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Preliminary Experiment of Non-Induced Plasma Current Startup on SUNIST Spherical Tokamak

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Abstract: Non-inductive plasma current startup is an important motivation on the SUNIST spherical tokamak. In this experiment, a 100 kW, 2.45 GHz magnetron microwave system has been applied to the plasma current startup. Besides the toroidal filed, a vertical field was applied to generate a preliminary toroidal plasma current without action of the central solenoid. As the evidence of the plasma current startup by the vertical field drift effect, the direction of the plasma current is changed with the changing direction of the vertical field during ECR startup discharge. We have also observed the plasma current maximum by scanning the vertical field in both directions. Additionally, we have used electrode discharge to assist the ECR current startup.

Keywords: ECR preionization, electrode discharge assistant

I. Introduction

ECR (Electron Cyclotron Resonance) is one of the non-inductive plasma current startup schemes. From 1980s, a number of ECR preionization experiments have been done on many tokamaks. These experiments have showed that the plasma current could be started up and sustained by electron cyclotron waves alone without ohmic heating. [1-7]

According to Ref. [8], the electrode discharge assisted ECR current start up has been experimentally demonstrated on the CT-6B tokamak. According to that experiment, we also used electrode discharge in our experiment to observe its characteristics.

SUNIST(Sino UNIted Spherical Tokamak) is a small device. Its parameters are as follows:

major radius	R	0.3	m
minor radius	a	~ 0.23	m
aspect ratio	A	~ 1.3	
elongation	κ	~ 1.6	
toroidal field at R_0	B_{T0}	~ 0.15	T
plasma current	I_P	0.05	MA
flux swing	ΔΦ	0.06	Vs

A magnetron microwave generator with a frequency of 2.45 GHz, output power of 100 kW and pulse length of 30 ms, is used for the experiment of the SUNIST ECR startup. The detectors for injected and reflected waves, absorbed loading of the reflected waves, vacuum and dc breakers are installed in the feeding line. In the preliminary experiment, a rectangular horn antenna injects waves to the plasma in the perpendicular direction with plasma torus.

II. Preliminary experimental results

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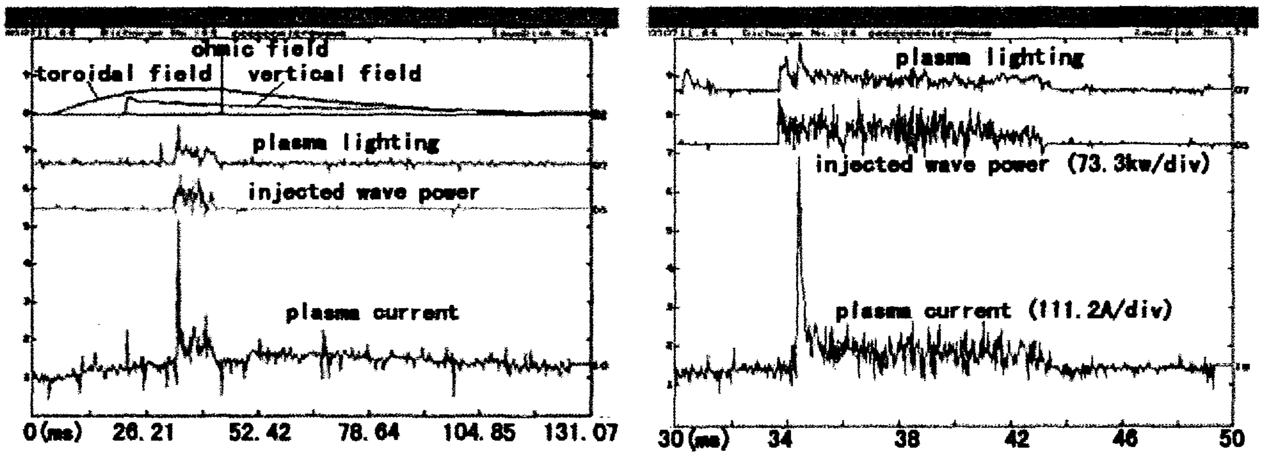
ECR wave current startup

The toroidal field, from to Gauss, has been selected to locate resonant layers in the appointed position inside the plasma. A small vertical field was applied during the microwave power pulse for the driving toroidal plasma current by the electron drift effect. A piezoelectricity valve supplied working gas pulse into the vacuum vessel with the < 1×10^{-5} Pascal of background pressure to keep above ~ 5×10^{-3} Pascal of hydrogen pressure during when the microwave power was applied. Microwave output power was kept around 20 kW because we could not improve the quality of the plasma current any higher above the power injected. One typical discharge is shown in figure 1 (A) on a large time scale and (B) on a short time scale for showing the discharge sequences and details. The plasma light signals extend as long as the microwave power is applies as usual, but the plasma current is just a peak with a hundred millisecond of bottom width. Sometimes, usually in a lower toroidal field, a group of plasma current peaks could be observed during the microwave, as shown in figure 2, accompanied by a group of plasma lighting signals.



