Recent Progress in the RF Hydrogen Negative Ion Source in NFRI

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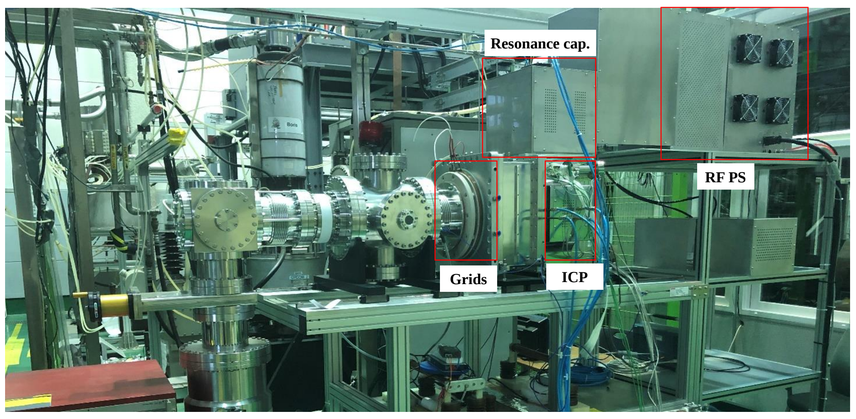
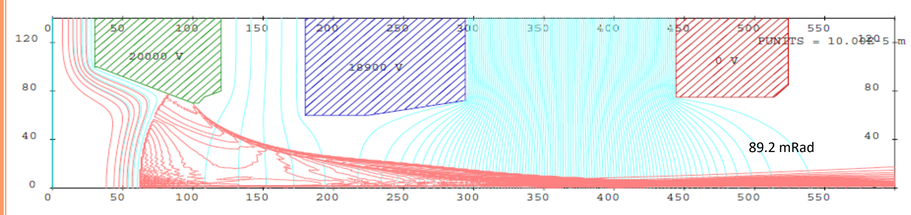
Abstract

A prototype radio frequency (RF) negative hydrogen ion source is under developing in the national fusion research institute (NFRI) in pursuing of the negative ion beam extraction of 200 keV, 0.5 A. The machine has extracted negative hydrogen ion beam since 2018, and recently two major upgrades have been implemented. The first upgrade is in the inductively coupled plasma (ICP) source. The ICP antenna is modified to supply a maximized RF current at the LC resonance frequency by installing additional capacitors. The RF power supply delivers 50 kW of RF power by active control of the RF frequency. A tungsten filament provides seed electrons just before the RF power is applied, and the plasma is generated by the RF power supply within 200 us. The second upgrade is in the series of the stackable high voltage power supplies. The output of the power supply is 20 kV / 1 A, and each power supply is floated and powered by batteries. So far, stacking is successfully applied to two modules, and will be extended. In this presentation, the details of the above upgrades and beam extraction result will be shown. In the near future, more upgrades will be followed: the plasma grid heater using hot oil circulation system will be used for Cs conditioning, and diagnostics using triple probe, CR based OES, and laser photo-detachment will be prepared.

RF Negative Ion Source R&D activity in NFRI



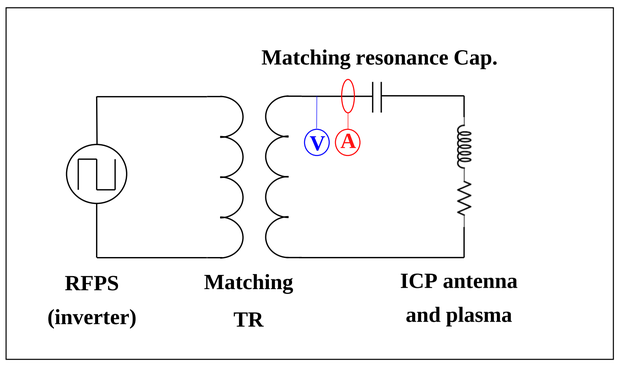
< Current picture of the RFNIS before upgrade. >



