§31. Performance Improvement of a D-D Fusion Neutron Source as a Calibrator for Neutron Detectors

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An inertial electrostatic confinement fusion (IECF) device is a glow-discharge-driven compact fusion neutron source (see Fig. 1), consisting of a spherical vacuum chamber as an anode at ground potential and a highly transparent central cathode grid at a negative potential $-V_c$. Ions produced between them are, on one hand, accelerated towards the center and the spherical focusing of these ions results in a steady-state D-D neutron yield of 10^7 - 10^8 sec^{-1}. On the other hand, the electrons inherently produced at the same time gain mostly the full energy corresponding to the bias $-V_c$ and hit the chamber, leading to a copious amount of undesirable X-ray emission. Furthermore, especially under a high operational pressure, the power consumption for the electron beams (see the clear spokes in the discharge photo in Fig. 1) exceeds 90 % of the total input, which greatly limits the efficiency and accordingly the neutron yield of the IECF with an applicable power input.

In this study, we have proposed a new IECF-based scheme to cope with this problem, by use of an additional gridded anode set concentrically between the cathode and the chamber as shown schematically in Fig. 2. We expect in this configuration the production of deuterium ions and electrons, focusing of the ions and D-D fusion reactions would take place within the gridded anode at a bias potential of V_a, while the escaping electron beams would pass through the gridded anode and reach the chamber with a reduced energy. The chamber at ground potential is thus expected to serve as a depressed collector of the electron beams, to reduce X-ray energy and flux, and to enhance the efficiency of the IECF, i.e. the neutron output per input power.

We have measured the X-ray dose equivalent rate (XDER) and the neutron production rate (NPR) by the double-grid IECF device, as functions of the biases V_c (<20 kV) and V_a (<33 kV). The results show clear dependence of the NPR on $V_c + V_a$ in Fig. 3 as expected. In contrast, the XDER in Fig. 4 is seen clearly dependent on V_a almost regardless of $V_c + V_a$ or V_c. Note that the XDER and NPR in the figures are both normalized by the cathode current.

Considering the X-ray dose rate by electrons is known to show approximately the forth power of the electron energy in the present energy range, the XDER independence from $V_c + V_a$ which exceeds V_a ($(V_c + V_a) / V_a \sim 1.8$ at most) indicates strongly a very high transmittance of the escaping electron beams through the gridded anode. The reason for XDER not depending on V_c but on V_a can also be explained by the fact that V_a exceeds V_c in the present experiments, i.e. the contribution by the secondary electrons from the chamber hitting the anode grid dominates the XDER.

Also, as the result, the XDER per NPR is found to reduce drastically, ~1/10 of the conventional single-grid IEC, owing to the strong dependence of XDER on the electron energy.

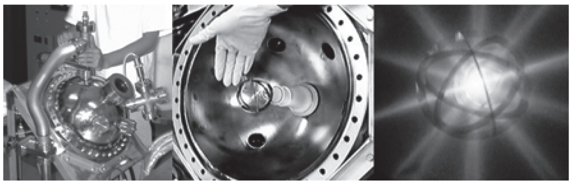

Fig. 1. A conventional single-grid IECF device and a discharge photo

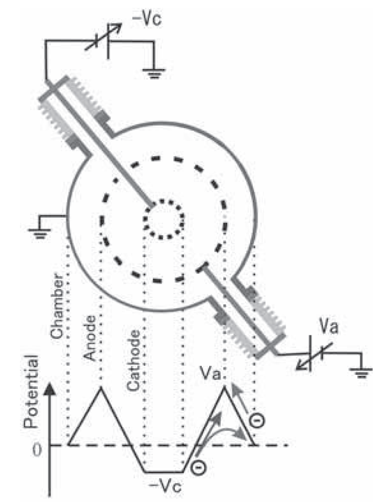

Fig. 2. Schematic cross-section of the present double-grid IECF device with the additional gridded anode

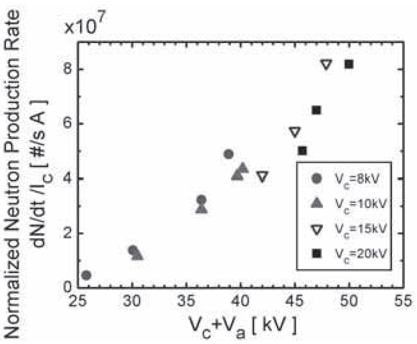

Fig. 3. Neutron yield normalized by the discharge current as a function of $V_c + V_a$ for various V_c

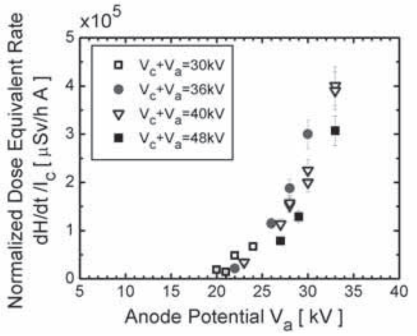

Fig. 4. X-ray dose equivalent rate as a function of V_a for various $V_c + V_a$