PRESENT STATUS AND THE OPERATION OF THE RIKEN ACCELERATOR RESEARCH FACILITY

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Abstract

The RARF (RIKEN Accelerator Research Facility) has an accelerator complex consisting of the K540 RIKEN Ring Cyclotron (RRC) as a main accelerator and its two injectors; variable frequency RIKEN heavy-ion linac (RILAC) and K70 AVF Cyclotron (AVF).

The RRC together with the AVF and the RILAC have provided routinely a beam time of more than 4400 hours through a year since 1993. Present status of the RARF operation and recent advances are reported.

1. Introduction

The RARF Accelerator system consists of a K540 ring cyclotron (RRC) as a main accelerator and its two injectors, a variable-frequency heavy-ion linac (RILAC) and a K70 AVF cyclotron (AVF). Recently charge state multiplier (CSM) has been added. A layout of these accelerators and transport lines are shown in Fig.5. The RILAC injection which started in 1986 provides ion beams of almost full mass range (A=4-209), of relatively low energy, 5-63MeV/nucleon. On the other hand, AVF injection which started in 1989 provides ion beams at high energies, 70-135MeV/nucleon, of lighter than A=86 (typically 40)

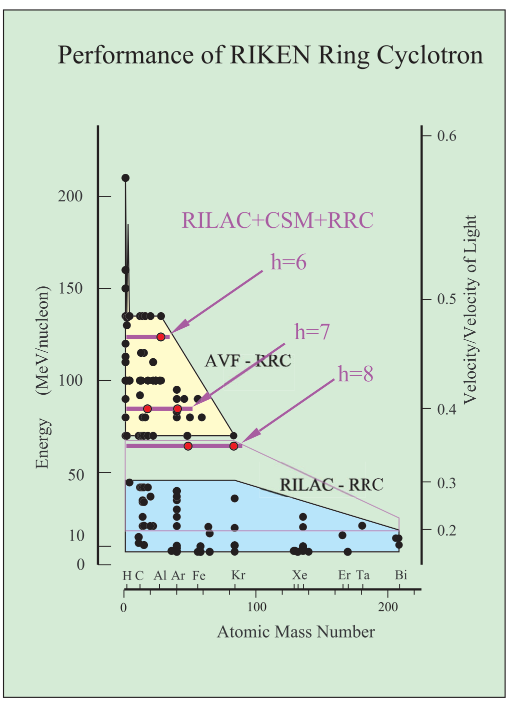

Fig.1 Performance of RRC

All beams which have ever accelerated are shown as solid circles on an energy-mass space.

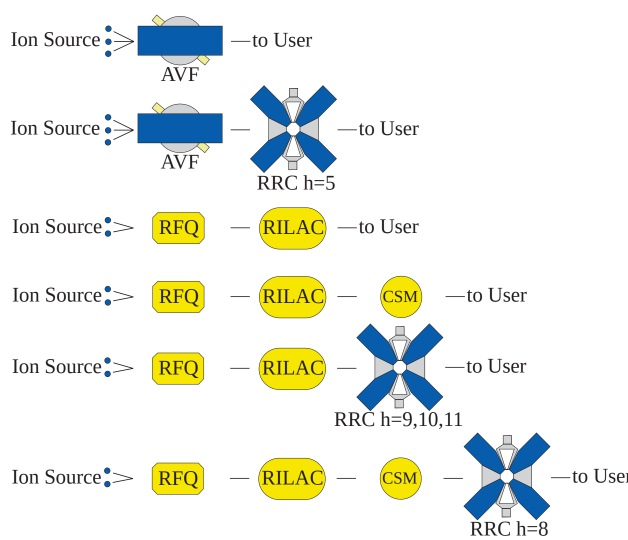

Fig.2 Block diagram of Acceleration mode

RILAC : Since 1981

RRC : Since 1986

AVF : Since 1989

RFQ : Since 1996

CSM : Since 2001

2. OPERATORS

2-1 Organization of operators

Since 1981, contracted operators from SHI Accelerator Service, Ltd (SAS) have been operating the accelerators under the supervision of The RARF operation staff. The SAS operator group consists of two sub-groups, the linac group with 6 members and the cyclotron group with 9 members.

