

THE DEVELOPMENT OF THE H⁻ ION SOURCE TEST STAND FOR CSNS

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Abstract

The type of the H⁻ ion source chosen for the China Spallation Neutron Source (CSNS) is the Penning surface plasma source. The designed output energy of the source is 50 keV and the pulsed beam current of H⁻ beam is 20 mA with a rms. emittance of 0.2 πmm.mrad. The construction of the H⁻ ion source test stand for CSNS is complete and commissioning of the source is in progress. Stable H⁻ ion beams with currents up to 50 mA and energies of 50 keV are achieved. Emittance measurement of the beam is also being prepared.

INTRODUCTION

The accelerator for CSNS is composed of an 81 MeV H⁻ linear accelerator (linac) as the injector and a 1.6 GeV Rapid Cycling Synchrotron (RCS) [1]. As the starting point, the H⁻ ion source is one of the significant parts of the linac. A reliable, stable and good performance H⁻ ion source is a prerequisite of a successful linac, accelerator and CSNS. The ISIS Penning surface plasma H⁻ ion source is chosen as the ion source of CSNS for the following reasons: (1) it completely satisfies the CSNS phase-I beam requirements; (2) it is the lowest cost compared to other types of ion source; (3) there is good collaboration between the Rutherford Appleton Laboratory (RAL) and Institute of High Energy Physics (IHEP). The main parameters of CSNS H⁻ ion source are listed in Table 1. As shown in Table 1, a pulsed beam current of 20mA with a norm. rms. emittance of 0.2 πmm.mrad, which is also basically the performance of the ISIS H⁻ ion source [2]. In addition, a pulsed beam width of about 500 μs also satisfies the multi-turn injection requirement of the RCS with a 100 kW beam power for CSNS phase-I.

Table 1: Main parameters of CSNS H⁻ ion source

Parameters	Value
Ion type	H ⁻
Output energy (keV)	50
Repetition Rate (Hz)	25
Pulsed beam current (mA)	20
Norm. rms. emittance (πmm.mrad)	0.2
Pulsed beam width (μs)	~500
Lifetime (months)	~1

R&D of CSNS H⁻ ion source started with the manufacture of the discharge chamber and the extraction electrode. The collaboration with RAL provided a

complete set of mechanical drawings. Several sets of discharge chambers and extraction electrodes have been manufactured domestically. Tests with these discharge chambers and the extraction electrodes on the H⁻ ion source test stand at RAL demonstrated that the performance of these components is exactly the same or better than those made in the UK for ISIS.

After the successful manufacture of the discharge chamber for the CSNS ion source, an H⁻ ion source test stand is constructed as one of CSNS R&D projects. The objectives of the H⁻ ion source R&D projects are, firstly to examine whether the performance of the discharge chamber in our test stand is the same as that in the RAL ion source test stand; and secondly to build a stable and reliable ion source test stand to facilitate further improvement of the ion source for CSNS.

CONSTRUCTION OF THE TEST STAND

The schematic layout of the H⁻ ion source test stand in the laboratory is shown in Fig.1. As shown in Fig.1, the H⁻ ion source test stand includes many subsystems or components such as the ion source discharge chamber itself, the power supply system, the control system, the vacuum system, the beam diagnostic system, the grounding system, the water-cooling and Freon-chilling delivery system, the Cesium delivery system, the hydrogen delivery system, and the high voltage platform, etc.

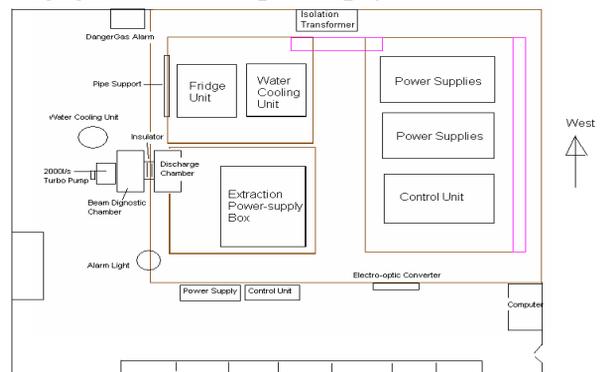


Figure 1: Schematic layout of the H⁻ ion source test stand.

