Recent Progress on the Design of High Heat Load Components

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Acknowledgment

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Outline

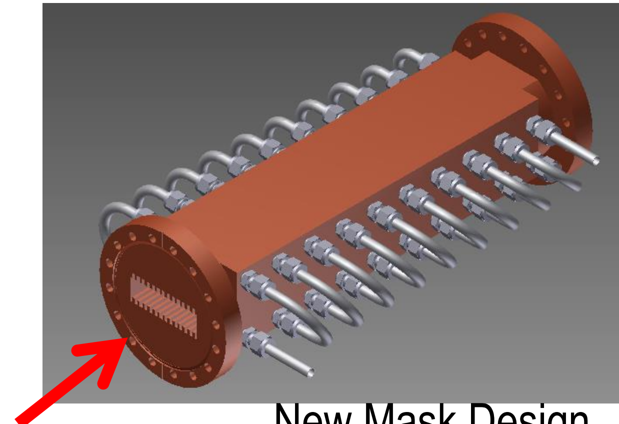
- Introduction – *Brief outline of the new design concept*
- Components of BM/3-PW Frontends at NSLS-II
- ID FE and Beamline Components
  - *FE Photon shutters and slits*
  - *FE Mask – problem and solutions*
  - *Beamline masks*
- *SR absorbers*
- Conclusions

Main Features of the New Design

1. Integral Conflat Flanges:
   - Single piece construction
   - No brazing (or welding)

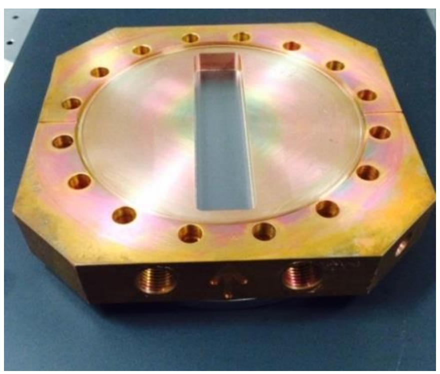
     Copper alloy, CuCrZr, is easy to weld → more design options

2. Copper Alloys Selection → CuCrZr and GlidCop

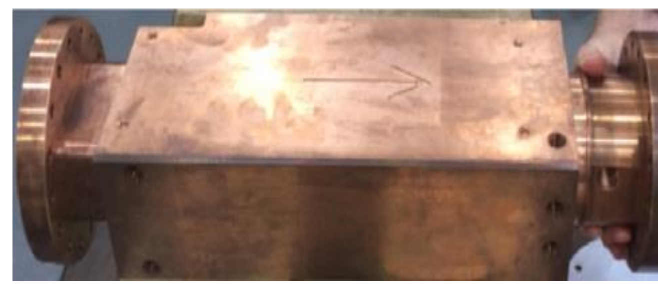


Beam

New Mask Design



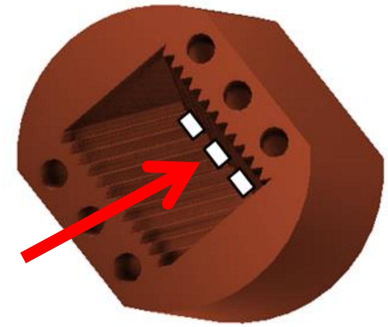
Be window diffusion brazed to Glidcop flange



CuCrZr mask with separate flanges to be welded

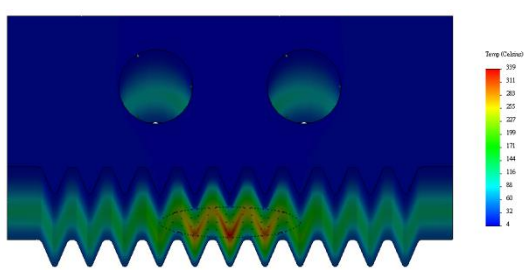
New Design Features (contd.)

