Strong anomalous absorption in second harmonic ECRH experiments due to low-threshold parametric decay instabilities and its consequences

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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. According to the predictions of theory developed in 80th the parametric decay instabilities (PDIs), which can accompany the ECRH experiments, were believed to be deeply suppressed by huge energy loss of daughter waves from the decay region. However, during the last decade many experiments have demonstrated excitation of the anomalous nonlinear phenomena in the ECRH experiments at TEXTOR, TCV, ASDEX-UG, TJ-II, LHD, L2-M, W-7X and FTU. The clearest evidence of the nonlinear effect was obtained at TEXTOR where the strong backscattering signal down–shifted in frequency and amplitude modulated by the magnetic island was observed. At ASDEX-UG recently emission of the half harmonic of the pump wave was observed in addition in such a situation. 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 and TJ-II. Besides this a substantial broadening of the power deposition profile was reported at T-10 in the second harmonic ECRH experiment.

In the present talk we present a review of experimental observations and develop a theoretical model taking into account, as distinct from the standard theory, the presence of a non-monotonous density profile, which always exist on the discharge axis or may be present due to the magnetic island, the density pump-out effect or ELM filaments. 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 primary PDI growth enhancing the UH wave fluctuations from the thermal noise level is saturated in our model due to both the secondary decays of the daughter UH wave that leads to excitation of the secondary UH and ion Bernstein (IB) waves 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 model for generation of the backscattered X wave, whereas emission of non-trapped UH waves and their coupling to the pump lead to generation of the pump-wave frequency sub-harmonics. 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. It also predicts substantial anomalous absorption in the range of 10% - 70% in the electron channel, which could be responsible for the broadening of the ECRH profile, 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. Results of theoretical analysis of anomalous absorption in the L-2M and W-7X stellarators where broadening of the power deposition profile and anomalous backscattering were observed will be presented in the talk.

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