2.6 Proton ratio of HL-2A bucket ion source

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The ion beam extracted from the ion source consists of $H^+_i$ and $H^+_i$ ions. All these particles interact with the neutralizer gas leading to neutralization and, for molecular ions, to dissociation as well as to excitation of resulting neutral atoms. The image spectrograph analysis of the Doppler shifted Balmer-α-radiation spectrum emitted from the excited fast neutral atoms in the beam gives the spectra distribution. The Balmer-α-radiation spectrum is collected in the neutralizer by a light guiding system designed by us as shown in Fig. 1.

![Fig. 1. Light guiding system.](image)

The lighting guiding system is installed in a diagnostic window in the neutralizer. There is a mirror to reflect the light emitted by excited collision with the angle of 30° between the direction of ion beam and the viewing direction, and the light from the other angle is absorbed by the black wall of pipe when these residual lights enter into the light guiding system. A convex lens used to focus the light to the light fiber is installed near the end of the light guiding pipe. The emitted light is collected by battery of lens and transported to the entrance slit of an imaging spectrograph by fiber optics.

Fig. 2 shows a typical spectrum, which consists of three blue shifted peaks of the full, half and the third energy components, obtained in the neutralizer for a 36 kV hydrogen ion beam with the ion current of 19 A.

The area integrals $S_i$ of the fitted Gaussian peaks represent the measured counts per spectral peak. The species distribution can be obtained by weighting the ratio of the peak integrals with the respective cross section ($\sigma^+\eta$) of $H_i$ spectra as follows:

$$\frac{n_i^+}{n_i^-} = \frac{S_i}{S_j} \frac{\sigma^+_i}{\sigma^-_i} = C_2 \frac{S_i}{S_j}$$ (1)

$$\frac{n_i^+}{n_i^-} = \frac{S_i}{S_j} \frac{\sigma^+_i}{\sigma^-_i} = C_j \frac{S_i}{S_j}$$ (2)

Where,

$$C_2 = \frac{\sigma^+_i}{\sigma^-_i}, C_j = \frac{\sigma^+_i}{\sigma^-_i}$$

![Fig. 2. The data obtained by spectrometer.](image)

![Fig. 3. Species distribution vs ion density.](image)

According to the equation above, the fraction of every component is calculated. With the increasing of the ion density, which in chamber is estimated to be two times than that near plasma grid, the fraction of the proton increases quickly, the

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fraction of $H_2^+$ decreases also very quickly. The fraction of $H_3^+$ decreases very slowly, even doesn’t change.

Fig. 3 Shows species distribution us ion density. Utilizing the model that Zhang Huashun and Yoshikazu Okumura, et al., devised the reactions with low cross section are neglected. For simplicity two species, $H^+$ and $H_2^+$, are considered, and $H_3^+$ doesn’t significantly affect the proton ratio. The expression for ratio of the distribution of $H^+$ and $H_2^+$ in chamber of ion source as derived below:

$$\frac{n_1}{n_2} = \frac{n_{1,2} \langle \sigma v \rangle_s}{\frac{1 + 2 \langle \sigma v \rangle_s}{n_{1,2} \langle \sigma v \rangle_s} + \frac{1}{n_2 \langle \sigma v \rangle_s}}$$

(3)

So take the parameters of the ion source into the equation above, it is found that the ion beam current ratio of $H^+$ ($I_1^+$) and $H_2^+$ ($I_2^+$) can be expressed as function of $n_e$:

$$\frac{I_1^+}{I_2^+} = \frac{C_0 n_1}{C_0 n_2} = \frac{\sigma n_1}{n_2} = 3.88 \times 10^{-34} \frac{V^2}{S} \frac{V}{n_e} + 1 \frac{2.06 \times 10^7 S}{n_2} \frac{V}{V}$$

(4)

And the expression of proton ratio is

$$R = \frac{I_1^+}{I_1^+ + I_2^+} = \frac{I_1^+}{I_1^+ + 1}$$

(5)

From the equation above, we can find that the proton ratio is related to the electron density in the ion source and the geometrical parameters. The value of proton ratio with the increasing of ion density in experiment is in agreement with that by calculation in theory utilizing the mode devised by Zhang Huashun and Yoshikazu Okumura, et al.