Inverse sawtooth-like activities in central J-TEXT plasmas with impurity injection

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Introduction: It is thought that sawtooth plays an important role in plasma confinement as well as controlling helium ash and impurities in the central region and ELMs at the plasma edge. It's found that sawtooth leads to the increase of central impurity transport and redistribution of impurity profile on tokamaks such as JET[1], Alcator-C[2],PB-X[3]. TEXTOR-94[4] as well as theoretical models[5]. In experiments , sawtooth usually broaden the impurity profile, but in some cases it makes impurity even more hollow. It depends on the initial distribution of impurity and the location of the q=1 surface[5]. Contrary to normal sawtooth in central plasmas, short- and long-time lasting inverse sawtooth-like activities have been observed in central J-TEXT plasmas with Ne gas impurity injection using gas puffing and Super-sonic Molecular Beam Injection (SMBI). In such discharges, it's found that the inverse sawtooth-like activities spread from q=1 surface to the center with the increase of electron density. Especially, strong m/n=1/1 mode exists on the inverse sawtooth-like activities around the q=1 surface. Besides, the occurrence of this phenomenon has relation with the amount of injected Ne and electron density. It will occur when the amount of Ne and electron density exceed a threshold.

Description of the experiments:

J-TEXT is a conventional tokamak with an iron core. It has a major radius R = 105 cm, and minor radius r = 25–29 cm with a movable titanium-carbide-coated graphite limiter[7]. The SXR imaging system consists of eight pinhole cameras which cover 128 channels that scan the main part of the plasma ($r/a \approx 0.7$) at the same toroidal location. The SXRs measure line integrated total radiation power in the photon energy above 1 keV. The total radiation detected by SXRs contains bremsstrahlung, recombination radiation as well as line radiation, which are determined by the profile of electron density ,electron temperature , Zeff and ionization state of all species.

Inverse sawtooth-like activities with species of impurity

Noble gas such as He, Ne and Ar injection experiments have been done during sawtooth discharge by gas puffing and SMBI. In these experiments, inverse sawtooth-like activities in central plasmas have been found on SXRs when Ne gas was injected by gas puffing and SMBI, which is different from the normal sawtooth on SXRs before. However, such phenomenon doesn't occur during He as well as Ar injection experiments. It means that the inverse sawtooth-like activities just have relation to the Ne impurities.

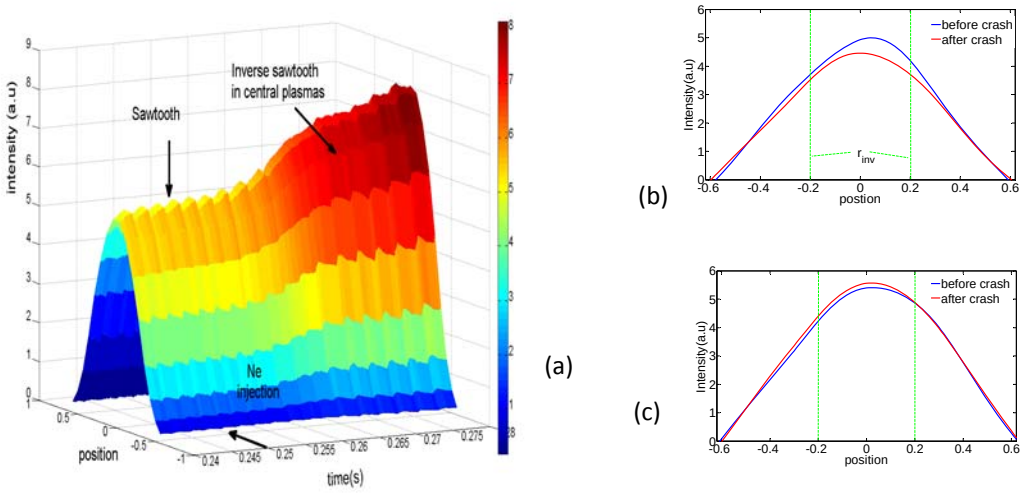

Figure 1. (a)Time evolution of SXR profile(line integrals, time averaged over40ms) for sawtooth discharge with Ne injection. The strong increase of radiation is due to the rise of n_e. The inverse sawtooth-like activities on central channels follow the increase of radiation;(b)、 (c) profiles before and after crash of SXR for sawtooth (b)and inverse sawtooth-like activities(c), the position is the normalized radius.

Figure 1 (a) shows a change from normal sawteeth to inverse sawtooth-like activities on central SXRs channels until 10 milliseconds after Ne impurities are injected. Figure 1(b) and (c) show the SXR profiles before and after a sawtooth crash and an inverse sawtooth-like crash. The peaked profiles during inverse sawtooth-like crash is different from the hollow profiles on ASDEX Upgrade[7].SXR in the central plasmas increase during a sawtooth crash but increase with an inverse sawtooth-like crash.

Inverse sawtooth-like activities with the amount of Ne and electron density

It's found that the inverse sawtooth-like activities have relation to the Ne impurity. In order to understand the phenomenon, further experiments have been done by modulating the amount of the Ne with gas puffing and SMBI. Figure 2 shows the result with different plasma current , in which the partial inverse sawtooth means that the SXRs close to the magnetic axis are still

normal sawtooth , but the SXRs near the q=1 surface change from normal sawtooth to inverse sawtooth. In gas puffing experiments, the Ne gas is injected into plasma by gas puffing valve which is controlled by voltage and pulse duration.