As shown in Fig.2, the ion source main body consists of the discharge chamber and its vacuum chamber, the extraction electrode, the Penning and deflecting magnets, the cold box, the accelerating electrodes, the feed-through for the chilling circulator, the vacuum chamber for the beam diagnostics, etc.

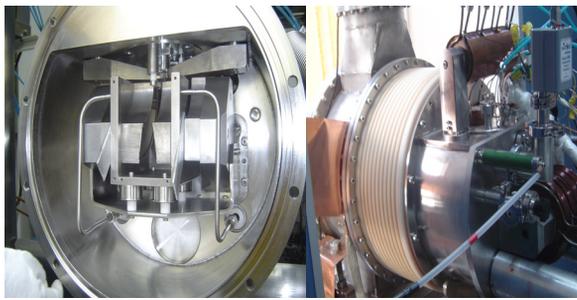


Figure 2: The ion source main body.

The power supplies include the Penning and deflecting magnets power supplies, the accelerating voltage power supply, the DC/AC discharge power supplies, the piezoelectric hydrogen valve power supply, the extraction power supply, the Cesium oven and Cesium transport pipe heater, the high-voltage isolating transformer, etc. In Fig.3, the main power supplies for the ion source are shown.

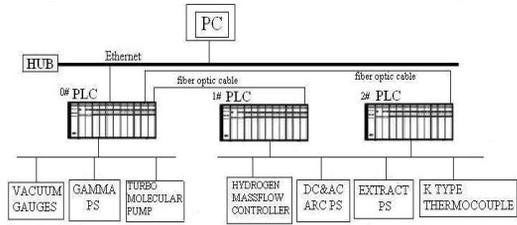


Figure 3: Main power supplies for ion source.

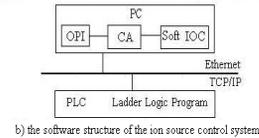
The control system is developed using Yokogawa FA-M3R Programmable Logic Controllers (PLCs) and Experimental Physics and Industrial Control System (EPICS). It is a local and two-level control system and will be linked with the remote control system through Ethernet in the future. It is composed of the front-end controller, the field control equipment (device interface) and the Ethernet network. The schematic of the control system structure is shown in Fig.4. Some of the devices controlled and monitored are shown as an example in Fig.4. The communication between the PLC and the PC employs the Ethernet based TCP/IP protocol by installing a driver supporting for Ethernet under EPICS.

In order to realize the integration of extendable systems, and to set up a friendly operator interface, the EPICS software is adopted and installed in the PC. The PC working as the front-end controller is the top-level control. The Operator Interface (OPI), Channel Access (CA) and the soft Input/Output Controller (IOC), based on the EPICS software toolkits, form the upper layer of

the control system. The soft IOC on the upper control layer functions as a hardware controller running the device interface modules (i.e. the PLCs). CA connects the client in OPI with the server in IOC, and provides the OPI with a transparent access to the IOC database. This software architecture allows the user to implement both the control and monitoring through the graphical user interface developed by the Extensible Display Manager (EDM) toolkit based on EPICS, and to create the state notation program with State Notation Language (SNL) in IOC. The graphical user interface is shown in Fig. 5.



a) a simple block diagram of the ion source control system architecture



b) the software structure of the ion source control system

Figure 4: Schematic of the control system structure.

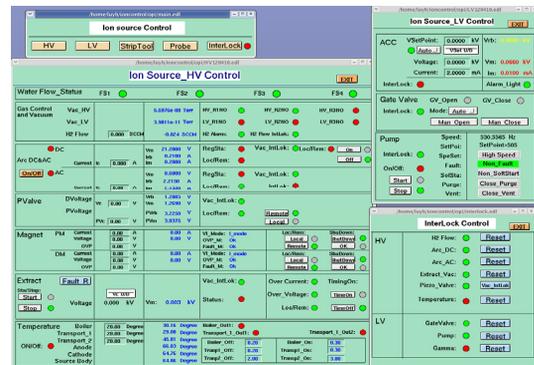


Figure 5: The graphical user interface of the control system.

The vacuum system consists of a 14 l/s mechanical pump, a 2000 l/s turbo-molecular pump, two sets of vacuum meters and gauges, a CF250 air actuated valve and a KF40 electromagnetic valve. The air actuated valve is remotely controlled and interlocked with the vacuum meter. With the pumps, the static vacuum pressure is about 10^{-7} torr. The construction of the H^- ion source test stand was finished at the end of 2009.

