Compact Torus Plasma Injector in High Repetition Rate

S.Shimamura, F. Oota, M.Kamata, T.Asai
Department of Physics, College of Science and Technology, Nihon University
1-8 Kanda, Surugadai, Chiyoda-ku, Tokyo, 101-8308, Japan

Abstract Compact torus plasma injection with high repetition rate has been experimented. A magnetized coaxial gun was able to generate a series of compact torus plasmas with the same helicity sign in a high repetition rate. A series of generated compact torus plasmas was injected into a drift tube. The second generated compact torus plasma interacted with the decayed first one. Therefore we observed the accumulation effect. The repetition frequency of the injection increased from 50, to 70, 100KHz. The ratio of accumulation effect increased remarkably by increasing the repetition frequency.
Keywords compact torus, spherical torus, high rep-rate CT injector, CHI, fueling, sustainment

1. Introduction An injection of compact torus plasma (CT plasma) by using a magnetized coaxial gun has been studied for a formation of an initial spherical tokamak plasma and for it's sustainment. (CT plasma also includes small spherical tokamak) The CT plasma can be injected deeply interior of the main spherical tokamak and the CT plasma supplies particle. Comparing with the other sustainment methods the CT plasma injection supplies many torus plasma components of main spherical tokamak plasma. The CT plasma itself has many plasma parameters and components of main tokamak plasma.

There are direct current (d.c.) injection method and pulse current (p.c.) injection method for CT plasma and helicity injection. In the pulse helicity injection, the magnetic field lines of injected CT plasma are connected intermittently with the field line of main ST plasma. Many plasma parameters are injected by the magnetic field line reconnection with the main spherical tokamak plasma.

For effective fueling and sustainment, single pulsed injection of small CT plasma is not sufficient in many cases [1]. Therefore high repetition rate CT injector is required. We have experimented on the CT plasma injection with high repetition rate and studied the effect of increasing repetition rate.

The CT plasma was generated by a small magnetized coaxial gun (It is also called as

Coaxial Helicity Injector: CHI). Using same polarity oscillating current as a power source, the magnetized coaxial gun can generate a series of the CT plasmas with high repetition rate.

A series of the generated CT plasmas was injected into a drift tube. The second CT plasma moved into the tube and interacted with the first CT plasma that was decayed. Therefore we observed the accumulation effect by the interaction between the second plasma and the first one, though the experiments were conducted in the drift tube.

The repetition frequency of the compact torus plasma was increased from 50, to 70, 100KHz. The ratio of accumulation effects increased remarkably by increasing the repetition frequency. The accumulation effect of helicity was estimated by the helicity balance equation for the pulse helicity injection [2],[3],[4]. Figure 1 shows applied voltage pulse and time evolution of normarized helicity.

2. Experimental apparatus The schematic drawing of experimental device is shown in Fig.2. The magnetized coaxial gun (1) generates and injects CT plasmas into the drift tube in high repetition rate. The diameters of inner, outer electrode and it's lengths are 2cm, 4cm and 20cm respectively. Fast acting valve (2) supplies He gas from this port. Drift tube (3) is set on in front of the magnetized plasma gun. In this experiment drift tube of pyrex glass is used mainly for the observation of side view plasma images by first gated image intensifier (FGII) camera. The diameter and the length of the drift tube are 10 cm and 100cm respectively. An external solenoid coil (4) generates axial magnetic guide field on the drift tube. The center conductor (5) is set on the axis of pyrex drift tube all the way long.

One of the discharge circuits to generate repetitive current pulses with the same polarity is shown in Fig.3 (a). The capacitance and the magnetized coaxial gun are connected with a transformer. Both primary circuit and secondary circuit have start switch. The primary discharge circuit of the transformer is switched on and when the current of the circuit reaches the peak value the secondary gun circuit is switched on.

In order to study the accumulation effect, 8.8μF capacitor of the gun was changed to 4.4μF and 2.2μF. Figure 3 (b) shows these current waveforms that flows into the magnetized coaxial gun. The solid, the doted and the two points broken line are the waveform in 8.8μ F capacitor($f = 50$ KHz), 4.4μ F ($f = 70$ KHz) and 2.2μF($f = 100$ KHz) respectively.

Magnetic flux loops lapped around on the pyrex drift tube measured the flux change in the guide field. The flux change was measured at four positions on the drift tube.

Two band-pass filters were prepared for the spectroscopic observation. Central wavelength of one filter was 468.6nm for the first ionized He ion line. Another one was 587.6nm for the excited neutral He atom.

3. Experimental results Accumulation effect was measured by the ration of peak flux changes for the numerical order of injected CT plasma to the first one. Figure 4 shows the flux change ratio for each repetition frequency of 50,70 and 100 KHz. In 50KHz, the ratio of flux change for the second CT plasma to the first CT plasma is typically 0.7. This figure also shows the ratios of the peak gun current normalized by the first peak gun current. The gun current ratio of the second pulse to the first one is 0.6. A slight accumulation effect was observed in this repetition rate. For 70KHz repetition frequency, the ratio of flux change for the second CT plasma to the first CT plasma is 1.2.The gun current ratio of the second pulse to the first one is 0.6 almost same as the former case. Therefore the accumulation ratio becomes large. For 100KHz repetition frequency, the ratio of the second flux change to the first one is 1.1 and the ratio of the third flux change to the first one becomes 1.2 even though the gun current decrease more. These results show the remarkable accumulation effect of increasing the repetition frequency from 50KHz to 70,100KHz.

The side view images of the injected CT plasma became better shape than the former experimental ones. Figure 5 shows one of the images. Using band passed filter, FGII camera took the side view image for some special spectral lines. Figure 6(a) shows CT plasma image using the band pass filter of the first ionized helium spectral line 468.6nm. Figure 6(b) shows the image using the band pass filter of the neutral helium line 587.6nm..

