

Characteristics of the Extracted Negative-Ion Beam in a Cesium-Free Negative-Ion Source using TPDsheet-U

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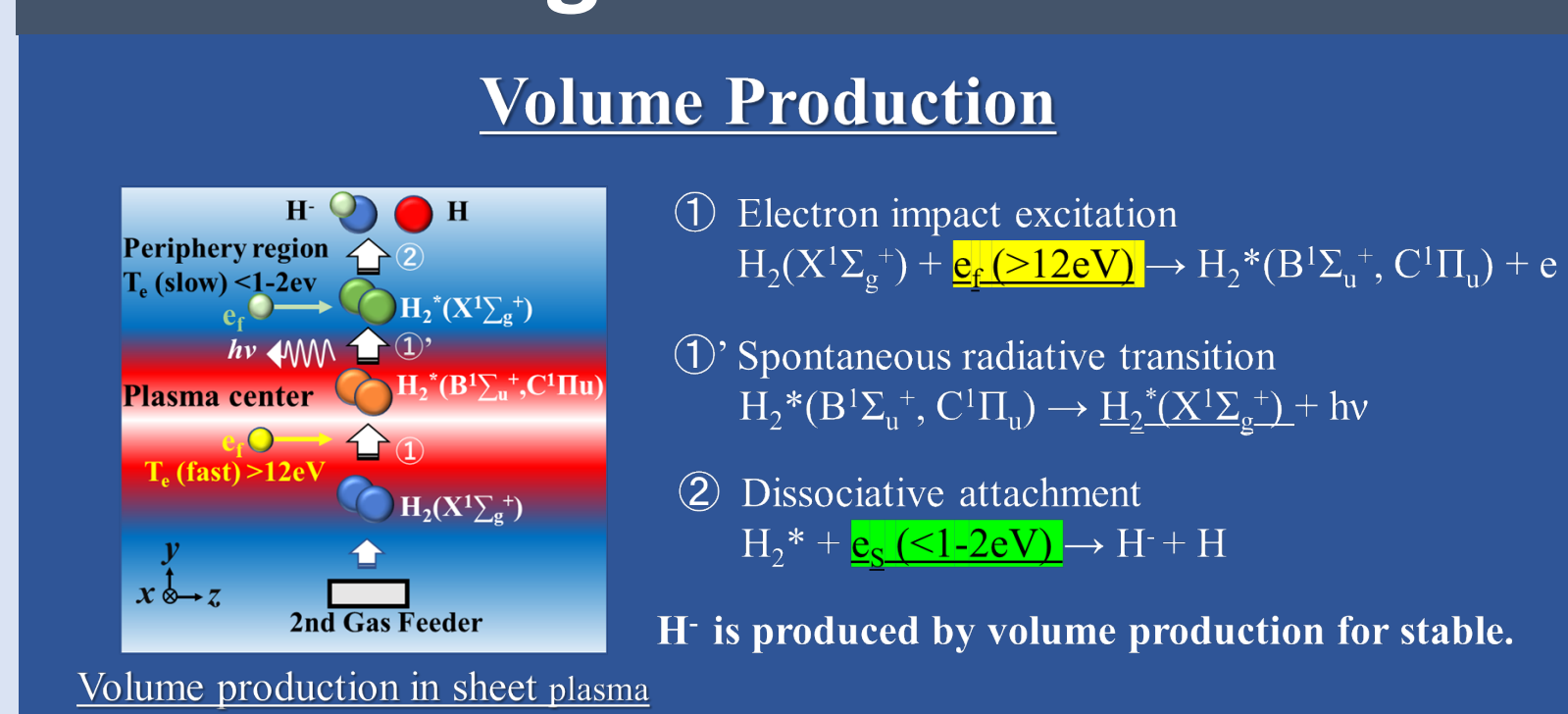
ABSTRACT

- This study reports a progress toward realizing a high-performance Cs-free negative ion source, that produces negative ions by volume production in a magnetized-sheet plasma device (TPDs sheet-U).
- Negative hydrogen ions are successfully extracted from the sheet plasma by single/multi-aperture grids, and the ratio of the extracted electron current $J_{EG}(e)$ and hydrogen negative-ion current $J_c(H^-)$, J_{EG}/J_c decreases from 10 to 0.2 with a soft magnetic material plate (SMP), which is a physical filter that prevents electron diffusion from the extraction region.
- The J_c is approximately 5-8 mA/cm² at V_{ex} of 10 kV, I_d of 80 A, the gas pressure of 0.3 Pa, and the magnetic field strength of 40 mT.

