IAC 2023

Overview of 10 Priority Beamlines for 4GSR and Construction States

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Outline

1. Introduction
2. Present status for beamline construction
3. Future Plan
4. Summary
NanoARPES results on HOPG sample obtained with the ANTARES microscope

- **3GSR, DBA→4GSR, MBA**
  - Brighter
  - More coherent
  - Low emittance

- 4GSR
  - Coherent speckle
  - High-sensitivity image acquisition through phase-contrast X-ray imaging

- High coherence
- Low coherence

- Measurement of 3D lattice, element and strain

u-spot ARPES ~ 90 μm (multi-domain)
nano-spot ARPES ~ 100 nm (single-domain)
4GSR Outline

- **Multipurpose Synchrotron Radiation Construction Project**
  - Period: 2021 July to 2027 June (6yrs)
  - Budget: 1.0454 Trillion KRW (≈ USD 750M)
  - Land: 540,000 m² / Building: 69,400 m²
  - Location: Ochang, Chungcheongbuk-do

Specifications

- Beam Energy: 4 GeV
- Beam Emittance: less than 100 pm-rad (CDR: 58 pm-rad)
- Circumference: 800m
- Beamlines: more than 40
- Accelerator: Gun, Injector LINAC, 4 GeV Booster
- Lattice: MBA-7 Bend Achromat

Beamlines in Phase-I

1. BioPharma-BioSAXS
2. Material Structure Analysis
3. Soft X-ray Nano-probe
4. Nanoscale Angle-resolved Photoemission Spectroscopy
5. Coherent X-ray Diffraction
6. Coherent Small-angle X-ray Scattering
7. Real-time X-ray Absorption Fine Structure
8. Bio Nano crystallography
9. High Energy Microscopy
10. Nano-probe

Priority support for industries
Support for Academic R&D
<table>
<thead>
<tr>
<th>Beamline</th>
<th>Photon Energy</th>
<th>Resolution</th>
<th>Photon Source</th>
<th>Exp.</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>② Material Structure Analysis</td>
<td>5~40 keV</td>
<td>ΔE/E &lt; 10^{-4}</td>
<td>Undulator</td>
<td>① XRD</td>
<td>Material Science, Energy material</td>
</tr>
<tr>
<td>③ Soft X-ray Nano-probe</td>
<td>0.1~5.0 keV</td>
<td>sub-micro beam ΔE/E&gt;15x10^{-4}@1keV</td>
<td>EPU</td>
<td>① XAS</td>
<td>Semiconductor, Material Science</td>
</tr>
<tr>
<td>④ Nanoscale Angle-resolved Photoemission Spectroscopy</td>
<td>0.1~2 keV</td>
<td>100 nm &lt; ΔE/E &lt; 10^{-4}</td>
<td>Undulator</td>
<td>① Nano-ARPE S</td>
<td>Semiconductor, Material Science</td>
</tr>
<tr>
<td>⑤ Coherent X-ray Diffraction</td>
<td>3~30 keV</td>
<td>sub-micro beam</td>
<td>Undulator</td>
<td>① XRD</td>
<td>Semiconductor, Material Science, Geosciences, Chemistry</td>
</tr>
<tr>
<td>⑥ Coherent Small-angle X-ray Scattering</td>
<td>4~40 keV</td>
<td>~ a few nm ~ μm  ΔE/E &lt; 2x10^{-4}</td>
<td>IVU</td>
<td>① SAXS/WAXS (GI 기법 포함) ② XPCS</td>
<td>Material Science, Chemistry</td>
</tr>
<tr>
<td>⑦ Real-time X-ray Absorption Fine Structure</td>
<td>5~40 keV</td>
<td>~ a few μm</td>
<td>Undulator</td>
<td>① XAFS</td>
<td>Material Science, Environments, Geosciences, Chemistry</td>
</tr>
<tr>
<td>⑧ Bio Nano crystallography</td>
<td>5~20 keV</td>
<td>1 Å &lt;</td>
<td>IVU</td>
<td>① MX</td>
<td>Bio.</td>
</tr>
<tr>
<td>⑨ High Energy Microscopy</td>
<td>5 ~ 100 keV</td>
<td>Spatial R. ~ 0.1μm</td>
<td>Superbend</td>
<td>① Projection imaging</td>
<td>Material Science, Energy material, Bio</td>
</tr>
<tr>
<td>⑩ Nano-probe</td>
<td>5~25 keV</td>
<td><del>50nm NanoProbe 1</del>10 μm</td>
<td>MicroProbe</td>
<td>① Ptychography/XRF ② XRS</td>
<td>Semiconductor, Material Science, Geosciences, Chemistry, Environments</td>
</tr>
</tbody>
</table>
### 4GSR Storage Ring Specification

