Status Report on the JAERI AVF Cyclotron

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Abstract

The JAERI AVF cyclotron has been operated smoothly for experiments in a variety of scientific fields without any serious troubles since the extraction of first beam in March 1991. The total operation time amounted to 24,700 hours in August 1999. We have delivered thirty-five kinds of ion beams and a series of cocktail beam. This paper describes present status of operation, maintenance, improvement and recent development.

1 Introduction

The TIARA (Takasaki Ion Accelerators for Advanced Radiation Applications) facility has been already constructed in 1992 for R&D in materials science such as semiconductor for space environment, materials for fusion reactor, new functional materials and biotechnology.

The cyclotron requires that many kinds of light and heavy ions can be delivered in a wide range of energies [1],[2]. In order to satisfy the various requirements from the researchers, our persistent efforts including excess working in many holidays have been made for new beam development, improvement of devices, maintenance and repair for the cyclotron components.

Total operation time already amounted to 24,700 hours at the middle in August 1999.

2 Present Status

2.1 Operation

The yearly machine time is divided into three beam-time periods, each of which is allotted 50%, 35% and 15% of the total time in turn, respectively. The weekly operation is usually carried out continuously for about 100 hours from Monday morning till Friday evening. Regular overhaul used to be scheduled for four weeks in summer.

Operation statistics of the cyclotron during past 8 years is shown in Fig. 1. The operation time for visitor's use with charge increases gradually every year, although the total operation time has shifted about 3200 hours on the average for recent 6 years.

The accelerated particles and their beam times are also shown in Fig. 2. The operation time for cocktail beam rather increases for recent 3 years especially, contrarily one for Argon ion decreases slowly. As the operation time is distributed to satisfy as faithfully as possible various requests from many researchers, the frequencies for accelerated particles and energies increase year by year as shown in Fig. 3.

And the number of beam course change is counted at 190 which is the almost same as operational days for a year. For this circumstance, utilization efficiency for the operation time becomes worse as a matter of course.

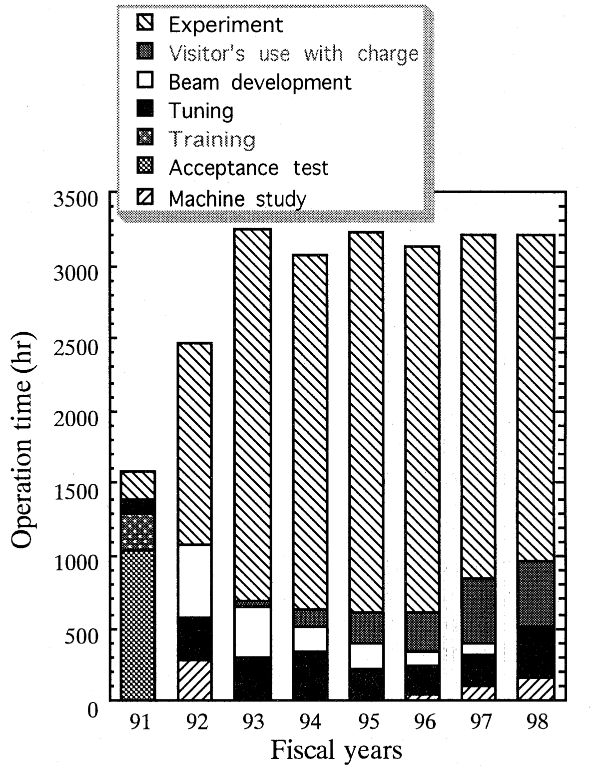

Fig. 1 Statistics of the cyclotron operation from 1991 to 1998.

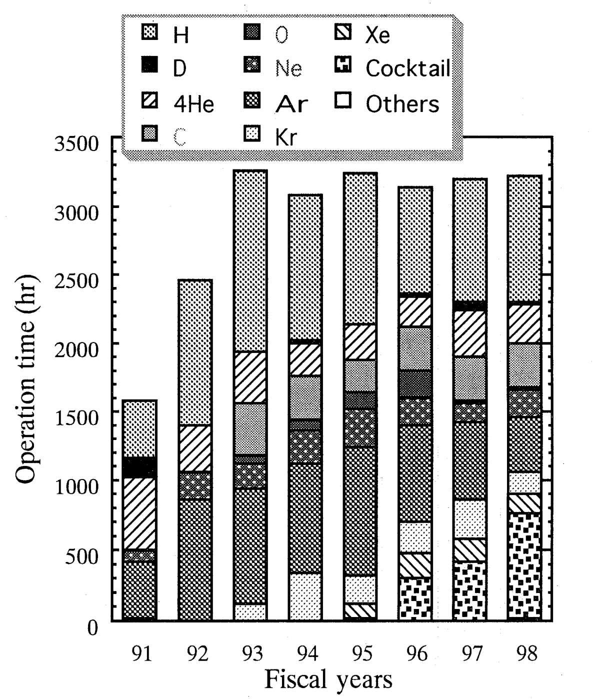

Fig. 2 Statistics of the accelerated particles and their beam time from 1991 to 1998.

