ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-TUPAB375

COMMISSIONING AND OPERATION OF SUPERCONDUCTING MULTIPOLE WIGGLER AT SIAM PHOTON SOURCE*

P. Sunwong†, S. Boonsuya, S. Chaichuay, T. Chanwattana, C. Dhammatong, A. Kwankasem, C. Preecha, T. Pulampong, K. Sittisard, V. Sooksrimuang, S. Srichan, P. Sudmuang, N. Suradet, S. Tancharakorn, Synchrotron Light Research Institute, Nakhon Ratchasima, Thailand

Abstract

A new insertion device, Superconducting Multipole Wiggler (SMPW) with the peak field strength of 3.5 T, was installed in the storage ring of Siam Photon Source as a radiation source for a new hard X-ray beamline. Cool-down process, as well as magnet training, was performed with careful tuning of liquid helium filling procedure for efficient management of liquid helium supply. The filling procedure was also optimized for safe operation of the magnet. The SMPW commissioning was successfully carried out with electron beam and the effect of SMPW on electron beam dynamics was observed. It can be minimized using quadrupole magnets and horizontal/vertical correctors.

INTRODUCTION

A Superconducting Multipole Wiggler (SMPW) was designed and manufactured by the National Synchrotron Radiation Research Center (NSRRC) [1] as a radiation source for a so-called ASEAN beamline, a new beamline of the Siam Photon Source. The beamline will utilize hard X-ray radiation with the photon energy between 5 - 20 keV for X-ray Absorption Spectroscopy (XAS) technique. With the capability of liquid helium liquefaction system at the Synchrotron Light Research Institute (SLRI) and the available space of 1.660 mm in the storage ring's straight section, a superconducting insertion device with the peak field strength at least 3.5 T and the number of periods at least 5 was chosen. Beam Position Monitors (BPMs) and horizontal/vertical correctors were also designed and manufactured for installation at upstream and downstream of the SMPW. This paper presents the specification, cool-down and training performance, and operation of the SMPW. Cryogenics system, liquid helium filling procedure and management of liquid helium supply at SLRI are also discussed.

SMPW SPECIFICATIONS

Detailed specifications of the SMPW are summarized in Table 1. The peak field strength is 3.5 T at the excitation current of 253 A. The number of periods is 6 with the period length of 77 mm. The good field region, where the field homogeneity is better than 0.5%, is ± 25 mm. The static heat load (designed value) is 1.54 W or 2.2 L/hr. The photon flux density is 2×10^{13} photons/s/mrad2/0.1%BW at the photon energy of 10 keV, the beam energy of 1.2 GeV and the beam current of 150 mA.

Table 1: Specifications of SMPW

Parameter	Design value
Peak field strength (T)	3.5
Period length (mm)	77
Number of periods	6
Pole gap (mm)	22.5
Clearance aperture (mm×mm)	15×106
Good field region (mm)	±25
Static heat load (W)	1.54
Beam duct material	Aluminium

A complete set of magnetic field measurement was obtained during the factory acceptance test at NSRRC using a Hall sensor scan and a stretch wire system. The results show that all magnetic field integrals are within the requirement, with the exception of the vertical first field integral (dipole integral) which can be corrected using the provided horizontal/vertical correctors. The transverse field homogeneity also meets the requirement, although the results of the Hall sensor scan from the vertical test in a test Dewar need to be included to allow a justification of the good field region due to limitation of the transverse sensor scan in the magnet.

CRYOGENICS SYSTEM

The magnet coils of SMPW are made of NbTi superconducting wire which needs to be immersed in liquid helium during the operation. The beam duct made of aluminium is semi-cold type with the temperature around 100 K. Cryostat of SMPW consists of liquid helium vessel, liquid nitrogen-cooled 80 K thermal shielding and 300 K vacuum vessel, which are designed to minimize heat leakage into liquid helium.

