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Observation of the ballooning mode that limits the operation space of the high-density super-dense-core plasma in the LHD

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The central beta of the super-dense-core (SDC) plasma in the Large Helical Device (LHD) is limited by a large scale MHD event called “core density collapse” (CDC). It is found that a new type of ballooning mode, quite localized in space and destabilized from the 3D nature of Heliotron devices, is the cause of the CDC. It is the first observation that the ballooning mode is excited where the global magnetic shear is negative.
High-density operation is one possible reactor scenario of helical confinement system. In the SDC type discharges, the electron density higher than 10ˆ21 mˆ-3 with Bt = 2.5 T is achieved in the LHD. The SDC plasma is characterized by the peaked density and pressure profiles. However, the central beta of SDC plasma is strongly limited by the CDC. The ballooning instabilities related with the 3D nature of helical systems, referred to high-n ballooning mode, is considered to be the cause of collapse. In the Heliotron devices, it was predicted that the local magnetic shear can be reduced around the local pressure gradient peak in the global negative magnetic shear region when the Shafranov-shift is large. The ballooning mode is driven by the pressure gradient in the bad curvature region when the local shear is reduced.
Just before the CDC events, pre-cursor oscillations at around 8 kHz have been found only in the outboard side. If the mode structure of the pre-cursor is localized around a flux tube connected to the outboard side of the horizontally elongated section (worst curvature region), two sharp peaks observed in the fluctuation profile can be understood. A newly developed 2D SX detector array reveals that this pre-cursor like movement is aligned to the local magnetic field line.
In order to avoid the CDC for achieving higher central beta, control of the ballooning mode by the reduction of the pressure gradient at the bad curvature region is experimentally performed. In the relatively low magnetic field experiment (Bt = 1.5 T), the pressure profile is broader than the profile with normal magnetic field Bt = 2.5 T. The operational boundary observed in the 2.5 T can be passed over and the central beta has reached about 10% with Bt = 1.5 T. It is the highest central beta achieved in the LHD. Therefore, the mitigation of the high-n ballooning mode is proved to be the key to achieve high central beta in the SDC type operation of the LHD.

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