Development of a permanent-magnet ECR ion source for a compact neutron source RANS-III

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1. INTRODUCTION

- At RIKEN, the Neutron Beam Technology Team have operated an accelerator-driven compact neutron source RANS (7 MeV proton linear accelerator (linac) + beryllium target) and RANS-Ⅱ (2.49 MeV 200 MHz RFQ linac + lithium target).
- Using RANS and RANS-Ⅱ, effective measurement techniques were established for the nondestructive inspection of soil erosion and salt damage inside concrete structures such as bridges.
- A transportable compact neutron source RANS-Ⅲ (2.49 MeV 500 MHz RFQ linac + lithium target) is under development for nondestructive testing of concrete structures such as bridges.
- Since the resonance frequency is inversely proportional to the cavity diameter, the cavity diameter and the weight of a 500 MHz RFQ linac are lower than in a conventional four-vane type RFQ linac.
- As part of the development, an injector, consisting of an ion source and a low energy beam transport line (LEBT), has been developed to inject a proton beam of approximately 12 mA into a RFQ linac that is small, lightweight, and has a low operating power.

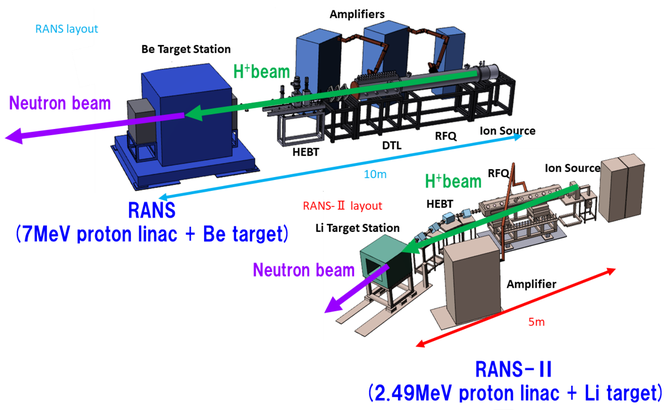

Fig. 1: RANS and RANS-Ⅱ

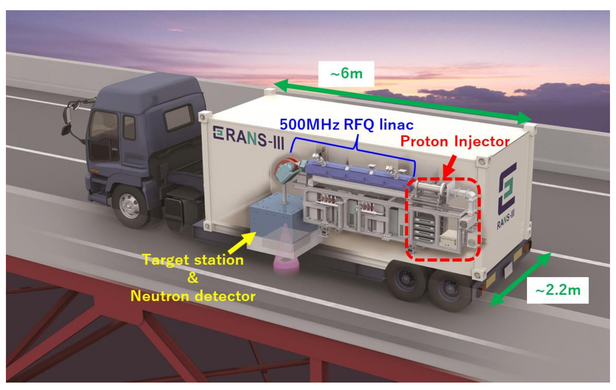

Fig. 2: Illustration of RANS-Ⅲ

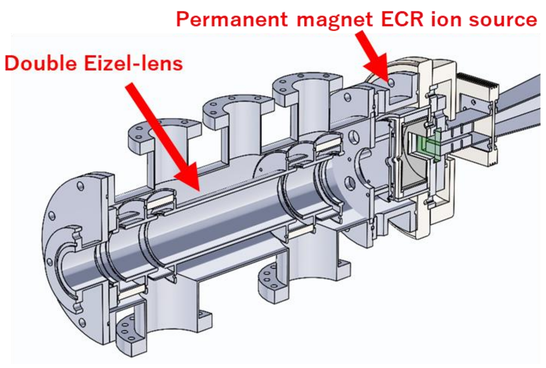

Fig. 3: Injector for the 500MHz RFQ

Table 1: Parameters of RANS-Ⅲ (Red : parameters of the injector)

Particle species	Proton
Electric strength [kilp]	1.35
Vane voltage [kV]	58.5
Input beam current [mA]	12
Input beam energy [keV]	30
Input emittance [π mm mrad ,6RMS]	0.2
Transmission [%]	84.4
Output beam current [mA]	10.1
Output beam energy [MeV]	2.49
Twiss parameter α	2.5
Twiss parameter ß [mm/mrad]	1.71

2. BEAM INJECTION SYSTEM FOR THE 500 MHz RFQ LINAC

2-1. PERMANENT MAGNET TYPE ECR ION SOURCE

- The ECR ion source consists of a 2.45 GHz magnetron, ridge tuner, RF window, plasma chamber, neodymium magnet, and extraction electrode system.
- Twenty-six neodymium magnets were installed on the sides of the plasma chamber, and iron electrodes were placed at both ends of the plasma chamber to form a magnetic field inside the chamber.

