PRESSURE PROFILES CALCULATION FOR THE CSRm AND BRing

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Abstract

A new large scale accelerator facility is being designed by Institute of Modern Physics (IMP) Lanzhou, which is named as the High Intensity heavy-ion Accelerator Facility (HIAF). This project consists of ion sources, Linac accelerator, synchrotrons (BRing) and several experimental terminals. During the operation of Bring, the heavy ion beams will be easily lost at the vacuum chamber along the BRing when it is used to accumulate intermediate charge state particles. The vacuum pressure bump due to the ion-induced desorption in turn leads to an increase in beam loss rate. In order to accumulate the beams to higher intensity to fulfil the requirements of physics experiments and for better understanding of the dynamic vacuum pressure caused by the beam loss, a dynamic vacuum pressure simulation program has been developed. Vacuum pressure profiles are calculated and compared with the measured data based on the current synchrotron (CSRm). Then the static vacuum pressure profiles of the BRing and one type of pump which will be used in the BRing are introduced in this paper.

INTRODUCTION

The HIAF project consists of ion sources, Linac accelerator, synchrotrons and several experimental terminals. The Superconducting Electron-Cyclotron-Resonance ion source (SECR) is used to provide highly charged ion beams, and the Lanzhou Intense Proton Source (LIPS) is used to provide H_2^+ beam. The superconducting ion Linac accelerator (iLinac) is designed to accelerate ions with the charge-mass ratio Z/A=1/7 (e.g. $^{238}U^{34+}$) to the energy of 17 MeV/u. Ions provided by iLinac will be cooled, accumulated and accelerated to the required intensity and energy (up to 1.4×10^{11} and 800 MeV/u of $^{238}U^{34+}$) in the Booster Ring (BRing), then fast extracted and transferred either to the external targets or the Spectrometer Ring (SRing). As a key part of the HIAF complex, SRing is designed as a multifunction experimental storage ring. A TOF detector system will be installed for nuclei mass measurements with isochronous mode. An electron target with ultra-low temperature electron beam will be built for Dielectronic Recombination (DR) experiments. Both stochastic cooling and electron cooling systems are considered to be equipped in order to provide high quality beams for experiments and compensate energy losses of internal target experiments. MRing is used for the ion-ion merging [1]. The layout of the HIAF project is shown in Fig. 1.

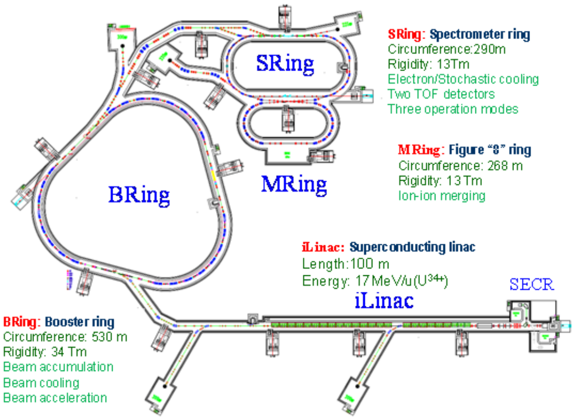

Figure 1: Layout of HIAF project.

CSRm VACUUM PRESSURE PROFILE

Static Pressure Profiles

The HIRFL-CSR complex consists of the main cooler storage ring (CSRm), Radioactive Ion Beam line (RIB) production and transfer line two (RIBLL2), experimental storage ring (CSRe), and experimental stations. The two existing cyclotrons, the Sector Focus Cyclotron and Separated Sector Cyclotron, at the Heavy Ion Research Facility in Lanzhou (HIRFL) are used as the injector system. The heavy ion beams from HIRFL are injected into the CSRm, then accumulated, electron cooled, and accelerated, before being extracted to the CSRe for internal target experiments and other physics experiments [2].

CSRm is a racetrack shape synchrotron that consists of four arc sections with the circumferences of 161.00 m. Each arc section is composed of four dipoles, five focusing quadrupoles, and three defocusing quadrupoles.

The total volume of the CSRm vacuum system is about 7200 L and the total inner surface is about 160 m^2 (not including the equipment inside the vacuum system). Sputter ion pumps (SIP) and titanium sublimation pumps (TSP) are selected as the main pumps, which are distributed in about 4 m along the rings according to the calculation. Sputter ion pumps with pumping speeds of 200~400 l/s remove non-getterable gases such as methane and argon. Titanium sublimation pumps have a high capacity for hydrogen at very low pressure, where the residual gas is mainly H_2 (90%). The pumps have an area of 5000 cm^2 of sublimated titanium and a pumping speed of approximately 2000 l/s for active gases [3].

