§4. Variation of Energy Distribution in a Bias-Type TWDEC Simulator Installed on GAMMA 10

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Traveling wave direct energy converter (TWDEC) was proposed for energy recovery of fusion produced protons of D-^{3}He reaction. For wide application of TWDEC, its working characteristics for ion flux with wide energy spread should be examined. A bias-type TWDEC simulator was designed and installed on GAMMA 10[1)]. In this report, the detail examinations of experimental results by orbit calculation are presented.

The structure of the decelerator of the TWDEC simulator was designed according to the particle trapping theory[2)]. In the design, the constant deceleration of $\alpha = 8 \times 10^{11}\,\mathrm{m/s^2}$ and the objective energy $E_{\mathrm{design}} = 0.8\,\mathrm{keV}$ were taken. In the measurement, the end-loss ions of GAMMA 10 was used, the energy distribution of which was proportional to $\sqrt{E - E_{\mathrm{s}}}\exp(-(E - E_{\mathrm{s}})/T_{\mathrm{i}})$ where $E_{\mathrm{s}} = 63\,\mathrm{eV}$ was shifted-energy and $T_{\mathrm{i}} = 295\,\mathrm{eV}$ was ion temperature.

With an application of the negative DC bias of $-0.6\,\mathrm{kV}$, energy distribution functions were measured as shown in Fig. 1(a) in which polynomial fitting was used for noise elimination. The dotted curve is without operation of RFs of TWDEC, in which the peak of the distribution is around 0.8-1 keV. In the application of RFs, the relative phase differences between the modulator RF and the decelerator RF ($\Delta\phi$) were taken to be inverse phases of $\phi_{\mathrm{E0}} + \pi$ and ϕ_{E0}. A constant uncertain value of ϕ_{E0} is due to the difference between paths from the signal sources to the electrodes. In the case of $\Delta\phi = \phi_{\mathrm{E0}} + \pi$ (solid curve), the amount of ions in the lower energy side than 0.8-1 keV is larger than that in the higher energy side. On one hand, in the case of $\Delta\phi = \phi_{\mathrm{E0}}$ (dashed curve), vice-versa. The contrastive variations were found between the cases with inverse settings of $\Delta\phi$. This is natural as the principle of TWDEC is an inverse process of linear accelerator, thus inverse setting of $\Delta\phi$ could be resulted in an accelerator characteristic.

These characteristics were examined by orbit calculations with experimental conditions. The incident energy distribution was taken to be a shifted-Maxwellian. In the results shown in Fig. 1(b), variations of distribution functions similar to that in Fig. 1(a) are found. By taking an appropriate value of ϕ_{C0}, the amount of ions in the lower energy side is larger than that in the higher energy side for $\Delta\phi = \phi_{\mathrm{C0}} + \pi$ (solid curve). For inverse phase of $\Delta\phi = \phi_{\mathrm{C0}}$ (dashed curve), vice-versa.

In the orbit calculation, the ion flux with narrow energy spread is introduced in which a Gaussian distribution was employed as the incident energy distribution. The samples of the results are shown in Fig. 2. The average energy of the incident ions (E_0) is 0.875 keV for Fig. 2(a). In this case, the energy regions with large amount of ions are changed from the lower side to the higher side than E_0 due to the difference of $\Delta\phi$, which is similar to Fig. 1. In the case of $E_0 = 1.2\,\mathrm{keV}$ (Fig. 2(b)), variations of distribution according to $\Delta\phi$ are unclear. In the application of ions with wide energy spread to TWDEC, characteristics for energy components close to E_{design} appears, which correspond to the trapped region designed.

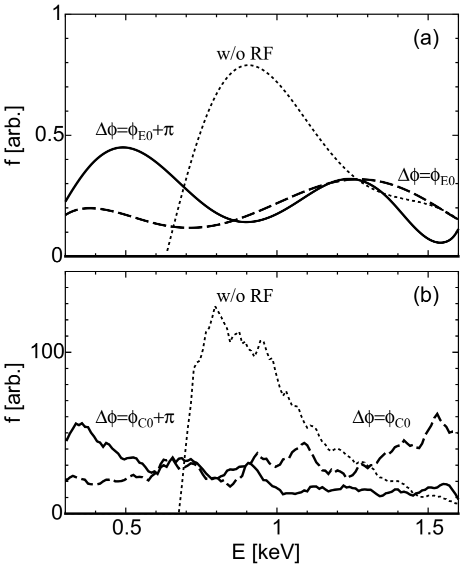

Fig. 1: Variation of energy distribution functions for incident ions with wide energy spread: (a) measured results and (b) calculated results.

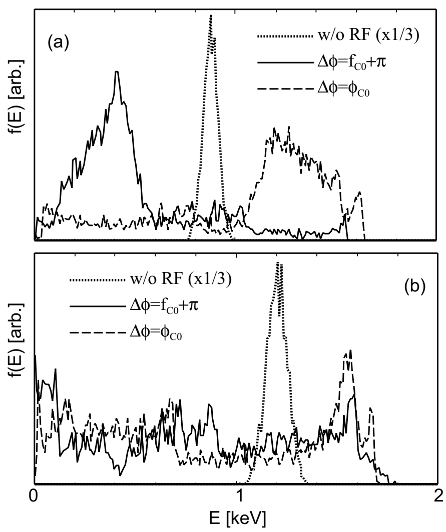

Fig. 2: Variation of energy distribution functions for incident ions with narrow energy spread. The average incident energies are (a) 0.875 keV and (b) 1.2 keV.

1) Takeno, H., et al.: Ann. Rep. NIFS (2009-2010) 485.
2) Katayama, H. and Sato, K.: J. Plasma Fusion Res. **77** (2001) 698.