Study of beamlet deflection and its compensations in a MeV accelerator

M. Kashiwagi, T. Inoue, M. Taniguchi, N. Umeda, L. R. Grisham[a], M. Dairaku, J. Takemoto, H. Tobari, K. Tsuchida, K. Watanabe, H. Yamanaka and K. Sakamoto

Japan Atomic Energy Agency (JAEA), 801-1, Mukoyama, Naka 311-0193, Japan
[a] Princeton Univ. Plasma Physics Lab., P.O.Box 451, Princeton, NJ 08543, USA

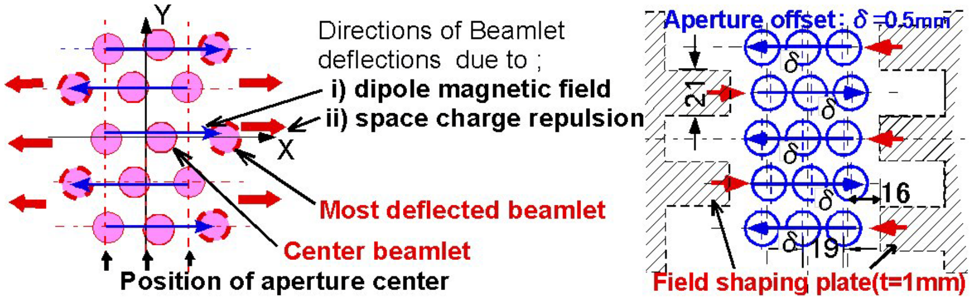
e-mail address of submitting author : kashiwagi.mieko@jaea.go.jp

A five stage multi-aperture and multi-grid (MAMuG) accelerator, called a MeV accelerator, has been developed in Japan Atomic Energy Agency (JAEA) for 1 MeV accelerator of ITER. A target of the current R&D is accelerations of 1 MeV, 200 A/m^2 H$^-$ ion beams for several tens of seconds. In the experiment, it appeared that beamlets were deflected by i) magnetic field and ii) space charge repulsion among beamlets, and caused excessive heat loads on grids [1]. In order to study the beamlet deflections and compensation methods utilizing an aperture offset and so-called "field shaping plate" (FSP), a three dimensional (3D) beam analysis utilizing OPERA-3d code was applied to the MeV accelerator.

A schematic view of the beam footprint in the MeV accelerator is shown in Fig.1 (a). The beamlets were extracted from apertures (14 mm in diameter) drilled in a lattice pattern of 3×5. The beamlets were deflected in alternate directions in each row by i) dipole magnetic fields generated in the extractor to suppress electron accelerations. Peripheral beamlets were also deflected outwards due to ii) the space charge repulsion among beamlets in the accelerator. The beamlets are most deflected by superposition of i) and ii), if the deflection direction was the same by i) and ii), as shown in Fig.1 (a) by dotted lines. The compensation methods are shown in Fig.1 (b). The aperture offset is applied to each row of apertures in alternate directions at the electron suppression grid (ESG). It steers the beamlets by the aperture offset, δ, of the electrostatic lens. Another compensation method is provided by the FSP, which is a metal plate of 1 mm thick attached at ESG. It generates electric field distortions, which steer the most deflected beamlets inward.

Before applying the compensation methods, the calculated beamlet deflection angle, θc, was 4.4 mrad due to i) and 4.5 mrad due to ii) at 1 MeV. In the most deflected beamlet, θc was 8.9 mrad by superposition of i) and ii). This, only with the FSP, reduced to 6.3 mrad. To compensate θc within 1 mrad, the necessary aperture offset was estimated to be 0.8 mm for center beamlets and 1.2 mm for the most deflected beamlets. In order to avoid beamlet interception at the ESG due to the large aperture offset, a conservative aperture offset of 0.5 mm was applied in the experiment. Results of the 3D beam analysis and experiment were compared at typical operational energies of 450 keV and 700 keV and showed good agreement. Details including compensation methods for next experiments are reported in this paper.

[1] M. Taniguchi, *et al.*, Rev. Sci. Instrum. **81** (2010) 02B101.



(a) (b)

Fig.1 Schematic view of beam footprint (a) and compensation methods in ESG (b).