The dynamic vacuum pressure calculation method which developed from the VAKDYN code [4] is implemented to calculate the equilibrium pressure profile for the CSRm. The newly developed simulation code is named as HIAF-DYSD. For the computation of the

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CSRm pressure profiles, the following parameters are used:

1. Along the CSRm, the beam pipe temperature is T=293 K.
2. There are two types of SIP and TSP at the CSRm, with the pumping speed of SIP1=200 l/s, SIP2=300 l/s, TSP1=1000 l/s and TSP2=2000 l/s for the hydrogen.
3. Operational experiences of many particle accelerators in the world suggests that, after the pretreatment mentioned above, the outgassing rate of the materials should be lower than $5*10^{-13}$ mbar*l/(s*cm^2) [3]. In this paper, the outgassing rate for hydrogen is assumed to be $7*10^{-13}$ mbar*l/(s*cm^2).

According the parameters mentioned above, the vacuum pressure profile for the CSRm is calculated and shown in the Fig. 2. With 8 gauges installed in the CSRm, measured vacuum pressure data was recorded and compared with the calculation result.

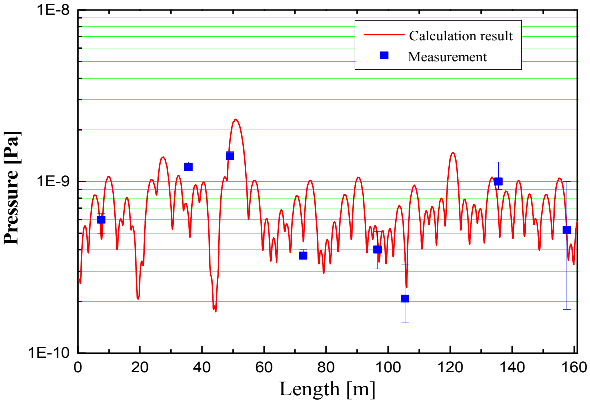

Figure 2: Static pressure profile for CSRm.

In the code VAKDYN and HIAF-DYSD, the Crank-Nicholson method is used to solve the differential equation that describes the pressure profile [4]. Another program (Bolide) which provided by Alexander Smirnov from Joint Institute for Nuclear Research (Dubna, Russia) is adopted to calculate the pressure profiles to do the comparison. The simulation result for the CSRm by using his code can be seen in Fig. 3.

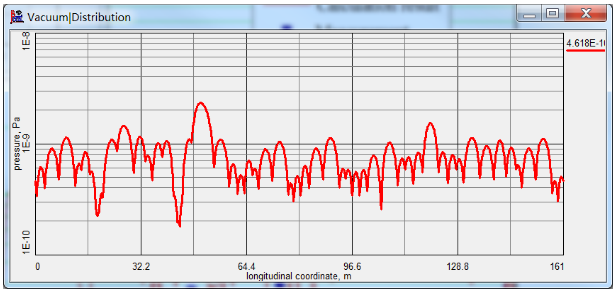

Figure 3: Static pressure profile for CSRm using Bolide.

According to the simulation result, the beam intensity is too low to make the vacuum pressure bump too much under the condition of high pump speed in the CSRm.

Dynamic Pressure Profiles

During the operation of heavy ion accelerator, the heavy ion beams are easily lost at the vacuum chamber along the ring when it is used to accumulate intermediate charge state particles. The vacuum pressure bump due to the ion-induced desorption in turn leads to an increase in beam loss rate [5]. The average dynamic pressure is calculated with the assumption that the heavy ion beams are lost continuously around the CSRm ring.

The uranium beam $^{238}U^{32+}$ that was accumulated in the CSRm in 2011 is chosen as the reference ion to simulate the beam loss distribution with the machine operation parameters. The desorption rate is assumed $2*10^4$ molec./ion as the input parameters for the ion-induced desorption part of the outgassing of the vacuum chamber walls coming from Lianc3 at CERN [6]. For the uranium beam, the number of the lost ions is $2*10^8$ ion/s. With the total surface 160 m^2, the total dynamic outgassing rate is estimated to be about $1*10^{-13}$ mbar*l/(s*cm^2). Dynamic pressure simulation for the hydrogen in the CSRm can be seen in Fig. 4.

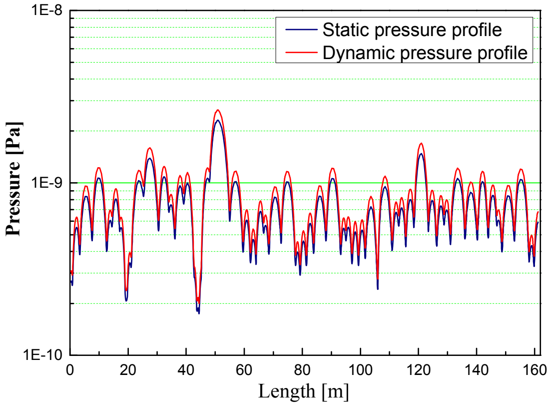

Figure 4: Dynamic pressure simulation for the CSRm.