2-2 Shift work

Fig.3 shows a typical pattern of the shift works of the SAS operators. 24 hours are divided in two shift times with 30 minutes overlaps. Two operators take shift for cyclotron and one take for linac.

	1	2	3	4	5	6	7
	Sun	Mon	Tue	Wed	Thu	Fri	Sat
A	◎	◎	☆	★	○	◎	☆
B	☆	★	○	◎	☆	★	■
C	■	○	◎	☆	★	○	◎
D	◎	☆	★	○	◎	☆	★
E	■	○	○	○	○	○	○
F	■	◎	☆	★	○	◎	◎
G	☆	★	○	◎	☆		■
H	■	☆	★	○	◎	☆	☆
I	■	○	◎	☆	★	◎	■

Fig.3 RRC Operator Shift Pattern

○ Regular ◎ Overtime work ☆ Night shift
★ Night shift dawn ■ Holiday

Rotation A - B - C - D - E
| |
I - H - G - F

3. Yearly schedule

One year is divided to 3 experiment periods along with 2 months of maintenance periods. Shift schedule is arranged according to the schedules of experiments.

4. Maintenance

Operators are assigned to trouble-shooting and routine maintenance activities for tasks. Maintenance is normally scheduled twice a year in summer (1.5 month) and winter (0.5 month).

5. Recent typical troubles

Ion source:

The sextuple permanent magnet of 10 GHz ECR ion source experienced significant strength loss (demagnetisation) after exposure to high temperature.

The insulation of plasma-chamber got worse.

RFsystem:

A variable transformer in the current source of the RRC No. 2 filament power supply burnt.

A sequencer unit for cooling water alarm system of the RRC No. 1 cavity was broken. Abnormal oscillation at 25.4 MHz made a water leak from a water tube in the feeder of brand-new driver of the RILAC No. 5 tank.

Abnormal oscillation of the RILAC No. 6 tank broke DC-blocker and a vacuum tube, and burnt the Teflon insulator in the feeder.

The copper sheets of the shooting plates in the No. 2, 5 and 6 tanks of the RILAC burnt.

Insulation of a socket for the vacuum tube of RFQ got worse.

Teflon made insulators in the CSM tanks seemed to increase X-rays and worsen vacuum property.

High-voltage system:

A controller of the high-voltage source for the electric deflection channel (EDC) was broken.

A rectifier of the high-voltage source for the electric inflection channel (EIC) was broken.

Spark caused vacuum leak from the insulators for the EIC and the EDC.

Cooling system:

A chillier for the ion sources was broken.

A pump of high-purity water-cooling system for RF and the injection and extraction instruments was broken.

Vacuum system:

A turbo-molecular pump of 10 GHz ECR ion source was broken.

A vacuum leak occurred in the CSM tank from badly welded parts.

A vacuum leak occurred in the RILAC No. 5 tank from a chapped insulator of the feeder.

A vacuum leak occurred in the AVF vacuum chamber from the deformed joint caused by malfunction of vacuum system for sub-vacuum chamber.

Frequent stop of the RRC vacuum system were experienced, probably caused by some electric noise.

Beam diagnostics:

Cooling water of the AVF beam probe (MDP) leaked.
Insulation of the AVF MDP got worse.

Bellows of the profile monitor had a vacuum leak.

Control system:
Renewed control system has been sometimes troubling.

Magnet:
One of the main coil of the RRC had a layer short.

6. New acceleration scheme

Since 2001, some acceleration scheme of the RRC with the RILAC injection was attempted in order to enlarge the variety of beams. We experienced the operation of h=8 schemes, e.g.:

2001/10 84Kr30+ at 63 MeV/nucleon h=8
2002/2 48Ca17+ at 63 MeV/nucleon h=8
2003/1 40Ar15+ at 63 MeV/nucleon h=8

Task awaiting solution
Beam losses while accelerating in the accelerators should be decreased.

