ID: EX/P2-21

Exploration of RMP ELM control on ITER similar shape (ISS) in KSTAR

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ABSTRACT

• Recent control advances at KSTAR enabled us to not only sustain the ITER-similar shape (ISS) in a stationary manner but also experimentally demonstrate the ISS-compatible RMP-ELM control in KSTAR for the first time, using the n=2, +90-deg phasing RMP.

BACKGROUND

• the estimated heatload by a single edge localized mode (ELM) burst may endanger machine safety of ITER: The RMP-ELM control, introduced first in [1], is anticipated to resolve the issue.

• RMP-ELM control has strong shape dependence; KSTAR has developed various method for this topic [2-4], but all for ”standard” shape (high-δ~0.6-0.8) - requires a dedicated test of RMP-ELM control to the ITER reference geometry, which has been challenging for KSTAR.

CHALLENGES / METHODS / IMPLEMENTATION

Challenge for achieving ITER relevant parameters in KSTAR

- low q95~3.1-3.4 requirement is prone to face n=1 mode-locking

- the independent control of up/down asymmetric triangularities with constraints by a large portion of up/down symmetric central solenoid (CS)

Access to ISS

Advanced magnetic controllers are integrated for the goal, including

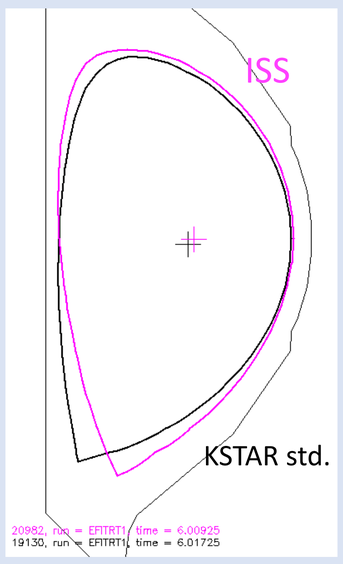
- enhanced vertical stabilization [5] decoupled from shape control

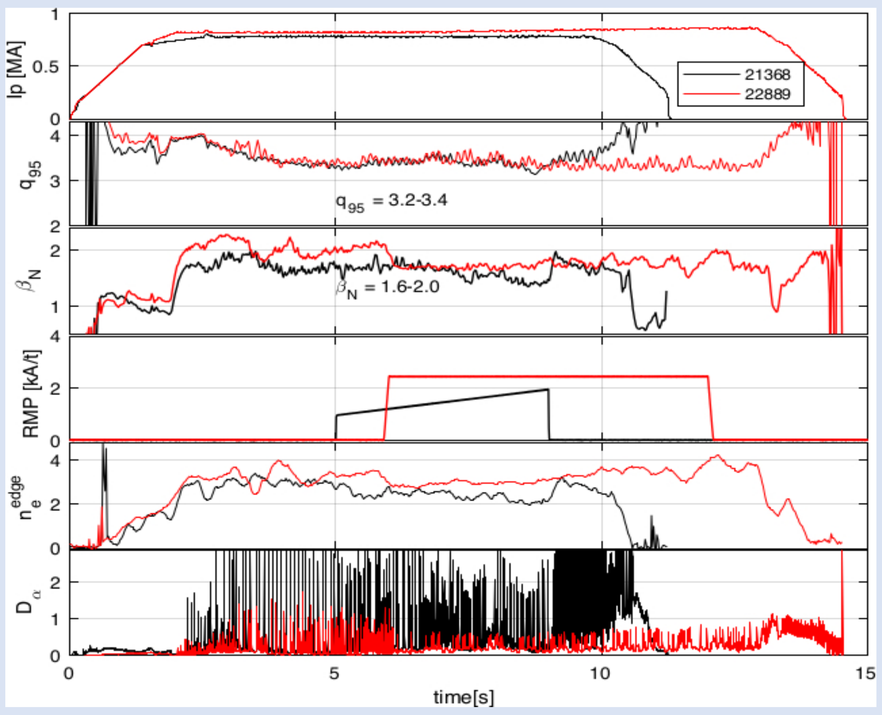
- a MIMO X-point controller for X-point position, more suitable to KSTAR

