8th Asia-Pacific Conference on Plasma Physics, 3-8 Nov, 2024 at Malacca

Saturation of parametric instabilities with a non-resonant daughter wave in RF H&CD scenarios

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Parametric Instability(PI) is one of the most important nonlinear wave-wave interaction in plasma physics, it can result in significant power loss in RF-plasma interactions. However, the saturation process of PI in magnetized plasmas, which is necessary for evaluating PI's effects in RF H&CD scenarios, is still unclear since most of the PIs occurred in such scenarios involve a non-resonant quasi-mode. Previous literature[1] on the saturation process of PI need the linear dispersion relation of each daughter wave to evaluate the saturation mechanism of plasma inhomogeneity, namely

$$\kappa = \Delta k_L - \Delta k_1 - \Delta k_0$$

Where κ is the wavenumber mismatch caused by plasma inhomogeneity, and footnotes $0,1,L$ interpret the pump wave and 2 daughter waves. In a quasi-mode PI, the wavenumber variation of the low-frequency quasi-mode Δk_L cannot be directly acquired by the linear dispersion relation, thus leads to difficulties when we need to analyze the saturation process and its effects on the efficiency of RF H&CD of such quasi-mode PI. Therefore, subsequent studies on the effect of PI in RF H&CD scenarios usually apply the finite pump profile as the only mechanism of saturation[2], which may results in an overestimation.

To solve this problem, we derived a new method to analyze the saturation process of quasi-mode parametric instabilities[3]. We used the spatial gradient of dielectric function to replace the wavenumber mismatch to evaluate the effects of plasma inhomogeneity, and acquired a unified model of both resonant and quasi-mode parametric instabilities. The amplification factor of a quasi-mode parametric instability in an inhomogeneous plasma with a finite pump profile is calculated using such method, and the effect of quasi-mode PI on the efficiency of typical RF H&CD scenarios is evaluated. we find that the finite pump profile will be the dominant saturation mechanism for most of the typical quasi-mode parametric instability scenarios.

References

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