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[1]University of Wisconsin-Madison, Madison, Wisconsin
[2]EURATOM/CCFE Fusion Association, Culham Sci. Centre, Abingdon, UK
[3]University of California-San Diego, La Jolla, California
[4]Lawrence Livermore National Laboratory, Livermore, California
[5]Oak Ridge National Laboratory, Oak Ridge, Tennessee

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Measurements of long wavelength density fluctuations in the pedestal region of DIII-D plasmas have revealed several important features of edge instabilities during type I ELMing and ELM-free discharges. These features, measured with a 2D array of beam emission spectroscopy (BES) channels, include: toroidal and spatial dependence of two distinct frequency bands of density fluctuations modulated with the ELM cycle; high frequency coherent (HFC) modes observed during high electron pressure gradient Quiescent H-mode (QH) plasmas exhibit long poloidal scale length and very short auto-correlation times, similar to characteristics expected of kinetic ballooning modes (KBM); and edge and core turbulence increases dramatically in plasmas for which ELMs are stabilized via application of an *n*=3 resonant magnetic perturbation. These observations provide key insights into the underlying turbulence and instability properties that limit pedestal height and width, and will help develop a predictive model for pedestal height, which is key to core plasma performance.

The long wavelength density fluctuations are measured using a 2D array of BES channels at $0.9 < r/a < 1$ during a ρ* scan while other non-dimensional parameters are held constant [1]. As shown in Fig. 1 two distinct bands of density fluctuations are observed propagating in opposite poloidal directions with the lower frequency band (50 k to 150 kHz) propagating in the ion diamagnetic direction (positive cross phase) and higher frequency band (200 k to 400 kHz) propagating in the electron diamagnetic direction (negative cross phase). These two-band structures are more prominent at higher toroidal field. They are modulated with ELM cycle and located in the region of maximum pedestal pressure gradient. It suggests that there are different underlying instabilities in the pedestal region. As also shown in Fig. 1, the density fluctuations saturate rapidly (~ a few ms) after an ELM crash at high toroidal field but more slowly (~10 ms) at low toroidal field. This is similar to the temporal behavior of the pedestal pressure gradient. The normalized density fluctuation powers scale inversely with toroidal field, but the structure of the lower frequency band turbulence (radial and poloidal correlation length) has a weak dependence on the toroidal field. This is consistent with the observation that the pedestal width has little dependence on the ρ* [1].

In high electron pedestal pressure QH mode discharges a set of HFC modes peaking around 150 kHz with a uniform frequency separation of 8 kHz are observed in the pedestal region [Fig. 2(a)]. The amplitude peaks just inside the separatrix. The edge harmonic oscillation (EHO) disappears when these HFC modes appear. The appearance of the HFC modes coincides with the saturation of the pedestal pressure [Fig. 2(b)]. There are a few widely space discrete ELM events [Fig. 2(c)] during the time window of the HFC modes, and it is seen that the ELM transiently