- real-time feedforward algorithm [6] for minimizing integral gain errors

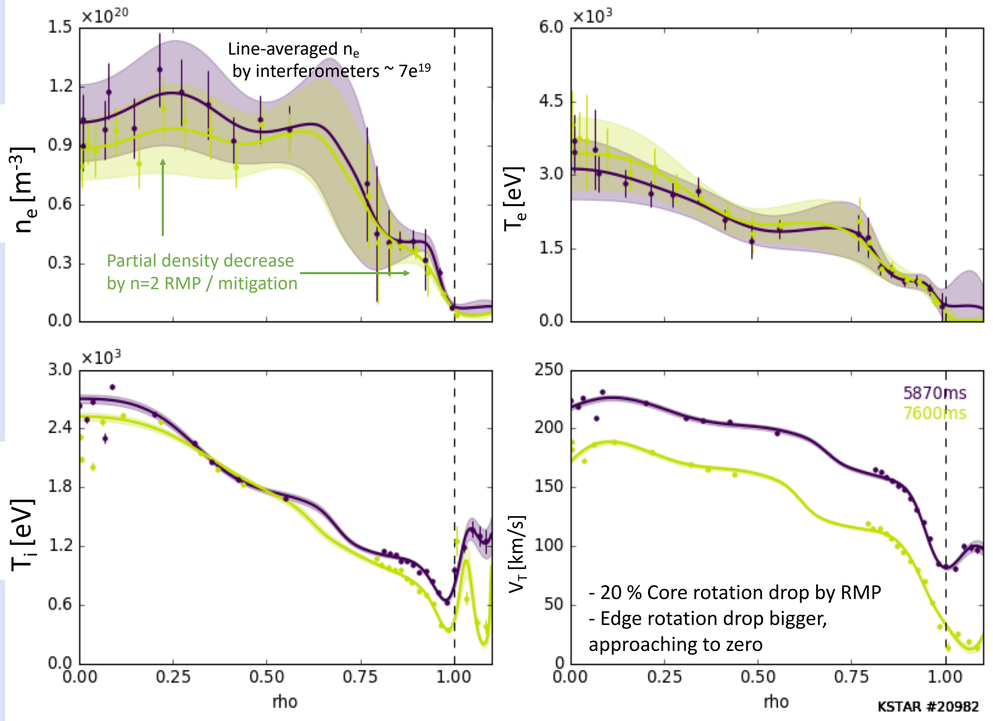
- in-vessel radial coils (IRC) to compensate radial movements by huge ELM bursts

ITER Similar Shape vs KSTAR std. shape for ELM suppression





ISS discharges obtained in KSTAR : Ip = 780-820 kA, q_{95} = 3.2-3.4, β_N = 1.6-2.0, κ~1.8, δ_u =0.5-0.55, δ_l=0.45 (red) P_{NB}=3MW, (black) #21368 using P_{NB} + P_{EC}=3 MW



High-density ISS profiles measured (#20982)

ν_{e^*} ~ 0.51,
ν_{i^*} ~ 0.39
at the pedestal top (ρ~0.89)

t=5870ms: no RMP

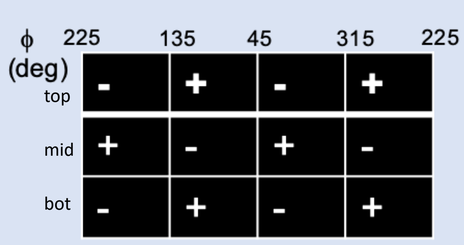
t=7600ms: n=2 RMP applied

OUTCOME: RMP-ELM suppression in ISS

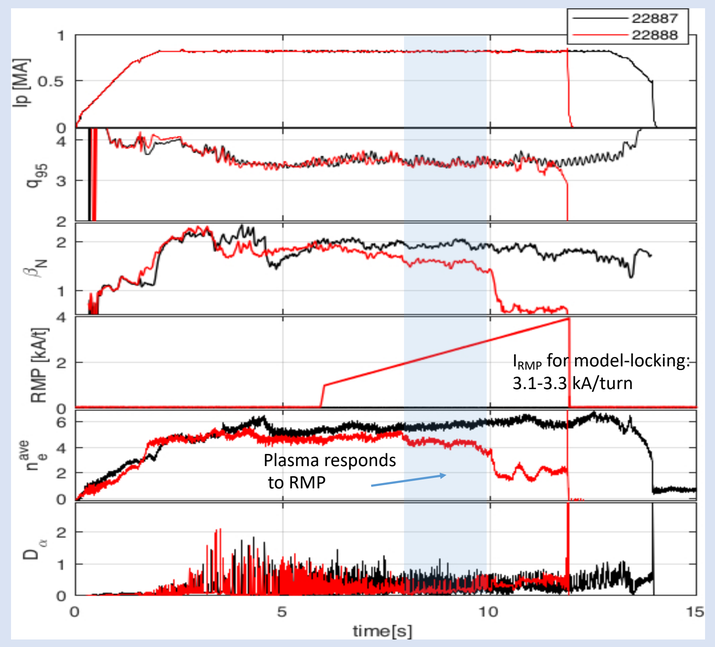
n=2, +90deg phasing RMP used for avoiding low-q95 mode-locking.

