Emittance measurement of high-intensity merged beam

M. Kisaki, K. Terai, A. Okamoto, S. Kitajima, M. Sasao, K. Tsumori[a], K. Shinto[b], and M. Wada[c]

Graduate school of Engineering, Tohoku University, Aoba, Sendai, Miyagi 980-8579, Japan
[a] National Institute for Fusion Science, Toki, Gifu 509-5292, Japan
[b] Japan Atomic Energy Agency, Rokkasho, Aomori 039-3212, Japan
[c] Graduate school of Engineering, Doshisha University, Kyotanabe, Kyoto 610-0394, Japan

E-mail address : kisaki.masashi@LHD.nifs.ac.jp

One of the most promising candidates for measurement of alpha particles produced by D-T reaction in ITER is the fast neutral beam probe method, where alpha particles are neutralized by double charge exchange reaction with a fast neutral helium beam in the 1-2 MeV energy range [1]. The possible method to produce such a high energy He^0 beam is the production of neutrals from negative ions by auto-detachment. The He^- is produced from He^+ via a two-step process in an alkali metal vapor cell whose conversion efficiency is less than several percent. At least 10 mA of He^- beam current is required to obtain enough S/N ratio for detection of confined alpha particles. The Fusion Plasma Diagnostic Laboratory in Tohoku University have designed and constructed a strongly focusing high-intensity He^+ ion source, whose three grids are concaved to converge multi-beamlets at a point of 750 mm apart from the plasma grid. In the previous study, the He^+ beam of 2.5 A and 27.6 keV was successfully produced and converged to 20 mm in diameter [2]. These values achieve requirements for production of enough He^- beam to measure alpha particles in ITER. As the next step, we have started an emittance measurement of the He^+ beam extracted from the ion source to design the beam accelerator.

The emittance of the He^+ beam was measured by means of a pepper-pot method. 9 (vertical) × 9 (horizontal) pinholes of 0.4 mm in diameter are arranged on a molybdenum (Mo) plate. Beamlets through pinholes are detected by a Kapton foil of 50 μm in thickness. A pattern on the Kapton foil printed by multi-beamlets from one of pinholes is shown in Fig. 1. A fine-structure is observed in the image. This structure corresponds to the arrangement of "all" apertures on the electrodes. A phase-space diagram of this beam pattern is shown in Fig. 2. Every emittance ellipse can be distinguished individually. The effective normalized emittance is estimated at 6.3 mm-mrad in Fig. 2.

[1] M. Sasao et al., Nucl. Fusion 35, 1619 (1995).
[2] M. Kisaki et al., Rev. Sci. Instrum 79, 02C113 (2008).

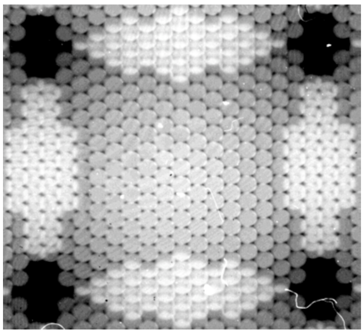

Fig. 1. Pattern on the Kapton foil printed by multi-beamlets from one of pinholes.

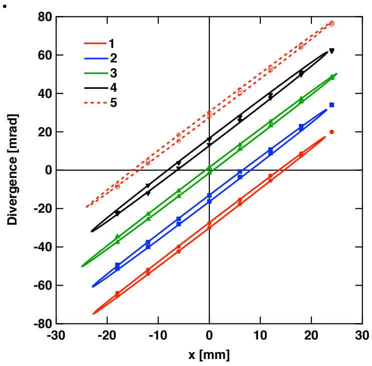

Fig. 2. Phase-space diagram.