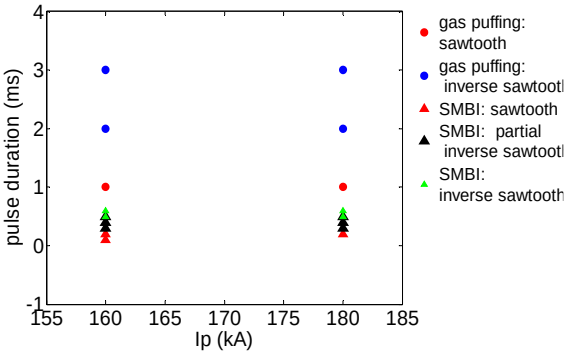

Figure 2. Inverse sawtooth-like activities with the amount of Ne injection.

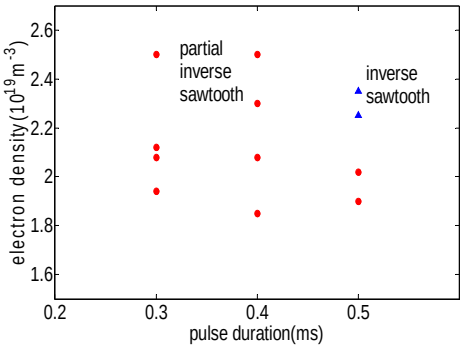

Figure 3. Inverse sawtooth-like activities with electron density by SMBI

The figure 2 also shows that when pulse duration exceeds 2ms , the sawtooth in central plasmas on all SXRs change to inverse sawtooth-like activities. In SMBI experiments, the amount of Ne injected into plasmas is in connection with the pressure of Ne as well as the pulse duration. Besides, figure 2 shows three types of phenomenon in SMBI experiments : Firstly ,when pulse duration is equal or less than 0.2 ms, the sawteeth on SXRs don't change; Secondly, when pulse duration is larger than 0.2 but equal or less than 0.5ms , the sawteeth activities in central plasmas change to partial inverse sawtooth-like activities; Finally, when pulse duration is larger than 0.5ms, the sawteeth activities in central plasmas change to totally inverse sawtooth-like activities. However, there is an exception when the pulse duration is 0.5ms, it's totally inverse sawtooth-like activities in central plasmas. In this condition, the electron density plays an important role. Figure 3 shows that when the SMBI pulse duration is 0.5ms, the totally inverse sawtooth-like activities will occur at larger plasma density.

m/n=1/1 mode superimposed on inverse sawtooth-like activities

It's often found that m/n=1/1 mode about 4.5kHz is superimposed on inverse sawtooth-like activities, which is different from the precursor oscillation before normal sawtooth crash. It means that the q=1 surface exists during the inverse sawtooth-like activities. For this kind of m/n=1/1 mode occurs after the inverse sawtooth crash, it may have relation with postcursor oscillation.

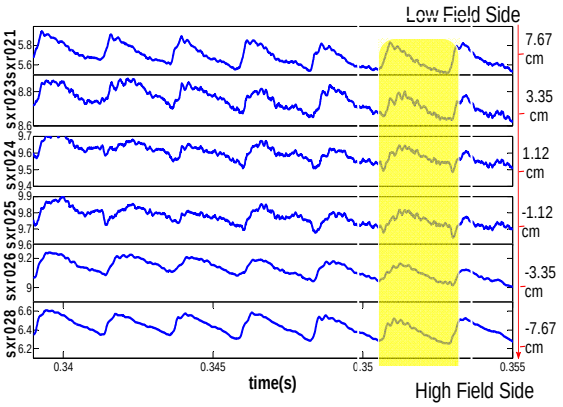

Figure 4. Inverse sawtooth-like activities on central SXRs channels

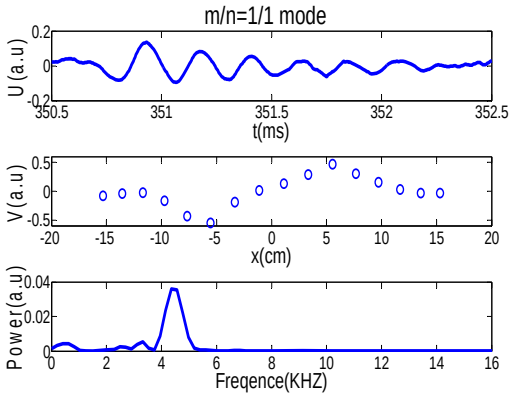

Figure5. SVD analysis of yellow area on Figure4. Tempora(U), spatial(V) eigenvectors and frequency of m=1mode on inverse sawtooth-like activities

Conclusion

Inverse sawtooth-like activities in central plasmas with Ne impurity injection have been found on J-TEXT. Lots of experiments have revealed that it has relation with Ne impurity, electron density as well as 1/1 mode. However, the mechanism is still unresolved. In the future, more characteristics of the q=1 modes will be further investigated. Their concurrence with respect to the Ne injection as well as other plasma parameters especially the T_e will also be analyzed.

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