INITIAL OPERATION OF HIRFL

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ABSTRACT

HIRFL consisting of a main accelerator K450 separated sector cyclotron (SSC) and an injector K69 sector focusing cyclotron (SFC) was commissioned on December 12,1988. Since then, five kinds of ion species have been provided for testing of terminal equipments and experiments of nuclear physics, atomic physics, nuclear chemistry, material science and radiobiology. High quality beams with transverse emittance less than 8π mm mrad, energy spread of about 0.3% and beam intensity ranging from 10^{11} to 10^{12} pps were extracted.

A 10 GHz ECR heavy ion source, CAPRICE with the 8m beam transfer line and the axial injection system from the bottom of injector SFC have got into operation this year and have achieved convenient performance.

The initial three year operation and the present status of HIRFL are presented in this report.

1. INTRODUCTION

On December 12, 1988, the first beam of $^{12}C^{6+}$ 50 MeV/N was successfully extracted from the main accelerator SSC coupled with the injector SFC. It had taken approximately 10 years since the construction of SSC started in 1978. Table 1 gives the mile stone for construction of HIRFL.

The scheme and parameter of HIRFL and the commissioning result have been described in previous publications[1-2]. Figure 1 recalls the general layout of HIRFL.

During the year 1989, the trial operation of HIRFL only delivered 50 MeV/N $^{12}C^{6+}$ beam. From 1990 to 1991, another two kinds of ion species, $^{16}O^{8+}$ 50 MeV/N and $^{12}C^{6+}$ 75 MeV/N have been provided for users according to the experimental requirement. After putting into operation of the ECR heavy ion source as an external ion source of SFC with the 8m beam transfer line and the axial injection system from the bottom of SFC, the ions of $^{20}Ne^{8+}$ 25 MeV/N and $^{40}Ar^{16+}$ 25 MeV/N have been accelerated. We are planning to get the designed top energy of HIRFL, 100 MeV/N $^{12}C^{6+}$ in the autumn this year. Table 2 lists the accelerated beams and the operated parameters of HIRFL.

Table 1. The mile stone for construction of HIRFL

	SSC
Nov.,1976	Project approval
1978	Earth broken
1976-1980	Theoretical study
	Model test
	Technical design
1980-1986	Construction
1987	Assembling
	Magnetic field measurement
1988	Vacuum pumping
	Rf conditioning
	Beam tuning
Dec.12,1988	First beam ($^{12}C^{6+}$ 50 MeV/N)
	SFC
1984	Shut down for conversion
May.17.1987	First beam
1992	Operation of ECR ion source

Table 2. The accelerated beams and the operated parameters of HIRFL

	Z	RF (MHz)	h	E (MeV/N)	I (μA)
		SFC			
^{12}C	4	6.26	1	4.5	5.0
^{12}C	4	7.53	1	6.6	5.0
^{16}O	5	6.26	1	4.5	5.0
^{20}Ne	4	13.54	3	2.3	1.0
^{40}Ar	8	13.54	3	2.3	1.0
		SSC			
^{12}C	6	9.39	2	50.0	0.4
^{12}C	6	11.29	2	75.0	0.4
^{16}O	8	9.39	2	50.0	0.4
^{20}Ne	8	13.54	4	25.0	
^{40}Ar	16	13.54	4	25.0	

High quality beams with transverse emittance less than 8π mm mrad, energy spread of about 0.3% and beam intensity ranging from 10^{11} to 10^{12} pps have been obtained. Roughly say, half of the beam time was used

