Application of an ECR ion source to the JAERI tandem accelerator

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Abstract

We have pushed forward an installation plan of an electron cyclotron resonance (ECR) ion source in the terminal of the JAERI tandem accelerator in order to increase beam intensity, beam energy and beam species.

1. Introduction

For heavy elements, maximum beam current from a tandem accelerator is limited by the lifetime of stripper foils. A way for stable acceleration of high intensity beams is expected to be opened by the use of the ECR ion source, since the beams from the source are highly charged and intense. The operation without foil-strippers bring us no influence of a change in the terminal voltage on the charge state of the beams. In addition, it is possible to accelerate noble gas ions, which are impossible for tandem accelerators. A compact ECR ion source, called "NANOGAN" [1,2], with a permanent magnet structure has been developed at GANIL, France, for accelerating the radio active ions [3]. Its size and reliability fit our plan.

2. Mount for the tandem terminal

Many difficulties have to be solved to install the source in the tandem terminal, such as problems with the limited space, power supply, cooling system, RF source, vacuum system, control system and beam optics. Some measures should be also taken into consideration against electronic discharges and high pressure, because the source environment is on a high voltage of 16 MV and in the high pressure gas of 0.45MPa. In spite of these difficulties, we could find some steps for solving above problems. The problems with the space, power supply and control system will be solved by the replacement of the Duo-plasmatron type ion source, which has been used so far, to the ECR ion source with some modifications. A TWT-type amplifier made for airplane is applied for the 10GHz RF source, and is set in the airtight vessel to keep it at the atmospheric pressure. For the vacuum system, an ion pump is used to enclose a gas flow. With an ion pump, noble gas ion extractions from the source were successfully examined for a few months.

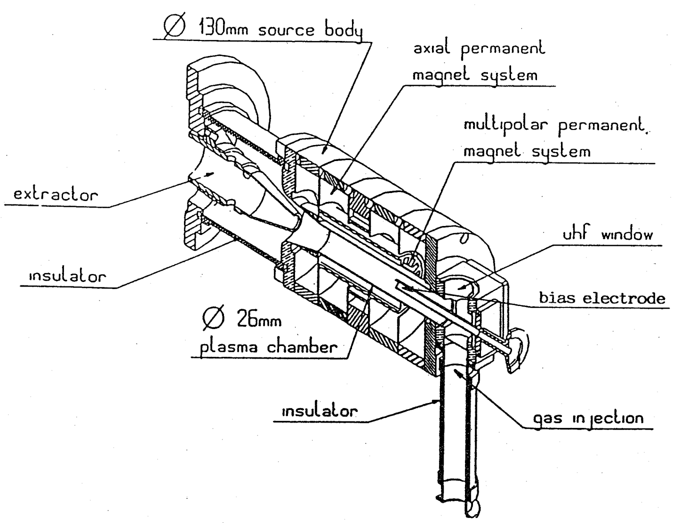

Fig. 1 NANOGAN : mechanical structure

3. Source optimization

Several experiments with the ion source until now have proved the performance as expected. The optimum condition and the simplification of the operational parameters were searched on the assumption of installing the ion source in the tandem accelerator. The results of this experiment enabled us to reduce the six operational parameters to the three, which were the gas flow, bias voltage and the RF power. This experimental procedure was brought from the experimental purpose, which was not to obtain maximum performance of the ion source, but to obtain stable intensity of ion beams against a change in the operational parameters. In

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addition to main gas, support gas as electron supplier were needed to obtain highly charged ion. For Ar ion, Fig. 2 indicates measured current intensities of different charge states as a function of mixing ratio. The highly charged ion (8+,9+) current do not depend on the gas ratio. So, the optimum ratio was chosen to be $Ar{:}O_2=1{:}10$ in order to restrain the load of the ion pump. Extracted current of Ar ions are shown in Fig. 3 as a function of RF power. Since the beam currents were changed gently, current adjustment can be attained by the control of RF power. RF tuner could be fixed, because beam intense was not changeable with a RF tuner adjustment. The gas flow, or the vacuum of the system was the critical parameter for the stable operation. For Ar^{8+} ion, it was 1.6×10^{-4} ($\pm$20%) torr$\cdot$l/sec optimum. A calibrated leak source was used for the gas-flow adjustment. A DC bias to the bias electrode (Fig. 1) was necessary to produce intense beam. With a DC bias apply of about 40~200V, a beam current was extracted at least ten times as intense as without the bias. The results of the experiment for three gases, Ar, Kr and Xe, mixed with N_2 or O_2 in above conditions, are shown in Fig. 4. The emittance for Ar ions from the above experiment was about 10mm$\cdot$mrad$\cdot$MeV$^{1/2}$ (80%) and the beam profile was very complicate.

4. Arrangement

The arrangement of the ion source is planned as is shown in Fig. 5. The ion beams extracted by 30kV from the ion source are focused by an einzel lens, and then the mass and charge of them are roughly selected by the 45° pre-analyzing magnet. The pre-analyzing magnet is used to reduce the load to the pre-acceleration tube, since the beams from the ion source amount to 2mA. After an acceleration by the 80 kV pre-acceleration tube and a beam selection by a 45° analyzing magnet, the beams are finally led to the tandem accelerator tube. Only a small part of beams are to be injected into the tandem accelerator after reducing the large emittance by several apertures.

