Explanation of anomalous backscattering and absorption in second harmonic ECRH experiments by low-threshold two plasmon decay

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Electron cyclotron resonance heating (ECRH) and current drive is widely used in toroidal plasmas and is considered for application in ITER for heating and neoclassical tearing mode control. The parametric decay instabilities (PDIs), which can accompany the ECRH experiments, are believed to be deeply suppressed by huge energy loss of daughter waves from the decay region, according to the predictions of theory developed in 80th under the assumption of a monotonous density profile [1]. However, during the last decade many experiments have demonstrated excitation of the anomalous nonlinear phenomena in the ECRH experiments at TEXTOR, TCV, TJ-II, ASDEX-U, LHD and FTU. The clearest evidence of the nonlinear effect was obtained at TEXTOR [2, 3] where the strong backscattering signal down–shifted in frequency and amplitude modulated by the magnetic island was observed. A convincing demonstration of the anomalous ion heating during the ECRH pulse under conditions when the energy exchange between the ion and electron components is negligible was obtained at TCV [4].

In the present talk we introduce a theoretical model taking into account, as distinct from the standard theory [1], the presence of a non-monotonous density profile, which always exist on the discharge axis or may be present due to the magnetic island or the density pump-out effect. We interpret the generation of backscattering signal and the anomalous ion heating as a result of secondary nonlinear processes that accompany a primary low – threshold two – upper hybrid (UH) – plasmon PDI of the pump X wave. The threshold of the primary PDI is shown [5] to be smaller than the one predicted in [1] due to the UH wave 3D trapping in the presence of the non-monotonous density profile and the finite-size pump beam. The primary PDI growth enhancing the UH wave fluctuations from the thermal noise level is saturated in our theory due to both the secondary decays of the daughter UH wave, that leads to excitation of the secondary UH and ion Bernstein (IB) waves [6], and the pump wave depletion. The threshold of this spontaneous parametric frequency down-conversion can be easily overcome for the secondary radially trapped UH wave. The coupling of different daughter UH waves is responsible in the theory for generation of the backscattered X wave. This mechanism appears capable of reproducing the fine details of the frequency spectrum of the anomalously reflected X wave and the absolute value of the observed backscattering signal at TEXTOR. It also predicts substantial anomalous absorption in the electron channel and explains the anomalous ion heating at TCV by the generation of the secondary IB waves which directly transfer the pump power to the ion component.

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