HEAVY-ION INERTIAL(HIF) DRIVER AND TARGET BASIC STUDY BY INTENSE HEAVY-ION LINAC AND HEAVY ION COOLER SYNCHROTORON

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ABSTRACT

We propse the basic experiments of driver and target for Heavy-Ion Inertial Fusion by Intense Heavy-Ion Linac[1] system for ion beam pumped laser experiment at T.I.T. and the Heavy-Ion Cooler Synchrotron. The accelerator complex which is discussed below, consist of nine heavy-ion linacs, a heavy-ion cooler synchrotoron, two strage rings, 24 beam buncher rings and a chamber of target-experiment[2].

INTRODUCTION

In recent years, development of accelerator technology, i.e.
(1) heavy-ion cooler-synchrotron with cooling and RF stacking for synchrotron technology,
(2) RF linacs of low and medium particle energy as IH[3] and IHQ[4] type structures, and
(3) ECR[5-7] type ion source for high charge-state ion,
produce a possibility of basic experiments for the driver and target of HIF.

A medium size heavy-ion linac and cooler synchrotron system is discussed below which will be alow experimental investigations on crucial issues of heavy-ion inertial fusion, predominantly in two areas:
(1) accelerator physics, in particular beam manipulation and beam dynamics studies in the space-charge-dominanted region and
(2) the physics of dense plasmas, including beam-target interaction and the study compressed matter high temperature.

Table-1 Parameters of Intense Heavy-Ion Linac at TIT

	RFQ	IHQ(1)
Charge-to-mass ratio	≧1/16	≧1/16
Energy Input (MeV/u)	0.005	0.2
Output (MeV/u)	0.2	0.6
Number of cell	272	76
Cavity Inner Diameter (cm)	74	72
Length (m)	4.0	4.0
Number of Cavity	1	1
Operation Frequency (MHz)	80	80
Synchronous Phase	-90° ~ -30°	-30°
Shunt Impedance (MΩ/m)	33	400
Acceleration Voltage (MV)	3.2	6.4
RF Power (wall loss) (kW)	80	46
Beam Load (kW at 5 mA)	16	32
RF Power Source (kW)	100	100

