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HIST up-grade scenario towards high performance using multi-pulsing CHI

HIST装置におけるマルチパルスCHIによる高性能化シナリオ

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The HIST device has been developed towards high-β and quasi-steady-state sustainment of high-q and low-q ST plasmas by Multi-pulsing Coaxial Helicity Injection (CHI) method. We have successfully demonstrated the flux/current amplification and sustainment of the plasmas in the double gun pulse experiment. We have investigated the characteristics of the double CHI driven ST plasmas.

1. Introduction

Coaxial helicity injection (CHI) was so far used to sustain spheromak and ST plasmas. A critical issue for CHI is achieving good energy confinement and sustainment simultaneously, since the stochastic magnetic file lines destroy significantly the magnetic flux surfaces. Multi-pulsing CHI or repetitive transient CHI has been proposed to resolve this key issue. The multi-pulsing operation is that after the plasma partially decays, a new CHI pulse is applied and the repeated driven and decay process yields a quasi-steady-state plasma. This multi-pulsing CHI experiment was successfully demonstrated in the SSPX spheromak device at Lawrence Livermore National Laboratory [1]. In the HIST experiments, this new CHI method has been examined for the high-q ST configurations.

2. Experimental device

The structures, sizes, capabilities, diagnostics, and operating conditions of HIST (R = 0.30 m, a = 0.24 m, A = 1.25) are described in detail in Ref. [2], but some diagnostic and additional capacitor bank systems for M-CHI operations are also described briefly here. The capacitor banks (V_{max} = 10 kV, C = 0.6-2.6 mF) are used for ST formation. The two sustainment banks (V_{max} = 900 V, 336 mF and C = 280 mF) have been prepared for the double gun pulsing experiment. The HIST device has surface poloidal pick-up coils, a current density probe, internal magnetic probing arrays, Ion Doppler Spectrometer (IDS), a three-axis MHD dynamo probe (Mach probe with magnetic pick-up coils), a three-axis Hall dynamo probe and a CO2 laser interferometer.

Figure 1 illustrates the HIST device. The HIST device can form and sustain the ST (high-q: q>1 and low-q and spheromaks: q<1) by utilizing the variation of the external toroidal field (TF) coil current I_{tf}. By operating the magnetized coaxial plasma gun (MCPG) with the condition of $\lambda_{gun}>\lambda_{FC}$, here $\lambda_{gun} = \mu_0 I_{gun}/\Psi_{bias}$ and λ_{FC} is the eigen-value (λ_{FC} = 8.53) of the flux conserver (FC), required during the driven phase, the magnetic helicity is transferred from the MCPG to the plasma.

