PRESSURE DISTRIBUTION OF THE TPS FE VACUUM SYSTEM

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Abstract

The front end (FE) is the primary area that shapes radiation power to conform to requirements for not only protection but also the beam-line users. A vacuum system (length about 14 m) connects the ultrahigh-vacuum storage ring to the beam line in Taiwan Photon Source (TPS). A fixed mask (FM), photon absorber (PAB) and slit are the major components with a large gas load, especially in insertion-device (ID) front ends, because of the synchrotron radiation. According to a formula P(pressure) = Q(outgas) / S(pump), the following issues are of concern to improve the vacuum: the small rate of outgassing of the vacuum chamber (Q_{TH}), the localization of the pumps (IP and NEG) to compensate for outgassing caused by photon-simulated desorption (Q_{PSD}), and the arrangement of the aperture and gas load. The basic distribution of pressure at the bending magnet (BM) and ID front ends is discussed.

INTRODUCTION

Taiwan Photon Source (TPS) is a 3-GeV synchrotron storage ring proposed for Taiwan. There are 48 bending sections designed for beam-line users, including 6 long straight and 24 standard straight sections. A front end, length about 14 m with masks, absorber, slits etc., is the bridge connecting the storage ring with the beam line. It not only shapes the synchrotron radiation to suit the requirements of a user but also protects the ultrahigh vacuum environment of the electron-storage ring. Figure 1 shows the layout of the ID front end [1]. All-metal gate valves (MGV) and quickly closing valves (FCV) are used to protect the vacuum, and sputtering ion pumps (IP) and lumped st-707 non-evaporable getter pumps (NEG) are installed near photon absorbers to increase the pumping efficiency. Stainless-steel materials are chosen for the vacuum chamber and GlidCop® materials as absorbers because of large thermal conductivity and equally high-yield-strength mechanical properties. In a typical front end, a fixed mask is the first region to produce desorption, PAB is the second, and the slit is the last one before the shielding wall. Table 1 lists the dimensions of the absorbers in the front ends. Decreasing the aperture size to shape the radiation power suits the beam-line user, but it is a big issue that influences the calculation of the pressure distribution because the conductance is limited.

Table 1: Dimensions of Absorbers at Front Ends

component	length /mm	upstream aperture H×V/ mm^2	downstream aperture H×V / mm^2
per mask	50	90 × 15	20 × 15
mask (BM)	50	20 × 15	90 × 15
mask 1	380	23 × 17	11 × 8.0
mask 2	380	15 × 12	11 × 8.0
PAB	450	30 × 12	30 × 12
slit 1	390	22 × 23	7.0 × 6.0
slit 2	390	22 × 23	7.0 × 6.0

PRESSURE CACULATION

We apply a continuity principle of gas flow to calculate the pressure distribution. The result of a one-dimensional algorithm is readily obtained with an iterative method. Figure 2 is a diagram of the principle of gas flow; we obtain the pressure in region dx according to Eq.1:

$$S_i P_i = Q_i + C_i(P_{i-1} - P_i) + C_{i+1}(P_{i+1} - P_i)$$

$$P_i^{(L)} = \frac{(C_i P_{i-1} + C_{i+1} P_{i+1} + Q_i)}{(C_i + C_{i+1} + S_i)} \quad (1)$$

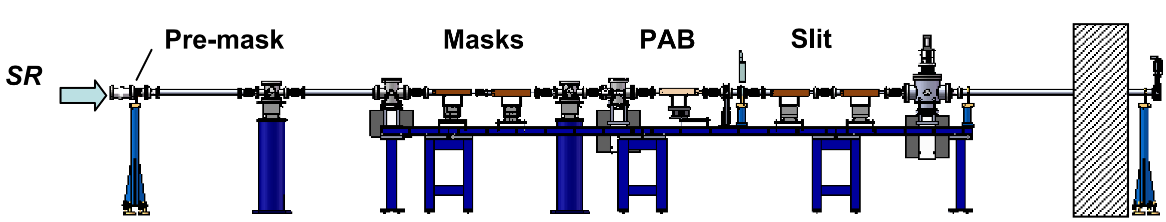

Figure 1: Layout of the insertion-device (ID) front end.

