First demonstration of sawtooth pacing using modulated ICRH on TEXTOR

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Until recently, sawtooth activity was considered a non-desirable by-product of efficient heating of tokamak plasmas. The potential of MHD-activity such as sawteeth and ELMs to avoid impurity accumulation has however shown that their presence can also be used to our advantage.

It was shown earlier on TCV using modulated ECRH power [1] that sawtooth can be triggered by sudden crashes in the ECRH power when modulating the power. Whereas TCV demonstrated the possibility to do sawtooth pacing using an electron heating scheme, sawtooth-locking often observed in ICRH power modulation experiments suggests that ICRH can force sawtooth crashes as well. Recent ICRF experiments in JET showed indeed that switching off ICRH in JET also triggers sawteeth, thus being a strong indication that an ion heating scheme could be equally effective (and possibly more relevant for fusion devices).

In plasmas on TEXTOR (R0 = 1.75m, a = 0.46m) at Bt = 1.9 T and Ip = 400kA, H minority fundamental cyclotron heating in a D plasma was used to reach high single pass absorption (80-100%), at H concentrations between 10-20%. ICRH heating at 29 MHz (resonance on axis) and power levels between 1-2 MW was used combined with 0.6-1.2 MW of D0 co-NBI at an acceleration voltage of 50 keV. Using modulated ICRH power (typically 50-80% modulation depth with frequencies between 20 and 50 Hz) at plasma densities of about 2x1019 m⁻³ it was observed that the sawtooth frequency tunes in to the modulation frequency provided the natural sawtooth frequency is lower than the frequency at which the power is modulated. At higher densities, lower ICRH power compared to the total power and lower modulation depth, the effect was no longer observed. In agreement with [2] a phase-lag between the sawtooth crashes and the ICRF power drop is observed. Theory predicts that the presence of a fast particle population in D(H) minority heated plasmas under such conditions is responsible for influencing the sawtooth behavior.

This is the first demonstration that sawteeth can be triggered using modulated ICRH and shows that ICRH has the same potential as ECRH for triggering sawteeth. Further experiments to explore the potential of this method as a function of device size are planned in coming experimental campaigns on JET.