Development of Cs-injection System for KFE RF hydrogen Negative Ion Beam Source

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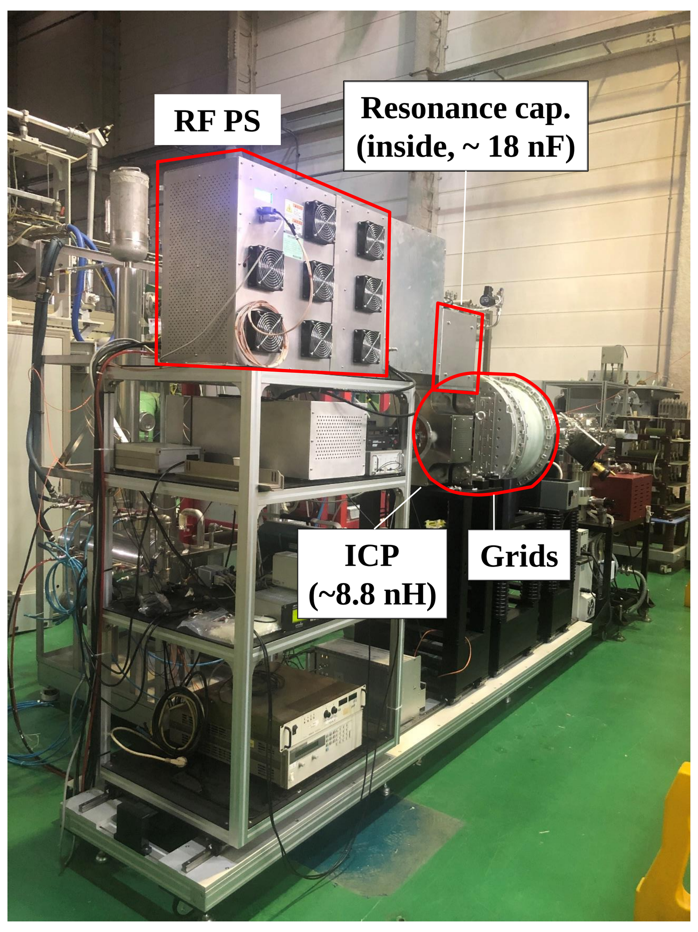
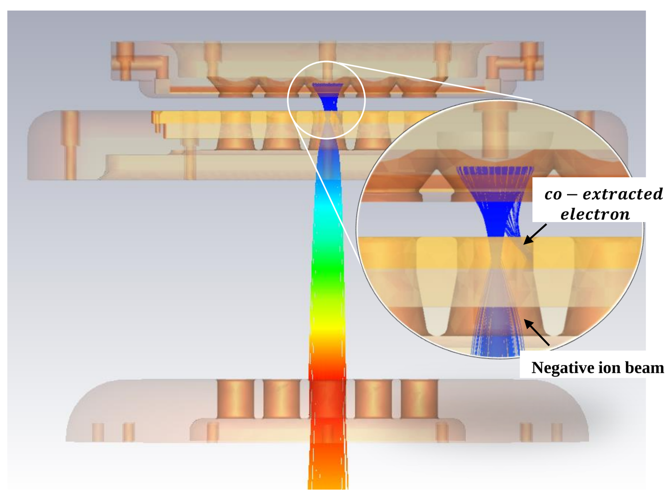
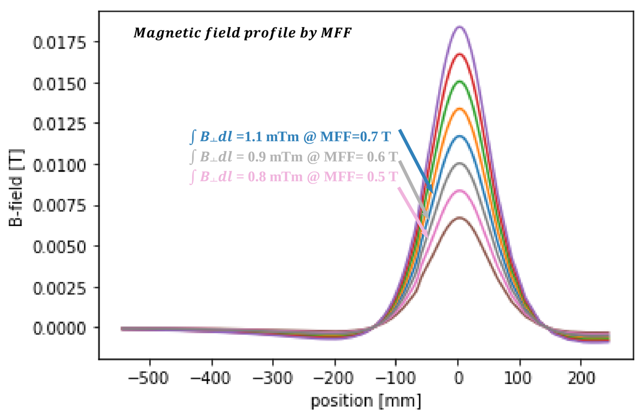
Abstract

