IMPROVEMENT OF VACUUM SYSTEM FOR BEPC INTERACTION REGION

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Abstract

BEPC Interaction Region (IR) vacuum system is one of the most important parts in storage ring vacuum system, the performance of IR vacuum system affects directly the background of BES detectors for the high energy physics experiments, therefore it is very significant to improve IR the degree of vacuum. This paper puts forward the methods which are used to improve the vacuum degree of IR vacuum system through installing NEG pumps near the colliding point, and predicts the affects of installing NEG pump in IR vacuum system through calculation methods of both mathematics and monte carlo simulation. In the meantime, proves the feasibility of improving IR vacuum degree by adding NEG pumps in the experiments. By the improvement for BEPC IR vacuum system, the static pressure of BEPC interaction region has decreased from initial value of 8×10^{-8}Pa to 2.7×10^{-8}Pa.

1 INTRODUCTION

BEPC storage ring vacuum system requires a pressure lower than 4×10^{-7}Pa to obtain a beam lifetime of 8~10 hours. The main gas load of vacuum system is produced by interaction of synchrotron radiation with the chamber wall. Extruded aluminum chamber has been used for easy fabrication, high thermal conductivity and low outgassing rate etc.. Roughing down to approximately 10^{-4}Pa is achieved by $0.11m^3/s$ turbomolecular pump groups, The main pumping is preferably achieved with distributed ion pumps working in field of the bending magnets. $0.5m^3/s$ sputter ion pumps are provided for special sections such as RF cavities, electrostatic separators and physics experimental regions. $0.1m^3/s$ ion pumps are connected to vacuum system to keep a high vacuum degree while distributed ion pumps don't operate. The 240.4m of the vacuum system are subdivided into 10 sectors by means of RF all metal gate valves.

One of the main reasons that affect the efficiency of BES detectors is interaction of beam with gases. Beam-gas bremsstrahlung events lead to lose beam particles and make the background of the detector. Electron-nucleus events lead to spurious triggers and cause the background of detectors. Therefore it is quite significant to decrease the pressure of interaction region to protect the detectors from the backgrounds.

2 METHODS OF DECREASING IR PRESSURE

To achieve the ultimate pressure regime of 10^{-9}Pa in the interaction region a sputter-ion pump combination with TSP or NEG pump is needed. Most existing particle accelerators and synchrotron sources beam lines, and similar devices have used and are successfully using these combinations to obtain the maximum pumping speed and the ultimate pressure for all the gases species. To decrease the pressure of BEPC interaction region we may adopt the way adding titanium sublimation pumps or NEG pumps in the vacuum system of the interaction region. According to our experiences in Lab, titanium evaporates on the internal surface of the vessel of about 6×10^{-8}Pa, pumping effect of titanium is not very obvious. As long as adding liquid nitrogen in the external surface of the sublimation pump good results can be achieved. However, it is not easy to carry out for putting liquid Nitrogen in the outside surface of the pump shell during accelerator operation.

The main residual gases are H_2, CO, CO_2, CH_4 in the vacuum system of storage ring, while non evaporable getters have very large pumping for H_2 and CO, they may be made into the different shapes matching with the beam pipes which have distinct geometry and requirements. NEGs' characteristics of simple, vibration-free and hydrocarbon-free operation make them very attractive for the vacuum system of storage ring. Therefore it is a good method used to improve the degree of vacuum of BEPC interaction region by installing NEG pumps in the vacuum system of interaction system.

3 THEORETICAL CALCULATIONS

Most vacuum chambers have very large diameter, so one may think that the internal pressure of vacuum chamber is uniform. Nevertheless, as the vacuum system of the accelerator, the beam pipes are thin and long, for such a vacuum system we generally use linear pumps or lumped pumps to evacuate. Fig.1 shows pumping structure of vacuum chamber.

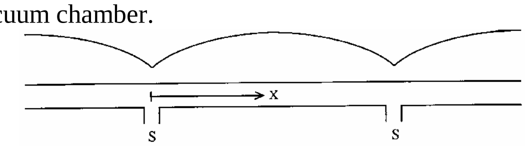

Fig.1 Pumping structure of vacuum chamber (bottom: chamber with pumping ports; top: pressure distribution)

One can use this simple model of vacuum system to obtain a rough insight into the performance of the pumping system. Assuming that the outgassing rate of all the vacuum chambers keeps constant and pumping gas stays stable for molecular flow regime. We define: the distance between pumps L(m), the effective pumping speed S(m^3/s), the pressure P(Pa), the specific molecular conductance C(m.m^3/s), the specific surface area A(m^2/m), the specific outgassing rate q(Pa.m^3/s.m^2), the gas flow Q(Pa.m^3/s).

