Development of the negative ion based neutral beam injector at KFE

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1. Introduction

As a part of a KSTAR and ITER non-procurement device development project, we at KFE and our KAERI colleagues have been investigating the negative ion neutral beam injector as diagnostic tool for KSTAR as well as the basic R&D for fusion reactors since 2016 as shown in table1[1]. A prototype radio frequency negative ion source (RFNIS) is developed at Korea Institute of Fusion Energy (KFE) and specifications of ion source in table 2. This presentation provides an overview of the recent progress made in the RFNIS project. To enhance the operational capabilities of the Inductively Coupled Plasma (ICP), the operation pressure range has been extended through filament-assisted start-up. By utilizing an LC resonance circuit and active control of the RF frequency, the delivered RF power has been maximized, enabling a power delivery of 30 kW to the ICP. Additionally, a high voltage output of 120 kV has been achieved through a series of stackable high voltage power supplies, with plans to further extend the high voltage capability to 180 kV. To enhance the production of negative ions on the surface, a Cs injector and PG heating system have been implemented for Cs conditioning. The presentation will also include the results of beam extraction, which will be compared to the beam optics simulation.

2016-2018	Design of ion source and power supply
2019-2020	Procurement of RF plasma generator, accelerator, and power supply(120kV)
2021-2022	Beam extraction w/o Cs
2023-present	Beam extraction and acceleration with 200C PG temperature control and Cs

Table. 1. Progress of negative ion source development.

Parameter	Description
Plasma source	RF driver + extension chamber
RF driver	50kW(500kHz)
Apertures	5*5 array, Ø16, spacing 22mm
Extractor	<10kV,
Accelerator	<200kV (single stage)

Table. 2. Parameters of RFNIS.

2. Equipment and experiments

In this section some of the techniques used to extract negative ion beams described. The equipment includes a Cs injector, high temperature flow system at plasma grid(PG).

2.1 Cs vapor injector

The negative ion source development for fusion requires adjustable, controlled and reliable evaporation of Cs vapor into the ion source for the efficient negative ion production. Cs vapor injection system is prepared to enhance the ion beam current density. The Cs supply system mainly comprises Cs oven, valve, and connecting tube [2]. The quantity of injected Cs is controlled by the oven temperature (150 ~250℃). Dispenser oven type is used and one dispenser straps can operate about two hours(22mg). Surface ionization detector (SID) is installed for Cs vapor flow measurement.

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2.2 Galden heating and circulation system for PG

PG temperature in the negative ion source should increase quickly and be maintained at around 200 ℃ to optimize the production of the negative ions. Galden HT270 oil heating & circulation system is installed with 13 kV isolators, and the target temperature of PG is 180 ℃. The Galden HT270 oil is heated upto 190 ℃ within 70 minutes. The plasma grid temperature is presumed to reach the target temperature according to the return oil temperature as shown in figure 1.

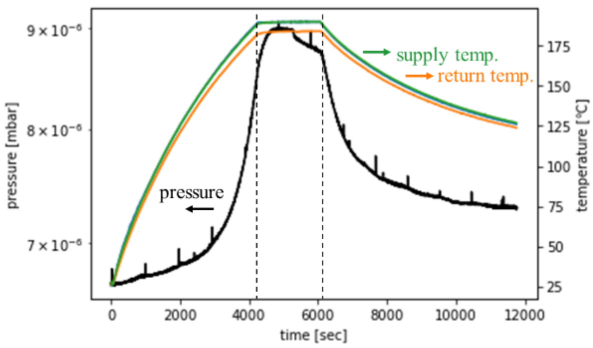

Fig. 1. Evolution of the temperature at PG and vacuum pressure.

2.3 extraction and accelerating power supply.

For the stable beam extraction, electrical circuit is done as shown in Figure1 and resistor(~300kohm) is connected to the parallel to the extraction power supply. To enhance negative ion density, the positive voltage(~60V) is on the plasma grid against chamber wall.

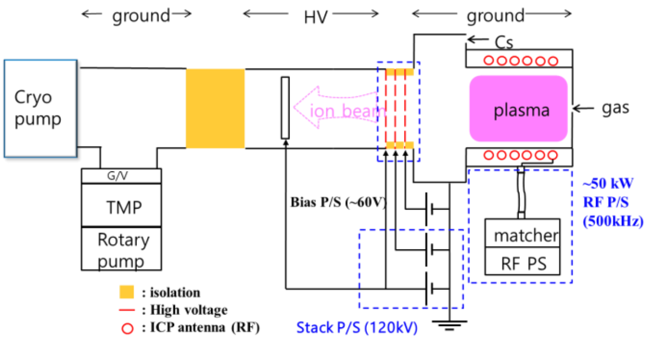

Fig. 2. Electrical circuit of RFNIS.

2.4 Beam extraction and divergence angle
Presently, the extract beam current is ~100 mA and the divergence angle is measured as ~2.8 degree.

3. Summary

RFNIS has equipped Cs injector and PG heater for the Cs seeded beam extraction experiment. Negative ion beam is extracted with Cs injection on 180 ℃ PG surface. Presently, the beam current is about 100 mA and the beam divergence angle is about 2 degree.

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REFERENCES

[1] S.H. Jeong, et al., negative ion beam extraction experiments on the KAERI negative ion source, FED, Vol.109, p. 186, 2016.
[2] U. Fantz, et al., Controllable evaporation of cesium from a dispenser oven, RSI, Vol.83, p.123305, 2012.