Current Status of Optics R&D Lab. and Future Plan

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X-ray Optics R&D

X-ray Optics Development

X-ray Optics Lab.

- Improvement of beamline performance through improvement of PLS-II old optics
- Verification through measurement evaluation of new optical system
- Beamline application and technological improvement through self-development of X-ray mirrors

Optics Test Beamline

- Evaluation of existing optical system stability and performance improvement
- Beam characteristic evaluation and optical device verification
- Development of local production of optical devices and improvement of technology

Contribution to localization of X-ray optical elements and improvement of beamline performance through the development of core technologies related to X-ray optical systems
Long Trace Profiler
- 1D slope measurement
- Autocollimator or Laser meas. type
- Individual enclosure

3D Optical Profiler
- Roughness measurement

Deposition System
- Single and multilayer deposition
- Magnetron sputtering type
- 2 coating areas and 4 sputtering cathodes

Stitching Interferometer
- 2D height measurement
- Fizeau interferometer type
- RADSI method
- Individual enclosure

Cleanroom
(expansion in progress x2.5)
- Class 1000
- Temperature 23 ± 0.5°C
- Humidity 55 ± 5%
- Temperature monitoring system
FOV (=stage) ~ 1~2 m
Lateral resolution mm ~
Vertical resolution 0.1 μrad

Easy to measure slope of sub-μrad on large mirror by **NO reference**
Many kinds of LTPs are developing among SR facilities.
Stitching Interferometer

1. Test Mirror
2. Reference Flat

Measurement data 1
Measurement data 2
Corrected measurement data 2
Tilt angle correction by flat mirror
Height correction between two data

Repeat

① Measuring area
② Reference Flat
① Flat Mirror

Flat Mirror
Test Mirror
Reference Flat of Interferometer

Measurement data
Height correction
Tilt angle correction
Stitching Interferometer

- Sample mirror size
  - (max) X 100 mm, Y 100 mm, Z 1000 mm
- Fizeau interferometer type stitching interferometer

Measured by PAL

Measured by KBSI

Made by JTEC

0.86 μrad RMS
Stitching Interferometer & LTP

- Full Area

**Clear Aperture**

![Graph showing Surface Shape, Stitching Interferometer, and Long Trace Profiler.](graph.png)

- **Height (μm)**
- **Slope (μrad)**
- **Position (mm)**

- **Surface Shape**
- **Stitching Interferometer**
- **Long Trace Profiler**
Thin Film Deposition System

- Sample mirror size
  - (max) 100 mm, 100 mm, 1000 mm
- Single layer / multilayer coating
- Differential deposition
- Co-deposition

Coating area 1, Coating area 2

Main chamber, Load lock chamber

Substrate, Vertical slit, Horizontal slit, Shutter, Sputtering cathode, Speed control
Differential Deposition

**Convolution**

\[ (f * g)(t) = \int f(\tau)g(x - \tau)\,d\tau = h(x) \]

**Deconvolution**

Calculate time (velocity) distribution by deconvoluting of unit coating spot and target shape.
Differential Deposition Test – 100 mm

100 mm long arbitrary shape differential deposition test

- Shapes smaller than the unit coating spot size are error due to measurement -> LPF 286 m\(^{-1}\)
- Successful fabrication of shape precision below 0.24 nm rms in the 100 mm range
Differential Deposition Test – 400 mm

400 mm long arbitrary shape differential deposition test

- Shapes smaller than the unit coating spot size are error due to measurement -> LPF 196 m⁻¹
- Successful fabrication of shape precision below 0.22 nm rms in the 400 mm range
Flat Mirror Fabrication using Differential Deposition

- Sample mirror size: Length 800 mm, Width 50 mm, Thickness 50 mm
- Differential deposition (co-deposition)
- Roughness reduction using carbon doped platinum film

Flat Mirror Fabrication using Differential Deposition

1. Si substrate surface
   - ROC = 88.6 km
   - Surface error = 98.4 nm RMS

2. PtC-coated surface

3. Pt-coated surface using a 50 mm aperture
   - ROC = 17046 km
   - Surface error = 1.09 nm RMS

4. Pt-coated surface using a 5 mm aperture
   - ROC = 17046 km
   - Surface error = 1.09 nm RMS
Flat Mirror Fabrication using Differential Deposition

Surface shape measured by a stitching interferometer

Residual error of the manufactured flat mirror

1 nm RMS

0.12 μrad RMS
Future Plan

22nd International Advisory Committee Meeting (November 13-14, 2023)

Machining

Direct removal process
- EEM, ELID, IBF, ALE...

Coating process
- Differential Deposition, ALD...

Metrology

Stitching interferometry
- RADS, MSI...

Line profiler
- LTP, NOM...

Simulation

Geometrical & Wave-optical simulation
- SHADOW, SRW...

X-ray test
Metrology Instruments for X-ray Optics

Field of view (FOV) / lateral resolution / vertical resolution

10 μm / 0.1 nm / 0.1 nm
10 mm / 1 μm / 0.1 nm
0.1 m / 0.1 mm / 0.1 nm
1 m / 1 mm / 0.1 μrad

Scanning probe microscope
Scanning white light interferometer
Fizeau interferometer
Long trace profiler

Roughness
Roughness, figure
Figure
Slope
Topmost atoms on the workpiece will preferentially adhere to and move onto the surface of the powder particle.
Optics Test Beamline

- 11B SURF
  (Synchrotron Utilized Optics RnD Facility)
  - Beam port: 11B
  - Ring energy: 3 GeV
  - Ring current: 400 mA
  - Bend angle: 0.2618 rad
  - Bending radius: 6.875 m
  - Central field: 1.4557 T
  - Gap at the center: 34 mm
  - Size of beam fan: 14H x 0.17V mrad
Optics Test Beamline

- White beam
- Monochromatic beam using Si(111) DCM

Free Space for Optics Test ~18m
**Optics Test Beamline**

- **Beamline Specifications**
  - Light source: Bending magnet
  - Photon energy: 2 ~ 40 keV
  - Energy resolution: $\Delta E/E \sim 1 \times 10^{-4}$
  - Flux: $> 1 \times 10^{12}$ photon/sec
  - Main devices:
    - optics (mirror, monochromator)
    - beam diagnostic device
    - focusing optics
    - exp. system

- **Research Areas**
  - Evaluation of existing optical system stability and performance improvement
  - Performance verification and calibration of X-ray optical elements and optical devices
  - On- and off-line measurement evaluation through cooperation with the X-ray optics lab
  - Development of local production of optical devices and improvement of technology

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Talbot-grating interferometry


Speckle-based metrology


X-ray focusing optics test

Thank you for your kind attention