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Comparison of ion source plasma response by extraction grid bias between hydrogen and deuterium operation in NIFS-RNIS

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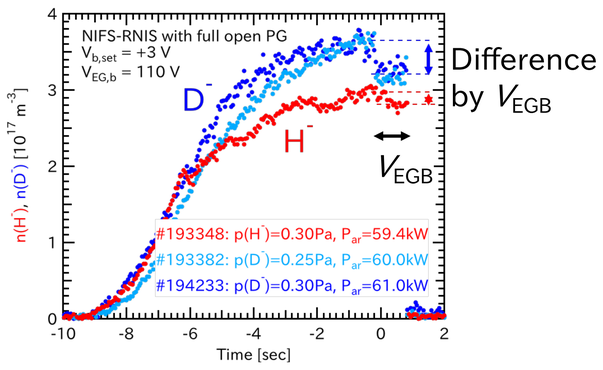
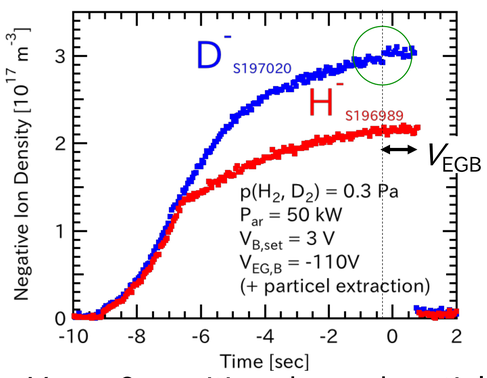
Introduction

- A study of particle motion in the vicinity of plasma grid contributes to optimize the plasma grid (PG) structure including magnetic configuration in cesium-seeded negative-hydrogen-ion sources.
- It is known that plasma parameters in the vicinity of the plasma grid are responded by beam extraction as well as bias voltage between discharge chamber and the plasma grid. Some previous studies has been explained physical meaning of the plasma parameter responses, as righthand side.
- Isotope effect is one of the important issues for negative ion source for fusion. A difference of negative ion density response between H and D operations by extraction grid bias, which is low beam extraction voltage apply between PG and extraction grid, has been observed in Research and development Negative Ion Source in NIFS (NIFS-RNIS) as below.



$V_{EGB} > 0$: negative charged particle attraction to the EG.



$V_{EGB} < 0$: positive charged particle attraction to the EG.

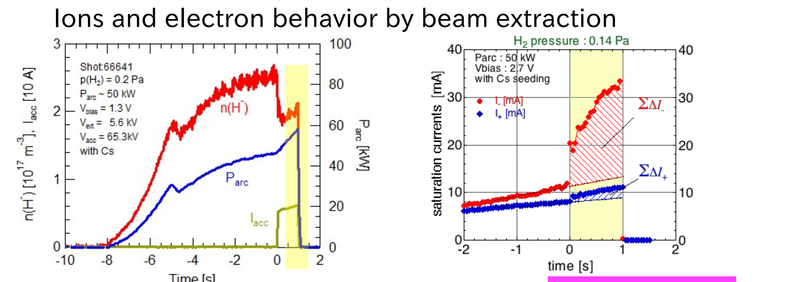
Objective

What is the origin of the isotope effect on the negative ion density and its response by the V_{EGB}?

Obtain a possible interpretation on this isotope effect.

Previous Research for H⁻ transport

Ions and electron behavior by beam extraction



No Beam Extraction

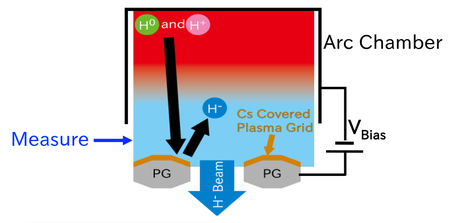
- H⁻ is produced on PG surface.
- Electron can not come near PG because of high H⁻ density.
- Negative ion plasma is generated.

