PROGRESS OF CONSTRUCTION OF THE TPS VACUUM SYSTEM

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Abstract

The construction of a vacuum system for the 3-GeV Taiwan Photon Source (TPS) was begun in 2010. The critical components such as bellows and gate valves with rf-contact shielding, pulsed magnet-kicker ceramic chambers, BPM, crotch absorbers etc. have been manufactured and tested. Aluminium-alloy (Al) vacuum chambers for the arc-cells have been machined and are undergoing welding in house. Mass production of vacuum equipment including ion gauges, ion pumps, NEG pumps and gate valves, has been contracted, with partial delivery following the schedule of the cell assembly. Assembly of each cell that contains two short Al straight chambers and two Al bending chambers has begun, and assembly and welding of the pre-aligned girders in a clean room on site to form a one-piece vacuum vessel of length about 14 m followed by baking under ultra-high vacuum are under way. The progress of developing a prototype and the status of construction of the TPS vacuum system are described in this paper.

INTRODUCTION

Taiwan Photon Source (TPS) will provide a low-emittance 3-GeV synchrotron light source. The vacuum system in the TPS electron-storage ring comprises 24 unit cells of which each has two bending chambers and four straight chambers. Aluminium alloy is chosen as the material of the 48 bending vacuum chambers. An aluminium bending chamber (length about 4 m) of this large size has these advantages [1]: (1) a large triangular chamber confines almost all sources of outgassing, which arises from photon-stimulated desorption (PSD) inside the bending chamber; (2) absorbers located as far from the photon beam source as practicable decrease the heat load on the absorbers; (3) vacuum pumps arranged in an antechamber and near the most important sources of outgassing increase the effective pumping speed and decrease the numbers of on-axis pumping ports.

The primary motives of choosing aluminium as the material for the vacuum chamber are the large thermal conductivity, ease of machining, small rate of outgassing, and experience over 15 years of fabrication in-house in Taiwan Light Source (TLS) at NSRRC. To make the vacuum chamber passively safe to dipole radiation at maximum operating beam current (400 mA), the vacuum chamber must withstand the radiation power loss, which is 7.11 kW per dipole (about 54.3 W/mrad) [1]. There are several exclusive designs in the construction of the TPS vacuum system. These designs must meet important performance criteria, namely:

1. Surface cleanliness to ensure the chamber's UHV surface conditions,
2. Dimensional control to minimize the RF-impedance,
3. Fewer flanges installation for lower beam impedance,
4. 14-meter one piece vacuum vessel,
5. Confined pumping with ante-chambers,
6. Oil-free pumping configuration,
7. Low reflection for Beam Position Monitor (BPM) design.

By following the above design considerations, they make TPS vacuum system unique from other accelerators. Both the conceptual design of the TPS vacuum system and the status of its construction are described in the following sections.

CHAMBER FABRICATION

Oil-Free CNC Machinging

Figure 1 illustrates the layout of the vacuum system in a one-unit cell. This unit cell of a vacuum system comprises two straight chambers, two bending chambers and other components, such as bellows, beam-position monitors (BPM), pumps, ion gauges, gate valves etc. Aluminium alloy (A6061-T651) is used as the chamber material, and CNC oil-free machining is applied throughout the entire fabrication. Each bending chamber consists of two plates as a clam-shell type. A CNC machine is used to fabricate the bending chambers. The working environment is in a clean area with little dust and the ambient temperature is controlled at 25 °C with less than 50 % humidity. Instead of conventional oil lubrication during machining, ethanol serves to cool the cutting tools and to protect the aluminium surface from oil contamination. The measured surface flatness of the aluminium plates after machining is less than 0.1 mm over length 4 m. The results of this machining show surface roughness, flatness and deformation of high quality throughout the entire process.

Cleaning with Ozonized Water

After machining, the plates are cleaned with ozonized water. Cleaning with ozonized water is an alternative process to remove surface contamination in the manufacture of bending chambers, before welding and assembly. In particular, this process promises to be significantly more environmentally benign than chemical

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etching procedures. Much research has revealed that ozone is effective to remove carbon from the surface [2] [3]. Ozonized water provides an effective solution for cleaning the bending chamber. An experiment of PSD was conducted with varied cleaning treatments. Figure 2 shows the relation of PSD vs. the accumulated beam dosage. The smallest yield of photon desorption, $\eta_B \sim 2 \times 10^{-5}$ molecules/photon at a beam dose of 1Ah, was attained with ethanol-CNC machining and cleaning with ozonized (30 ppm) water.

