Flow patterns of H^- ions measured with Directional Photodetachment Langmuir Probe

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Outline

- Introduction
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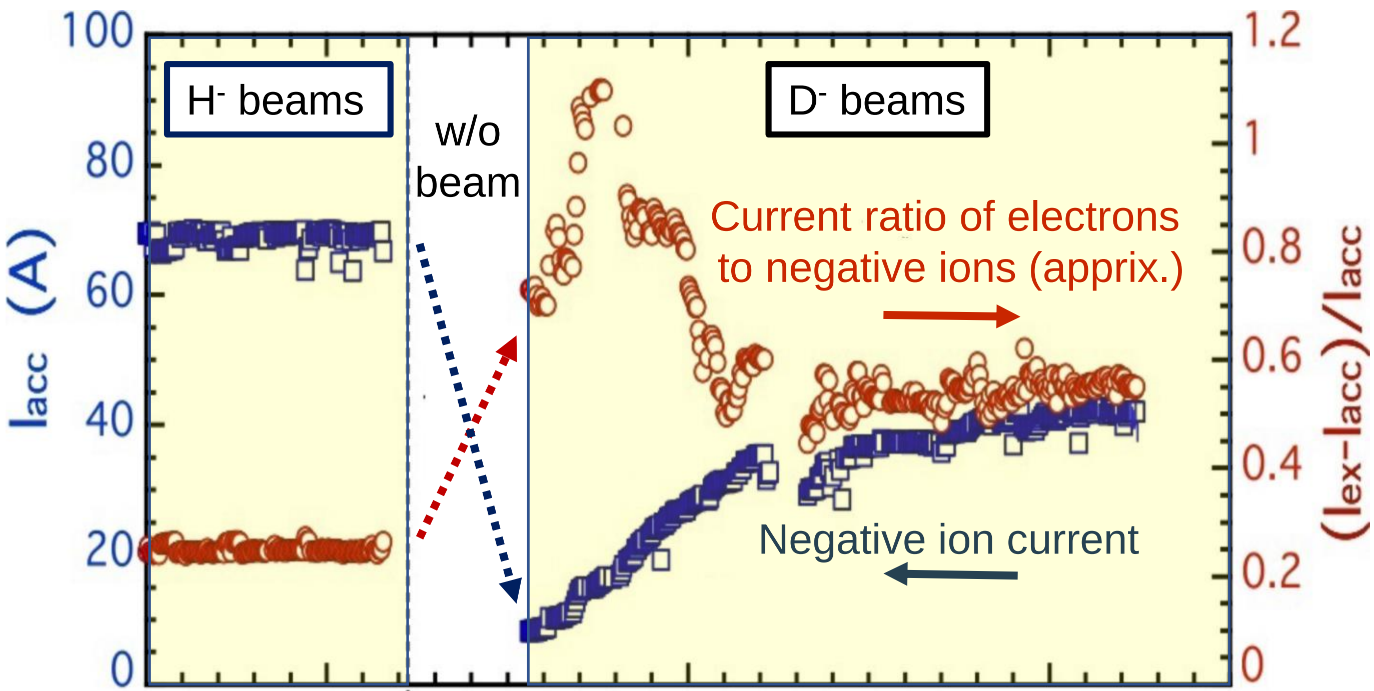
- Magnetic field at measured region of H^- flow pattern
- Trajectories of H^- ions at the measured region
- Weak points of DPLP and future plan
- Summary

Introduction

- Understanding of negative-ion behavior through its production to extraction.
  - Where H^- ions are mainly extracted in the extraction region?
- Investigation of magnetic field influence to H^- ion transport.
- Prospect of the difference between production yield of H^- and D^- ions.

Difference between H^- and D^- beams

- The changes of negative ion current and current ratio of co-extracted electrons to negative ions have shown in the figure below.
- To simplify, acceleration current (Iacc) and subtracted current of extraction current (Iext) to acceleration current is approximated to negative ion and electron currents.
- The change was drastic and improvement for D^- beams is required.



Changes of the current ration of electrons to negative ions after replacing the operational gas from H_2 to D_2.

