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Linear and nonlinear KAW physics in cylindrical plasmas

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Kinetic Alfvén Waves (KAW) [1-3] are ubiquitously generated in magnetized space and laboratory plasmas due to the existence of the continuous spectrum of shear Alfvén waves (SAW), with the corresponding spatial phase mixing and resonant absorption [4-8]. Unlike SAW, KAW are characterized by microscale perpendicular structures, of the order of the thermal ion Larmor radius, which are responsible of the transverse (to the ambient magnetic field) propagation of wave packets as well as the finite parallel electric field. Furthermore, these features have important consequences on heating, acceleration and transport processes connected with KAW [3].

Historically, KAW generation by mode conversion of SAW in laboratory plasmas and their absorption has been investigated with emphasis on plasma heating [9-12]. The mode converted KAW are typically strongly damped/absorbed by thermal electrons right after SAW mode conversion, and spatially localized near the SAW resonant absorption layer. This also has strong impact on the corresponding nonlinear processes [10].

In this work [13], we will focus on the opposite limit; i.e., when the mode converted KAW are weakly absorbed in a periodic magnetized plasma cylinder. In particular, we show that KAW may be excited as resonant cavity modes in the region between the magnetic axis and the resonant absorption layer of SAW generated externally by an antenna launcher. In this way, large amplitude KAW may be generated time asymptotically, despite the relatively small coupled antenna power. This case has little relevance for plasma heating, but these large amplitude KAW have interesting nonlinear implications for the plasma equilibrium. In particular, we demonstrate that KAW may generate convective cells by modulational instability as shown in [14]. Taking a “theta pinch” as paradigm example for maximizing the nonlinear coupling and minimizing electron Landau damping of the mode converted KAW, we analyze the nonlinear excitation of convective cells and the spatial dependence of the modulational instability growth rate. An important consequence of plasma nonuniformity is the poloidal symmetry breaking due to plasma diamagnetic effects, which cause convective cells to have a finite frequency [15] and not to be simply exponentially growing. Meanwhile, the modulational instability growth rate is enhanced [15] over the corresponding uniform plasma limit [14]. The possibility of controlling convective cell generation in a magnetized plasma cylinder and the corresponding parallel electric field generation will be discussed.

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