<table>
<thead>
<tr>
<th>Parameter</th>
<th>4GSR</th>
<th>PLS-II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam energy [GeV]</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Beam current [mA]</td>
<td>400</td>
<td>250 (Max. 400), Top-up mode</td>
</tr>
<tr>
<td></td>
<td>Top-up mode</td>
<td>Top-up mode</td>
</tr>
<tr>
<td>Circumference [m]</td>
<td>798.8</td>
<td>281.82</td>
</tr>
<tr>
<td>Lattice structure</td>
<td>Multi-Bend</td>
<td>Double-Bend</td>
</tr>
<tr>
<td>Super-period</td>
<td>28</td>
<td>12</td>
</tr>
<tr>
<td>Emittance [pmrad]</td>
<td>62</td>
<td>5800</td>
</tr>
<tr>
<td>RF frequency [MHz]</td>
<td>499.877</td>
<td>499.96</td>
</tr>
<tr>
<td>Bunch length [ps]</td>
<td>10.68 (without HC)</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>53.43 (with HC)</td>
<td></td>
</tr>
<tr>
<td>Number of Bunches</td>
<td>1065</td>
<td>300</td>
</tr>
<tr>
<td>Energy spread</td>
<td>0.12%</td>
<td>0.1 %</td>
</tr>
</tbody>
</table>
다목적방사광가속기구축사업단

Supercell Structure

- 28 supercell (12.85°/cell)

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

B port

 Shielding door

A port

[7 Bend Achromat : 4 LGBM, 2 DQM, 1 CENT]

- Steer
- Stabilize
- Store electrons racing

- Undulator (U)
- Quadruple Magnet (QM)
- Longitudinal Gradient Bending Magnet (LGBM)
- Center Bending Magnet (CENT)
- Dipole Quadrupole Magnet (DQM)
- Sextupole, Octopole, Correction Magnet

- Steer
- Stabilize
- Store electrons racing
**Typical Beamline Layout**

- **Photon Source**
  - Bending Magnet
  - Undulator
  - Wiggler

- **Mirror system**
  - FMM (22 m)
  - M1 (30 m)
  - DCM (34 m)
  - M2 (36 m)

- **Experimental hutch**
  - Slits
  - Sample (67.8 m)
  - KB Mirror (65 m)
  - 2nd Focusing system

- **Beam Position Monitor**

- **Different Monochromator Type**
  - Grating
  - Multilayer
  - Crystal

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22nd International Advisory Committee Meeting (November 13-14, 2023)
Deliver the required X-ray beam to the experiment:
- Energy and bandwidth
- Spot size
- Divergence/convergence

**Preserve source characteristics**; intensity, brightness, coherence...

- Handle the **heat load of the beam**
- Optimize signal / background
- Be very stable and reproducible, in position, intensity and energy
- Be safe to operate
- Be user friendly to operate
- Achieve all the above within a reasonable budget!
## Photon Sources