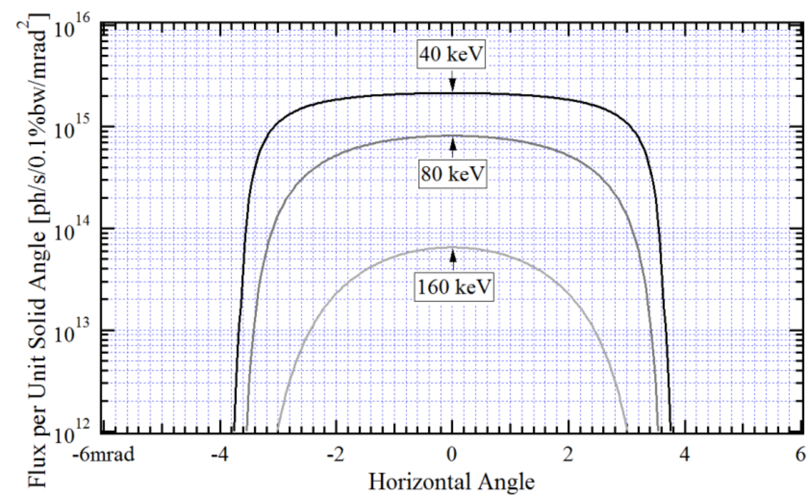
3. Beam Interception – only vertically
   - Common designs - vertical beam size is usually the same.
   - Multiple apertures are easily made.
   - Parts can be made in advance.



A mask with 3 apertures

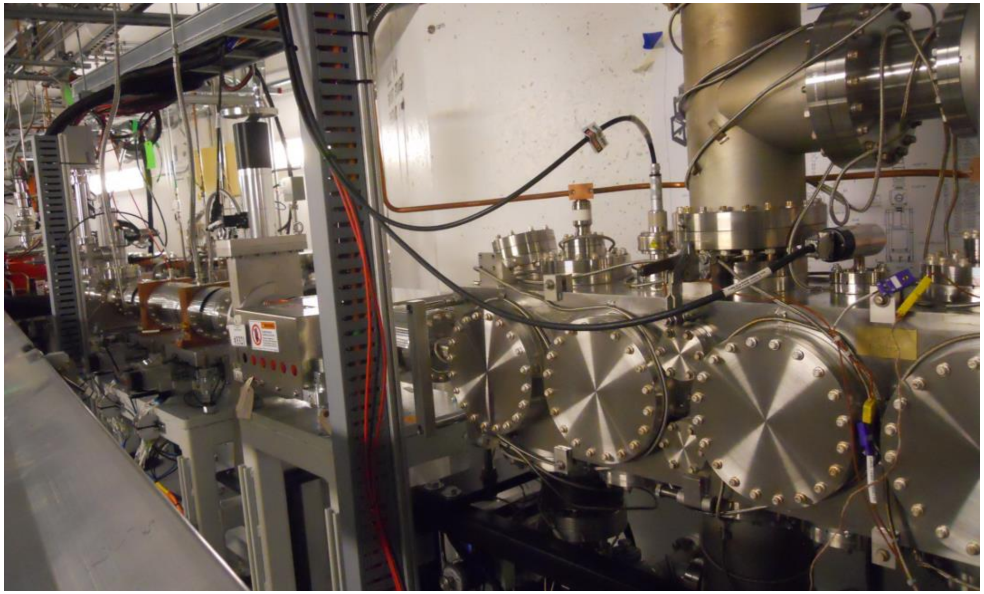
4. Internal fins:
   - Thermal efficiency
   - Trapping of scattered beam



