§8. Improved Beam Transport System and Charge Changing Processes in a Tandem Accelerator for LHD-HIBP

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For the purpose of extending the diagnostic range in high density and high temperature plasmas, the Au^- beam current of the plasma-sputter-type negative ion source is characterized and is improved. The output beam current is measured by a Faraday cup located approximately 50 cm downstream from the extraction electrode. The target holder, the heat shield inside the ion source, the extraction hole, and the Einzel lens are newly designed and replaced to new components. These components contribute to the stable beam output and low cesium consumption.

The gold negative ion source described above has been installed into the HIBP system. The extractor and Einzel lens system have been designed by the PBGUNS commercial computer code [3] to obtain well focused beams at the entrance aperture of the 50 kV accelerator, shown in Fig.1. The Au^- beam current is measured at the entrance and the exit of the sector magnet to know the present situation of beam transport and to improve the actual injected beam current into the tandem accelerator. The beam profile is measured by FC0 with the slit of 1 mm in height and 15 mm in width, located at the entrance of the 50 kV accelerator. The measured beam profile, shown in Fig. 2, is integrated over the vertical direction to obtain the total beam current. The Au^- beam current at the energy of 13.9 keV was more than 46 μA by FC0 with the optimum Einzel lens voltage of 13.6 kV. The measured beam diameter at the full width at the half maximum (FWHM) is 16.1 mm, which agrees closely with the designed diameter computed by PBGUNS. The estimated value is still higher than the measured one at FC1. Therefore the beam is lost partly at the sector magnet, and mainly at the diaphragm of ϕ10 mm.

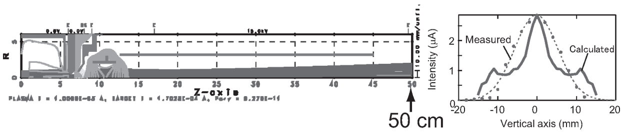

Fig. 1 Electron loss cross sections for Au^+ and Au^{2+} by proton impact.

For the optimum operation and further development of the HIBP system, the conversion efficiency from Au^- to Au^+ is assessed experimentally and theoretically. At the projectile beam energy of 3 MeV, the resulting ions are separated by the electrostatic plates at the exit of the tandem accelerator, and are measured by the Faraday cup (FC2). The observed fractions are defined as the measured beam current divided by both the charge and the projectile Au^- beam current. Experiments on charge-changing reactions in argon gases are commonly performed at the background gas pressure from $2x10^{-5}$ to $1.2x10^{-4}$ Pa. Then the gas pressure inside the gas cell is calibrated relatively using the gas pressure measured by the vacuum gauge at the exit of the tandem accelerator.

The fractions F(i) are calculated numerically solving a set of six differential equations for Au^i component system, where i denotes the ion charge from -1 to +4. To solve the above differential equations, we calculated and obtained the cross sections of elastic scatterings, electron loss and capture cross sections for all six components. The results of both calculations and measurements exhibit a similar tendency. In the present calculation, we found that the electron capture processes influence significantly the charge fractions for the target thicknesses above $0.8x10^{15}$ cm^{-2}. From the experimental aspect, the present experiments still have a margin of enhancement for the Au^+ fraction. According to our prediction, we could enhance the fraction transmitted from 0.13 to 0.22 by controlling the projectile beam optics.

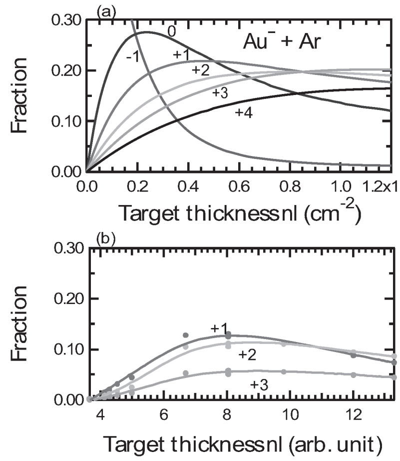

Fig. 2 (a) Calculated and (b) measured fractions of Au in Ar gas. Projectile Au^- beam has the energy of 3 MeV.

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