The maximum power of the high-voltage source for re-buncher should be increased.

The lifetime of carbon stripper foils should be lengthened.

7. Conclusion

The SAS operators are working on the basis of support of the staff of RARF who shows below.

RIKEN Operation Staff
M. Kase, H. Akiyoshi, M. Fujimaki, S. Fujita,
Y, Higurashi, E. Ikezawa, N. Inabe, S. Ito, T. Kageyama,
O. Kamigaito, M. Kidera, S. Kohara, M. omiyama,
M. Nagase, T. Nakagawa, H. Sakamoto, N. Sakamoto,
Y. Sakata, S. Yokouchi, I. Yokoyama

SAS Operators
H. Isshiki, H. Akagi, T. Maie, K. Takahashi, N. Tsukiori, K. Kobayashi, R. Ota, M. Nishida, K. Masuda, T. Aihara,
T. Ohki, H. Hasebe, H. Yamauchi, A. Uchiyama,
K. Oyamada

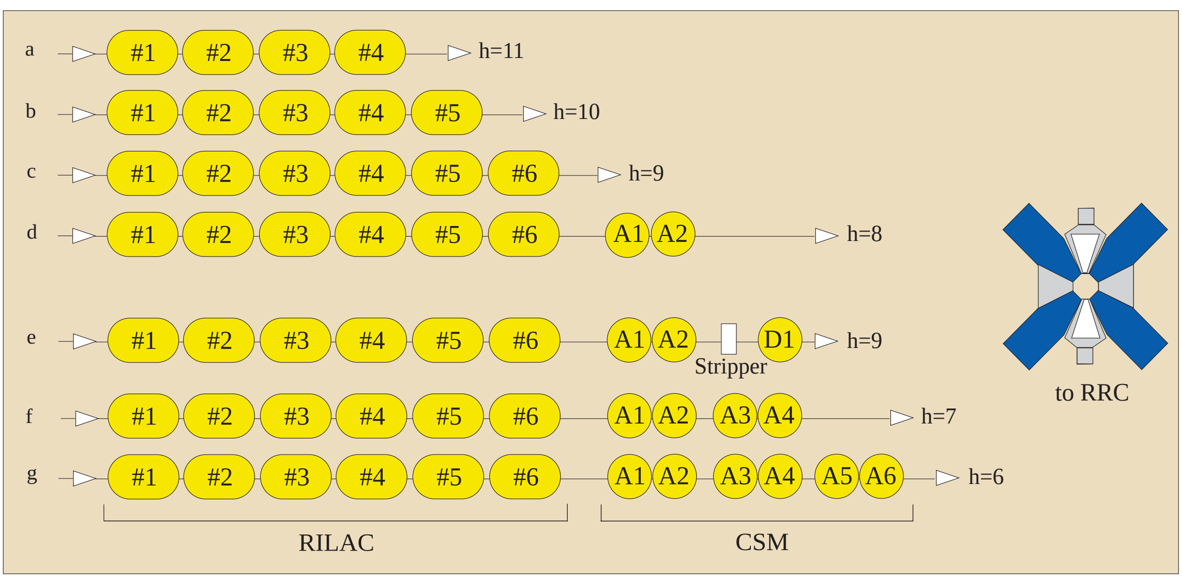

Fig.4 Various accelerating mode in RILAC injection scheme. The final energies after the RRC are indicated in Fig.1. The mode (a), (b), (c), and (d) have been already used for experiments (see Fig.1). The mode (e) is the normal usage of the CSM; higher charge-state of the ion is available. Harmonic number in the RRC can be decreased to 6 when the CSM cavities are fully used (g).