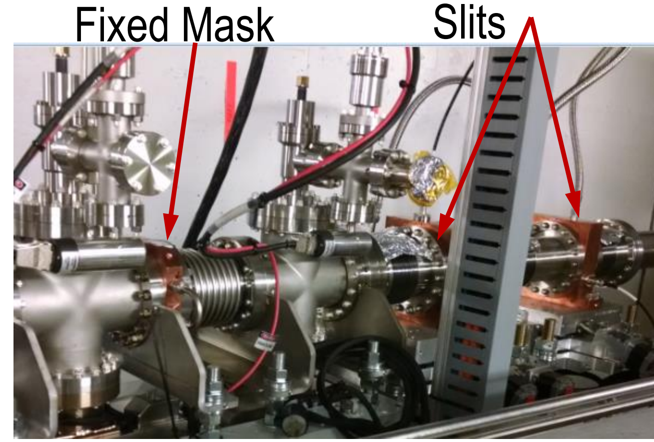


NSLS-II HEX Superconducting Wiggler Horizontal Fan Size

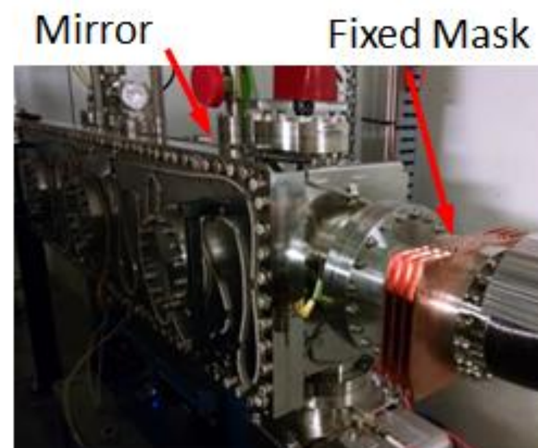
BM/3-PW Frontends at NSLS-II



NSLS-II BM Frontend



Fixed Mask and Slits (with BPMs)

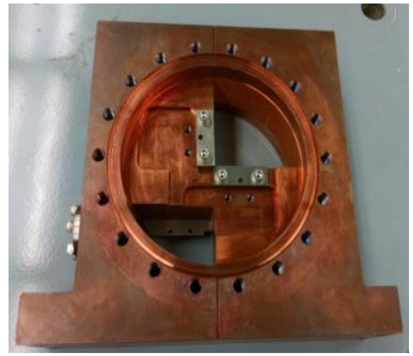


XFP Mirror and a Fixed Mask

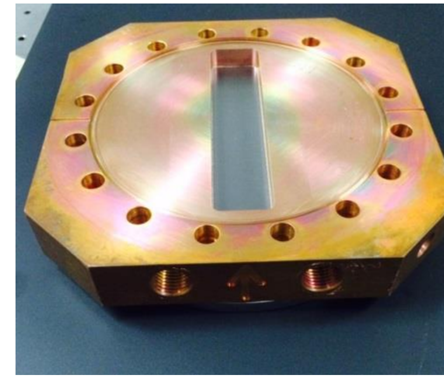
- Three BM/3-PW frontends were installed at NSLS-II in May 2016. All copper components were made from CuCrZr flanges (except for diffusion-brazed Be windows)

