

Design, Construction, Assembly and Vacuum Test of X-Ray Beamline Front End Chamber at SLRI.

S. Chaichuay, M. Phanak, M. Sophon, S. Srichan, D. Bumrungkoh and S. Duangnil

Synchrotron Light Research Institute (Public organization), 111 University Avenue, Suranaree, Muang District, NakhonRatchasima 30000 Thailand

Email: sarunyu@slri.or.th

Abstract

In the storage ring at the Synchrotron Light Research Institute (SLRI) a new insertion device, a multipole wiggler (MPW), has been successfully installed and provides hard x-ray since September 2013. A new front end chamber for the insertion device has been designed to utilize as much hard x-ray as possible and to split the x-ray beam into three brunches. The front end chamber consists of three pairs of horizontal slits, one pair of vertical slits, three sets of heat absorbers, three sets of x-ray fluorescent screens and one beam shutter. The front end chamber was also considered to maintain the storage ring vacuum pressure. The chamber has been installed during the machine maintenance period in June 2014. Due to the short time period of installation, the assembly and pre-alignment procedures of the front end chamber had to be finished completely while the reachable vacuum pressure had to be satisfying as well before the installation. These procedures and the results of vacuum testing will be presented and the front end chamber design will be described.

1. Introduction

In September 2013 the Synchrotron Light Research Institute (SLRI) succeeded with the installation of a 2.4 Tesla multipole wiggler (MPW) into the storage ring to produce hard x-rays. A high-energy x-ray beam was passing through the old front end chamber of beam line 1 (BL 1). To take as much as possible advantage of the hard x-ray and to split the beam into three brunches, a new front end chamber had to be designed. The BL 1 should provide three techniques to the users of SLRI. BL 1.1 will provide the multiple X-ray technique, BL 1.2 will provide X-ray tomography and BL 1.3 will provide SAXS (Small Angle X-ray Scattering). Also for the achievement of these techniques a new front end chamber had to be designed and fabricated. Figure 1 shows the layout of the new front end chamber. All components of the chamber were designed to withstand a power density of 50 W/mrad² at 1.2 GeV and 200 mA [1].

2. Design

The front end chamber consists of a cylinder tube with a diameter of 304.8 mm and a length of 1567 mm. The extracted beam is split by the horizontal slits and vertical slits in the front end chamber. Each branch receives a total horizontal fan of radiation of 3 mrad. Figure 1 shows the layout of the front end chamber. Each component is listed sequentially as follows: (1) vertical slit for three brunches, (2) horizontal slit for BL1.3, (3) horizontal slit for BL1.1, (4) horizontal slit for BL1.2, (5) fluorescent screen for BL1.3, (6) fluorescent screen for BL1.1, (7) fluorescent screen for BL1.2, (8) heat absorber for BL1.2, (9) heat absorber for BL1.3, (10) heat absorber for BL1.1 and (11) beam shutter for three brunches. All the components of the chamber are designed to withstand a heat power 200 W (maximum) at 1.2 GeV and 150 mA [1]. The chamber size is determined as small as possible within the limits of the maximum beam. The front end chamber is supported by six adjustable struts (cone joints, V joints and flat joints) which are functioning as a highly precise alignment tool.

3. Finite Element Analysis

The Finite Element Analysis (FEA) was performed by the commercial program SolidWorks Simulation. Figure 2 shows a maximum temperature of 53.95 °C for the heat absorber at a total heat power of 200 W and a convection coefficient of 1,800 W/m².°C. The determination of the convective heat transfer coefficient is shown in table 1.

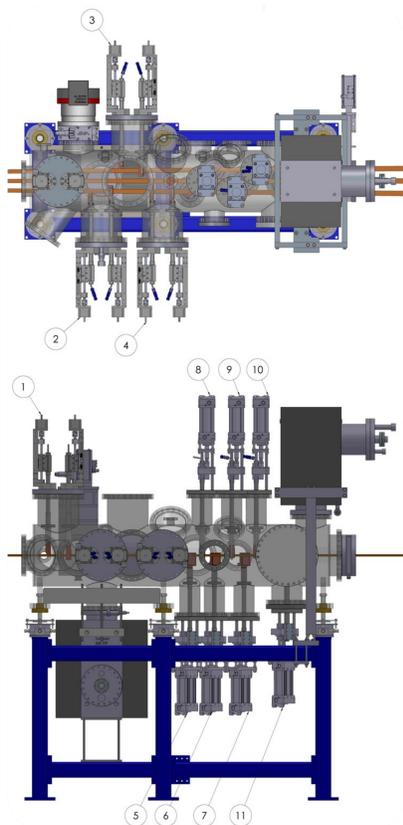


Figure 1. Front End Chamber

Table 1. Equation for determine convection heat transfer

Hydraulic diameter	$D_h = \frac{2ab}{a+b}$, Rectangular duct, a=5mm., b=20mm.
Reynolds number	$Re = \frac{\rho V D_h}{\mu}$, Velocity water 0.33 m/s at 30 °C
Friction factor	$f = (0.790 \ln Re - 1.64)^{-2}$, turbulent flow given as Smooth tubes
Nusselt number	$Nu = \frac{(f/8)(Re-1000)Pr}{1+12.7(\frac{f}{8})^{0.5}(Pr^{1/4}-1)}$
Convection coefficient	$h = \frac{k}{D_h} Nu$

Table 2. Properties of saturated water (Liquid) @30 °C [4].

