

Improvement of an Inertial Electrostatic Confinement Fusion Device by a Magnetron-Discharge-Based Built-In Ion Source

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An inertial-electrostatic confinement fusion (IECF) device is a compact discharge-type fusion neutron/proton source, consisting of a spherical vacuum chamber as an anode, and a central hollow cathode grid, where a glow discharge takes place. Positive ions generated are then accelerated to the center, and mostly after passing through the transparent hollow cathode, they are decelerated to stop in front of the anode, and again accelerated toward the central cathode again. These sloshing ions result in a high ion density at the center, and accordingly a high fusion reaction rate. Production of sufficient full-energy ions in the vicinity of the anode (chamber) and reduction of unnecessary charge-exchange (neutralization) with background gases are both essential to a drastic enhancement of ions' energy and lifetime leading to a higher fusion reaction rate.

For this purpose, we have proposed a magnetron discharge-type built-in ion source. Unlike other external ion sources, this ion source does not require additional positive extraction electric fields, which tend to make the ions to hit to the opposite anode. Moreover, the magnetron type built-in ion source has an extremely simple configuration to preserve the advantageous IECF features of compactness and robustness, essential to practical application.

In the previous experiments by use of a magnetron-type ion source consisting of a coaxial inner anode at a high voltage and a permanent magnet outside the grounded cathode, it is found that background gas pressure is reduced and ion beam energy increased, though this configuration is still not ideal in the viewpoint of ions' recirculation since produced ions have still considerable energy even at the opposite anode.

To resolve this demerit, we applied the inner coaxial electrode with a inner permanent magnet at a negative high voltage based on the numerical analyses. We designed a new magnetron-type ion source with a further refined configuration. It consists of an anode (grounded nozzle of 35 mm ϕ inner diameter), a coaxial cathode (20 mm ϕ diameter) at a negative voltage, and a cylindrical water-cooled permanent magnet (Nd-Fe) inside the cathode tube. Magnetron discharge then takes place by these localized electric and magnetic fields, and by shifting the inner cathode in the axial direction, evaluation of the influence of cathode position to discharge current and ion extraction characteristics is made.

This magnetron-type ion source shows a good performance, showing discharge current as high as 60 mA at a cathode voltage of 3.0 kV under H₂ gas pressure of 3.0 Pa. For further enhancement of discharge current, an optimal magnetic field distribution by use of additional magnets outside the nozzle is now being studied both experimentally and numerically.