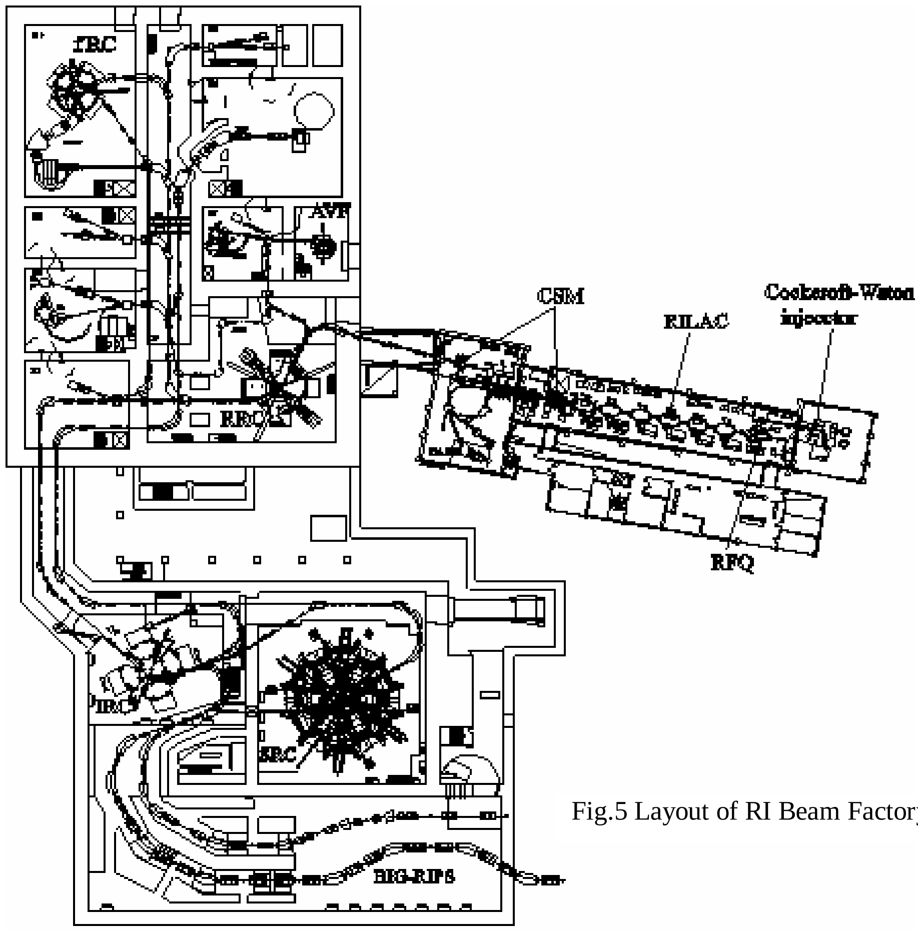

Fig.5 Layout of RI Beam Factory (RIBF)

Type	RIKEN Heavy Ion Linac RILAC Variable Frequency Wideroe	Charge State Multiplier CSM Variable Frequency Wideroe	
Number of tank	6	6+1	
Frequency Range	18-40MHz	A1,2,D1:36-76.4MHz A3,4,5,6:75.5MHz	
Maximum Energy	3MeV/nucleon	6MeV/nucleon	
Charge to mass ratio	1/2-1/27		
Injector	Cockcroft-Walton +8GHz ECR I.S RFQ + 18GHz ECR I.S		
	AVF	RIKEN Ring cyclotron RRC	
K-value	70MeV	540MeV	
Number of sectors	4	4	
Maximum magnetic field	1.7T	1. 67T	
Number of cavities	2	2	
Frequency Range	12-24Mhz	18-45MHz	
Ion source	10GHz ECR I.S 14GHz ECR I.S P.I.S		
	The fixed-frequency ring cyclotron fRC	The intermediate ring cyclotron IRC	The superconducting ring cyclotron SRC
K-value	510MeV	980MeV	2500MeV
Number of sectors	4	4	6
Maximum magnetic field	1.65T	1.9T	4.5T
Number of cavities	2	2+1	4+1
Frequency Range	36.66MHz	18-38.2MHz	18-38MHz

Fig.6 Specifications of RIBF Accelerators