PROCEEDING OF HIRFL

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1. OUTLINE

The layout of Heavy Ion Research Facility at Lanzhou (HIRFL) is a cyclotron complex as shown in Fig.1. It consists of an ECR ion source, a short beam line between ECR and SFC, an injector SFC (Sector Focusing Cyclotron) with energy constant K=69, a pre-beam line, a main cyclotron SSC (Seperated Sector Cyclotron) with energy constant K=450, a post-beam line and 7 experimental devices as well as a bypass beam line used to transport low energy beam from SFC to the experimenal devices directly. Besides them, a Radioactive Ion Beam Line at Lanzhou (RIBLL) was constructed and operated in July of last year successfully.

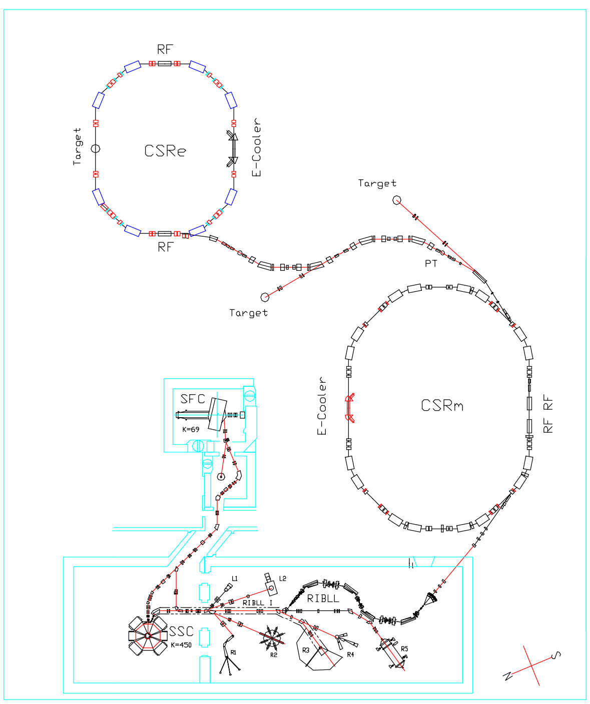

Fig.1 The layout of HIRFL, RIBLL and CSR

2. OPERATION STATUS

After the ECR ion source and corresponding beam line were ensembled in 1992, the cyclotron complex was running for physicists about 3500 hours each year. The running efficiency which is defined as the ratio of the beam time afforded to the physical experiments over the time of the total operation of machine is increased one year by one year and it is more than 75% now. Up to now more than 40 species of beam were running to physicists.

3. UPGRADE FOR HIRFL

3.1 Vector Resultant Phase Shifter

There are 6 sets of RF amplifier with different frequency region and power in RF system of HIRFL. The No.0 cabinet was added as a refrence phase to improve the phase stability of RF system. By using the vector resultant principle, a new 360^o phase shifter adjusted by microprocessor with phase resolution of better than $\pm 0.1^o$ has been developed and took the place of the mechanical phase shifter. As we know, the mechanical phase shifter has transient interruption of output signals in the process of shifting the phases of input signals. This short-term signal interruption could disturb the beam a lot in the accelerator. Furthermore, the mechanical phase shifter has some other shortages such as short lifetime, low reliability, large volume, etc. So it is necessary to use the vector resultant phase shifter instead of the mechanical one.

3.2 ECR Ion Sources

3.2.1 The Improvement of Existing ECR Ion Sources

Some improvements for the 10 GHz ECR ion sources on line have been done[1)]. The plasma electrode is made of aluminium instead of stainlesssteel. And it is moved towards the plasma chamber about 12 to 15 mm. A thin aluminium tube is put into the plasma chamber tightly so as to generate more secondary electrons. A new configuration of the axial mirror magnetic field and a new structure of the hexapole were tested. The results shown in Table1 indicate that the improvements are very effective.

