VACUUM SYSTEM FOR TPS BOOSTER

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Abstract

The booster of Taiwan Photon Source (TPS) is designed to have small beam emittance and full energy injection 3 GeV ramped up from 150 MeV. It is a synchrotron accelerator of circumference 496.8 m, located concentric with the electron storage ring in the same tunnel. The vacuum system for the booster is divided into six super-periods; each has nine chambers for bending magnets. The beam duct is made of thin stainless-steel tube extruded to an elliptical cross section of inner diameters 35 mm×20 mm and thickness 0.7 mm. All chambers will be supported on the inner wall of the tunnel. The straightness of the extruded thin chambers is controlled within 2.5 mm in length 4 m. The bending chamber is made by mechanically bending the straight tube. All beam ducts will be cleaned chemically before welding, with flanges or BPM chambers, to form the long chambers in the clean room before installation. The vacuum pumps are arranged to be distributed to fulfill an average pressure $<1\times10^{-6}$ Pa. The detailed design and the construction status are described in this paper.

DESIGN OF TPS BOOSTER

The booster in TPS is a synchrotron accelerator connecting the linear accelerator and the electron storage ring. Its circumference is 496.8 m; it is concentric with the storage ring in the same tunnel. The electron energy in the booster increases from 150 MeV to 3 GeV with great stability and small beam emittance.[1]

Vacuum Chamber

The vacuum pipe of the booster must conform to the cross section of the various magnets and the beam stay clear. The eddy currents, deformation on pumping and cost of manufacture should be minimal. The vacuum chamber is made of thin stainless-steel (304) tube extruded to an elliptical cross section of inner diameters 35 mm×20 mm and thickness 0.7 mm. The straightness of the extruded thin chambers is controlled within 2.5 mm in length 4 m. The bending chamber is made by mechanically bending the straight tube. Figure 1 shows the cross section of the quadrupole magnet with the vacuum chamber.

Lattice Period

The vacuum system of the TPS booster includes six lattice super-periods. Nine bending chambers (two of length 0.8 m and seven of length 1.6 m) at the bending section in one lattice period.[1] A long straight section includes an elliptical straight vacuum pipe, bellows and pumping chamber.

One period contains two short straight sections close to the entrance of the inner wall, and includes one standard round stainless-steel vacuum pipe and pumping chamber for convenience of maintenance. Two sector gate valves at the end of the section effect isolation from the bending sections.

The booster injection and extraction septum with its in-vacuum kicker are installed in sections one and six to connect the Linac to Booster (LTB) and Booster to Storage ring (BTS). The radio-frequency vacuum system is installed at the beginning of section four.

Ten beam position monitors (BPM) are installed near a quadrupole or corrector magnet in each period. The cross section of the BPM chamber is the same as the elliptical pipe for welding and impedance. The screen monitor is at the beginning of each section. The strip line kicker and fast current transformer are installed at section four.

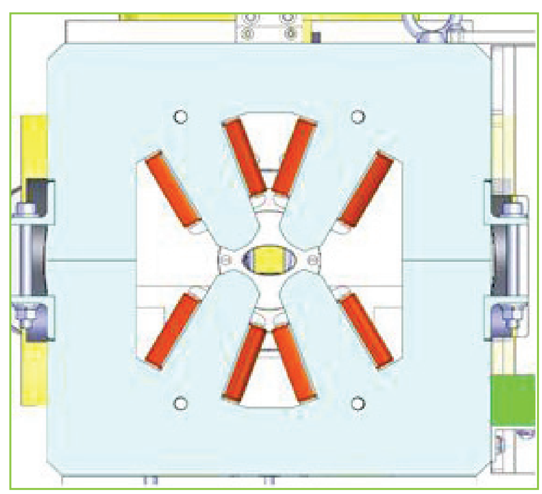

Figure 1: Cross section of the quadrupole magnet with the vacuum chamber.

Pumping Distribution

The pumping chamber is linked to each downstream of the dipole bending pipe. There are ion pump (150 L/s), turbo-molecular pump, cold-cathode gauge and all-metal angle valve on the pumping chamber. The ion pump (500 L/s) and NEG pump (350 L/s) are mounted on the in-vacuum kicker chamber.

Support of the Vacuum System

The support of the vacuum chamber is mounted on the inner wall of the tunnel. To diminish the effect of ferromagnetic materials on the electron beam, the support near the vacuum chamber is made of aluminum. The supports of the BPM and dipole magnet chamber not only can fix the chamber but also align the position. The deviation of the alignment should be less than 0.3 mm. The spring of the ion-pump support facilitates installation.

