Heavy Ion Linac Complex for the Japanese Hadron Facility

Noboru TOKUDA, Shigeaki ARAI, Toshitaka FUKUSHIMA,
Toshiyuki HATTORI[A], Teruhisa MORIMOTO, Eiki TOJYO, and Nozomu UEDA
Institute for Nuclear Study, University of Tokyo
[A]Research Laboratory for Nuclear Reactors, Tokyo Institute of Technology

ABSTRACT

The heavy ion linac system for the Japanese Hadron Facility is being designed; the emphasis is laid on acceleration of exotic nuclei. Ions of exotic nuclei and those of stable heavier nuclei with a charge-to-mass ratio larger than 1/60 will be accelerated by a chain of a split coaxial RFQ, Interdigital-H linacs, and Alvarez ones. Ions of lighter stable nuclei with a charge-to-mass ratio larger than 1/7 will be preaccelerated by a four-vane RFQ, boosted by another IH linac, and injected to the above Alvarez linac chain. The layout of the heavy ion linac complex is described.

1. Introduction

Acceleration of exotic, or unstable, nuclei is an important issue in the Japanese Hadron Facility Project. The scheme of the acceleration is as follows: high intensity protons from the 1-GeV linac[1)] bombard target and yield exotic nuclei; they are analyzed in an ISOL (Isotope Separator On-Line) installed with an ECR ion source; single-charged ions are extracted and accelerated from 1 keV/u up to 8 MeV/u through a heavy ion linac chain. The minimum charge-to-mass ratio (q/A) of the ions acceptable with the linac system is set at 1/60, compromised between requirement of nuclear physicists and feasibility of linac technology. The linac chain consists of a split coaxial RFQ (SCRFQ), interdigital-H (IH) linacs, and Alvarez ones. Single gap cavities will follow the Alvarez linacs to adjust the final energy, continuously variable in a range from 0.17 to 8 MeV/u, as is requested by nuclear physicists. Ions of stable nuclei, say $^{238}U^{4+}$, can be be accelerated as well as exotic nuclei. Lighter stable ions with a q/A-value larger than 1/7 are preaccelerated by a four-vane RFQ and another IH linac; then, they are injected to the Alvarez linac chain. An interim report about the layout of the heavy ion linacs is presented in the following.

2. Linac Layout

As described above, the ions to be accelerated are classified into three groups: exotic nuclei, heavier stable ones, and lighter stable ones. The expected properties of the beams from the ion sources are summarized in Table 1. The acceleration of exotic nuclei has the priority to that of the other; hence, the linac system should be optimized for this acceleration. The capability required to the system is summarized in Table 2. The categories 'initial' and 'future' in the table means that a linac system will be completed after two steps. We will first complete a 6.5 MeV/u linac system that accelerates ions with a mass number below 60; nickel will be the heaviest ion. The system will be then extended so as to accomplish the maximum energy of 8 MeV/u and the heaviest ion of uranium. The extension will be realized by reinforcing the rf power supplies and adding another Alvarez tank and single gap cavities.

The linac composition is given in Table 3. The main line, which accelerates exotic nuclei and heavier stable ones, consists of a SCRFQ, IH linacs, Alvarez ones, and single gap cavities to regulate the output energy. The energy ranges shared by the linac types have been determined so that the overall acceleration voltage is minimized; two gas strippers are assumed in the calculation. The linacs are designed to be capable of uranimum ions, which will be accelerated after the reinforcement in the power supplies in the second step. The IH and the Alvarez linacs are divided into rather short tanks, accordingly low energy gain per tank, because the function of the continuously-variable output energy is attainable by using only a few single gap cavities. With a gap voltage of 1 MV, two cavities are necessary for nickel ions, and four for uranium ones.

At the bottom of Table 3, the linacs for lighter stable nuclei are listed. The preaccelerator is a 102-MHz four-vane RFQ, for which the TALL RFQ[2] could be used. The output beam from the RFQ will be boosted by a short IH linac and injected to the Alvarez linac chain on the main line.

3. Concluding Remarks

The linac system presented here is subject to further much work for refinement. We must work out the drift tube tables of the IH and the Alvarez linacs, and design the interlinac beam transport lines with a stripper, a rebuncher, beam monitors, and a bypass for isotope separation. Experimental studies must be also conducted particularly on the cavity structures of the SCRFQ and the IH linacs. As for the SCRFQ, it has been decided to construct a prototype cavity based on the experience with the 50-MHz model.[3] The cavity will be fully scaled except in lingth, about 4 m, and will accelerate ions.

References

1) Y. Yamazaki, this meeting.
2) N. Ueda *et al.*, Proc. 6th Symp. Accel. Sci. & Tech., 1987, p. 59.
3) S. Arai *et al.*, this meeting.

Table 1. Expected performace of the ion sources.

	exotic nuclei	heavier stable nuclei	lighter stable nuclei
Type	ECR in ISOL	ECR	ECR
Charge–to–mass ratio	$\geqq$ 1/60 (q = 1)	$\geqq$ 1/60	$\geqq$ 1/7
Beam current	$10^5 \sim 10^8$ pps (10^{12} pps max.)	~0.1 mA	~0.1 mA
Energy	1 keV/u	1 keV/u	8 keV/u
Norm. emittance	< 1 π mm•mrad	0.6 π mm•mrad	0.6 π mm•mrad
Duty factor (%)	$\lesssim$ 30%	$\lesssim$ 30%	$\lesssim$ 30%

Table 2. Required capability of the heavy–ion linac system.

	initial	future	notes
Charge–to–mass ratio	$\geqq$ 1/60		Single–charged ions from ISOL
Max. mass number	60 ($^{59}Ni^{+}$)	238 ($^{238}U^{4+}$)	
Max. output energy (MeV/u)	6.5	8	
Output energy range (MeV/u)	0.17 ~ 6.5	0.17 ~ 8	Continuously variable
Beam Intensity (mA)	5		For stable ions of q/A = 1/60
Norm. emittance (mm•mrad)	1 π		For exotic nuclei
Duty factor (%)	10	$\gtrsim$ 30	For exotic nuclei

Table 3. Scheme of the heavy–ion linac complex. Stable lighter ions from the 102–MHz IH linac are injected to the Alvarez linac chain. Tough not listed here, single gap cavities of 1 MV per gap are located at the high energy end, two cavities for nickel and four for uranium. The quantities in the parenthes are those after the future extension.

Exotic nuclei and heavier stable ones							
Linac type		SCRFQ		IH		Alvarez	
Frequency		17 MHz		51 MHz		102 MHz	
Length		~20 m		~25 m		~35 m	
No. of tanks		1		5		6 (7)	
Energy	1 keV/u		0.17 MeV/u		1.4 MeV/u		6.5 MeV/u (8.0 MeV/u)
Max. A/q		60		9.9 (26.4)		3.5 (8.5)	
Heaviest ion		$^{59}Ni^{+}$ ($^{238}U^{4+}$)		Ni^{6+} (U^{9+})		Ni^{17+} (U^{28+})	
Accel. volt.		10.1 MV (10.1 MV)		12.1 MV (32.5 MV)		17.7 MV (56.1 MV)	
Lighter stable nuclei							
Linac type		four–vane RFQ		IH			
Frequency		102 MHz		102 MHz			
Length		7.2 m		~3 m			
No. of tanks		1		1			
Energy	8 keV/u		0.80 MeV/u		1.4 MeV/u		
Max. A/q		7		7			
Accel. volt.		5.54 MV		4.20 MV			