CNIC-1638/13
CNNC-0003

Microwave Ion Source for Accelerator Driven Sub-Critical System

CUI Baoqun BAO Yiwen LI Liqiang

JIANG Weisheng WANG Rongwen

China Institute of Atomic Energy, Beijing, 102413

Abstract: A microwave ion source is under developing for a demonstration prototype of a accelerator driven sub-critical system at CIAE (China Institute of Atomic Energy), 100 mA hydrogen beam has been extracted from the source through a 7.3 mm aperture in diameter, proton ratio is more than 85%, reliability has been tested for 100 h without any failures.

Key words: Microwave ion source, Accelerator driven sub-critical system, Reliability

INTRODUCTION

The goal of CDPADS (China Demonstration Prototype of Accelerator Driven Sub-critical system) project is to develop the technologies needed for designing an accelerator driven sub-critical system for nuclear waste transmutation according to the Rubbia's proposal[1]. The proposal is based on a high current continuous wave proton linear accelerator that will drive a sub-critical system to transmute nuclear waste or even to generate energy. The program was developed by CIAE, IHEP and PKU under the support of DSTC in the end of 1999. The system consists of two main parts: the accelerator and the sub-critical system. CIAE is in charge of ion source, low energy transportation section and the sub-critical system, as well as some aspects related to this system, IHEP will handles the design of RFQ. The proton source must fulfill three requirements at same time[2]: proton current higher than 50 mA, root square normalized emittance below 0.2 πmm • mrad and reliability close to 100%.

Since 1999 under the support of NCNSF a microwave ion source has been developed and tested, the source is able to fulfill the first requirement; a 100 h reliability test has been carried out without failure while there are still some improvements required.

At present, the source is tested at 30 kV; and a 100 kV, 110 mA HV power supply is under development. To efficiently accelerate the proton beam in RFQ, 80 keV energy of proton beam is required.

1 THE SETUP OF ION SOURCE

The design of the source is shown in Fig. 1. The microwave power obtained with a 2.45 GHz/1 kW magnetron is coupled to the cylindrical stainless steel chamber (100 mm in diameter and 100 mm long) through a three stubs tuning unit and a ridged wave guide. The microwave window for vacuum sealing is placed behind a bend section in order to avoid any damage due to the back streaming electrons.

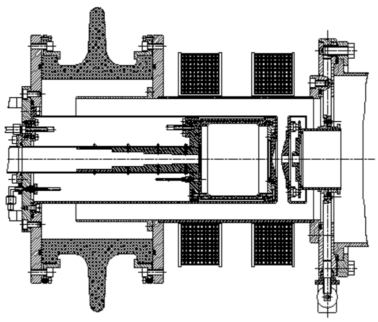

Fig. 1 The schematic of microwave ion source

Two movable coils at ground potential with separate power supply allow to vary the position of the electron resonance zones in the chamber and to produce the desired magnetic field configuration. The design has been aimed to simplify the maintenance especially in the extraction zone.

The unique design of ridged wave guide fulfils two goals at same time: optimizing the coupling between the microwave generator and the plasma chamber, making it possible that the ridged wave guide realizes a progressive match between the impedance of wave guide and impedance of plasma chamber and concentrates the electric field at plasma chamber to maximum the resonance. With an unique configuration, the boron nitride disk between ridged wave guide and the plasma chamber, the weakest point which tend to break up while bombarded by back streaming electrons according to our experience, is free of risk caused by back streaming electrons.

The extraction geometry of this source is traditional three electrodes. Besides plasma electrode, the suppress electrode biased at –2 kV to ground is used to prevent the secondary electrons which neutralize the space charge of high intensity proton beam from accelerating back to high voltage electrode. The electrode next to suppress electrode is at ground potential to shield electric field in extraction region. At 30 keV energy, the extraction system works reliably, to achieve our final goal (80 keV) and improve the emittance, the extraction system will be modified if necessary.