Negative ion yield and current ratio of D^- are different from considered related to the changes of plasma characteristics and isotope effect.

to be presented by K. Ikeda et al., later in this conference

NIFS Research Negative Ion Source (NIFS-RNIS)

Production and transport of H^- and D^- ions in source plasmas

Diagnostics related to the production to extraction of negative ions

- Cs dynamics
- Dynamics of charged particles
- negative ion flow

Mechanism of the electro-static shielding and meniscus formation in negative ion plasmas

Electrostatic shielding and sheath formation in negative ion plasmas

- Response of electrostatic field
- Measurement in the vicinty of plasma grid

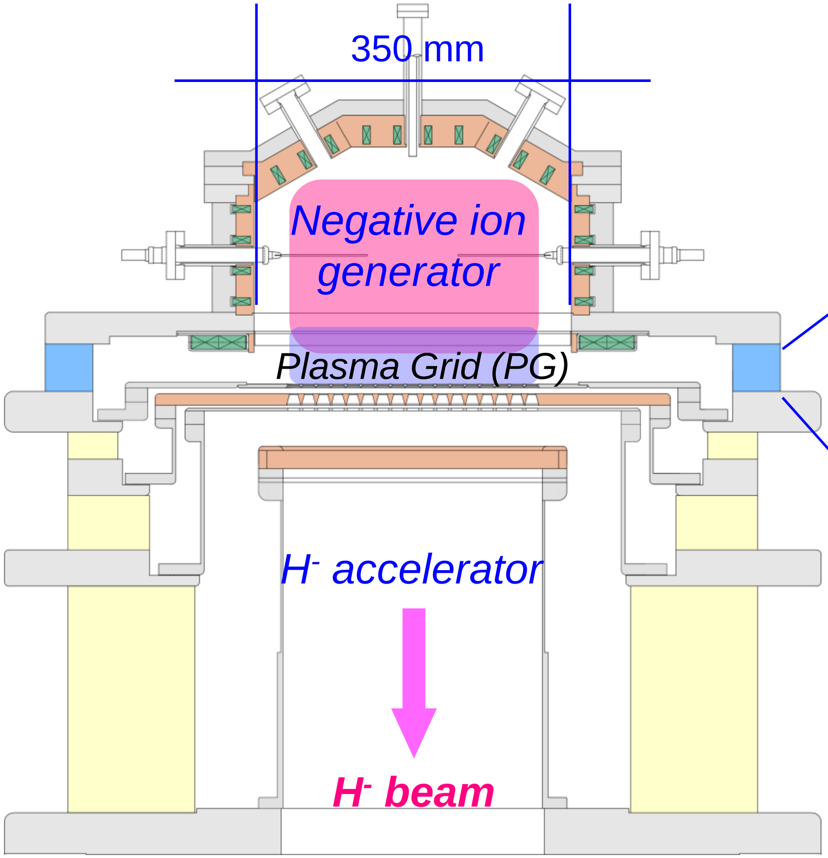
Beamlet transport

Beamlet monitoring

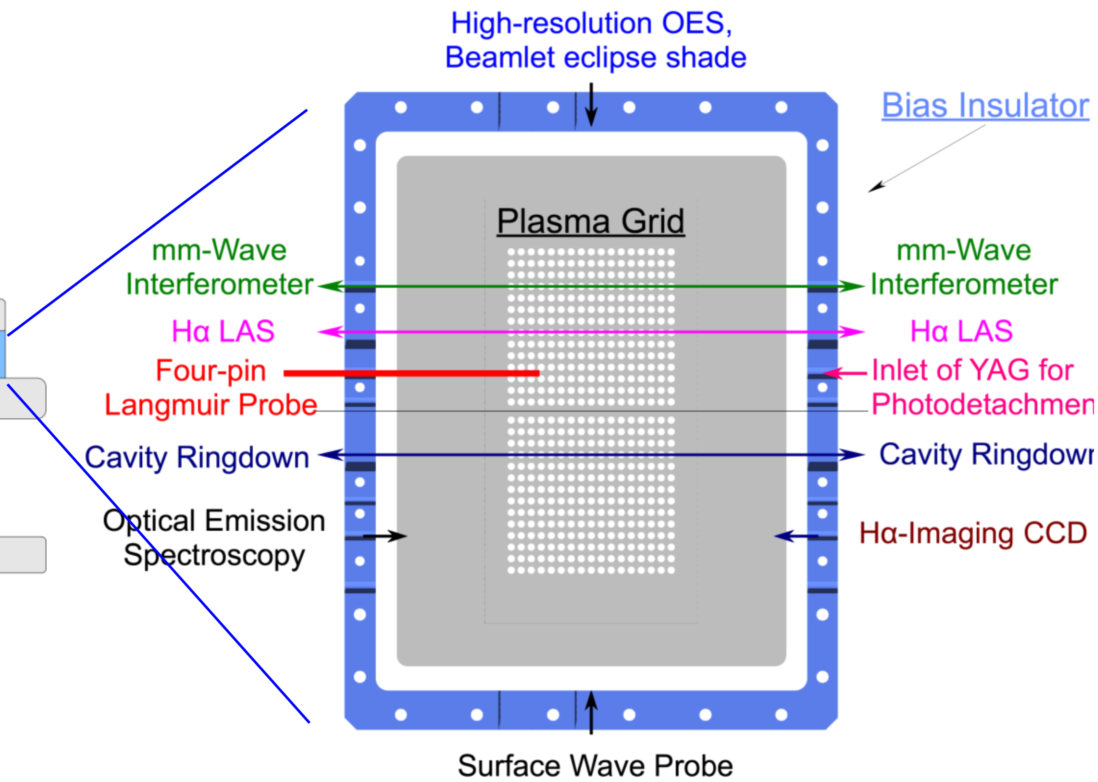
- Phase space analysis
- Charge compensation
- Beamlet interaction

NIFS Research Negative Ion Source (NIFS-RNIS)

- Filament-arc source with a pair of filter magnets.
- Size of arc chamber [mm]: 350 (W) x 700 (H) x 230 (D).
- Several diagnostic modules are installed on the bias insulator with the thickness of 52 mm



