§2. Experiment on Direct Energy Conversion in a Small-Scale CUSPDEC Device

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A small-scale experimental device is used to study the basic characteristics of discrimination of electrons and ions in the cusp magnetic field. Ions separated from electrons are guided to an ion collector, which is operated as a one-stage direct energy converter.

Once the ions and electrons are discriminated by the slanted cusp magnetic field, it is necessary to decelerate and collect ions to recover their kinetic energy and generate electricity. A plane-electrode-type ion collector[1)] is located at a point cusp region of exit side of the cusp magnetic filed. In Fig. 1, the current to the ion collector normalized to its value at V = 0 is plotted versus V for various acceleration voltages V_{acc} of the plasma source, where V is the collector voltage. When the value of V is high enough for each V_{acc}, the collector current reduces to zero (even negative for V_{acc} = 290 V due to generation of secondary electrons or insufficient separation of electrons). This means that when the value of V is set at an appropriate value, a large fraction of ions is decelerated almost to zero velocity and flows into the ion collector plate at a high positive potential. A load resistor connected to the ion collector would obtain electric power, which is directly converted from the kinetic energy of incoming ions.

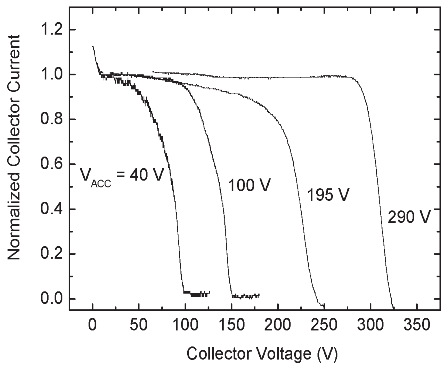

Fig. 1. Normalized ion collector current versus the collector voltage for several V_{acc}.

We plot the output power P, i.e., the ion collector current times V, as a function of V in Fig. 2 for the case of V_{acc} = 290 V in Fig. 1. The curve has a maximum at a certain voltage, which we call the optimum operating voltage V_{opt}. If the incoming ions have an energy distribution function represented by the delta function and secondary and/or ionization electrons are negligible, the V-I characteristics would be such that the collector current is constant at I_0 until the collector voltage exceeds the value V_{max} corresponding to the ion energy, then goes to zero abruptly. In this case, the conversion efficiency defined by $\eta = P(V = V_{opt}) / (I_0 \cdot V_{max})$ is 1.

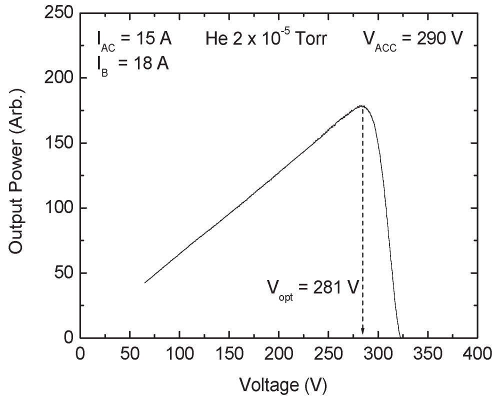

Fig. 2. The output poweras a function of the ion collector voltage for V_{acc} = 290 V.

In the case shown in Fig. 2, using V_{max} = 325 V from Fig. 1, the value of η is calculated to be 0.84. The energy distribution function is measured to find that ΔE/E is 0.1, where ΔE is the full width half maximum of the energy distribution function with E being the average energy.

Open circles plotted in Fig. 3 represent the values of η as a function of ΔE/E. In our experiments, since the energy of the primary ions is low, the charge exchange with and the ionization of the residual gas are negligible. Therefore, the loss of I_0 would be produced by the secondary electrons from the electrodes or the wall. The loss of I_0 is estimated from the electron current at large V in the V-I curve of the ion collector to be 5–10 %. The dotted curve in Fig. 3 is a fit to the experimental points with the assumption that η = 0.95 for ΔE/E = 0.

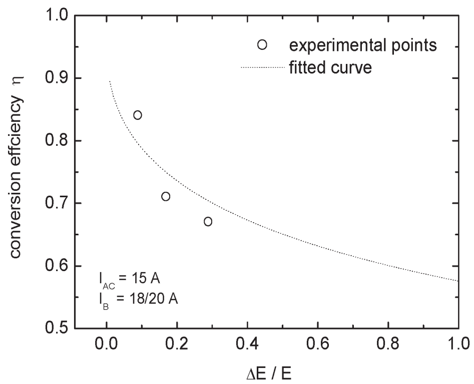

Fig. 3. The values of η as a function of ΔE/E with the dotted curve fitted to the experimental points.

Reference

1) Barr, W. and Moir, R.: Nucl. Technol. /Fusion, **3**, 98 (1983).