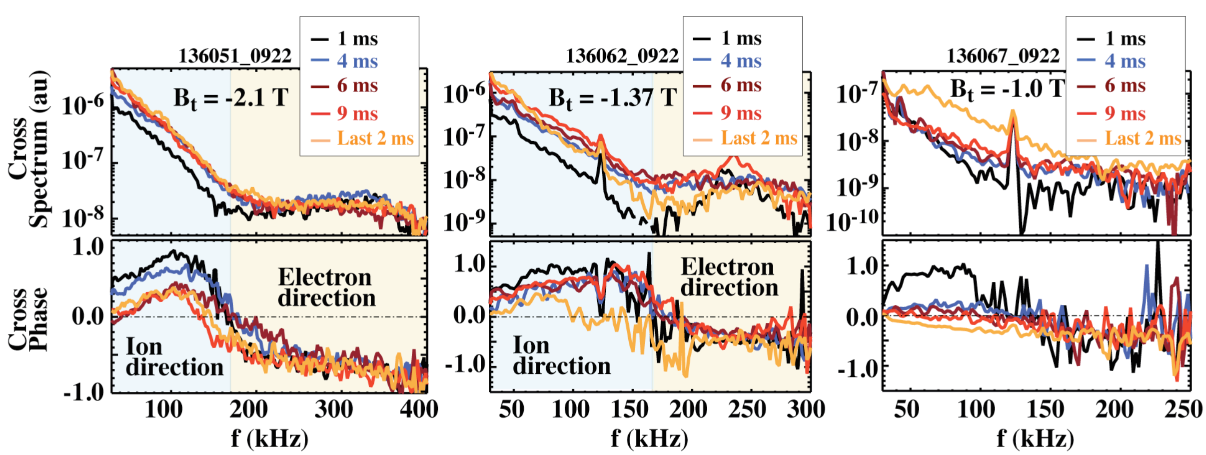

Fig. 1. Pedestal density fluctuation cross spectrum and cross phase (ΔZ = 1.2 cm) for different times relative to an ELM crash at three values of toroidal field at *r/a*~0.95.

suppresses the HFC modes and reduces the pedestal pressure. Between ELMs, HFC modes increase in amplitude along with the pedestal pressure. These HFC modes have several features that are expected for KBM, which are predicted to limit the pedestal pressure gradient: long poloidal scale length (somewhat larger than ITG modes) and very short auto-correlation time (τ_c ~ few μs), with the non-linear decorrelation rate comparable to or exceeding the very high local E×B shearing rates. The toroidal mode number is estimated to be around 20 based on comparison to ELITE [2] mode structures, and the poloidal mode number *m*~100. More theoretical analysis and simulations are being performed to help identify the nature of these HFC modes.

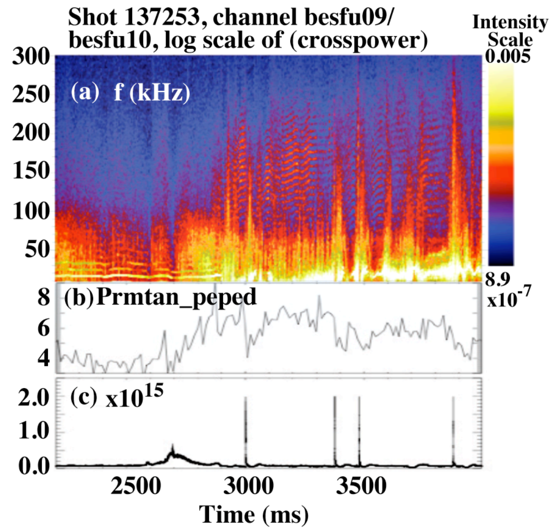

Fig. 2. (a) Cross spectrum between two poloidally separated BES channels showing HFC from ~100-250 kHz starting from time ~2900 ms to 4900 ms; (b) Electron pedestal pressure; (c) Edge D_α light.

Edge and core turbulence is observed to increase dramatically in plasmas for which ELMs are stabilized via application of an *n*=3 resonant magnetic perturbation (RMP), relative to the ELMing phase. Figure 3 compares the radial profile of normalized long-wavelength density fluctuations in the ELMing phase with those during the RMP ELM-suppressed phase. Broadband fluctuations, which extend up to 400 kHz, are enhanced predominantly in the range of 0.6<*r/a*<0.9, with a curious null in the fluctuation enhancement near *r/a*=0.5; particle transport likewise increases dramatically during the RMP ELM-suppressed phase with a significant reduction in density. The fluctuation enhancement commences within 20 ms of RMP application, and is further enhanced during the ELM-suppressed phase. Likewise, when the RMP is turned off, fluctuations are reduced within ~10 ms, before ELMs resume. This behavior suggests that the RMP causes the enhanced turbulence that results in increased particle transport and reduced density, although the complex interplay of density, density gradient, particle transport and rotation make this a highly nonlinear process.

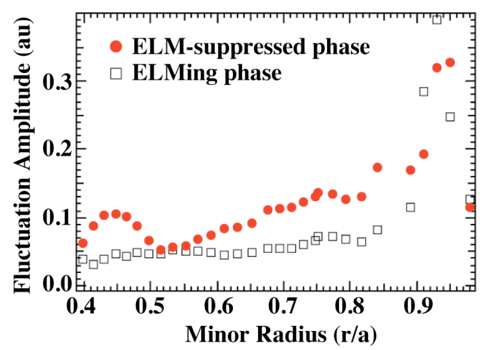

Fig. 3. Comparison of profile of normalized density fluctuation amplitude during RMP ELM-suppressed phase and ELMing phase.

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