CONCEPTUAL DESIGN OF SUPERCONDUCTING HEAVY ION LINEAR INJECTOR FOR HIAF*

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Abstract

A heavy ion accelerator facility, High Intensity Heavy Ion Accelerator Facility (HIAF), has been promoted by Institute of Modern Physics IMPof Chinese Academy of Sciences (CAS). The injector of the accelerator facility is a superconducting linac(HIAF-linac). It is a high intensity heavy ion linac and works on pulse mode. The final energy is 100 MeV/u. The accelerated species are from Prton to Uranium. The linac works with both laser and ECR ion source. The designed current is 1.0 emA. The general concept of HIAF and the preliminary design of linear injector are presented in the paper.

INTRODUCTION

High Intensity Heavy Ion Accelerator Facility (HIAF) will be a national user facility. The proposed HIAF facility is based on a heavy-ion linac with a minimum energy of 100 MeV/u for all ions at a beam current 1.0emA. This advanced facility will provide high intensive ion beam for high energy nuclear science to understand the fundamental forces and particles of nature as manifested in nuclear matter. The HIAF project will include three parts, ion linac injector, the rings and experiments facility. The concept HIAF-linac design will be introduced as following.

The proposed linac design is based on the goal of constructing a reliable, low-maintenance, state-of-the-art accelerator with proven technology and robust operating stability that will minimize downtime and ensure production of intense beams for world-class experiments. The design of the driver linac is largely determined by the requirement of a 100 MeV/u, 1.0 mA uranium beam, and the need to accelerate a wide range of ions while limiting the uncontrolled beam loss below 1 W/m, high power SC machine to facilitate hands-on maintenance. The accelerator lattice design must provide adequate transverse and longitudinal acceptance.

Fig. 1. shows a concept schematic layout of the linac facility.

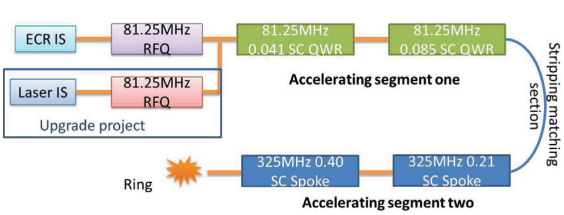

Figure 1: The concept layout of HIAF-linac.

* Supported by the National Natural Science Foundation of China (Grant No.11079001)

As shown in the Fig.1, HIAF-linac will be consisted of front end, superconducting(SC) accelerating segment one, stripping and matching section and superconducting accelerating segment two.

In this paper, concept design of each section are presented.

FRONT END DESIGN

Front end section includes ECR, LEBT and RFQ. The ECR will provide high charge ions beam at both CW and pulse mode. LEBT has two functions, one is to select the charge state from hybrid charge beam, the other is to match the beam to RFQ entrance. The RFQ will accelerator ion beam from 0.02MeV/u to 0.4MeV/u. The layout of the front is shown in Fig. 2 shows the schematic layout of front end. As shown in the figure, one prebuncher is located in

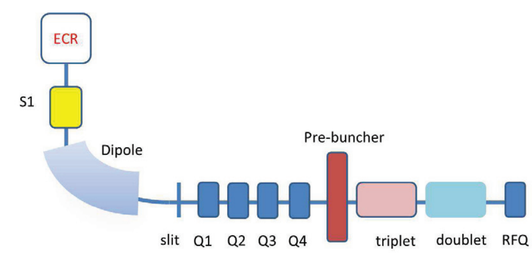

Figure 2: The schematic layout of front end.

the LEBT to decrease the longitudinal emittance to meet the requirement of the acceptance in superconducting section.

The design goals were to minimize the longitudinal emittance and transverse emittance, the RF power, and the structure length. After several optimizations, the parameters of RFQ were found to minimize output longitudinal emittance and maximum transmission. The RFQ was designed using DESRFQ[1] code. The final design structure parameters will be simulated by Track code[2]. RFQ cell profile at different section are shown in the Fig. 3

SUPERCONDUCTING ACCELERATING SEGMENT ONE

Beam from the front end will be injected into the SC linac. Two types of accelerating structures in fourteen cryomodules are used to achieve energy of 15MeV/u for uranium in segment one. Segment one will be approximately 80.2m long and will accelerate the uranium beam from 0.4 to 15 MeV/u when the beam current is 1mA. Segment one includes two periodic structures. Three cryomodules, each containing six β_{opt}=0.041 λ/4 cavities op-