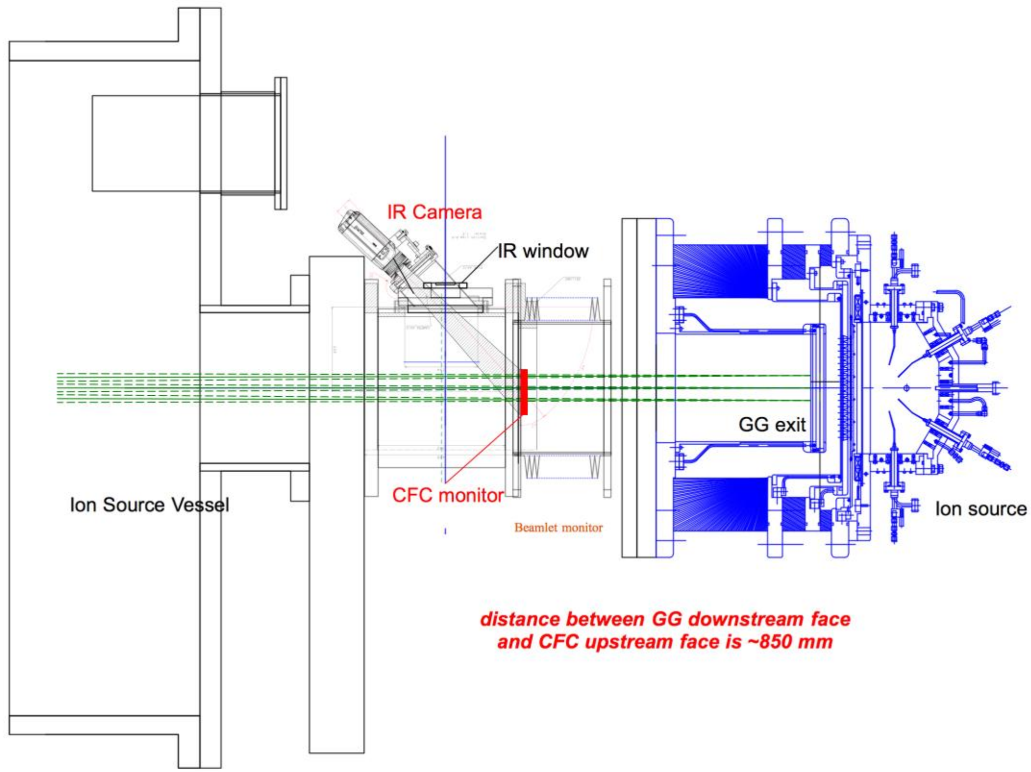
Cross-sectional view of NIFS-RNIS



Arrangement of diagnostic system viewing from back-plate side

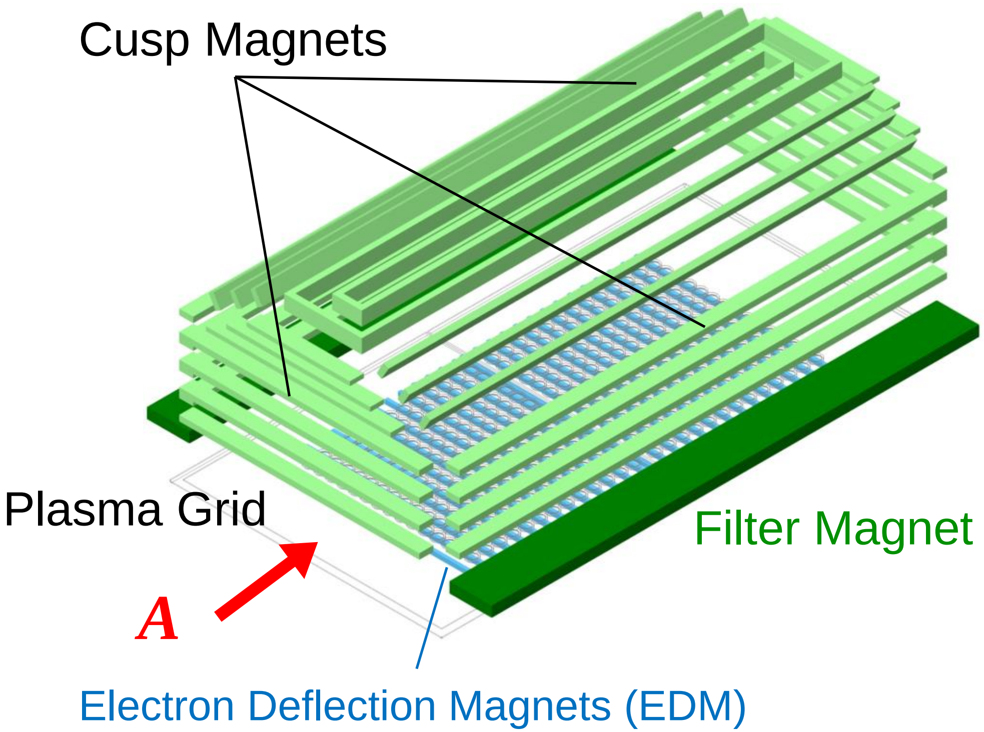
Beamlet monitoring

- Movable beamlet monitor made of CFC graphite
  - To analyze the beamlet profiles and deflections
  - 343mm (W) x 254mm (H) and available to monitor all the beamlets accelerated from a single segment.
- Beamlet emittance meter
  - Phase space analysis
- Multi-Faraday cup (4 x 8 array)
  - To monitor the change of beamlet profile during beam acceleration



