ADVANCED INJECTION SYSTEM OF LIGHT IONS (AISLI) FOR DIELECTRIC WALL ACCELERATOR*

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Abstract

Dielectric wall accelerator (DWA) is a kind of acceleration system with high electric field gradients up to 400 MV/m and very compact dimension, for example ϕ 30 mm x 50 mm, which has the ability to accelerate the particles with any charge to mass ratio. To demonstrate the high gradient tiny acceleration system, a compact injector is required, which should deliver a 50 mA/40 keV pulsed H^+ converging beam to the entrance of DWA. Based on the experimental results obtained on the test bench, a six electrodes injector was developed at Peking University (PKU). In this paper we will describe the preliminary experimental results as well as the details of the new compact injector which named as Advanced Injector System of Light Ions (AISLI).

INTRODUCTION

Dielectric wall accelerator (DWA) is a new acceleration concept that can generate an extremely high gradient up to several hundred MV/m for a short pulse beam with any charge to mass ratio particle [1]. As mentioned in literature [2], a compact proton injector capable of delivering sub-ns proton bunches, and high gradient insulators (HGI) with high surface breakdown strength are two of the five essential elements to make a proton DWA accelerator compact. Sitting the HGI in oil tank is a solution to increase the HGI surface breakdown strength. A space between the proton injector and HGI for adaption is needed. To better understanding the DWA concept, a ϕ 30 mm x 50 mm HGI will be used to demonstrate its acceleration ability. Beam need for this HGI demonstration is a 50 mA/40 keV converging square pulse proton beam. Its repeat frequency is 50 Hz. The width of each pulse is 200 ns. Besides, the injector should be a very compact one so that it can match DWA's tiny features with reasonable dimension. Parameters of the injector are listed in table 1.

To meet the requirement of the tiny DWA, a 20 cm long proton injector including 8 cm adaption space for ion tank are developed at Peking University (PKU). It consist of on a permanent magnet 2.45 GHz Electron Cyclotron Resonance Ion Source (PMECRIS) [3] and an electrostatic focusing LEBT based on the preliminary experimental results obtained on PKU LEBT test bench. This injector is named as Advanced Injection System of Light Ions (AISLI). In part II, we will present the preliminary experimental results based on PKU ion source test bench. In part III we will give a description of AISLI, emphases are located on PBGUNS code simulation, methods for the beam producing, beam focusing, pulse shape controlling. At the end of this paper we will give a summary and anticipation.

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Table 1: Proton Injector Key Performance Parameters Required by DWA

Peak Current	mA	50
Energy	keV	40
Emittance	π mm.mrad	≤0.2
Radius at entrance of HGI	mm	5
Frequency	Hz	50
Pulse width	ns	200
Space for adaption	mm	80

PRELIMINARY EXPERIMENT ON PKU ION SOURCE TEST BENCH

General Consideration

A proton injector is a facility to generate plasma, create an expected ion beam and transport it into accelerator. The core of it is an ion source and a low energy beam transport part (LEBT).

There are more than 50 kinds of ion source around the world. Scientists at LLNL chose a spark source to produce proton beam for their DWA [2]. At PKU a permanent magnet 2.45 GHz Electron Cyclotron Resonance Ion Source (PKU PMECRIS) has been chosen. This is not only because researchers at PKU are skillful on this kind of ECRIS [3-5], but also because the unique feature of it, high ion beam density, high reliability, ability to operate both in CW mode and in pulsed mode, good reproducibility and low maintenance and long lifetime. Because of those characteristic, 2.45 GHz ECRIS is popular as a high current ion source in the world [6-10]. By using permanent magnet to replace the solenoid, the ECR ion source body is about 100 mm, and even smaller.And accessories to support source operation on high voltage platform become less. This will benefit the miniaturization the whole injector.