ISBN 978-3-95450-122-9

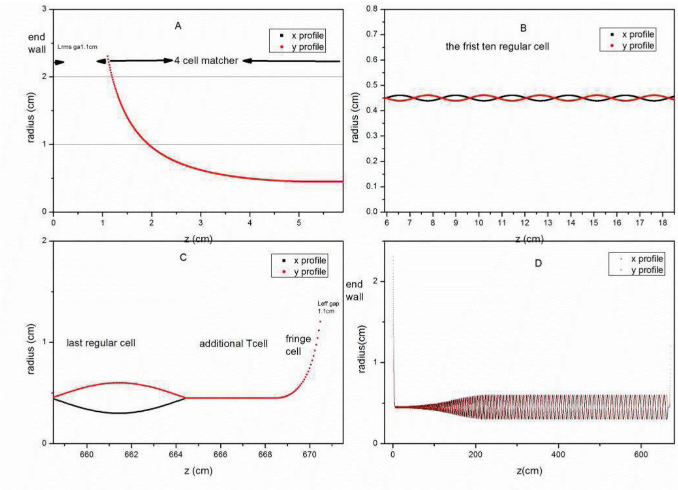

Figure 3: RFQ cell profile at different section: (A) input matcher,(B) regular cell(C) output T cell and fringe cell (D) all cells along the RFQ.

erating at 81.25MHz and three superconducting solenoidal magnets will accelerate the beam from 0.4 to 1.54MeV/u as the first period structure. For the β_{opt}=0.041 $\lambda/4$ section, the full periodic structure will be adopted instead of compact periodic structure which need matching between cryomodules[3]. The full periodic structure can avoid the formation of beam halo caused by mismatch. The disarrange is the period phase advance for long periodic structure is lager than 90°, while for the low beam current, this is not an issue.

The other kind of periodic structure consists of four β_{opt}=0.085 $\lambda/4$ cavities and one superconducting solenoidal magnets. Eleven cryomodules, each containing eight β_{opt}=0.085 $\lambda/4$ cavities operating at 81.25MHz and two superconducting solenoidal magnets will accelerate the uranium beam to 15MeV/u. Fig. 4shows the schematic layout of the cryomodules for each type in segment one. Fig. 5shows the transverse and longitudinal phase advance

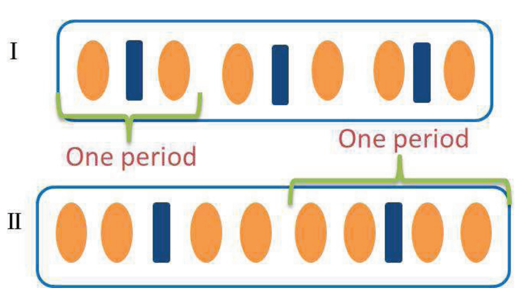

Figure 4: The schematic layout of the cryomodules for each type in segment one.

for the uranium beam. As shown in the Fig.5, the phase advance changes smoothly in the regular section. While there are some jumps at the cavity type transition section where

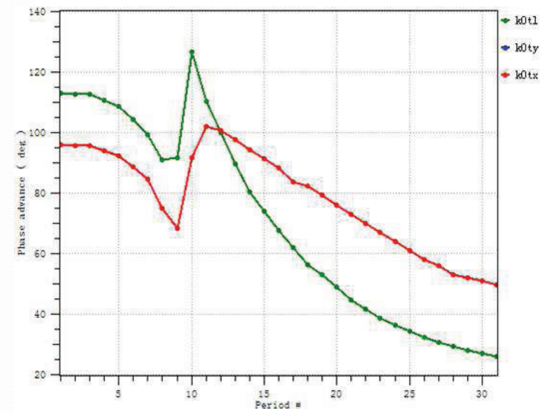

Figure 5: The transverse and longitudinal phase advance for the uranium beam .

several period are used to do match. The beam parameters on entering and exiting the segment one are summarized in Table. 2. The simulation results substantiate that the design will meet performance requirements.