Table1 Typical data of 10 GHz ECR ion sources

Ions	Beam Current (eμA)			
	ECR1 When Imported	ECR1 After Modified	ECR2 Trad. Mode	ECR2 New Mode
$^{40}Ar^{8+}$	110	220	245	430
$^{40}Ar^{9+}$	45	90	125	300
$^{40}Ar^{11+}$	10	40	25	80

3.2.2 The Construction of a New ECR Ion Source

In order to get the ions with higher intensity and higher charge states especially for the heavy elements and metal elements, a new 14.5 GHz ECR ion source (Fig.2) was designed, constructed and tested last year. There are high axial magnetic field (field peak 1.5 tesla) and radial hexapole field (1.0 Tesla on the chamber wall) in the ion source. A long plasma chamber with effective length 300 mm and double wall was particularly designed in order to increase plasma volume. Two kinds of configuration, one is the coaxial line, another one is the rectangular wave guide respectively, was considered in the ion source so that two microwave frequency heating could be tested. The preliminary results obtained on test bench by single 14.5 GHz frequency are shown as follows: O^{6+} 520eμA, O^{7+} 520eμA, Ar^{8+} 460eμA, Ar^{11+} 130eμA, Ar^{12+} 55eμA and so on.

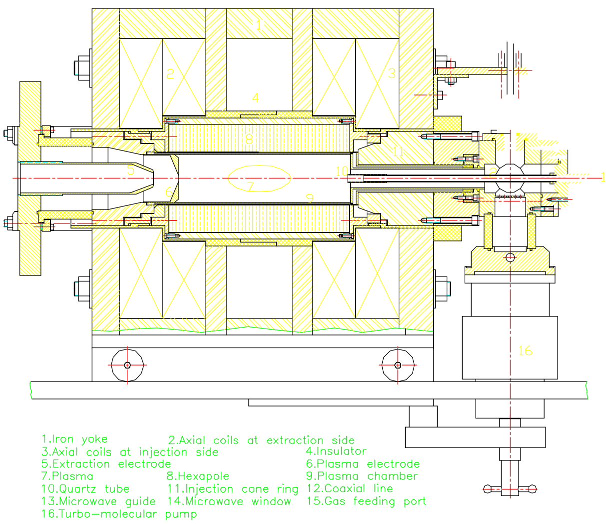

Fig. 2 14.5 GHz ECR ion source

3.3 The Buncher System on the ECR Beam Line

On the ECR beam line which is deserved to transfer beam from ECR ion source to SFC, a saw-tooth wave form buncher was installed together with the line in early 1992. But the operation since then showed that it worked below the expectation. It can increase the extracted beam intensity by 4 times at the best cases for the first harmonic acceleration mode (H=1), and by 6 times at maximum for the third harmonic acceleration mode (H=3), compared with the case of no buncher in work. A detailed study shows that the main reasons for the present low bunching efficiency are low available bunch voltage, nonlinearity of the bunching wave form. Then on the base of the study, a new buncher system was proposed and is under construction. The new buncher system consists of two bunchers B_{01} and B_{02}, respectively working at the SFC acceleration mode H=1 and at the mode H=3 (Fig.3).

The reasons to do so are: (1) a single buncher is difficult to give good bunching efficiency for the both modes, the short bunching distance demands high bunching voltage and generates high energy spread in the case of H=1, but the long distance gives too important space charge effect in the case of H=3. (2) the new method is to increase the match efficiency between SFC and SSC. Due to the mismatching of the two cyclotrons (R_{ext}(SFC)=0.75 m, R_{inj}(SSC)=1.0 m) the longitudinal match efficiency between the two cyclotrons is only 50% in theory in most cases except SFC at H=3 and SSC at H=4 where the efficiency is 100%. We simply reduce the bunching frequency by half ($f_{BUN}=f_{RF}/2$), here called half-frequency bunching. The beam corresponded to the original two packets could be squeezed into one by the buncher. But it needs double bunching voltage and some changes on the RF systems due to the working frequency range expanded from 6-18 MHz to 3-18 MHz. The direct forming of saw-tooth wave by recharging and discharging method is used to get higher voltage, the performance on the testbench has shown the good results. In order to get rid of the problem of the stray electric field and get lower bunching voltage requirement in the case of H=1, we choose a buncher structure of two gaps drift tube type with the sacrifice to take symmetric triangle wave instead of saw-tooth wave.