Investigate

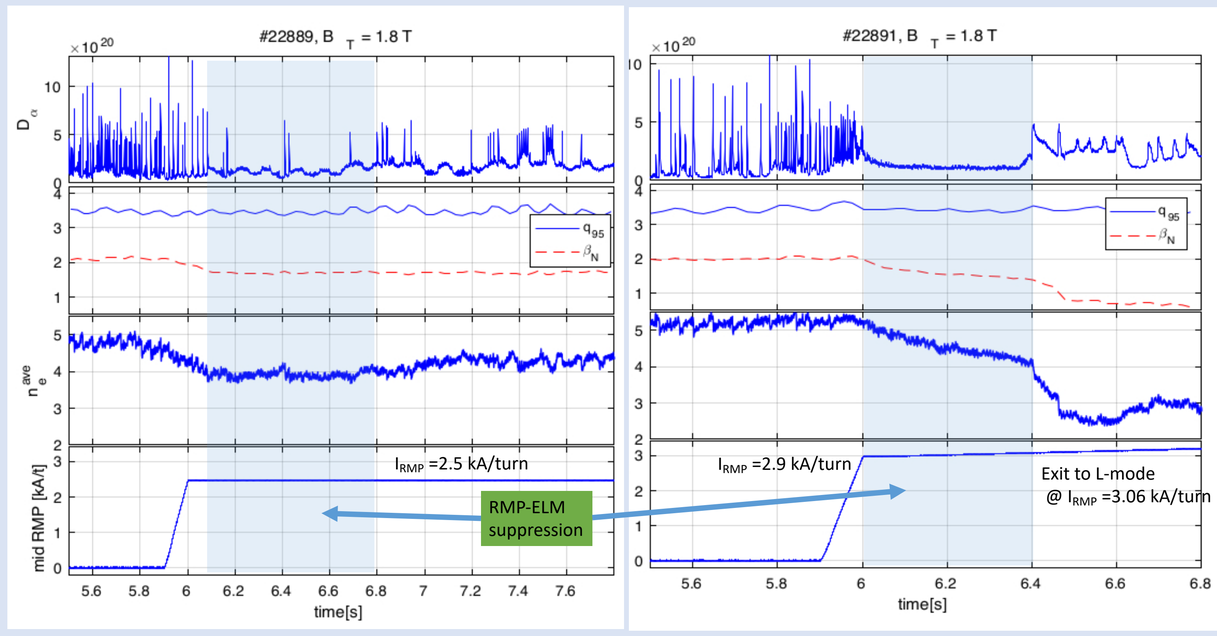
- **density**: suppression at mid-range n_e^{ave}~5-6$e^{19}m^{-3}$, strong mitigation at high density n_e^{ave}~7$e^{19}m^{-3}$
- **Strength of RMP current**: suppression observed at 2.5 – 2.9 kA/turn
- **other remarks:**
  - n=1 RMP application led to immediate disruptions
  - locking threshold (3.1-3.3 kA/t) is very close to the effective range
  - Accompanied by global density pumpout & βp drop, similar as the ”standard” n=2 RMP experiment with q_{95}=3.3-3.6



n=2, +90deg phasing RMP configuration & Br direction



Mode-locking threshold measurement for ISS



ISS + RMP-ELM suppression by n=2, +90 degrees phasing RMP at line-averaged ne ~ 4-6 e^{19} m^{-3}.

CONCLUSION

- A special plasma target reflecting ITER shape, for exploration of RMP-ELM control, is developed in KSTAR at experimentally accessible range
- The observed ELM responses at the ISS by n=2 RMP shows similar characteristics of the typical RMP-ELM suppression found at KSTAR using the KSTAR standard shape
- The RMP-ELM control has strong dependency on the plasma density

ACKNOWLEDGEMENTS / REFERENCES

Acknowledgements Works supported by R&D Program of "KSTAR Experimental Collaboration and Fusion Plasma Research (EN2101-12)" through the Korea Institute of Fusion Energy (KFE) funded by the Korean Ministry of Science and ICT, and National and Research Fund (NRF- 2019M1A7A1A03088443). The material includes work supported by the U.S. DOE, Office of Science, Office of Fusion Energy Sciences, under Award # DE-SC0010685.

- Part of the data analysis was performed using the OMFIT integrated modeling framework [7]

References

[1] T.E. Evans, R.a. Moyer, K.H. Burrell, M.E. Fenstermacher, I. Joseph, A.W. Leonard, et al., Nat Phys 2 (2006) 419–423.
[2] Y.M. Jeon, J.K. Park, S.W. Yoon, *et al.*, Phys. Rev. Lett. 109 (2012) 1825–5.
[3] Y. In, Y.M. Jeon, J.K. Park, *et al.*, Nucl. Fusion 59 (2019) 056009–15.
[4] M. Kim, J. Lee, W.H. Ko, S. Hahn, Y. In, Y.M. Jeon, et al., Phys. Plasmas (2020) 1–12.
[5] D. Mueller, S.-H. Hahn, N.W. Eidietis, *et al.*, Fus. Eng. Des. 141 (2019) 9–14.
[6] M.L. Walker, M.J. Lanctot, S.-H. Hahn, 2016 IEEE Conference on Control Applications (CCA) (2016) 605–610.
[7] O. Meneghini, S.P. Smith, L.L. Lao, O. Izacard, Q. Ren, J.M. Park, et al., Nuclear Fusion 55 (2015) 083008.