<table>
<thead>
<tr>
<th>Photon Source</th>
<th>Ty.</th>
<th>Periods length [mm]</th>
<th>Total Length [m]</th>
<th>Photon Energy(keV)</th>
<th>#</th>
<th>Applicable BL</th>
<th>Beam Port</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bending Magnet</td>
<td>BM</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>#09. HEMicroscopy</td>
<td>BM10</td>
</tr>
<tr>
<td>Out-vacuum Undulator</td>
<td>EPU</td>
<td>78</td>
<td>2</td>
<td>0.1 ~ 3.2</td>
<td>1</td>
<td>#03. Soft X-ray NanoProbe</td>
<td>ID26-1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>98</td>
<td>3.6</td>
<td>0.05 ~ 2</td>
<td>1</td>
<td>#04. NanoARPES</td>
<td>ID25</td>
</tr>
<tr>
<td>In-Vacuum Undulator</td>
<td>IVU</td>
<td>20</td>
<td>3</td>
<td>5 ~ 40</td>
<td>2</td>
<td>#06. CoSXAS</td>
<td>ID20</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>#08. BioNX</td>
<td>ID22</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td>3</td>
<td>3 ~ 40</td>
<td>5</td>
<td>#01. BioPharma.</td>
<td>ID21</td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>#02. Mat. Structure</td>
<td>ID24</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>#05. CoXRS(CDI)</td>
<td>ID19</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>#07. Realtime XAFS</td>
<td>ID23</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>#10. NanoProbe</td>
<td>ID10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5</td>
<td>2 ~ 7</td>
<td></td>
<td>1</td>
<td>#03. Soft X-ray NanoProbe</td>
<td>ID26-2</td>
</tr>
</tbody>
</table>
### Properties of Photon Source

<table>
<thead>
<tr>
<th>Undulator</th>
<th>(Unit.)</th>
<th>IVU20</th>
<th>IVU22</th>
<th>IVU24</th>
<th>EPU78</th>
<th>EPU98</th>
<th>BM</th>
<th>PLS-II (IVU20)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Period Length</td>
<td>[mm]</td>
<td>20</td>
<td>22</td>
<td>24</td>
<td>78</td>
<td>98</td>
<td>-</td>
<td>20</td>
</tr>
<tr>
<td>Periods</td>
<td></td>
<td>148</td>
<td>134</td>
<td>123</td>
<td>23</td>
<td>34</td>
<td>-</td>
<td>68</td>
</tr>
<tr>
<td>Device Length</td>
<td>[m]</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3.62</td>
<td>0.186</td>
<td>1.4</td>
</tr>
<tr>
<td>$K_{\text{max}}$ value</td>
<td></td>
<td>1.90481</td>
<td>2.3007</td>
<td>2.7458</td>
<td>$K_x$6.95</td>
<td>$K_c$4.39</td>
<td>$K_p$5.65</td>
<td>$K_x$9.24</td>
</tr>
<tr>
<td>$B_{\text{max}}$</td>
<td>[T]</td>
<td>1.02</td>
<td>1.12</td>
<td>1.22</td>
<td>$B_x$0.95</td>
<td>$B_c$0.60</td>
<td>$B_p$0.77</td>
<td>$B_x$1.01</td>
</tr>
<tr>
<td>Gap$_{\text{min}}$</td>
<td>[mm]</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>15</td>
<td>15</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>$\epsilon_{\text{1st}}$</td>
<td>[eV]</td>
<td>2699.6</td>
<td>1893.9</td>
<td>1327.3</td>
<td>77.48 / 97.28 / 114.84</td>
<td>35.48 / 46.41 / 40.96</td>
<td>$E_0$ 21280.8</td>
<td>1618.78</td>
</tr>
<tr>
<td>Total Power</td>
<td>[kW]</td>
<td>12.47</td>
<td>14.97</td>
<td>17.94</td>
<td>6.61 / 4.37 / 5.21</td>
<td>13.75 / 10.44 / 11.87</td>
<td>1357.83</td>
<td>2.91</td>
</tr>
<tr>
<td>Max.Power Density</td>
<td>[W/mrad$^2$]</td>
<td>164.1</td>
<td>164.1</td>
<td>165.5</td>
<td>24.31</td>
<td>38.06</td>
<td>Lin. Pow. Density (kW/mrad) 0.216</td>
<td>22.5</td>
</tr>
<tr>
<td>Max.central cone</td>
<td>[mrad]</td>
<td>$\Sigma_x$ 0.0093</td>
<td>$\Sigma_x$ 0.0109</td>
<td>$\Sigma_x$ 0.0129</td>
<td>$\Sigma_x$ 0.0854</td>
<td>$\Sigma_x$ 0.0956</td>
<td>$\Sigma_y$ 0.0341</td>
<td>$\Sigma_y$ 0.0171</td>
</tr>
</tbody>
</table>
Brilliance and Photon Flux

