§13. Numerical Diagnostics of Gyrokinetic Turbulent Transport Simulations in Helical Plasmas

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Recently, simulation studies of plasma turbulence in three-dimensional magnetically confined system show important aspects of plasma turbulences. Quantitative comparisons between the simulations and the experimental results have been strongly demanded. We have performed numerical diagnostics using gyrokinetic turbulence simulation data in helical plasmas. In this report, we show the turbulence analysis results by the numerical diagnostics with simulated two-dimensional phase contrast imaging method [1)].

There exists a lot of plasma turbulence codes developed for the simulations in experimental magnetic configurations. The GKV-X code, which is a local flux-tube gyrokinetic Vlasov code, has been developed for quantitative comparisons with experiments in three-dimensional systems [2)]. One of the ways for the comparison is by analyzing the various simulation data with the routines to give same diagnostics. The turbulence diagnostic simulator[3)] is a combination of turbulence codes, measurement modules such as a heavy ion beam probe and phase contrast imaging, and analysis routines, to carry out numerical experiments of plasma turbulence, which can be utilized as the platform of the data analyses. The turbulence diagnostics are carried out with data from the gyrokinetic simulations in Large Helical Device (LHD) by using the diagnostic simulator.

In the three-dimensional equilibrium corresponding to the LHD experiment with high-ion temperature, the flux-tube gyrokinetic simulations of turbulent transport driven ion temperature gradient have been carried out with the GKV-X code. Quantitative comparison of the thermal diffusivity coefficient has shown the good agreement with experiments[4)]. We should compare other turbulent characteristics such as the turbulent spectrum with the experimental results for the validation of the simulation study. We develop an analysis routine for the GKV-X data, taking into account of the line of sight of the experimental diagnostics used in the phase contrast imaging (Fig. 1). Since the GKV-X code employs the magnetic surface coordinate, it is necessary to interpolate the simulation data for evaluating the physical quantities in the real coordinate space. Therefore, the spatial resolutions in the diagnostic simulator are limited by those of the simulation, $\delta r \sim 0.4$[mm] and $\delta\phi \sim 50$[mm]. For the two-dimensional spectrum analysis of density perturbation, the profiles are obtained, and efficiency of the method to resolve the local spectrum is tested. The obtained signal by the phase contrast imaging is integrated along the line of the sight. Assuming the parallel wavenumber $k_\parallel = 0$, the typical k direction (k_y/k_x) can be set, corresponding to the magnetic field direction. The magnetic field direction changes with the variation of the magnetic field in the vertical direction, which can use for the reconstruction in helical plasmas. The extracted component is dominant in the certain vertical position. For the other positions, the contributions are not negligible due to a finite width in the local k spectrum. In this way, the wavenumber spectrum of the turbulence fluctuations taking account of the line of sight of the phase contrast imaging have been obtained for the comparison[5)].

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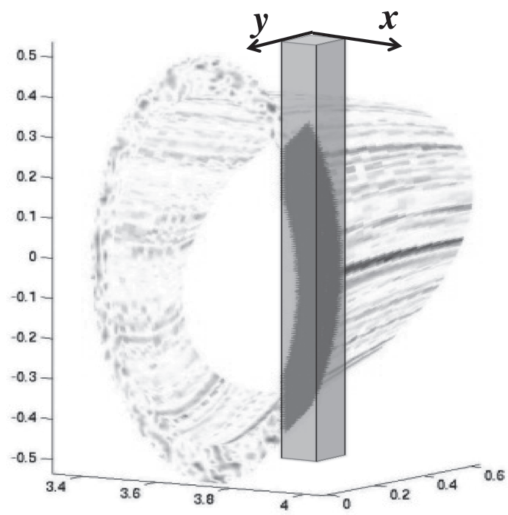

Fig. 1: The illustration for the phase contrast imaging in the turbulence diagnostic simulator. The spectrum of the turbulence fluctuation is evaluated in the elongated rectangular region along the line of sight of the phase contrast imaging.

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4) M. Nunami, *et al.*, Phys. Plasmas **19**, 042504 (2012).

5) N. Kasuya, *et al.*, JPS annual meeting, Sendai (2016) 21pAE-5.