§34. Enhancement of Thermalized Neutron Flux Density by a Discharge-Based Fusion Neutron Source

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An inertial electrostatic confinement fusion (IECF) device is a discharge-based compact fusion neutron/proton source consisting of a spherical vacuum chamber as an anode at ground potential, and a highly transparent central cathode grid at a negative potential of ~100 kV. Ions are accelerated towards the center as they gain energy from the applied electric fields and the spherical focusing of ions results in steady-state D-D neutron production rates of 10^7 - 10^8 sec^{-1}. In this study, an extremely compact IECF device shown in Fig. 1 has been developed in order to meet the requirement of compactness for many neutron-source applications. At the same time we also aimed at an effective thermalization and focusing of the 2.45 MeV neutrons from the D-D fusion reactions.

As shown in Fig. 2, the new device consists of double jacket chambers to provide sufficient water cooling, having the diameters of inner and outer chambers of 20 cm and 30 cm, respectively. The effective water-cooling has enabled very stable operation at high dc discharge currents of over 80 mA. As a result, the design target of 1×10^7 sec^{-1} dc neutron yield has been achieved at a cathode voltage of 80 kV and 80 mA.

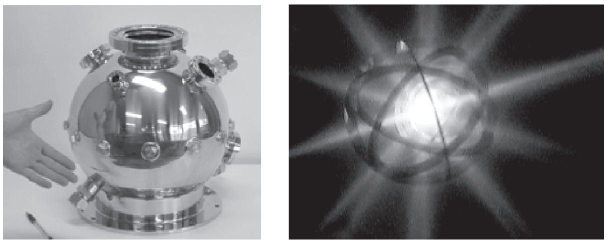

Fig. 1. Double-jacket chamber for a water-cooled IECF and a discharge photo within a gridded cathode

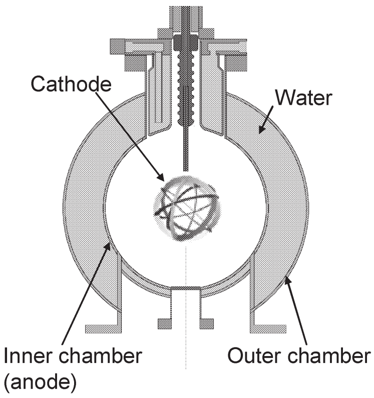

Fig. 2. Schematic cross-section of the water-cooled IECF device, with the gridded cathode held at the center of the double-jacket chamber as the anode

Also, the 5 cm thickness of the water coolant between the double jacket chambers was designed to assure a reflection of 2.45MeV D-D neutrons downward, where a thinner 1 cm thick water jacket is installed at the bottom. This non-uniformity of the water jacket thickness resulted in multiplied neutron flux downward as shown in Figs. 3 and 4. In these figures θ denotes the angle with respect to the vertical from the device center.

Figure 3 shows experimental and numerical neutron count rates by a ^{3}He proportional counter, virtually the angular distribution of thermal neutron flux density, because the counter shows much higher sensitivity for lower neutron energies. The MCNP simulation takes into account the energy dependence, and the existence of the surrounding concrete walls as well. The envisaged downward focusing was observed both experimentally and numerically, though the reflection from the surrounding wall is found to blur out the downward peak.

In contrast, the numerical result from MCNP on neglect of the surrounding wall in Fig. 4 shows more clear focusing effect. Unlike Fig. 3, it shows the flux density distribution of the neutrons of all energies. These results revealed that the non-uniformity of water jacket thickness is effective for focusing the neutrons, especially fast neutrons.

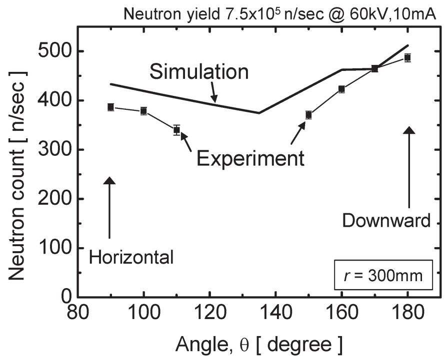

Fig. 3. Pressure – voltage characteristics by experiments and simulations for various cathode diameters ranging from 50 to 95 mm ϕ

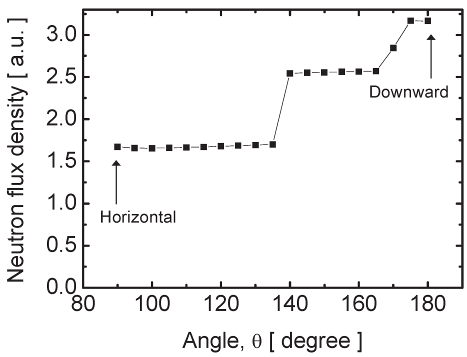

Fig. 4. Normalized neutron yield by magnetron ion source aided IEC as a function of operation gas pressure