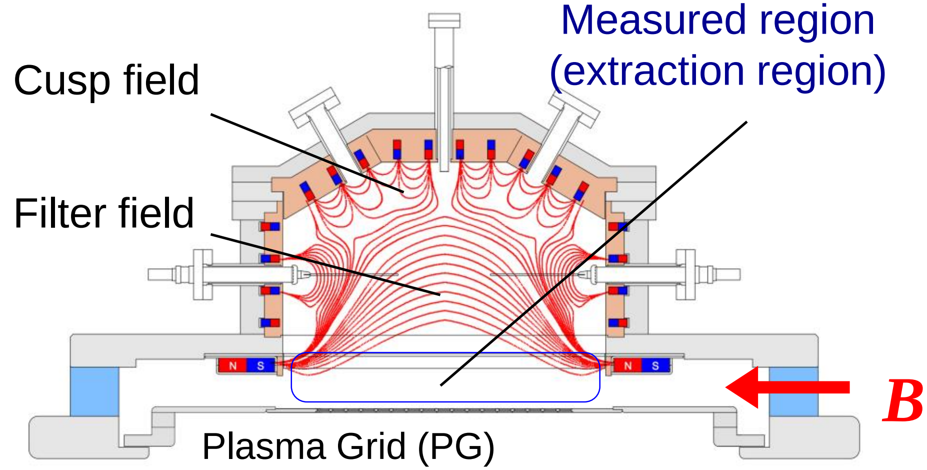
Structure of Magnetic Field

Skelton view of peripheral magnets arranged for NIFS RNIS

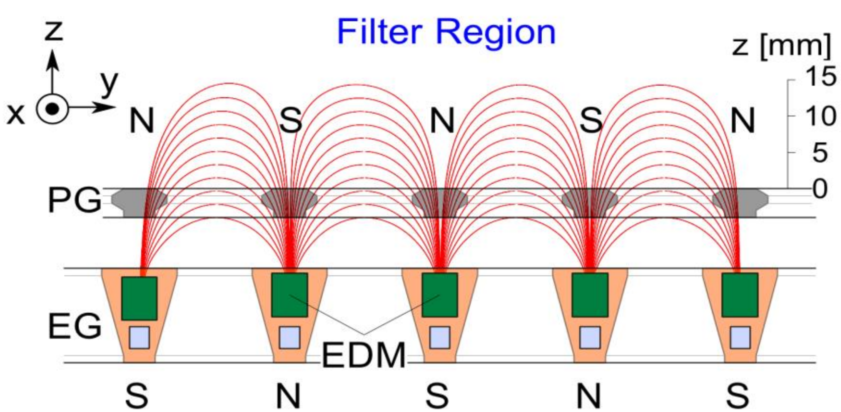


Region between filter magnets and plasma grid, extraction region, is the interest region of this research.