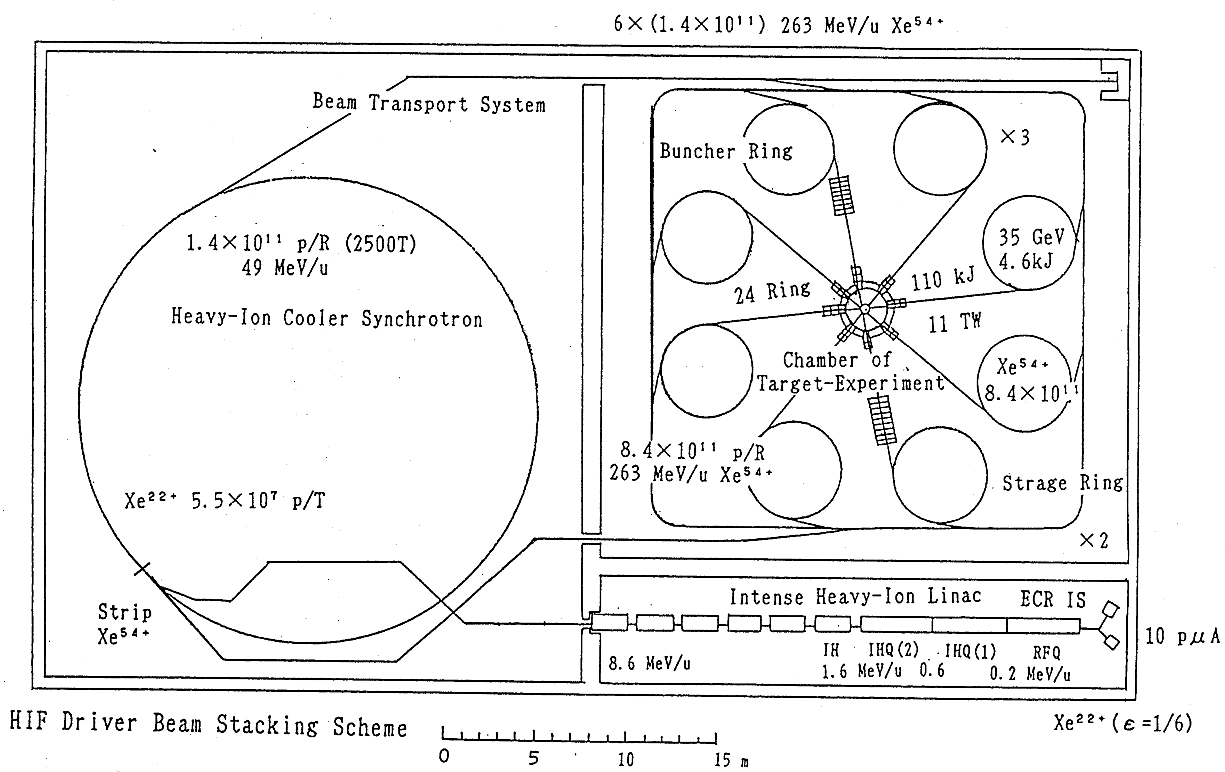

Fig.1 Layout of Accelerator Complex for Basic Experiments of Driver and Target for HIF

ACCELERATOR SYSTEM OF EXPERIMENTAL STUDY FOR HIF

The facility for experimental basic-study of HIF consists of nine heavy-ion linacs, a heavy-ion cooler synchrotoron, two strage rings, 24 beam buncher rings and a chamber of target-experiment. Fig.1 shows a layout of the facility.

Table-2 Parameters of Intense Heavy-Ion Linac(Ⅱ)

		IHQ(2)	IH
Charge-to-mass ratio		≧1/6	≧1/6
Energy Input	(MeV/u)	0.6	1.6
Output	(MeV/u)	1.6	8.6
Number of cell		46	132(total)
Cavity Inner Diameter	(cm)	74	46
Length	(m)	4.0	2.0
Number of Cavity		1	6
Operation Frequency	(MHz)	80	160
Synchronous Phase		-30°	-20°
Shunt Impedance	(MΩ/m)	180	160
Acceleration Voltage	(MV)	6.0	7.0×6
RF Power (wall loss)	(kW)	67	1000(total)
Beam Load	(kW at 5 mA)	30	200(total)
RF Power Source	(kW)	100	200×6

The heavy-ion linac system has nine cavities. The first and second module are acceleration system ofintense heavy-ion for experiments of heavy-ion pumped laser at Tokyo Institute of Technology. The first module is a four -vane RFQ structure and the second one is an IHQ (Interdigital H structure with RF Quadrupol focusing type linac) structure. The final output energy is 0.6 MeV/u.

The RFQ cavity is designed to accelerate particle injectedat 5keV/u with charge to masds ratio (q/A) of 1 - 1/16 up to0.2 MeV/u. The structure is designed by mean of computer code GENRFQ and PARMTEQ. The Intense Heavy-Ion Linac System accelerates particle of 7.2 mA (q/A of 1/16) and deposition power-density are peak power of 240 and 80 GW/m^2 at 0.6 and 0.2 MeV/u of Oxygen ion, respectively. The main parameters of Intense Heavy-Ion Linac System are summarized in Table-1.

Post-IHQ(1) linac i.e. the linac system of an IHQ(2) cavity and six IH cavities are designed to accelerate particle with q/A = 1/6 up to 8.6 MeV/u. The main parameters of Intense Heavy-Ion Linac(Ⅱ) System are summarized in Table-2.

Table-3 Main Parameters of Cooler Synchrotoron

Maximum Magnetic Rigidity		6.1	T・m
Max. Beam Energy	Proton	1.1	GeV
	Ion(q/A=1/2)	370	MeV/u
Injection Energy		8.6	MeV/u
Circumference		77.8	m
Average Radius		12.4	m
Radius of Curvature		4.05	m
Length of Long Straight Section		4.2	m
Rising Time of Magnet Excitation		3.5	sec
Max. Field of Dipole Magnets		15.0	kG
Max. Gradient of Quadrupole Mag.		70	kG/cm
Revolution Frequency		0.31 - 3.75	MHz
Harmonic Number		2	
Vacuum Pressure		10^{-11}	Torr

The accelerated heavy-ion by the linac system are stored by mean of RF stacking and electron cooling stacking and are accelrated up to energy of maximam magnetic field. The main parameters of the Heavy-Ion Cooler Synchrotron as TARN-Ⅱ[8] are summarized in Table-3.

