Bending Magnet and 3-Pole Wiggler Frontend Design

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October, 2014
Outline

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- Frontend Overall Design Approach and Challenges
- Frontend Components Design
- Summary and Conclusion
**Introduction**

**Frontend serves the following purpose:**

- It transports the required synchrotron radiation from the source to the first optics enclosure.

- It protects the storage ring vacuum.

- It removes the undesired heat from the synchrotron beam.

- It collimates the Bremsstrahlung radiation to a safe level.
Sources for the NSLS-II BM port beamlines:

- **Source Type:** 3PW and BM
- **Nominal magnetic field at source location:** 3PW (1.2 T) & BM (0.40 T)
- **Usable photon energy range:** 1-31 keV
- **Maximum fan power (500mA current):** 3PW (250 W) & BM (69 W)
- **Maximum Power Density:** 3PW (365 W/mrad²) & BM (115 W/mrad²)
- **Beamline Horizontal Acceptance Fan:** 0.2-3 mrad
- **Beamline Vertical Acceptance Fan:** 0.15-0.6 mrad
Frontend Overall Design Approach & Challenges

**Challenges**

- Full passive protection to the frontend components.
- Geometric Envelope as opposed to Active Interlock Envelope for full passive protection.

**Design Approach**

- Ray tracing to locate and size the components.
- Multiple flange absorbers for the progressive trimming of synchrotron beam.
- Fixed mask and flange absorbers are double sided conflate flanges. (BNL Patent Pending)
- Glidcop AL-15 and Copper Chromium Zirconium as a flange material.
Frontend Ray Tracing

**Horizontal Synchrotron Ray Tracing**

[Diagram showing ray tracing for horizontal synchrotron]
Material Properties

- **Thermal Conductivity (RT):**
  - Glidcop Al25, Al15: 344 - 365 W/(m.K)
  - Cu-Cr-Zr: 314 - 335 W/(m.K)

- **Elastic Modulus:**
  - Glidcop Al15, Al25: 130 GPa
  - Cu-Cr-Zr: 123 GPa

- **0.2% Yield Strength, (RT, Cold Worked):**
  - Glidcop Al15, Al25: 470 - 580 MPa
  - Cu-Cr-Zr: 350 - 550 Mpa

- **Coefficient of Thermal Expansion:**
  - Glidcop Al15, Al25: 16.6 µm/K
  - Cu-Cr-Zr: 17.0 µm/K

Cu-Cr-Zr (C18150) is 1/4\(^{th}\) the price of Glidcop AL-15.

Cu-Cr-Zr is readily available in different forms and sizes from many suppliers.

Cu-Cr-Zr loses its strength rapidly if exposed to sustained temperatures > 500°C.

Glidcop is the choice if brazing is required.


(Tests on Cu-Cr-Zr Conflate Flanges and Flare Fitting Connections)

Fixed Mask / Flange Absorber Design

- Fixed mask defines the beam size and shadow collimator aperture.
- Fixed mask is water cooled and interlocked to the machine EPS.
- External fins are added to fixed mask to provide natural convection and equipment protection from loss of water flow.

Fixed Mask / Lead Collimator (BC1) Assembly
Fixed Mask Thermal Analysis

**Analysis Parameters**

- Distance from Source ~ 7.9m
- Total Power (3PW & BM) = 319 W
- Assumed heat transfer coefficient of 10 W/m².K for natural convection.
- Assumed film coefficient of 0.4 W/cm².°C for a flow rate of 1GPM in Ø0.375” cooling channel.

