TPS FRONT END DESIGN IN NSRRC

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Abstract

National Synchrotron Radiation Research Center (NSRRC) will build a new 3GeV, 400mA synchrotron accelerator machine. Several different IDs have been proposed and the corresponding front ends are designed. Beam lines of IU20, IU28, SW48 and EPU70 will be the phase I requirement. Due to different power load and density flux, fixed masks, photon absorber, slits, photon absorber and photon beam position monitor will all be customized to meet the beam line user requirements as well as the thermomechanical limits. Overall front end layout, analysis results of the high heat load components are illustrated; experiments of photon beam position monitor, front end pressure distribution due to thermal and photon stimulated desorption outgassing analysis, are also presented in this paper.

INTRODUCTIONS

Taiwan Photon Source (TPS) project in NSRRC will build a 3 GeV, 400mA high energy density synchrotron radiation facility. A 518meters circumference storage ring will provide total of 48 beam lines (24 insertion device (ID) and 24 bending magnet (BM) beam lines) for the users. This includes 6 long sections (14m) and 18 short sections (7m) ID devices. Some of the insertion devices will generate very high density power level, and yet some wigglers produce not only high density but also wide horizontal fan of radiation. The mechanical design of front end in TPS thus becomes challenging in order to shadow not only its high power density radiation but also to shape its small beam size.

Due to geometry constrain, the length of ID front end is around 9m whereas 13m for BM front end, therefore a 2m mirror table might be installed in BM front end. Transverse distance between the centres of front end to the outside tunnel wall varies from 60cm to 1m. As is shown in Figure 1 shows typical TPS front end components includes pre-mask, fixed masks (FM), photon absorbers (PAB), x-ray photon beam position monitors (XBPM), slits, heavy metal shutters (HMS), beryllium window, fast closing valve, gate valves and interlock system. Bellows, ion pumps and transition tubes are used to connect among above components to secure the UHV environment in nano-torr (10^{-9} torr) range.

KEY COMPONENTS

Fixed Mask

Fixed mask is the first high heat load components in front end to shape either BM or ID synchrotron radiation, A 400mm long copper bar with rectangular tapered tunnel is fabricated via EDM for beam to pass through. Take IU20, for instance, the tapered angle is defined by upstream and downstream apertures, it is design such as way that it should intercepts approximately 50% of the total power during normal operation. (Total power of IU20 is 12.35 Kw). 8 circular water channels are machined along the longitudinal direction to dissipate the heat. However, the design criterion is both two fixed masks should be able to take full heat load if beam miss-steering occurs. Assembly of fixed mask is shown in Figure 2.

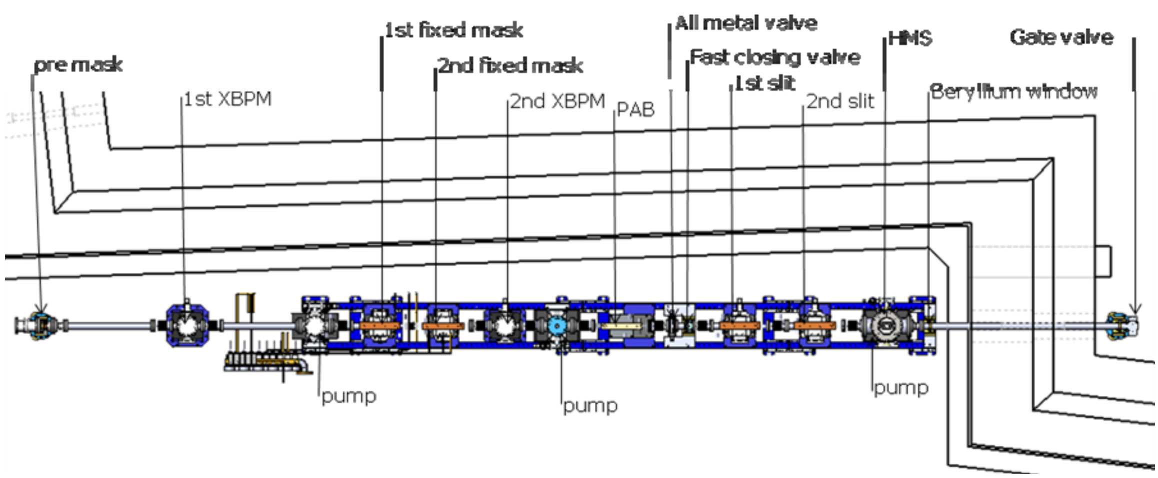

Figure 1: Top View of Typical TPS ID Front End.

