Recent Progress on the Design of High Heat Load Components

Sushil Sharma
NSLS-II / BNL
Acknowledgment

Co-authors: C. Amundsen, F. DePaola, F. Lincoln, J. Tuozzolo

Discussions: I.C. Sheng (TPS), P. Marion (ESRF), L. Volpe (SIRIUS)
Outline

• Introduction – *Brief outline of the new design concept*

• Components of BM/3-PW Frontends at NSLS-II

• ID FE and Beamline Components
  ➢ *FE Photon shutters and slits*
  ➢ *FE Mask – problem and solutions*
  ➢ *Beamline masks*

• *SR absorbers*

• Conclusions
Main Features of the New Design

1. Integral Conflat Flanges:
   - Single piece construction
   - No brazing (or welding)
   
   Copper alloy, CuCrZr, is easy to weld → more design options

2. Copper Alloys Selection → CuCrZr and GlidCop

Be window diffusion brazed to Glidcop flange
3. Beam Interception – only vertically
   • Common designs - vertical beam size is usually the same.
   • Multiple apertures are easily made.
   • Parts can be made in advance.

4. Internal fins:
   • Thermal efficiency
   • Trapping of scattered beam
BM/3-PW Frontends at NSLS-II

- Three BM/3-PW frontends were installed at NSLS-II in May 2016. All copper components were made from CuCrZr flanges (except for diffusion-brazed Be windows)

NSLS-II BM Frontend

Fixed Mask  and Slits (with BPMs)

XFP Mirror and a Fixed Mask
BM/3-PW Frontend Components

- 24 components of integral-flange design were built and installed. Another ~ 25 are in construction.
- None of the components developed vacuum leak or required re-torquing.
- During initial vacuum processing of the components, a few components developed leaks due to burrs on the knife edged. The design of the knife edge was modified. *(F. DePaola et al., MEDSI 2016)*
CuCrZr can be easily welded by GTAW or e-Beam welding →

- Machining can be reduced by making the flanges separately.
- New designs are very similar to the existing designs except that no brazing is required.
New Mask Design

- The beam is intercepted by top and bottom surfaces consisting of sine-wave fins.
- At the downstream end, the EDM wire leaves a gap of ~ 0.5 mm with an optimum wire size of 0.3 mm.
- More than 1 kW of beam power can escape through this gap and can melt even water-cooled copper at normal incidence.
- Closing this wire gap became a very challenging problem. It could not be closed even with a large force (~ 100,000 kgf).
The downstream flange acts as a beam stop. For an ID beam of 100 kW/mrad$^2$ an $8^\circ$ inclined surface is required.

The flange is welded to the main body after sine-wave surfaces are created.

After welding, the nominal aperture is machined both in the main body and the flange.
FE Analysis – Flange Beam Stop

- The beam footprint is extended in the vertical direction because of 8° angle.
- In the footprint of the beam has a Gaussian power distribution.
- A sine wave gap leads to a ~50% lower temperature rise than a horizontal gap.

Max. Temp. (Sine Wave Gap) = 312° C

Max. Temp. (Horiz. Gap): 486 °C
Applied load = 2,200 kG  
Max. von-Mises Stress =336 MPa  (Yield stress = 350 MPa)  
Maximum bulge = 0.5 mm
Fixed Mask – Option 3

- This option is based on easy weldability of CuCrZr.
- The split mask is made in top-half and bottom-half.
- The two halves are then welded on the sides and then to the flanges
  - No EDM wire gap.
  - Length of the masks is not limited by EDM machine.
  - Fin geometry can be optimized.

Image 1: Split Mask

Image 2: Full Penetration Welds in a Prototype

Image 3: Fins with Cross-cuts

Image 4: Vacuum Leak Test
Beamline Masks

White Beam Mask

Pink Beam Mask

Recently (June 2016) an ID beamline at NSLS-II had an urgent situation. 1 white beam mask and 2 pink beam masks were not received in time because of Glidcop brazing problem.

- These parts were built in 10 days in a small machine shop.
- All knife edges were machined on a manual lathe.
NSLS-II Crotch Absorbers:

- Brazing of the bent copper tubes in the grooves of the Glidcop body turned out to be very difficult.
- Initially only 6 crotch absorbers were installed. At other 54 locations absorbers without apertures were installed.
- Each time a frontend is installed the crotch absorber must be replaced and the entire cell must be baked out.
New Crotch Absorber Design

- New design from a single round bar of CuCrZr (no brazing or welding).
- Step 1: Conflat flange, beam aperture and water channels.
- Step 2: Back stop and nose tip. Spring wrapped copper tubes are inserted in the water channels.
- Step 3: The nose tip is bent to be in the mid-plane.

- The nose tip was successfully bent in a prototype.
- Thermal FE analysis shows a moderate temperature of 131°C at the nose tip.
Summary and Conclusions

• A considerable progress has been made at NSLS-II in the implementation of the new HHL design concept first presented at MEDSI2014.

• Three BM and 3-PW frontends have been installed with all masks, slits, photon shutters and Be windows made from integral Conflat flanges (mostly in CuCrZr).

• The fixed mask design has been further developed and various options for solving the wire EDM gap problem have been investigated.

• Many beamline masks/shutters and SR crotch absorbers will be based on this design in the future.