3.4 The Improvement of ECR Beam Line

After several years operation we found that the original existing ECR beam line constructed in 1992 was not satisfactory. Firstly, the beam line was too short so there were no enough space to ensemble some diagnostics elements for the beam monitor and emittance measurement. Secondly the distance from ECR ion source to analysis magnet should be little short to decrease the effect of space charge and the sputter of ions on the inner wall of the pipe because of which the vacuum pressure in the pipe was not good. Thirdly, the resolution of the original 45^o bending magnet used as the analysis magnet was too low, it was difficult to choose the available ions. To solve these problems, a new ECR beam line was designed, constructed and tuned last year[2)]. The layout of new beam line is shown in Fig.3. Two ECR ion sourcses
installed on the beam line symmetrically make it possible switching on from one to another conveniently. Because there are only a short straight section from ECR ion sources to the analysis magnets and two slits after the magnets, the sputter from beam on the inner-wall of pipes behind the analysis magnets will be decreased obviously. It will give two aspects of advantage: keepping better vacuum pressure in the pipes and decreasing space charge effect. Using 90^o analysis magnets instead of old 45^o one the resolution of charge states will be changed

from 20 to 65. The beam tuning shows that the transparency of beam along this beam line is increased.

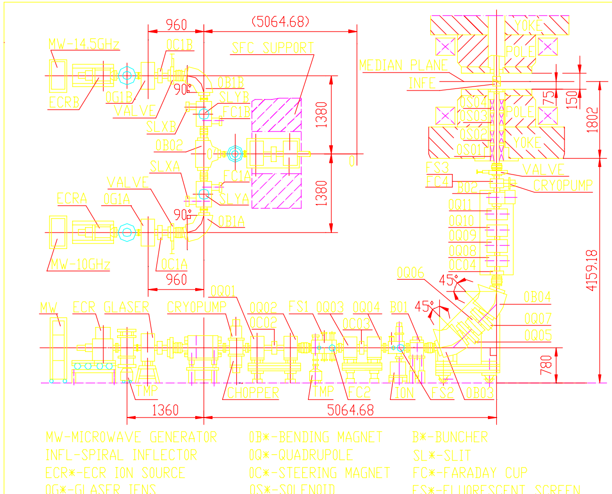

Fig. 3 14.5 GHz ECR ion source

3.5 Renew of the Control System

A VAX/8350 computer has been used for the original control system in HIRFL for more than ten years. But it was very difficult to satisfy the operation of the machine because of too old and no more spares to do the maintainance (The production of VAX/8350 was canceled in the factory). In the meantime, the touch panal on the consol was not very convenient. A new contribution control system which consists of some high-level micro-computers, workstations and so on was finished. The new system has been used for the beam tuning and the operation of the machine since November of last year. Everything looks well.

4. RIBLL AND CSR

In July of last year, RIBLL(Radioactive Ion Beam Line at Lanzhou) was constructed, tuned successfully.

In the designing of RIBLL, the following specifications were considered: decreasing spot size of primary beam on the target to decrease the emittance of RIB, using an antisymmetric double achromatic structure to increase the acceptance of this device, changing projectile direction of primary beam to obtain the polarized RIB and so on.

The layout of RIBLL is as shown in Fig.1. The RIBLL has been run for 2100 hours. The results indicate that all of the characteristics of RIBLL are satisfactory. On the device, the beam of the drip line nuclei with short lifetime such as ^{8}He, ^{11}Li and ^{14}Be were already obtained.

CSR (Cooling Storage Ring) is a multipurpose cooling storage ring system shown in Fig.1, and consists of a main ring (CSRm) and an experimental ring (CSRe). The existing HIRFL will be used as its injector system. The heavy ion beams from HIRFL will be accumulated, cooled and accelerated in the main ring, and then extracted fast to produce radioactive ion beams (RIBs) or highly charged state heavy ions. After that, the secondary beams(RIBs or highly charged state ions) can be accepted by the experimental ring for internal target experiments.

Two electron coolers located in the long straight sections of CSRm and CSRe respectively, will be used for beam accumulation and providing high quality beams for internal target experiments.

In June of last year, our govement has already approved this project in principle. The detail description about the status of RIBLL and CSR project will be reported in this conference.

5. SUMMARY

After the improvements mentioned above were finished last year, the beam intensity of HIRFL is increased obviously. HIRFL is easier to be tuned and operated then that before. In 1998, a new SFC vacuum chamber and a new buncher B1 located between injector SFC and main accelerator SSC will be designed and constructed if the funds are possible. If so, the beam transparency will be increased greatly.

RFERENCE

[1] 刘占稳 等，ECR 新工作模式，《高能物理与核物理》Vol. 20, No. 10 (1996).

[2] J.Y. Tang et al. The 14th International Conference on Cyclotrons and Their Applications P265-268