A prototype radio frequency (RF) negative hydrogen ion beam source is developed in Korea Institute of Fusion Energy (KFE). The target is to extract negative ion beam with 200 keV, 0.5 A for 100 ms. The RF power supply of 400 kHz delivers over 40 kW to the ICP without the Faraday shield. The plasma is generated and turned off within 120 us, and the RF power supply is stabilized within tens of milliseconds. The negative ion beam is successfully extracted, and the negative ion beam and the co-extracted electron current are separately measured. Since the beam current is limited to only about 30 mA, Cs assist is needed for the beam current enhancement. The Cs vapor injector and the plasma grid heating system are prepared to Cs assisted negative ion beam extraction. The Cs dispenser and SID are installed for Cs injection and its amount measurement. The Galden oil heater and the circulation system are installed to heat the plasma grid over 200 Celsius degree to optimize the surface interaction. The plasma grid temperature is assumed by the supply and return oil temperature. The plasma grid is successfully heated, and the weaknesses such as vacuum sealing o-ring are protected by water cooling. The enhancement of the ion beam current and suppression of co-extracted electron current by Cs vapor injection will be presented.

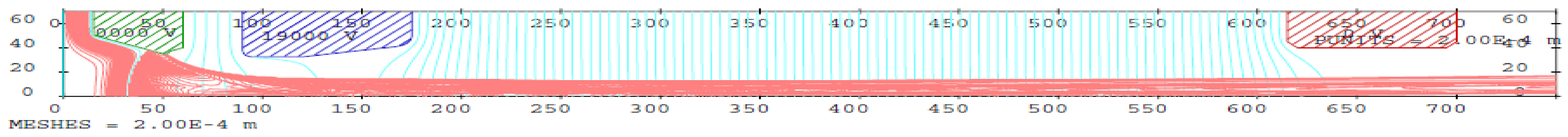
KFE RF Negative Hydrogen Ion Source (RFNIS)





