§16. A Method to Infer Internal Mode Structure with HIBP and Magnetic Probes


Heavy ion beam probe (HIBP) can measure potential fluctuations directly with no disturbance to high temperature plasma, and has possibility to estimate mode structure from the profile of potential fluctuation amplitude if the corresponding fluctuation is identical from the background turbulence. This report describes a method to infer the internal mode structure using the HIBP by a help of magnetic probes in the case that detectable potential fluctuation is weak and buried in the background.

The measurement was carried out on ECR-heated plasmas in CHS with the following operational conditions; toroidal magnetic field Bt=0.88T, magnetic axis R_Axis=0.92m, and the line-averaged density n_e~4x10^{18}m^{-3}. In the plasmas, the fluctuation power spectrum of magnetic probes, as is shown in Fig. 1(a), indicates a peak exists around 130kHz. On the other hand, potential signals of HIBP has no appreciable peak in the power spectrum of Fig. 1(b), therefore, estimation of the mode structure from the potential fluctuation amplitude is difficult. Then, coherence is examined between magnetic field and potential fluctuations, as shown in Fig. 2. Obviously, a significant peak exists around 130kHz, corresponding to the spectrum of the magnetic field fluctuation. This result suggests that the mode localization should be estimated from the coherence. Radial profile of the coherence is shown in Fig. 3. The plotted coherence values are the peak values obtained by Gaussian fitting to coherence curves around 130kHz. The mode should be localized around $\rho=0.5$ where the profile has a high value, since higher coherence implies that the mode amplitude should be higher as is discussed below.

The definition of the coherence is described as $\text{coh}=\frac{|E[X(f)] \cdot Y(f)|}{\sqrt{|E[X^2(f)]| \cdot E[Y^2(f)]}}$, $X$ and $Y$ are the complex Fourier coefficients of potential and magnetic signals, respectively, and $E$ denotes ensemble average. The signals are assumed to be composed of two parts, as $X(f)=X_{\text{mode}}(f)+X_{\text{noise}}(f)$ and $Y(f)=Y_{\text{mode}}(f)+Y_{\text{noise}}(f)$. The subscripts, mode and noise, mean the electromagnetic fluctuation part of the mode and noise part, respectively, (which containing electrostatic fluctuation part). Assuming $Y_{\text{mode}}(f) \gg Y_{\text{noise}}(f)$ and using ensemble average, we deforms above definition and obtains a next simple description, $\text{coh}=\frac{1}{\sqrt{1+|E[X_{\text{noise}}(f)]|^2/E[X_{\text{mode}}(f)]^2}}$. As a result, the coherence is a function for fraction of amplitudes for $X_{\text{noise}}(f)$ and $X_{\text{mode}}(f)$. Even if signal-to-noise ratio is $-1$ (or $X_{\text{mode}}(f) \sim X_{\text{noise}}(f)$), the formula shows that the coherence gives a high value, i.e., $\text{coh} \approx 0.703$. Hence, in case that signal-to-noise ratio is very low (or in case that a mode amplitude is comparable to amplitude for background level of the fluctuation), the radial location of the mode is possible to be inferred using coherence between HIBP and magnetic probes.

In summary, we present a simple method to deduce inner mode structure using HIBP and magnetic probes. The method will be widely applicable to other diagnostics to sense the internal fluctuations.

![Fig. 1. Typical power spectra of (a) magnetic probe signal and (b) potential signal detected by HIBP at $\rho=0.6$.](image)

![Fig. 2. Coherence between magnetic probe signal and potential signal ($\rho=0.6$). A clear peak exists around 130kHz.](image)

![Fig. 3. Radial profile of the peak value for the coherence around 130kHz between magnetic and potential signals. The mode is localized at $\rho=0.5$.](image)