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

Masuda, K., Kipritidis, J., Nagasaki, K., Yamamoto, Y., Noborio, K. (Inst. Advanced Energy, Kyoto Univ.),
Kajiwara, T., Yamagaki, Y. (Grad. Schl. of Energy Sci., Kyoto Univ.),
Tomita, Y., Kawahata, K.

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 grid, which is highly transparent to ions. An issue for 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.

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

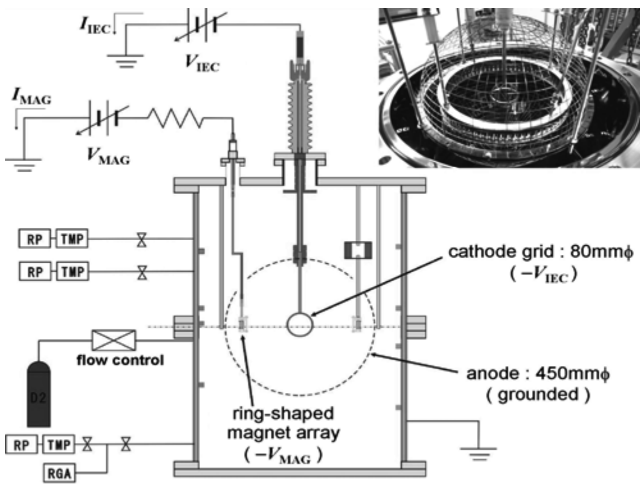

Fig. 2. Schematic cross-section and photo of electrodes arrangement of the newly developed IEC driven by the internal RS-MIS.

Towards this aim, we have introduced the concept of IEC driven by an internal ring-shaped magnetron ion source (RS-MIS, see Fig. 2). The glow discharge is replaced by a low pressure dc magnetron discharge as the internal ion source in the vicinity of the anode, provided by a ring-shaped array of permanent magnets. This 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 IEC. As the result, the D-D neutron yield shows nonlinear dependence on the grid current, which is very indicative of the envisaged beam-beam reactions.

The present new IEC scheme with the RS-MIS extended the accessible low pressure limit very much down to 5 mPa. This increased the importance of ion beam optics in terms of ion recirculation (oscillatory motion of ions within the anode, prior to striking the feedthrough rod, see Fig. 3), because, for tens keV and 5 mPa, the mean free path for deuterium ion charge exchange is of the order of 10 m (tens cm for the glow driven IECs for comparison), which is much longer than the typical anode diameter.

In this context, we designed a 5-stage feedthrough with four intermediately biased electrodes shown in Fig. 4. Numerical simulations suggested improvement in ion recirculation current by a factor of 3 due to recovery of the spherical symmetry in electric field distribution.

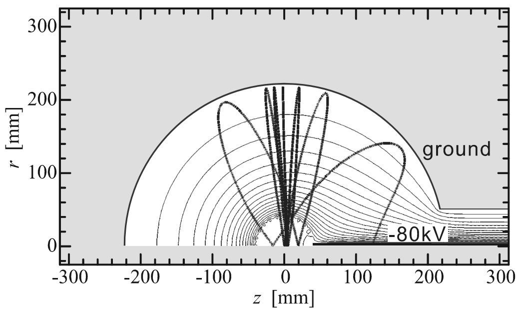

Fig. 3. Calculated potential contours and an ion trajectory. The ion is seen to hit the high-voltage feedthroug rod after five oscillatory motions.

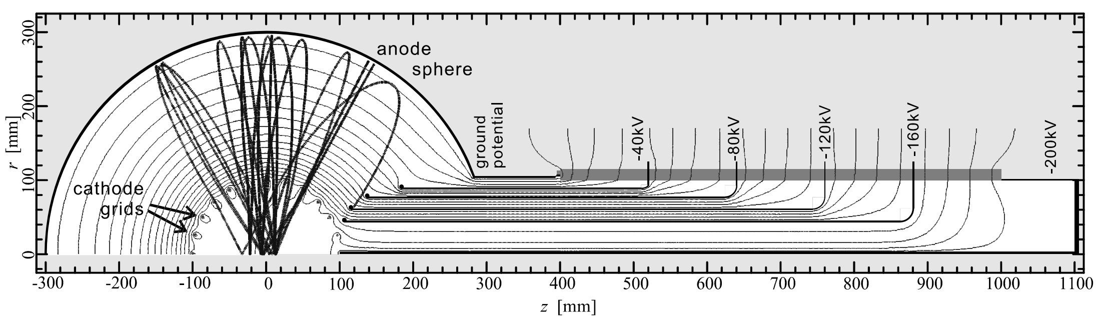

Fig. 4. Cross-sectional view of an IEC with a 5-stage feedthrough, calculated potential contours and an ion trajectory.