Helium liquefaction system (HELIAL 1000) for Siam Photon Source has liquefaction capacity of 20 L/hr without liquid nitrogen pre-cool. It is feasible to supply liquid helium to two superconducting insertion devices; the existing Superconducting Wavelength Shifter (SWLS) and the new SMPW. CRYOFLEX® transfer line with 4-tube design (CERN type) is chosen to transfer liquid helium from liquid helium distributor (or valve box) to the SMPW because it has a low value of heat loss and it is easy to install. Heat loss of the CRYOFLEX® transfer line is approximately 40 mW/m, not including the loss at couplings and joints. Total length of the transfer line is 30 m. The transfer line uses liquid nitrogen as thermal shielding so additional

* Work supported by Synchrotron Light Research Institute
† Email address: prapaiwan@slri.or.th

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-TUPAB375

liquid nitrogen line has to be installed, besides the liquid nitrogen line for SMPW's thermal shielding.

INSTALLATION AND COMMISSIONING

The SMPW was successfully installed in the storage ring of Siam Photon Source in August 2018 at the center of straight section between the bending magnets BM04 and BM05. The process after installation includes (1) pumping and purge of liquid helium and liquid nitrogen vessels, (2) pumping the 300 K vacuum vessel to 1×10^{-4} torr or lower, (3) particle cleaning of the liquid helium vessel with continuous flow of nitrogen gas and (4) repeating pumping and purge for at least three times. The SMPW is then cooled-down with liquid nitrogen first, followed by liquid helium to 4.2 K. Temperature and pressure of the SMPW during the cool-down process are illustrated in Fig. 1. The temperatures T1 - T4 are measured at the bottom of liquid helium vessel, the magnet arrays and the protection diodes which should be immersed in liquid helium when the SMPW is in operation. The temperatures T5 and T6 are measured below the Nb_3Sn/Cu bus bar and the temperatures T7 and T8 are measured below the vapor-cooled current leads, as shown in Fig. 2.

The SMPW was tested at NSRRC to evaluate its performance such as superconducting and cool-down behaviours, static heat load and magnetic field quality. During the first cool-down at NSRRC, the maximum training current achieved is 269 A. During the second cool-down at SLRI, the maximum training current of 266 A, which is 5% above the nominal current of 253 A, was achieved. Training performance of the SMPW tested at SLRI is shown in Fig. 3. Temperatures of the cryostat, magnet arrays and current leads were also monitored and confirm a consistency between the two cool-downs. Static heat load of the SMPW is 2.2 W measured at NSRRC and 2.0 W measured at SLRI. These are corresponding to an approximated liquid helium consumption of 3.1 L/hr and 2.8 L/hr, respectively.

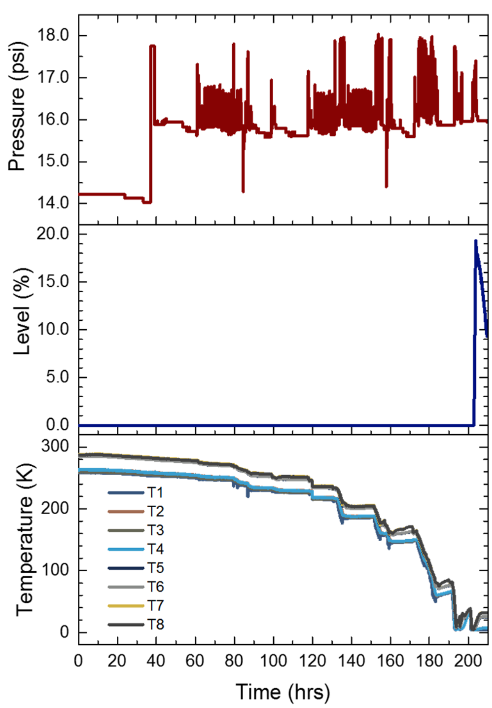

Figure 1: Liquid helium vessel pressure, liquid helium level and temperature inside the cryostat of SMPW during the cool-down process performed at SLRI.