BRing VACUUM PRESSURE PROFILE

Static Pressure Profiles

BRing is used to accumulate and accelerate ions provided by iLinac up to high intensities and energies. A two-plane painting injection system, which means that ions can be injected both in horizontal and vertical phase space simultaneously, is designed in order to get highly accumulation gain factor. Both fast extraction and slow extraction systems are equipped in BRing, in order to deliver ion beam to targets or experimental terminals.

The Booster Ring has a threefold- and mirror-symmetric lattice over its circumference of 530 m. Each super period consist of 8 DF structure arc and FODO straight sections. Sputter ion pumps (SIP) and titanium sublimation pumps (TSP) are also selected as the main pumps. The space between two dipoles is only 600 mm and not long enough to install normal TSP, therefore, a new type of pump NEXTorr will be installed in the limited space.

The NEXTorr D 2000-10 is an extremely compact pump which integrates sputter ion pump and NEG pump technologies with larger pumping speed (2000 L/s) and capacity to sorb gases. The getter cartridge is made of porous sintered getter disks stacked in a highly efficient gas trapping structure featuring pumping speed in excess of 2000 l/s (H2). The cartridge is integrated into a CF 100 flange containing heating elements for the getter activation [7].

With the defined pumping speed of TSP, SIP and NEXTorr, the static pressure profiles of BRing with 4 period sections can be seen in Fig. 5.

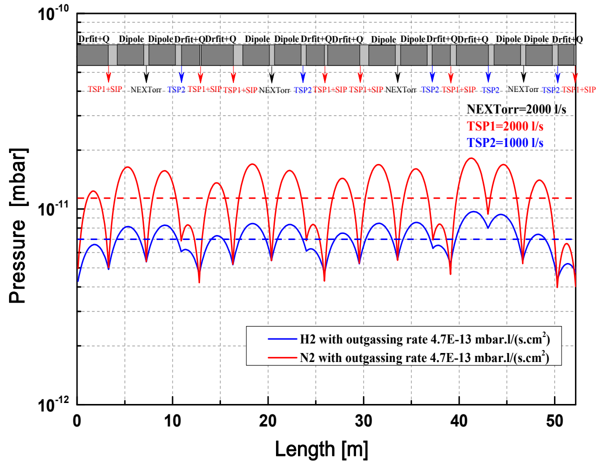

Figure 5: Static pressure profile for 50m part in BRing.

Setup to Measure Ion Induced Desorption Rate

The effect of ion-induced molecular desorption significantly influences the operation of low charge-state heavy ion accelerators and has an important impact on the design of future machines [8]. Therefore, an experimental setup to measure the ion induced desorption rate is designed and installed at the CSRm. Fig. 6 shows the layout of this setup.

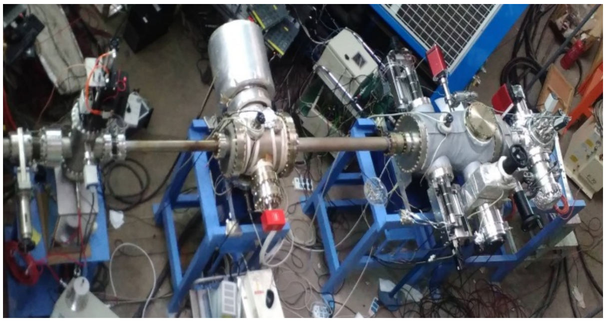

Figure 6: The layout of experimental setup.

This setup consists of three chambers: first chamber which installed an Integrating Current Transformer (ICT), Al_2O_3 fluorescence screen is used to measure the beam current and align the incoming beam; the second chamber which installed a TSP, SIP and NEXTorr is used to pump out the desorption gases; the experimental chamber is equipped with a pressure (extractor) gauge and a residual gas analyzer (RGA) to measure the total pressure increase and the partial pressure distribution during ion bombardment.

More beam test will be conducted in this setup to measure the ion induced desorption rate of different materials in the future.

CONCLUSION

The vacuum pressure profiles for the CSRm and BRing have been calculated by using the newly developed code. An experimental setup has been installed at the CSRm and will measure the ion beam induced desorption rate in the near future. Based on the simulation results and measurement data, the collimation system for the BRing is under designing.

ACKNOWLEDGEMENT

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