Brilliance vs Photon Energy

Photon Flux vs Photon Energy
### Beamline Goal

<table>
<thead>
<tr>
<th>구분</th>
<th>내용</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light Source</td>
<td>IVU22 (L=3.0 m)</td>
</tr>
<tr>
<td>Photon energy</td>
<td>5-20 keV (optimized at 8-25 keV)</td>
</tr>
<tr>
<td>Energy resolution</td>
<td>(\Delta E/E \sim 2 \times 10^{-4})</td>
</tr>
<tr>
<td>Beam size</td>
<td>&lt; 10 (\mu)m at the detector</td>
</tr>
<tr>
<td>Length scale</td>
<td>(\sim 3 - 4480) Å</td>
</tr>
<tr>
<td>Time resolution</td>
<td>(\sim 10) Hz</td>
</tr>
<tr>
<td>Beam flux</td>
<td>(10^{12} - 10^{13}) ph/s @ 16.02 keV</td>
</tr>
<tr>
<td>Sample to Detector Distance</td>
<td>0.5 ~ 6 m</td>
</tr>
<tr>
<td>Techniques</td>
<td>(Solution) SAXS/WAXS</td>
</tr>
</tbody>
</table>

### 3D structure of therapeutic biological molecules

- Overall structure of therapeutic molecules
- Overall status of biological molecule/drug complex
- Docking model of protein-protein complex

### End-station layout for high throughput Bio-SAXS technique

**Variable \(q\)-range vacuum chamber**

- Sample environment
  - Manual sample changer robot
    - ARINAX, BIO-SAXS
    - Minimum sample volume (5ul)
    - Standard 96 well plate
    - Static & flow mode
    - Temperature control (4°C - 60°C)
  - SEC-SAXS system
    - Agilent infinity 1260 system, RI, UV, MALS, & DLS
    - Separation and Analysis of polydisperse species or mixture

**Sample environment**

- Detector is placed in the vacuum chamber to facilitate SDD change

**Variable \(q\)-range vacuum chamber**

- Sample Exposure Unit (SEU)
- Sample Changer Unit (SCU)
- Control Software
- Control Electronics Rack
- Fluid Management Unit (FMU)

Example: 12 ID-B, APS
02. Material Structure Analysis

**Photon Source**

- IVU24 (L = 3.0 m)

**Photon energy (hv)**

- 5~40 keV
  - Main: 20 keV for HRPD

**Energy resolution (∆E/E)**

- ~ 1.3 x 10^{-4} (Si (111))
- ~ 2.7 x 10^{-5} (Si (311))

**Beam size (FWHM)**

- ~ 600 (h) x 230 (v) μm² @sample (69m for XAFS)
- ~ 670 (h) x 230 (v) μm² @sample (75m for HRPD)

**Beam flux**

- ~ 1 x 10^{13} ph/s @sample

**Techniques**

- XAFS: Step scan mode
- HRPD: Multi-analyzer detector system

---

**Experimental hutch**

- 2D-detector:
  - Movable
  - 5 axis motion: XYZ, yaw, pitch

- Gas auto-exchange system required

- * Fluorescence detector
- ** Hexapod sample stage

- Multi sample holder
- Sample stage to configure various experiments

---

**High-Resolution Powder Diffraction (HRPD)**

- Multi-Analyzer Crystals
- Sample (Rotation)
- 3-circle diffractometer

---

**X-ray Absorption Fine Structure (XAFS)**

- Slit
- I₀ chamber
- Sample
- I₁ chamber
- I₂ chamber

- I₂ detector

- Gas auto-exchange system required

- * Fluorescence detector
- ** Hexapod sample stage

- Multi sample holder
- Sample stage to configure various experiments

---

* Flight beam path and the stage for in-situ experiment (orange box) should be aligned together
**Nano-XPS/XAS for Branch 1**
- Scanning Photoemission Microscopy
- Dynamic beam size incl. zone-plate focusing
- Spatial resolving VB, core-level photoemission

