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OPERATION OF ECR AND MULTI-CUSP ION SOURCES FOR JAERI AVF CYCLOTRON

W.Yokota, I.Ishibori, S.Okumura, T.Agematsu, M.Fukuda, T.Nara, T.Kamiya, Y.Nakamura, and K.Arakawa
Takasaki Radiation Chemistry Research Establishment
Japan Atomic Energy Research Institute
1233 Watanuki-machi, Takasaki-shi, Gunma-ken, 370-12, Japan
and
T.Tachikawa, K.Ishii, Y.Hayashi, K.Iso, and, T.Satoh
Sumitomo Heavy Industries, Ltd.
5-2 Sobiraki-cho, Niihama-shi, Ehime-ken, 792, Japan

Abstract

Two ion sources, a multi-cups ion source for light ions and an ECR ion source for heavy ions, were installed for the JAERI AVF cyclotron. Operation of the sources at JAERI started in February, 1991. The ability of ion generation required for beams injected into the cyclotron has been attained. Some characteristics of the ion sources, improvement of the sources and preliminary results of beam transport to the cyclotron are described.

Introduction

A multi-cusp and an ECR (JAERI OCTOPUS) ion sources constructed at Ion Beam Applications s.a. (IBA) in Belgium were tested and connected with the computer control system at Niihama works of Sumitomo Heavy Industries, Ltd. (SHI) in 1990. The results of beam generation by the JAERI OCTOPUS were reported elsewhere[1,2].

The installation of the sources and the cyclotron at JAERI was completed in early 1991. The beam generation test of the sources, acceleration by the cyclotron and transportation of beams to the end of beam lines have been performed[3]. We are going to make careful optimization to obtain the best ion productivity of the sources in the near future.

ECR ion source operation

Generation of ion beam

The ion generation test at JAERI has been made for O^{6+}, Ar^{8+}, Ar^{13+} and Kr^{20+} to ensure that their beam currents satisfy required values, and the test was successful for every ion species. The beams except for O^{6+} were injected into the cyclotron, and acceleration and beam extraction tests have been carried out. The currents measured at beam course ends also satisfied those expected. The He^{2+} beam was also produced by the OCTOPUS and was supplied for the cyclotron. The typical RF power of the 1st and the 2nd stages were 0 W and 290 W, respectively.

Coolant temperature effect

It was found that the productivity of highly charged ions appeared to correlate to the temperature of the 2nd stage chamber coolant. An accidental rise of the coolant temperature clearly showed this tendency, which resulted in degradation of ion production ability. For that reason a chiller for the chamber cooling was additionally installed with the ion source to reduce the temperature from 30°C down to 20°C.

The reason why the reduction of the coolant temperature increases ion productivity is not made clear. It is one of possible explanations that a temperature drop of the chamber wall makes gas pressure a little lower, and raises the density of high charge state ions due to the decrease of a charge exchange ratio of ions to neutral gases. In fact, a slight change of the gas pressure which is not indicated in a vacuum gauge often leads to an appreciable beam current change of highly charged ions. Though we had no chance to investigate this phenomenon, it is expected that further study of the relation between the generated beam current and the coolant temperature improves the productivity of highly charged ions.

X-ray leakage

The X-ray leakage outside the source was measured in dose-rate equivalent by an ionization chamber for designing radiation shielding of the OCTOPUS[2]. Dose-rate dependence on the 2nd stage RF power and the thickness of shielding material was observed when generating Ar and Kr ions. The X-ray shield was designed so that the dose-rate outside the shielding can be below 6 μSv/h under operation of the source. The 2nd stage cavity, the main X-ray source, was covered by a laminate lead of 50 mm thick. Large gaps between coils and an iron yoke or TMP's were screened by lead. To shield the residual X-rays escaping from these local shields, an iron cage of 22 mm thick was installed to surround the ion source.

The highest dose-rate of 37 μSv/h, however, was observed when the source was optimized to generate O^{6+} with the 2nd stage power of 700 W. Much less dose rate of about 5 μSv/h was observed for Ar^{8+} and Kr^{13+} generation with the 2nd stage RF power of 900 W and 1200 W, respectively. Additional shielding will be necessary on the basis of further dosimetry at different source parameters.

Multi-cusp ion source operation

The multi-cusp ion source is of the same type as that installed at Orsay (France)[4]. The side view for the source is shown in Fig.1. The cylindrical source chamber (15 cm length, 10 cm inner diameter) is made of copper. A tungsten filament of 15 cm long is set in the central axis of the chamber. The arc plasma is confined by four rows of ten SmCo magnets mounted on the outer side of the chamber and six SmCo magnets at an end of the chamber. The beam extraction system consists of an extraction and a movable puller electrodes between which the gap is variable. The extracted beam is focused by a Glaser lens. The source can be simply operated mainly by filament voltage, arc current, gas flow and puller position. The life time of the filament is a few hundreds hours.