PROTOTYPE OF THE TPS BOOSTER VACUUM SYSTEM

The prototype of the vacuum system is part of the first lattice period of length 8.8 m as shown in Figure 2. It contains most of the main structure of the booster. The vacuum pipes, after chemical and ozonate water cleaning, [2,3] were welded with the flange and BPM chamber to form a complete straight chamber as shown in Figure 3.

The vacuum system was roughing through the pump chamber (Figure 4) equipped with one turbo-molecular pump and a dry mechanical pump after the support alignment and assembly of the system. The three ion pumps were activated when the pressure was less than 1×10-6 torr and the turbo-molecular pump was isolated with a metal angle valve.

The pumping down curve is shown in Figure 5. The ultimate pressures without baking from upstream to downstream are 1.2x10-9, 7.9x10-9 and 3.7x10-9 torr respectively. The rate of outgas measured with a building up method are 2x10-8, 1x10-7 and 1x10-7 torr L/s. The ultimate pressure fulfills the criterion of the booster pressure (1x10-8 torr), but may improve by baking the system. The mass spectrum from a residual-gas analyzer appears in Figure 6. The major residual gases are water vapor, hydrogen, carbon monoxide, carbon dioxide and hydrocarbons.

The deformation of the BPM chamber welded to the elliptical tube is larger than expected. Since the vacuum pipe is thin and long, this deformation is difficult to control. A connection flanges between the BPM and the elliptical vacuum pipe may be adopted.

Figure 2: The layout of vacuum system for booster prototype.

Figure 3: The picture of straight chamber with BPM.

Figure 4: The picture of pumping chamber.

ISBN 978-3-95450-115-1

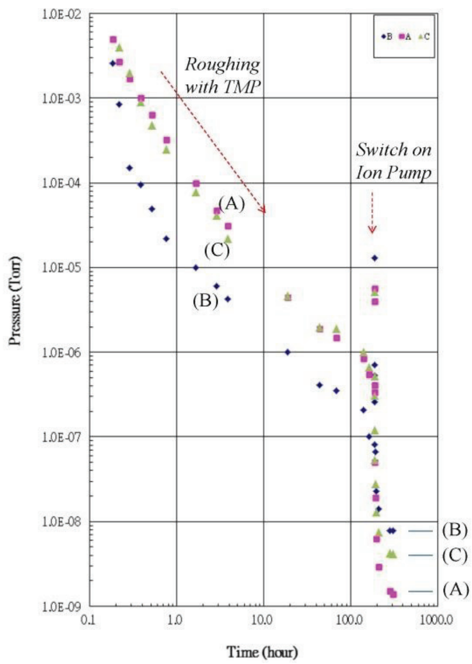

Figure 5: Pumping down curve for a prototype of the booster vacuum system near (A) upstream, (B) middle, and (C) downstream locations.

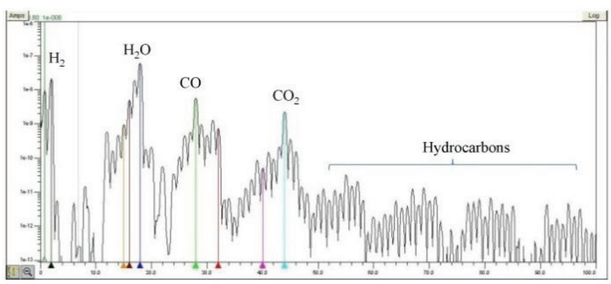

Figure 6: Mass spectrum for a prototype of the booster vacuum system.

CONCLUSION

The TPS booster is a synchrotron accelerator of circumference 496.8 m, designed for small beam emittance and full injection-energy of 3 GeV. It includes six lattice super-periods and nine bending chambers (two of length 0.8 m and seven of length 1.6 m) in each lattice period. From consideration of the cross section of the magnet to ensure that the beam stay clear, eddy currents and deformation on pumping, the cross section of the elliptical stainless-steel pipe is 35 mm×20 mm and thickness 0.7 mm.

There are ion pump (150 L/s), turbo-molecular pump, cold-cathode gauge and all-metal angle valve on each pumping chamber. The vacuum chamber of the booster prototype will be cleaned chemically and with ozonate water prior to the installation. The ultimate pressure may attain 10-9 torr with baking.

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