§37. Neutral Particle Behavior in the Edge Plasma of TRIAM-1M Tokamak Measured Using Zeeman Spectroscopy (NIFS04KUTR001)

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Standard passive spectroscopy yields only a line-integrated emission along the viewing chord. In order to obtain the local plasma parameters, active methods such as the charge exchange spectroscopy, which makes use of a neutral beam injection, have been applied for highly-charged (usually hydrogenic) ions in core region. We have been developed a method in which local information can be obtained from the Zeeman patterns even in the device without NBI [1]. In principle, this method can be applied both to the core and the boundary region. We have shown that the radial position of emission, temperature and the flow velocity in the position can be determined from the best-fit of the spectral line shape calculated by taking into account the Zeeman profile, the Doppler broadening and the Doppler shift [2]. In the present report, we have applied this method to the flow measurement of neutral atoms in the edge region [3].

The experiments were performed in the TRIAM-1M super-conducting tokamak under the condition of 8.2 GHz lower hybrid current driven discharge. The magnetic field strength of about 7 T at the plasma center was generated using sixteen Nb_3Sn super-conducting toroidal field coils. The plasma boundary shape was restricted by three D-shaped poloidal limiters and one vertically movable limiter installed in the upper port of the vacuum vessel. All plasma-facing components were made of molybdenum.

The emission from the atoms was observed using fan-shaped 25 viewing chords in the poloidal section. In front of the objective lenses, a linear polarizer was attached with its polarization axis perpendicular to the toroidal field direction for the observation of the σ components. The collected emission was dispersed using a spectrometer (Acton Research AM-510) having a focal length of 1 m and equipped with a 1800 grooves/mm ruled grating. The dispersed image was detected by an electrically cooled back-illuminated CCD (Andor DU440-BU2). The dimension of the CCD chip is 2048 x 512 pixels and each pixel size is 13.5 x 13.5 μm^2.

The flow velocity of hydrogen and helium atoms were measured based on the Doppler shift of the separated spectra. Figure 1 shows the measured flow velocity profiles for the cold temperature components (< 1eV) of the hydrogen and helium atoms. The velocities were measured as projections on the viewing chords. A positive value of the velocity denotes a red-shift of the spectrum directing towards the inboard side, while a negative value shows the opposite. One can see that the obtained flow profiles indicate an inward neutral flow in both the hydrogen and helium cases. The reason for the inward neutral flow can be explained from the initial velocity and the momentum balance in the radial direction. With the neutral pressure gradient and ion-neutral friction forces, the neutral momentum balance equation in the radial direction can be written as

$$m_0 n_0 \frac{dv_{r0}}{dt} = -\nabla_r p_0 + m_0 (v_{ri} - v_{r0}) n_0 n_i \langle \sigma v \rangle_{i0(ela,cx)},$$

where m_0, n_0, v_0 and p_0 are the neutral mass, density, drift velocity, and pressure, respectively. v_i and n_i are the ion velocity and density, and $\langle \sigma v \rangle_{i0(ela,cx)}$ is the reaction rate of ion-neutral elastic and charge exchange collisions. The source and sink terms due to the recombination and ionization processes in the continuum equation are included as $v_{r0} \nabla_r n_0 = S$, namely the $\nabla_r p_0$ term, where v_{r0} is assumed to be constant and S represents the summation of the source and sink terms. The ratio of the pressure gradient force (inward) to the ion neutral friction force (outward) in the above equation can be written with the thermal velocity v_{th0} and scale length L_{n0} of the neutrals as $R \approx -v_{th0} / L_{n0} n_i \langle \sigma v \rangle_{i0(ela,cx)}$. Under the achievable experimental condition of TRIAM-1M, the ratio R becomes larger than unity, that is to say the pressure gradient force is at least several times larger than the friction force. Moreover, one should bear in mind that the initial velocity when the neutrals are released from the wall is directed inward. It can be concluded, therefore, that the neutral dynamics is mainly dominated by the radial neutral pressure gradient. In addition, in the figure, the observed inward flow velocity is higher in the case of hydrogen than helium. This fact also suggests that the flow is driven by the pressure gradient in which the velocity is inversely proportional to the mass.

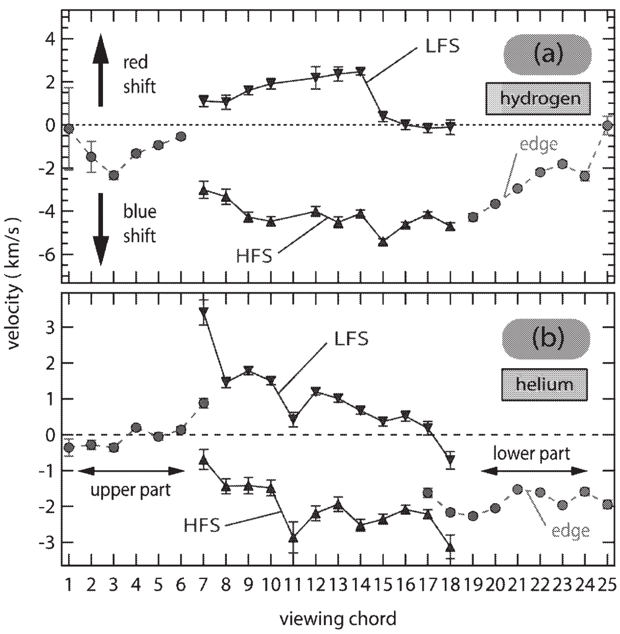

Figure 1: The measured flow velocities of the cold temperature components of hydrogen and helium atoms.

References

1) J. Weaver, *et al. Rev. Sci. Instrum.* **71** (2001) 1664.
2) T. Shikama, *et al. Phys. Plasmas* **11** (2004) 4701.
3) T. Shikama, *et al. Plasma Phys. Control. Fusion* **48** (2006) 1125.