BM/3-PW Frontend Components

Convection (air) cooled mask

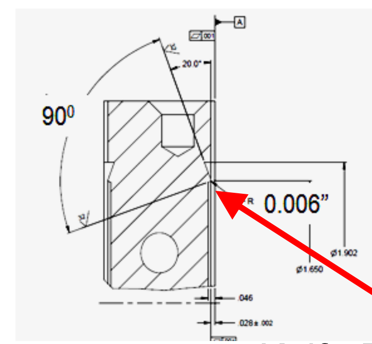


Water-cooled slit

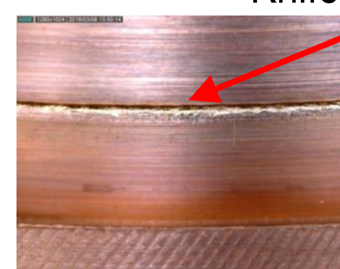


Be Window

- 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)*



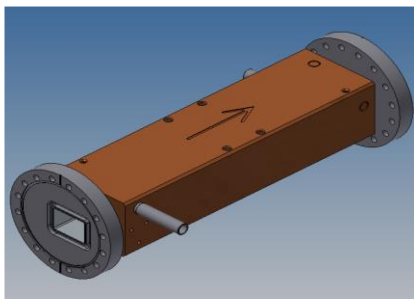
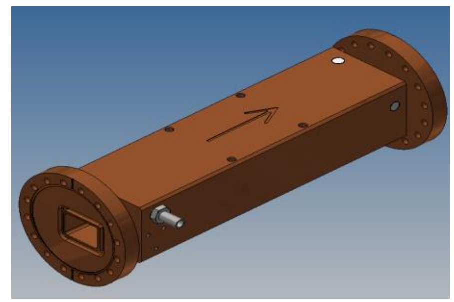
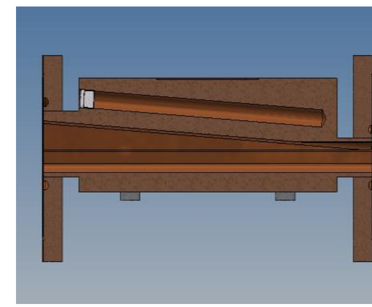
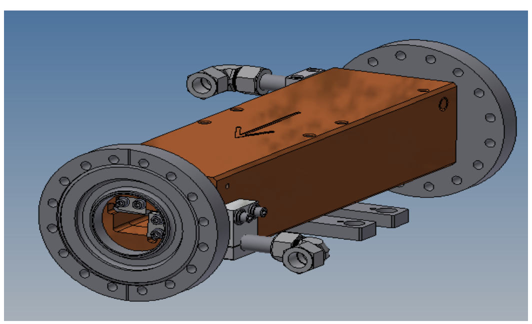
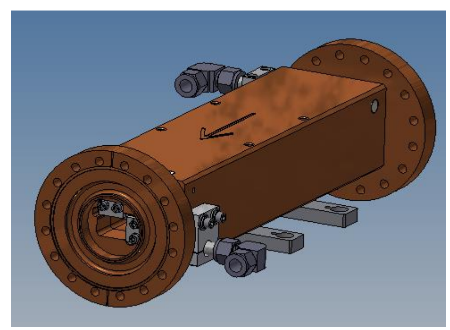
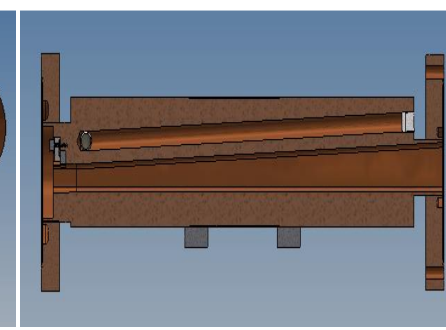
Knife Edge