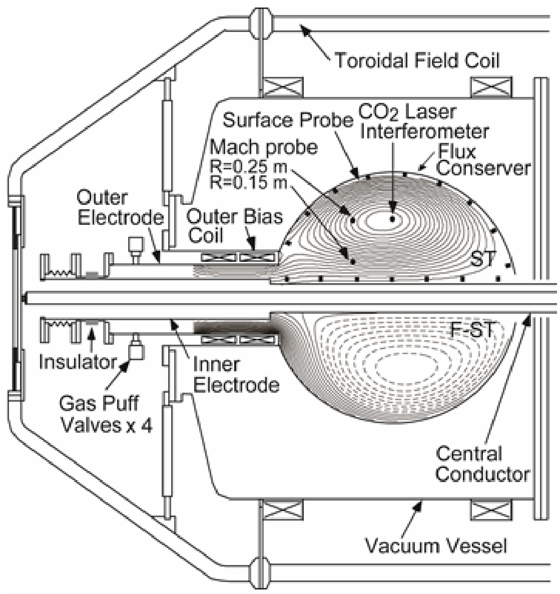

Fig.1. HIST device

3. Results from double pulsing CHI experiment

Figure 2 illustrates temporal evolutions of the toroidal plasma current I_t, the line averaged electron density $\langle n_e \rangle$ in the core, the edge poloidal magnetic field $B_{p.in}$, $B_{p.out}$ at the inboard side (R=0.15 m) and the outboard side, respectively, $\lambda_{OFC} = \mu_0 I_t/\Psi_t$ in the OFC region (at R~0.1 m) and λ_{core} in the core region (at R~0.25 m) in the comparison of single and double pulsed discharges. The injection gun current is I_{gun} ~30 kA in the both operations and the gun bias flux Ψ_{bias} is adjusted properly. In this shot, the MCPG has been secondly pulsed at $t \sim 1.5$ ms and then we have observed that the toroidal current I_t is effectively amplified against the partially resistive decay. In addition, the life time t_{life} has increased up to 7 ms which is longer than that in the single CHI case ($t_{life} \sim$ 4 ms). The line averaged electron density $<n_e>$ and the outer edge field $B_{p.out}$ last between $t = 1.5$ ms and $t = 5$ ms in a steady-state manner as shown by Fig.1 (b), (d). The toroidal current in the core has been driven until $t \sim 5$ ms and after then started to decay exponentially.

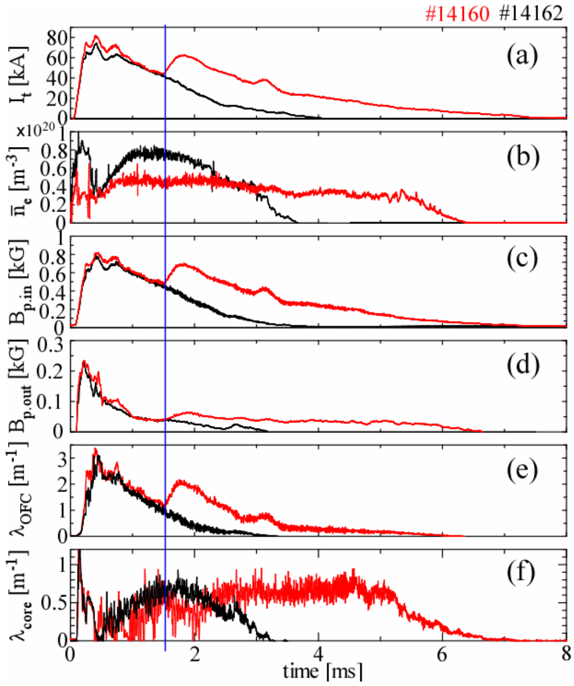

Fig.2.Time evolution of (a) I_t, (b) $<n_e>$, (c) $B_{p.in}$, (d) $B_{p.out}$, (e) λ_{OFC}, (f) λ_{core}, in the comparison of single (#14162) and double pulsed discharges (#14160)

Figure 3 illustrates a relationship between a plasma life (sustained and decay) time and a current gain (amplification ratio) and also a comparison between the second gun pulse timing of 1.5 ms (near the driven phase) and 2.5 ms (near the decaying phase). The current gain is defined by the fraction of the toroidal current I_t at the second pulse peak to just before the second pulse. It was found that the second pulse at t=2.5 ms has a larger current gain which means more effective current amplification. In the case of t=2.5 ms, the plasma current can be sustained during longer time than t=1.5 ms. It seems to be important for the Multi-pulsing CHI method that the repetitive gun pulse should be applied while the plasma decays sufficiently.

4. Summary

We have successfully demonstrated the flux/current amplification and sustainment of the plasmas in the double CHI pulse experiment. We have investigated the characteristics of the double CHI driven ST plasmas.

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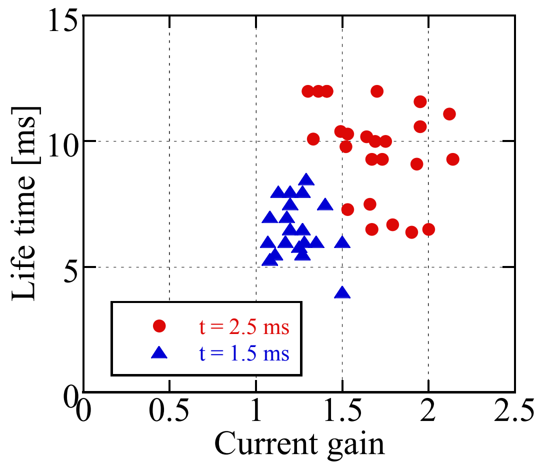

Fig.3. Comparison of the current gain and the life time between the second pulse timing at $t \sim 2.5$ ms and $t \sim 1.5$ ms

References

[1] S. Woodruff, et al., Phys. Rev. Lett. **90**, 205002-1 (2004).
[2] M. Nagata, et al., Phys. Plasmas **10**, 2932 (2003).