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Flow measurement in double-pulsing CHI experiment on HIST

HIST装置におけるダブルパルスCHI実験でのフロー計測

Mitsuru Ishihara, Kengo Ito, Takafumi Hanao, Keisuke Matsumoto, Tiki Higashi, Yusuke Kikuchi
Naoyuki Fukumoto, Masayoshi Nagata

石原　充, 伊藤兼吾, 花尾隆史, 松本圭祐, 東 大樹, 菊池祐介, 福本直之, 永田正義

Graduate School of Engineering, University of Hyogo
2167 Syosya, Himeji City, Hyogo 671-2280, Japan
兵庫県立大学大学院工学研究科　〒671-2280 兵庫県姫路市書写2167

Flux amplification and sustainment of the spherical torus (ST) configurations by operating in Multi-pulsing Coaxial Helicity Injection (M-CHI) method have been demonstrated in the Helicity Injected Spherical Torus (HIST) device. We have measured the radial profiles of the flow velocities by using Ion Doppler Spectrometer and Mach probes. The result shows that poloidal shear flow exists between the open flux column and the most outer closed flux surface.

1. Introduction

The new CHI method, so called multi-pulsing CHI (M-CHI) [1] was applied for a high temperature spheromak on SSPX at LLNL [2]. It is important to investigate plasma flow, dynamo and mode structures between the spheromak and ST plasma configurations. Thus, we have tested double pulsing operations on the HIST device in order to explore the usefulness of the M-CHI for the ST configurations. In this experiment, we have investigated the plasma flow profile and ion heating due to dynamo in the double-CHI driven ST plasma by using Ion Doppler Spectrometer (IDS) and Mach probes.

2. Experimental setup and results

The HIST device is a low aspect ratio torus with major radius R=0.30 m, minor radius a=0.24 m, and aspect ratio A=1.25 [3] (see Fig.1). 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, C=195 mF and 335 mF) have been prepared for the double gun pulsing experiment. The HIST device can sustain the ST by utilizing the variation of the external toroidal field (TF) coil current I_{tf}.

Figure 2 illustrates temporal evolutions of the (a) toroidal plasma current I_t, (b) the line averaged electron density $\langle n_e \rangle$ in the core, (c), (d) the edge poloidal magnetic field $B_{p.in}$, $B_{p.out}$ at the inboard side (R=0.15 m) and the outboard side (R=0.45 m) and the ion Doppler temperature T_{iD} (OII: 441.5 nm) in the comparison of single and double pulsed discharges. By secondly pulsing the MCPG at t = 1.5 or 2.5 ms during the partially decay phase, total plasma current is effectively amplified against the resistive decay. The core current density is generated due to dynamo. By secondly pulsing the MCPG at t = 1.5 or 2.5 ms during the partially decay phase, the total plasma current is effectively amplified against the resistive decay. The core current density is generated due to dynamo. The edge λ in the OFC is larger than the core λ, causing helicity transport from the edge to the core. Ion Doppler temperature T_{iD} increases from 20 eV up to 30 eV after the second CHI pulse, suggesting the ion heating due to dynamo.

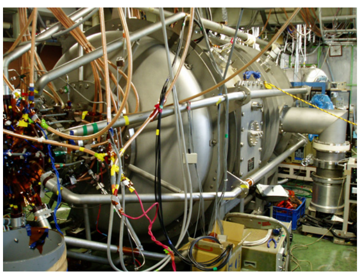

Fig.1. HIST

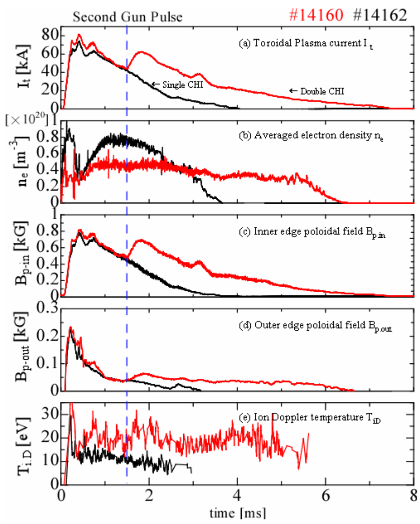

Fig.2. Time evolution of (a) I_t, (b) $\langle n_e \rangle$, (c) $B_{p.in}$ (R=0.15 m), (d) $B_{p.out}$ (R=0.45 m), (e) T_{iD} in the comparison of single (#14162) and double pulsed discharges (#14160).

