MF-OV15

1st Asia-Pacific Conference on Plasma Physics, 18-22, 09.2017, Chengdu, China

Attainment of high electron beta and new QSH regime in a low-aspect-ratio Reversed Field Pinch

S. Masamune[1], A. Sanpei[1], H. Himura[1], N. Mizuguchi[2], T. Akiyama[2], T. Mizuuchi[3], K.J. McCollam[4], D.J. Den Hartog[4], R. Paccagnella[5]

[1] Kyoto Institute of Technology., Japan, [2] NIFS, Japan, [3] IAE, Kyoto University, Japan, [4] University of Wisconsin-Madison, USA, [5] Consorzio RFX, Italy

The reversed-field pinch (RFP) is a compact, high-beta magnetic confinement concept. The great advantage of the RFP is that it requires weak external toroidal magnetic field. Recent RFP research has developed two scenarios for confinement improvement: plasma current profile control to suppress the core-resonant dynamo modes, and quasi-single helicity (QSH) scenario which allows only a single dominant mode to grow. In the QSH scenario, magnetic surfaces recover inside the magnetic island associated with the dominant mode.

RELAX is a low-aspect-ratio (A=R/a=0.5m/0.25m) machine to explore geometrical optimization of the RFP configuration. It is operated without a conducting shell, so, the SS vacuum vessel acts as a resistive shell. Typical plasma parameters are n_e~10^{19} m^{-3}, $T_e(0)$~100-200 eV at I_p of 50-100 kA. Recent effort has been put on resistive wall mode (RWM) stabilization and QSH studies in low-A geometry [1]. One of the characteristics of low-A RELAX plasmas is that globally stable RFP plasmas are realized over a wide range in (Θ, F) space where Θ (=B_{pa}/<B_t>) is the pinch parameter and F (=B_{ta}/<B_t>), the field reversal parameter, with poloidal field B_p and toroidal field B_t [2]. RFP plasmas in shallow reversal region (F<0, close to 0) are characterized by transient QSH state as discussed in ref. [3], with helically deformed plasma core from soft-X ray diagnostic and field line trace with ORBIT code. Easy access to QSH is one of the results of low-A geometry.

In deep-reversal region where F around -0.5 and -1.0, axisymmetric RFP with low fluctuation level is realized. It was reported that active feedback stabilization of a single m/n=1/2 mode using toroidal and poloidal saddle coil arrays consisting of 64 saddle coils, the most unstable RWM in RELAX, resulted in longer discharge duration with improved electron poloidal beta β_{pe} (=$2\mu_0 p_{e0}/B_{pa}^2$) [4,5]. The feedback system has been modified to suppress sideband effect arising from poloidal currents at two poloidal gaps in the vacuum vessel; we have used additional independently controlled 6 power supplies for the saddle coils at the 2 poloidal gaps [1]. As a result, the discharge duration has been further improved to the iron-core-saturation-limited longest one. The m=1/n=2 mode amplitude is lowered particularly in the current rise phase due to compensation for the sideband effect by the independent control localized near the gaps. The RFP plasma performance has also been improved; β_{pe}, almost equal to the total electron beta in the RFP configuration, has reached to ~15% from ~10% with previous control system. β_{pe} increases up to ~15% with T_e of 100-200 eV in the normalized-density region n/n_G<0.3, where n_G is the Greenwald density. The achieved electron beta is close to the region where we expect sizable fraction of bootstrap current in A=2 RFP geometry [6]. It is under preparation to perform density and beta limit studies in low-A RFP using additional fueling.

The new finding related with QSH is that the magnetic mode spectrum shows spontaneous transition to and back-transition from QSH even in deep-reversal region with active feedback control of RWM. Figure 1 shows time evolution of the m=1 magnetic modes along with soft-X ray (SXR) emission. The dominant m/n=1/4 mode grows spontaneously with suppression of the remaining modes, typical to QSH. The QSH transition accompanies the enhanced SXR emission in flat-topped current phase, the most prominent case being identified at 1.6-1.8 ms. In the figure, we also show a Poincare plot during the QSH at 1.7 ms. using the ORBIT code, indicating the possibility of formation of helical magnetic axis. The change in magnetic topology in deep reversal discharges may be related with improved axisymmetry of the magnetic boundary brought about by the modified feedback control system. Equilibrium reconstruction implies that the m/n=1/4 mode is internally non-resonant. The observed transition to QSH in deep reversal region may indicate another route of relaxation from axisymmetric to helical RFP state through growth of non-resonant mode, as pointed out in refs. [6,7].

[1] S. Masamune et al., 26th IAEA FEC, EX/P5-22, 2016
[2] R. Ikezoe et al., PPCF, 53, 025003 (2011);
[3] K. Oki et al., Fusion Sci. Technol. 63, 386 (2013).
[4] R. Ueba et al., Plasma Fusion Res. 9, 1302009 (2014);
[5] H. Tanaka et al., Plasma Fusion Res. 9, 1302057 (2014);
[6] S. Masamune et al., IAEA-FEC25 EX/P3-52, 2014
[7] N. Muzuguchi et al., PFR 7, 2403117 (2012)

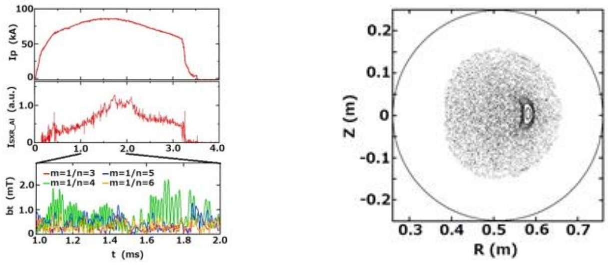

Figure 1. Transition to single-mode dominated RFP state in deep reversal RFP (left) with a Poincare plot (right).