**APXPS & HAXPS**

03. Soft X-ray Nano-probe

<table>
<thead>
<tr>
<th></th>
<th>EPU78(L=2 m)</th>
<th>IVU24(L=1.5 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$E_{1s}$</td>
<td>77.45 ~114.73 eV</td>
<td>1336.4 eV</td>
</tr>
<tr>
<td>Energy range</td>
<td>90 – 3,200 eV</td>
<td>2000 ~ 5000 eV</td>
</tr>
<tr>
<td>Beam size at Sample</td>
<td>70 nm × 140 nm</td>
<td>10.8 µm x 8.4 µm</td>
</tr>
<tr>
<td>Brillance</td>
<td>1.18 × 10^{19} at 15 mm gap</td>
<td>1.11925 × 10^{21} at 5 mm gap</td>
</tr>
</tbody>
</table>

**Tender XPS/XAS for Branch 2**
- Tender X-ray Photoemission Spectroscopy & XAS
- Non-destructive bulk property probe.
### 04. Nanoscale Angle-resolved Photoemission Spectroscopy (NanoARPES)

<table>
<thead>
<tr>
<th>Light Source</th>
<th>EPU98 (L=3.6 m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon energy (hv)</td>
<td>0.1 – 2 keV [Optimize: 50 ~200 eV]</td>
</tr>
<tr>
<td>Energy resolution (ΔE/E)</td>
<td>20,000</td>
</tr>
<tr>
<td>Beam size</td>
<td>100 x100 nm² by FZP</td>
</tr>
</tbody>
</table>
| Beam flux | • 10^{12} - 10^{13} ph/s @ 90eV ~ 2,000eV  
  • 10^{10} - 10^{12} ph/s @ 2,000eV ~ 3,200eV |

### End-stations

<table>
<thead>
<tr>
<th>nano-ARPES</th>
<th>µ-ARPES</th>
</tr>
</thead>
</table>
| - nano-focusing optics: Zone plate @ Capillary mirror  
- Hemisphere electron analyzer  
- Photon energy range: 100-200 eV  
- Energy Resolution: < 10 meV @ 100 eV  
- Photon flux: ~ 10^{11} ph/s with ZP @ 100 eV | - micro-focusing optics: K-B Mirrors or Capillary Mirror  
- Hemisphere electron analyzer with spin detectors  
- Photon energy range: 100 – 2000 eV  
- Energy Resolution: < 5 meV @ 100 eV  
- Photon flux: > 10^{12} ph/s @ 100 eV |

![Diagram of NanoARPES setup with various optical elements and beamlines](image_url)
<table>
<thead>
<tr>
<th><strong>Light Source</strong></th>
<th>IVU24 (L=3.0m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Photon energy</strong></td>
<td>3 – 30 keV</td>
</tr>
<tr>
<td><strong>Energy resolution (ΔE/E)</strong></td>
<td>&lt; 2 x 10^{-4}</td>
</tr>
<tr>
<td><strong>Beam size</strong></td>
<td>&lt; 500 nm ~ few micron at the sample</td>
</tr>
<tr>
<td><strong>Beam flux</strong></td>
<td>~10^{13} ph/s at the sample</td>
</tr>
<tr>
<td><strong>Techniques</strong></td>
<td>CDI, (time-resolved) Nanobeam X-ray Diffraction</td>
</tr>
<tr>
<td><strong>Experimental hutch instrument</strong></td>
<td>EH1) 6-circle diffractometer (Kappa)</td>
</tr>
<tr>
<td></td>
<td>EH2) CDI chamber, Flight path</td>
</tr>
<tr>
<td><strong>Detector</strong></td>
<td>Lambda 250k, Eiger2 X 1M, Eiger2 X 4M, 7-channel SDD</td>
</tr>
</tbody>
</table>

![Diagram of Coherent X-ray Diffraction (CXD)](image)

