OPERATION STATUS AND UPGRADING OF HIRFL*

J.Y. Tang, Y.F. Wang and B.W. Wei
Institute of Modern Physics, Lanzhou 730000, China

Abstract

The operation status and the undergoing upgrading at HIRFL machine are presented. The accelerated ion species with the machine have been expanding, including metallic ions and higher energy with the new ECR ion source. The upgrading of HIRFL as the pre-accelerator of CSR storage ring has been processing steadily. The new 14.5GHz ECR ion source has been put in operation in early 1999. A full-superconducting ECR ion source of 18GHz is under design. The manufacture of the new vacuum chamber for SFC is just finished and the installation is to be started. The construction of the new B1 buncher is nearly to be finished, and the off-line test and the installation will be started soon. Another two identical bunchers will be ordered after the test. The beam distribution system is under upgrading to make all experiment stations separate from the others and the time-sharing mode possible, and a new cancer-therapy station is also under construction. The other upgrading items include the yoke enlarging of SFC, beam diagnostics, computer control and beam distribution system.

1 INTRODUCTION

With the completion of RIBLL radioactive beam line in 1997, HIRFL has been delivering its nearly half beam time to the radioactive beam physics. The new project CSR cooler storage ring has been approved officially in November 1999, the existing facility HIRFL will play as the injector and has to be upgraded when keeping the routine operation. By the year of 2004 when the CSR project is scheduled to finish [1], the beam intensity from the main cyclotron SSC should be increased 10 to 100 times (from light ions to heavy ions) compared with the present level, and the acceleration range should be extended from C-Xe to H-U. In order to increase the efficiency of beam utilization, the beam distribution system has to be upgraded. Each experiment station will be shielded from the others and from the trunk line. They will share the beam time among them and with CSR.

2 OPERATION STATUS

Since the last conference [2], the operation of HIRFL has been going routinely but with the acceleration range extended to metallic ions and heavier ions. Annual operation time is about 5000 hours in mean and the beam time for both experiments and machine studies is about 3000 hours in mean. The failure time has been increased slightly in the last years partially due to the aging of devices and partially due to more beam species, especially metallic ions. Usually every year there are two shutdown periods, one and half month in summer and half month in winter (Chinese New Year).

With the effort to increase the transmission efficiency of HIRFL and the putting into operation of the new ECR ion source (ECR3), the available beam intensity to experiments has been increasing for both light ions and heavy ions. For light ions, the routine beam intensities from SSC are around 100~300enA, and around 10~50enA for medium-heavy ions like Krypton, Xenon. The beam intensity from SFC varies from 5eμA for light ions to 200enA for Xenon.

3 INCREASING BEAM INTENSITY

Since the main object of CSR project is focused on radioactive beam physics, high intensities of primary beams are needed to get enough secondary beams. Therefore, HIRFL is required to deliver 3eμA for light ions and 10~50enA for heavy ions in order to get high ion accumulation in the CSR main ring. The experiments at HIRFL medium-energy experiment stations, especially RIBLL also ask for higher beam intensity.

For achieving the goals, the main upgrading effort should go to the increasing of the transmission efficiencies in all transfer sections of HIRFL, especially in the part of the main cyclotron SSC. Several key subsystems have been drawn out to be upgraded emphatically, such as the SFC vacuum system, rebunchers B1 and B2, SSC RF system etc.

The rebunchers B1 and B2 have been redesigned with new structure and new parameters [3], since the old ones don't work. Their function modes have been also redefined. The rebunchers work at different modes according to the beam energy to reduce the maximum voltage requirement in the case of high energy and to avoid the non-linearity in the case of low energy. The rebuncher B2 can be the auxiliary one with B1 to squeeze the phase length or be for the energy compensation as the energy matching between the two cyclotrons is very important. The first one of the two rebunchers has been finished the construction and is under parameter checking and the cavity-amplifier joint test. The construction of the second one should be started soon.

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The strong magnetic field leakage at SFC imposes serious problem to the transfer of very low energy beam in the axial injection line from ECR ion source to SFC. We have to put more time to tune the beam line, and the injection efficiency is reduced. The problem comes from the enlargements of the magnet pole diameter from 1.5m to 1.7m and of the magnet gap due to the introduction of sectors when the cyclotron was upgraded from a classical one to an isochronous one in 1984-87. The measurement and the MAFIA computation show about 10~20G stray magnetic field in the horizontal line and up to 300G in the vertical line. The chosen solution to take over the problem is to add 15cm thickness iron at the two sides of yoke (see Figure 1) and to put some magnetic shielding on the ceiling of the basement (where locates the ion sources and the injection line). The MAFIA computation shows that the stray magnetic field level should reduced to the one third or lower of the present case according to the main field level. The work will be taken in the period of replacing SFC vacuum chamber from June 2001 to May 2002.