2.2 *Maintenance and Repair*

A few examples of the maintenance and repairs performed in a couple of years are as follows:

(1) The accumulation of induced radioactivity in the acceleration chamber is making it more difficult to conduct maintenance work inside the cyclotron. The strong sources of radiation are the electrostatic deflector (100mSv/h) and the magnetic channel (160mSv/h). For the protection against radiation hazards, it replaced some of the strongly activated parts, such as the electrode of the electrostatic deflector, main probe, magnetic channel and magnetic channel probe in January 1998.
(2) Many nylon tubes in the beam transport system so far have been replaced in turn with thick rubber tubes that have excellent durability.
(3) About 4000 switches with small rectangular buttons, which were assembled in the local control panels, were exchanged to reliable new types.
(4) The cooling copper pipes spirally wound on the outer cylinder of the two RF resonators were renewed on account of the advance of water leakage.
(5) More than 300 fans equipped in the power supplies and the control racks were also replaced with new ones.
(6) The vacuum in the cyclotron which had deteriorated at about 2×10^{-4} Pa during the latest half fiscal year, had brought a serious attenuation of highly charged ions especially, was improved to $1\text{-}2\times10^{-5}$ Pa at last by the discovery of air leakage from the probe head of magnetic channel.

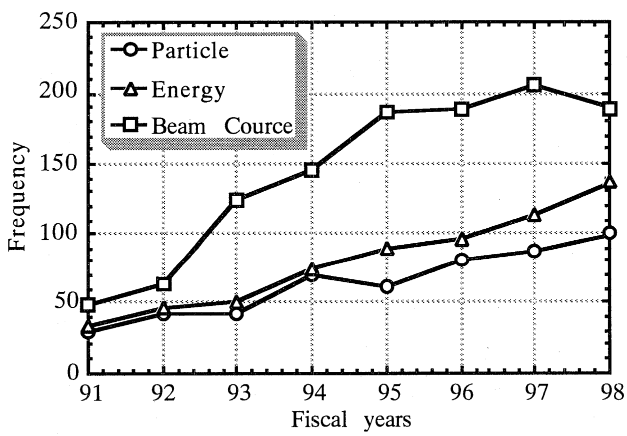

Fig. 3 Frequency of particle, energy and beam course change from 1991 to 1998.

2.3 *Improvement*

Some improvements for the cyclotron system are described as followings:

(1) Two pairs of phase slit consisted of 5 mm rod pillar were replaced with new structure of "L" shape as shown in Fig. 4, because it was clarified that the spatial restriction for beam spread was insufficient based on the analysis for beam phase at the central region.
(2) Three controllers for the several attenuators installed in the injection line were manufactured, and they are set three experimental rooms so that many researchers are able to control freely according to their demands.

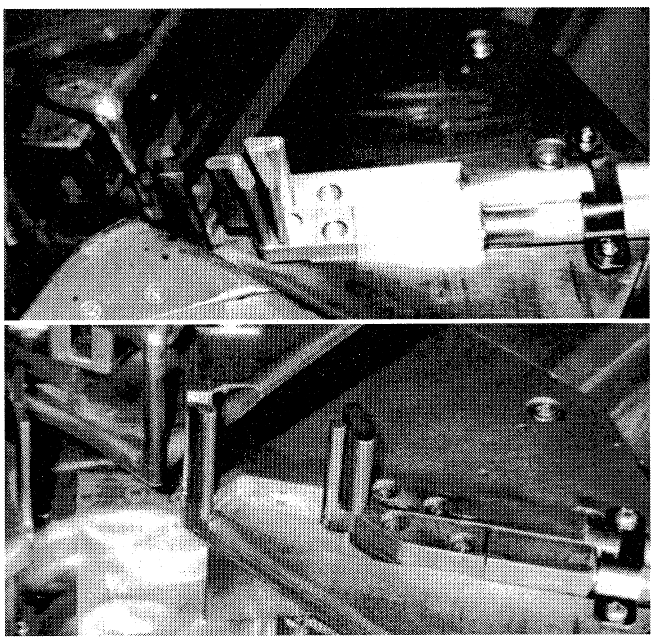

Fig. 4 Upper: a new pair of phase slit at the central region after improvement. Lower: an old phase slit before improvement.