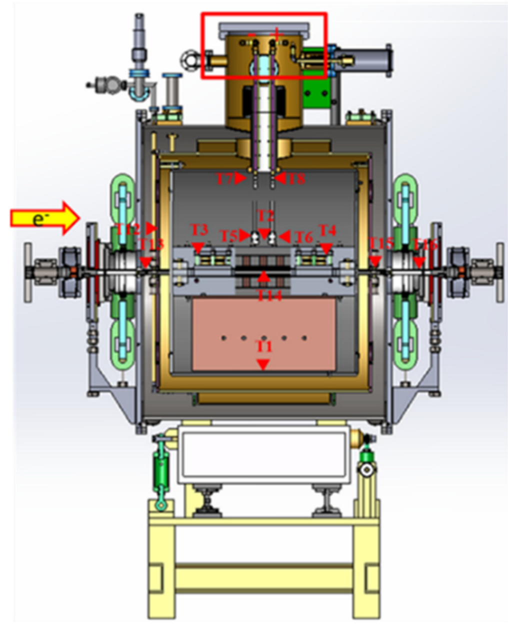

Figure 2: Position of temperature sensors within the cryostat of SMPW.

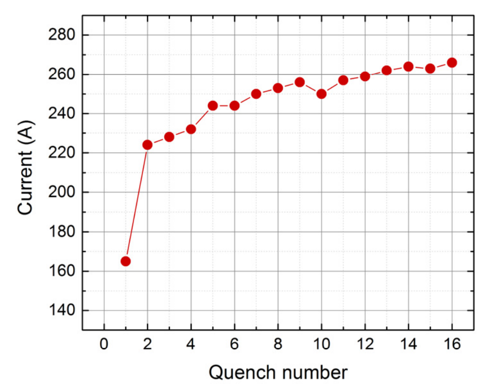

Figure 3: Training performance of SMPW.

Commissioning of SMPW in the storage ring of Siam Photon Source was performed at 1.2 GeV full energy injection. The process is not difficult compared to the commissioning of 6.5 T SWLS and 2.2 T Multipole Wiggler in 2013 [2]. The beam can be injected at the nominal SMPW field of 3.5 T without any effect on the injection efficiency.

Influence of the SMPW on electron beam dynamics was also measured. The betatron tune shift and closed orbit distortion were observed. They can be minimized by adjusting the magnetic field of quadrupole magnets in the matching cell near the SMPW, the two main quadrupole families and the horizontal/vertical correctors installed at the upstream and downstream. Detailed commissioning results of the SMPW with electron beam are reported elsewhere.

