4. Basic Research and Development

The research activities of the HYPER-I (High Density Plasma Experiment) have been focused on the measurements of flow and structure formation. Because it has been understood that neutral particle flow plays an important role in the physics of the anti-E × B vortex, the development of the two-dimensional neutral particle flow diagnostics was started using the laser induced fluorescence (LIF) spectroscopy with argon gas. The quenching of the meta-stable atoms is a problem for a high density plasma ($n_e \sim 10^{19} m^{-3}$). Laser light chopping and lock-in amplifier technique was used for improving the signal to noise ratio.

Another scheme of LIF for the flow measurements of helium ions and atoms were developed. Two-photon absorption process is selected to excite helium ion from n=3 to n=5 and the emission of different wavelength is detected without the interference of stray light of exciting laser. For the measurement of helium atoms, a similar two-photon process was considered with slightly different wave length of the Nd:YAG laser. Both measurements can be conducted using the same dye and the same laser transmission optics.

Experiments to establish the Mach number measurement method with the facing-double probe (FDP) was performed using HIPER-I helium plasma ($n_e \sim 10^{16} m^{-3}$). The plasma flow along the magnetic field was measured and compared with the conventional Mach probe. The Mach number measured by FDP was 0.29 ± 0.04 and that by the Mach probe was 0.22 ± 0.09. The similarity of results confirms the availability of relatively simpler method of FDP.

Relatively simple method of probe measurement of ion temperature was evaluated using HIPER-I plasmas. The probe consists of disk-shape and cylindrical electrodes with cylindrical insulator surrounding them. The probe was inserted radially to the helium and argon plasmas and the measured ion temperatures were compared for three different heating power. Higher value of temperature was obtained for higher heating power in general but exceptional data were also obtained which is supposed to due to the effect of E × B drift motion.

Collision experiments of highly charged ions (HCI) with excited atoms were conducted using NICE device (Naked Ion Collision Experiment). Rubidium (Rb) was used for the excited atom with laser illumination for the excitation. Highly charged iodine ions I^{30+} were produced in NICE and injected to Rb atoms. Electron capture was measured for iodine beam.

For the basic research of electron-ion collisions, intense singly charged ion beam with 1 to 10 mA current was prepared. However the reduction of the space charge effect is very important for such a high density ion beam source in order to obtain good Auger spectroscopy. A low energy electron shower and a tungsten wire electron emitter was introduced to reduce the positive ion charge. Improvement in the Auger spectra was observed.

To contribute to the understanding of behaviors of hydrocarbons in the divertor and edge plasma region of fusion device with carbon-based plasma facing components, the charge transfer cross sections were studied for H^+ ions in collisions with C_xH_y molecules. Since the database for H^+ + C_3H_4 and C_3H_6 was poor, these cross sections were measured and compared with a model proposed by R. K. Janev.

A supersonic helium atomic beam source was developed for the purpose of the electric field measurements with polarization laser-induced fluorescence (LIF) spectroscopy. Combination of a gas injection nozzle and a skimmer with a horn aperture made it possible for the gas flow to be collimated within 1.1° and of high density $1.4 \times 10^{20} m^{-3}$.

Magnetized non-neutral plasma of electrons confined in the electro-magnetic traps was studied theoretically and experimentally. A closed model was proposed based on the drift-kinetic equation within a framework of the quasi-linear theory. The essential points derived from the theoretical model were quantitatively examined in the experiments.

Ion trajectories in the cylindrical plasma with E × B rotation were studied with the relation to the confinement improvement with the electric field and the ion species separation application. Ten concentric circular rings were used as biased electrodes to control the electric field profile. Experiments started using $1 \times 10^{16} m^{-3}$ plasma produced by 7 MHz RF source.

An experiment of controlling the composition of positive ions (molecules) was done using the 915 MHz ECR plasmas. H^+, H_2^+, H_3^+ were measured with a quadrupole mass spectrometer. By adjusting the magnetic field strength profile along the axis, a condition of strong H_3^+ production was found. A special wave propagation scheme is possible candidate for such a special condition.

Quenching process of plasma torch with gas flow injection was studied. CO_2 and H_2 gas mixture was introduced to the argon plasma torch. The vibrational and rotational temperatures were measured with a different admixture ratio of H_2 component in the gas flow.

Fundamental characteristics of a pyroelectric detector designed for the neutral particle beam measurements were measured using positive ion beams. By comparing the pyroelectric signal with a beam current flux measurement, good linearity for the power (energy) and the current (flux) was obtained. Reflection of low energy ions from a vanadium alloy was studied varying the incident angles. TE011 mode cavity was prepared for the detection of the cyclotron resonance maser instability. Neoclassical parallel viscosity was studied analytically for the drift-optimized magnetic configuration of heliotron devices.

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