Contribution ID: **27** Type: **Invited (Plenary Session)**

Modification of Alfvén Eigenmode Drive and Nonlinear Saturation Through Variation of Beam Modulation in DIII-D

Tuesday, 3 September 2019 10:05 (35 minutes)

Recent DIII-D experiments show that small variations in neutral beam modulation period, even with constant time averaged power input, can have a dramatic impact on the beam driven Alfven eigenmode spectrum and resultant fast ion transport. Neutral beam modulation is a common technique used in fusion experiments for regulation of injected power and various diagnostic applications, however, the period is often chosen arbitrarily or to accommodate hardware constraints without regard for the physics implications. When one beam is temporarily turned off or replaced by an unlike beam (different geometry or injection voltage), a bump-on-tail like distribution in velocity space is transiently created that can provide free energy for instability drive. The persistence of the bump-on-tail feature depends on, among other things, the modulation period. Continuous modulation which is fast compared to the slowing down time creates a more persistent velocity space inversion while slow modulation transiently creates a bump-on-tail associated with each beam pulse before filling in. For heating scenarios where different modulated beams are interleaved, the time-dependent mix also depends heavily on the modulation period. The dependence of the unstable AE spectrum on these effects is investigated in the current ramp phase of DIII-D discharges by varying beam modulation periods in a sequence of discharges with interleaved tangential and perpendicular beams. Imaging neutral particle analyzer (INPA) measurements confirm a persistent bump-on-tail feature for short modulation period. As the modulation period is incrementally increased from 7 ms to CW, the underlying mode spectrum changes from steady toroidicity induced Alfven eigenmodes (TAEs) at large radius and reversed shear Alfven eigenmodes (RSAEs) at mid-radius to modulated TAEs at large radius and a spectrum of chirping beta induced Alfven eigenmodes (BAEs) at mid-radius. The mode induced neutron deficit is also observed to decrease as modulation period is increased. In addition, for longer modulation periods, individual TAEs are found to be unstable at each tangential beam pulse with instability setting in at increasingly higher values of local fast ion density as the minimum safety factor decreases –an effect explained by reduced coupling to side-band resonances. Further, while the individual TAE frequencies are relatively constant, the saturated mode amplitudes exhibit up to 75% variation on timescales of ˜10-100 mode periods. For scenarios in which maximum beam power is not required, these results indicate that fine-scale tailoring of beam modulation and interleaving may offer additional opportunities for instability control.

*Supported by the US DOE under DE-FC02-04ER54698

Country or International Organization

United States

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Session Classification: Plenary

Track Classification: Control of Energetic Particle Confinement