§22. Phase Space Images of a Strongly Focusing He^+ Beam

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In the self-burning phase of first generation fusion reactors, a DT plasma is heated by fusion-produced alpha particles. Measurement of the spatial and energy distributions of alpha particles is essential to study alpha-particle induced instabilities, various types of anormalous transport on ITER. A beam neutralization alpha particle measurement system using an energetic He^0 beam is proposed for ITER[1]. In this system, the He^0 beam is produced through an auto-detachment[1] of an 1-1.5 MeV, 10 - 100 mA He^- beam.

To form an He^- beam through the two-step electron capture process in alkali vapor, a strongly focusing He^+ beam is required. A He^+ bucket source has been developed and a He^+ beam is extracted from a set of three-stage concave electrodes with 301 apertures. The beam current and the beam size of 2A, and 20 mm in diameter, respectively, were achieved at the beam energy of 20 keV.

In order to design the major accelerator, it is important to measure the emittance. The emittance of 301 merging He^+ beamlets from the source was measured using a pepper-pot plate and a Kapton foil with an arrangement shown in Figure 1. The pepper-pot plate had 10x10 holes of 0.2 mm in diameter. Separation to an adjacent hole is 4 mm. A movable diagnostic stage was used to scan the emittance along the beam direction.

Figure 2 shows one of the measurements results at the beam waist (z = 762 mm), when I_{beam} = 1.15 A, V_{acc} = 16 keV. The distance between the pepper-pot plate and a Kapton foil was 40 mm. The 301 beamlets were clearly separated in a burnt footprint image for each pepper pot hole, showing the phase space mixing was prevented at this condition. Further study will be carried out by using digitized image data, as shown in Fig. 3.

Presentations & Publications

[1] Fine-structure characteristics in the emittance images of a strongly focusing He^+ beam, M. Sasao, T. Kobuchi, M. Kisaki, H. Takahashi, A. Okamoto, S. Kitajima, O. Kaneko, K. Tsumori, K. Shinto, and M. Wada, Rev. Sci. Instrum. 81, 02B115 (2010)
[2] M. Kisaki, et al., "Emittance Measurement of High-intensity Merged Beam", presented at The 2nd International Symposium on Negative Ions Beams and Sources, Nov. 16-19, 2010
[3] M. Sasao, et al.,"An Alpha Particle Measurement System using an Energetic Neutral Helium Beam for ITER", presented at The 2nd International Symposium on Negative Ions Beams and Sources, Nov. 16-19, 2010

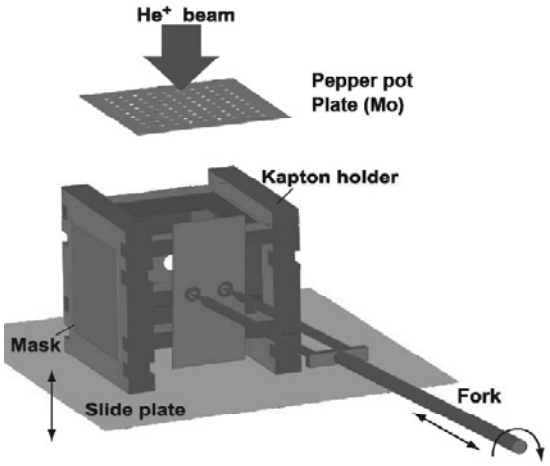

Fig. 1 Measurement arrangement of the emittance. On the Kapton foil holder, 3 foils can be set. The distance between the foil and the pepper pot was changed in 25–70 mm.

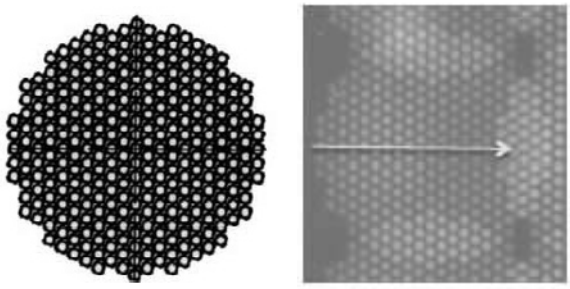

Fig. 2 Arrangement of apertures on each electrode (left) and a burnt footprint image from one pepper pot hole (right).

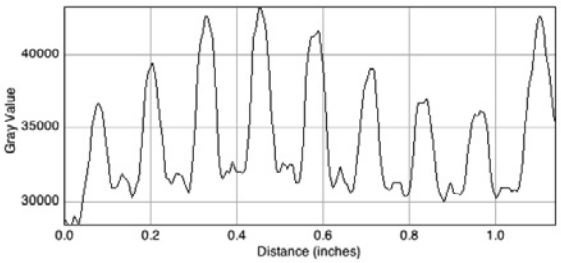

Fig. 3 Burnt footprint data digitized along a line shown in Fig. 2 (right).

[1] M. Sasao et al., Development of an Energetic He^0 Beam Injector for Fusion Application, Proceedings of the 22nd IAEA Fusion Energy Conference, http://www-naweb.iaea.org/napc/physics/FEC/FEC2008/papers/ft_p2-28.pdf.