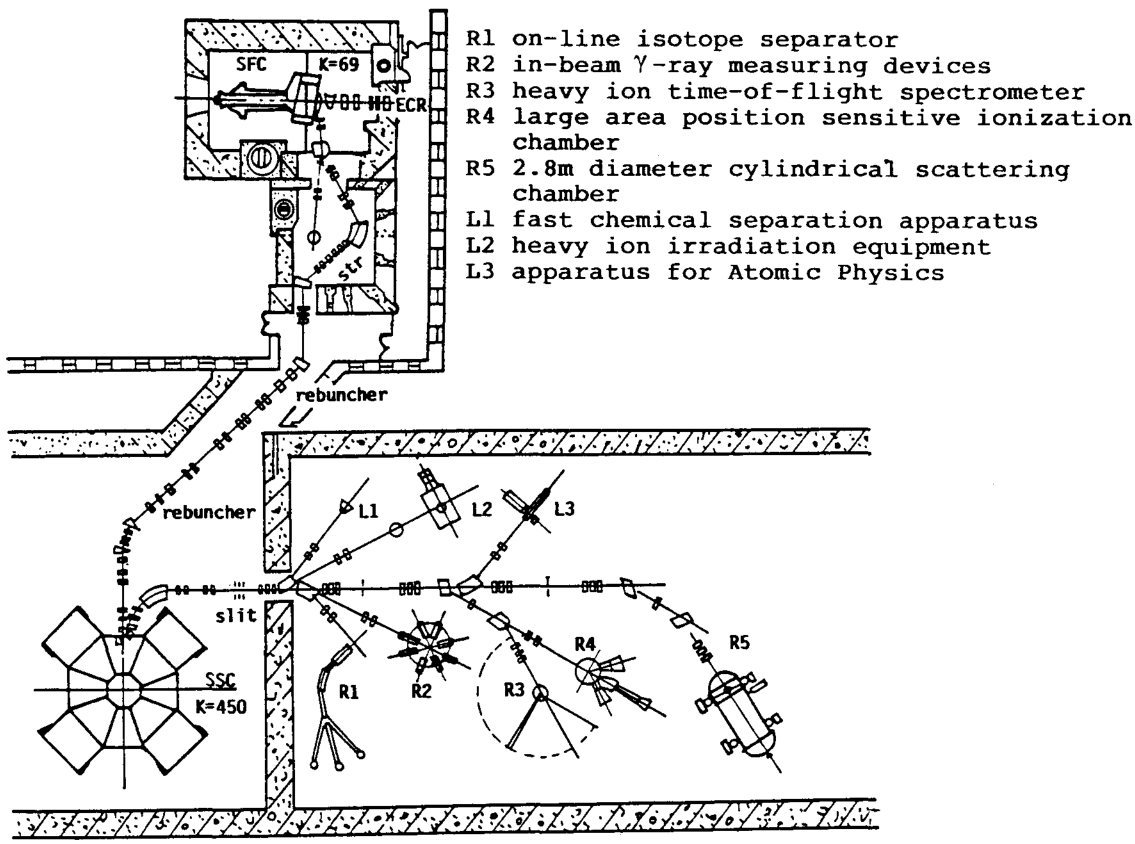

Fig.1. The general layout of HIRFL. R1- Isotope Separator, R2- In Beam Gamma-ray Measuring Device, R3- Heavy Ion Telescope, R4- Large Area Position Sensitive Ionization Chamber, R5- Heavy Ion Scattering Chamber, L1- Fast Chemical Separation Apparatus, L2- Irradiation Terminal, L3- Atomic Physics Terminal.

for machine tuning and testings of the terminal equipments and the rest was used for experiments. The beam time used for experiments was about 3500 hrs from 1989 to May of 1991. Among them, 70 percent was used for nuclear physics and nuclear chemistry and 30 percent was used for atomic physics, material science and radio biology.

The initial three year operation and the present status of HIRFL are presented in this report.

2. OPERATION STATUS

2.1. ECR Ion Source

The CAPRICE type ECR ion source made in Grenoble has achieved convenient performance in IMP. It has been not only used for the injector SFC as an external ion source but also for the atomic physics experiments.

The improvement to CAPRICE has been done recently by adding a conical iron ring to the end of the injection stage to make the first magnetic field mirror peak of the ECR stage more narrow. It could facilitate the plasma diffusion from the first stage to the second as the distance between the stages is smaller than before. As a result, the higher beam current more than 250μa both for $^{20}Ne^{4+}$ and $^{40}Ar^{8+}$ has been extracted from the CAPRICE ion source under the condition of extraction voltage and plasma electrode hole being 15kV and 6mm respectively[3]. The main parameters of CAPRICE is given in table 3.

Table 3. Main parameters of CAPRICE

Microwave generator	
frequency	10 GHz
output max.	2.5 kW
power consumption	10 kW
Magnetic field	
B max.	0.9 T
B min	0.3 T
power consumption	35 kW
hexapole	$SmCo_5$
B at cavity wall	0.4 T
Vacuum	10 torr
first stage	10 torr
second stage	10 torr
Pumping speed	
first stage	50 1/s
second stage	450 1/s
Extraction geometry	
electrode hole	6 mm
puller hole	16 mm
gap	33 mm

