Analysis of the $H^-$ Extraction in the Linac4 Negative Ion Source by 2.5D Particle Simulation

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ABSTRACT

Linac 4 creates a surface negative ion source that is produced to require 50 mA of H$^-$ at a normalizing emittance of 0.25 fs-rm. In order to achieve the requirements, it is necessary to understand the mechanisms of the H$^-$ beam extraction and optimize the process. Recently, the effects of the operation parameters (e.g., magnetic filter and plasma electrode shape) on the H$^-$ extraction have been investigated by the simulations [4] and the experiments [1-3]. However, the optimization methods have not been completely analyzed. Therefore, the purpose of this study is to analyze the operation parameters and re-investigate the effects of the extraction conditions on the H$^-$ beam current and divergence in the Linac4 negative ion source by using the 2D-PIC model. 2D models are useful to understand the basic physics of the H$^-$ extraction [5-7] and are suitable for a wide range of the parameter surveys of the operation parameters. In this study, the mechanisms of the H$^-$ transport and extraction are investigated for the first step to validate the model and to take important effects into account for a reasonable parameter survey. We have analyzed the beam divergence in the volume case and the effects of the following collisions on the H$^-$ extraction have been analyzed in the surface case; elastic ($H^+_2 - H^+_2$) and charge exchange ($H^+_2 - H^-$). In the volume case, the typical tendency between the beam divergence and the extraction voltage has been obtained. The results show that the beam divergence depends on the shape of the plasma meniscus. In the surface case, the $H^-$ current has increased and the $H^-$ divergence has decreased due to the collisions. This is because the flow reversal at the deep position was caused by the collisions in the Linac4 negative ion source; the flow reversal of the $H^+$ ions due to the collisions of $H^+_2 - H^-$ and $H^-$ possibly becomes one of the important mechanisms of the H$^-$ extraction.

SIMULATION MODEL

The tendency of the current with a minimum value which is the typical tendency obtained in the experiments has been obtained.

RESULTS

As seen in Fig. 3, each total H$^-$ current is 20–25 mA and the e/ω$^2$ ratio is 2–6 in both cases. The beam waveform is different for the extraction voltage, where $vp_k$ is electron Debye length ($vp_k = 1.05 	imes 10^9$ ns) and field lines are uniform in the z direction.

CONCLUSION

In this study, three cases (Volume Source, Surface source case and Surface source case) shown in Table I have been calculated.

The simulations have been calculated under the conditions shown in Tables (4,9,10) with the time step $\Delta t = 0.4/vp_k$, where $vp_k$ is plasma frequency ($vp_k = 5.65 \times 10^9$ rad/\textmu s).

REFERENCES