<i>IAC (Nov. 13-14, 2023)</i>
### 06. Coherent Small-angle X-ray Scattering

<table>
<thead>
<tr>
<th>Light Source</th>
<th>IVU20(L=3.0m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Brilliance: ~2x10^{15} phs/s/0.1%BW, Coherence fraction: 0.05x0.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Photon energy(hv)</th>
<th>4 – 40 keV → 7 – 30 keV</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Energy resolution(ΔE/E)</th>
<th>~ 1 x 10^{-4}(Si (111)) ~ 3x10^{-5}(Si(311))</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Beam size</th>
<th>&lt;10 μm @ 2Ddetector ( ~ 1 μm @ sample for μSAXS/WAXS )</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Beam flux</th>
<th>~10^{13} phs/s @ sample</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Techniques</th>
<th>μ(GI)SAXS/WAXS XPCS</th>
</tr>
</thead>
</table>

**End-station layout**

**Detector**

<table>
<thead>
<tr>
<th>Dimension</th>
<th>155.1 X 162.15 mm²</th>
<th>155.1 X 162.15 mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pixel size</td>
<td>75 X 75 μm²</td>
<td>75 X 75 μm²</td>
</tr>
<tr>
<td>Dynamic range</td>
<td>~ 10⁷ photons/pixel/s</td>
<td>~ 10⁷ photons/pixel/s</td>
</tr>
<tr>
<td>Readout rate</td>
<td>Up to 1120 Hz</td>
<td>Up to 1120 Hz</td>
</tr>
</tbody>
</table>

- X, Y, Z direction and Tilt around Y

**q-range & correlation time**

- Max. q : 2.5 Å⁻¹ at SDD=25cm
- Min. q : 0.001 Å⁻¹(471nm) at SDD=8m
- Horizontal detector movement for XPCS : 2θ = 0~30°
- Time scale: a few μsec ~ hundreds of second
- Coherence length @ sample : ~ 0.02 mm x 0.09 mm
07. Real-time X-ray Absorption Fine Structure

**Beamline Goal**

<table>
<thead>
<tr>
<th>Light Source</th>
<th>IVU24 (L=3.0m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon energy(hv)</td>
<td>4 – 40 keV</td>
</tr>
<tr>
<td>Energy resolution(ΔE/E)</td>
<td>~ 5 x 10⁻⁴ (Si (111))</td>
</tr>
<tr>
<td>Beam size (at sample, FWHM)</td>
<td>~ 30 x 10 μm² (focused)</td>
</tr>
<tr>
<td>Beam flux</td>
<td>~10¹³ phs/s @ sample</td>
</tr>
<tr>
<td>Time scale</td>
<td>Step scan ~ 20 min</td>
</tr>
<tr>
<td>Techniques</td>
<td>XAFS, Quick-XAFS, XES, HERFD-XANES</td>
</tr>
</tbody>
</table>
End-station layout

- Main experiment
Absorption spectroscopy: XAFS, QXAFS
Emission spectroscopy: XES, HERFD-XAS

- Design goal
Wide energy range: 4 ~ 40 keV
High photon flux: ~ 10^{14} ph s^{-1}
Small beam size: ~ 21 (H) x 7 (V) μm²

XES & HERFD-XAS

von Hamos spectrometer at SuperXAS beamline

- Multi-crystal von Hamos spectrometer
- 2D detector

→ Si(200), Si(200), Si(220)
Ge(111), Ge(200, Ge(220)

Equipment for In-situ measurement (examples)

- Optical table
- In situ XAFS & XES
- 2D detector
- In-situ XAFS & XES
- Grided gas ionization chamber
- Fluorescence detector
- Multi-sample holder & Hexapod stage

Feasibility tests

07. Real-time X-ray Absorption Fine Structure
## Beamline goals

<table>
<thead>
<tr>
<th>Light Source</th>
<th>IVU20(L=3.0m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photon energy (hv)</td>
<td>5 ~ 20 keV</td>
</tr>
<tr>
<td></td>
<td>[Optimize: 6.5 ~ 20 keV]</td>
</tr>
<tr>
<td>Energy resolution</td>
<td>$\sim 1 \times 10^{-4}(\text{Si (111)}$)</td>
</tr>
<tr>
<td>Beam size</td>
<td>$\sim 16 \text{ (h)} \times 4 \text{ (v)} \mu\text{m}^2$ at sample</td>
</tr>
<tr>
<td>Beam flux</td>
<td>$\sim 10^{13} \text{ to } 10^{14} \text{ phs/s @ sample}$</td>
</tr>
</tbody>
</table>