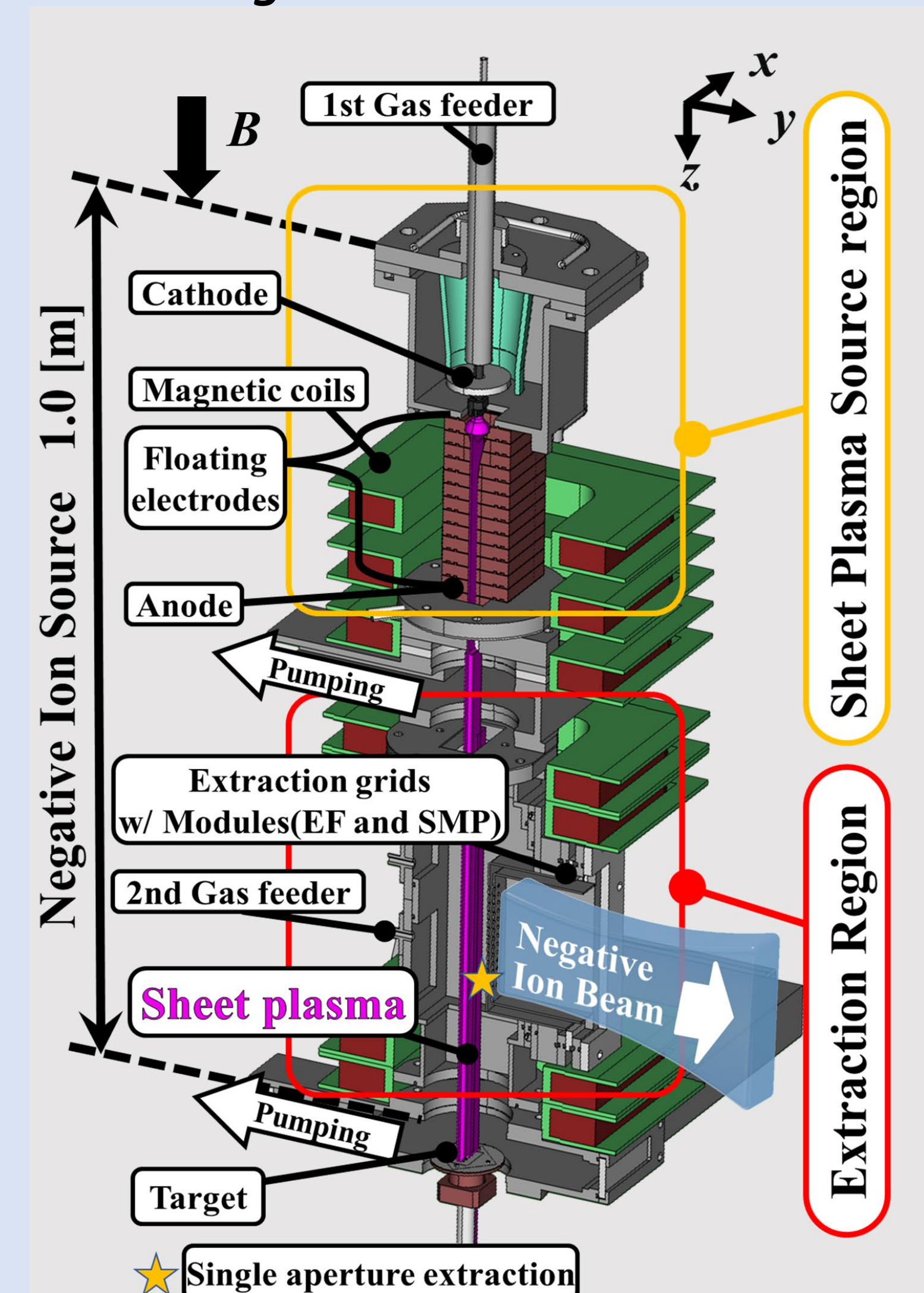
BACKGROUND

- Most negative-ion sources use Cs to comply with the strict requirements. However, a careful control of the amount of Cs vapor is required, and regular maintenance becomes difficult for long-time operations. Thus, the Cs consumption must be reduced, or alternative method for a Cs-free ion source is highly necessary.
- The reduction of electron co-extraction is also a common and essential issue for all negative-ion sources. A co-extracted electron causes power wastage and a high heat load of the extraction grid.
- This study presents a design of Cs-free negative ion source using volume production in TPDsheet-U with a single- and multi-aperture grid and the characteristic of the developed extraction system on it. We have applied a soft magnetic material plate (SMP) in this study. to reduce the electron co-extraction.