Plasma density was not measured in this experiment, however, averaged density from the former measurement by He-Ne laser interferometer showed $1.5\times10^{20}m^{-3}$ at peak density.[3]

4. Summary Increasing 2.0 times the repetition rate, the ratio of flux change raised from 0.7 to 1.2. The ratio of the second gun current to the first current decreased to 0.6. The accumulation effect increased remarkably.

References [1] T.Ogawa,N.Fukumoto,M.Nagata,T.Uyama,et.al. Nuclear Fusion,39,1911(1999) [2] C.W.Barns et.al.,Phys.Fluids,29,3415(1986) [3] S.Shimamura, K.Matsuura, T.Takahashi, Y.Nogi. J.Plasma Fusion Res. Vol.3 (2000), P494-497P [4] S.Shimamura, J. Nitou, M. Hayakawa, F.Oota, J Plasma Fusion Res. SERIES, Vol.6 (2004), P492-495

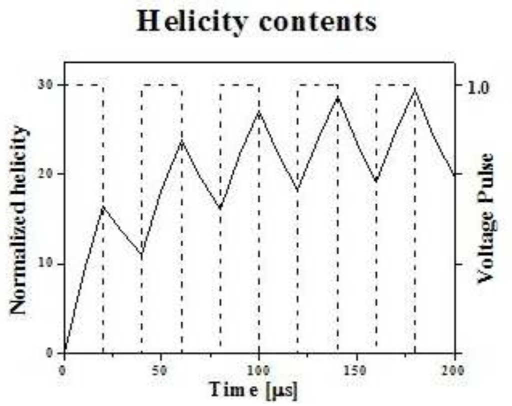

Fig. 1 Time evolution of normarized helicity

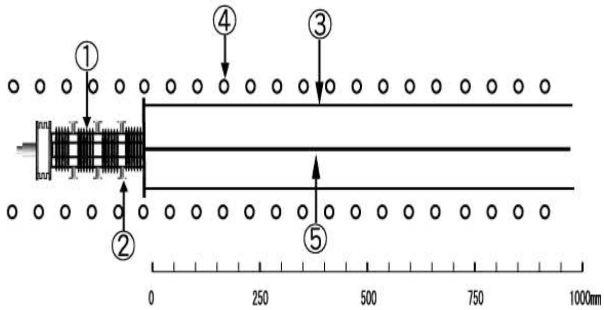

Fig.2 Experimental setup

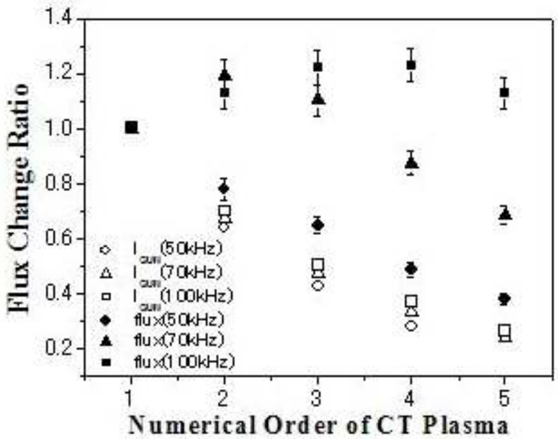

Fig. 4 Dependence of accumulation effect on repetition frequency

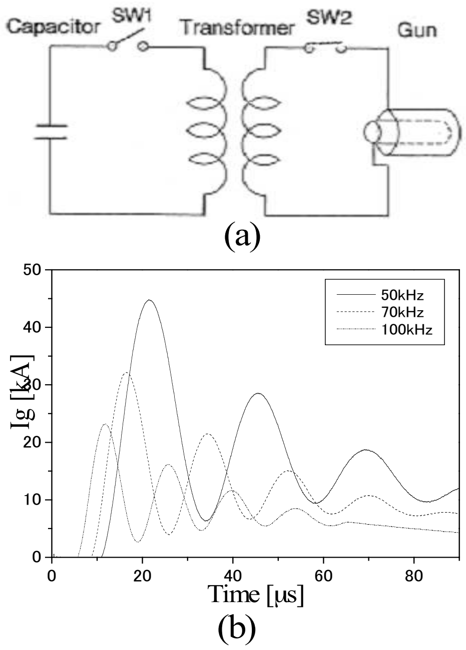

Fig. 3 (a) Gun discharge circuit (b) Gun current

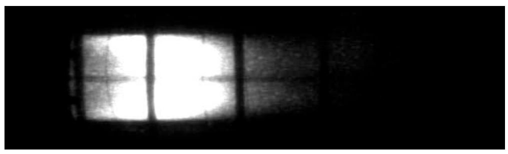

Fig. 5 Side view image of CT plasma in drift tube(t=45us)

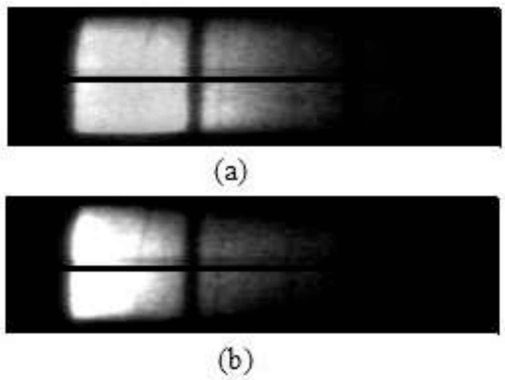

Fig. 6 (a) side view image through band pass filter(468.6nm) (b)band pass filter (587.6nm)