White paper for ReNeW, Theme 5

A scenario for steady state low-aspect-ratio RFP sustained by pressure-driven and RF/NBI-driven currents

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The pulsed reactor scenario based on OFCD for current ramp up and self-similar current ramp down during which we expect favorable confinement and subsequent nuclear fusion reaction is the most reliable one at present. Here we would like to point out another scenario (with some high risks) for steady state RFP. This scenario depends on helical RFP equilibrium without magnetic stochasticity for favorable confinement and on pressure-driven bootstrap and RF/NBI-driven currents for current sustainment at low aspect ratio (low *A*).

In our RELAX experiment (R/a=0.51m/0.25m) with *A* of 2 at KIT, it has been demonstrated that a quasi-single helicity (QSH) state can be achieved at lower current than in other RFP's. Moreover, rotating Helical Ohmic state has been realized in very shallow reversal case, magnetic topology of which appears to be similar to the Single Helical Axis (SHAx) state in RFX. They may be attributable to the fact that the safety factor is increased, and the spatial separation of major resonant surfaces in the core is increased at low aspect ratio[1]. The helical RFP equilibrium has been sustained via the laminar dynamo mechanism which does not accompany magnetic stochasticity. Formation of a transport barrier of electrons has been demonstrated in SHAx state in RFX. In such improved confinement with helical RFP equilibrium, we may expect the beta value as high as ~30%, which has already been achieved in MST. The remaining issue is to establish a scenario for attaining to a purely single helicity state by suppressing the neighboring secondary modes.

The trapped particle fraction is also increased at low aspect ratio. An equilibrium analysis has shown that the pressure-driven bootstrap current should become measurable in RELAX if the beta value of ~25% could be achieved[1]. If the beta limit of RFP would be as high as ~60%, then we should expect substantial fraction of the pressure-driven bootstrap current with precise control of pressure and temperature profiles. In any case, auxiliary current driven by either RF (EBW, LH) or NBI is required to sustain steady state RFP.

Low *A* may also have some advantages from technological point of view. At low *A*, the number of toroidal field (TF) coils can be reduced for a given value of toroidal ripple. A large bore radius of the TF coils brings about negligible increase in total magnetic energy because the toroidal field is almost 0 outside the plasma. So, we would expect more space around the TF coils. This enables us to design RF or NBI systems with more flexibility than for conventional RFP. Feedback stabilization of RWM in low-*A* RFP might bring about some problem arising from toroidal effect. Another problem would be to specify the radial location of the feedback coils to guarantee sufficient controllability. We would need enough space between the first wall surface and outermost flux surface of the for RF launcher.

In any case, we have to make contribution to ITER, and have to be ready for receiving scientific outputs from ITER as inputs for feedback to realize circulation of knowledge, for fertilizing the field of fusion science.

[1] S.Masamune et al., 22nd IAEA Fusion Energy Conference, Geneva, EX/7-Rb, 2008.