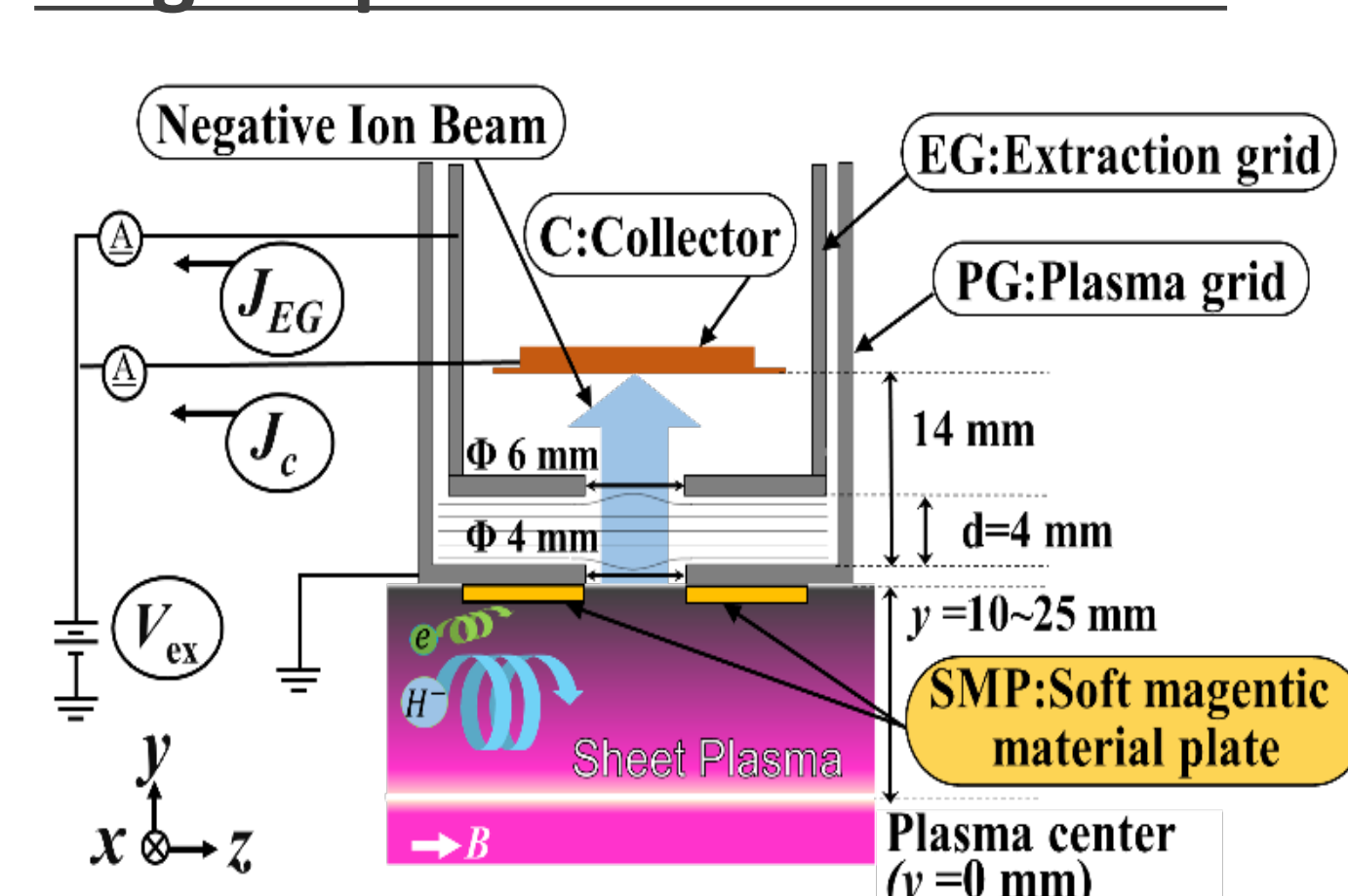
Cs-Free Negative-Ion Source TPDsheet-U



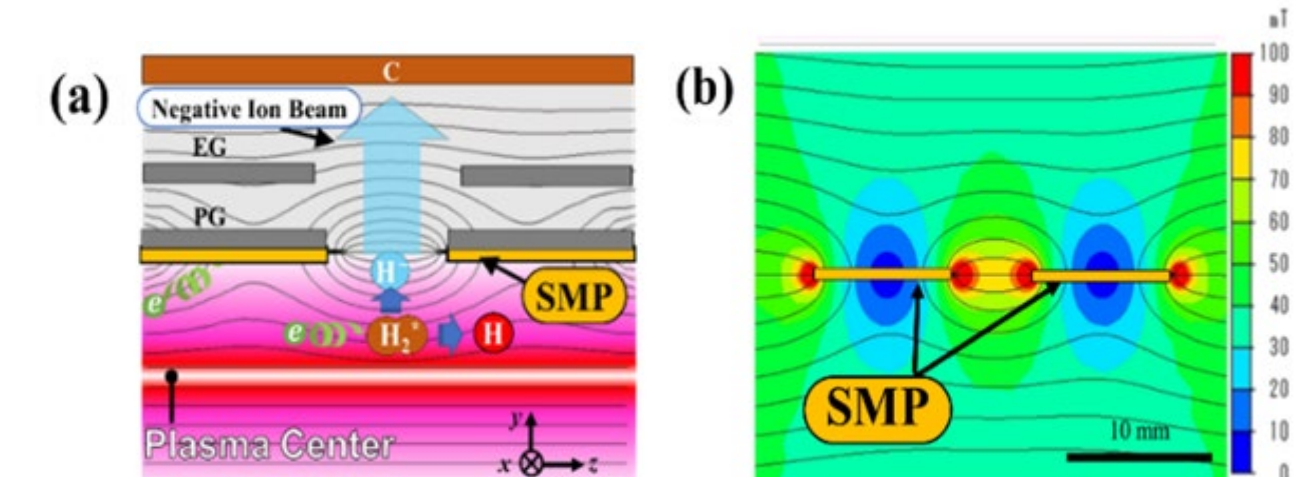
Cs-Free Negative-Ion Source TPDsheet-U



Single-Aperture Grid with SMP

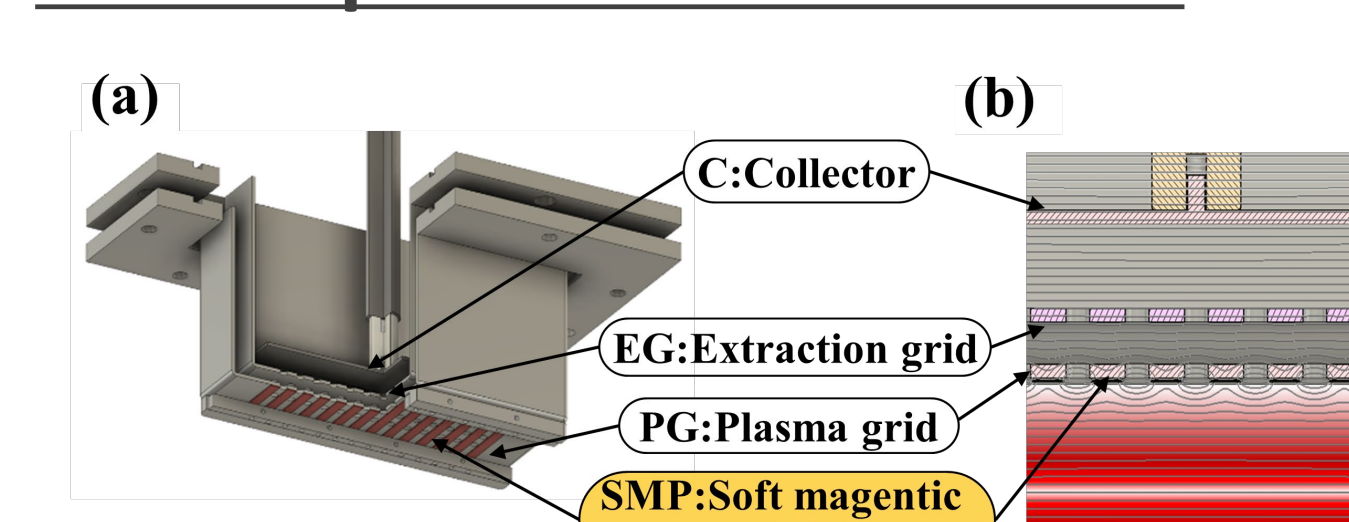


SMP was positioned near the PG aperture on the source plasma side (thickness: 0.3 mm; width: 30 mm; and length: 10 mm)



The electron current can be effectively reduced bending the magnetic field lines and by trapping electrons with the SMP at the extraction region.

Multi-Aperture Grid with SMP



OUTCOME

Basic Characteristics of Sheet Plasma

A magnetized sheet plasma is suitable for generating negative hydrogen ions through dissociative attachment because the distance between the region containing high-energy electrons (10–15 eV) and low-energy electrons, which is the region just in front of the grid ($y = 10 - 25$ mm).

