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Development of Penning Ion Gauge for in-situ measurement of neutral pressure in VEST

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A Penning Ion Gauge (PIG) has been developed to measure the responsive temporal changes of neutral pressure inside the magnetic fusion devices, and has been successfully operated in Versatile Experiment Spherical Torus (VEST) [1].

In magnetic fusion devices under the high vacuum conditions, the ionization type gauges are widely used to monitor the neutral pressure. It is divided into two well-known methods based on the operating principle: 1) the hot cathode, commonly known as the ASDEX gauge [2], 2) the cold cathode, known as the Penning ion gauge (PIG) with the internal permanent magnets. For the context, here is the brief explanation of typical penning discharge. The geometry of the penning cell consists of a long cylindrical anode at the center and cathodes at both ends. An electric potential is applied between the anode and cathode to initiate discharge. Then, the magnetic field should be applied perpendicular to the cathodes plate for the enhancement of the electron confinement through gyro motion. As a result, the discharge in penning cell can occur at much lower pressure compared to conventional gap discharge.

Although other commercial PIGs have been used in the magnetic fusion devices, their locations are usually far away from the main device to avoid exposure to time-varying magnetic field conditions. However, it poses a drawback to observing the temporal behavior of neutral pressure that the length from the main chamber duct to the gauge installation location is extended. As shown in figure 1), note that the developed in-situ PIG is different from other commercial PIGs that utilize internal magnets, as it utilizes the device's operational magnetic field (toroidal and poloidal field in tokamaks) to measure with fast time-responsiveness. For the in-situ operation of PIGs, the PIG should be designed and developed with careful consideration in terms of time-varying magnetic field conditions in device.

To check its reliability during in-situ operation, feasibility tests are conducted by specifically investigating both the Penning discharge mode transition and the effect of magnetic field alignment on the Penning discharge. The mode transition [3] of Penning discharge is clearly observed, confirming the developed PIG is applicable to the operation regime of VEST. The PIG is also designed to measure discharge current stably during magnetic field angle variation of up to 15°. In addition, it has been verified that the operation range of PIG can be expanded by increasing inverse aspect ratio of the gauge cell geometry. Finally, the developed PIG is installed in VEST, measuring a milli-second order temporal changes in neutral pressure within a range of 3×10^{-5} mbar to 1×10^{-3} mbar, under the magnetic field angle variation of up to 15°. As a result, it is successfully measured rapidly evolving neutral pressures resulting from the plasma wall interaction [4] during ohmic discharges in VEST.

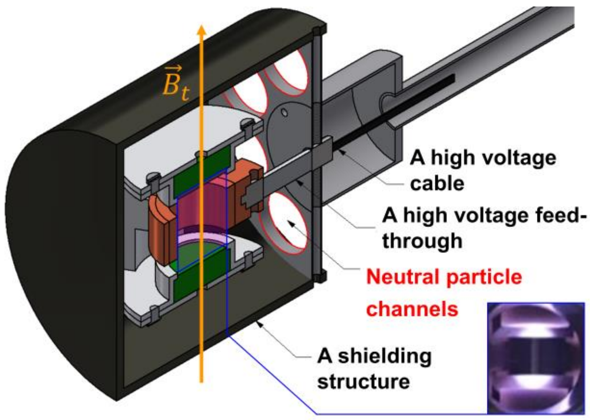

Figure 1) A cross section view of the VEST in-situ PIG head with a toroidal magnetic field vector

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