§8. Characteristics of Au^- Beam Source for a Heavy Ion Beam Probe of the LHD

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Gold negative ion beams are required for the purpose of understanding of plasma behaviors, especially the potential profile and density fluctuation in the Large Helical Device. A sputter type negative ion source is adopted for a heavy ion beam probe (HIBP) system, which has been built to diagnose LHD plasmas. During the fiscal year 2002, the gold negative ion beam of a few micro amperes has been achieved at the exit of the ion source. However in the HIBP system of the LHD, we need to inject stable gold negative ion beams of at least a hundred micro amperes at the entrance of the 3 mega volt tandem accelerator. Therefore we have measured the characteristics of the ion source for higher Au^- beam current and have started to optimize the ion source at a test stand facility.

Two ion sources were manufactured for the use at the test stand facility in the diagnostic building and the actual facility in the LHD building. The size of the cylindrical ion sources is 8 cm in diameter and 9 cm in length. The gold target for sputtering is inserted into the ion source. The distance between the gold target and the extraction hole is 3 cm. The electrostatic extraction system consists of an electrode with the 5-mm-diam. hole. The source body is connected to a negative voltage, V_{acc}, of the acceleration power supply, which varies over 0 – 20 kV, while a voltage, V_L, of the Einzel lens electrode is adjusted to the optimum beam current measured by a Faraday cup. The Faraday cup with a secondary electron suppressor is located at about 50 cm down stream from the plasma electrode. With adding the cesium vapor into the ion source, the ion source was operated for a few hours.

Using the ion source of the test stand facility, the Au^- beam extraction has been carried out for obtaining the maximum beam current. The time trend of gold negative ion current is plotted in Fig. 1. The Au^- beam current of 30 μA is yielded at the target voltage Vt = 500 V and the beam energy of 10.5 keV. We could not keep the stable discharge in this condition. The discharge voltage was kept below 10 volts, and so the gold target could not be sputtered by xenon ions, but the gold target could be sputtered by cesium ions, because the ionization potential of xenon is 12.13 eV.

Figure 2 shows the same as the above experiment, but the electron suppressor magnet is removed. A pair of magnets produces the vertical magnetic field with respect to the beam axis near the extraction hole. The vertical magnetic field reduces the burden imposed on the beam acceleration system by electron beam suppression. However we found that the strong vertical magnetic field decreases the electron and ion densities in front of the gold sputter target. It leads to the reduction of ions for sputtering. By the removal of the electron suppression magnets, the ion density in front of the gold sputter target increases, and it follows the increase of Au^- beam current up to 39 μA. Since the high density plasma on the Au^- beam trajectory neutralizes the Au^- beam, farther investigation of the influence of the electron suppressor magnets is needed by changing the magnetic field strength.

In both cases, the LaB_6 cathode was broken after about a half minute operation. To maintain the higher Au^- current more than 10 μA, we have to look for a new cathode with longer life, instead of the present type of the LaB_6 cathode. In addition, the precise temperature control of the gold target would be essential, because the cesium layer on the gold target depends strongly on the production probability of gold negative ions.

At the LHD-HIBP beam line, Au^- beam current of about 5 μA was operated stably and was injected into the LHD vacuum vessel successfully using the same ion source described above.

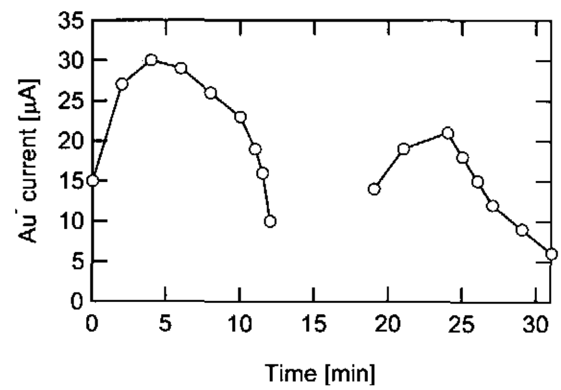

Fig. 1. Temporal Au^- beam current measured by the Faraday cup.

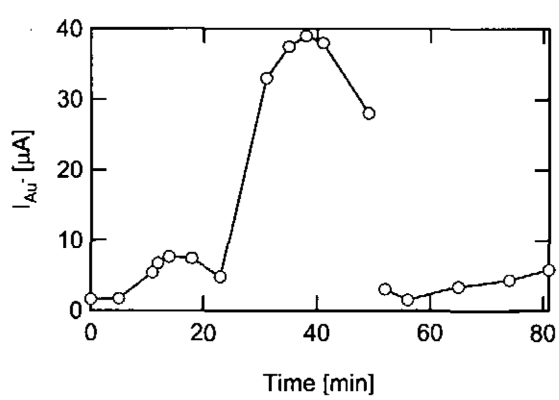

Fig. 2. Temporal Au^- beam current measured by the Faraday cup. The electron suppressor magnet near the extraction hole is removed.