(3) An insulation material of the deflector for the high voltage feeding was altered polyethylene (PE) into polyethylene telephthalate (PET) for the sake of the improvement of electrical characteristics.

3 Beam Development

3.1 *Cocktail Beam Acceleration*

Cocktail beam is very convenient for the experiment because the LET of ion beam can be changed within a few minutes over a wide range. A series of cocktail beam consisted of $^{15}N^{3+}$, $^{20}Ne^{4+}$, $^{40}Ar^{8+}$ and $^{84}Kr^{17+}$, whose ratios of mass to charge (M/Q) nearly equal 5, has been already delivered [3]. The energy of this cocktail beam is the same 3.75 MeV/u for each species.

Another group of $^{4}He^{+}$, $^{12}C^{3+}$, $^{16}O^{4+}$, $^{20}Ne^{5+}$ and $^{40}Ar^{10+}$ with M/Q=4 is now being developed [4]. At the present time, each species of cocktail beam can not be separated completely, since the proper M/Q resolution of the cyclotron itself is poorer than the difference of the ratio of M/Q between ion species and some extra impurity ions such as $^{56}Fe^{14+}$ and $^{52}Cr^{13+}$ are often extracted simultaneously [3].

Furthermore, we are trying to generate cocktail beam with M/Q=2 which is fully stripped ions.

3.2 *Extraction Current and Transmission*

A lot of particles accelerated and extracted so far are listed in Table 1. The extraction efficiency is defined by a ratio of the beam current detected with the main probe at 900 mm of the cyclotron radius to that with the Faraday cup (FC) just after the cyclotron. On the other hand, the overall transmission is estimated by a ratio of the beam current with the FC just downstream the analyzing magnet in the injection line to that with the FC just after the cyclotron.

As both quantities of extraction efficiency and overall transmission have been obtained with the good tuning condition, in practical these values are rather deteriorated for long-term operations and many alterations of cyclotron tuning.

3.3 Machine Development

The principal items in connection with machine development are described as follows:

(1) A new ECR ion source called "HYPERNANOGAN" together with an additional injection line was installed at the end of last March [5]. On the test operation, intense $^{40}Ar^{14+}$ ions of 10 eμA and some metallic ions such as Ta^{19+} and Pb^{23+} were observed.

(2) Not only a few VAX control computers for whole cyclotron system were renewed to updated personal ones, but also all of the control program was rewritten completely [6]. Furthermore, an arrangement of the control room and new consoles was also modified largely for the environment creation of comfortable control.

(3) Temperature measurement using a number of Pt resistance thermometer elements and E-type thermocouples fixed around the cyclotron is being carried out energetically [7]. We are planning to reconstruct in next March 2000 after the inter-comparison and consideration between temperature measurement and heat analysis will be done carefully.

References

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Table 1: Results of extracted intensity and overall transmission.

Ion	Energy (MeV)	Extracted Intensity (eμA)	Extraction Efficiency (%)	Overall Transmission (%)
H^+	10	12	80	27
	20	5	77	21
	30	5	67	22
	45	30	79	14
	50	5	44	14
	55	5	63	14
	60	5	57	22
	65	3	-	12
	70	5	42	12
	80	3	47	13
	90	10	48	7.7
D^+	10	11	29	3.7
	35	40	59	4.6
	50	20	49	7.2
$^{4}He^{2+}$	20	5.5	69	11
	30	1.4	42	10
	50	20	62	17
	100	10	32	10
$^{12}C^{3+}$	75	1.8	38	5.7
$^{12}C^{5+}$	220	0.25	77	22
$^{16}O^{5+}$	100	1.7	34	8.1
$^{16}O^{6+}$	160	1.9	58	21
$^{16}O^{7+}$	225	0.2	54	10
$^{16}O^{7+}$	335	0.05	29	4.2
$^{20}Ne^{6+}$	120	1.6	53	18
$^{20}Ne^{7+}$	260	0.33	70	19
$^{20}Ne^{8+}$	350	1.5	63	23
$^{36}Ar^{8+}$	195	2.5	63	13
$^{36}Ar^{10+}$	195	0.1	43	1.2
$^{40}Ar^{8+}$	175	3	73	15
$^{40}Ar^{11+}$	330	0.6	86	20
$^{40}Ar^{13+}$	460	0.03	63	24
$^{84}Kr^{18+}$	400	0.04	60	2
$^{84}Kr^{20+}$	520	0.05	72	22
$^{129}Xe^{23+}$	450	0.2	72	11