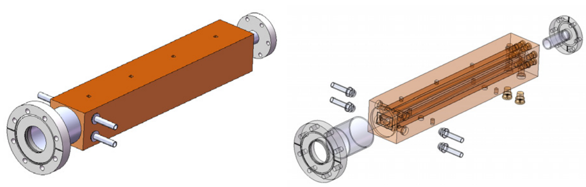

Figure 2: Assembly Design of TPS Fixed Mask.

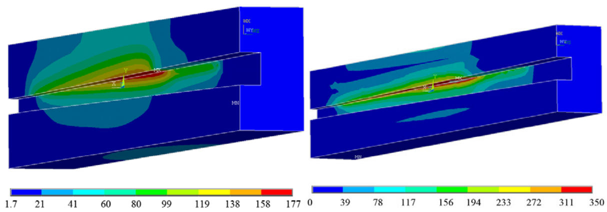

Figure 3: Temperature and Thermal Stress Contours of TPS Fixed Mask.

Figure 3 illustrates temperature and effective stress contours of TPS fixed mask when IU20 radiation power strikes on the heating surface. Maximum temperature rise is 177 ^{o}C and thermal-induced effective stress is 350 MPa. (Note that yield strength of GlidCop® is 393 MPa at 250 ^{o}C . In the analysis model we assume that total IU20 ID has beam miss-steering such that the entire power profile deposits on the tapered surface. The peak power density is around 12 w/mm^2 after nearly 1^o grazing angle is taken into account.

X-ray Beam Position Monitor (XBPM)

Diamond blade type of X-ray Beam Position Monitor (XBPM) will be adopted for the TPS ID front end. Shu[1] in APS has successfully designed this type of XBPM and is widely used. TPS has extensive collaboration with APS and Spring-8. ID XBPM prototype collaborated with APS has been installed in Spring-8 BL12XU front end for data testing and data measurement [1] whereas BM XBPM is installed in TLS in NSRRC for testing.

Photon Absorber (PAB)

The function of Photon absorber (PAB) is either during emergency, or during replacement of downstream beam line components, which should be protected from being heated by radiation power. The design of PAB is very similar with that of FM, the only difference is instead of a tapered surfaces, there is a straight 12mm × 12mm rectangular aperture for IU20 ID to pass through during normal operation, on top of rectangular aperture two horizontal grazing surfaces are designed to shadow the rest of synchrotron power when situations occurs, bellows are connected on both sides of the PAB for the flexible movement when PAB is pushed down by air piston.

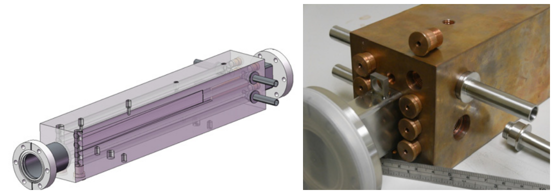

Figure 4: Semi-transparent View and Prototype Assembly of TPS PAB.

Figure 4 shows semi-transparent view and prototype of PAB pre brazing assembly. Since fixed masks are designed to take first 50% of the total power, the rest of 50% will be deposited on PAB when air piston is pushed down; the temperature and thermal stress have been reported in [4].

Slits

Two slits will be installed nearly at the end of the front end (before HMS). Beam line users are able to obtain their defining aperture by adjusting the slits openings, transversely and vertically. Design of the slit is also very similar to that of fixed mask. The interception of the apertures of two slits defines the final beam size for the users. These two GlidCop® water cooled absorbers are designed to take rest of the power at the worst situation, when two slits move on opposite directions such that no beam is coming out from ID front end.

Heavy Metal Shutter (HMS)

Heavy metal shutter (HMS) is the last UHV component before synchrotron radiation escapes from storage ring tunnel. The function of heavy metal shutter primarily is used to block the Bremsstrahlung Radiation.

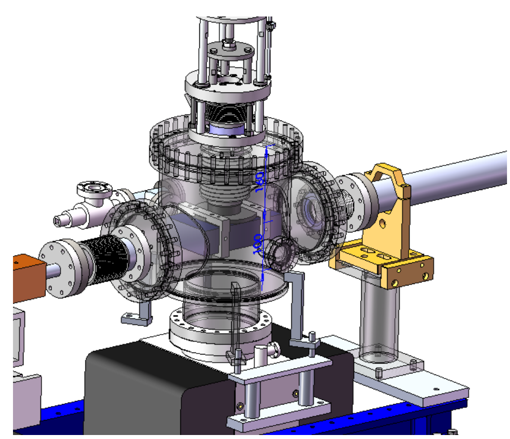

Figure 5: Semi-transparent View of TPS HMS Design.