### Techniques

- Experimental Hutch: X-ray crystallography
- Wet Laboratory: crystallization facility

## Biomacromolecule crystal structure

- High resolution (~1 Å)
- Understanding life science at the molecular level
- Chemical drug design support
- Antibody Drug study support

## Structure-based drug design

- High-throughput structure analysis
- Identification Fragment Definition
- Accelerated Sculpture Design
- 500 data/day

---

### Beamline goals

- **Light Source**: IVU20(L=3.0m)
- **Photon energy (hv)**: $5 \sim 20$ keV [Optimize: $6.5 \sim 20$ keV]
- **Energy resolution ($\Delta E/E$)**: $\sim 1 \times 10^{-4}(\text{Si (111)}$
- **Beam size**: $\sim 16 \text{ (h)} \times 4 \text{ (v)} \mu\text{m}^2$ at sample
- **Beam flux**: $\sim 10^{13} \text{ to } 10^{14} \text{ phs/s @ sample}$

### Techniques

- Experimental Hutch: X-ray crystallography
- Wet Laboratory: crystallization facility

---

### Structure-based drug design

- High-throughput structure analysis
- Identification Fragment Definition
- Accelerated Sculpture Design
- 500 data/day
**Design goals**

- Imaging spatial resolution: a few μm (1 μm)
- Photon energy: 10-130 keV
- Beam size: 200 mm
- CT scan taking time: Minutes
- Phase contrast effect (Refraction detection limit): < 0.1 μrad
- Sample position: 100 m
- In-situ/operando sample space: a few m
- Max sample weight: 300 kg

**Multiscale Imaging**


**Experimental Equipment**

- **Experimental hutch design**
  - High aspect ratio X-ray microscope
  - Field of View: 200 x 25 mm², 1.3 x 1.3 mm²
  - Pixel size: 5 μm, 0.25 μm
  - Pixel number: 200 million, 25 million
  - Data size: 400 MByte/img, 50 MByte/img
  - 3D data size: 16 TByte/set, 1 TByte/set

- **In-situ/operando tester**
  - Dimension (LxWxH): 820 mm x 630 mm x 180 mm
  - Weight: 216 kg
  - Max. Capacity: 10 kN
  - Stroke Space: 1400 mm

Lang et al. (2023), e-Journal of Nondestructive Testing 28(3). Multiscale Phase-Contrast Tomography at BM18
Nano-Coherent imaging

- Energy: 5-25 keV
- Beam size: ~ 100 nm - ~ 50 nm
- Exp.: In-situ Coherent imaging
- Resolution: < 50 nm (XRF), < 5 nm (Imaging)
- Photon flux: $10^9 - 10^{11}$ phs/s @ Sample

Nano-Scanning microscopy

- Exp.: Ptychography, Nano-XRF, Multimodal imaging

**Design of endstation**

**Beamline Goal**

**Expected results**

Beaml ine Floor Plan  
(Oct. 30 2023) Present

ID08
ID09
ID10

ID10: #10 NanoProbe (150 m)
BM10: #09 HE Microscopy (100 m)

ID11,12,16: Harm. Cavity 2+2+2
ID13,14,15: RF cavity  2(2)+4+4

ID01: Injection

ID26: #03 Soft X-ray NanoProbe
ID25: #04 NanoARPES
ID24: #02 Material Structure
ID23: #07 RealtimeXAFS
ID22: #08 BioNX.
ID21: #01 BioPharma-BioSAXS
ID20: #06 CoSAXS
ID19: #05 CoXRD (CDI)

BM15: Diagnostic BL
BM01*: Diagnostic BL

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

- 09. HE Microscopy BL (L=100 m)
- 10. NanoProbe BL (L=150 m)

- Key point
- Vibration
- Radiation Safety
- Thermal stability

- Slab for Vibration Damping
  - 1 m Slab structure
  - Similar to Petra-III, ALBA, ESRF-EBS.

