## §4. Neutral Flow Field Measurement Using a Single-mode Tunable Diode Laser

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Formation of vortices has been a topic of interest in plasma physics, since vortices are considered to play an important role in transport and turbulence. A plasma in a magnetic field is subjected to drift motions, among which *E* x *B* drift is the key mechanism for producing vortical motions.

Recently, an anti-*E* x *B* vortex, which is characterized by rotation opposite to the *E* x *B* direction, has been observed in a magnetized plasma. This result suggests that there exists a force acting on ion fluid which dominates the electric field. Momentum transfer during charge exchange interaction between ions and neutrals may drive the anti-*E* x *B* vortex, because the force generated in this process is expected to be large (Sena effect) and its direction is opposite to the electric field.

Although visualization of neutral velocity field is needed to study the dynamics of plasma interacting with neutrals, it has not been done so far. The main reason is that the expected flow velocity is too slow to be detected by LIF Doppler spectroscopy with conventional laser technique.

Spectral bandwidth of extended cavity diode laser (ECDL) is narrow enough for measuring slowly flowing neutrals. To realize a high-resolution LIF Doppler spectroscopy, however, calibration method for absolute frequency should be established. An absorption line of iodine is usually adopted as the reference frequency, but the absorption line is subjected to Doppler broadening (typically 1GHz), and the conventional method for frequency calibration is not enough for our present requirement

It is much more suitable to use Doppler-free spectrum in the reference frequency determination. We have developed a new LIF system by integrating saturated absorption spectroscopy. Figure 1 shows the (a) LIF spectrum, (b) saturated absorption spectrum, (c) resonance output of a Fabry-Porot interferometer, of the new system. There are three Lamb dips in Fig.1(b). The width of Lamb dip is very narrow (typically a few tens MHz) so that the frequency calibration is carried out with much higher precision. We have utilized the center Lamb dip as the reference frequency. It is worth pointing out that the position of center Lamb dip corresponds to the origin of velocity axis (see Ref.1)

To confirm the long-time stability of the whole system, we have repeated, under the same discharge condition, the LIF measurements for 5 hours, and observed the dispersion of peak position of the LIF spectrum. Figure 2 shows the peak position of LIF spectrum as a function of time, where the open circles indicate the peak position. As seen in the figure, the deviation of peak position from the mean value is within a range of ±3MHz. The corresponding dispersion in velocity is ±2 m/s, which gives the maximum velocity resolution of the present system. It is emphasized that the deviation of peak position becomes large when we use an iodine cell for frequency calibration, which is also shown in Fig.2.

In the three-year LHD collaboration program, we have developed a high-resolution LIF system[1)] using a narrow line-width tunable diode laser. Saturated absorption spectroscopy is introduced for the laser frequency calibration, and the velocity resolution of ±2 m/sec is achieved. The experiments with an ECR argon plasma revealed that this high performance is maintained for at least 5 hours. The radial flow velocity of metastable argon atoms has been successfully measured. It is found that there exists a radially inward flow of the order of 10 m/sec, which is probably driven by neutral depletion in the central region of the plasma[2)]. The detailed results will be reported elsewhere. Since visualization of neutral flow field has not been done yet, the newly developed LIF system will become a powerful tool for studying boundary plasma.

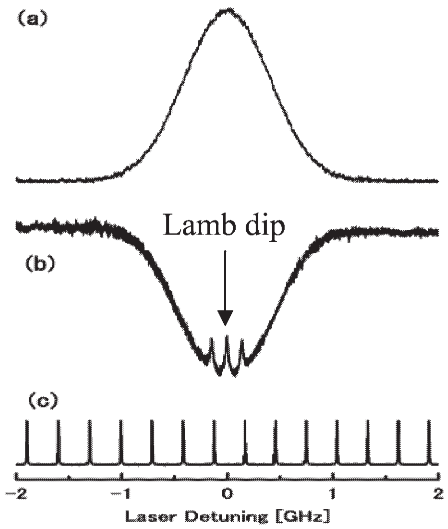


Fig.1 (a): LIF spectrum; (b): saturated absorption spectrum; (c): output of Fabry-Perot interferometer.

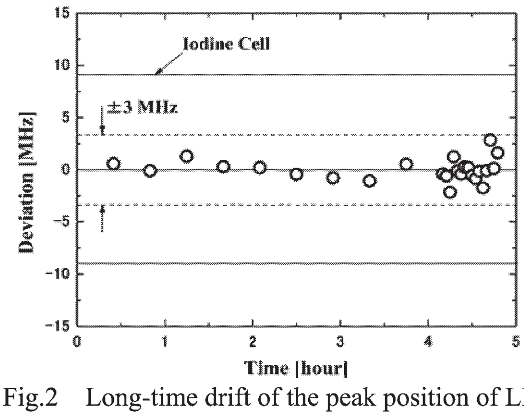


Fig.2 Long-time drift of the peak position of LIF spectrum

1) Aramaki M. et al Rev. Sci. Instrum. 80 (2009) 053505
2) Tanaka M.Y. et. al. Frontiers in Modern Plasma Physics (AIP, New York, 2008) vol. 57