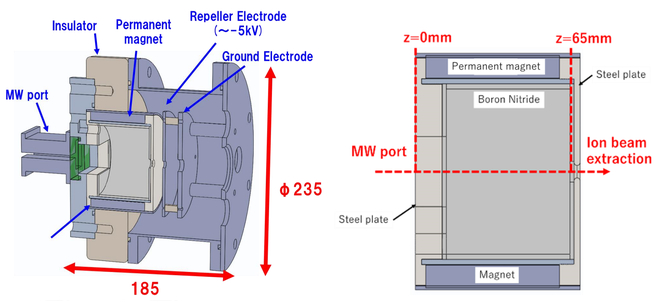

Fig. 4: The permanent magnet type ECR ion source

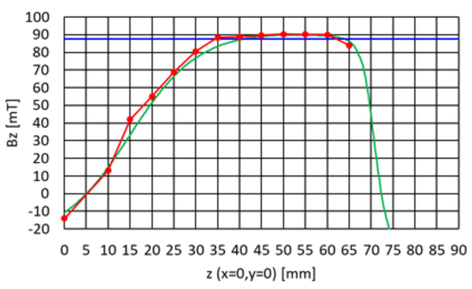

Fig. 5: Magnetic field on axis
Red dots: measurement
Green line: simulation

2-1. DOUBLE EINZEL LENS

- The LEBT consists of two sets of deceleration-acceleration type Einzel lenses and drift electrodes.
- As an initial condition, the beam distributions from the ion source were obtained by CST PARTICLE STUDIO.
- In order to maximize the matched beam current, we simulated and optimized each parameter (Table 2) using General Particle Tracer.

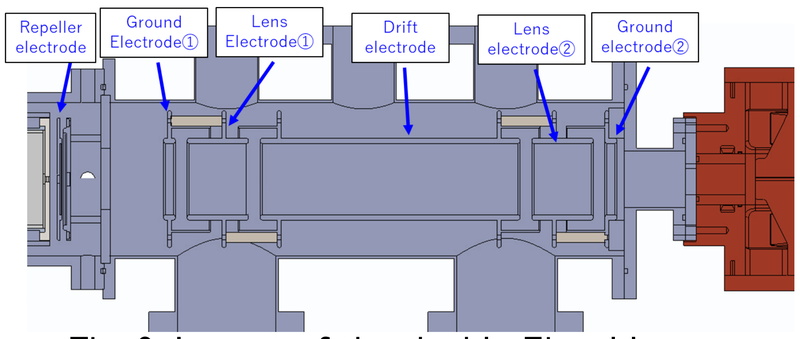

Fig. 6: Layout of the double Einzel lenses

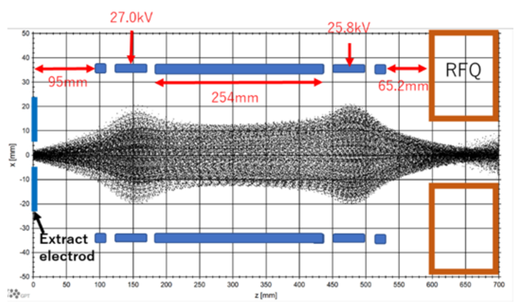

Fig. 7: Beam tracking simulation

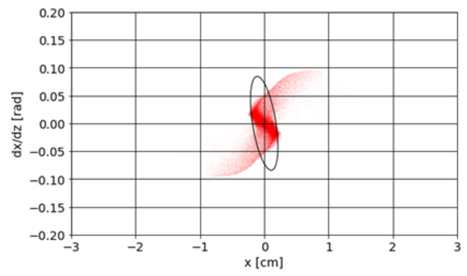

Fig. 8: Simulated beam distribution at the RFQ entrance
(Transmission: 71 %,
Injection beam: 13.5 mA)

