§1. Improvement of the Data Analysis Technique for Density Fluctuation Measurement by the Laser Imaging Method

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We developed a laser imaging method (LIM) with a folded beam to obtain information concerning the spatial distribution of electron density fluctuations in magnetically confined plasmas. The LIM produces real images of the fluctuations, so it is possible to use standard signal analysis tools such as FFT tools. However, the characteristics of these phenomena have blocked researchers from exploiting the full potential of LIM with the standard analytical methods alone: i) signal decomposition is not performed by the hardware, so it is necessary to perform a multidimensional (spatiotemporal) analysis via software (on the other hand, this also allows for significant diversity in processing); ii) it is a transmission measurement method, so the signal is line-integrated along the beam axis; iii) a wavenumber spectral analysis must be carried out with a small number of spatial data; and iv) the polar coordinate system is the most useful as it can specify the propagation directions of fluctuations. With LIM in particular, a method of analysis with superior resolution of the wavenumber spectrum is required, as the LIM method has, under certain conditions, to identify the spatial locations of the fluctuations from the analysis of their propagation directions.

Therefore, the authors have carried out investigations of a 2-dimensional maximum entropy method (MEM) with polar coordinates as a means of analyzing data that is appropriate for LIM. The MEM in particular is anticipated to provide a high spectral resolution, in spite of the low number of data.

Figure 1 shows an example contour plot of the calculated spatial spectrum from measured LIM data on CHS by conventional 2-D Fourier Transform (FT). It is not very clear in the figure, but ridgelines were observed in an x pattern in the low-wavenumber region. These ridgelines lay in a direction close to that of the magnetic lines of force in the LCMS (Last Closed Magnetic Surface) of the CHS; this suggests that the fluctuations were strong at the periphery of the plasma. However, the width of the analyzed distribution was around 32° at k=0.5mm^{-1}, close to the simulated angular resolution, so there is a high probability that the analyzed distribution is heavily distorted. Also, if we estimate the spatial resolution (z_{reso})[1] from the angular resolution at the edge of the plasma, it is then about 20 cm ($z_{reso}/a \approx 1$).

Figure 2 shows the results of the analysis by the developed 2-dimentional MEM[1] with polar coordinates using the same data, just as was done above for the FT. The reader can see that the resolution has been improved from the fact that the borders of the spectrum are sharper than they were after FT processing. We can evaluate that the distribution width (HWHM) was 1.7 – 3.7° at k=0.5mm^{-1}, far smaller than that in the FT results.

A maximum entropy method in polar coordinates was proposed in order to obtain a high spatial resolution of the propagation of fluctuations in the plasma. This method was shown to be capable of providing a high propagation resolution with fewer data points than is required by the FT method, even when there are gaps in the data. This method was then applied to the fluctuation data obtained by CHS. The results showed a great improvement in resolution over that obtained in the FT analysis, and an effective spatial resolution was obtained in the physical investigation using the CHS.

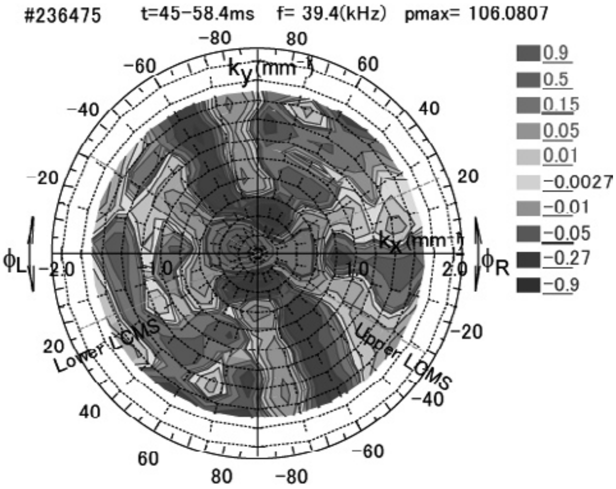

Fig. 1 Results of spatial spectrum analysis by polar coordinate FT The fluctuation components were quite strong in the directions of the magnetic lines of force at the upper and lower LCMSs.

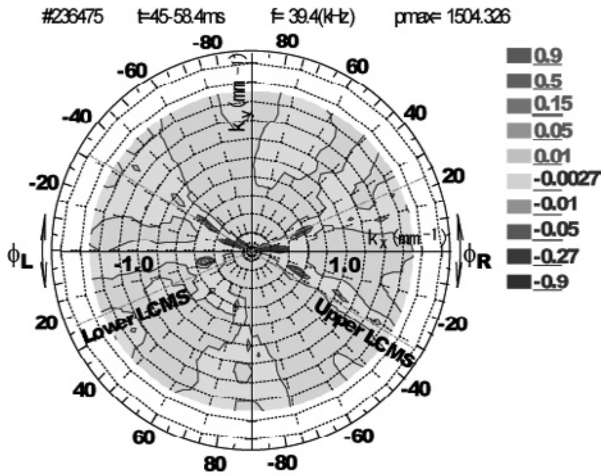

Fig. 2 Example of analytical results on spatial spectrum under polar coordinate MEM The contours are more clearly defined than in the FT.

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