Density, ρ	996.0 kg/m ³
Thermal Conductivity, k	0.615 k W/m.°C
Dynamic Viscosity, μ	0.798 x 10 ⁻⁸ kg/m.s
Prandtl Number, Pr	5.42

Table 3. Shows some typical values for the convective heat transfer coefficient [3].

Medium	Heat Transfer Coefficient h W/m ² .°C
Air (natural convection)	5-25
Air/superheated steam (forced convection)	20-300
Oil (forced convection)	60-1800
Water (forced convection)	300-6000
Water (boiling)	3000-60,000
Steam (condensing)	6000-120,000

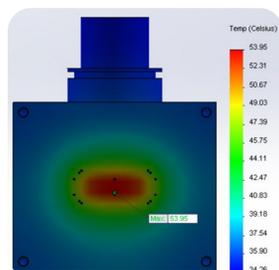


Figure 2. Temperature for h 1800 W/m².°C. (Material: OFHC Copper)

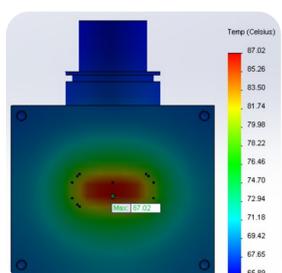


Figure 3. Temperature for h 300 W/m².°C. (Material: OFHC Copper)

The convection coefficient is generally accomplished in a research laboratory. Many handbooks contain tabulated values of convection heat transfer coefficients for different configuration. Table 3 shows some typical values for the convective heat transfer coefficient [3]. We chose the minimum value of the convective heat transfer coefficient at 300 W/m².°C in table 3 for worst heat transfer. We used this value for the simulation and received a maximum temperature of 87.02 °C (Figure 3).

4. Assembly and Vacuum Test

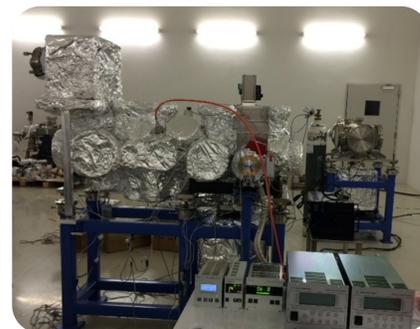


Figure 4. Baking front end chamber in vacuum lab



Figure 5. Assembly all component in Vacuum lab



Figure 7. Beam on the fluorescent screen

In order to install the front end chamber to the storage ring a vacuum test was carried out after the assembly process. A set of vacuum pumps was attached to the chamber (turbo molecular pump, 685 l/s and a dry scroll pump, 250 l/min). A pressure of 4.4 x 10⁻⁸ torr was reached. In addition a helium leak test was performed to ensure the leak tightness of the system. The detection range of the helium leak test is less than 1.0 x 10⁻¹⁰ torr. To obtain UHV level, the front end chamber was baked at a temperature of 150°C for seven days. A pressure of 2.0 x 10⁻¹⁰ torr was achieved.

The horizontal slits, vertical slits, heat absorbers, fluorescent screens and the beam shutter were assembled on a manipulator (shown in figure 5) and vacuum leak tested one by one. After passing the leak test the components were assembled to the front end chamber and an alignment of all parts was carried out. After that a second baking process was started. This time the front end chamber and all components mentioned above were baked. As a result a vacuum pressure of 2.3 x 10⁻¹⁰ torr was obtained.

Figure 6 shows the front end chamber completely installed to the storage ring. Figure 7 shows the cross section of the x-ray beam falling on a fluorescent screen behind the horizontal and vertical slits.

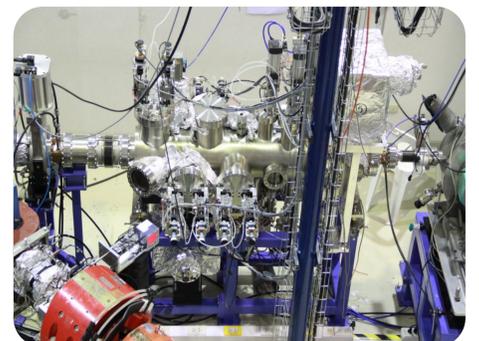


Figure 6. Front end after installation to the storage ring

5. Conclusion

We designed and installed a new front end chamber for BL 1 to the SLRI storage ring which is able to split the synchrotron beam into three brunches. The installation was done during the machine maintenance period in 2014. Although there was a small time window, it was possible to assemble, align and test the front end chamber as well as installing it successfully and punctual to the storage ring.

6. Acknowledgements

The author would like to express special thanks to the staff of the Mechanical Development Section for their dedication to complete the installation. The author would also like to thank Mr. Methae Sophon and Mrs. Supawan Srichan for consulting and their help during the design- and installation process. Also thanks to the staff of the Component Fabrication Section for the fabrication of all components. Furthermore the author would like to thank Mr. Oliver Utke for helping to complete this paper.

7. References

- [1] M. Sophon, Thermal and Deformation Analyses of the New 2.4 T Multipole Wiggler Vacuum Vessel at Siam Photon Source, SLRI, (2013).
- [2] YUNUS A. CENGEL, "Internal Forced Convection", Heat Transfer, Second Edition, 2003, USA, p.419-441.
- [3] SOLIDWORKS Help, Convection Heat Coefficient, solidworks.com, 2012