Accelerated heavy-ion by the synchrotron are stored the strage ring (1) and ring (2). The ions are extracted from the strage ring (2) and 24 buncher rings. 24 beam compressed are extracted same time from buncher rings. Final focused ions are bombarded the target of HIF basic experiment. The main parameters of the strage ring and buncher ring are summarized in Table-4.

Table-4 Main Parameters of Strage and Buncher Ring

		Strage Ring	Buncher Ring	
Number of Ring		2	24	
Maximum Magnetic Rigidity		6.1	6.1	T・m
Max. Beam Energy	Proton	1.1	1.1	GeV
	Ion(q/A=1/2)	370	370	MeV/u
Circumference		93.4	15.6	m
Average Radius		14.9	2.5	m
Radius of Curvature		1.4	1.4	m
Length of Long Straight Section		21.2	1.7	m
Max. Field of Dipole Magnets		45.0	45	kG
Vacuum Pressure		10^{-11}	10^{-11}	Torr

BEAM STACKING METHOD OF THIS SYSTEM

For only basic experimental study of target, the accelerator system is not only large heavy-ion linac system as an electric power plant of HIF, but also medium size heavy-ion linac and cooler synchrotoron in recent years developments of accelerator technology.

The ECR type heavy-ion source generates heavy-ion of 10 - 100 pμA with q/A = 1/6. The ion is accelerated up to 8.6 MeV/u by the Intense Heavy-Ion Linac System and the transmission is about 90 %.

For example, we will tell the ion stacking method concerning Xe ion. The linac accelerate Xe^{22+} ion up to 8.6 MeV/u. The Xe of 5.5×10^{7} particles by single-turn injection method are stored by meam of RF stacking and electron cooling stacking up to 1.4×10^{11} particles (stacking of 2500 turns), and accelerated up to 49 MeV/u.

The Xe ion are extracted from the synchrotron by mean of farst extraction method and injected to the strage ring (1). Next, extraced Xe^{22+} ion from the strage ring (1) is injected by fully stripped method, and the Xe^{54+} ion is accelerated up to 263 MeV/u of maximum energy.

The ion is extracted from the synchrotron and injected to the strage ring (2). The Xe^{54+} of 1.4×10^{11} particles are stored to the strage ring (2) up to 8.4×10^{12} particles of space-charge limit of the strage ring(2) by six times repetition of the injection scheme.

The ion is extracted from the strage ring (2) and injected to the buncher ring. The total kinetic energy is 35 GeV and stored energy in the buncher ring is 4.6 kJ. 24 beam (total energy is 100 kJ) of compressed to about 10 ns (peak power is 11 TW) are extracted same time from each buncher ring. Final focused Xe ions are bombarded the target of HIF experiment to aim at break even of pellet fusion.

Expected performamce of HIF target experiments are shown in Table-5.

Table-5 Expected Performance of HIF target Experiments

Ion	Ne^{10+}	Ar^{18+}	Kr^{36+}	Xe^{54+}
Number of Ion (Strage Ring)	4.3×10^{12}	2.2×10^{12}	1.1×10^{12}	8.4×10^{11}
Energy MeV/u	370	311	285	263
Total E. GeV	7.4	12.5	24	35
Energy kJ	6.1	5.3	5.0	4.6
Average Range (g/cm2)	28	12	6	3
Number of Ion on Target	1.0×10^{14}	5.3×10^{13}	2.6×10^{13}	2.0×10^{12}
Energy kJ	146	127	120	110
Peak Power (10ns) (TW)	14.6	12.7	12.0	11.0

SUMMARY

The accelerator system for only basic experimental study of target is not only large heavy-ion linac system as an electric power plant of HIF, but also medium size heavy-ion linac and cooler synchrotoron in recent years developments of accelerator technology.

We propse the basic experiments of driver and target for Heavy-Ion Inertial Fusion by Intense Heavy-Ion Linac system and the Heavy-Ion Cooler Synchrotron as TARN-II.

This accelerator facility is possible to aim at break even of pellet fusion.

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