Ion Pumps

Several 500 Litres/second ion pumps will be installed in TPS front end. In high thermal outgassing on high heat load components, (such as FM, PAB and Slits) photon stimulated desorption effects dominates the pressure distribution in ID front end. Simulation shows relatively high pressure occurs in these areas. Methodology and the simulation results can be found at [4].

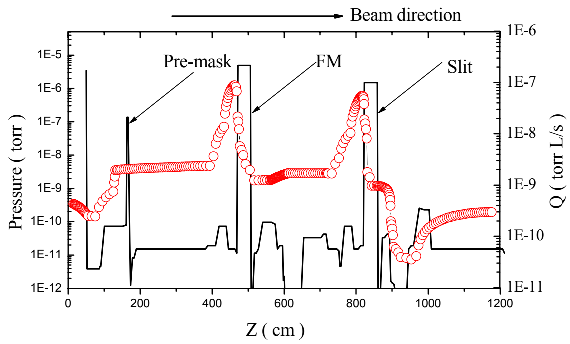

Figure 6: Estimated Pressure Distribution of TPS IU20 Front End Due to Photon Stimulated Desorption.

Figure 6 shows PSD simulation pressure result along IU20 ID front end. Note that ID photon induced electron per second for each high heat components can be as high as nearly 10^{18} by integrating 1st, 3rd and 5th harmonic photon flux densities.

Tunnel Wall

Tunnel wall thickness of TPS is between 1 to 1.2 m, a 25 cm wide, 30cm deep cable trench will be constructed followed the outside tunnel wall pattern, it is used for embedding power cables for magnets, ID and also for front end. There is a 30cm wide $\times$ 15cm height, 15cm depth underpass cable trench facing the beam line wall. Wall opening for future beam lines are either for BM or for ID, 25cm $\times$ 25cm square opening is for ID whereas 65cm $\times$ 25cm for BM. Note that beam centre of BM front end is not at the centre of the wall opening. The main reason for this offset is to compromise 1^o clockwise rotation of storage ring chamber related to the starting angle of dipole magnet. Figure 7 illustrates the front view of both BM and ID front end wall opening looking up beam direction.

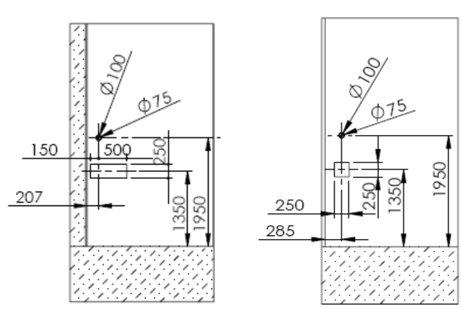

Figure 7: TPS Wall Opening for Beam Line (Left: BM, Right: ID Front Ends).

Since TPS has no ratchet door on outside wall, there will be a 75mm view hole on top of front end centre. The purpose for this view hole is to align between beam line components and that inside of the storage ring.

BEAM SHAPING

As suggested by Sakurai [5], the ID beam size needed by beam line user in general is at that of fist harmonic, which is approximately 0.05mrad (as shown in Figure 8). Since the total power of IU20 is 12kW, we evenly distribute the power load along high heat load components. First and second fixed masks will take 6kW power (~ 50%); slits are able to take the rest of 6kW when they are fully closed. And when PAB dropped down due to emergency situations, it will receive the rest of 6kW as well.

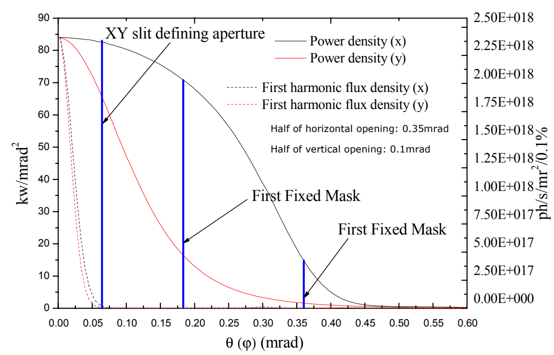

Figure 8: Spatial Distribution of First Harmonic Flux vs. Peak Power Density.

CONCLUSIONS

Typical TPS front ends design is nearly completed. Several prototypes are fabricated and tested; pressure distribution due to thermal outgassing has been studied and optimized. Length of the front end as well as beam line holes dimension on the tunnel wall are also finalized for the civil construction. There are other key components such as fast closing valve; beryllium window will be also implemented. Differential pumping will be also considered in the front end design.

REFERENCES

[1] C. K. Kuan, et al., “Development of an X-Ray Beam-position Monitors for TPS”, MEDSI/pan-American SRI 2008 Meeting.

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[5] Y. Sakurai, et al., “Conceptual Design of Spring-8 Front Ends”, Rev. Sci. Instrum. 66 (2), February 1995.