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ELM Pace-making and Long-pulse ELM-stable H-mode operation with LHCD in EAST

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A new control technique for the edge-localized modes (ELMs) by pace-making with low-hybrid current drive (LHCD) power modulation has been demonstrated, for the first time, in the EAST superconducting tokamak. The achievable pace-making frequency is up to 120Hz, which appears to be limited only by the pedestal recovery time. LHCD leads to the density pump-out and local flattening of the density gradient near the separatrix, associated with the LHCD-induced edge stochastic magnetic region by driving helical current filaments along the magnetic field lines in the scrape-off layer, similar to the effect generated by the RMPs. The density and pressure gradients just inside the stochastic region (near the pedestal top) are steepened, which destabilizes the ELMs. High pedestal and good global energy confinement have been achieved due to the expansion of ballooning boundary with increasing pedestal width and the shift of peak gradient region radially inward. The triggered ELMs are mostly small ELMs since the ELM collapses occur mainly in the steep gradient region near the pedestal top. In addition, a stationary ELM-stable H-mode regime has been achieved in EAST with 4.6GHz LHCD. This regime allows near fully non-inductive long-pulse ($20s$) operations, which exhibits relatively high pedestal and good global energy confinement with H_98y2 near 1.2, good impurity control, and capability of operation at relatively high density ($\langle n_e \rangle / n_{GW} \sim 0.5$). The enhanced pedestal height and global energy confinement are the result of an expansion of the ballooning stability boundary brought about by the local flattening of the density gradient near the separatrix, increase of the pedestal width and shift of the peak gradient region radially inward. These profile changes are resulted from the combined effect of LHCD-induced edge plasma ergodization and edge-coherent-mode-induced density pump-out. Such a stationary ELM-stable H-mode regime transitions into a steady small-ELM region with divertor peak heat flux less than $5MW/m^2$, when additional heating power from NBI, ICRF or 2.45GHz LHCD is applied. This small-ELM regime offers a suitable candidate for high-performance steady-state H-mode operations. Nearly fully non-inductive (loop voltage $0.1V$) long-pulse ($20s$) small-ELM H-mode plasmas have been achieved with bootstrap current fraction of ~ 35

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Primary author: Dr XU, Guosheng (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China)

Co-authors: Dr WAN, Baonian (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China); Dr LI, Guoqiang (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China); Dr GUO, Houyang (General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA); Dr WANG, Huiqian (General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA); Ms JIA, Manni (Institute of Plasma Physics, Chinese

Academy of Sciences, Hefei 230031, China); Mr WANG, Mao (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China); Mr YANG, Qingquan (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China); Dr OSBORNE, Thomas (General Atomics, PO Box 85608, San Diego, CA 92186-5608, USA); Mr GONG, Xianzu (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China); Mr YE, Yang (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China); Mr WANG, Yifeng (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China); Dr LIANG, Yunfeng (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China)

Presenter: Dr XU, Guosheng (Institute of Plasma Physics, Chinese Academy of Sciences, Hefei 230031, China)

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