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

Effects of plasma nonuniformity on toroidal Alfvén eigenmode nonlinear decay

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In magnetically confined fusion plasmas, shear Alfvén waves (SAWs) can be resonantly excited by energetic particles (EPs), and in turn, induce EP anomalous transport loss across magnetic surfaces, resulting in plasma performance degradation and possibly damage of plasma facing components. With the EP anomalous transport rate determined by the amplitude and spectrum of the electromagnetic perturbations induced by the SAW instabilities, Refs. [1,2] investigated the nonlinear saturation of toroidal Alfvén eigenmode (TAE) via ion induced scattering and obtained the saturation spectrum for TAE and the corresponding EP transport coefficient. Lately, Ref. [3] demonstrated that the plasma nonuniformity can change the parametric decay of kinetic Alfvén waves (KAWs) both qualitatively and quantitatively. This suggests to include the plasma nonuniformity in the parametric decay of TAE and investigate the potential effects.

In this work, the parametric decay of a pump TAE (into a sideband TAE and drift sound wave) in nonuniform plasmas is investigated using nonlinear gyrokinetic equation, as a starting point for further analysis of TAE cascading and final saturation. It is found that, the plasma nonuniformity not only significantly enhances the nonlinear coupling cross-section, but also qualitatively modifies the decay process. Specifically, the condition for spontaneous decay becomes the toroidal mode number of the sideband TAE being higher than that of the pump TAE, instead of the frequency of the sideband TAE being lower than the pump TAE in uniform plasmas, as shown in figure 1. The consequences on TAE saturation and energetic particle transport are also discussed.

References
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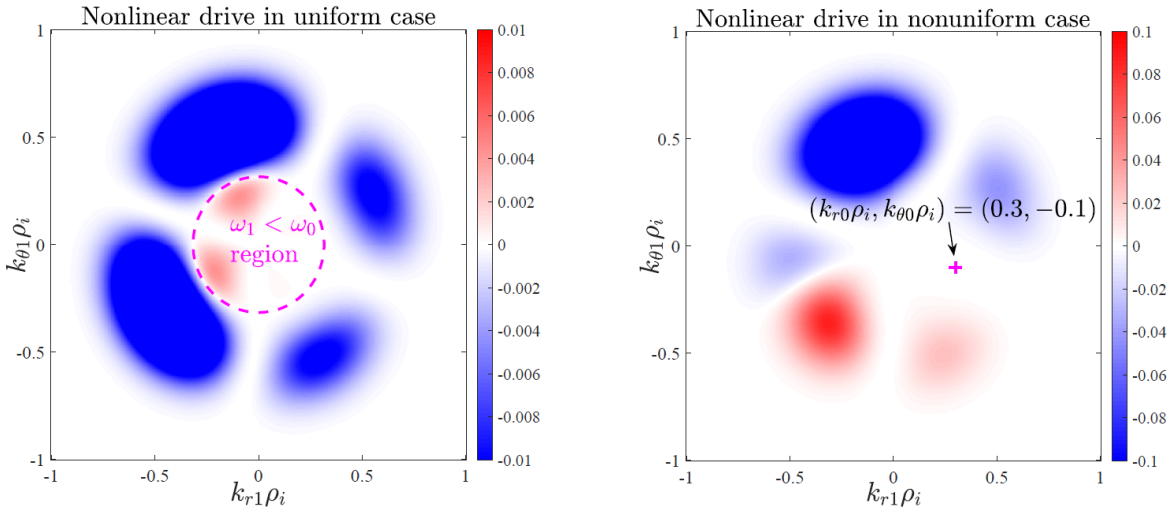

Figure 1. Contour plot of the nonlinear drives in uniform (left) and nonuniform (right) plasmas, with the subscripts 0,1 denoting the pump and sideband TAE respectively. By comparison, one can tell that the nonlinear coupling cross-section is significantly enhanced and the spontaneous decay condition changes from frequency downward decay to the upward decay of toroidal mode number, noting $k_\theta \simeq -nq/r$.