(A) (B)

Fig. 1 Typical discharge of ECR current startup, A and B in large and small time scales respectively

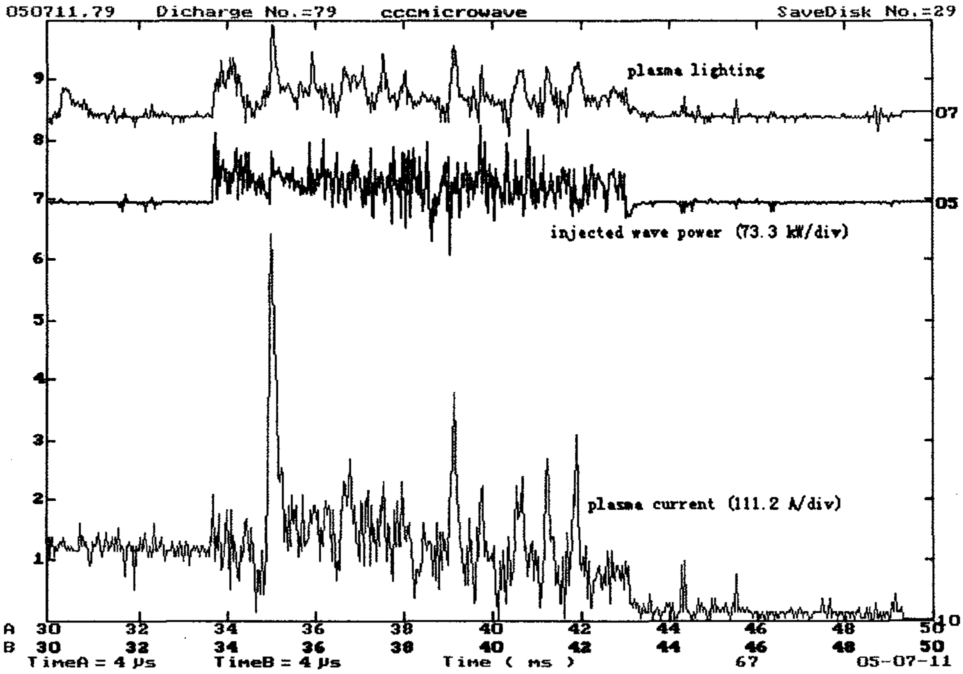


Fig. 2 A group of plasma current peaks

Figure 3 shows a driven plasma current changes along with the vertical field, which is evidence of driving the net toroidal plasma current by the vertical field drift effect in ECR plasma. The scattering higher I_P data relate to the wall condition.

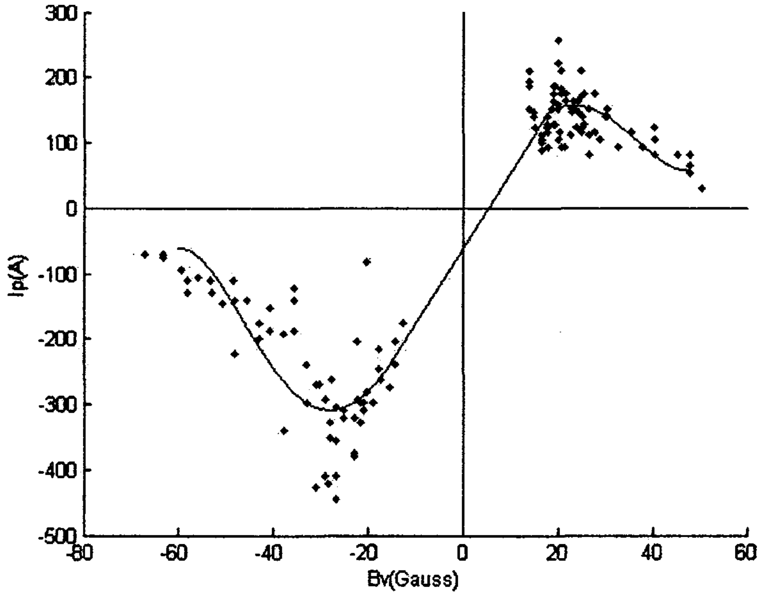
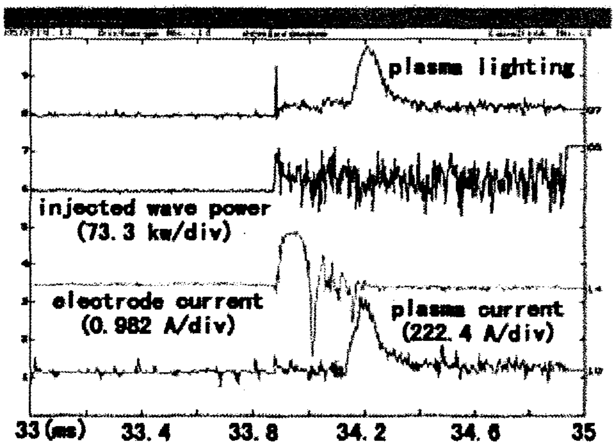