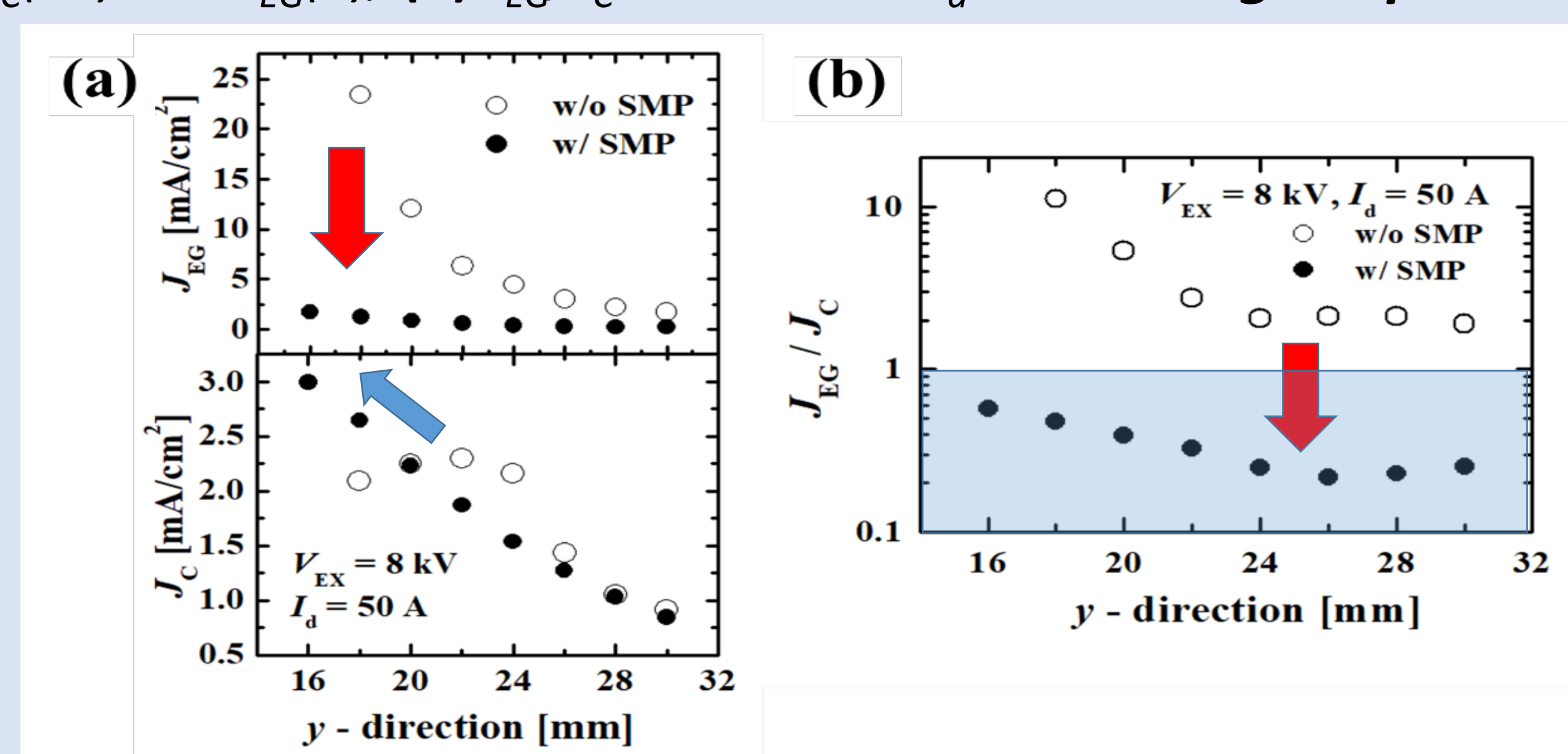
Effects of the SMP on Extracted Ion Beam of Single

The SMP is effective in reducing the electron co-extraction. The ratio of the extracted electron current $J_{EG}(e)$ and hydrogen negative-ion current $J_c(H^-)$, J_{EG}/J_c decreases from 2 to 0.2 with SMP, which is a physical filter that prevents electron diffusion from the extraction region.