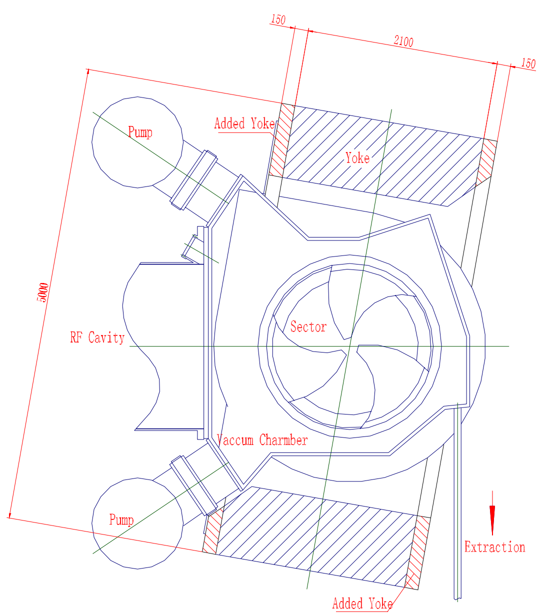

Figure 1. Schema for SFC yoke enlarging

The present RF system of SSC does not give the desired acceleration voltage and amplitude stabilization. That makes both the injection efficiency and extraction efficiency quite low. The turn separation at SSC injection in the case of harmonic two is only about 5~6mm as the Dee voltage is only about 60% of the designed value, and up to 40% of the beam is lost mainly due to this reason. The test study shows that many components of the two amplifiers have devalued their characteristics to well below the designed values since 15 years' operation, and decreased the total amplitude stabilization. We have to decide either to order two new amplifiers or to refit the present ones, and hope to increase the Dee voltage by 50% and amplitude stability from the present $\pm 1\times 10^{-3}$ to $\pm 2\times 10^{-4}$.

The other items to be improved for the reason of transmission efficiency are the residual first harmonic magnetic field component at the SSC injection region, the beam alignment and phase space adaptation in the beam lines.

4 TOWARDS VERY HEAVY IONS

In near future, HIRFL should be able to accelerate all kinds of ions, from proton to Uranium as the research fields expand at HIRFL-CSR. With only one injector SFC, it is some difficult to accelerate so large energy range (or charge to mass ratio range) always with good transmission efficiency. Two problems, low vacuum level and axial injection including the central region at SFC have to be solved. In order to get high possible energy, high charge state from ECR ion source has to be used; therefore, the vacuum level in SFC and its axial injection line is very critical. Due to its structure, it is not easy to establish the mean vacuum of 1×10^{-6}Pa in the acceleration region. A new SFC vacuum chamber with double vacuum levels, low vacuum zone and high vacuum zone, is being under construction [4]. Four big cryogenic pumps will be used for the pumping of the vacuum chamber and the big RF cavity.

In order to reduce the space charge effect, the SFC central region has been designed to inject the very heavy ions with bigger injection radius (3.6cm, namely bigger extraction voltage at the ECR ion source). Smaller radii (2.5cm and 3.0cm) are for light ions and medium-heavy ions. The central region takes also the advantage of potential RF voltage to give the total acceleration turn number small (about 50), and this will make the single turn extraction easy to achieve and reduce the beam loss due to the charge exchange in the vacuum.

5 HIGHER BEAM UTILIZATION EFFICIENCY

In order to increase the beam utilization efficiency, the beam transfer and distribution system is under upgrading. The experiment stations area is rearranged and all the experiment stations will be shielded from each other and from common areas (see Figure 2). They have been designed to share the beam time and even different kinds of beams. It is possible to transfer low energy beam from SFC and medium energy beam from SSC to the experiment stations at the same time by using pulsed bending magnets and pulsed quadrupoles [5]. With a second injector cyclotron PDC (Proton Dedicated Cyclotron, a 10MeV fixed energy commercial type cyclotron, under construction) connected to SSC, we can get low energy ion beams from SFC and 125MeV proton beam for experiments at the same time. The proton beam is asked for the study of “single particle event” in the spatial electronics.