The maximum pressure can be calculated

$$P_{\max} = Aq(\frac{L^2}{8C} + \frac{L}{S}) \qquad (1)$$

and the average pressure

$$P_{av} = \frac{1}{L}\int_0^L P(x)dx = Aq(\frac{L^2}{12C} + \frac{L}{S}) \qquad (2)$$

The pumping structure of the vacuum chamber in BES may be simplified into that of above L section. The colliding point is in x=L/2, and it has the maximum pressure. To decrease the pressure of the vacuum chamber in BES, it is a good choice to add the NEG pumps of large pumping speed as near BES as possible. Fig.2 shows the positions of the NEG pumps in the interaction region.

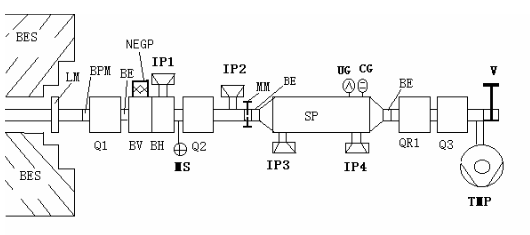

Fig.2 Distribution of 1/2 IR vacuum devices

From equation (1) can get the pressure of colliding point:

P_{max}=6.6×10^{-7}Pa

From (2) the average pressure of the vacuum chamber in BES:

P_{av}=5.6×10^{-7}Pa

In the condition not adding the NEG pumps in BES:

p_{max}=7.6×10^{-7}Pa

p_{av}= 6.6×10^{-7}Pa

Through the above calculation one can find the pressure of the colliding point decreases to 6.6×10^{-7}Pa from the initial value of 7.6×10^{-7}Pa after installing the NEG pumps, and the average pressure of BES chambers also decrease to 5.6×10^{-7}Pa from 6.6×10^{-7}Pa. The degree of vacuum was obviously improved near the colliding point.

Because there is a complicated structure in IR vacuum system, the above calculation is carried out through simplifying the irregular pipes into the standard shapes. In addition, the pumping speed of the pumps is not constant with the variety of the pressure. Especially the outgassing rates of IR vacuum chamber are related to the surface treatment, the period of exposure to atmosphere, humidity and temperature. So the above calculations are only approximate one.

We use the "pressure" program developed in CERN to carry out the simulation calculation for the pressure profile of IR vacuum system. Fig.3 shows computer simulation pressure distribution of IR vacuum chamber. The original point is the colliding point, 9.73m is the distance from the colliding point to the gate valve.

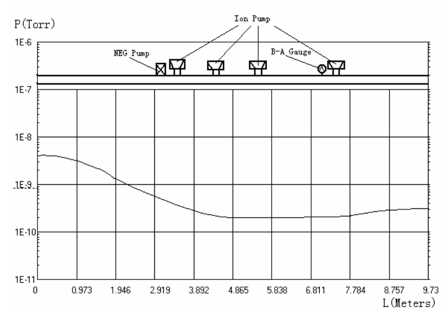

Fig.3 pressure distributions of IR chambers in Computer simulation

From the above curve one can find that the pressure of the colliding point is 5.5×10^{-7}Pa, it is similar with the result of the mathematical calculation of 6.6×10^{-7}Pa. The average pressure of the simulation calculation in BES vacuum chamber is 3.7×10^{-7}Pa, while that of mathematical calculation is 5.6×10^{-7}Pa. Because the above two kinds of calculation methods adopt the approximation to suit for the standard model, the error is inevitable, but for the vacuum system these errors are allowable. Fig.4 shows the pressure distribution of both with NEG pumps and without NEG pumps in BES interaction region. The upper curve is the pressure profile without NEG pumps and the down curve is that with GP 500 NEG pumps made of SAES getters company. From the figure one can know that the vacuum degree of the interaction region is improved obviously after adding NEG pumps.