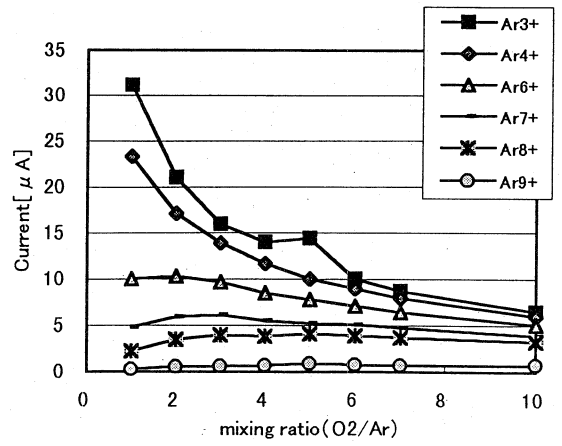

Fig. 2 Relation between gas mixing ratio and extracted ion current.

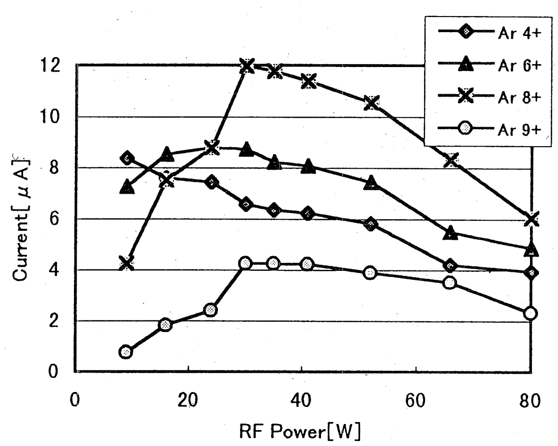

Fig. 3 Relation between RF power and extracted ion current.

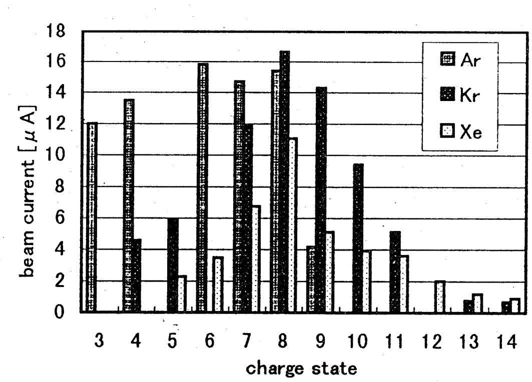

Fig. 4 Charge state distribution for three gases, Ar, Kr and Xe, mixed with N_2 or O_2.

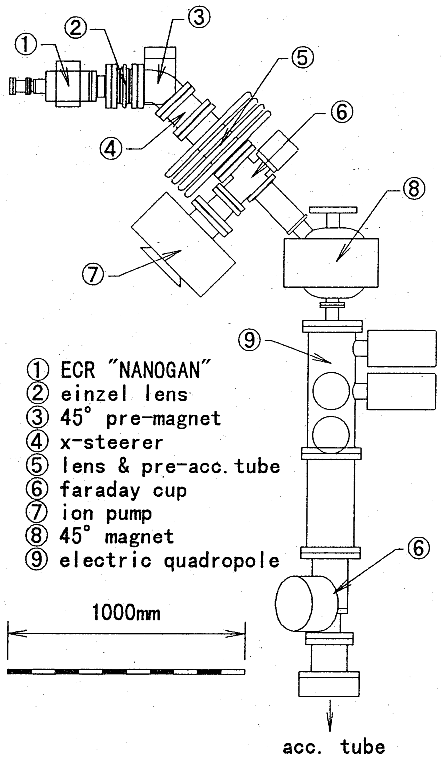

Fig. 5 Installation arrangement of the ECR ion source.

5. Expected performance

The expected performance from a terminal ECR ion source, is showed in Fig. 6. The top three solid curves are Ar, Kr and Xe currents available from the terminal ECR ion source as a function of energy accelerated. Number indicated are the charge states. The three broken curves are those obtained with the 2nd stripper foil. The three curves at the bottom are for Sn, Cu and Cl ions accelerated by the tandem accelerator using a negative ion injector when the terminal voltage is 16MV. The terminal ECR ion source can provide 10 times more intense beam currents than a negative ion source does. Comprehensive examinations including the beam optics and the control system will be made in the near future prior to the installation in the high voltage terminal. The installation and the experiments with the ECR ion source will be carried out in 1998. Acceleration of heavy metal ions is also considered as our future plan.

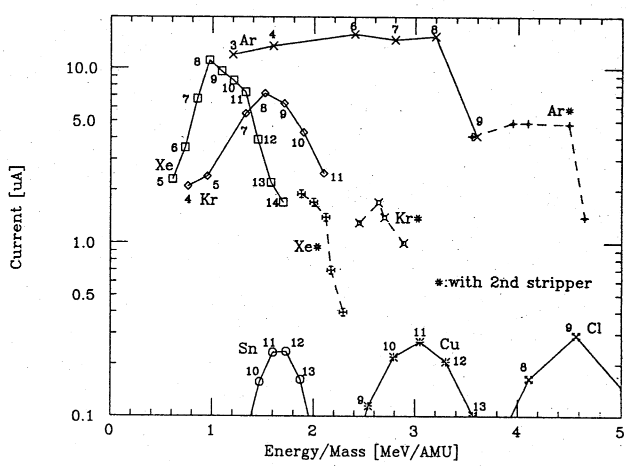

Fig. 6 Expected beam currents in the terminal of a tandem accelerator from a terminal ECR ion source (upper three curves) and from a conventional negative ion source (lower three curves).

Reference

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