DESIGN OF THE NEW DISTRIBUTED ION PUMPS FOR TRISTAN AR

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Abstract

The new DIPs (Distributed Ion Pumps) for TRISTAN AR were designed to improve the pumping speed. A considerable care was also taken to their simplicity and reliability. The cell diameter etc. were optimized using the empirical formula. The pumping speed was estimated as larger than 160 l/s/m at the pressure 4×10^{-9} Torr, which would lead the beam lifetime to be longer than 10 hours at the beam energy 6.5 GeV and the beam current 20 mA.

Introduction

In order to utilize regularly the TRISTAN AR (Accumulation Ring, TAR) as an electron positron collider and a synchrotron light source, in a future plan, the beams with longer lifetime and higher luminosity are essential and the reorganization of the present vacuum systems is now in the examination. This report describes the design of the new DIPs for the main pump of the TAR in relation to that problem.

In June 1989, the average pressure of the TAR is 2.1×10^{-8} Torr (the partial pressure of CO $P_{CO}=1.0\times10^{-8}$ Torr) at the beam energy E_b=6.5 GeV and the beam current I_b=20 mA. The beam lifetime τ_b was about 4 hours and is restricted by the pressure especially of CO. The pumping speed of the present DIP was estimated as 50 l/s/m at most. The DIP should have higher pumping speed first of all to improve τ_b. Set here the lowest level of τ_b to be 10 hours at E_b=6.5 GeV and I_b=20 mA, as a guide in the design, the pumping speed should be larger than 130 l/s/m at the pressure $P_{CO}=4\times10^{-9}$ Torr.

Design

Structure

Although the beam chamber has the curvature radius of 23 m, the straight unit of DIP with the length of 500 mm was designed to simplify the manufacturing. Five units are combined in a bending magnet.

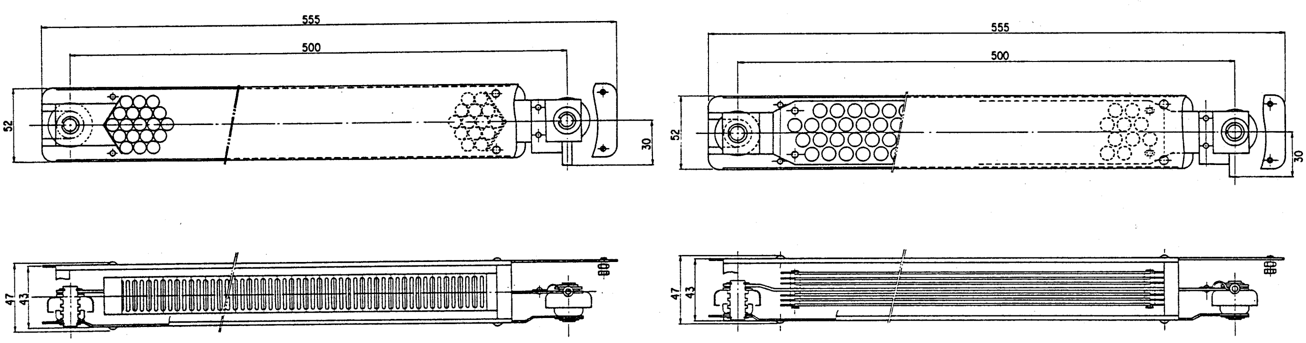
The two DIPs, Model 1 and Model 2, which have the different anode structures and cannot be compared with clearly by the calculation, are designed to select the best one. The one unit of Model 1 and Model 2 DIPs are shown in Fig.1(a) and (b), respectively. Model 1 has the traditional cylindrical cells, on the other hand, Model 2 has the perforated plates as an anode. The main parameters of Model 1 and Model 2 are listed in the Table 1.

The dipole type Penning cell was adopted because of its simplicity and easy handling. Furthermore, in order to add the higher reliability to the performance of the DIP than the present one, the more deliberate care, such as the elimination of any bolt in the assembling and no insulation between the cathode and the chamber etc., are taken in the design.

Table 1

The main parameters of Model 1 and Model 2 DIP.

	Model 1	Model 2
Type	Diode type	
Anode type	Cylinder	7 Plates
Materials		
Anode	Al 1050	
Cathode	Pure Ti	
Small Parts	SUS 304	
Length	500 mm/unit, 5 unit/magnet	
Size	47 h x 52 w	
Surface Area	8000 cm^2/unit	2800 cm^2/unit
Weight	100 g/unit	900 g/unit
Cell Number	220 /unit	140 /unit
Cell Diameter	9 mm	
Cell Height	26 mm	



(a) (b)

Fig.1 Structure of (a) Model 1 and (b) Model 2 DIP.

The anode is insulated from the cathode by the cylindrical ceramics at both ends. The ceramics is covered by the caps to protect the surface from the sticking of the sputtered metals. This ceramics are also used as a joint between the adjoining units.

The high voltage of 5.5 kV is supplied to the anode at one end of the combined DIP. The feed-through with the ICF034 flange is inserted to the multi-contact connector on the anode.