Figure 3 displays comparison of a radial profile of poloidal and toroidal flows (a)(b), electron density (c) and radial electric field E_r (d) between before and after the second CHI pulse. The result from the measurement shows that poloidal flow velocity shear exists between the OFC and the last closed flux surface, i.e., at the separatrix. As seen in Fig.3 (a), there is a large poloidal flow in the ion diamagnetic direction at the OFC with the peak at R = 0.15 m. The poloidal flow shear may be caused by the diamagnetic drift of ions $\boldsymbol{v}_{pol}=-\nabla p\times\boldsymbol{B}_t/ZenB^2$ that being larger than the $\boldsymbol{E}_r\times\boldsymbol{B}_t$ drift because of a steep density gradient there as shown in Fig.3 (c). This is consistent with the observation that the OFC has a diamagnetic toroidal magnetic field structure. The negative $\boldsymbol{E}_r \sim\nabla p_i/en-(\boldsymbol{v}\times\boldsymbol{B})$ (the inward way to the magnetic axis) may be produced by the cross field flow rather than the ion pressure gradient. It should be noted that the direction of the toroidal ion flow in the OFC is anti-parallel to that of the electron flow. The second CHI pulse tends to increase the poloidal flow shear and decrease the toroidal flow shear which suggests that the ion flow is driven in the poloidal direction by the CHI pulse.

Figure 4 shows the poloidal flow profile of the impurity and neural particles obtained by the IDS measurement of OII and H_β spectral lines. Although this is not a local flow, the shear profile of the OII impurity flow is similar to the Mach probe data, but the direction in the OFC (R< 0.1 m) is not reversed. On the other hand, we can see that the H_β poloidal flow is reversed in this region. This reason is unclear at present. According to the formula $\boldsymbol{v}_{pol}=\boldsymbol{E}_r\times\boldsymbol{B}_t-\nabla p\times\boldsymbol{B}_t/ZenB^2$, the diamagnetic drift velocity of impurity particles is decreased by a factor of Z as compared to the $\boldsymbol{E}_r\times\boldsymbol{B}_t$ drift so that the diamagnetic poloidal flow velocity of the OII impurity particles is slower than that of the ion.

3. Summary

We have successfully demonstrated the flux/current amplification and sustainment of the plasmas in the double gun pulse experiment. Mach probe and IDS measurements have shown that there is the strong poloidal flow shear due to the ion diamagnetic drift around the separatrix.

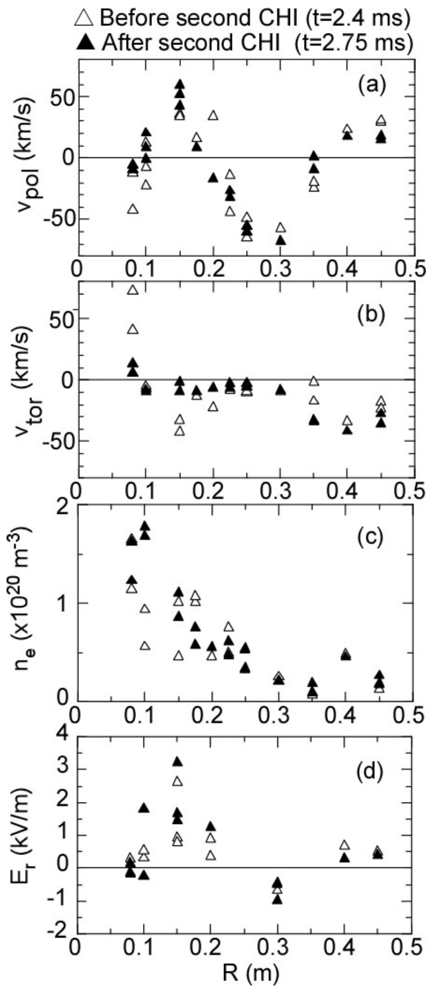

FIG. 3. Radial profiles of (a) v_{pol}, (b)v_{tor}, (c) n_e, (d) E_r.

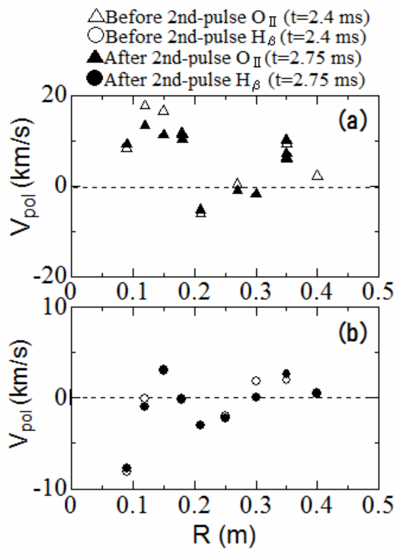

FIG. 4. Radial profiles of (a)V_{pol} of OII, (b)V_{pol} of H_β.

References

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