Current status and future plan for Control system of Two-Region Arc Plasma (TRAP) Ion Source

Dae-sik Chang*, Tae-Seong Kim, Seung Ho Jeong, Kihyun Lee, Jeong Tae Jin
Korea Atomic Energy Research Institute, Daejeon, Republic of Korea
*Corresponding author: dschang@kaeri.re.kr

***Keywords : Two-Region Arc Plasma, Ion Source .**

1. Introduction

The Korea Atomic Energy Research Institute (KAERI) is currently developing a Two-Region Arch Plasma Ion Source (TRAP). The system is characterized by two zones with different plasma temperatures without the use of external filter field magnets. The TRAP ion source has been fully fabricated except for the beam extractor and is currently installed in the experimental chamber, where studies of the plasma discharge characteristics are underway. The TRAP ion source control system has also been configured to perform plasma discharge characterization experiments, and an extension of the control system for future beam extraction experiments is under consideration. This paper is an introduction to this work.

2. TRAP ion source experimental set up

The TRAP ion source consists of two major components as shown in Figure 1. It is a multi-cusp bucket plasma discharge chamber and a slit-type beam extraction system. The plasma generators of TRAP ion source have a common bucket-type arc chamber surrounded and arranged by multiple rows of permanent magnet columns on the outside to improve plasma discharge efficiency. [1] It also has four filaments that emit primary electrons, placed on the left and right sides, for a total of eight filaments.

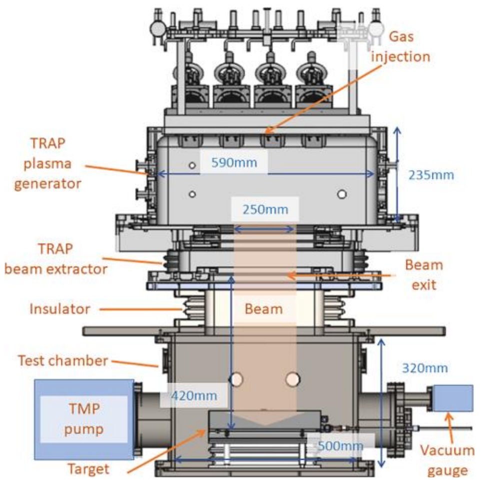

Fig 1. A design of the TRAP ion source and Test chamber assembly.

The slit-beam extractor consists of four grids, called G1, G2, G3, and G4, and can accelerate ions in the plasma grid up to 30 keV. Grids G1, G2, and G3 are positioned on the upper electrode flanges, and grid G4 is located on the lower electrode flange. The TRAP ion source is an electrically grounded ion source, so the target is connected to the G4 grid to maintain the same potential, and is powered through a high-voltage feedthrough. The G2 grid is powered at 2 kV/2A, the G3 grid is powered at 10 kV/500mA, and the G4 grid is powered at 30kV/300mA. To suppress secondary electrons from the target, the G4 grid is biased 200V lower than the target by connecting a Zener diode. Figure 2 shows a simplified power connection diagram for the TRAP ion source experimental setup.

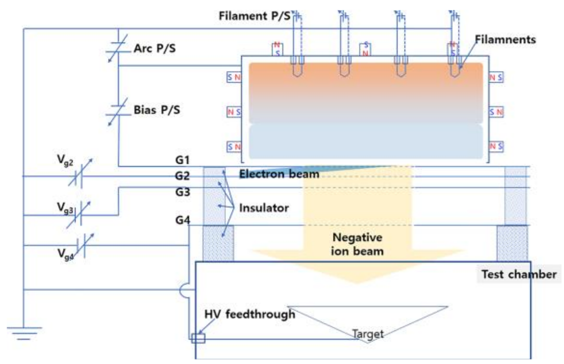

Fig 2. Power connection diagram of the TRAP ion source experimental setup

3. Control for TRAP ion source

A remote operation system has been developed for the TRAP ion source. Figure 3 shows the sequence for beam setup operation of the TRAP ion source.

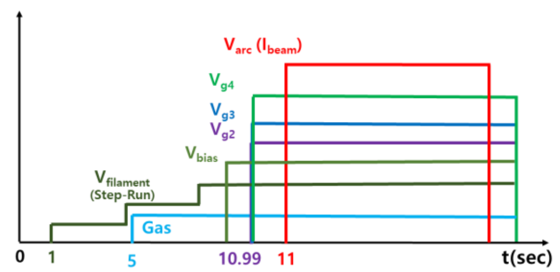

Fig 3. Operation setup time chart

The control of the ion source must be able to individually control the DC power supply for the eight filaments and use the arc power supply to generate the DC arc discharge. There must be also be a way for the filament power supplies to be operated simultaneously.

The control of the filament power supply has been implemented using the standard Modbus protocol, using broadcast mode when simultaneous control is required and unicast mode when individual control is required. When operating eight filament power supplies simultaneously, the voltage and current of all eight can be monitored with eight data acquisitions per second for each power supply. [2]

The arc power supply used for four power supplies connected in series, and an in-house module called K-MIO has been used as an interface device to enable pulse operation.

Table 1. Control equipment of TRAP ion source

functionality	specification	interface	Notes
Filament	30V/400A 8ea	Modbus RTU	Can be operated individually/ simultaneously
Bias	35V/400A 1ea	Modbus TCP/IP	
Arc	20V/1000A 3ea, 40V/1000A 1ea	K-MIO (RS-485)	Connect in series for final 100V/1000A configuration
G2	2kV/2A	K-MIO (RS-485)	
G3	10kV/500mA	K-MIO (RS-485)	
G4	30kV/300mA	K-MIO (RS-485)	
Gas	MKS type 247	K-MIO (RS-485)	

Currently, plasma discharge tests have been performed using filament power supply, arc power supply, and MFC, and Figure 4 is the operating screen. In the plasma discharge test operation step, both CC(current control)/CV(voltage control) modes can be used, and eight voltage/current values are set simultaneously and then executed.

Fig 4. Operator Interface of TRAP ion source for plasma discharge

4. future plan

How to achieve good uniformity in a large area ion source is a challenge. [3] Uniformity can be achieved by controlling the filament current, which can be done by monitoring the beam profile at the target and controlling it, but it can also be done by detecting changes in filament resistance. Considering the complexity of the ion density distribution in the plasma chamber caused by the arc discharge and the beam extraction process, the former may be the more effective option, but the latter is still necessary to create a meaningful control algorithm for controlling the current in the filament.

Plasma density difference at each filament can cause changes in filament resistance over time, which can lead to fluctuations in electron emission from the filaments, resulting in non-uniform beam. If there is a way to detect small current changes in individual filaments to identify and suppress changes in filament resistance, the goal of beam uniformity can be achieved to some extent.

5. conclusion

TRAP ion source can be used for neutral beam injection (NBI) systems in fusion tokamaks, but can also be used in commercial applications where large area ion beams are required. Most important is the stable management of beam uniformity and filament resistance, which can be achieved by controlling the filament current of this ion source and will be confirmed in future experiments.

REFERENCES

[1] Tae-Seong Kim, Seung Ho Jeong, Kihyun Lee, Dae-sik Chang, Jeong Tae Jin, Calculation of negative ion beam loss for two-region are plasma negative ion source, Fusion Engineering and Design 199, 2024.

[2] MODBUS over Serial Line Specification and Implementation Guide V1.02.

[2] M. Naito, Y. Ando, Y. Inouchi, H. Tanaka, N. Miyamoto, Ion sources for large area processing (invited) Rev. Sci. Instrum. 71, 1023-1028, 2000.