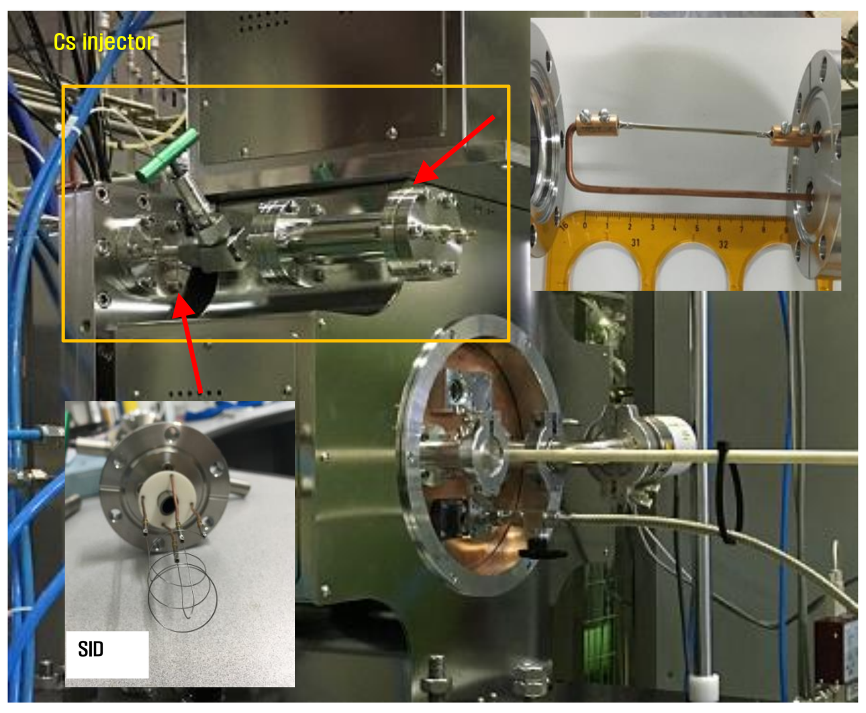


- **The final goal of KFE RFNIS is to achieve 200 keV / 0.5 A ion beam extraction for 100 ms.**
- **RF PS is designed to generate 50 kW resonant ICP inside the AlN chamber. (rising time~100 us, decay time~50 us, freq. ~ 400 kHz, frequency matching.)**
- **IGUN simulation is used to design the grid and to optimize the operation condition.**
- **Stackable battery DCPSs generates 120 kV, and it will be extended upto 200 kV.**
- **MFF and EDF using permanent magnets are optimized based on the CST magnetic field simulation. (M. Froschle, et al., FED 88, 1015 (2013).)**
- **EPICS based control system is applied, and the data are transferred to the MDSplus server.**
- **So far, 30 kW RF plasma is generated to extract 10 kV 60 mA hydrogen negative ion beam.**
- **To enhance the ion beam current, Cs injection and PG heating system are on preparation.**
- **The optimal temperature of PG is varied due to the chamber condition, [M. Yoshida et al., AIP Conf. Proc. 2052 040008 (2018).] but in general the optimum PG temperature is 120 - 200 °C. The initial goal of the PG temperature in KFE RFNIS is to reach 180 °C.**



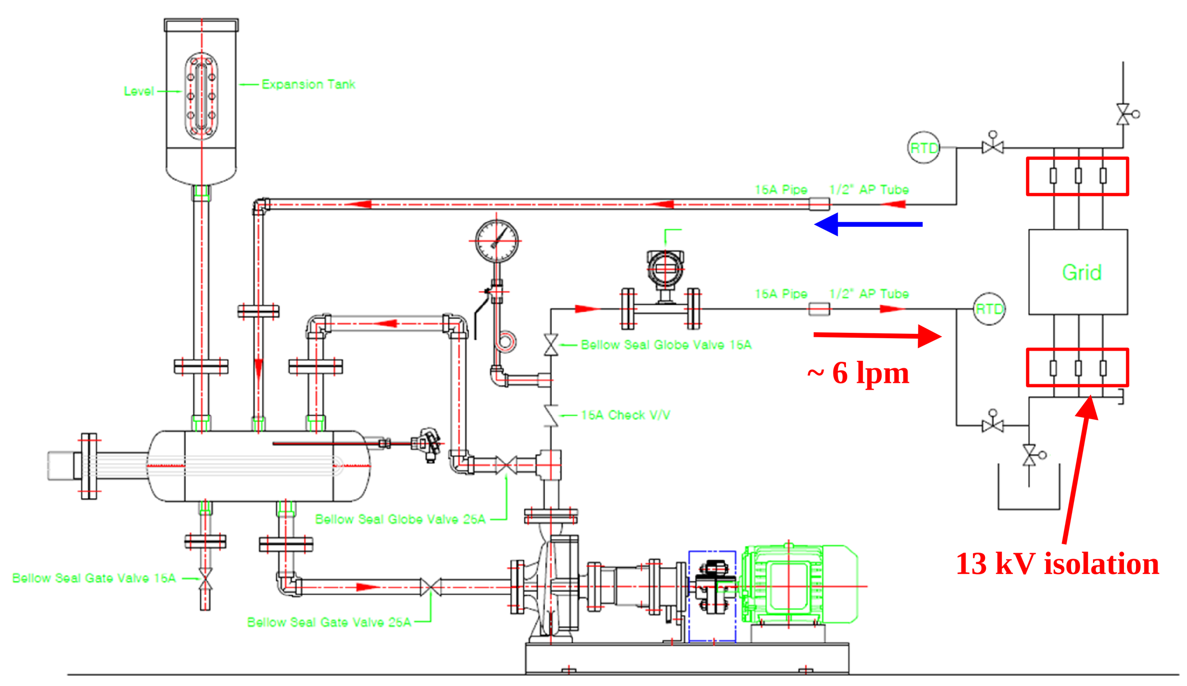
Cs Injection System & Plasma Grid Heater

