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POSSIBLE WAYS TO SUPPRESS ANOMALOUS ABSORPTION AT ECRH

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ABSTRACT

Possible approaches to reduce the anomalous absorption rate associated with the low power-threshold two-upper hybrid (UH)-plasmon parametric decay instability (PDI), which is excited by an extraordinary pump wave in X2 ECRH experiments in the vicinity of the local maximum of the plasma density profile, are analyzed. A universal case of only one trapped upper hybrid wave is considered as well as the case of two trapped UH waves leading to the strongest PDI. It is shown that because of a rather low power-threshold for this instability, its complete suppression in ECRH experiments with MW microwave beams is hardly possible. However, it is demonstrated that increasing the pump beam radius allows reducing the related anomalous absorption rate.

Electron Cyclotron Resonance Heating

Powerful microwave generators - gyrotrons - are available on the market

According to fixed theoretical notion:

The power absorption should be well-localized $\delta R \propto \frac{T_e}{m_e c^2} R$

The power absorption should be very effective in hot plasma of large fusion devices $\Gamma >> 1$ at $T_e \geq 1$ keV and $R > 1$ m

Based on the proposed three-wave interaction model (Piliya & Rosenbluth) the most dangerous scenarios of microwave decay were analyzed (Cohen 1991). Their power thresholds were found to exceed drastically the power of current and future gyrotrons.

The method is planned for application in ITER to control the neoclassical tearing mode and to heat plasma.

Recent unexpected observation of anomalous phenomena

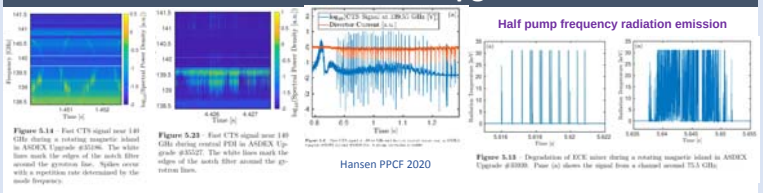
Plasma emission with frequencies shifted with respect to the gyrotron frequency (TEXTOR, ASDEX-UG, W-7X)

Ion acceleration (TJ-II, TCV)

Power deposition profile broadening&non-local transport(T-10,TJ-II, LHD)

All these anomalous effects were observed in the presence of a ***nonmonotonic*** density profile arising due to the presence of a magnetic island, a pump-out effect, blobs and streamers at a plasma edge and in the centre of a plasma column

Parametric Decay Instabilities (PDI) with Rotating Magnetic Islands, near the Plasma Center and in Connection with Edge Localized Modes at ECRH in ASDEX-Upgrade



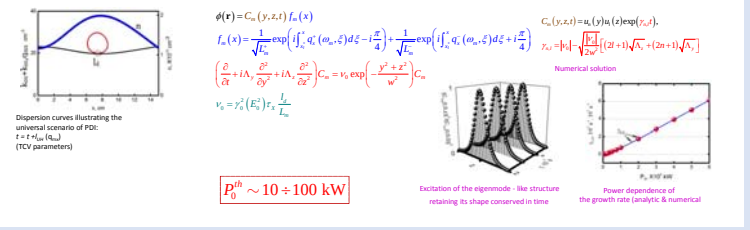
CHALLENGES

Physical reasons and consequences of anomalous effects at a low pump power:

- Anomalous phenomena can be interpreted as a result of low power-threshold parametric excitation of trapped daughter waves.
- Low threshold excitation of PDI is due to the suppression of daughter wave convective losses in the direction of plasma inhomogeneity because of a non-monotonic density profile. The absolute PDI is excited due to localization of daughter waves on a magnetic surface caused by a powerful microwave beam of finite width.
- The most effective PDI scenario is related to the parametric excitation of trapped upper hybrid (UH) waves:
- A more universal PDI: $t = t + l_{UH}$ in which only one trapped UH wave is excited.
- The strongest PDI: $t = l_{UH} + l_{UH}$ in which two trapped UH waves are excited.
- Typical thresholds for different experiments: 40 kW - 300 kW
- Theoretically predicted anomalous absorption rate: 10% - 80%