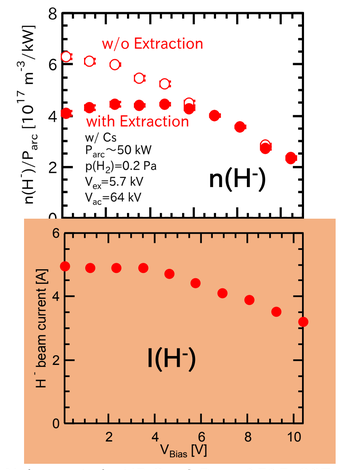
Just after Beam Extraction

- H⁻ decreases by H⁻ beam extraction.
- Electron comes near PG due to satisfy quasi-neutrality.
- H⁺ also come by ambipolar diffusion.

K. Tsumori et al., Rev. Sci. Instrum. 83, 02B116 (2012)

H- density variation by bias and extraction voltages





No Beam Extraction

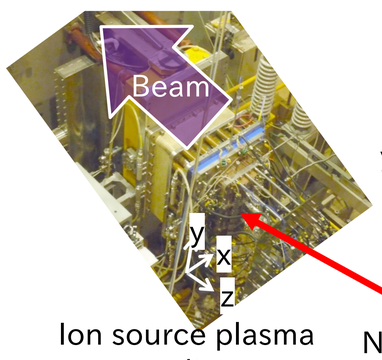
- The H⁻ particle reaching measure area is suppressed by positive bias voltage due to decreasing the surface produced H⁻ energy after sheath of the PG.

During Beam Extraction <in Low V_{Bias}>

- The H⁻ density drops by the beam extraction.
- The negative ion plasma is affected more by the beam extraction voltage than by the bias.

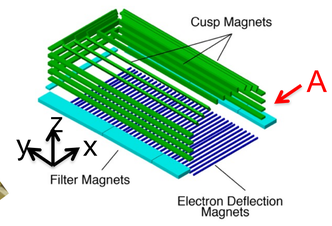
H. Nakano et al., AIP Conf. Proc. 1515, 237 (2013)

NIFS-RNIS and diagnostics with bias (V_{bias}) and EG bias (V_{EGB})

