§8. Development of a Compact Multicusp Ion Source of He^+

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A compact ion source has been developed for the purpose of the alpha particle diagnostics. The system to measure the velocity and spatial distribution of fusion produced alpha particle requires a helium neutral beam with the energy of 0.5 MeV per nucleon and current density of about 0.1-1 mA/cm^2. A beam of He^- ions can be reliably produced by means of double charge exchange of He^+. Since the conversion efficiency by double charge exchange from He^+ to He^- in Rb vapor is 2 % at 8 keV, a positive helium ion beam at a current density of about 5-50 mA/cm^2 must be injected into a Rb gas cell with a good beam optics. Recently Sasao et al. have reported that an He^- current of 0.07 mA through an aperture of 6 mm in diameter, can be produced by using a compact multicusp ion source in the dc mode of operation.

The ion source is newly developed for the increase of He^+ beams. The size of the cylindrical ion source is 8 cm in diameter and 9 cm in length. The extraction system consists of three electrodes with the 6-mm-diam. holes, the plasma electrode, the lens electrode, and the ground electrode. The source body is connected to a potential of the acceleration power supply, V_{acc}, which varies over 0 – 20 kV, while the voltage of the lens electrode, V_L, is adjusted to the optimum beam current, measured by a Faraday cup located at the beam down stream.

The beam current is measured at 18 cm down stream from the plasma electrode by using a Faraday cup with an entrance aperture of 4 cm in diameter. The full width at half maximum of the beam is confirmed to be less than 4 cm. The He^+ beam current is plotted in Fig. 1 as a function of the extraction voltage, $V_{ext}=V_{acc}+V_L$. The He^+ beam current of 17 mA(60 mA/cm^2) is yielded at 15 keV when the discharge current is 16 A.

The emittance of extracted He^+ beams is measured by using an emittance meter, which consists of multi-slits and Faraday cup. The normalized emittance, $\varepsilon_n(=\beta\gamma\varepsilon)$, is shown in Fig. 2 as a function of the He^+ beam current at the optimized beam optics. Here $\beta = v/c$, v is the beam velocity, c is the speed of light, γ corresponds to the usual relativistic mass correction factor, and ε is the unnormalized beam emittance. The normalized emittance, ε_n, seems to be larger with the increase of the beam current for optimized beam optics. When the discharge current is kept constant, the normalized emittance does not change significantly. The emittance increase is reasonable because the emittance as well as the ion temperature depends on the discharge conditions inside the ion source.

Electron densities and electron temperatures in front of the plasma electrode are obtained from probe I - V characteristics at helium gas pressures, 4, 14, 23 mTorr inside the ion source. Electron densities and temperatures are of the order of 10^{11} cm^{-3} and less than 10 eV, respectively. The electron densities and temperatures increase with the higher discharge current, while the plasma potential changes from 2 V to 12 V. Even if the helium gas pressure is different, the He^+ beam current is linearly proportional to $n_e\ T_e^{1/2}$. When the helium gas pressure in the ion source reaches 23 mTorr, the gas pressure in the beam line is of the order of 10^{-5} Torr at most. The effect of gas neutralization on extracted beams is confirmed experimentally by means of the injection of the hydrogen gas into the beam line up to 10^{-4} Torr. No clear change of the beam radius is observed at about 50 cm down stream from the plasma electrode.

In the above experiments, the potential of plasma electrode is the same as that of the anode. When the plasma electrode is biased much lower than the plasma potential, the negative bias onto the plasma electrode is confirmed to improve the plasma density dramatically. The optimization of the bias of the plasma electrode should increase the He^+ beam current at the same discharge current.

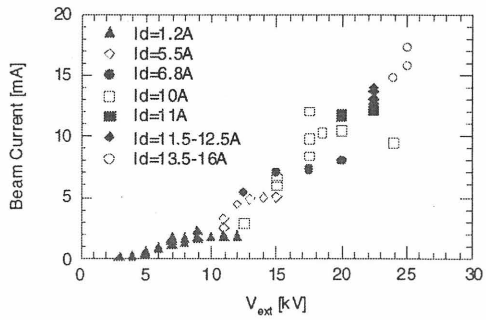

Fig. 1 Dependence of He^+ beam current as a function of extraction voltage.

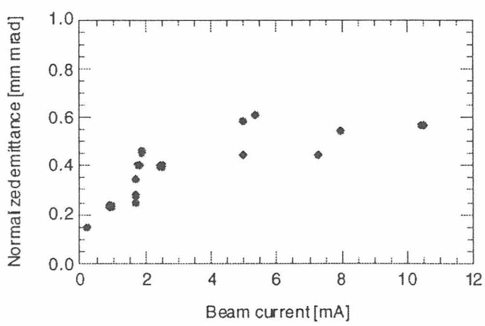

Fig. 2 Characteristics of normalized emittance with increasing the beam current.

References

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