2 THE EXPERIMENTAL RESULTS

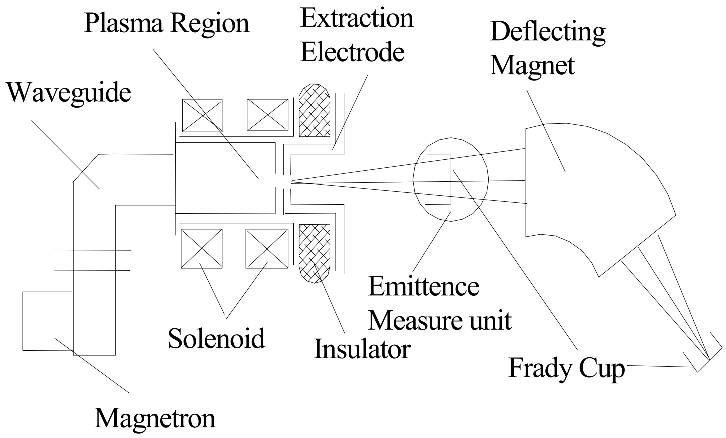

Fig. 2 The experimental setup

Fig. 2 shows the experimental setup: the 30 keV high voltage platform which has been upgrade to 100 keV recently and the low energy beam transfer line (LEBT) devoted to the beam analysis and characterization are used for testing the ion source. The LEBT line consists of a Faraday cup, an emittance measuring unit and a deflect magnet which can be used to measure the proton ratio of the beam. It is worth to notice that the oil diffusion pump is used to evacuate the system in which the contamination of oil has a significantly impact on the spark in extraction region. A new test bench is under construction which will be equipped with current transformer (DCCT), high power beam stop, emittance measuring unit and evacuated by turbo molecule pump that will greatly decrease the contamination from the diffusion oil. The solenoid to focus the beam is under design.

At first, the test is performed at an extraction voltage of 30 kV (instead 80 kV requested) when a 100 kV, 110 mA high voltage power supply is under development. The aperture of the plasma electrode is 7.3 mm in diameter. In this configuration, 70 mA of the extracted current can be routinely generated, emittance measured by pepper pot method is much smaller than required for injecting into RFQ. (Fig. 3) A multi-slits and single thread emittance measuring unit has been installed and more accurate measurement will be carried out soon.

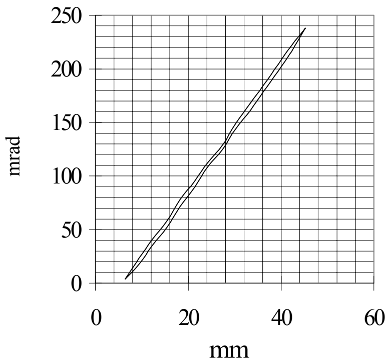

Fig. 3 Emittence plot of ion beam

By selecting a slice of the beam to pass through a deflection magnet, the proton ratio is measured. The result shows that proton ratio is more than 85% that satisfied the requirement of the system. The proton ratio slightly varies with the changes of microwave power but no significant effect is found.

Finally we have investigated the more stringent request concerning the reliability with a 100 h test. The Table 1 presents the parameters of the source during the test.

Table 1 Source parameters during the test

Extraction Voltage	30 kV
Microwave power	800 W
Beam current	60 mA
Vacuum pressure	1×10^{-3} Pa

After the conditioning of a few hours, the source has been operating for 100 h without any spark down (Fig. 4). The source have not required any particular tuning during 100 h, except for a few variations the gas inlet hydrogen pressure in the plasma chamber and intentional tune down of discharging power for accordance with variation of power line voltage. A new magnetron power supply to eliminate the fluctuation of the power line voltage has been ordered to fulfill the requirement.

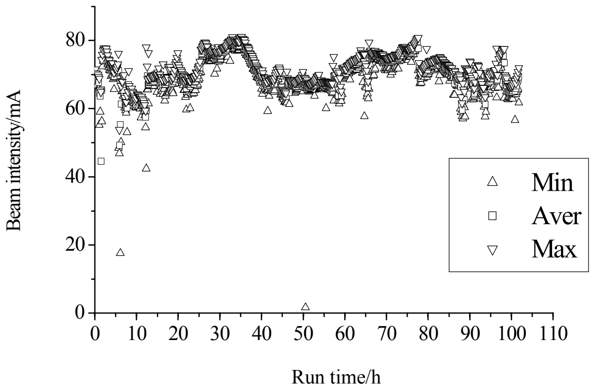

Fig. 4 Beam current Vs elapsed time 100 hours test

3 CONCLUSION AND FUTURE DEVELOPMENTS

In Table 2, the status of the source is compared with the requirements. The beam energy will be increased to 80 keV when the HV power supply is available. A new test bench equipped with necessary characterization unit and oil free vacuum system will be installed at the end of this year. After the more accurate conditioning of emittance measurement unit, the emittance measurement will be done.

Table 2 Status of the ion source

	Required	Status
Beam Energy	80 keV	30 keV
Beam Current	50 mA	60 mA
Reliability	≈100%	100%(100 h)
Beam Emittance	≤0.2 πmm • mrad	---

REFERENCES

1 Carminati F, Klapish R, Revol J P, et al. Report No. CERN/AT/93-47

2 Ciavola G, Gammino S. Report, LNS, OCT 21, 1996

用于加速器驱动洁净核能系统的微波离子源

崔保群 包铁文 李立强 蒋渭生 王荣文

中国原子能科学研究院，北京，102413

摘　要：介绍了正在研制的用于加速器驱动洁净核能系统的微波离子源，通过离子源 7.3 mm 的引出孔可以引出 100 mA 的氢离子束，质子比好于 85%，离子源成功地通过了 100 小时可靠性试验。