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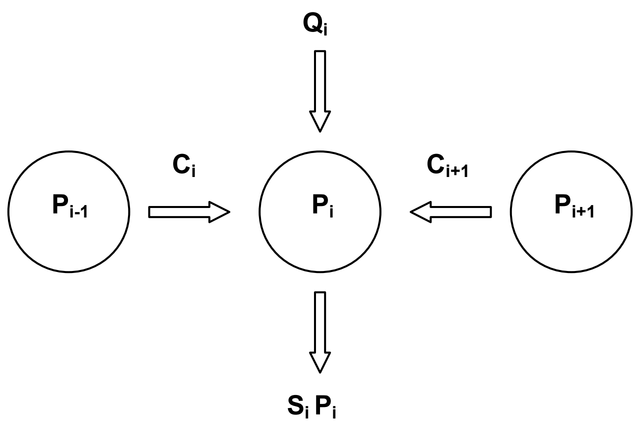

Figure 2: Equilibrium with the gas flow principle.

in which appear effective pumping speed S_i, pressure P_i and desorption rate Q_i, in region i, and C_i is the conductance between regions i-1 and i.

Gas Desorption

The rate Q of desorption includes thermal desorption (Q_{TH}) and photon-stimulated desorption (Q_{PSD}). Q_{TH} arises from the chamber wall and depends on the material. Stainless steel is the material chosen for the vacuum chamber, for which Q_{TH} is about 2.0×10^{-12} Torr L s^{-1} cm^{-2} near 300 K. Q_{PSD}, which is much greater than the rate of thermal desorption, is the major source of gas, and can be estimated [2]. A desorption coefficient η of value 1.0×10^{-5} molecules/electron is used to calculate Q_{PSD}.

Iterative Program Setting

Figure 3 depicts the layout of the iterative program diagram, in which S_i, C_i and Q_i need to be calculated and $P_i^{(0)}$ is first set as 1.0×10^{-9} Torr [3]. A sputtering ion pump and a non-evaporable getter pump, with effective pumping speeds 120 and 440 L/s respectively, serve as the principal pumps. The conductance C_i depends on the ratio of dx and D, the diameter of the vacuum chamber, because the conductances of the aperture, short tube and long tube differ. Here the size of dx approximated as D is used in various vacuum cross sections of the front ends.

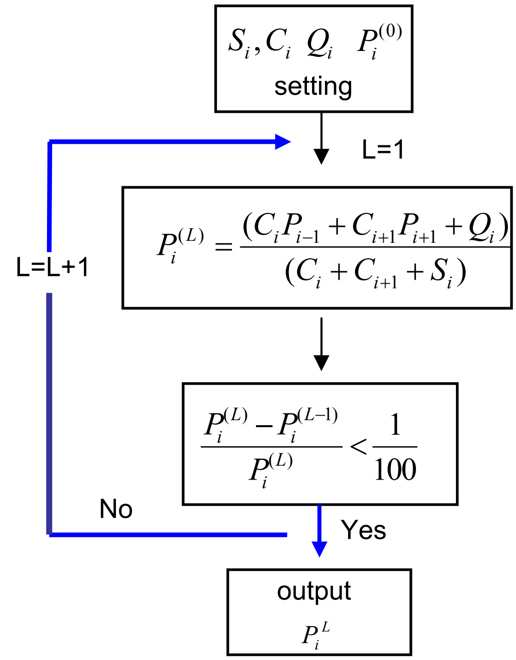

Figure 3: Schematic layout of the iterative program.

RESULTS AND DISCUSSION

Pressure Distribution of the BM Front End

In the BM front end, the pre-mask and mask were designed to accept the power radiated from the bending magnet. Vacuum tubes 100CF and 150CF serve as vacuum chambers. The conductance from a smooth and straight vacuum chamber is thus superior to that of an ID front end. The pressure distribution of the BM front end is shown in Figure 4; the greatest desorption occurs in the pre-mask region because it is stimulated by photons. The average pressure is 4.81×10^{-10} Torr.

