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Variation of magnetic fluctuations of low aspect ratio tokamak and RFP plasmas in RELAX

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Recently, middle-size toroidal machines that were originally constructed to operate as reversed-field-pinch (RFPs) have been utilized to study circular cross-section tokamaks [1, 2]. Such machines can systematically change the safety factor q profile by small degree in the range between a positive $q(a)$ that characterizes tokamak and a negative $q(a)$ that qualifies RFP configuration in same machine, where a is the minor radius of a toroidal plasma. This control allows for systematic studies of unexplored topics such as the dependence of the two-fluid states on the magnetic shear.

The RELAX machine was originally constructed to study low aspect ratio RFP plasmas. The major and minor radii of vacuum chamber are 0.51 m and 0.25 m, respectively, and the aspect ratio is 2. It is predicted that smaller aspect ratios would increase magnetic shear and reduce magnetic fluctuations. In addition, the distance between plasmas and the vacuum wall is very closed in RELAX, which would increase stability, facilitating two-fluid effects. To comparatively low aspect ratio tokamak and RFP plasma in the single machine, especially in correlation with two-fluid effects, the toroidal system, including support structures and power supplies, has been upgraded [3]. After the upgrade, the current flowing into the toroidal field coil can reach 21 kA, which produces toroidal field B_ϕ of approximately 0.2 T at the center of the vacuum chamber. This current value is approximately four times higher than that require for producing standard RFPs.

Preliminary experiments on producing tokamak plasma in the RELAX are conducted. Figure 1 shows typical waveforms for tokamak and RFP plasma in RELAX. In preliminary experiments forming tokamak plasma, the plasma current I_p, the loop voltage V_l, the duration time, and the toroidal magnetic field at the plasma edge are 20 kA, <10 V, 5.5 ms, and 0.08 T, respectively. On the other hand, in the case of RFP, they were 60 kA, 40 V, 2 ms, and -0.01 T, respectively. The V_l of the tokamak is reduced to less than a quarter of that of the RFP, and the fluctuations are also suppressed. This extends the duration time by a factor of 2.5 or more.

The magnetic fluctuations are compared for each plasma. Figure 2(a) and (b) show normalized fluctuation components of the magnetic field at the plasma edge. Those are normalized by the corresponding amplitude of magnetic field $|\boldsymbol{B}|$ in tokamak and RFP. In RFP case, the toroidal component b_ϕ, which is perpendicular to the magnetic field lines, is approximately 20 %, while poloidal component b_θ, which is parallel to the magnetic field line, is less than 10%. On the other hand, in the case of tokamaks, the b_ϕ (parallel) and b_θ (perpendicular) are approximately 0.3 % and 2 %, respectively. All components of the tokamak are suppressed by approximately one order of magnitude compared to the RFP, indicating that the magnitude of the magnetic fluctuations is dependent on the magnetic configurations. However, it is indicated that the perpendicular fluctuation is always larger than the parallel one, regardless of their magnetic configurations.

References
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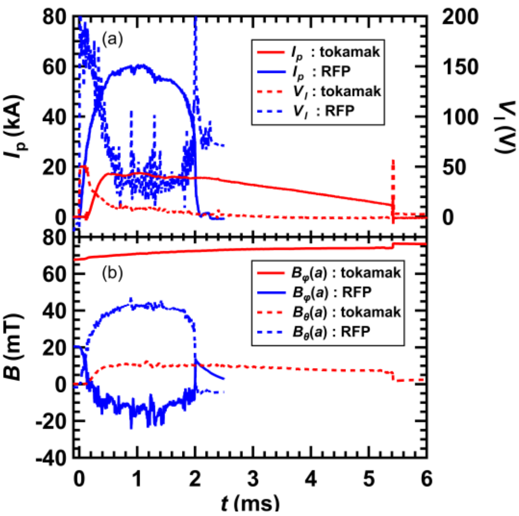

Figure 1. Typical waveforms of (a) plasma current (solid), loop voltage (dashed), and (b) magnetic field at the plasma edge for tokamak (red) and RFP (blue) plasma.

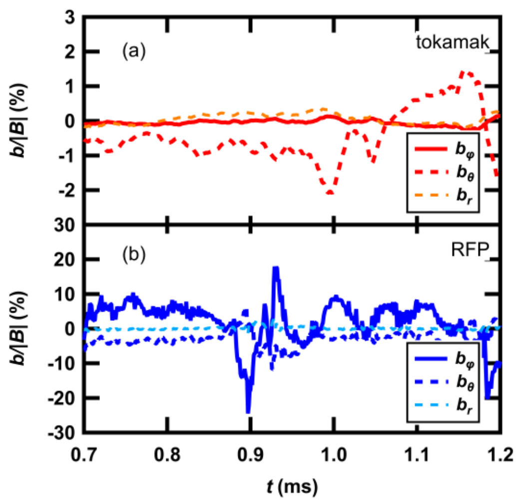

Figure 2. Comparison of the time evolution of normalized magnetic field fluctuations in (a) tokamak and (b) RFP plasmas.