The time-sharing method will take even more advantage in the future when CSR rings join in operation, as CSR needs beam for injection only 7s over 17s period.

A new station of “Cancer-Therapy Study by Heavy Ions” is being constructed in the basement at the same time. This is to use the maximum energy of 120MeV/u of Carbon beam for the clinical therapy study of superficial cancers. The penetration depth is about 30mm at maximum. The techniques developed here are expected to be adapted for the full body therapy with 430MeV/u of Carbon beam after CSRm will be completed in 2004. A study group including accelerator engineers, biologists and physicians is forming to push forward the program that is expected to begin the real beam treatment in 2002.

6 CONCLUSIONS

In order to match up the requirement of HIRFL-CSR project, HIRFL accelerator facility have been upgrading to augment the beam intensity (to get 10eμA@SFC and 3eμA@SSC for light ions), to extend the acceleration range (from C-Xe to H-U) and to increase the beam utilization efficiency (beam time sharing between experiment stations and different beams with sharing time), when keeping the routine operation in maximum. The upgrading emphases at the present stage are on the SFC vacuum, SFC yoke enlarging, the new rebunchers and the beam distribution system.

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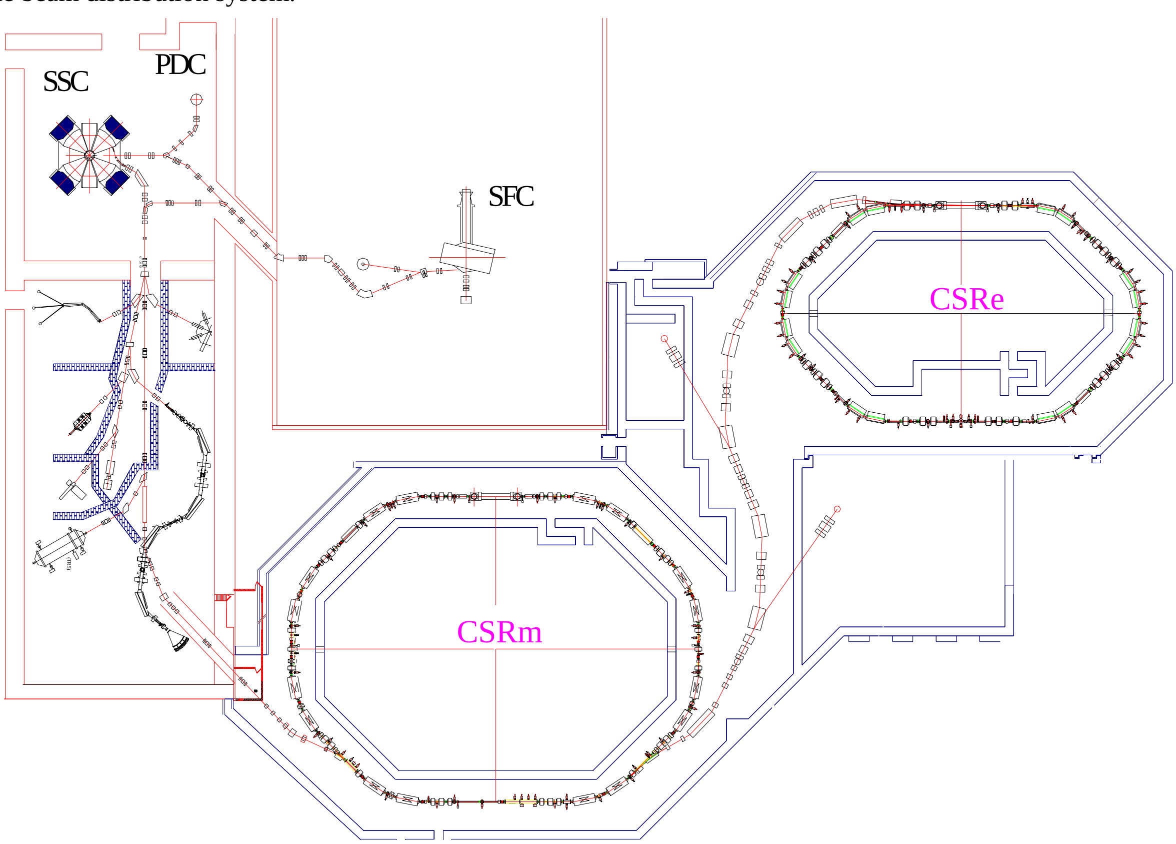

Figure 2. Layout of HIRFL-CSR