4. Basic, Applied, and Innovative Research

As an inter-university research institute, NIFS activates collaborations with researchers in universities as well as conducting world-wide top level researches. The collaboration programs in basic, applied, and innovative research support research projects motivated by collaboration researchers in universities. It is also important to establish the academic research base for various scientific fields related to fusion science and to maintain a powerful scientific community to support the research. Programmatic and financial support to researchers in universities who work for small projects are important.

For basic plasma science, NIFS operates several experimental devices and offers opportunities to utilize them in the collaboration program for university researchers. A middle-size plasma experimental device HYPER-I is prepared for basic plasma research. The compact electron beam ion trap (CoBIT) for spectroscopic study of highly charged ions, atmospheric-pressure plasma jet devices for basic study on plasma applications, and other equipment are operated for collaborations.

(I. Murakami)

Positive and negative ion reflections of low-energy ion beams from materials surface

We have studied the reflection of the positive and the negative hydrogen ions from the Highly oriented pyrolytic graphite (HOPG) and Mo surfaces on injection of several hundreds of eV to 1 keV of ion beams of H^+, H_2^+ and H_3^+ ions. The energy spectra of reflected ions were detected by a momentum analyzer, and both reflected positive and negative peaks were investigated [1]. The results showed clear difference between atomic and molecular ion injections. The intensity ratio of reflected negative to positive ions H^-/H^+ increased as the incident beam energy per nucleon decreased only when molecular ion beams are injected (Fig. 1). This implies that negative ions are more produced upon beam-surface interaction when molecules are injected. The incident energy dependence of the H^-/H^+ ratio was not observed for the H^+ ion injection. This could be explained by the difference in negative ion production processes between atomic and molecular ions. Both are neutralized once as they approach the surface. On the one hand, atomic ion requires tunneling effect for the electron capture to become a negative ion. The other hand, the molecular ion dissociates as an ion pair of H^+ and H^- via excitation to an anti-bonding state of molecule.

(N. Tanaka, Osaka University)

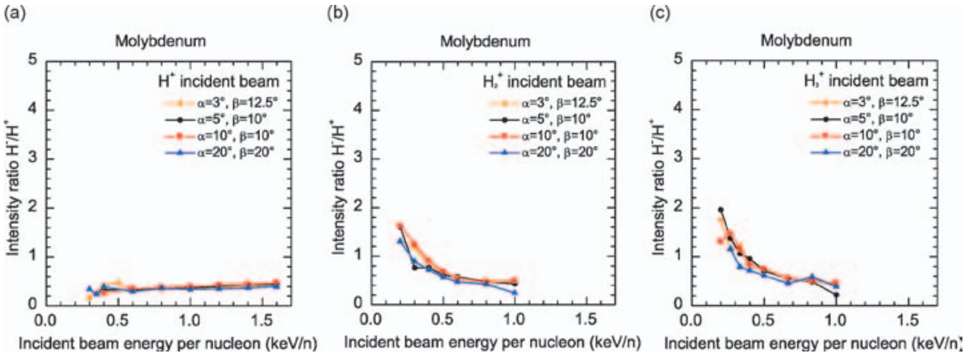

Fig. 1 Incident-beam energy dependence of the negative to positive ion intensity ratio for the incident beams of (a) H^+, (b) H_2^+, and (c) H_3^+ on the molybdenum target. [1]

Experimental turbulent transport study using electroconvection turbulence

Turbulent transport is a basic subject in a variety of research fields, such as fusion plasma, normal fluids, space/astrophysical plasmas, quantum fluids, and superfluid. An electroconvection (EC) turbulence, which can be driven by electric field in a liquid crystal, was newly applied to turbulent transport study. Due to the excellent controllability and easy flow pattern measurement (see Fig. 2), the diffusive nature of turbulent transport was clearly identified in an EC turbulence. The effective diffusion coefficient is observed to increase with Rayleigh number, which is consistent with normal fluid turbulence [2]. We also observed a variety of interesting phenomena such as rotational effects on turbulent transport, turbulence penetration toward convectively stable region, deviation of velocity distribution function of tracer particles in EC turbulence etc. The turbulence suppression effect due to flow shear which is a very important phenomenon in magnetically confined fusion plasma experiments will be also investigated in the future.

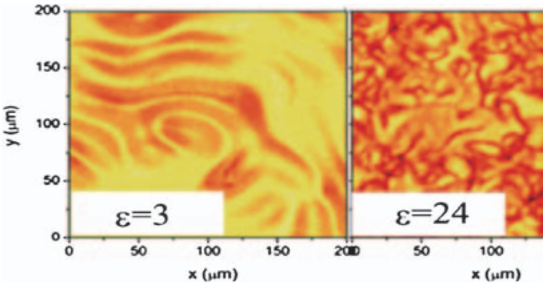

Fig. 2 Flow pattern of electroconvection turbulence with the normalized Rayleigh number of ε = 3 and ε = 24. The brightness indicates the parallel velocity to the line of sight.

(Y. Hidaka, Kyushu Univ., K. Nagaoka)

Multi-wavelength high-time resolution spectroscopy of atmospheric pressure plasma

Measurement of the electron temperature and density is one of the essential issues in atmospheric pressure plasma. Utilizing continuum emission due to bremsstrahlung of electron colliding with neutral particles is a promising method. On the other hand, high-time resolution is required because the plasma is usually produced in pulsed operation. Optimal color bands have been determined from a time-averaged spectrum of an atmospheric pressure plasma device in NIFS as shown in Fig. 3. The electron density $n_e = 3\times10^{19}$ m^{-3} and $T_e = 0.3$ eV is deduced from the bremsstrahlung curve fitting of the spectrum. Then, we have developed a two-color spectrometer with interference filters based on a grating spectrometer for high-time resolution spectroscopy [3]. Instantaneous emission in the 527 – 537 nm pass band measured with the spectrometer reaches about 3 μW/cm^2/sr, which is one order higher than that for the time-averaged spectrum. The result implies that high density plasma is ejected from the device in a short duration of about 0.1 ms.

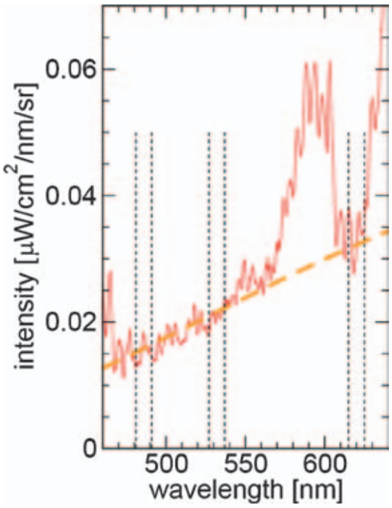

Fig. 3 Spectrum of atmospheric pressure plasma consists of bremsstrahlung continuum (fitted by thick broken curve) and band emission (560 – 600 nm). Dotted lines show candidates of filter pass band for high-time resolution spectroscopy.

[1] N. Tanaka *et al.*, Rev. Sci. Instrum. **91**, 013313 (2020).

[2] K. Nagaoka, S. Hotta, Y. Hidaka, T. Kobayashi, K. Terasaka, S. Yoshimura, High Energy Density Physics vol.31 79–82 (2019).

[3] A. Okamoto, *et al.*, Plasma Fusion Res. **14**, 1201165 (2014).

(A. Okamoto, Nagoya Univ.)