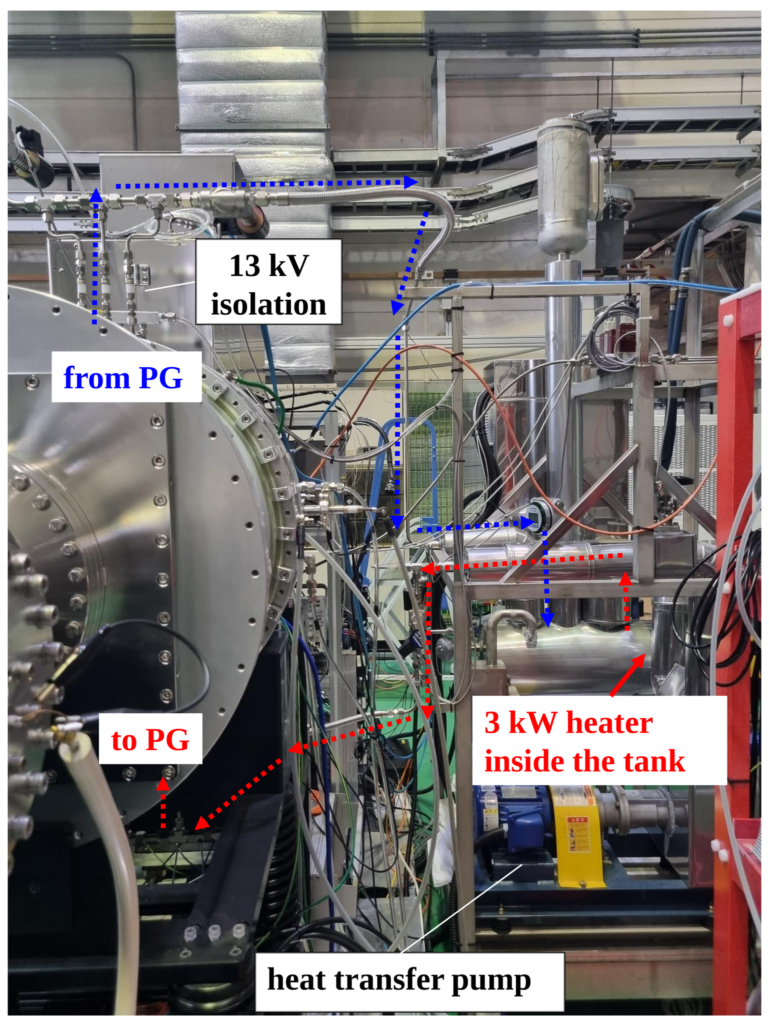
Cs Injector and SID



- **Cs vapor injection system is prepared to enhance the ion beam current density. (Cs dispenser 22mg)**
- **Surface ionization detector (SID) is installed for Cs vapor flow measurement.**