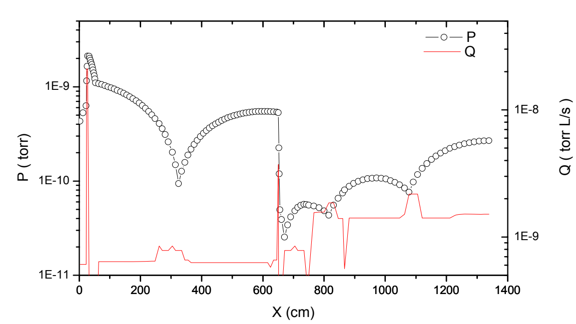

Figure 4: Pressure distribution of the BM front end.

Pressure Distribution of ID Front End

An outgassing rate, 5.23×10^{-6} Torr L s^{-1}, might be produced in the ID front end because of the power of insertion devices. Mask 1, mask 2 and the slit are the main regions accepting the radiation power then stimulating desorption. The conductance limits the pressure distribution according to Figure 5, which illustrates the cross-sectional distribution of the front end. The arrangement of desorption by power was done to avoid the gas load that is produced only in one region. Figure 6 is the pressure distribution for which radiation power is dispersed in mask 1, mask 2 and slit 1; the average pressure is 1.08 $\times 10^{-6}$ Torr.

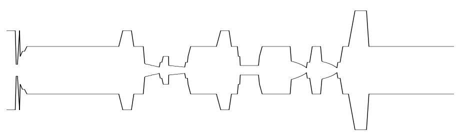

Figure 5: Cross section of the ID front ends

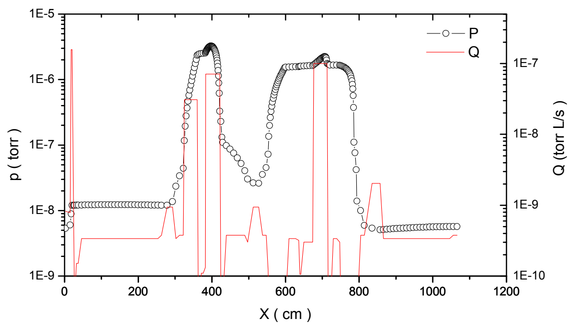

Figure 6: Pressure distribution of the BM front end

According to the formula P(pressure) = Q(outgas) / S(pump), increasing the pumping speed S or decreasing the outgassing rate Q decreases the pressure P. In the ID front end, the pressure is worst in the regions of large gas loads, which are also regions of poor conductance. Increasing the effective pumping speed to 500 L/s, adding pumps between regions of poor conductance and modifying the position of the absorber in the front end were done to improve the pressure distribution. Figure 7 shows the pressure distribution after modification; the average pressure is decreased to 8.44×10^{-8} Torr, which is an improvement.

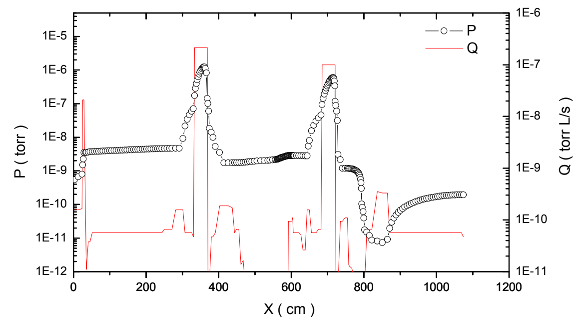

Figure 7: Pressure distribution of the ID front end after modification

CONCLUSIONS

The pressure distribution of the BM and ID front ends has been determined using the continuity principle of gas flow. The average pressure is 4.81×10^{-10} Torr in the BM front end and 8.44×10^{-8} Torr in the ID front end after modification. To improve the pressure distribution of the ID front end, the effective pumping speed was increased, pumps were added between regions of poor conductance and the positions of absorbers were modified. Another method or program will be used to verify and to reproduce these results in the future.

REFERENCES

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