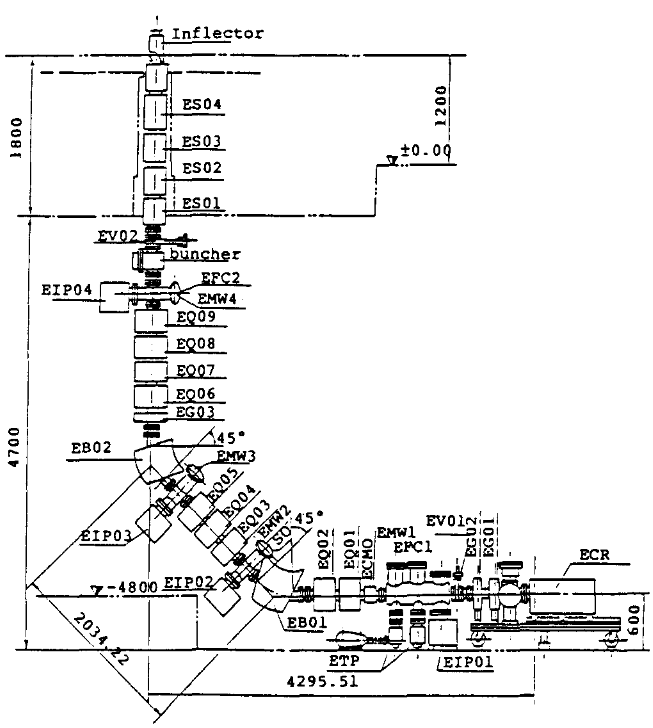

Fig.2. The beam transfer line from ECR ion source to the center of SFC

2.2. SFC

Figure 2 shows the beam transfer line from ECR ion source to the center of SFC. Two Glasser type lenses focus the beam from ECR ion source into waists at the diagnostics position. The other two match the beam to the 90° achromatic deflection section which consists of two 45° dipoles and three quadrupoles. This section also provides charge state selection with the charge state resolution of 1/20°which is only enough for ions up to Ta. 4 quadrupole lenses are placed subsequently to match the phase spaces. At the entrance of yoke hole a buncher consisting of two parallel mesh plates forming a single gap and excited by an rf power supply with sawtooth shape voltage is placed, and then four solenoid lenses focus the beam to the spiral electrostatic inflector which is located at the center of SFC. The inflector bends the beam direction by 90° and brings the ion trajectories on to the median plane of SFC. Table 4 gives the main parameters of the spiral electrostatic inflector. The steering magnets are

Table 4. The main parameters of the spiral electrostatic inflector

Electric radius (Re)	6.0 cm
Magnetic radius (Rm)	2.5 cm
k (Re/2Rm)	1.2
Distance between electrodes	0.8 cm
Width of electrode	2.0 cm
Injection radius of SFC	4.5 cm
Extraction voltage of ECR ion source max.	20 kV

arranged along the beam line for adjusting the optical axis. The preliminary results show that the beam transfer efficiency from ECR ion source to inflector is about 60%, and the vacuum pressure is about 10^{-5} pa. in the beam line tube.

After installing of the axial injection system, the magnetic field in the centre region of SFC should be remeasured. We decided to map all the required magnetic field from the center of SFC to outmost radius for ten magnetic field levels up to 16 kG. The isochronous field accuracy obtained by directly exciting the main coil and coaxial coils is about 10^{-3} which is good enough for guarantee the primary accelerating procedure and easy for isochronous optimization by using the center phase probes.

Besides of remapping the magnetic field, some other improvements to SFC had been done. The Dee box was rebuilt to meet the axial injection system requirement, the main coil was rebuilt also as it had been used 30 years and its power supply, the DC generator was replaced by a silicon rectifier set. In order to eliminate oil backstreaming and to improve the vacuum, we substituted two cryopumps combined with turbomolecular pumping units for original diffusion pumps. 5×10^{-5} pa pressure was obtained for the $15m^3$ vacuum chamber of SFC with an effective pumping speed of about 30000 l/s[4-5].

2.3. SSC

The operation of SSC is quite satisfactory. The beam emittance was measured by using three multiwire profilers located along the distribution beam line near the exit of SSC and the beam emittance less than 8π mm mrad was obtained. The energy spread was measured by using the ^{197}Au target elastic scattering method and the energy spread better than 3×10^{-3} was obtained.

Owing to large consumption of liquid nitrogen, the Balzers cryopump of RKP 800 with a combined pumping speed of about 14000 l/s was replaced by the HIRFL 800 cryopump without using liquid nitrogen. All of the helium compressor of HIRFL 800 cryopumps is installed on a non-radiation area outside the SSC hall. An expander is connected to a compressor with 60 m stainless steel tube which is easy to operate, monitor and maintain. The pumping speed of HIRFL 800 cryopump has been tested at a standard test dome to be 25000 and 27000 l/s for nitrogen and hydrogen respectively in the molecular flow region. The auxiliary pumping system consisting of four turbo-molecular pumps of type TPH 5000 manufactured by Pfeiffer has been suspended as the new powerful cryopump could put into operation at the pressure as high as 10 pa. By using the pumping system, after one hour pumping the pressure is reduced to about 10 pa in the SSC vacuum chamber. Then four HIRFL 800 cryopumps can be started. Within 6 hours cool down, the pressure of 10^{-5} pa could be obtained[6-7].

3. FUTURE PROGRAM

A by-pass beam transfer line guiding the beam from SFC to the terminal equipments at the experimental hall directly is under constructing. It will be completed next year. By using the existing beam distribution line, from the slit position to R3, the heavy ion telescope terminal, a second emission beam line has been planned(Fig.1). The optical design has been completed and the technical design is now under progress.

4. REFERENCE

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