LEBT is used to transport and to match the beam created and extracted from the ion source to accelerator. Beam focus can be done with electrostatic [10] or magnetic elements [6,8] within LEBT. The beam usually presents a cylindrical symmetry because of the geometry of the extraction system. In order to preserve this symmetry and to simplify the beam tuning, magnetic solenoid lenses or electrostatic einzel lenses are more commonly used than quadrupole lenses. During a high intensity beam LEBT designing, beam focus method selection should count seriously emittance growth, space charge effect, beam transmission efficiency [6,11]. In the meantime, the dimension of LEBT is also an important factor for this decision. Compared with a magnetic LEBT, the disadvantages of electrostatic LEBTs are obvious, no space charge compensation, intrinsical optical aberrations, beam halo creasing and beam divergence enlarging. All this shortcomings will lead beam emittance growth rapidly with its intensity (especially for current of several tens of mA). However, the design of electrostatic LEBTs is simplified by the fact that no repelling electrode for the neutralizing particle trapping. So the beam lines are very compact. As an example, the SNS injector is composed by an H- ion source with a 12 cm long LEBT equipped with two einzel lenses [10]. At PKU we choose an electrostatic type LEBT to match the proton beam with the HGI for this compactDWA.

Experiment Setup

When the frame of the proton injector used for DWA is fixed with electrostatic type, preliminary experiment is launcher to verify this scheme before the detail design on the proton injector done on PKU ion source test bench. Fig. 1 is the skeleton diagram of this test bench before modification. It consists of a permanent magnet 2.45GHz ECR ion source, a tri-electrode extraction system, a slit-grid emittance measurement device and an analysis magnet.

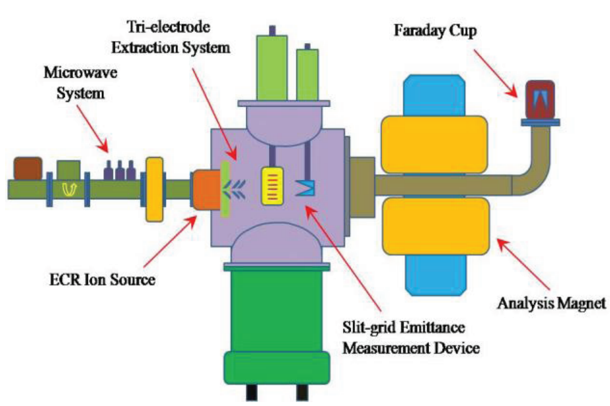

Figure 1: The skeleton diagram of PKU Ion Source Test Bench.

This ECR ion source on the test bench has the ability to produce 120 mA of H^+, 83 mA of D^+,50 mA of O^+, 63 mA of N^+, 70 mA of Ar^+ and 65 mA of He^+ ion beams with a ϕ6 mm extraction aperture at at 50 keV [5].

The distance between each two neighbor slits is 2 mm that locates 200 mm away from the ion emit aperture [12]. Modification will be done by insert an electrostatic lens between the suppressing electrode and the ground electrode.

Preliminary Experimental Results

Figure 2 is 50 mA/40 keV H+ beam transverse distribution obtained using slit-grid emittance measurement device on PKU ion source test bench. As shown in Fig. 2, the beam diameter is about 5 slits that equal to 10 mm, and its rms emittance is only about 0.1 π mm.mrad. This result proves that our preliminary experiment satisfies the requirement of DWA.

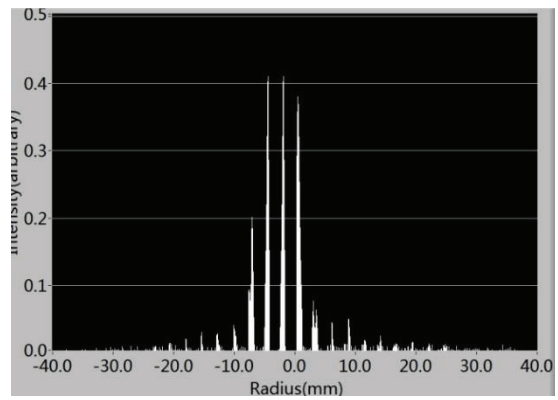

Figure 2: The transverse distribution of 50 mA/40 keV H^+ beam at the location of DWA entrance.

