6 - 23 A Negative Hydrogen Ion Source for PET Cyclotron

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A negative hydrogen ion source together with a test stand was developed for PET cyclotron at IMP to meet the requirement of 0.5 mA, 70π • mmd • mrad dc H^- beam at 25 keV, as shown in Fig. 1. After more than two years' investigation, design, fabrication, lab construction, tuning and optimization, 1 mA dc H^- beam was recently extracted from the first negative hydrogen ion source at IMP.

Fig. 1 H^- source test bench.

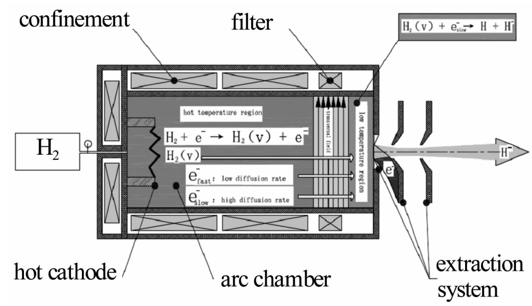

Fig. 2 Principle for the arc discharge H^- source.

With Tantalum wire as hot cathode and hydrogen gas as operation material, the source generates negative hydrogen ions via arc discharge in an arc chamber. As shown in Fig. 2, fast electrons with energy near 60 eV from the cathode bombard the hydrogen gas to create partially ionized plasma, which contains vibration excited hydrogen molecules ($H_2(v)$). To generate higher plasma density, Halbach hexapole magnet rather than conventional multi-cusp magnet was used for confining the plasma. The radial field distribution is given in Fig. 3. A transversal dipole magnet was set as a filter to separate the plasma into two regions, one low temperature region and the other high temperature region, due to transversal diffusion rate of electrons in magnetic field depending on the electron temperature. Fig. 4 shows the axial distribution of the dipole magnet field. In the low temperature region, H^- ion is created by associatively detaching $H_2(v)$ with slow electron about 1 eV.

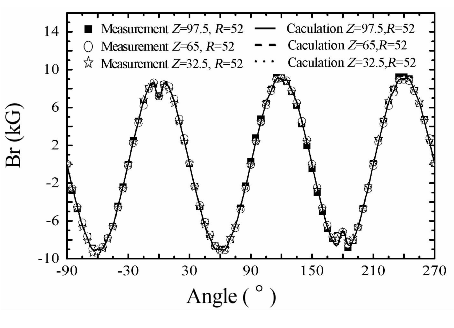

Fig. 3 Radial magnetic field for H^- source.

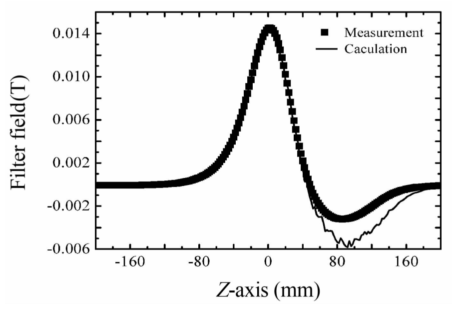

Fig. 4 Transversal magnetic field on Z-axis.

A three-electrode extraction system was designed and fabricated to study beam extraction optics without obviously changing the plasma condition, as shown in Fig. 5. Two stepper motors were used to separately control axial position of the extraction electrode and the ground electrode. The axial position of the plasma electrode can also be adjusted to change the thickness of the filter field by rotating thread connection of the plasma electrode to the arc chamber. Electrons were extracted and dumped to the extraction electrode with energy below 6 keV from the plasma by the strayfield. A dipole electromagnet, and a cone with a ϕ18 outlet aperture at the axial position of about 180 mm from the plasma electrode were set together to ensure it is H^- beam intensity we measured with a downstream Faraday cup.

In 2011, when the source and test bench was preliminarily constructed, we began to study the source. During this period, we improved the filament structure to prolong its working lifetime to more than 60 h. We studied arc discharge state under different gas pressure and filament power. On Dec. 29, 2011, the first commissioning was done by using a two-electrodes extraction system, and 171 eμA dc H^- beam was measured with a $\Phi55$ opening Faraday cup at 590 mm downstream from the plasma electrode.

Fig. 5 The three-electrode extraction system.

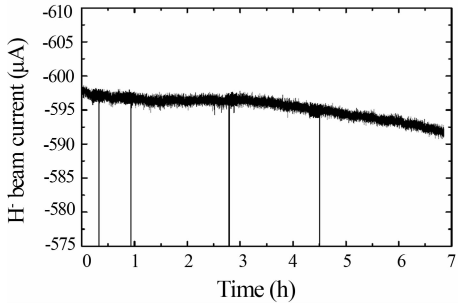

Fig. 6 Beam stability within 7 h.

In 2012, we solved several other problems and began to tune the source with the three-electrode system. We shielded ceramic tubes in the water cool filament bases with stainless steel rings to protect them from bombardment by plasma. Six acrylic glass sheets were mounted on the inner side of the metal cover of the cabinet for the power supplies floated on high voltage, which decreased high-voltage drain current from 3.5 to 0.3 mA. An outside protection circuit, including electronic components such as voltage-dependent resistor (VDR), transient voltage suppressor (TVS), spark gap (SPG), resistor, and capacity, was designed to protect equipment working on the high voltage platform from high-voltage surge. To reduce stripping rate of H^- ions by residual H_2 molecule and other particles, four 700 L/s pumps were used on drift tube instead of original combination of a 1300 L/s pump and a 700 L/s pump, meanwhile the Faraday cup was moved upstream to 380 mm from the plasma electrode.

On Jan 5 th, 2013, more than 1 mA dc H^- beam was extracted using the three-electrode system with parameter setting as follow: a $\Phi5$ hole aperture plasma electrode, a $\Phi10$ hole aperture extraction electrode at 4 mm from the plasma electrode, and a $\Phi14$ hole aperture ground electrode at 35 mm from the plasma electrode. As is shown in Fig. 6, the beam stability of 600 μA dc H^- was tested within 7 h, and the data result showed the fluctuation was better than five thousandths. Further experiments to improve the source performance are scheduled.

6 - 24 A Low Energy Beam Transport System for C-ADS

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To treat the spent nuclear fuel from the power stations in china, a project named China Accelerator Driven System (C-ADS) has been proposed and related R/D has begun since 2011. The accelerators designed for the C-ADS are a superconducting CW proton linac and a room temperature radio frequency quadrupole (RFQ). A 2.45 GHz electron cyclotron resonance (ECR) proton source and a low energy beam transport (LEBT) system are employed to produce and transport a cw proton beam of 10 mA to the RFQ. These apparatus have been designed and are under construction at the Institute of Modern Physics (IMP) in Lanzhou, China.

A dual-solenoid LEBT has been designed for the C-ADS accelerator injector. Fig. 1 shows the layout of the LEBT in which a Test Chamber 2 takes the place of the RFQ for early development. To reduce the length of drift-1 for less aberration, test chamber-1 is placed after the solenoid-1 instead of between the ion source and the solenoid-1. A DCCT with magnetic field shield is incorporated in drift-2 to monitor the CW beam current. To better match the downstream RFQ, the LEBT requires a shortest possible drift-3. However, elaborate engineering efforts have to be taken to accommodate, in a very limited space, a water-cooled collimator, a fast beam chopper, a water-cooled cone, an ACCT and an electron trap. A compromise in accommodating all the required apparatus needed for the transport line has lead to a LEBT of 1670