High flux
nano-XRD beamline for Science
under extreme conditions

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Project Contributors:

Beamline conceptual design: K. Martel
Ray tracing simulations: J. Reyes Herrera and M. Sanchez del Rio
Heat load calculations: P. Brumund
Mirrors geometry and coatings: R. Barrett and C. Morawe
X-ray source definition: J. Chavanne

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and from external companies: Microplan, Cinel
Main objectives:

- Build a new high pressure X-ray diffraction, fluorescence and imaging beamline.
- Take full advantage of the EBS to address the challenges defined in the scientific case.
Materials at and beyond the current limits of static pressures and high temperatures

Double-stage diamond anvil cell

Pressure to 1000 GPa (10^7 bars)
Dubrovinsky et al., Nat. Comm., 2013

Solving the fluid H_2 to fluid H transition

High photon flux
Monochromatic → Pink beam
Fast melting, kinetics of chemical reactions at extreme conditions

Exploring extreme temperature states using laser heating

Converting ID27 into a nano-XRD/XRF beamline
New type of experiments: Tomography

Exploiting X-ray beam coherence

Providing XRI capabilities
basic principles:

- Reduce the number of optical elements to a minimum to improve the stability of the beamline and optimally exploit the intrinsic beam properties.

- Exploit the very low horizontal emittance of the EBS (No need for a secondary source)
  → Simplified optical configuration in “horizontal geometry”

Main elements:

- Water-cooled DMM
- LN2-cooled Si(111) DCM
- Three KB mirrors
-U18 cryo-undulator (CPMU18) placed in the middle of the ID27 straight section → minimum gap of 5mm (K-value=2.127).

-Best system in terms of photon flux and tunability.

-It will replace the two currently installed U23 in-vacuum undulators.
OPTICAL DESIGN – OH1 WHITE BEAM OPTICAL HUTCH

Re-used ID27/OH

- Photon Absorber & Shutter (existing)
- Pink Beam Viewer
- Pink Beam Attenuators
- Secondary slits
- DMM 31 meters from source
- White Beam Viewer
- HPPS
- Existing Granite Table (from existing mono)
- X-ray beam
Re-used ID27/EH1
Large thermo-stabilized experimental hutch (+/-0.1 K)

3 KB mirror systems for different beamspot sizes and energy domains

3 goniometers:
- Laser heating (YAG and CO2)
- Heavy duty (PE press, cryostat)
- Nano-goniometer

3 detectors
Eiger2/CdTe for XRD
PCO/CMOS for XRI
Vortex SSD for XES
hexapod with 6 piezo-actuators

YZ scanning with 20 nm precision
<table>
<thead>
<tr>
<th></th>
<th>KB#1</th>
<th>KB#2</th>
<th>KB#3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coating/Multilayer</td>
<td>Pt</td>
<td>W/B₄C</td>
<td>Ir/Al₂O₃</td>
</tr>
<tr>
<td>Energy range (keV)</td>
<td>15-25</td>
<td>33(fixed)</td>
<td>30-60</td>
</tr>
<tr>
<td>Total Transmission</td>
<td>60-70%</td>
<td>74%</td>
<td>64% (at 30 keV)</td>
</tr>
<tr>
<td>ΔE/E FWHM</td>
<td>&gt;10%</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>Length $L_h/L_v$ (mm)</td>
<td>200/200</td>
<td>170/170</td>
<td>300/300</td>
</tr>
<tr>
<td>Useful $M_h/M_v$ (mm)</td>
<td>180/180</td>
<td>140/140</td>
<td>250/250</td>
</tr>
<tr>
<td>$p_h(m)/q_h(m)$</td>
<td>110/0.30</td>
<td>110/0.50</td>
<td>110/1.2</td>
</tr>
<tr>
<td>$p_v(m)/q_v(m)$</td>
<td>110/0.55</td>
<td>110/0.70</td>
<td>110/0.80</td>
</tr>
<tr>
<td>Working distance from enclosure (mm)</td>
<td>200</td>
<td>450</td>
<td>550</td>
</tr>
<tr>
<td>Incidence angles at centre Maximum</td>
<td>$\theta_h = 2.48$ mrad</td>
<td>$\theta_v = 2.71$ mrad</td>
<td>$\theta_{cen} = 7$ mrad</td>
</tr>
<tr>
<td>Aperture H/V (mm)</td>
<td>0.47/0.5</td>
<td>1.0/1.0</td>
<td>1.8/1.8</td>
</tr>
<tr>
<td>Slope errors (mrad)</td>
<td>100</td>
<td>100</td>
<td>300</td>
</tr>
<tr>
<td>ideal spot HxV (nm)</td>
<td>210/190</td>
<td>380/340</td>
<td>1700x2000</td>
</tr>
<tr>
<td>Target spot size VxH (nm)</td>
<td>200x300</td>
<td>350x500</td>
<td>2000x2000</td>
</tr>
<tr>
<td>Metrology</td>
<td>Fixed</td>
<td>Fixed</td>
<td>Bending</td>
</tr>
</tbody>
</table>
### EXPECTED FLUX AT SAMPLE POSITION

<table>
<thead>
<tr>
<th>Energy [keV]</th>
<th>15 (KB1)</th>
<th>33 (KB2)</th>
<th>60 (KB3)</th>
<th>ID27 old storage ring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam spot size</td>
<td>0.22x0.28</td>
<td>0.47x0.34</td>
<td>2x2</td>
<td>2x3</td>
</tr>
<tr>
<td>Photons/s</td>
<td>$7.10^{12}$</td>
<td>$1.1.10^{13}$</td>
<td>$2.2.10^{12}$</td>
<td>$0.9.10^{11}$ (at 33 keV)</td>
</tr>
<tr>
<td>DCM</td>
<td>$5.0\times10^{14}$</td>
<td>$7.10^{14}$</td>
<td>$1.10^{14}$</td>
<td>NA</td>
</tr>
<tr>
<td>Photons/s</td>
<td>$\Delta E/E=1.5.10^{-4}$</td>
<td>$\Delta E/E=2%$</td>
<td>Pink beam</td>
<td></td>
</tr>
</tbody>
</table>

Gain x100 in monochromatic to x1000 in pink beam
Frame rate: 0.2 Hz  
Sensitivity <20 % at 30 keV  
dynamic range: 13 bits

Frame rate: 250 Hz  
Sensitivity >90 % at 30 keV  
dynamic range: 20 bits
Timetable of the project:

- Feb. 2020: Beginning of construction
- March 2021: Radiation test
- April: Beamline commissioning
- Mai-June 2021: User operation