

§1. High Density Plasma Experiment HYPER-I

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High Density Plasma Experiment-I (HYPER-I)¹⁾ is a linear device that consists of ten magnetic field coils and a cylindrical vacuum chamber 30 cm in diameter and 200 cm in axial length (Fig. 1). The plasmas are produced by electron cyclotron resonance (ECR) discharges of various gas species with a 2.45 GHz microwave injected along the magnetic field line through a quartz window at an open end of the chamber in the high-field side; this microwave injection method has an advantage that excited electron cyclotron wave is not subjected to density cutoff and that the highest attainable density of the HYPER-I plasma is two orders of magnitude higher than the cut-off density for the ordinary mode with the same frequency.

The HYPER-I device has been utilized for a number of collaborative research activities in NIFS, especially in basic plasma experiments on ion flow structures and in developments of novel high-precision diagnostics using various lasers. One of the strengths of HYPER-I is the flexibility of experimental conditions. A high power klystron amplifier (80 kW CW max.) is available for the microwave source, which provides wide controllability in microwave power input. The gas species and the neutral gas pressure can be controlled by mass flow controllers. The magnetic field configuration can be adjusted by the positions of the coils, and the magnetic field strength by a dc power supply. By setting those three external control-parameters, i.e. the microwave power, the neutral gas species and the pressure, and the magnetic field configuration, the HYPER-I device is capable of producing a variety of plasmas to explore various plasma phenomena. The HYPER-I device also offers a variety of electrical and optical diagnostics as described below.

For electrical diagnostics, five relocatable probe-driving systems enable us to perform various probe measurements, e.g. conventional Langmuir probes, directional Langmuir probes (DLPs), and emissive probes, in different axial and radial positions, which provide information on the electron temperature, electron density, and plasma potential. The high-impedance wire grid (HIWG) with fast voltage followers has been developed for two-dimensional measurement of the floating potential variation due to an intermittent change in electron flux, which has been found in the HYPER-I device recently.²⁾ The DL750P ScopeCorder (Yokogawa) can be used for multi-channel waveform recording up to 16 channels.

For optical diagnostics, two tunable external cavity diode lasers (ECDL) systems and a 30 Hz tunable pulsed

dye laser system are available to perform the laser induced fluorescence (LIF) measurement of metastable argon neutrals and metastable argon ions, which give the velocity distribution functions of those target particles. A very high accuracy calibration of the frequency of ECDLs can be performed by introducing a saturated absorption spectroscopy unit into the LIF systems. Utilizing the Doppler-free Lamb dip as a frequency standard, we have achieved the maximum velocity resolution of 2 m/s.³⁾

In addition, an image intensified CCD camera (ICCD) system has been introduced to conduct two-dimensional optical emission spectroscopy measurement, which is in full-fledged operation in this fiscal year. Optical band-pass filters for various line emissions (helium, neon, and argon) have also been prepared. This system can be used to obtain time-resolved images of optical emission on the plasma cross-section.

The research activities of the HYPER-I experiment group cover a broad range of topics. The achievements of this fiscal year reported in this annual report are as follows: (i) Axial profiles of density and electric field in a diverging magnetic field associated with ion streamline detachment, (ii) Statistical analysis of an intermittent phenomenon recently observed in the HYPER-I device, (iii) Wave excitation by low-frequency amplitude modulation of microwave, (iv) Development of a Fabry-Pérot interferometer for wavelength calibration of the pulsed laser system, (v) Development of a tunable *optical vortex*⁴⁾ laser for a novel plasma spectroscopy, and (vi) A preparatory experiment of shock wave excitation using the Double Plasma device at Oita University.

- 1) Tanaka, M. Y. et al.: Rev. Sci. Instrum. **69** (1998) 980.
- 2) Yoshimura, S. et al.: Europhys. Conf. Abstracts **36F**, *proceedings of 39th EPS and 16th ICPP* (2012) P2.181.
- 3) Aramaki, M. et al.: Rev. Sci. Instrum. **80** (2009) 053505.
- 4) Torres, J. P. and Torner, L. (ed.), *Twisted Photons – Applications of Light with Orbital Angular Momentum* (Wiley-VCH, Weinheim, 2011).

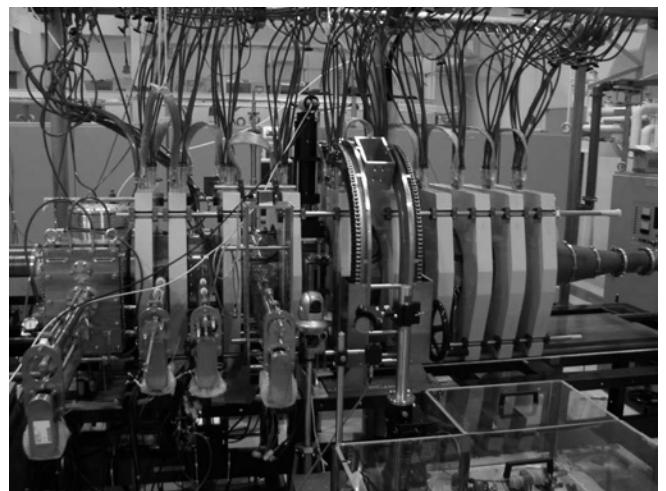


Fig. 1 A side-view photo of the HYPER-I device.