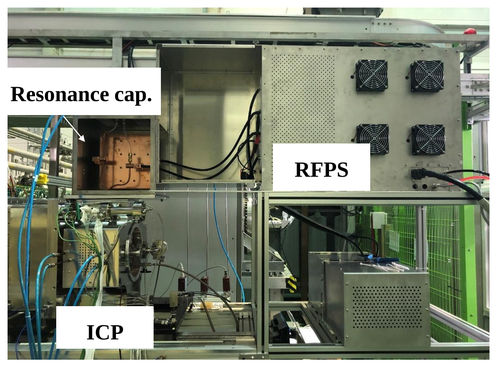
< IGUN simulation result for 20 kV 10 mA ion beam. >

- The final goal of the R&D activity is to achieve 200 keV / 0.5 A ion beam extraction for 100 ms.
- A possible application as a diagnostic neutral beam for KSTAR is considered.
- The system has been assembled with the under-specification devices so far, but is being upgraded now.
- RF PS is designed to generate 50 kW resonant ICP inside the Aluminum Nitride chamber.
- HV is applied by stackable battery DCPSs upto 60 kV, which will be extended.
- EPICS based control system is applied, and the data are transferred to the MDSplus server.
- So far, 16 kW RF plasma is generated to extract 10 kV 10 mA hydrogen negative ion beam.
- Cs injector is prepared, and the preliminary study is presented by Dr. Park at the same P3 session.
- Future plan:
  - 200 keV accelerator with MFF and EDF using permanent magnets will be installed soon.
  - PG heater using Galden HT 270 for Cs conditioning is on preparation.
  - For diagnostics, triple LP, OES, and laser photodetachment are on preparation.

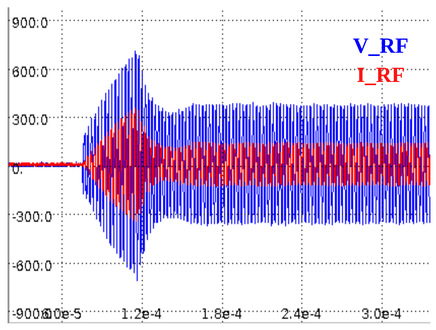
RF power supply and stackable HV power supplies



< Schematics of resonance ICP. >



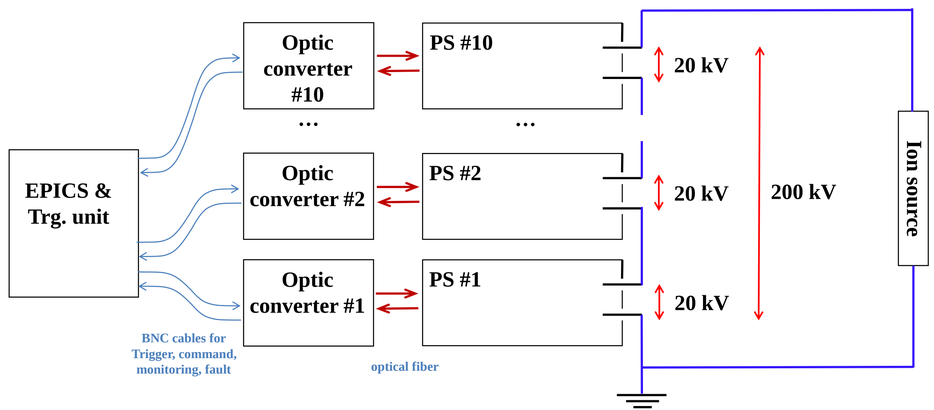
< RFPS and the resonance capacitors. >



< RF wave form. >

- Capacitors are installed to generate resonant ICP, and TR is used to fit the plasma load to RFPS specification.
- Dynamic frequency tuning is applied for matching, and the plasma is generated within 150 us at 400 kHz.
- Startup filament is used for start-up, and is turned off ~50 ms before RF power is applied
- The delivered power reach 16 kW as of now. (Z_load ~ (1.53 – 1.29j) Ohm)

Stackable HV power supplies

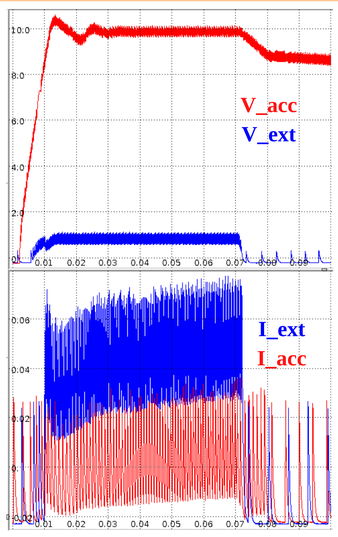


< Schematics of serial DCPS stack for the acceleration grid. Parallel stack will be applied to the extraction grid. >