Materials

The anode material is Al 1050, which was chosen because of 1)low gas desorption rate after the baking of 150℃[1], 2)light weight and 3) easy manufacturing. The anodes receive the ultrasonic cleaning in the triethane bath and are cleaned in the concentrated nitric acid followed by pure water.

The cathode is composed of the pure Titanium. That was adopted because of their high activity to the active gases. The cathodes also receive the ultrasonic cleaning in the triethane bath and then cleaned in the pure water.

The ceramic insulator is 95% Al_2O_3. The ceramics are baked at 800℃ for about 15 minutes in the vacuum. The other parts of SUS 304 are cleaned in the ethanol bath.

After the assembling, the DIPs are baked in the vacuum at 150℃ for 24 hours.

Cells

The cell diameter was optimized using the empirical formula proposed by H.Hartwig et al.[2]. As is well known, the pumping speed increases as the magnetic field and reach the maximum at HMF (High Magnetic Field) mode. The smaller the cell diameter, the higher the magnetic field at the transition to HMF mode, B_{tr}. Then the cell diameter should be selected as small as possible maintaining the HMF mode in the operation range of magnetic field. For the TAR, the bending magnetic field varied from 3.6 kG to 11.5 kG together with the beam energy. We get the cell diameter d_a=0.82 cm from the formula using the parameter of B_{tr}=3.6 kG, the pressure $P=4\times10^{-9}$ Torr and the applied voltage u_a=5500 V. The cell diameter was fixed as d_a=0.9 cm finally considering the error in the welding or assembling.

The cells of model 1 are cylindrical Each cells are welded by the EBW (Electron Beam Welding). In order to enlarge the conductance the six narrow slits (2 mm x 22 mm) are made on the surface.

The cells of Model 2 consist of the 7 perforated plates. The DIP with the perforated plate anode is said to have larger pumping speed than that with the cylindrical anode[3]. It is also reported, however, that the small ratio of the cell diameter d_a to the gap between anode plates g_a gives the lower pumping speed than that of the cylindrical anode[4]. In the latter study, the pumping speed of the perforated plate anode was 1.3 times larger for $d_a/g_a=4$, but 0.4 times for $d_a/g_a=2$. In our design, d_a=9 mm and g_a=2 mm, the ratio d_a/g_a is larger than 4.

Estimation of the pumping speed

Gas loads

The main gas loads of DIP are the gas desorption from the chamber induced by the synchrotron radiation and the thermal gas desorption.

The gas desorption induced by the synchrotron radiation Q_p at 20℃ is given as[5]

$$Q_p = 3.9\times10^{-3}\ \eta\ I_b E_b/\rho, \qquad [\mathrm{Torr\cdot l/s/m}] \qquad (1)$$

where η:the quantum efficiency [molecules/photon], I_b:the beam current [mA] and ρ:the curvature radius [m]. If I_b=20 mA and $\eta=2\times10^{-5}$ are set, the gas desorption at each beam energy becomes as shown in Fig.2.

On the other hand, the surface area of the chamber and DIP at unit length is less than 1000 cm^2. Assuming the gas desorption ratio at room temperature as 1×10^{-12} Torr·l/s/cm^2, the thermal gas desorption Q_t is less than 1×10^{-8} Torr·l/s/m. Thus, we have only to consider the Q_p in the operation with beams.

Estimation of pumping speed

By the H.Hartwig et al., the pumping speed S_1 of one cell in the HMF mode is given as follows for N_2[2].

$$S_1 = 9.1\times10^{-4}\ \{1-1.5\times10^6 P/(1+4\times10^6 p)\} P^{0.1} l u_a \times \{1-1.5\times10^4\ (\sqrt{(B-B_{tr})} r_a P)/u_a\} \quad [\mathrm{l/s}]$$

$$\fallingdotseq 9.1\times10^{-4}\ P^{0.1} l u_a\ [\mathrm{l/s}] \quad \text{for } P<1\times10^{-7}\ \text{Torr}, \qquad (2)$$

where l:the cell height and r_a:the cell radius. The pumping speed of the ion pumps for the active molecules such as N_2, CO and CO_2 is almost equal except for H_2[6], and Eq.(2) can be used to the calculation for CO. The total pumping speed S_0 is given by

$$S_0 = N\ f_c\ f_s\ C \ \equiv\ S_a\ P^{0.1} \quad [\mathrm{l/s/m}], \qquad (3)$$

where N:the cell number per unit length, f_c=0.8:the factor including the structural conductance of IP[2] and f_s=0.75:the decrease due to the saturation[2]. The factor C is the one considering the effect of the perforated plate anode, and here C=1.0 for Model 1 and C=1.3 for Model 2.

Now we consider the practical system as shown below, where $Q_{ex}=Q_p+Q_t$:the gas desorption from the beam duct, Q_i : the gas desorption from the DIP, P_{ex}:the pressure in the beam chamber, P_i:the pressure in the DIP and C_s=500 l/s/m : the conductance of the slit between the beam duct and the DIP.