ISBN: 978-3-95450-214-1 ISSN: 2673-5490 doi:10.18429/JACoW-IPAC2021-TUPAB375

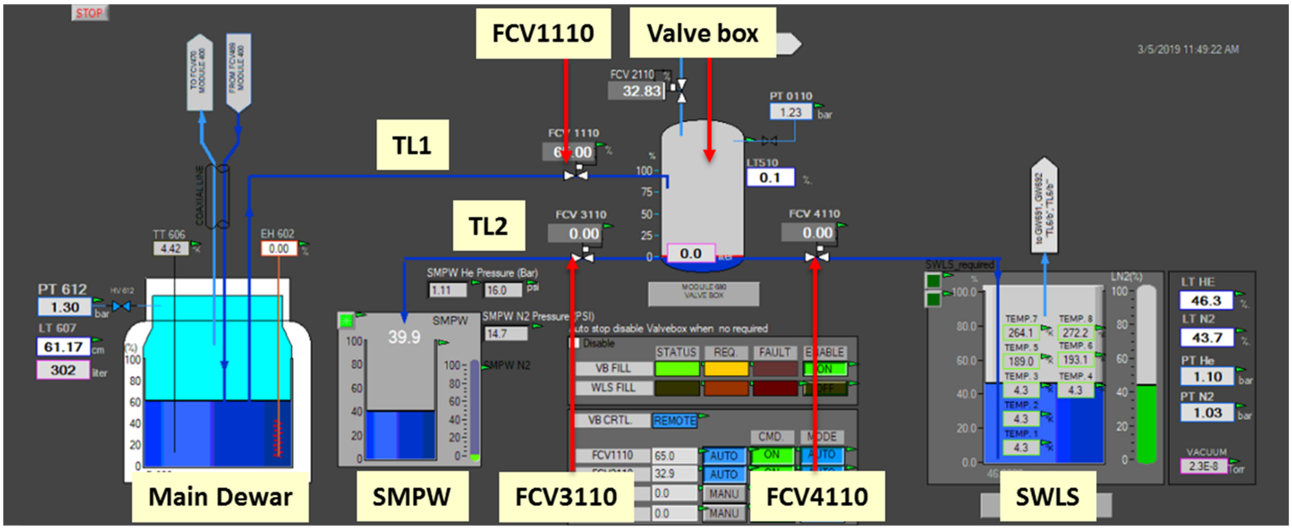

Figure 4: Schematic diagram of liquid helium supply at SLRI.

OPERATION AND MANAGEMENT OF LIQUID HELIUM

In order to safely operate the vapor-cooled current leads, temperature and voltage across the current lead are monitored and added to the interlock system. The voltage across the current lead must be less than 0.15 V and the temperature at the bottom end must be lower than 25 K. This is to ensure that the Nb_3Sn/Cu bus bar between the current lead and the magnet arrays is operated in the superconducting state. Process for liquid helium filling was optimized and it was found that the maximum current lead temperature at the bottom end can be controlled below 25 K and the maximum voltage rise across the current lead is below 10 μV at the nominal current of 253 A. The filling process is set to start when liquid helium level falls below 80% and stop when the level reaches 95%. As a result, the superconducting magnet and protection diodes will be always immersed in liquid helium. In addition, the filling valve is controlled such that the pressure inside liquid helium vessel is between 1.05 to 1.18 bara.

Figure 4 illustrates the diagram of liquid helium supply at SLRI. Liquid helium from helium liquefaction system is kept in the main Dewar and transferred to one of the two superconducting insertion devices using the valve box. The process of liquid helium filling for the SMPW is as follows.

1. The transfer line between the main Dewar and the valve box (TL1) is pre-cooled with liquid helium.
2. The valve box is cooled with liquid helium. Liquid helium level in the valve box increases.
3. The CRYOFLEX® transfer line (TL2) is pre-cooled with liquid nitrogen.
4. The valve FCV3110 is slowly opened.
5. Liquid helium level in the SMPW increases. Liquid helium level in the valve box reduces to zero.

During each filling, 30.3 L of liquid helium is filled into the magnet. With the consumption of 2.8 L/hr, the SMPW needs to be filled every 10 hours. On the other hand, the SWLS operated at 308 A needs liquid helium filling every 15 hours. It is important to manage the filling efficiently and we have avoided filling of the two magnets at the same time.

CONCLUSION

The 3.5 T SMPW designed by NSRRC was successfully tested and installed in the storage ring of Siam Photon Source before commissioning with electron beam. The effect of SMPW on electron beam dynamics was observed and it can be minimized by using quadrupole magnets and horizontal/vertical correctors.

Magnet training of the SMPW was still required even after the second cool-down. The maximum training current achieved 5% above the nominal operating current after 16 quenches. Cool-down and training performance is consistent with that performed by NSRRC. Liquid helium filling procedure was optimized such that the current lead's temperature and voltage drop are within the safety limit of operation.

ACKNOWLEDGEMENTS

The authors are particularly grateful to NSRRC team, J. C. Jan, H. H. Chen, F. Y. Lin, C. H. Chang, C. S. Hwang and G. H. Luo, for a great collaboration and support throughout the project. In addition, many thanks to SLRI team for the good teamwork during installation and commissioning.

REFERENCES

[1] J. C. Jan *et al.*, "Design of a 3.5 T Superconducting Multipole Wiggler", in *Proc. IPAC'17*, Copenhagen, Denmark, May. 2017, pp. 3564-3567. doi:10.18429/JACoW-IPAC2017-WEPVA127

[2] P. Sudmuang *et al.*, "Commissioning of the 2.4 T Multipole Wiggler and the 6.5 T Superconducting Wavelength Shifter at Siam Photon Source", in *Proc. IPAC'14*, Dresden, Germany, Jun. 2014, pp. 1192-1194. doi:10.18429/JACoW-IPAC2014-TUPRO068