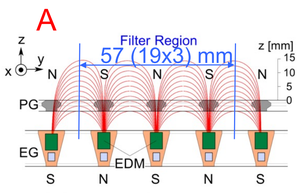


Ion source plasma coordinate

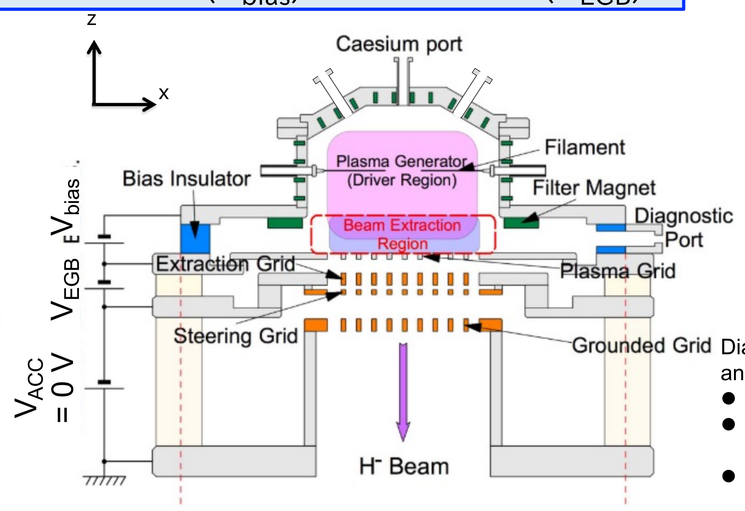
NIFS-RNIS

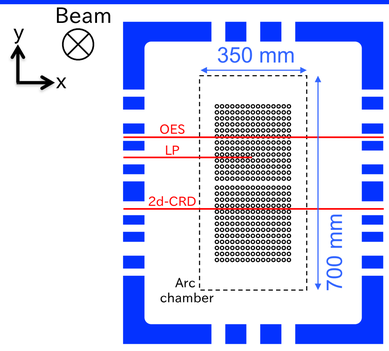


Magnet Configuration



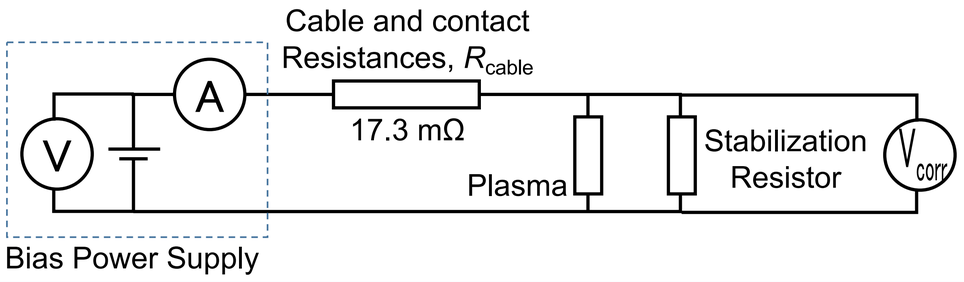
Magnetic structure in the vicinity of plasma grid





Diagnostics configuration on bias insulator between arc chamber and plasma grid

- OES line is at 19 mm from PG.
- LP is positioned at 14 mm from PG above almost in between PG aperture vertical centers.
- 2d-CRD line set at 17.5 mm from PG.

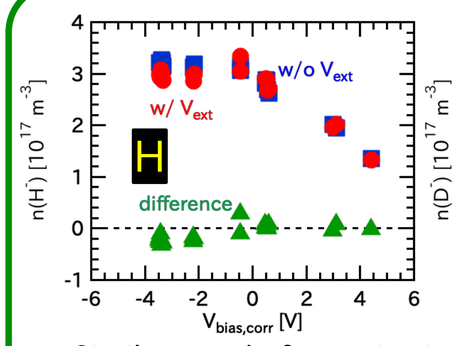


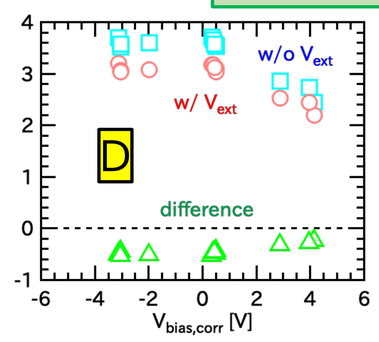
Bias voltage is corrected from output voltage of the bias power supply (V_{bias}) by the cable and contact resistances as following.

$$V_{bias,corr} = V_{bias} - I_{bias} R_{cable}.$$

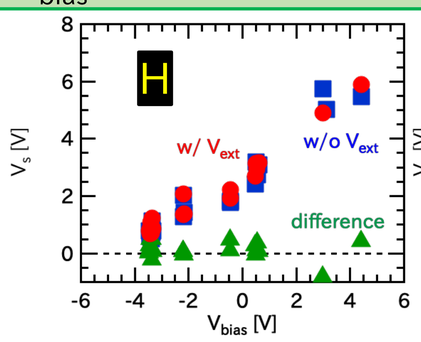
The corrected bias voltage by the cable and contact resistance is the same as the voltage directly measured between the PG and the arc chamber during plasma discharge.

