§5. Physics Study of Strongly-focusing Beam Emittance by the 3A He^{+} Ion Source

Sasao, M., Kisaki, M., Terai, K., Kitajima, S., Okamoto, A. (Tohoku Univ.),
Shinto, K. (JAEA),
Wada, M. (Doshisha Univ.),
Kaneko, O., Tsumori, K., Kobuchi, T.

For the measurement of the spatial and velocity distributions of fusion-produced alpha particles in a burning plasma, an energetic He^0 beam produced by auto-electron detachment from He^- is considered as an active probe beam[i]. In this system, the He^- beam is produced by the double charge-exchange reaction of He^+ ions in the alkali metal vapor cell with the charge exchange efficiency less than a few per cent. A high-intensity and strongly-focusing He^+ beam was developed for the application to ITER[ii]. The He^+ ion source consists of a plasma chamber 300 mm in diameter and 280 mm in length surrounded by a set of permanent magnets that form a cusp magnet field, 4 or 8 filaments and three concave multi-aperture electrodes. From the electrode center area of 100 mm in diameter, 301 beamlets are extracted through apertures 4 mm in diameter. Concave electrodes were chosen so that the extracted beam focuses into an acceptable size of an alkali vapor cell. The source was installed on the NBI test stand at National Institute for Fusion Science with a vacuum chamber of 1 x 1 x 1 m^3 for diagnostics. In this chamber, a Rogowski coil and a movable carbon beam dump target (100 x 100 x t2 mm^3) were installed. The beam dump temperature was observed from the backside of the target with an infrared camera installed outside the chamber to obtain the 2D beam current density distribution[iii]. A beam current higher than 2A was achieved with the minimum beam radius of 11.3 mm, at the beam energy of 20 – 25 keV, which is suitable to be converted to He^- in an alkali vapor[iv].

A pepper-pot(PP) plate combined with a kapton foil was installed on the movable frame for the carbon target to measure the emittance[v]. The molybdenum PP plate had 9x9 holes of 0.4 mm in diameter. Three kapton foil sheets and one metal plate were fixed on the 4 surfaces around the rotation axis of a cubic holder. Optimum number of beam shots of 0.4 sec duration was accumulated watching the foil color change. In this way, three samples were irradiated without vacuum break. The irradiated foils were taken out from the chamber, scanned by an EPSON film scanner and the burn patterns were converted to digital data.

Fig.1 shows an example of a kapton foil irradiated (a), the expanded and digitized kapton burn pattern (d_{pk} = 30 mm) from the center hole of the PP(b), which reflects the arrangement of the extraction apertures of the electrode (c), and the expanded view of one of digitized burn pattern when d_{pk} = 60 mm(d), where d_{pk} is the distance between the PP and a kapton foil.

The emittance diagram of obtained from the center five foot prints shown in Fig. 1(d). No phase space mixing was observed even the 301 beamlets merged into a beam.

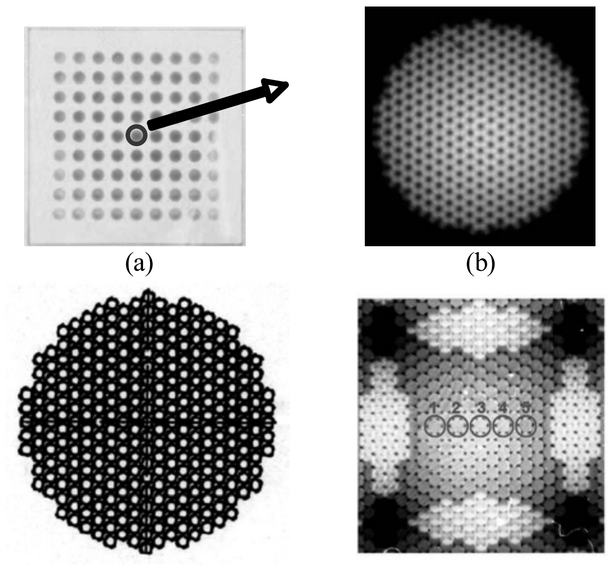

Figure 1. (a)Photograph of an irradiated kapton foil, (b) the digitized burn pattern through the center hole of the PP when d_{pk} = 30 mm, (c) the 301 aperture arrangement of the electrode, and (d) expanded view of the burn pattern when d_{pk} = 60 mm.

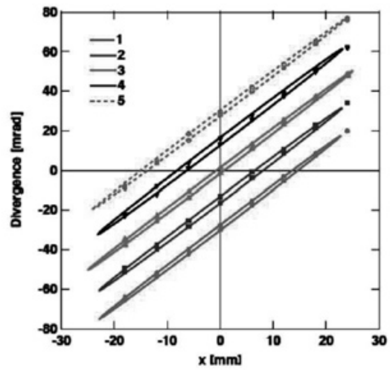

Figure 2. Emittance diagram of 5 merging beamlets from the strongly focusing He^+ ion source. Numbers are corresponding to the beamlet shown in Figure 1(d).

[i] M. Sasao *et al.*, Rev. Sci. Instrum, **77**, 10F130 (2006).
[ii] K. Shinto *et al.*, PAC conf. Proc. 2630 (2006)
[iii] M. Kisaki *et al.*, Rev. Sci. Instrum. **79**, 02C113 (2008)
[iv] T. Kobuchi, M. Kisaki, K. Shinto, A. Okamoto, S. Kitajima, and M. Sasao, K. Tsumori, O. Kaneko, M. Nishiura, M. Wada, to be submitted
[v] M. Sasao *et al.*, Rev. Sci. Instrum. **81**, 02B115 (2010)