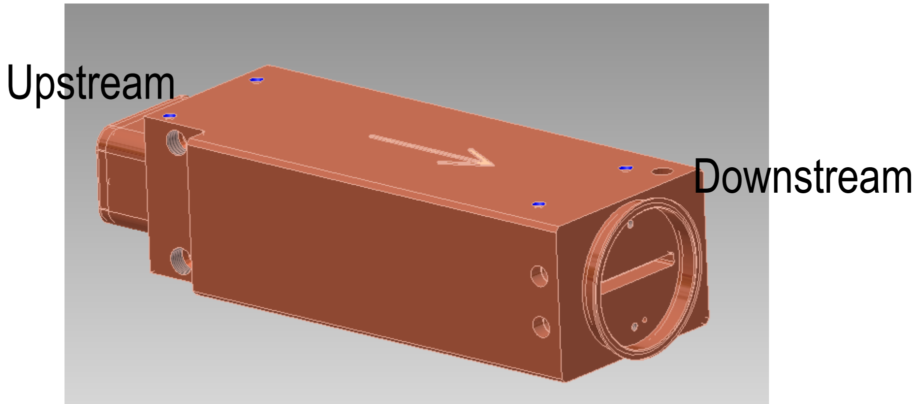
ID Photon Shutters and Slits

CuCrZr can be easily welded by GTAW or e-Beam welding →

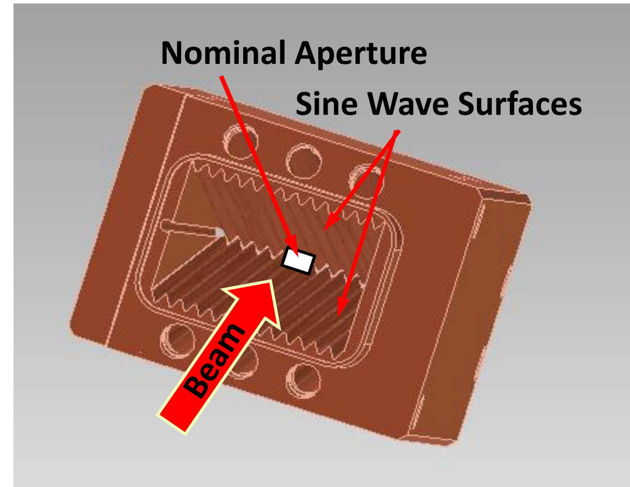
- Machining can be reduced by making the flanges separately.
- New designs are very similar to the existing designs except that no brazing is required.

	Existing Design	New Design	
Photon Shutter			
Slit			

New Mask Design

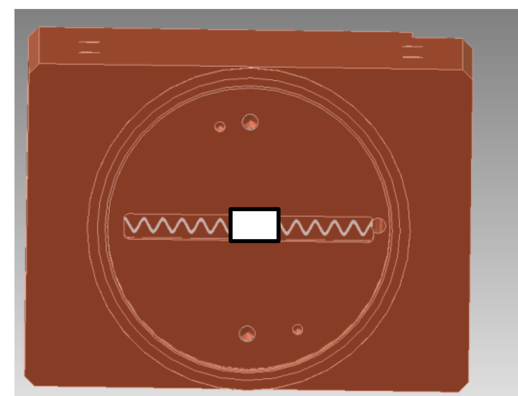


Fixed Mask Body



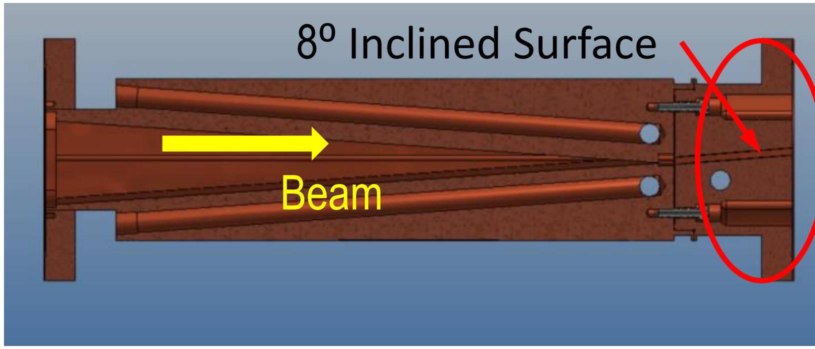
Upstream End

- 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)



Downstream End

ID Mask Prototype – Option 1



Flange Beam Stop

Prototype

- The downstream flange acts as a beam stop. For an ID beam of 100 kW/mrad^2 an 8^0 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.