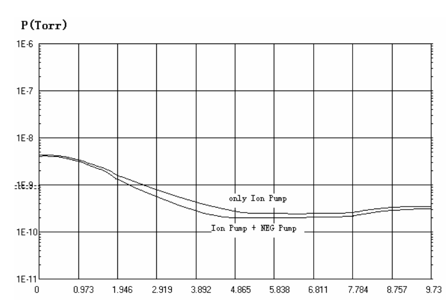

Fig.4 Comparison of pressure distribution between with NEG pumps and without NEG pumps in interaction region

4 Experimental results

We carried out baking of 48 hours for IR vacuum system at 200°C, the system was roughed with a turbomolecular pump group during bakeout. Fig.5 is mass spectra during

IR vacuum chambers baked, the main residual gases are H_2 and H_2O. A great deal of water molecules were adsorbed by the internal surface of the vacuum system exposed to atmosphere during the examining and repairing of BES devices, so the water molecules can be desorbed in high temperature and pumped off by the turbomolecular pump group. Other gases diffused from the surface of the vacuum chamber such as H_2, CO, CO_2 can be pumped off by turbomolecular pump group also. As the turbomolecular pump has relatively lower compression ratio for H_2 than for other gases the partial pressure of hydrogen is high.

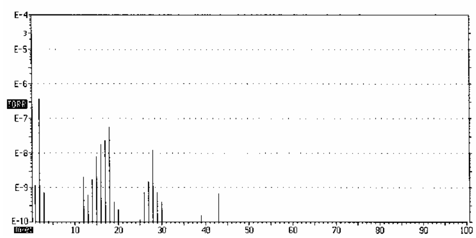

Fig.5 Mass spectra in interaction region during bakeout

The pressure of IR vacuum system has achieved 1.33×10^{-5}Pa after 48h of baking and pumping, then the NEG pumps were activated. Fig.6 shows the mass spectra during the NEG pumps activation, H_2 partial pressure raises obviously. This is because hydrogen doesn't form a stable combination with the getter alloy, some of the hydrogen sorbed at low temperature can be released at higher temperature. In addition, during the activation phase there is also a desorption of gases from the getter cartridge. This is due to the physisorbed gases which form the external monolayers covering the surface of the getter material, while the internal chemisorbed layers are diffused into the bulk of the getter material. Desorbed gases include H_2, H_2O, CO, CO_2 and CH_4 etc. In order to minimize the gases desorption, during baking the vacuum system, the getter cartridge should be maintained at a relatively higher temperature than other components of the system. This procedure minimizes the migration of the gases desobed from the wall of the system towards the getter cartridge which has a real surface area much larger than the vessel walls themselves.

After the NEG pumps were activated at the temperature of 450^0C for 50 minutes, we stopped the heating and switched on ion pumps. The pressure started being improved and went down to 3.6×10^{-8}Pa in 72h. The pressure kept on decreasing gradually and has reached 2.7×10^{-8}Pa in 10 days. Due to the limits of condition, only installing B-A gauges in the electrostatic separators to measure the pressure of the interaction region. But these measuring results are good agreements with that of monte calro simulation. Therefore, we may confirm that it is very effective for adding NEG pumps near the interaction point to decrease the pressure of the interaction region.

The mass spectra in the time when IR vacuum system arrived at the ultrahigh vacuum are showed in Fig.7. Through using combination of ion pumps with NEG pumps, the partial pressure of the residual gases in the system reduced obviously and IR vacuum system became fairly clean.

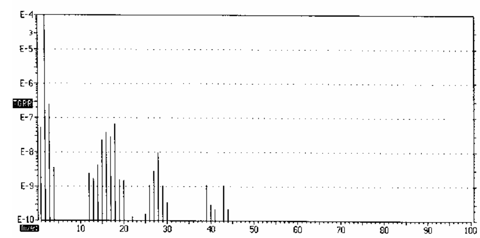

Fig.6 Mass spectra during NEG pump activation

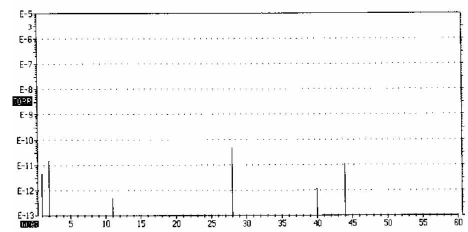

Fig.7 Mass spectra in the time when IR reaches ultrahigh vacuum

5 CONCLUTION

The performance of IR vacuum system has been improved by adding NEG pumps. We can find from the results of the measurement that the static pressure of the separator in the interaction region has decreased from initial value of 8.0×10^{-8}Pa to 2.7×10^{-8}Pa and the partial pressure of the residual gases has reduced also. This is very important for prolonging the beam life and cutting down the background of BES detectors. In addition, figuring out that the pressure of BES colliding point is about 6.0×10^{-7}Pa, while this pressure can meet the need of BES detectors completely.

ACKNOWLEDGEMENTS

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