The extraction voltage of the source is designed to cover a wide range of 3 kV to 20 kV, according to a wide acceleration energy range of the cyclotron. When the original extraction and puller

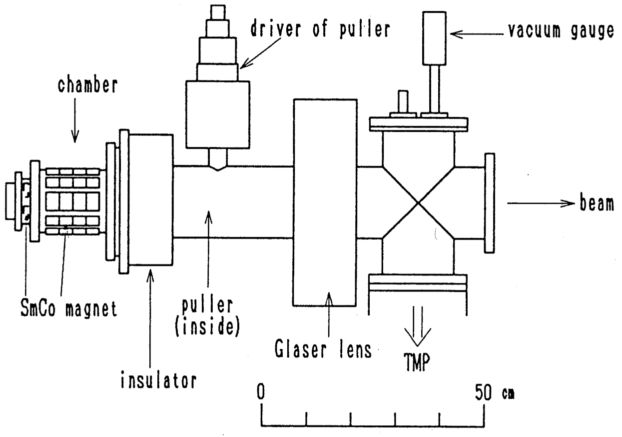

Fig. 1 Side view of the multi-cusp ion source.

electrodes with a single hole of 6.5 mm diameter were in use, sufficient beam was not obtained from the multi-cusp source at a low extraction voltage. A lot of beam current was lost after the puller electrode because of a large divergence of the extracted beam. To reduce the divergence by using the smaller aspect ratio of the diameters to the gap of the extraction and the puller electrodes, they were replaced by multi-hole type electrodes. As a result, beam current increased by ten times at an extraction voltage of 3 kV, by using electrodes with nineteen holes 1.8 mm in diameter. The maximum beam currents of H^+ (1.3 emA) and D^+ (1.0 emA) at 20 kV are obtained so far with good stability, whose short term flutter is less than 5 % by peak-to-peak.

Beam transmission to the cyclotron

A schematic layout of the ion sources and the injection line to the cyclotron is shown in Fig.2. It consists of a 90° analyzing magnet (EAM) for the OCTOPUS, an inflection magnet as an analyzer for the multi-cusp source, a 90° bending magnet for vertical injection into the cyclotron and eight solenoid lenses. Eight chambers, each of which provides with Faraday cups, X-Y slits and beam profile monitors, are installed for beam diagnosis. A set of emittance monitor for the OCTOPUS was also installed on the beam line down the EAM (ES2). The beam acceptance of the line is designed at 400π mm*mrad to maximize the transmission of large emittance beams from the OCTOPUS[5]. The measured emittance of Ar^{8+} beam from OCTOPUS was less than 300π mm*mrad, and was much smaller than the acceptance of the injection line.

Preliminary results of measured beam transmission are listed in Table 1. They are lower than that expected from the transport calculation and the beam

Table 1 Beam transmission along the injection line. Beam currents were normalized by that measured by the Faraday cup after the analyzer. See the Fig. 2.

OCTOPUS source:

ion	Vex(kV)	ES2	IS1	IS3	IS5
He^{2+}	10.2	1.0	0.94	0.82	0.81
	8.5	1.0	0.92	0.77	0.69
	3.4	1.0	0.78	0.72	0.71
Ar^{13+}	11.7	1.0	0.72	0.63	0.55
Ar^{8+}	10.1	1.0	0.88	0.79	0.71

Multi-cusp source:

ion	Vex(kV)	IS1	IS3	IS5
D^+	11.0	1.0	0.69	0.50
	3.1	1.0	0.73	0.58
H^+	3.1	1.0	0.59	0.51

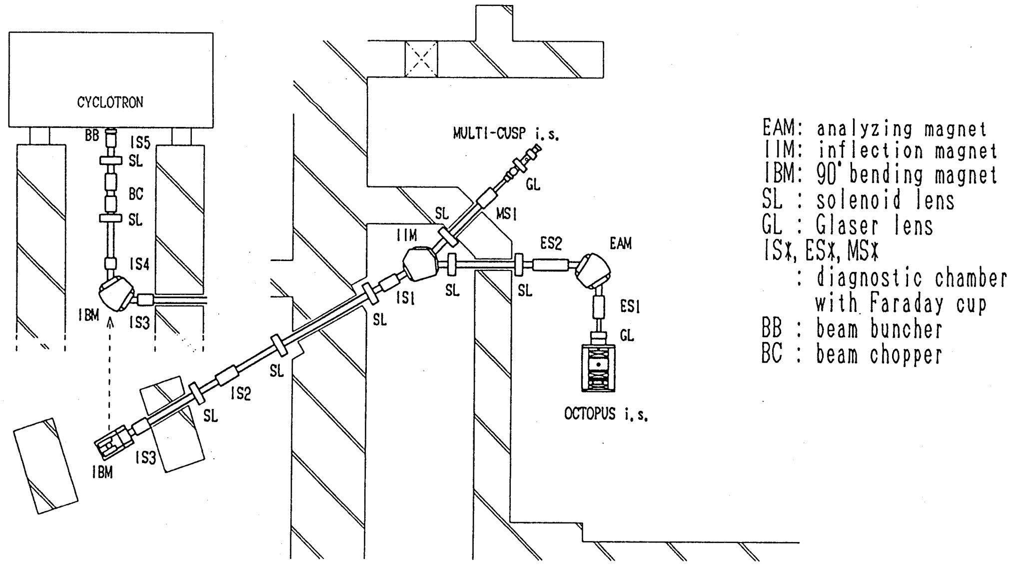

Fig. 2 Schematic layout of the ion sources and the injection line.

loss due to residual gases in the beam line, which is estimated at 5 % or less from the vacuum in the line. The transmission for the multi-cusp source is lower than that for the OCTOPUS source. It may result from an effect of space charge, since the beam transmission for multi-cusp source was influenced by beam intensity.

Summary

Two years and a half has passed since the JAERI OCTOPUS and the multi-cusp sources started generating ion beams. A number of problems have been solved and the performance of the sources has been improved by many minor changes so far for this period. We still have some problems, which has been left unsolved, such as the coolant temperature effect, and it is desired that the beam transmission to the cyclotron will be improved. Further data collection and investigation should be continued to solve the problems, and we are also planning to produce higher beam currents and diversify ion species, especially metal ions.

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