Both fabrication and cleaning of straight chambers differ from those of bending chambers. All straight chambers are made by aluminium extrusion, which is the preferred method to manufacture continuous shapes of a complicated profile. After the straight chamber is made, a conventional chemical cleaning with strong alkaline etching is applied to remove surface contamination and to produce a fresh oxide layer.

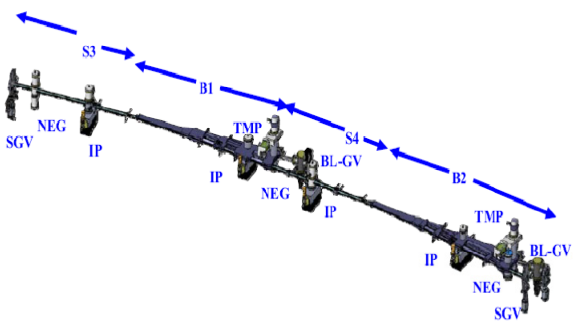

Figure 1: Assembly drawing of a vacuum system in one unit cell, excluding S1 and S2 chambers.

Automatic Welding

After the bending chambers are cleaned with ozonized water, the chambers are moved to a welding room that is a clean room of class 1000 with the temperature controlled at 25 °C and less than 50% humidity. The welding work is separable into two parts: one is the manual welding of pumping ports, curved sides, end ports and cooling tubes, and the other involves automatic welding. An automatic welding system has been developed to weld both nonparallel straight sides, with six torches ignited simultaneously. This automatic welding system has a XY stage that is built and configured to provide high-performance positioning along multiple welding axes [4]. The system comprises six welding torches to implement simultaneously two longitudinal, nonparallel side welds of an aluminium chamber. This automatic welding system, which has been developed in NSRRC, is an innovation using computer-based software to control the welding movements, and six torches precisely outputting welding energy. The welding parameters, such as the speed, current and rate of feed, are controlled with LabVIEW. Together with the six-torch welding and clamp-free method, this welding system can provide a condition of decreased distortion and minimal residual stresses through the symmetrical welding process.

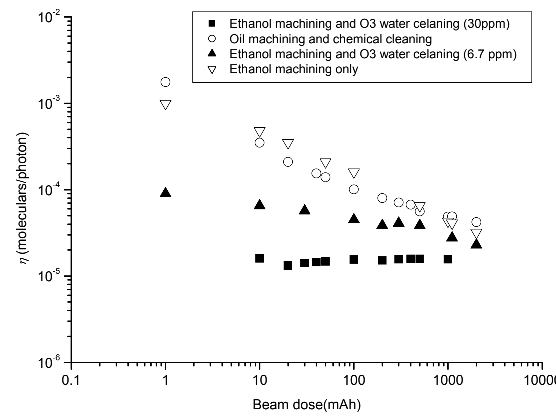

Figure 2: Photon-stimulated desorption (PSD) results with various surface treatments.

VACUUM COMPONENT CONFIGURATION

The TPS vacuum system comprises 24 unit cells. Figure 1 shows the layout drawings of a typical vacuum system for one cell of the vacuum system. Each cell contains two sector gate valves with RF contact shielding (SGV), six ionization gauges (IG), ten non-evaporable getter (NEG) pumps, eight sputtering ion pumps (IP), and eight turbomolecular pumps (TMP). The vacuum chambers inside the cell contain two short S-ducts of S3, S4, and two B-ducts of B1, B2. The S1 and S2 S-ducts are on both ends of the cell isolated with the two SGV.

A notable point is the impedance of the vacuum system that can influence the electron beam, the so-called broadband impedance. To decrease this impedance, RF-contact structures must be considered for use in those discontinuous cross sections of the beam duct. For all metal gate valves, 48 in total, a RF-comb type contact finger of VAT Series 47 is adopted, shown in figure 3. Another component that might cause impedance is the bellows. The number of bellows is decreased to 48; they are welded directly to the bending chambers. This practice also minimizes the quantity of flanges in the ring and also decreases the impedance. For the design of bellows, contact fingers are pressed with springs to ensure that the contact finger can touch the arbitrarily shaped inner wall. Figure 4 indicates an actual inside view of the bellows used in the storage ring.