Upstream End

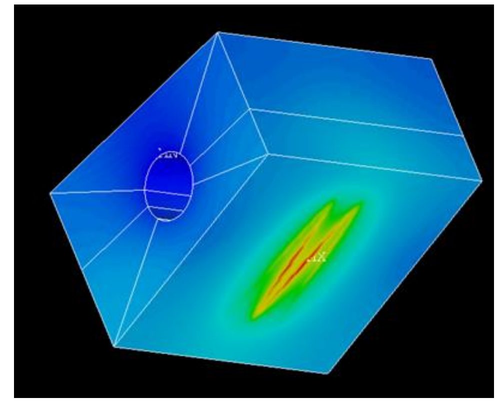
Downstream End

Upstream Weld

Downstream Weld

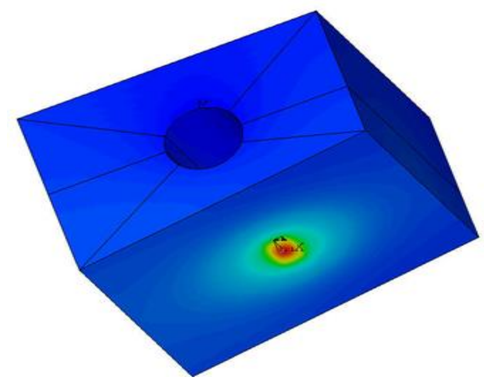
FE Analysis – Flange Beam Stop

FE Model – Beam footprint
from a Sine Wave Gap



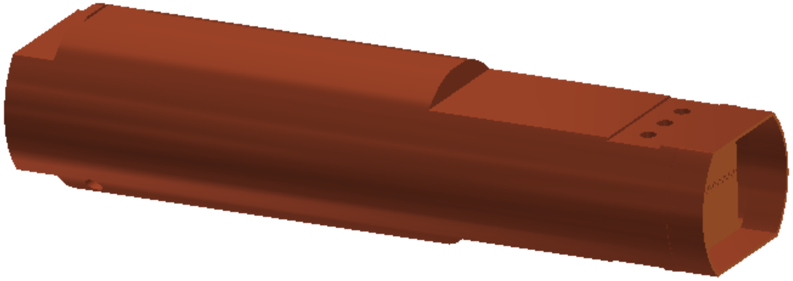
Max. Temp. (Sine Wave Gap) = 312^{0} C

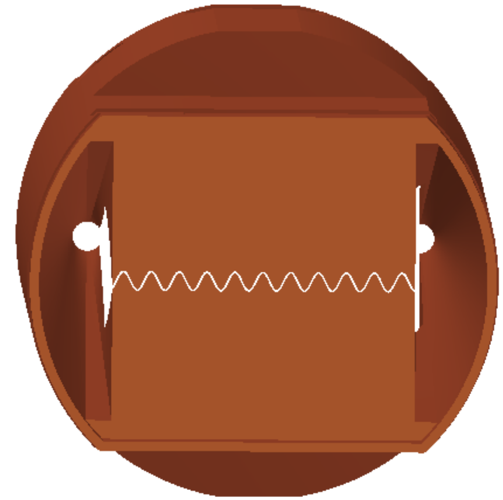
- The beam footprint is extended in the vertical direction because of 8° angle.
- In the footprint of the beam has a Gaussian power distribution.
- A sine wave gap leads to a ~50% lower temperature rise than a horizontal gap.



Max. Temp. (Horiz. Gap): 486 ºC

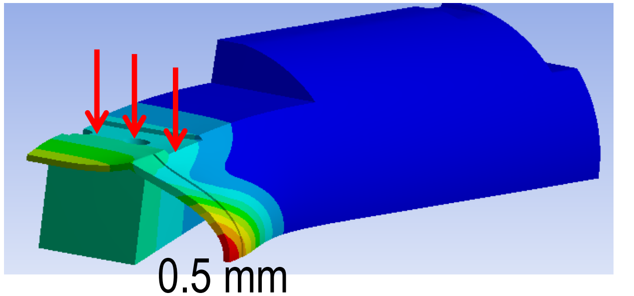
Fixed Mask – Option 2





- The side walls are hollowed out by wire EDM at the same time as when the sine wave surfaces are created.
- A force is applied to close the gap on the downstream end. The downstream flange is then inserted and welded.

