# §38. A Novel Scheme for Low-Pressure Operation for Performance Improvement of Discharge-Driven D-D Fusion Device as a Calibrator Neutron Source

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Inertial Electrostatic Confinement (IEC) aims to produce controlled nuclear fusion reactions by converging ions of a $D_2$ or $D_2$-$^3$He glow discharge through concentric spherical electrodes (see Fig. 1). A discharge is typically produced in a 0.5-1 Pa gas by applying a large negative voltage (50-100 kV) to the central cathode, which is highly transparent to ions. An issue for glow discharge IEC is that the gas itself neutralizes ions limiting their acceleration and confinement. Here the neutron yield in a $D_2$ gas increases linearly with the cathode grid current. Moreover there is only a small contribution from energetically favorable 'beam-beam' reactions where the yield is expected to be proportional to the current-squared. A crucial goal for IEC is thus to improve the contribution of beam-beam reactions by increasing the ratio of cathode current to gas pressure.

Towards this aim, we have introduced the concept of IEC driven by an internal ring-shaped magnetron ion source (RS-MIS). The glow discharge is replaced by a low pressure (units of mPa) dc magnetron discharge using perpendicular electric and magnetic field vectors in the vicinity of the anode grid, provided by a ring-shaped array of small cylinders each containing a permanent magnet and where source ions are extracted using the traditional gridded cathode. This is shown in Fig. 2. Unlike the use of external ion sources, RS-MIS prevents the loss of ions to the chamber (anode) as ions are created at a potential lower than ground. Moreover, the radial focus is expected to enhance the beam density at the center.

The present new scheme is found to provide cathode grid currents as large as 1 mA at 5 mPa ($D_2$) successfully, an order-of-magnitude improvement of the current-pressure ratio over the glow driven mode. As the result, the D-D neutron yield shows nonlinear dependence on the grid current as seen in Fig. 3. Also interestingly, the neutron yield turns out to increase as the $D_2$ gas pressure decreases below 10 mPa as seen in Fig. 4. Both of these phenomena are very indicative of the envisaged beam-beam reactions.

Future experimental work must aim to determine the fractions of beam-gas, beam-grid and beam-beam fusion contributions in the present IEC scheme of high current-pressure ratio, using collimated proton detection for example.

Fig. 1. A conventional glow-discharge-driven IECF device.

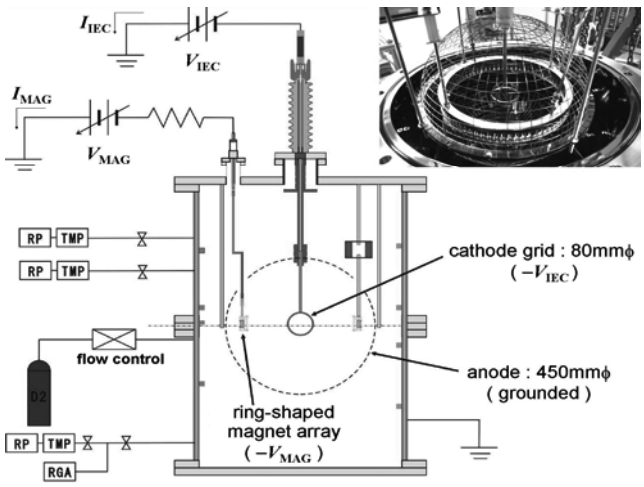


Fig. 2. Schematic cross-section and photo of electrodes arrangement of the newly developed IEC driven by the internal RS-MIS.

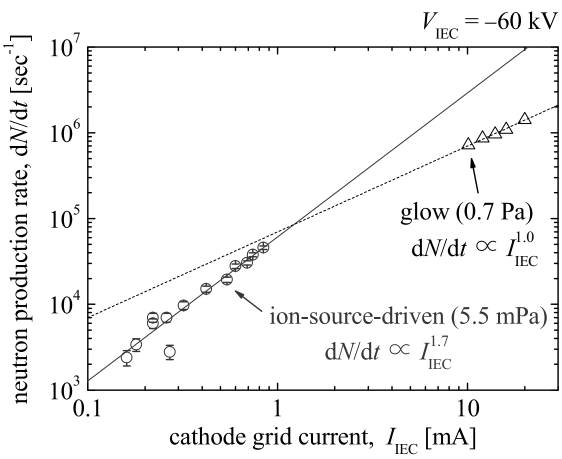


Fig. 3. D-D neutron yield as a function of cathode grid current by the RS-MIS-driven IEC, compared with the conventional glow-driven operation.

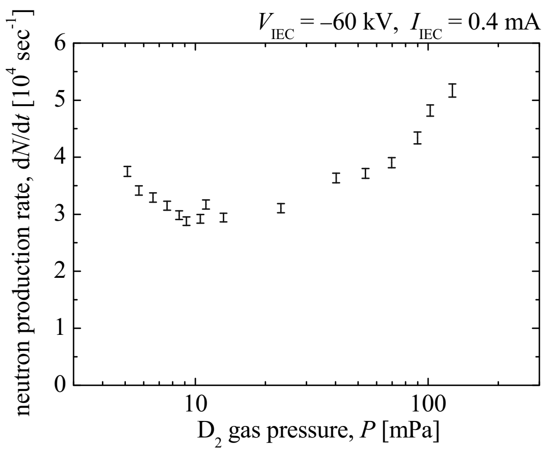


Fig. 4. D-D neutron yield as a function of gas pressure for a constant cathode grid current.