§24. Basic Investigation of Direct Energy Conversion for D-^{3}He Fusion

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In a conceptual design of the direct energy converter (DEC) for FRC-based D-^{3}He fusion reactor, CuspDEC separates electrons and thermal ions from fusion protons and converts kinetic energy of the thermal ions into electricity via Venetian blind type electrodes, while Traveling Wave (TW) DEC produces RF power from the protons in a similar way as TWT. We investigate the operation of these DECs by the tiny-scale simulation experiments and by the numerical simulation.

We have constructed a CuspDEC experimental device, which consists of the ion/electron source, the guide field section, and the slanted cusp section. The ions and/or electrons with energies of 1-10 keV and $\leq$ 10 eV, respectively, are injected into the cusp where the magnetic field lines are vented with the variable angle ranging 90-135°. Larger angles are expected to be effective in separating electrons from ions or separating ions with different energies. The flow of particles will be measured by using Faraday cups and charge collectors.

The result of the numerical simulation of this device predicts that the electrons follow the magnetic field to enter the line cusp region, and the 1-keV ions with pitch angles of less than 15° go through the cusp and reach to the point cusp end for the magnetic field strength of $\sim$ 1 kG, indicating almost complete separation. In the case of the pitch angle of 20°, 38% of ions can not be separated from electrons.

We have also performed the basic experiment for TWDEC[1] using He-ion beam of $\sim$ 4 keV and modulation/deceleration RF at 7-MHz. The ratio of the voltage on the electrodes to the beam energy V_{dec}/V_{ex} is about 0.07, which is nearly the same as the design value of $\sim$ 0.1 used in reactor-based TWDEC for 14.7-MeV protons. The thermal spread of the beam energy is about ± 5 %, which is slightly larger than those from the FRC reactor. The length of the decelerator Λ_{dec} was varied from 0.2 to 2Λ, where Λ is the one wavelength given by the beam velocity divided by the RF frequency.

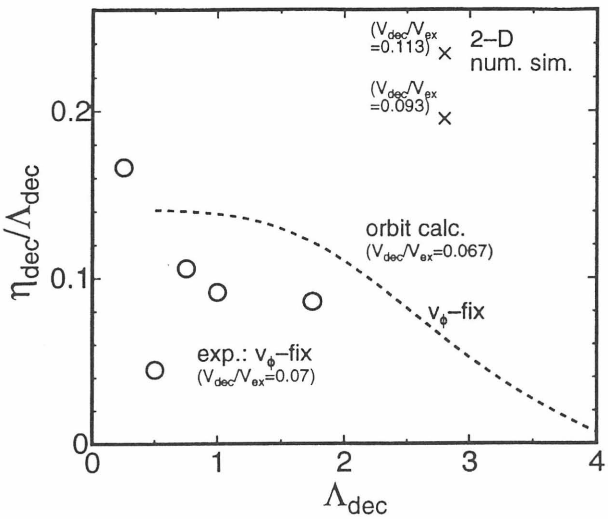

Fig. 1 Energy conversion efficiency per one wavelength for TWDEC.

The measure energy conversion efficiency of the decelerator per one wavelength is plotted in Fig. 1 by open circles as a function of Λ_{dec}. The dotted line indicates the result of one-dimensional (1-D) calculation for the experimental condition. We see that the experimental data are very close to the 1-D calculation. The crosses show the results from 2-D numerical simulation of reactor-level TWDEC[2] with higher V_{dec}/V_{ex}, longer modulator length than for the experiment, and no thermal spread of the beam. These conditions would yield apparently higher energy conversion efficiency than for the experimental conditions. It can be said that the experimental results are within the scope of the 2-D simulation.

References

1) Noda K. and Yasaka Y., Fusion Technol. **33** (1998) 93.

2) Ishikawa M., Kudo T. et al., Fusion Eng. and Design **41** (1998) 541.