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DEVELOPMENT OF 2.45 GHz ECR ION SOURCES AT IMP

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Abstract

The Ion Source Group at IMP has undertaken series of high intensity ion beam R&D projects. The first project is the development of the intense proton source and low energy beam (LEBT) for China Initiative Accelerator Driven Sub-Critical reactor (*CiADS*). The specific characteristics of the proton source are long term operation reliability and beam manipulation for the commissioning needs of the SRF accelerator. A low energy beam transport system is used to deliver 35 keV H^+ beam to the entrance of a 2.1 MeV RFQ. And then the 2.1 MeV proton beam is further accelerated by the superconducting cavities to 25 MeV and eventually goes into a high power beam dumper. The 2nd project is the development of the intense ion source for Jinping underground Nuclear Astrophysics experiments (JUNA). The ion source was requested to provide 10 emA H^+, 10 emA He^+ and 2.5 emA He^{2+} beams for the study of (p, γ), (p, α), (α, p) and(α, γ) reactions in the first phase of the JUNA project. The main challenges of ion source for JUNA project are production of intense He^{2+} beam, control of the beam contaminations and wide beam energy range（70~800keV）beam commissioning. Other projects mainly include the development of pulsed intense proton source and LEBT for Compact Pulsed Hadron Source (CPHS) at Tsing Hua university and the commissioning of an intense H_2^+ ion source. In this paper, the studies of this intense beam injector system, for instance, beam intensities, species and ratio, beam transmission efficiency in LEBT and also the beam matching to the downstream accelerator system will be presented.

INTRODUCTION

The Ion Source Group at IMP has undertaken series of high intensity ion beam R&D projects including development and operation of intense proton source for intense beam accelerators and special experimental platform. A project named China Initiative Accelerator Driven Sub-Critical (CiADS) was launched and begun construction in 2011 by Chinese Academy of Sciences[1-3]. The CiADS project mainly included superconducting Linac, a spallation target and beam line. The major target of superconducting linac is to demonstrate the key technologies of 10 mA CW beam of superducting front-end linac. As a key component of linac, the performance of ion source is very important. a 2.45GHz ECR ion source with the energy of 35 keV was developed to meet the requirements of superconducting linac. Next project named Jinping underground nuclear astrophysics (JUNA) project. Experimental investigations of such tiny reaction rates in laboratories at the earth's surface are hampered by the cosmic-ray back ground into detectors. Jinping Underground Laboratory for Nuclear Astrophysics is being constructed. The project need design of a 10mA, 400kV accelerator. Electron Cyclotron Resonance (ECR) ion source is selected to produce required ion beams such as H^+, He^+, He^{2+}. The 2.45 GHz ECR ion source has been proved to be able to produce very high beam currents and was successfully used in ADS at the Lanzhou Institute of Modern Physics [1]. Detailed reports on ion source and the elements of beam transport on the platform will be introduced in addition. In this paper, the status of ion source of CiADS project and development of JUNA project were present.

I. RUNNING STATUS OF THE INTENSE PROTON SOURCE FOR ADS LINAC

To produce the requested 10 mA proton beam for China Accelerator Driven Sub-Critical system(C-ADS) [2,3], electron cyclotron resonance (ECR) ion source operating at 2.45 GHz have been developed. As shown in Fig. 1, the cutaway view is the configuration of the proton source and extraction system. The proton source includes a waveguide, all-permanent magnet source body and discharge chamber. A dual-ridge waveguide is connected with the plasma chamber through the microwave window in order to couple microwave power efficiency. The plasma chamber was made of copper, which is 70 mm long and 54 mm in diameter. In order to obtain the small initial emittance, a diameter of 4 mm hole was designed to extraction proton beam. A 3-electrode extraction geometry was designed to extract the 20 mA, 35 keV ion beam. Meanwhile, in order to enhance the operation life of plasma electrode, the Molybdenum electrode with high temperature resistance was fabrication.

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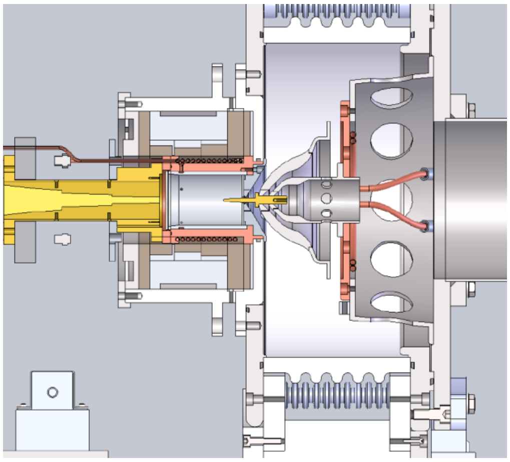

Figure 1: Configuration of the proton source and extraction system.

