§8. Beam Current and Focal Point Evaluation of a Strongly-Focusing High-Intensity He^+ Ion Source Developed for Fusion Produced Alpha Particle Diagnostics

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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 300 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 temperature image at the beam target heated by the He^+ beam has been observed by the IR camera as shown in Fig. 1(a). Figure 1(b) shows the temperature profile of the beam radial direction along the broken line in Fig. 1(a). A 1/e-holding beam profile half-width, $r_{1/e}$, obtains by assuming Gaussian distribution.

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 0.024 $AV^{-1.5}$, 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[4]. The beam target lift movable in the direction of the beam axis is made possible to measure the path length distribution of r1/e. Figure 2 shows the path length distribution of the $r_{1/e}$ as a function of the measurement position. Solid line shows the following curve approximation,

$$r_{1/e}^{\;2} = (\theta_{div} z)^2 + (z - f)^2 (r_{1/e,0} / z)^2 \quad (1),$$

where θ_{div} is a divergence angle, z is a path length from the electrode, f is a focal length, and $r_{1/e,0}$ is a 1/e-holding beam profile half-width at the extraction electrode position (L = 0 mm). The beam waist position and its radius, and divergence angle have been evaluated 487 mm, 12.3 mm, and 22.7 mrad, respectively. The design of the alkali metal vapors, setting position and aperture size, has been made possible.

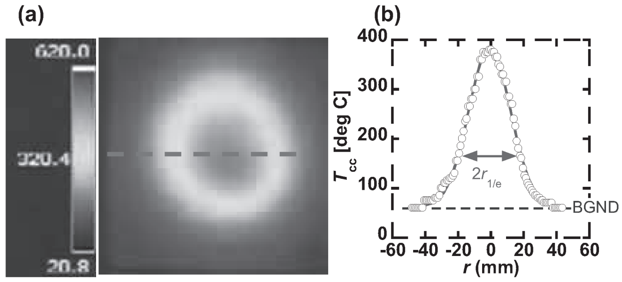

Fig. 1 (a) IR image of the beam dump carbon target irradiated by He^+ ion beam.
(b) Temperature radial profile on broken line. 1/e-holding beam radius is observed by assuming Gaussian distribution.

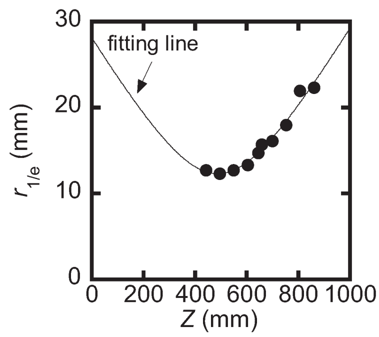

Fig. 2 Path length distribution of 1/e-holding beam profile half-width, $r_{1/e}$.

1) M. Sasao *et al.* : Nucl. Fusion **35** (1995) 1619.
2) M. Sasao *et al.* : Rev. Sci. Instrum. **77** (2006) 10F130.
3) Shinto, K. *et al.* : Proc. of EPAC2006 (2006) 1726.
4) Kisaki, M. *et al.* : Rev. Sci. Instrum. **79** (2007) 02C113.