The target pressure of TPS to be achieved in the presence of the maximum beam current is about 1×10^{-7} Pa, which requires a rate $q < 1.3\times10^{-10}$ Pa m/s of thermal outgassing, and a yield $\eta < 1\times10^{-6}$ molecules/ photon of PSD [1]. TPS pumps, composed of sputtering-ion pump (200 L/s) and the lumped pumps (GP500 MK5 St707 NEG, 350 L/s) are installed near the crotch absorbers and the beam ducts for an efficient pumping configuration. The NEG is effective to pump the major outgases H_2 and CO, whereas the ion pump is helpful to pump all gases especially CH_4 and noble gases He, Ne, Ar. Figure 5 shows the optimized pressure 4.9×10^{-9} Pa that has been achieved after baking in the laboratory. The pressure of the ring is monitored with extractor gauges; these gauges are installed at the same pumping port as the ion pumps. Each gauge is separated about every 3 m. With this interval, the pressure can be monitored separately in both straight and bending chambers. A residual-gas analyzer is also installed in every unit cell for further advanced vacuum monitoring.

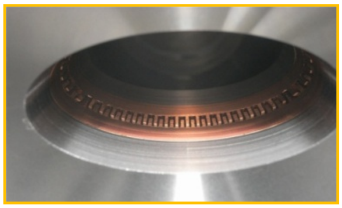

Figure 3: Sector gate valve with come type finger.

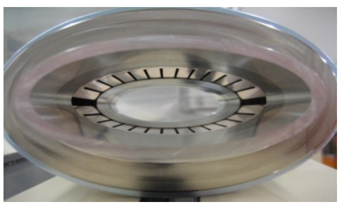

Figure 4: Bellows with RF-finger.

In addition to the vacuum chamber assembly, the entire unit cell is transported to the tunnel with a carrier without venting to the air. Figure 6 shows the carrier that has been recently verified to transport the unit-cell vacuum system. The advantage of this design is to diminish the installation time. All 24 cell vacuum vessels can be prepared and pre-baked in the laboratory in advance to save time and manpower for assembly in situ and baking in the tunnel. Thereby, this carrier not only provides a highly precise installation but also diminishes the baking in situ.

CONCLUSION

An innovative design concept at TPS is to connect two short straight chambers and two bending chambers using welding to make them into a one-piece vacuum vessel (length ~14 m), and only two bellows are also welded at the beginning of each bending chamber. Together with fewer bellows, this one-piece vessel possesses only two flanges that are located on both ends. This practice assists in decreasing the impedance and makes the vacuum system unique relative to other accelerators. Oil-free CNC machining, ozonized water cleaning, clean-room welding, RF-contact finger gate valves, RF-contact finger bellows, and a carrier (length 14 m) have been introduced in the vacuum system of the TPS storage ring. By means of the oil-free CNC machining and ozonized water cleaning, a minuscule rate of outgassing was obtained. Constructed with an autowelding system, welded chambers are verified to be free of leakage. To date, more than half the chambers have been completed and are ready for assembly. Moreover, three unit cells of the vacuum system have been assembled and placed in the storage area for future installation in the tunnel. A 14-m carrier was also tested for transport of the vacuum system. The unit-cell vacuum system can be completely assembled every three weeks, and all 24 cells are expected to be completed by the end of year 2012. According to the pumping data, all related manufacturing processes fulfil a promise of building a complete aluminium vacuum system for TPS.

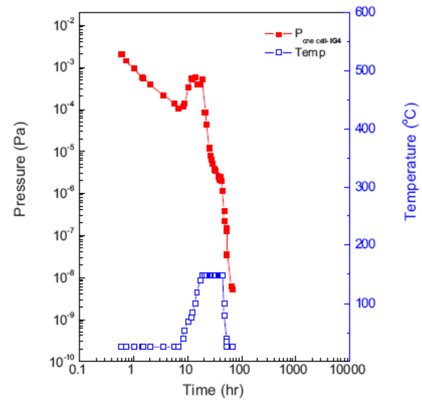

Figure 5: Pressure curve for unit cell vacuum system.

Figure 6: Photo of a one-unit cell carrier.

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