[Beam Duct]		[DIP] S0
Qex	Cs	Qi
Pex		Pi

Replace the P in Eq.(3) by the P_i, the effective pumping speed S_{eff} is given as follows.

$$P_i = \{(Q_{ex}+Q_i)/S_a\}^{1/1.1}$$
$$P_{ex} = P_i+Q_{ex}/C_s$$
$$S_{eff} = Q_{ex}/P_{ex}. \quad (4)$$

Figures 3 and 4 show the S_{eff} and P_{ex} calculated for the gas load given in Fig.2 assuming the thermal gas desorption ratio as 1×10^{-12} Torr·l/s/cm^2. The parameters used for the present DIP is N=86, C=0.4 and the surface area is 2300 cm^2. In the operation with beams, the pumping speed of Model 1 is larger than Model 2because of mainly the difference of cell number. On the other hand, at the base pressure, that is, the pressure below 3×10^{-10} Torr where the thermal gas desorption is dominant, the small surface area gives

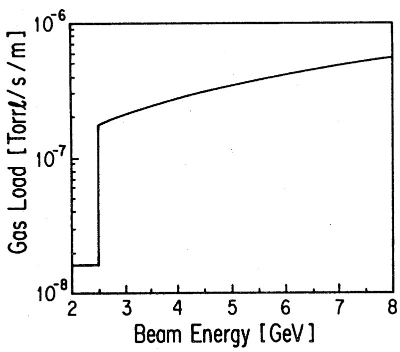


Fig.2 Gas loads of TAR at I_b=20 mA.

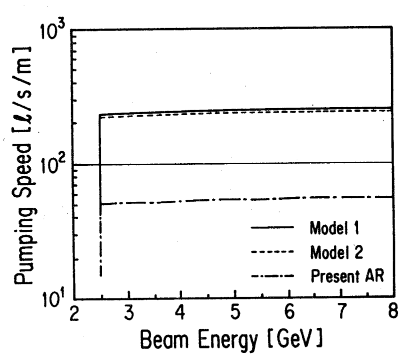


Fig.3 Calculated pumping speed for each DIP.

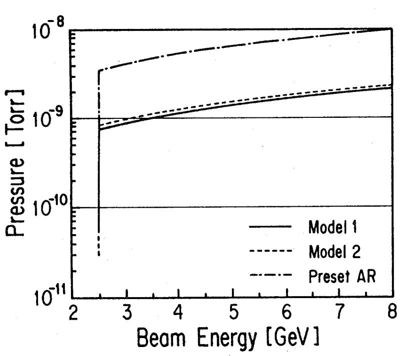


Fig.4 Calculated pressure in the beam duct for each DIP.

Model 2 the larger pumping speed. It is found any way that the calculated pumping speed of nearly 200 l/s/m can be obtained for each DIPs at $P_{ex}=4\times10^{-9}$ Torr. Installed in the beam chamber actually, however, a part of the DIP is out of the uniform magnetic field region for the case of TAR. The estimated pumping speed of larger than 160 l/s/m can be obtained in the ring after all.

For the thermal gas desorption ratio of 1×10^{-11} Torr·l/s/cm^2, however, the pumping speed decreases rapidly below 1×10^{-9} Torr and the pumping speed at the pressure in concern decreases to nearly 150 l/s/m. Therefore, the baking of the chambers and DIPs is indispensable to get the sufficient pumping speed.

Comparison with NEG

Here, we compare the pumping characteristics of DIP with the NEG (Non-Evaporable Getter pump). The pumping speed of the NEG (St101, produced by SAES Getters) reaches as much as 1000 l/s/m just after the activation, but it decreases as absorbing the gas and become several hundred l/s/m after the absorption of 10^{-2} Torr·l/m[7]. For the TAR the gas load at E_b=6.5 GeV and I_b=20 mA is about 4×10^{-7} Torr·l/s/m, and the gas desorption reaches to 10^{-2} Torr·l/m after 7 hours. Thus we need frequent conditioning or activating of NEG, which leads to the shortening of the lifetime of that. The DIP is supposed to be more suitable for the main pump of the TAR than NEG.

Summary

The two-type new DIPs are designed for TAR to improve the pumping speed. The great care was also taken for their simplicity and reliability. The pumping speed calculated considering the thermal gas desorption gives that of larger than 160 l/s/m at the pressure 4×10^{-9} Torr·l/s/m, which leads the beam life time longer than 10 hours for the beam energy 6.5GeV and the beam current 20 mA. One of DIP out of two will be used practically after the bench tests.

Acknowledgments

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References

1. J.R.Chen, K.Narushima and H.Ishimaru, J.Vac.Sci.Tech. A3 (1985) 2188.
2. H.Hartwig and J.S.Kouptsidis, J.Vac.Sci.Tech. 20 (1982) 1010.
3. J.S.Chou, J.Vac.Sci.Tech. A5 (1987) 3446.
4. J.M.Laurent and O.Grobner, IEEE Trans.Nucl.Sci. NS-26 (1979) 3997.
5. C.Benvenuti,R.Calder and O.Grobner,CERN-LEP-VA/87-66.
6. S.L.Rutherford, Trans.10th.Natl.Vac.Symp.A.V.S. (Macmillan,1963) 185.
7. C.Benvenuti and F.Francia, J.Vac.Sci.Tech. A6 (1988) 2528.