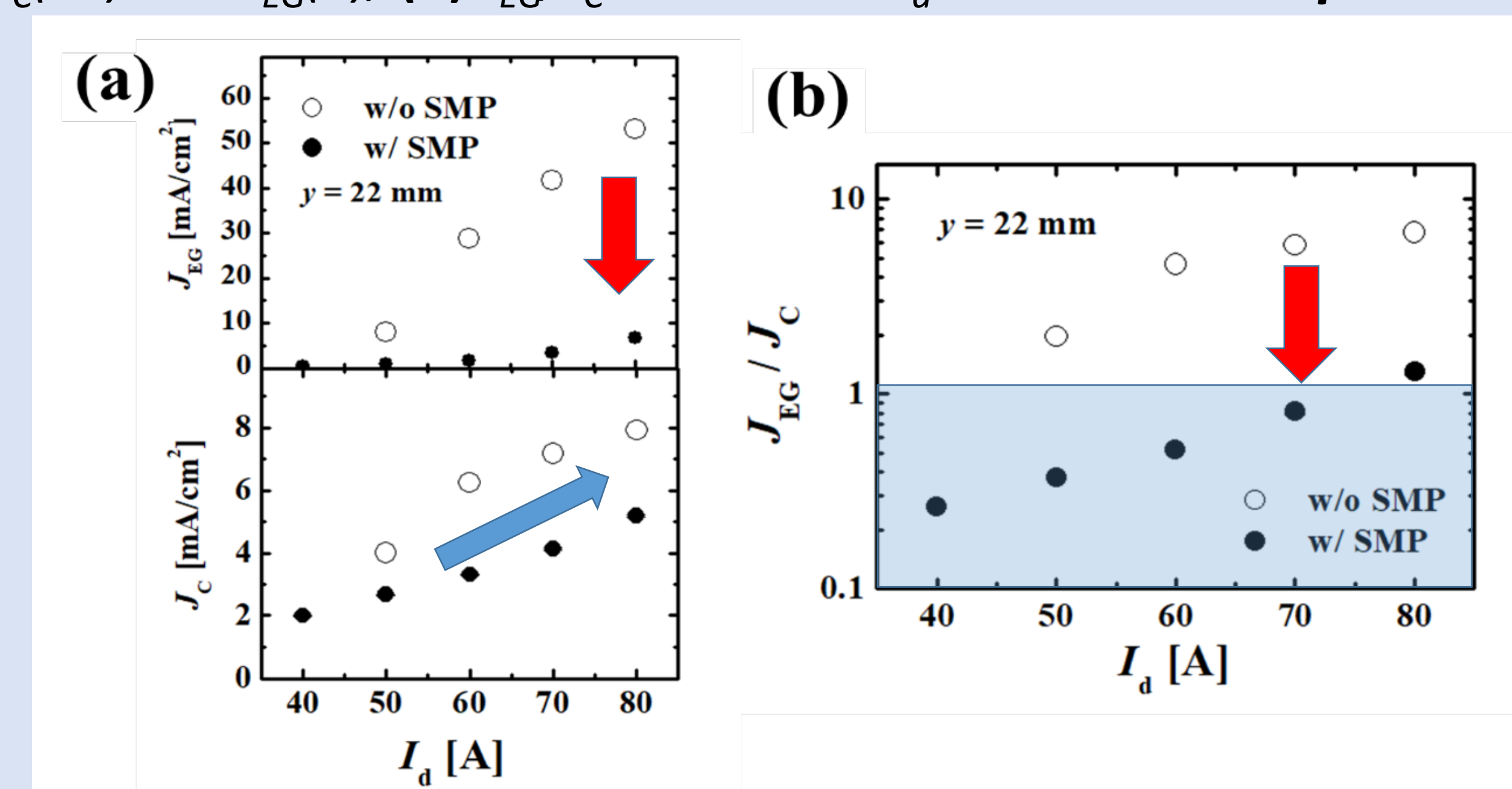
Extracted Ion Beam of Multi-aperture Grids with SMP

Negative hydrogen ions have been successfully extracted from the sheet plasma on the multi-aperture grids. The negative ion current density J_c was about 5-8 mA/cm² under the following conditions: extraction voltage V_{ex} of 10 kV, discharge current I_d of 80 A, gas pressure of 0.3 Pa, and magnetic field strength of 40 mT. The electron current $J_{EG}(e)$ with the SMP is reduced by about 85% compared to that without the SMP.

(a) $J_c(H^-)$ and $J_{EG}(e)$, (b) J_{EG}/J_c ratio versus I_d on the *Single-Aperture Grids*



(a) $J_c(H^-)$ and $J_{EG}(e)$, (b) J_{EG}/J_c ratio versus I_d on the *Multi-Aperture Grids*



CONCLUSION

- In this work, the characteristics of extracted beam current by single and multi-aperture grids with SMP are investigated in a magnetized sheet plasma system without Cs seeding (TPDs sheet-U).
- The SMP is effective to reduce the J_{EG}/J_c as a physical filter to prevent the diffusion of electrons from the extraction region.
- The performance of the current density of the negative hydrogen ion beam J_c without Cs on TPDsheet-U is approximately half of that of the negative ion source on ITER-NBI with Cs.

REFERENCES

- [1] K. Hanai, et.al., Fusion Eng. and Des. **146** (2019)2721.
- [2] H. Kaminaga, et.al., Rev. Sci. Instrum. **91** (2020) 113302.

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