§2. Full Scale Positive Helium Ion Source for Alpha Particle Measurement

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In order to measure spatial and velocity distribution of the produced alpha particles in the core plasma, an active beam probe method using the double-charge-exchange reaction with 1-2 MeV neutral hulium (He^0) beam in the 10 mA current range has been proposed[1]. A high energy accelerator coupled to an alkali metal vapors cell for production of negative helium ions (He^-) from positive helium ion (He^+) realized a high energy beam of He^0 through electron auto-detachments from He^- during the free flight in a drift tube[2]. A He^+ ion beam of more than 3 A intensity is required to produce a 10 mA He^- ion beam as the conversion efficiency of double-charge-exchange process from He^+ ions is less than several percent. A highly concentrated beam of He^+ is required to let it pass through small apertures of a charge-exchange cell to form the He^- ion beam.

A strongly-focusing high-intensity He^+ ion source designed as a beam source for the energetic He^0 beam probe system made of three concaved electrodes[3]. The electrodes form 301 beamlets extracted through 4 mm diameter apertures arranged across the 100 mm in diameter extraction area. These multi-aperture electrodes are arranged to merge beamlets at a focal point at 750 mm downstream from the extraction electrode.

The effects on the arc efficiency (= beam current/arc power) of the ion source due to the discharge filament structure (straight type and L-shape type filaments), size (filament diameters of 2 mm and 1.5 mm), number, and the locations have been studied. Choice of the appropriate filament structure improved the arc efficiency by 17 %[4].

However, the beam waist position evaluated by the measurement system with an IR camera was 487 mm, which was very close to electrodes comparing with focal point of the concaved electrodes. And the temperature distribution of beam with a distortion was observed on the beam dump carbon target at the downstream position from the beam waist. Figure 1(a) shows the contour plot of the temperature distribution with the distortion, the peak position shifts outside from the center. The deformation of the acceleration electrode is also confirmed, which may be caused by a heat load from arc plasma.

Three electrodes with non deformation are made with same construction, because the acceleration electrode has a plastic deformation by large heat load. The temperature distribution image of a beam by these electrodes is symmetry as shown in Fig. 1(b). Therefore, the deformation of the electrode causes the distortion of the temperature distribution image. A strongly cooling system for electrodes needs to contain the heat load.

The beam waist position and its radius have been evaluated from the path length distribution of $r_{1/e}$ on the perveance ($I_{beam}V_{acc}^{-1.5}$) of 0.020 $AV^{-1.5}$, where I_{beam} is the He^+ ion beam current evaluated from difference between the acceleration electrode current and deceleration electrode current and V_{acc} is the acceleration voltage of the beam. Figure 2 shows the path length distribution of the $r_{1/e}$ as a function of the measurement position. The beam waist position and its radius, and divergence angle have been evaluated 720 mm, 11.3 mm, and 15.0 mrad, respectively.

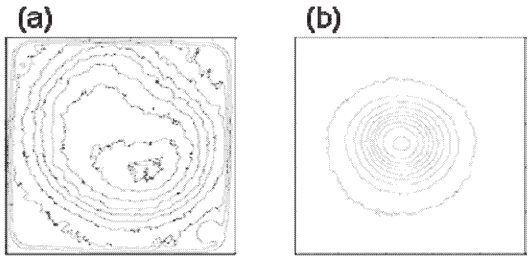

Fig. 1 Contour plot of IR image of a beam dump carbon target irradiated by He^+ ion beam for the electrodes (a) with plastic deformation and (b) without deformation.

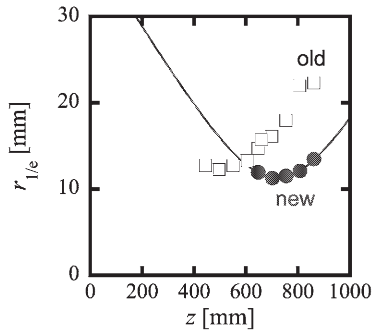

Fig. 2 Path length distribution of 1/e-holding beam profile half-width, $r_{1/e}$.

1) Sasao, M. *et al.* : Nucl. Fusion **35** (1995) 1619.
2) Sasao, M. *et al.* : Rev. Sci. Instrum. **77** (2006) 10F130.
3) Shinto, K. *et al.* : Proc. of EPAC2006 (2006) 1726.
4) Kobuchi, T. *et al.*: Rev. Sci. Instrum. **79** (2008) 10F316