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ELM suppression sustained by an edge low-*n* mode excited by divertor impurity seeding in detached H-mode plasmas in EAST

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Simultaneous control of large ELMs and divertor heat load in a metal wall environment is crucial for steady-state operation of a tokamak fusion reactor. A new scenario for ELM suppression compatible with radiative divertor has been demonstrated, for the first time, in the EAST tokamak. An n = 1 mode [Fig. 1(f)] along with its harmonics, initiating from the oscillation of a radiation belt on the high-field side SOL near the X-point [Fig. 1(h)], is excited during impurity seeding with CD_4 in the H-mode plasmas at a sufficiently high impurity concentration. Robust ELM suppression has been achieved with the presence of this mode in a wide q_{95} range (4.5-6.5) and a wide heating power range (with source power up to 9 MW). Along with ELM suppression, partial detachment with target electron temperature T_{et} ~ 10 eV [Fig. 1(d)] have been achieved without degradation of the global energy confinement [Fig.1(c)]. In addition, the active feedback control of either T_{et} or divertor radiation with impurity seeding has been demonstrated in this regime.

This n = 1 mode has been observed only in H-mode and disappears as the heating power decreases down to near the L-H threshold power. Excessive impurity seeding also leads to mode suppression. In addition to CD_4, a similar mode has been observed in EAST with neon, argon, helium, lithium and boron seeding, although the excitation of the mode with neon and argon appears to be more difficult. The mode drives particle transport as evidenced by follows. Firstly, the mode can induce oscillation in the divertor Dα and density [Fig. 1(i-j)]. Secondly, the high-Z impurity concentration is suppressed [Fig. 1(e)], and the estimated W impurity confinement time is < 200 ms (close to the typical ELMy or the EDA H-mode[1] in EAST), which may suggest that sufficient particle transport is driven across the pedestal so that a stationary H-mode can be sustained.

A model based on impurity-radiation-driven drift instability[2] has been developed to explain the excitation mechanism of this n = 1 mode. This instability is destabilized as the local T_e in the radiating region is reduced down to the negative-slope T_e range in the impurity radiation loss function, given sufficiently high impurity concentration [Fig. 2]. This new ELM control scenario appears to be insensitive to impurity species, q_{95}, heating power and plasma toroidal rotation, while being compatible with the divertor detachment, thus offering a promising solution to the control of both ELM-induced transient and steady-state divertor heat loads for long-pulse H-mode operation.

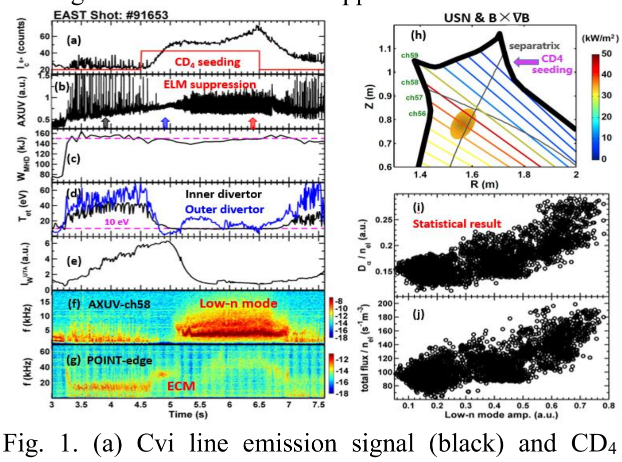

Fig. 1. (a) Cvi line emission signal (black) and CD_4 injection valve voltage (red). (b) Absolute extreme ultraviolet (AXUV) photodiode signal. (c) Plasma stored energy. (d) Electron temperature T_{et} of divertor plate. (e) Tungsten emission intensity from the plasma core. (f-g) edge fluctuation measured by AXUV and polarimeter interferometer. (h) AXUV chords with colors corresponding to radiation power. (i-j) low-n amplitude versus the normalized Dα and total flux.

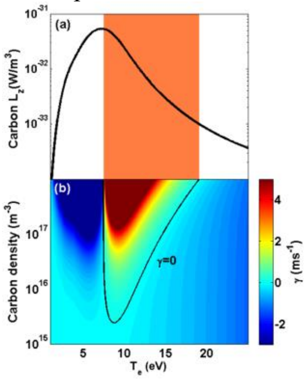

Fig. 2. (a) Radiation loss function for carbon with a negative-slope T_e range. (b) Growth rate of impurity-radiation-driven n = 1 drift instability as a function of electron temperature T_e and Carbon density.

References

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