Table 1: Beam parameters in superconducting acceleration segment one

parameter	Qty or Type	Unit
Segment one length	80.18	m
Charge states	34+	
Input energy	0.4	MeV/u
Output energy	15	MeV/u
Cavity Cryomodule Configuration		
$\lambda/4$ β_{opt} 0.041		
Number of cryomodules	3	
Number of cavities/cryomodule	6	
Number of solenoids/cryomodule	3	
Number of cavities	18	
Number of solenoids	9	
Rf frequency	81.25	MHz
Epk 31.25	MV/m	
Cryomodule length	5.46	m
Cavity Cryomodule Configuration		
$\lambda/4$, β_{opt} 0.085		
Number of cryomodules 11		
Number of cavities/cryomodule 8		
Number of solenoids/cryomodule 2		
Number of cavities 88		
Number of solenoids 22		
Rf frequency	81.25	MHz
Epk	31.25	MV/m
Cryomodule length	5.8	m

STRIPPING AND MATCHING SECTION

The stripping and matching section will be an 180° arch structure to save the longitudinal space. Stripping section will strip the U^{34+} beam to U^{76+} at 15 MeV, the energy is choose referring the stripping experiment in RIKEN[4]. The type of stripping film is under study. Also the longitudinal matching function will be realized with a serial of bucher cavities are used to match the beam from 81.25MHz to 325MHz. A set of quadrupoles are used to match the beam to stripping film and the entrance of superconducting accelerating segment two.

SUPERCONDUCTING ACCELERATING SEGMENT TWO

In the baseline driver linac, two kind of uranium beam, which are U^{76+}(stripped beam) and U^{34+}(un-stripped beam), will be accelerated in superconducting accelerating segment two. The section will be approximately 96 m long consisting of a total of twenty four accelerating cryomodules. The first fifteen cryomodules, each containing six spoke 021cavities operating at 325 MHz, will be used to accelerate the uranium beam from 15 MeV/u to 34 MeV/u. There is one superconducting solenoidal magnet in each cryomodule of Segment two for transverse focusing. Each period in the Spoke021 section consists of six spoke cavities (β_{opt}=0.21) and one superconducting solenoid. The period length is 3.76 m. The subsequent nine cryomodules, each containing six spoke cavities operating at 325MHz, will be used to accelerate the beam from 34 MeV/u to 50MeV/u.Each period in the Spoke040 section consists of six spoke cavities (β_{opt}=0.40) and one superconducting solenoid.

The section two will accelerate U^{34+} beam from 15MeV/u to 50MeV/u and U^{76+} beam from 15MeV/u to 100MeV/u. The superducting spoke cavity, whose β is 0.21 and 0.40, will be adopted for the mature technology in the ADS project. The transit time factor of superconducting spoke cavity for U^{76+} and U^{34+} is shown in Fig. 6 As shown in Fig. 6, the transit time factor of superconducting spoke cavity are larger than 0.5 for the two charge state beam. The beam parameters on entering and exiting the segment one are summarized in Table. 2. The simulation results substantiate that the design will meet performance requirements.

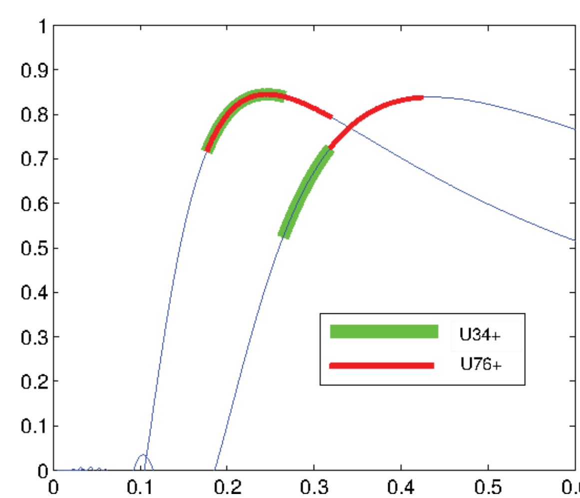

Figure 6: The transit time factor of superconducting spoke cavity for two kinds of beam.

Table 2: Beam parameters in superconducting acceleration segment one

parameter	Qty or Type	Unit
Segment two length	80.18	m
Charge states	76+	
Input energy	15	MeV/u
Output energy	100	MeV/u
Cavity Cryomodule Configuration		
Spoke β_{opt} 0.21		
Number of cryomodules	15	
Number of cavities/cryomodule	6	
Number of solenoids/cryomodule	1	
Number of cavities	90	
Number of solenoids	15	
Rf frequency	325	MHz
Epk 35	MV/m	
Cryomodule length	3.76	m
Cavity Cryomodule Configuration		
Spoke, β_{opt} 0.40		
Number of cryomodules 9		
Number of cavities/cryomodule 6		
Number of solenoids/cryomodule 1		
Number of cavities 72		
Number of solenoids 9		
Rf frequency	325	MHz
Epk	35	MV/m
Cryomodule length	4.36	m

SUMMARY

The general concept of HIAF and the preliminary design of linear injector are presented in the paper. The preliminary design of each section is finished. While more optimization work need to be done in the further.

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ISBN 978-3-95450-122-9