Applied load = 2,200 kG
Max. von-Mises Stress =336 MPa (Yield stress = 350 MPa)
Maximum bulge = 0.5 mm



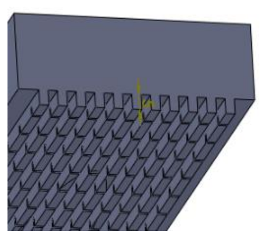
Fixed Mask – Option 3

Split Mask

Full Penetration Welds in a Prototype

- 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.

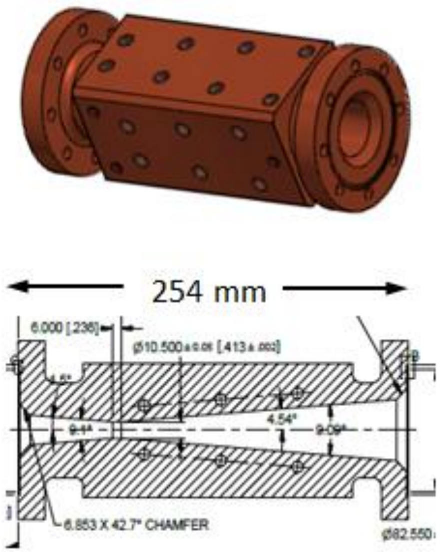
Fins with Cross-cuts



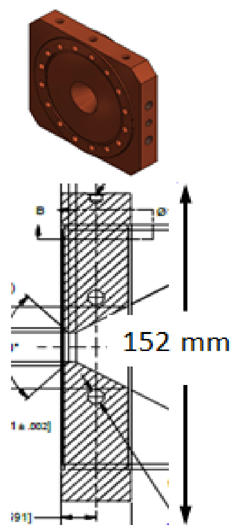
Vacuum Leak Test

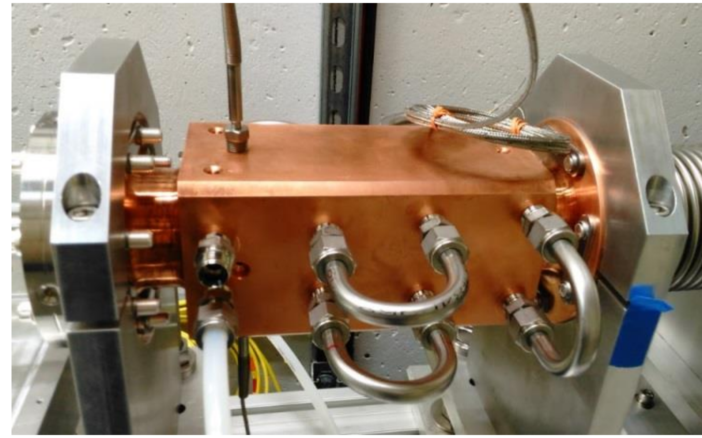
Beamline Masks

White Beam Mask



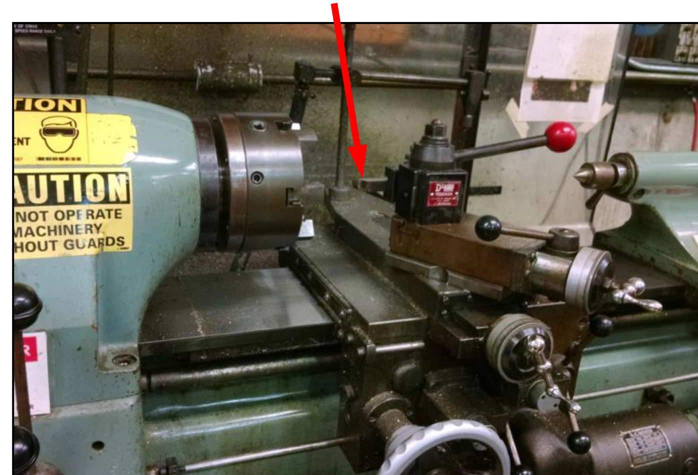
Pink Beam Mask





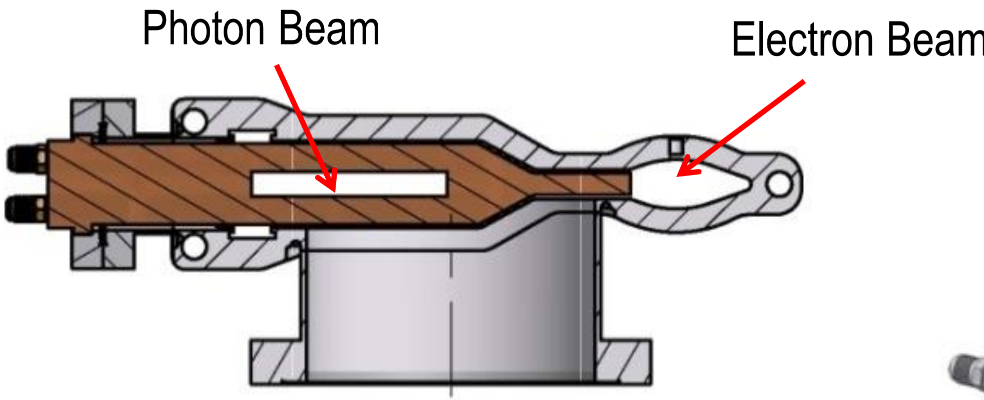
White Beam Mask as Installed

Knife Edge Cutting Tool