THE PROTON INJECTOR(AILIS) FOR DWA

Based on experimental results gained on the PKU Ion Source test bench, an H^+ injector consisted of the proton source and LEBT is shown in Fig. 3. The ion source is a PKU PMECRIS, just a copy of D^+ ion source developed for PKUNIFTY. The LEBT electrodes basically form two electrostatic einzel lenses that provide two-parameter matching into HGI at its entrance plane. The central electrode of the second lens is split into two isolated quadrants, and electrostatic voltages can be superimposed on the main potential to provide angular steering in the horizontal and vertical directions. Kicker that follows the second lens is used to chop the 50 Hz/0.5 ms H^+ beam generated by microwave power into 50 Hz/200 ns shape. The kick-off beam will be absorbed at the water-cooling flange just before the ion tank.

Preliminary study using the code PBGUNS [13] with 40 keV/50 mA proton beam transport is illustrated in Fig. 4.

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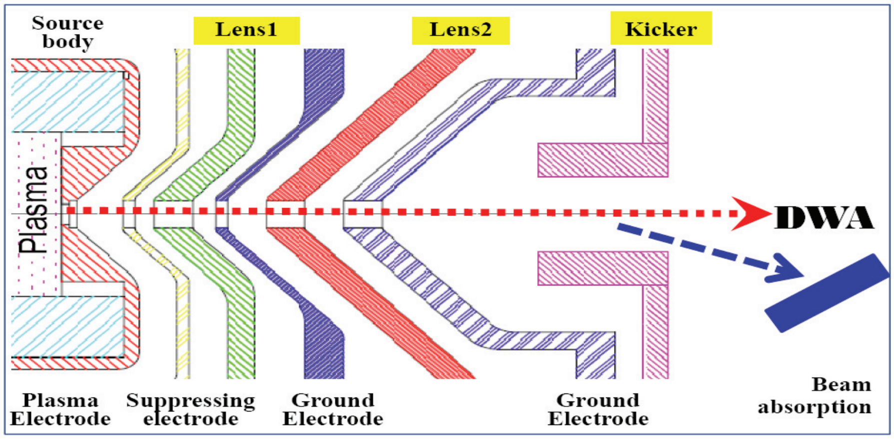

Figure 3: The schematic view of AISLI (un-scaled).

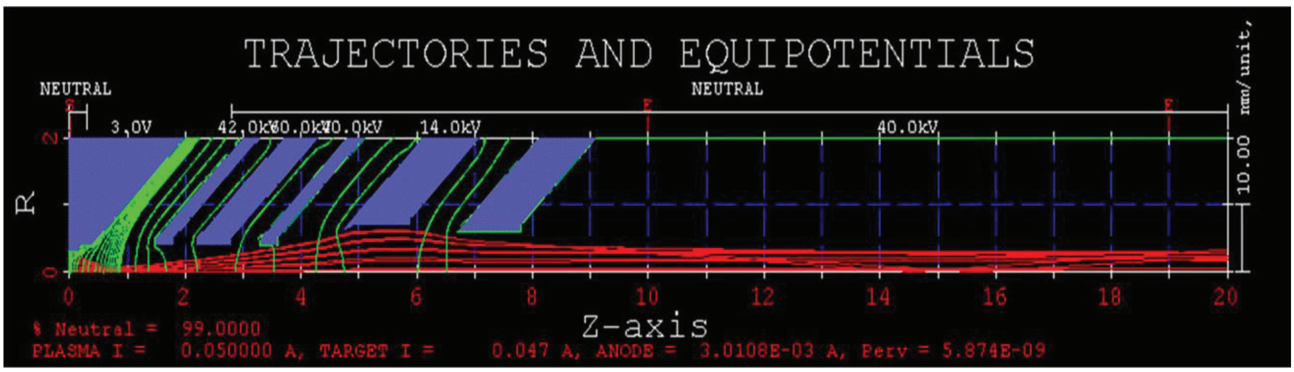

Figure 4: PBGUNS simulation of AISLI for 50 mA H^+ beam.

SUMMARY AND ANTICIPATION

According to the preliminary experimental results, a novel design of the proton injector (AISLI) for DWA has been developed. Two electrostatic einzel lenses are adopted to adjust the proton beam for matching with DWA. The commissioning of AISLI will be done in the near future, and we expect to obtain a 50 mm/40 keV proton beam with the diameter less than 10 mm at the entrance of the dielectric wall accelerator.

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