§10. Evaluation of Path Integral Effect in CHS HIBP

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A heavy ion beam probe (HIBP) is a unique diagnostic instrument which can measure local plasma potential and its fluctuations. However, in the presence of MHD activities, acceleration or deceleration of both primary and secondary beams is caused by the fluctuating vector potential $\partial A/\partial t$ along the beam trajectories (path integral effect). It is possible to be a contamination of space potential measurement. We have evaluated those effects during a bursting MHD instability in the Compact Helical System (CHS), which is considered to be an m/n=2/1 interchange instability.

The probing beam passing through the plasma gains energy due to acceleration by the electric field along the beam trajectory. It is expressed as follows:

$$\delta W = \int_a^b q\mathbf{E}\cdot d\mathbf{L}$$

$$= \int_a^b q\left(-\nabla\phi - \frac{\partial \mathbf{A}}{\partial t}\right)\cdot d\mathbf{L}, \qquad (1)$$

where ϕ is the scalar potential, $\mathbf{A}$ is the vector potential, a and b are initial and final positions of the beam. In the HIBP for toroidal helical devices, the beam travels a certain distance in the toroidal direction and the path integral term should not necessarily be neglected.

In order to calculate the path integral term, it is necessary to know the detailed spatial structure of the vector potential, both plasma inside and outside. It is not easy to do in the real CHS configuration. In this study, model vector potentials for a cylindrical plasma column are assumed through theoretical and experimental approaches. Firstly, simple spatial structure of the vector potential in the plasma is assumed based on an interchange mode theory and the contribution of the path integral term is evaluated. Here we take a fixed boundary plasma model and vector potential outside plasma is neglected. Then based on these model calculations and experimental results of the spatial profile of the normalized T-B difference signal, we will estimate again the path integral term inside plasma more realistically (Fig. 1). We will estimate the vector potential outside plasma from the magnetic probe data which can be smoothly connected to the profile of plasma inside.

Resulting path integral effects are obtained for each radial position as shown in Fig. 2, where δ represents the phase relation between the beam line and the poloidal mode structure of the instability. It is confirmed that the path integral effect due to the fluctuating vector potential inside the plasma is negligible for the observed MHD instabilities in CHS[1].

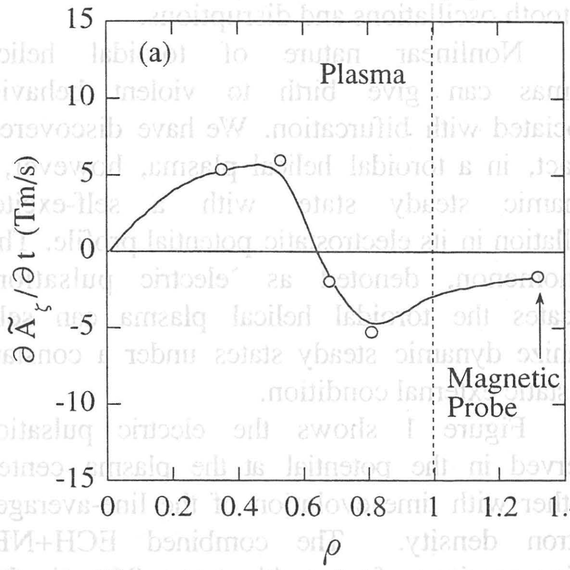

Fig. 1: Time derivative of the vector potential on the assumption of scalar potential .

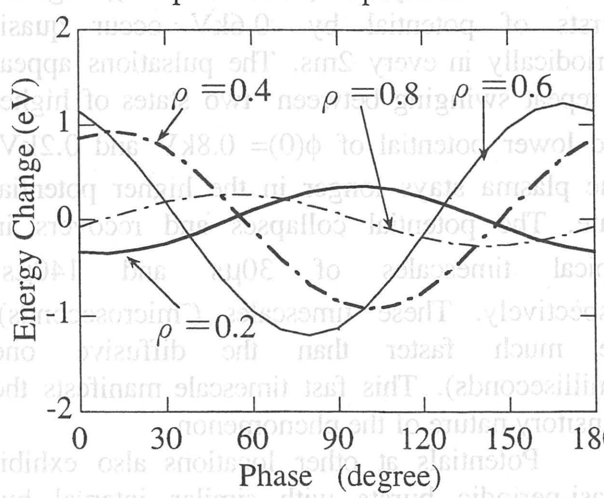

Fig. 2: The path integral effect due to the realistic fluctuating vector potential.

References

[1] S. Lee et al., J. Plasma Phys. and Fusion Res. Proc.of ITC-8.(1998) 273