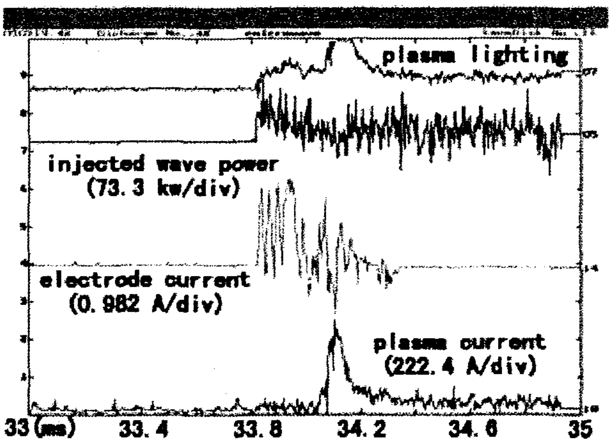
Fig. 3 Plasma current vs vertical field

ECR wave startup with the assistance of electrode discharge

We have tried to apply a voltage between a pair of electrodes located at the top and the bottom respectively, scanned the electrode voltage and changed the voltage direction. Preliminary results have shown the plasma current could increase above 10% (Fig. 4) in the common direction of the two kinds of driven mechanisms; contrarily, the plasma current would be counteracted more obviously (Fig.5). But just in the counter-direction electrode discharge we can observe the electrode current.

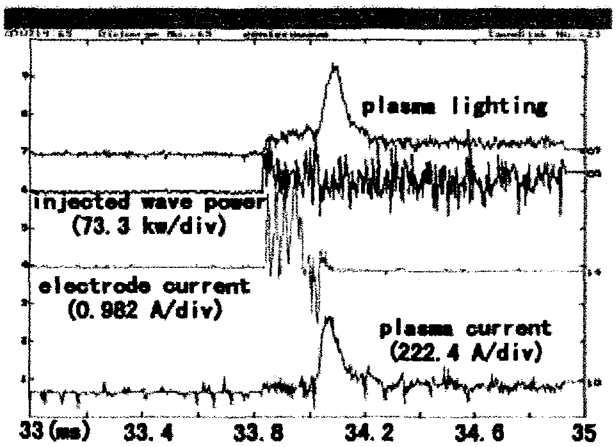


(A)

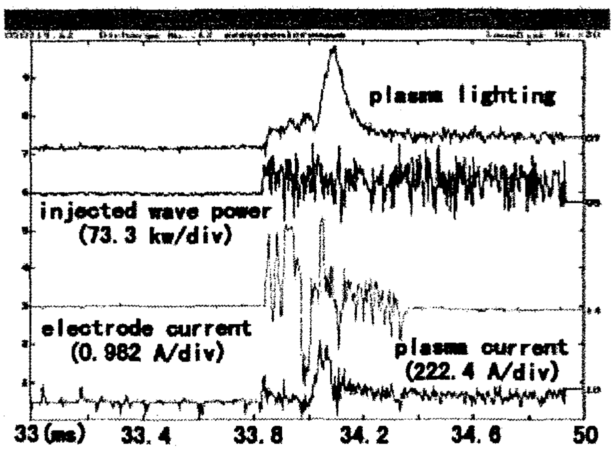


(B)

Fig. 4 ECR current startup with electrode discharge's assistance in common direction, A and B without/with electrode discharge



(A)



(B)

Fig. 5 ECR current startup with electrode discharge's assistance in counter direction, A and B without/with electrode discharge

Usually, the electrode current is limited by an ion saturation current and exists in the same pulse duration with the ECR plasma current. We have obtained one special discharge that the current of plasma and electrode is cutoff with the same time scale of the injected wave (Fig. 6).

