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Plasma Dynamo Experiments in the HYPER-II Device

HYPER-II装置を用いたプラズマダイナモ実験

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Plasma dynamo experiments with the HYPER-II device have been performed in order to clarify the structure formation of large scale magnetic field in plasmas. The high density and high electron temperature plasma is produced by electron cyclotron resonance heating in a weak magnetic field region. The magnetic Reynolds number of HYPER-II plasma exceeds unity, and the energy of plasma is comparable to the magnetic energy. The radial electric field in the plasma is controlled by a multi-cylindrical electrode. The effect of plasma rotation on the structure formation of large scale magnetic field is studied by directly evaluating the nonlinear helicity effects.

1. Introduction

Large scale magnetic fields can be ubiquitously found in universe. The amplification of the seed magnetic field due to the plasma flow has been called "dynamo", and the structure formation of dynamo magnetic field is one of the major subjects in astrophysics. The origin of magnetic field is closely connected with the motion of electrically conducting fluids, i.e., liquid metal and plasma. Many theoretical and numerical efforts have been performed to understand the dynamo effect, so far, but the mechanism has not been fully understood because of complex behavior of turbulent fluids. There are experiments using liquid metal or water for the dynamo, and the stationary magnetic field production has been reported.[1] On the other hand, the experiment using plasma has hardly been performed.

Recently, we have started an experimental study using a high density and high temperature cylindrical plasma. Flow dominated plasma is produced in weak magnetic field region, where ions are unmagnetized. The plasma rotation profile, whose shear is the energy source of nonlinear electromotive force, is experimentally controlled using a multi-cylindrical electrode. In the poster session, we will present the planning experiment with the HYPER-II device.

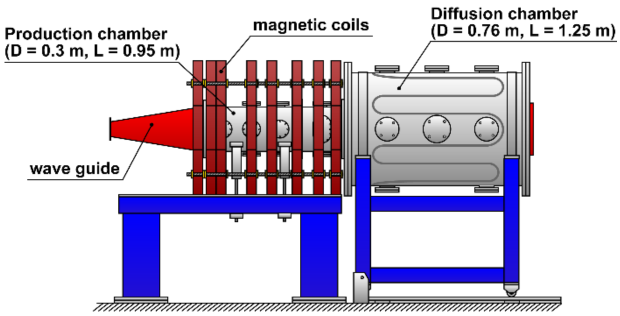

Fig. 1. Schematic of the HYPER-II device.

2. Experimental Apparatus: HYPER-II device[2]

Figure 1 shows the schematic of the HYPER-II device (Kyushu Univ.). The HYPER-II device consists of two cylindrical chambers with different radii. The plasma production chamber is 0.3 m in inner diameter and 0.95 m in axial length. The eight magnetic coils are set around the chamber, and a weakly diverging magnetic field is produced. The plasma is produced by electron cyclotron resonance (ECR) heating with a 2.45 GHz microwave launched from the high magnetic field side along the field line. The large-volume diffusion chamber with 0.76 m in inner diameter and 1.25 m in axial length is connected to the production chamber. The magnetic field in the diffusion chamber is weak (typically 10-400 Gauss) and the field line is strongly diverging.

A multi-cylindrical electrode, which consists of three cylindrical electrodes with 30 mm, 90 mm and 150 mm in diameter, is introduced in the plasma production chamber ($z = 0.65$ m) to control radial electric field in the plasma. Each electrode can be independently biased, and thus, we can flexibly control the radial electric field profile. An $\mathbf{E} \times \mathbf{B}$ azimuthal plasma rotation is induced in the strong magnetic field region, where **E** and **B** stand for the electric field and the magnetic field, respectively. Since the magnitude and inhomogeneity (shear) of plasma rotation is essential to the amplification of seed magnetic field, we can experimentally study the effect of nonlinear helicity effects[3] (alpha effect and turbulent cross helicity effect) on the structure formation of large scale magnetic field.