Table 2: Parameters of the LEBT

1) Distance between ground electrode and lens electrode① [mm]	95
2) Drift electrode length [mm]	254
3) Distance between lens electrode② and RFQ electrode [mm]	145
4) Voltage of lens electrode ① [kV]	27.0
5) Voltage of lens electrode ② [kV]	25.8
Input emittance [π mm mrad ,6RMS]	0.2
Beam current from the ion source [mA]	20.0
Beam current to the RFQ linac [mA]	13.5
Transmission [%]	71.0

3. CURRENT PROGRESS

- To evaluate the characteristics of the ion beam from the ion source, a beam property test was conducted using a test bench. (Fig. 9)
- The peak beam current in the Faraday cup was measured for hydrogen gas and microwave power.
- At a gas flow rate of 12 CCM and a microwave output of 2000 W, the beam current is about 2.5 mA. (Fig. 11)

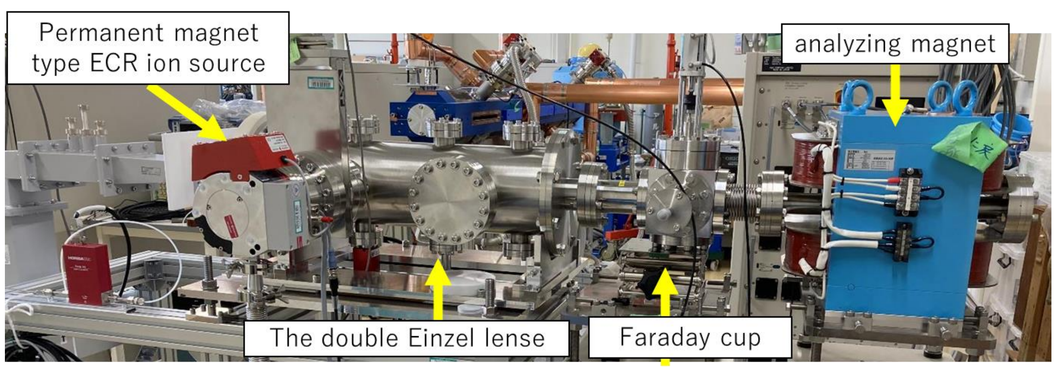

Fig. 9: Test bench for the ion source

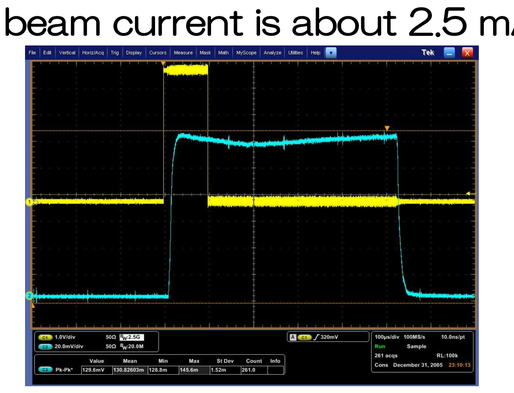

Fig. 10: Beam pulse
(Ch1:TTL, Ch2: Beam pulse)

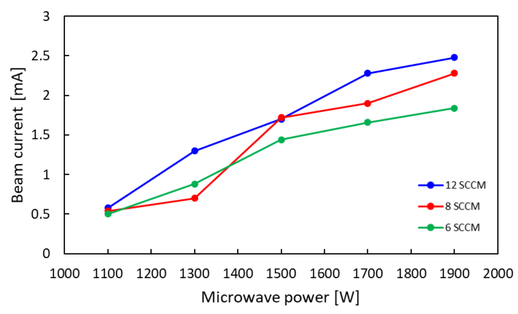

Fig. 11: Peak beam current as a function of gas flow and microwave power

4. SUMMARY & FUTURE PLAN

- A permanent magnet type ECR ion source and a double Einzel type LEBT have been developed as an injector for the transportable compact accelerator neutron source RANS-III.
- Using the test bench, we measured an ion beam current of 2.5 mA at a gas flow rate of 12 SCCM and a microwave power of 2000 W.
- In the future, We will improve the magnetic field and RF coupling of the ion source to increase the beam current, and then conduct beam acceleration tests with the 500 MHz RFQ linac.