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Numerical study of the plasma meniscus shape and beam optics in RF negative ion sources

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In order to extract intense ion beams with good beam optics from hydrogen negative ion sources, it is important to control the shape of the plasma meniscus (i.e. beam emission surface). In our previous study [1], it is shown that the plasma meniscus in the negative ion source depends on the H- -electron density ratio as well as the bulk plasma density. Recently, it is pointed out experimentally that the poor beam optics in the RF negative ion sources may be due to the fluctuation of the shape of the plasma meniscus resulted from the fluctuation of the plasma density[2].
The purpose of this study is to clarify the physical mechanism for the poor beam optics in the RF discharge numerically. Especially the dependence of the shape of the plasma meniscus on bulk plasma density is investigated. For this purpose, 3D-PIC (three-dimensional Particle-in-Cell) simulation was conducted for a model geometry of the extraction region for the Linac4 H- ion source in CERN. The preliminary results show that the shape of the plasma meniscus depends on the bulk plasma density: In the case of the optimum plasma density, the plasma meniscus shape is flat, and the resultant beam optics is good. If the plasma density is slightly higher (12 %) than the optimum density, the plasma meniscus shape is convex while if the plasma density is slightly lower (20 %) than the optimum density, the plasma meniscus shape is concave. In these plasma densities, the beam optics is poor. This result qualitatively agrees with the typical experimental result, and supports the above hypothesis for the poor beam optics in the RF negative ion sources.

[1] K. Hayashi, et al., Effect of negative ion sheath on beam extraction in negative hydrogen ion sources , International Conference on Ion Sources 2021, oral presentation, online, September 2021.
[2] Y. Haba et al., Jpn. J. Appl. Phys., 59 SHHA01 (2020).

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