3. Experiments

Figure 2 shows the electron density as a function of input microwave power in high argon gas pressure discharge (0.5 Pa) and low pressure discharge (0.01 Pa) cases. These quantities were measured with a Langmuir probe at z = 0.8 m, where z is the axial position from the microwave launching position. The high electron density plasma is successfully produced, and the density is higher than the critical density of ordinary wave (7.5×10^{16} m^{-3}) in the higher gas pressure operation. In the lower gas pressure operation, the density is comparable to the critical density, but the ionization degree is high (typically 10%).

The electron temperature is higher than 5 eV in the lower gas pressure operation. Using the experimental data in the HYPER-II plasmas, we evaluate the magnetic Reynolds number, $R_{\mathrm{m}} = UL/\eta$, which describes the degree to which magnetic fields are frozen into a moving plasma with magnetic diffusivity η. Here, U and L and are the flow velocity and the characteristic scale length. Figure 3 shows the magnetic Reynolds number as a function of electron temperature. The HYPER-II plasmas have high R_{m} (typically > 10), which is comparable to that of the Earth.

The azimuthal rotation profile of flow dominated plasma is controlled using a multi-cylindrical electrode (see F. Kawazu *et al.*; 19PA-049 in the poster session). The angular velocity and the magnitude of shear of mean plasma rotation are changed by controlling the biasing pattern, and the helicity is injected.

4. Conclusions

We have performed a laboratory plasma experiment to study the phenomena with related to astrophysics and geophysics. We will study the effect of mean helicity on feedback processes between large scale magnetic field structure and nonlinear helicity effect by directly measuring the nonlinear cross helicity and the nonlinear electromotive force.

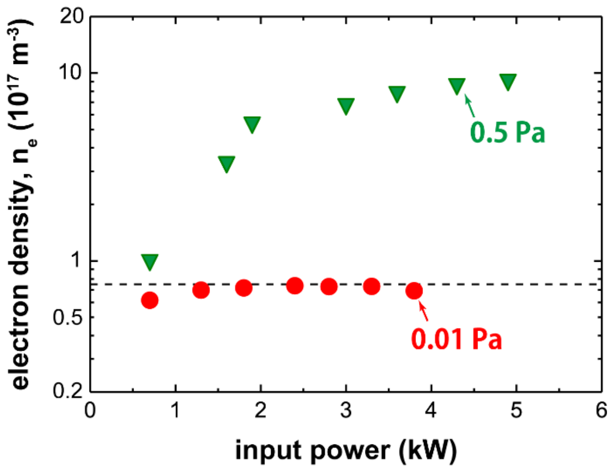

Fig. 2. Input microwave power dependence of the electron density in lower (0.01 Pa, circles) and higher (0.5 Pa, triangles) argon gas pressure cases. A dashed line indicates the critical density of the ordinary wave.

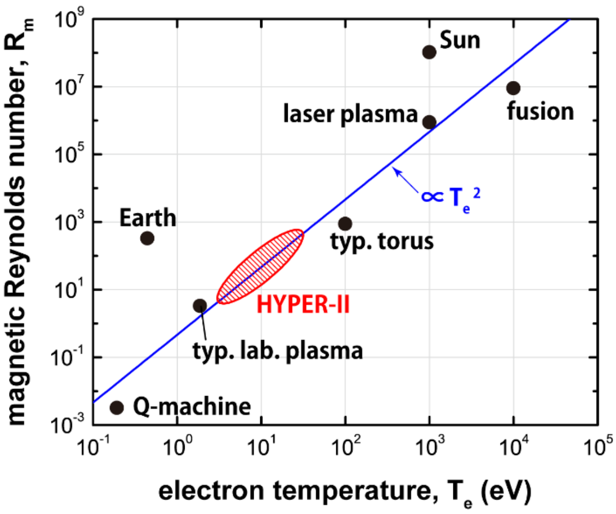

Fig 3. Magnetic Reynolds number as a function of electron temperature for various plasmas and the Earth. A solid line indicates the scaling function with a dependence of T_{e}^2.

Acknowledgments

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References

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