5. Basic, Applied and Innovative Researches

This section collects the reports of the NIFS collaboration researches in the basic plasma physics and the plasma physics application including researches for developing innovating concepts of magnetic confinement fusion. In addition to LHD device, NIFS supplies a middle-size plasma experimental device HYPER-I for the basic plasma research. Plasmas are produced with 80 kW CW microwave of 2.45 GHz and high density plasmas ($n_e > 10^{19}m^{-3}$) are obtained with the special heating scheme for overcoming the cut-off density of microwave. Several kinds of gas species are used with precise mass flow controllers. The neutral density is also carefully controlled as well as the plasma density to give well-defined experimental conditions. Reliable infrastructures for the device operation and full set of diagnostics provide useful environment for the cooperation researches on basic plasma physics. In the next page, six research reports are summarized for HYPER-I.

The progress of the experimental research on TU-Heliac (Tohoku University Heliac) is reported. The bifurcation phenomena of the plasma poloidal flow is extensively studied with two perturbation controls. The magnetic field perturbation is applied with two pairs of cusp field produced by the external perturbation coils. Another perturbation is given by the electric field produced by a biasing electrode. The variation of the poloidal flow were measured with a multi-points Mach probes and the gradual increase of the flow velocity was detected when the electric currents in a biasing electrode was increased. The measurements of the flow velocity distribution are also successful with a multi-channel spectrometer. Another report gives the data analysis results of the two-dimensional maximum entropy method (MEM) with polar coordinates for the H mode transition phenomena in CHS experiments. With the increase of the spatial resolution obtained by the enlarging the range of the regularization parameter in MEM, it was found that there are components which appear to extend to the opposite side of the plasma column.

From the basic experiments on the plasma turbulence, the analysis of particle tracing data is reported. By observing the random movements of glass spheres in the liquid crystal, the traveling distance was statistically analyzed for a given time periods based on the Hurst index. By changing the applied voltage on the liquid crystal, it was confirmed that the Hurst index approaches to the value of 0.5, which corresponds to the normal diffusive processes. When the voltage is low, the super-diffusive nature is also observed. Experiments with the effect of the rotation are planned with the Rossby number of 0.1.

The effects of magnetic nozzle field of MPDA (Magneto-Plasma Dynamic Arcjet) were investigated at Tohoku University for the magnetic field range up to 0.5 T. The plasma acceleration was increased with the magnetic field and the large thrust of 8 N was obtained with B = 0.28 T. The exhausted plasma flow velocity and ion temperature were measured by a spectrometer. They are increased with the magnetic field. While the plasma flow speed is gradually decreasing in the downstream region, the ion temperature increases due to the conversion of the flow energy to the thermal energy. The spatial distribution of plasma parameters of shock wave in an arcjet plasma was measured at Hiroshima University with an electric probe. The compression wave formed in the expansion region causes higher plasma density, resulting in the bright recombining plasma emission.

Characteristics of high current stabilized arc plasmas with a current density of GA/m^2 was studied in Kanazawa University. Images of the cathode hot spot were captured using a fast color camera. The local hot cathode spot rotates and heats the Hf cathode surface gradually and forms the larger cathode spot on the center of the electrode. For the purpose of studying the dynamic response of tungsten surface in the fusion device against the high plasma heat load, it is planned to replace the cathode material from Hf to tungsten.

Four cooperation researches are reported in the field of atomic and molecular sciences. Dependence of reflectivity of low energy ions on the surface conditions of silicon and graphite surface was investigated at RIKEN SPring-8. The charge transfer cross-sections of low energy tungsten ions with hydrocarbon molecules was studied in Kinki University. Plasma atomic processes were studied for the sputtered atoms on tungsten surfaces under the irradiation of Kr^+ ions and Ar^+ ions by analyzing the visible emissions. The iono-luminescence of thin Er_2O_3 coatings excited by slow highly charged ions influx was measured for the understanding of the energy transfer from highly charged ions to thin films.

Finally in the innovative concept researches for the magnetic confinement fusion, a new magnetic configuration is proposed for the improved design of LHD experiments. The analysis of magnetic configurations has been made for LHD experiments making a use of Fourier modes of plasma boundary shapes. It was found that the number of essential Fourier modes is very small for determining the fundamental characteristics of magnetic configuration for the confinement. By controlling two essential modes of helical excursion of the plasma column (non-planar structure of torus) and the rotating triangularity, a new configuration was proposed for the better performance of confinement. This configuration has a good neoclassical confinement similar to the inward shifted LHD configuration (R_{ax} = 3.6 m) together with the reduced Shafranov shift. These features are very important for high-beta experiments because the present configurations have a big degradation of the confinement due to a large Shafranov shift when the plasma beta is increased.

(Okamura, S.)