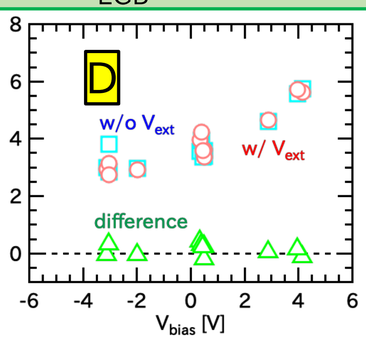
Results of V_{bias} scans with and without V_{EGB} = 110 and discussion



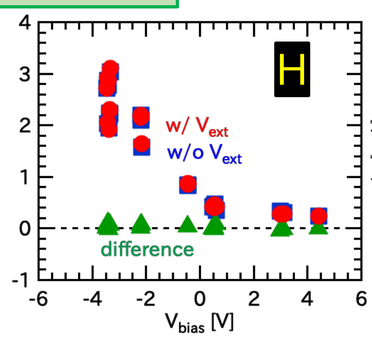


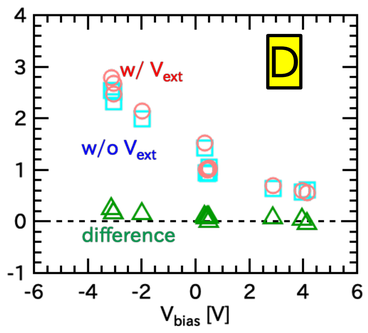
- Similar trend of negative ion density has been observed.
- The n(D⁻) is higher in no V_{EGB} condition and responds largely by V_{EGB}.





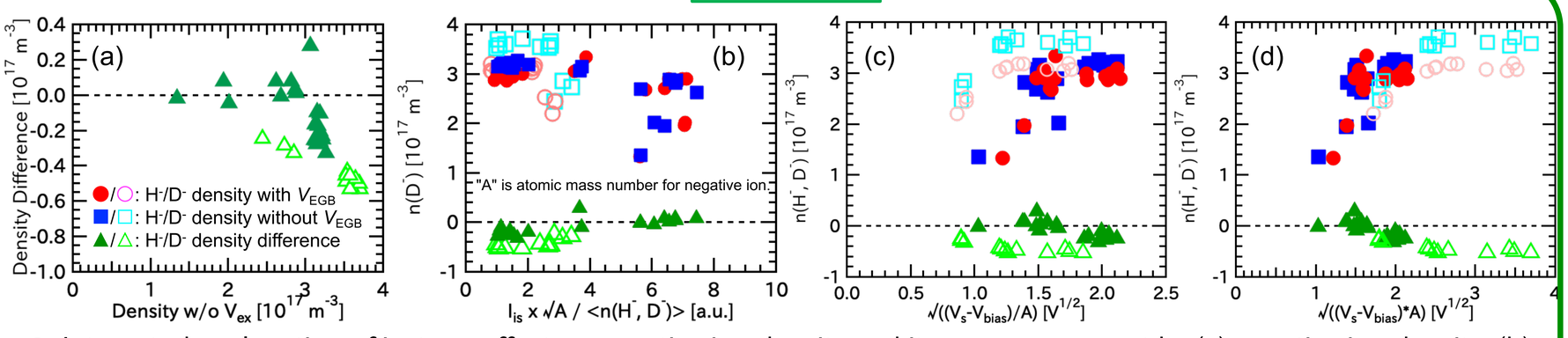
- Both plasma-space potentials V_s is similar in high V_{bias}.
- V_s does not change much by V_{EGB}.





- Higher plasma density is estimated from similar ion saturation currents (I_{is}).
- I_{is} does not change much by V_{EGB}.

Discussion



- Integrated explanation of isotope effect on negative ion density and its response cannot by (a) negative ion density, (b) electronegativity, and (c) negative ion emission speed from the PG.
- Momentum direction to anti-beam direction, which is proportional to Larmor radius along to electron deflection magnetic (EDM) field line parallel to the PG, can be one of the candidates for the integrated explanation.

Summary

- The n(D⁻) largely responds than the n(H⁻) by V_{EGB}.
- Negative ion density variations has been studied by V_{bias} variation with V_{EGB}.
- The Larmor motion along the EDM field is one of the possible candidates to explain the isotope effect on the negative ion density and its response in the vicinity of the PG by V_{EGB}.

✓ Appendix: Bias voltage actually applied between the PG and the arc chamber is corrected by the cable and contact resistance.

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