 0.1 µrad (tang.) ≤ 0.5 µrad (sag.)	11 mos. / 11 mos.	$145k for 6

* 0 = upward, 90 & 270 = sideward, 180 = downward

Issues

- M1, M2, M3: no issues other than delivery time
- M4: measured figure : tang. (4.7 µrad), sag. (9.9 µrad) spec, did not meet spec
  - Replacement mirror meeting specifications is expected
- KB mirrors, Grating substrates: no issues

SIX Beamline Optics

Mirror Name	#	Figure	Dimensions (Optical Area)	Material, coating	Mirror orientation *	Specified figure error (RMS)	Delivery time after award (contract / actual)	Cost (direct)
M1 Horiz. deflection mirror (BL)	1	Plane	310 x 20 mm^2	Si, directly-cooled, Au	90	≤ 0.2 µrad	13 mos. / 17 mos.	$88k
M2 Vert. deflecting mirror (BL)	1	Plane	430 x 20 mm^2	Si, directly-cooled, Au	0	≤ 0.1 µrad	13 mos. / 17 mos.	$79k
M3 Horiz. focusing mirror (BL)	1	Elliptical cylinder	400 x 15 mm^2	Si, Au	90	≤ 0.5 µrad	7 mos. / 11 mos.	part of $750k system
M4 Refocusing mirror (BL)	1	Ellipsoid	250 x 6 mm^2	Si, Au	90	≤ 0.5 µrad (tang.) ≤ 1 µrad (sag.)	14 mos. / 30 mos.	part of $475k system
M5 Parabolic mirrors (S)	2	Parabolic	250 x 10 mm^2	Si, Au	90, 270	≤ 0.5 µrad (tang.) ≤ 2 µrad (sag.)	20 mos. / 25 mos.	$90k for 2
M6 Vertical focusing mirror (S)	1	Elliptical cylinder	300 x 40 mm^2	Si, Au	180	≤ 0.1 µrad	11 mos. / 11 mos.	$99k
M7 Vertical deflecting mirror (S)	1	Plane	525 x 40 mm^2	Si, Au	180	≤ 0.05 µrad (tang.) ≤ 0.2 µrad (sag.)	19 mos. / 20 mos.	$130k
Grating substrates (BL)	6	Plane	200 x 15 mm^2 200 x 25 mm^2	Si	180	≤ (0.05, 0.2) µrad (tang./sag.) ≤ (0.1, 0.4) µrad (tang./sag.)	11 mos. / 12 mos.	$68k for 2 $105k for 4
Grating substrates (S)	4	Plane	200 x 40 mm^2	Si	0	≤ (0.05, 0.2) µrad (tang./sag.) ≤ (0.1, 0.4) µrad (tang./sag.)	11 mos. / 11 mos.	$132k for 2 $44k for 2

* 0 = upward, 90 & 270 = sideward, 180 = downward

Issues

- M1: actual tangential figure error spec 0.27 µrad, accepted (negligible effect on BL performance)
- M2, M3, M5, M6, M7, and grating substrates: no issues
- M4: measured figure: tang. (0.49 µrad, met spec), sag. (~8 µrad, did not meet spec)
  - Replacement mirror meeting specifications is expected

Summary of NEXT Optics Procurement Experience

- Technical
  - Figure & finish specs met for uncooled flats, spheres, toroids, cylinders
    - Includes bi-morph mirrors (SMI) and flat grating substrates (ESM, SIX)
  - Figure spec nearly, but not quite, met for cooled mirrors
    - Impact on beamline performance is negligible; all cooled mirrors accepted
  - Figure spec not met for soft x-ray ellipsoids
    - Relatively small sagittal radius, making metrology & feedback difficult
    - Mitigating measures implemented (replacement)
  - Finish specs met
- Schedule
  - Good experience for flats, large-radius spheres, toroids, and cylinders, incl. elliptical cylinders (for KBs)
    - Average delivery times: 14.1 / 14.7 months (contract / actual)
  - Relatively poor experience for cooled mirrors and soft x-ray ellipsoids
    - Average delivery times: 14.1 / 21.5 months (contract / actual)

Further analysis

- Possible subjects of beamline procurement experience for further analysis
  - Mirror holders, benders
  - X-ray crystals, esp. directly cryo-cooled
  - Grating holders
  - Grating rulings
  - Lenses, e.g. CRLs
  - Optical component mechanical systems