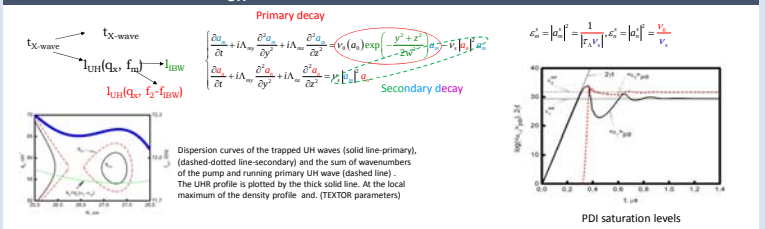
❑ Not realistic to suppress completely in MW – range ECRH experiments, but possible to reduce the anomalous absorption rate.

Growth rate and threshold of $t = t + l_{UH}$ PDI

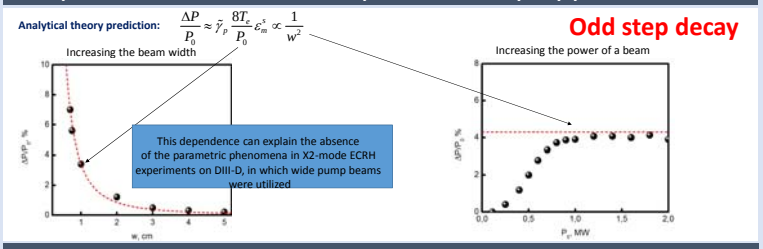


$P_0^{th} \sim 10 \div 100$ kW

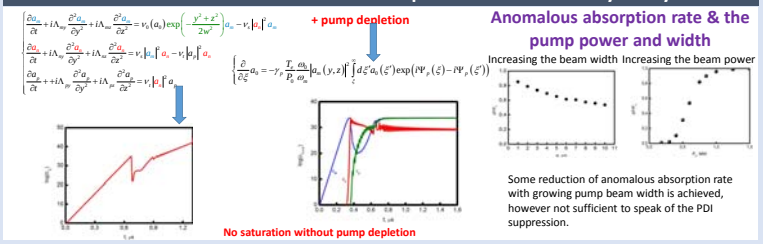
Saturation of t = t + l_{UH} PDI due to odd-step cascade of secondary decays



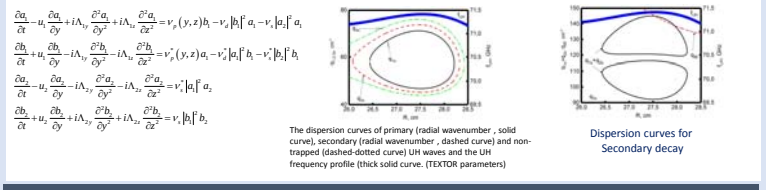
Dependence of the anomalous absorption rate on the pump power and width



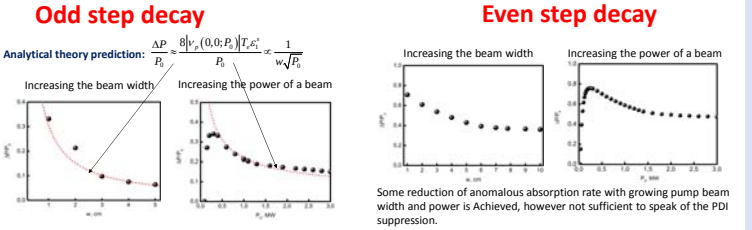
PDI saturation in the case of even-step cascade of secondary decays



Saturation of t = l_{UH} + l_{UH} PDI due to odd-step cascade of secondary decays



Dependence of the anomalous absorption rate on the pump power and width



CONCLUSION

- The low-power-threshold parametric decay instabilities responsible for anomalous phenomena routinely observed in ECRH experiments at tokamaks and stellarators in the presence of non-monotonous plasma density profile are leading to substantial anomalous absorption of the microwave power (10% – 80%)
- The anomalous absorption in the range of 10%-80 % is possessing a potential to explain the evident broadening of pump wave power deposition profile in ECRH experiments.
- It is shown that the growth of the pump beam radius, leading to decrease of the two-UH plasmon parametric decay instability power-threshold, is able to reduce substantially the anomalous absorption rate caused by this instability.