§12. Simple Emittance Measurement of H⁻ Beam Using Pepper-pot Method

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Emittance is defined as the area occupied by the particle beam in the phase space. It is related to the expansion of the energy distribution of the particles in the beam. Hence the low emittance beam has a good quality in that it is able to run a long distance with small expansion of the beam radius. In the case of the negative hydrogen ion (H⁻) beam for the negative-ion-based NBI on the LHD (LHD-NNBI), it is naturally expected that emittance is low enough for the neutralized hydrogen beam to reach the LHD plasma without expansion.

A simple apparatus for emittance measurement using pepper-pot method is developed. Figure 1 shows the emittance gauge. There are drilled 37 pinholes of 0.2 mm in diameter (12 vertically, 12 horizontally, 12 diagonally and one at the center) on a stainless steel plate of 1.0 mm in thickness. The images of beamlets through this multi-pinhole plate, called "the pepper-pot", are directly exposed and recorded on a Kapton foil. This gauge is very compact compared with the tools for the usual pepper-pot method that records the pepper-pot pattern on the fluorescent screen by a CCD camera.

Using this apparatus, emittance is measured in the case of the H⁻ beam from the large negative ion source, which is the 1/3 scaled test device for the LHD-NNBI.

As the first trial of this apparatus, emittance of the H⁻ beam is measured with the ion source operated under the following condition; hydrogen gas pressure in the ion source 1.0 Pa, arc discharge power 35 kW, extraction voltage 7.9 kV, acceleration voltage 79.4 kV and typical H⁻ beam current 6 mA (10 mA/cm² in current density). Compared with the beam current density profile by Faraday cup, Kapton foil shows a good linearity against the beam intensity in the energy range of this experiment (Fig. 2).

The 95% emittance value normalized by the beam energy is measured as 0.59 mm mrad. This very low emittance shows that this ion source achieves the enough specification for the LHD-NNBI.