- Radiation Safety : PTL and Exp. Hutch Concrete
  - HE Microscopy : 5 ~ 100 keV
  - NanoProbe : 5 ~ 25 keV

- House in house hutch structure
Canted BL Available (for Phase-II)

- 1 mrad canted study for 4GSR
  ➔ Apply to design

Undulator Configuration

- 0.4 mrad canted
Two U33(L=2.4 m)

Example)
- APS 2-ID BEAMLINE, UPGRADE TO CANTED CONFIGURATION
- Corrector Dipole BPM


Considering Timing Structure (for Phase-II)

Normal Mode

Single Bunch

Hybrid camshaft mode

Hybrid mode with gated chopper
<table>
<thead>
<tr>
<th>Beamline</th>
<th>Photon Energy</th>
<th>Resolution</th>
<th>Photon Source</th>
<th>Exp.</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>① BioPharma-BioSAXS</td>
<td>5~25 keV</td>
<td>SAXS: 1 Å 이하, ΔE/E &lt; 10^{-4}</td>
<td>IVU24</td>
<td>①</td>
<td>Bio-SAXS</td>
</tr>
<tr>
<td>② Material Structure Analysis</td>
<td>5~40 keV</td>
<td>ΔE/E &lt; 10^{-4}</td>
<td>IVU24</td>
<td>①</td>
<td>HRPD, XRD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>②</td>
<td>XAFS</td>
</tr>
<tr>
<td>③ Soft X-ray Nano-probe</td>
<td>0.1~5.0 keV</td>
<td>sub-micro beam, ΔE/E &gt; 15×10^{-4} @1 keV</td>
<td>EPU78+IVU24</td>
<td>①</td>
<td>XAS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>②</td>
<td>XPS</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Semiconductor, Material Science</td>
</tr>
<tr>
<td>④ Nanoscale Angle-resolved Photoemission Spectroscopy</td>
<td>0.1~2 keV</td>
<td>Optimize: 50 ~200 eV, 100 nm &lt; ΔE/E &lt; 10^{-4}</td>
<td>EPU98</td>
<td>①</td>
<td>Nano-ARPES</td>
</tr>
<tr>
<td>⑤ Coherent X-ray Diffraction</td>
<td>3~30 keV</td>
<td>sub-micro beam</td>
<td>IVU24</td>
<td>①</td>
<td>XRD</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>②</td>
<td>CDI</td>
</tr>
<tr>
<td>⑥ Coherent Small-angle X-ray Scattering</td>
<td>4~40 keV</td>
<td>~ a few nm ~ µm, ΔE/E &lt; 2×10^{-4}</td>
<td>IVU20</td>
<td>①</td>
<td>SAXS/WAXS (GI 기법 포함)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>②</td>
<td>XPCS</td>
</tr>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>Material Science, Chemistry</td>
</tr>
<tr>
<td>⑦ Real-time X-ray Absorption Fine Structure</td>
<td>5~40 keV</td>
<td>~ a few µm</td>
<td>IVU24</td>
<td>①</td>
<td>XAFS</td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td>Material Science, Environments, Geosciences, Chemistry</td>
</tr>
<tr>
<td>⑧ Bio Nano crystallography</td>
<td>5~20 keV</td>
<td>1 Å &lt;</td>
<td>IVU20</td>
<td>①</td>
<td>MX</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bio.</td>
</tr>
<tr>
<td>⑨ High Energy Microscopy</td>
<td>5 ~ 100 keV</td>
<td>Spatial R. ~ 0.1µm</td>
<td>Centerbend</td>
<td>①</td>
<td>Projection imaging</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Material Science, Energy material, Bio</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>* Spatial Resolution : 0.1 µm→0.3-0.5 µm</td>
</tr>
<tr>
<td>⑩ Nano-probe</td>
<td>5~25 keV</td>
<td>~50nm</td>
<td>IVU24</td>
<td>①</td>
<td>Ptychography /XRF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Semiconductor, Material Science, Geosciences,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>* Tandem U., Two Branched Beamline</td>
</tr>
</tbody>
</table>

Support for industries
Priority support for industries
Support for Academic R&D
Summary
Goal: Prepare Another Successful Playground for Science

- Overview of beamline construction status.
- High Heat Load devices (PBPM, Mask, DCM) need study & developing.
- Human resources training and planning.
- Need to adapt and introduce for contemporary experimental method.
Thanks to:

All 4GSR  Project Supporting Division