§1. High Density Plasma Experiment HYPER-I

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High Density Plasma Experiment-I (HYPER-I) is a versatile linear device for coordinated research, which consists of ten magnetic field coils and a cylindrical vacuum chamber whose sizes are 30 cm in diameter and 200 cm in axial length (Fig. 1). The plasmas are produced by electron cyclotron resonance (ECR) heating with a 2.45 GHz microwave which is injected along the magnetic field from an open end in the high-field side. This injection method allows us to obtain overdense plasmas readily without the limitation due to the cut-off density.

A high power klystron amplifier (80 kW CW max.) is available as the microwave source, which provides a wide range of controllability in microwave power input. The neutral gas pressure can be controlled by mass flow controllers, and the magnetic field strength can be varied continuously by the power supply. By adjusting those three experimental conditions, the HYPER-I device can produce a variety of plasmas to explore various plasma phenomena.

The HYPER-I device also offers powerful diagnostics. Five radial probe-driving systems, which can be relocated to different axial positions, and an axial probe-driving system installed on the two-dimensionally movable end-flange are equipped; various probe measurements such as conventional Langmuir probes, directional Langmuir probes (DLPs) and emissive probes can be conducted. Three tunable extended cavity diode laser (ECDL) systems and a pulsed tunable dye laser system is available to perform the laser induced fluorescence (LIF) measurement of metastable argon neutrals and ions. In addition, an image intensified CCD camera was introduced to develop a two-dimensional (2-D) optical emission spectroscopy (OES) measurement in this fiscal year.

The research activity of the HYPER-I group covers a broad range of topics. Some of the achievements in this fiscal year are described below. The HYPER-I device provides a unique opportunity to perform a variety of plasma physics experiments to collaborating researchers and graduate students.

(i) *LIF and OES Measurements*

An ultrahigh-resolution LIF measurement system has been developed by the last fiscal year, which enables us to study the structure of slowly flowing neutrals precisely. By using this system, we have identified the importance of the chemical potential of neutrals on the formation of a class of vortices which counter-rotate to the $\boldsymbol{E} \times \boldsymbol{B}$ drift. The LIF system can be used for ion velocity distribution function (IVDF) measurement by replacing the ECDL with a suitable one. Preliminary result on asymmetric IVDF was obtained in a plasma with steep density gradient, which is referred to as plasma hole.

The LIF measurement using the pulsed dye laser was applied to measure absolute ion flow velocity around an obstacle in a plasma, which aims at comparing the viscosity of the plasma with that of ordinary fluid.

2-D OES system with the ICCD camera has been developed to measure spatial profiles of electron density and temperature. The collisional-radiative model code for the image data analysis is being prepared.

(ii) *Intermittent Electron Flux*

Spontaneous excitation of pulsed magnetic fluctuations observed in the HYPER-I plasma were found to be related to the occurrence of intermittent high-energy electron flux (IHEF). To investigate the spatial structure of the IHEF, we have newly developed a wire-grid probe (WGP), which detects the rapid change of floating potential due to the inflow of high-energy electrons. The WGP has successfully taken the snapshot of IHEF with which the size of the IHEF was estimated to be about 35 mm.

(iii) *Development of Novel Diagnostics*

Several experiments for developing novel diagnostics are being underway with the HYPER-I device. (a) The testing phase of a neutral helium beam probe (HeBP), which aims at application to edge plasma diagnostics in LHD, has been completed. The HeBP system is now installed on LHD, and will be used in the next (the 15th cycle) experimental campaign. (b) The modulation of neutral pressure due to plasma fluctuations has been measured with a piezoelectric transducer, which may become a new tool for studying behaviors of neutral particles. A possible correlation between the fluctuations of neutral pressure and that of ion saturation current has been found. (c) The characteristics of the novel probe named "reversed Gundestrup type probe (RGP)" has been examined. The RGP characteristics showed expected deformation under the existence of plasma flow, however, unexpected large negative voltages were seen in some cases, which need careful examination.

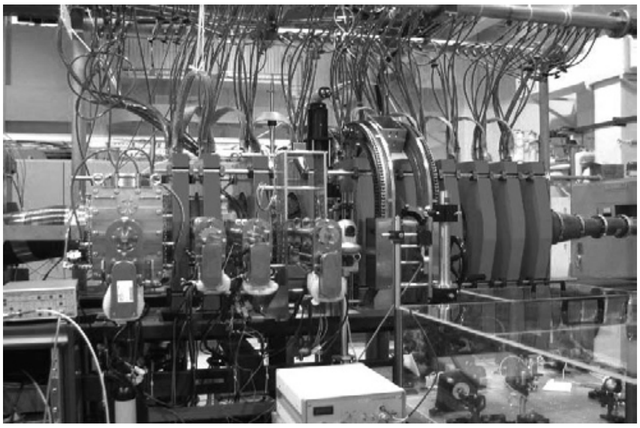

Fig. 1 The HYPER-I Device