Galden HT 270 Heating & Circulation System

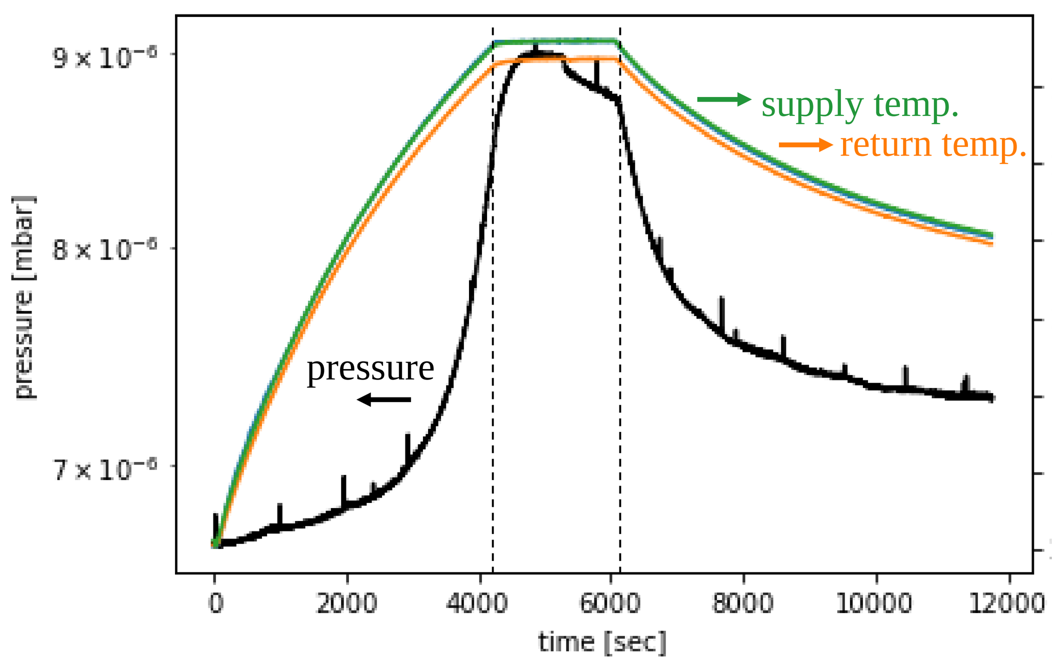




- **Galden HT270 oil heating & circulation system is installed with 13 kV isolators, and the target temperature of PG is over 200 °C.**
- **Heat transfer pump (DSVH-25-A) with differential pressure of 1.1 bar and 70 lpm is usable upto 350 °C.**
- **The flow is set as ~6 lpm by adjusting the pump speed and bypass valve.**
- **As of now, PG temperature monitoring system is not prepared.**

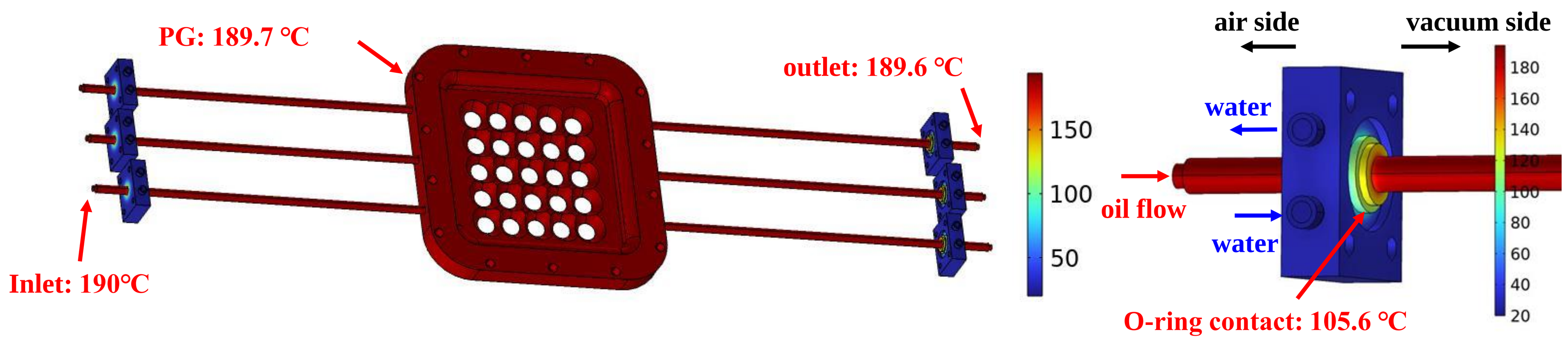
Commissioning of Plasma Grid Heater System

Temperature & Pressure Trace of Plasma Grid Heater



- **The Galden HT270 oil is heated upto 190 Celsius degree within 70 minutes.**
- **The plasma grid temperature is presumed to reach the target temperature according to the return oil temperature.**
- **ΔT=T_supply – T_return ~ 6 °C is maintained.**
- **The chamber pressure increases as the grid temperature increases, but there is no significant evidence of the oil leak.**

Heat transfer and flow calculation by Comsol Multiphysics



- **The PG oil flow channel is installed via a vacuum seal with o-ring.**
- **Since the o-ring cannot hold high temperature, the vacuum seal block is cooled by water.**
- **Comsol multiphysics is used to find the temperature of the vacuum seal, and the loss by the water cooling.**
- **The o-ring contact is maintained at 105.6 °C while the PG is maintained ~ 190 °C, which is slightly higher than the outlet oil temperature.**
- **In the simulation, the heat loss through the PG support structure is not considered, so ΔT=T_supply – T_return is relatively low.**
- **The simulation including other important structures will be performed to accurately obtain the PG temperature.**

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