- 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.

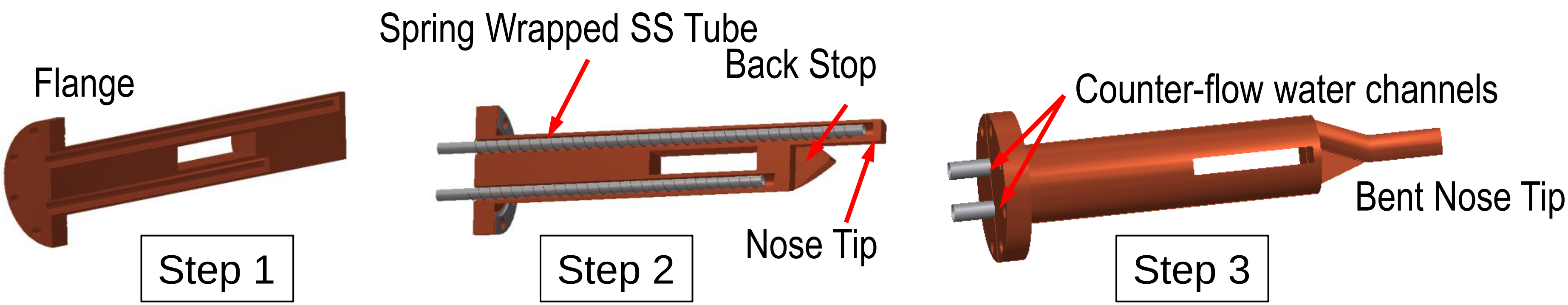
NSLS-II Crotch Absorber



NSLS-II Crotch Absorbers:

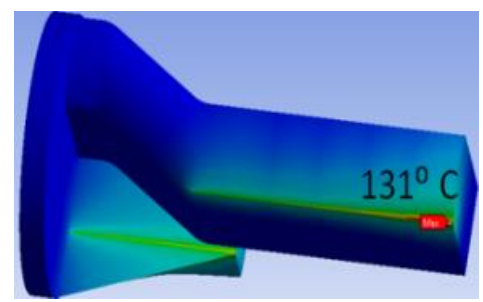
- Brazing of the bent copper tubes in the grooves of the Glidcop body turned out to be very difficult.
- Initially only 6 crotch absorbers were installed. At other 54 locations absorbers without apertures were installed.
- Each time a frontend is installed the crotch absorber must be replaced and the 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 131^0 C at the nose tip.

Prototype Bent Nose Tip



Thermal FE Analysis

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.