COMMISSIONING OF THE ION SOURCE

Before commissioning the ion source, all subsystems for the H^- ion source test stand are tested independently. The extraction electrode system is conditioned for extraction voltages up to 24 kV without H_2 flow and 20kV with H_2 flow. The post extraction accelerating voltage is conditioned up to 55keV. The deflecting magnet is tested to 8 A, and the Penning magnet to 6A.

The commissioning of the ion source starts from the application of the DC discharge. The DC discharge is normally applied for about 30 minutes. The purpose of the DC discharge is as follows: (1) the low current conditions the discharge chamber without Cesium; (2) to heat up the discharge chamber to the operating temperature of around 500°C; (3) to allow examination of the performance of the discharge chamber. Since the maximum output voltage of the DC discharge power supply is 1kV, the DC discharge parameters (such as vacuum pressure, H₂ flux, the Penning magnetic field and the deflecting magnetic field) requirements are not as strict as for the pulsed discharge. The extraction voltage is applied at the same time to condition the extraction electrode. The stability of the extraction field is highly dependent on the vacuum pressure and the stability of the DC discharge. When the DC discharge current, the temperature of the electrodes in the discharge chamber, the extraction voltage, the temperature of the Cesium oven and transport all satisfy the conditions required for a pulsed discharge, the low current DC discharge can be directly switched to high current pulsed discharge without any adjustment of the discharge parameters. In Fig.6, a typical DC discharge current curve is shown.



Figure 6: DC discharge current (pink), the peak current about 18A and pulse width about 15ms.

The pulsed discharge and beam extraction must occur simultaneously. Since the Penning surface plasma H⁻ ion source requires Cesium to operate, there will inevitably be some Cesium vapour diffusing out of the discharge chamber and part of the Cesium will deposit on the extraction electrode. As the Cesium deposited on the electrode accumulates, the capability to withstand the extraction voltage between the discharge chamber and the extraction electrode is diminished. However part of the extracted beam (H⁻ ions and electrons), especially the electrons will bombard the electrode and cause heating which serves to prevent the accumulation of too much Cesium on the extraction electrode. Fig.7 shows the pulsed discharge current and the extraction current (both the H⁻ ions and electrons). The pulsed discharge current is about 50A with a pulse width of 800 μs and the extraction current is about 300 mA with a pulse width of 520 μs. The pulsed discharge current is adjustable from about 30A to 50A, and the extraction current also varies with the discharge current. In Fig.7, the voltage output of the piezoelectric hydrogen valve power supply is also shown (yellow).



Figure 7: Pulsed discharge current (red) of 50 A with a pulse width of 800 μs and the extraction beam current (green) about 300 mA with a pulse width of 520 μs.

After the pulsed discharge is stable, the power supplies including the piezoelectric hydrogen valve power supply, the H₂ flow controller, the Penning magnet supply, the deflecting magnet power supply and the pulsed discharge power supply are all switched to remote mode from manual mode. The door of the high voltage cabin is closed. Then the accelerating voltage is applied and raised up to 50 kV. The accelerating power supply is interlocked with the door, and the accelerating voltage is automatically increased by the control system. In Fig.8, the output H⁻ ion beam with energy of 50 keV and a current of 53 mA is shown. The pulse width is 520 μs and the repetition rate is 25 Hz. 48 hours continuous operation of the test stand is also carried out, and more than 8 hours stable operation without interruption has been achieved.

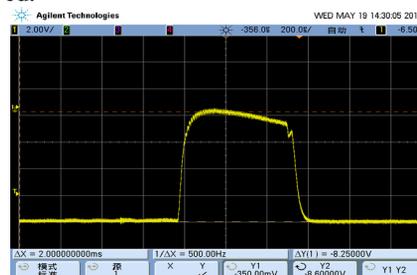


Figure 8: H⁻ ion beam with energy of 50 keV and a current of 53 mA.

REFERENCES

- [1] CSNS Conceptual Design Report (IHEP, China, 2005).
- [2] J. W. G. Thomason, R. Sidlow, "ISIS ion source operational experience", EPAC2000, Vienna, Austria, June 2000, p.1627 (2000).