In order to ensure SRF commissioning and reliability of MPS, an electrostatic-chopper has been installed in the LEBT line that can chop the beam into a pulsed one, and a on-line beam current tuning device was installed in the LEBT to obtain a step value of 0.1mA. In order to obtain the continuously variable beam currents, a set of specially designed on-line tunable circular beam slit has been developed, as shown in Fig. 2. Based on the calculation of proton beam envelope, the maximum diameter of the slit aperture was set to 40 mm. By adjusting the slit opening, the relationship between the aperture and passing beam current could be built. This is very useful tool to control the beam conditions for downstream linac commissioning. And thus it can obviously improve beam commissioning efficiency and reduce the beam loss in the accelerator. The total operation time of the proton source is up to 4000 hours since 2014. Figure 3 shows the operation log with the time of 240 hours. During the machine commissioning with 10 mA pulse beam at 35 keV with a repeat frequency of 1Hz, pulse width of 20 μs for beam emittance measurement and correction of the beam orbit in the MEBT. Many beam trips caused with linac MPS were seen in Fig. 3. During the commissioning period, the Superconducting linac was successfully accelerating the 12.6 mA pulse beam with the energy of 26.1 MeV, a repeat frequency of 1Hz. The 25MeV SRF Linac has been the first superconducting accelerator prototype in the world.

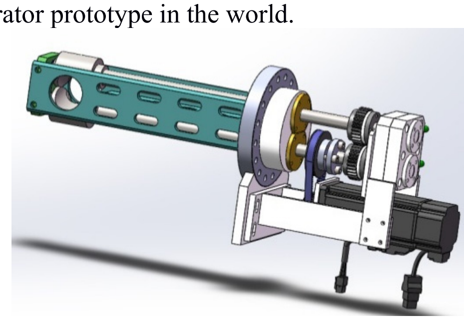

Figure 2: Continuous aperture with servodriven

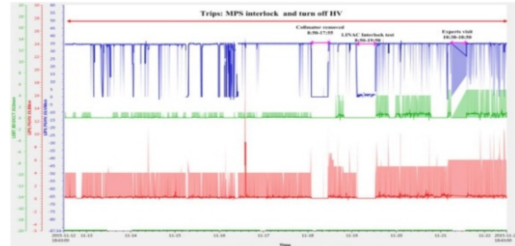

Figure 3: Operation log of the ion source with the time of 240 hours

II. COMMISSIONING RESULTS OF INTENSE BEAM ION SOURCE FOR JUNA PROJECT

The 400 kV high current accelerator is designed to deliver intense low energy proton and alpha beams for JUNA experiments. In 2017, the ion source and LEBT had been successfully developed and connected to the accelerator tube on the ground at Beijing city. Figure 4 shows the front view of the 400 kV accelerator facility. The ECRIS and LEBT system was floated on the 400 kV high voltage platform. In order to research the reliability of the ion source, a 3 hours uninterrupted reliability test has been done with the beam energy of 50 kV and the current intensity of 16.0 mA. The result is shown in Fig. 5, where the red solid line is beam energy, and the blue line represents the total beam current of helium.

Figure 4: Front view of the 400kV high voltage accelerator

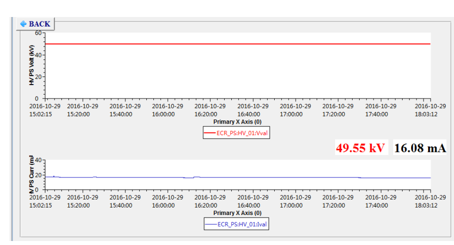

Figure 5: Beam reliability of helium was monitored for 3 hours at the energy of 50 kV

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RESULTS

The first stage of the experiments was performed with an extraction system consisting of a 5 mm aperture plasma electrode and a 10 mm aperture puller electrode separated by 11 mm. The following scheme of gas

CONCLUSIONS

We measured dependencies of the negative ion current on various parameters of the two chamber high-frequency gasdynamic ECRIS, leading to the optimization of the extraction system and the gas feed line pressure. A negative ion current density of 80 mA/cm^2 through 1 mm plasma electrode was demonstrated.

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