< Optic converter, battery, and DCPS. >

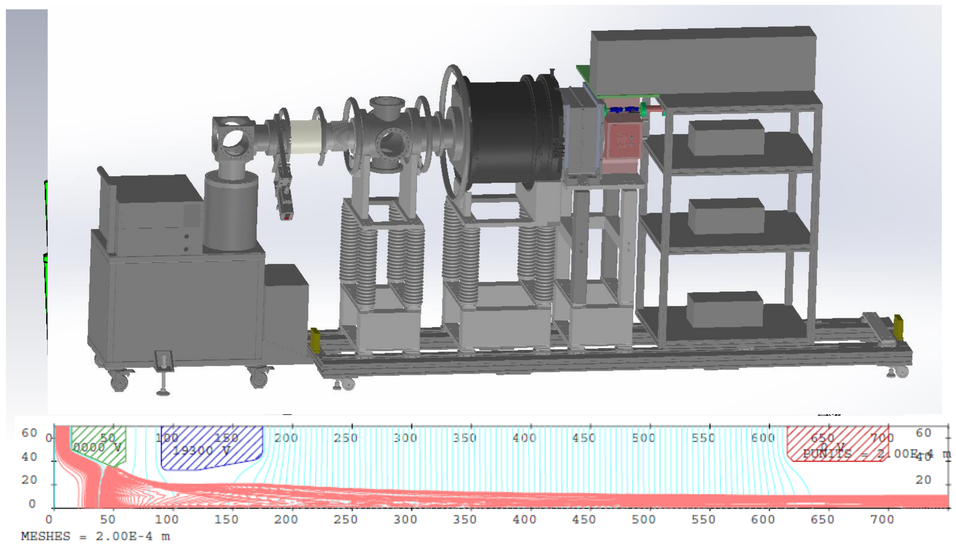
- Stackable battery DCPSs are applied to extraction (10 kV/1A) and acceleration (60 kV/1A) electrodes for pulse operation.
- Serial stack is applied to the acceleration grid to increase the output voltage, and parallel stack is applied to the extraction grid to increase the output current.

RF waveform and Beam Extraction

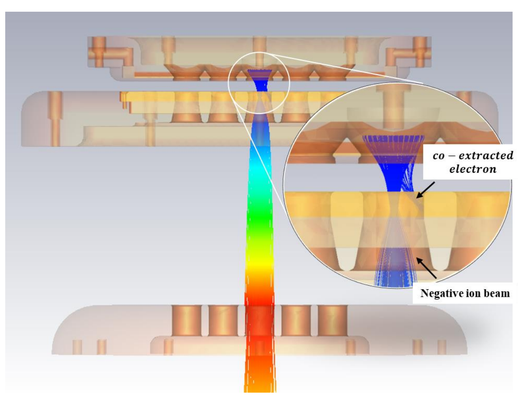


- RF plasma of 16 kW is generated to extract 10 kV / 10 mA negative ion beam for 70 ms without Cs seeding.
- As of now, the co-extracted electron current seems about 3 times higher than negative ion beam current.
- V and I are measured and the data are transferred to oscilloscope via V-F and F-V converter. (the data transfer method will be modified to reduce the noise.)
- The pulse length is limited because the Faraday shield, grids, and ion dump are not actively cooled.

Upgrade plan



< Schematics of the new accelerator upgrade and igun simulation result. >



< Beam simulation under electron deflection field. >

- RF PS will be optimized to deliver 50 kW.
- The new accelerator for 200 kV with MFF and EDF will be installed soon.
- PG oil heater are on preparation.
- The beam will be extracted with Cs.
- Triple LP, OES and laser photo-detachment will be applied for plasma diagnostics.

* Please visit Dr. Park's poster at the same session (P3) to see the preliminary Cs seeding study at the same machine.

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