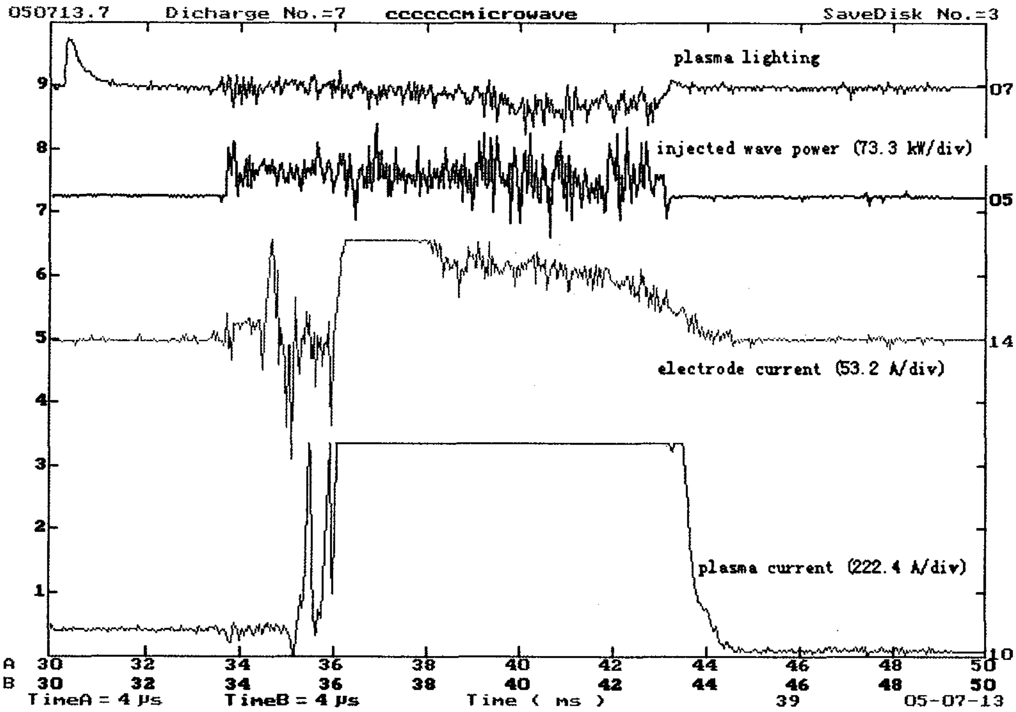


Fig. 6 Special discharge of ECR current startup with electrode assistance

III. Remaining questions

The preliminary results of the ECR plasma current startup with/without the electrode's assistance have indicated that a suitably applied vertical field could drive the toroidal plasma current, but it is more important to address a series of issues for the upcoming experiments.

Firstly, this kind of plasma current peak is impossible to develop to a typical ST plasma current. We have not considered the mode conversion to EBW in a microwave launch system, and then we face the density cut off problem of the ECR wave propagation in plasma. Modifying the feeding line and antenna is the only way to convert the mode to electron Bernstein wave.

The discharge shown in Fig. 9 suggests that there is a discharge regime with no density cut off problem in the ECR current startup with the assistance of the electrode discharge. The question is how to find it and to develop it from an occasional event to being reproducible. There were a few special discharges in the ECR current startup with the electrode assisting on the CT-6B tokamak. The currents of the electrode and plasma extended over the injected wave. There have been comments that that would be the arc phenomena, which should be avoided. But from the ratio between the plasma and electrode current, it is consistent with the plasma current driven mechanism by electrode discharge.

In preliminary experiments, the background pressure of the vacuum vessel increased from less than 1×10^{-5} Pascal up to a balanced value, $\sim 3\times10^{-5}$ Pascal. The driven plasma current decreased with the increase in the background pressure just like scanning the fuelling gas to a higher pressure. It is necessary to control the wall condition for further experiments.

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References

[1]GILGENBACH, R.M., et al., Nucl. Fusion 21 (1981) 319.
[2]NAKAO, S., OGURA, K., et al., Phys. Lett. 94A (1983) 405.
[3]CHO, T., et al., J. Phys. Soc. Jpn. 53(1984) 187.
[4]KUBO, S., et al., Phys. Rev. Lett. 50 (1983) 1994.
[5]SHIMOZUMA, T., et at., J. Phys. Soc. Jpn. 54(1985) 1360.
[6]TANAKA, H., et al., Nucl. Fusion 31(1991) 1673.
[7]HAN G., YAO X., et al., Nucl. Fusion, Vol. 38, No. 2 (1998) 287.
[8]ZHENG S., YANG X., et al., Nucl. Fusion, Vol. 40, No. 2 (2000) 155.