**Glidcop AL-15 Fixed Mask**

Temperature Contour Plot, Tmax ~ 87°C

**Cu-Cr-Zr Fixed Mask**

Temperature Contour Plot, Tmax ~ 93°C
**Fixed Mask Thermal Analysis (Natural Convection Only)**

**Analysis Parameters**

- Distance from Source ~ 7.9m
- Total Power (3PW & BM) = 319 W
- Assumed heat transfer coefficient of 10 W/m².K for natural convection.
- Typically the heat transfer coefficient value for natural convection ranges from 5-25 W/m².K

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**Glidcop AL-15 Fixed Mask**

Temperature Contour Plot, Tmax ~ 298°C

**Cu-Cr-Zr Fixed Mask**

Temperature Contour Plot, Tmax ~ 305°C
Beryllium Window Design

- Water cooled Be Window.
- Provide isolation to storage ring vacuum from beamline vacuum.
- Window thickness (250 µm).
- Window aperture (10mm x 92mm).
- Polished to RA < 100 nm RMS on both sides.
- Diffusion bonded assembly bakeable to 450°C.
- Capable of sustaining > 2.4 bar pressure differential.
Be Window Test Results

- Leak check before and after the diffusion bonding at room temperature.
- Leak check and pressure test was performed after repeated thermal cycling up to 150°C.
- Pressure test was performed to check the window strength.

**Prototype Be Window**

**Test Setup**

<table>
<thead>
<tr>
<th>NSLS-II NexGen Beamline Front-End Beryllium Window Leak and Pressure Tests</th>
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</thead>
<tbody>
<tr>
<td><strong>Be-Window Leak Check and Pressure Test</strong></td>
</tr>
<tr>
<td>(2 identical independent sets at both sides of Be)</td>
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</tbody>
</table>

#### Leak/P-test at Room Temp using helium

- pump side-1 to LV, feed He to side-2 (1.5 atm) | open / close | mTorr / 1.5 atm | < 2x10⁻¹⁰ |
- pump side-2 to LV, feed He to side-1 (1.5 atm) | close / open | 1.5 atm / mTorr | < 2x10⁻¹⁰ |

(temperature rise at rate of 50-deg C per hour)

#### Leak/P-test at 70-deg C using helium

- pump side-1 to LV, feed He to side-2 (1.5 atm) | open / close | mTorr / 1.5 atm | < 2x10⁻¹⁰ |
- pump side-2 to LV, feed He to side-1 (1.5 atm) | close / open | 1.5 atm / mTorr | < 2x10⁻¹⁰ |

(temperature rise at rate of 50-deg C per hour)

#### Leak/P-test at 120-deg C using helium

- pump side-1 to LV, feed He to side-2 (1.5 atm) | open / close | mTorr / 1.5 atm | < 2x10⁻¹⁰ |
- pump side-2 to LV, feed He to side-1 (1.5 atm) | close / open | 1.5 atm / mTorr | < 2x10⁻¹⁰ |
X-Y Slits Design

- Water cooled, normal incidence design.
- Allow full independent adjustment of all four blades.
- Maximum Opening (50 mm H x 10 mm V)
- Minimum Aperture Size (-10 mm, fully closed, overlapped)
- Allow selection of any part of the beam.
- Position Resolution < 1 µm
- Aperture Stability (1 µm or better over any 24-hour period)
- Repeatability (5µm)
- Beam intensity monitoring.
Photon Shutter Design

- Water cooled, normal incidence design.
- Stops synchrotron beam whenever safety shutters are closed.
- Integrated into the machine PPS.

Photon Shutter/Bremsstrahlung Collimator Assembly

Photon Shutter

- Open Position

- Closed Position
Summary & Conclusion

- **Full passive protection.**
  - Any beam deviation is acceptable for frontend components.
  - Progressive trimming of fan using flange absorbers.
  - Flange absorbers shadow lead collimators.
  - Components protection in absence of water flow by natural convection.

- **Cost effective design.**
  - No welding or brazing required for mask, slits, absorbers & photon shutter.
  - Cu-Cr-Zr is 1/4\textsuperscript{th} the price of Glidcop AL-15.
  - Cu-Cr-Zr is available in different forms (bars, sheets & plates) and sizes.
  - Standardized components for mass production.

- Glidcop AL-15 double sided CF flange is needed for Be window.

- Design work in progress for five NSLS-II BM port beamlines
  - Two frontends will be installed in 2015.
Acknowledgement

- Dick Hseuh
- Eugene Hu
- Frank DePaola
- Frank Lincoln
- John Tuozzolo
- Jeff Keister
- Paul Northrup
- Sushil Sharma

Thank you for your attention!