Magnetic field viewing from A side



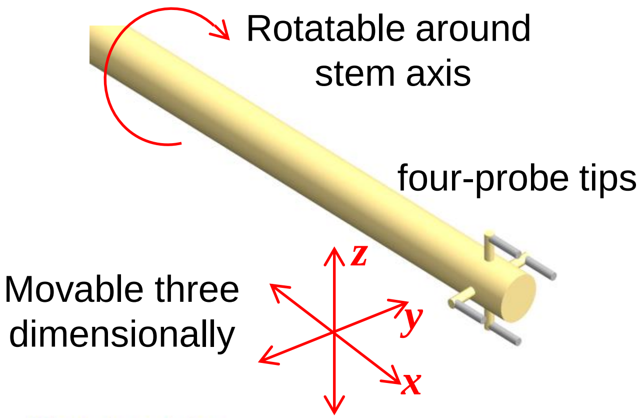
Magnetic field viewing from B side



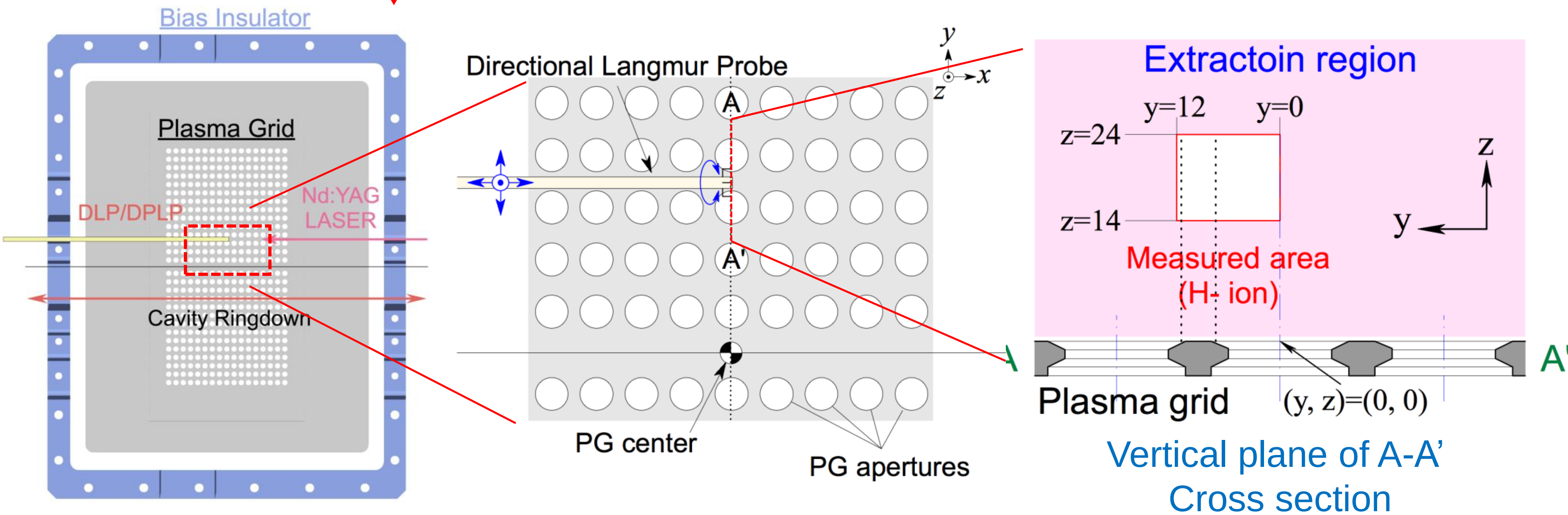
*EDM: electron deflection magnet

Installation of Directional Photodetachment Langmuir Probe (DPLP)

Directional Photodetachment Langmuir probe

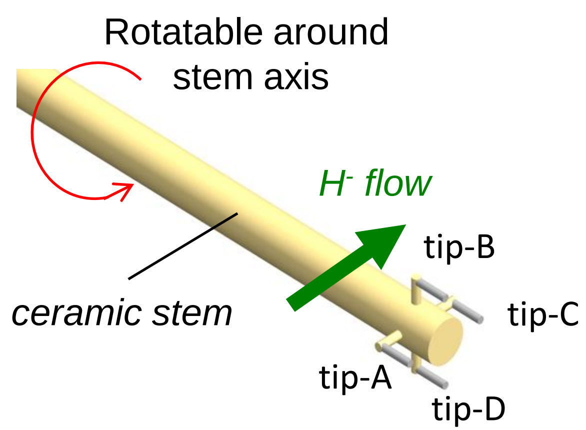


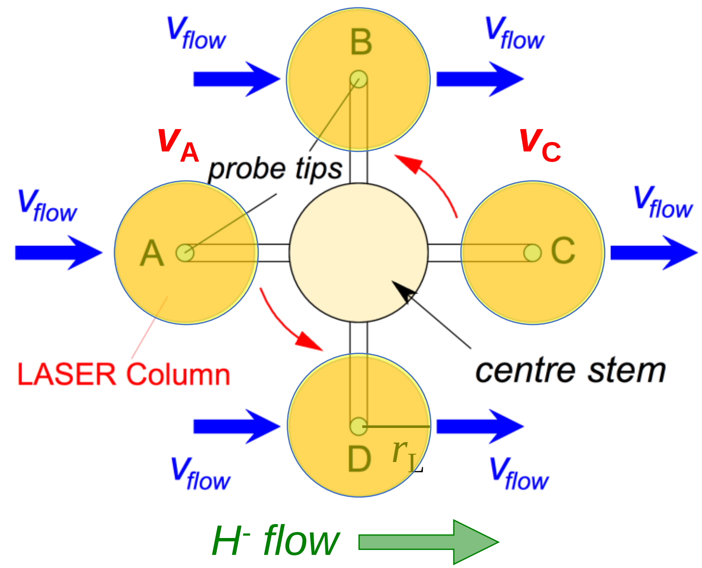
- DPLP has 4 probe tips with 2 mm lengths and 0.5 mm diameters.
- The probe is 3-dimensionally movable and rotatable around the axis of central ceramic stem.

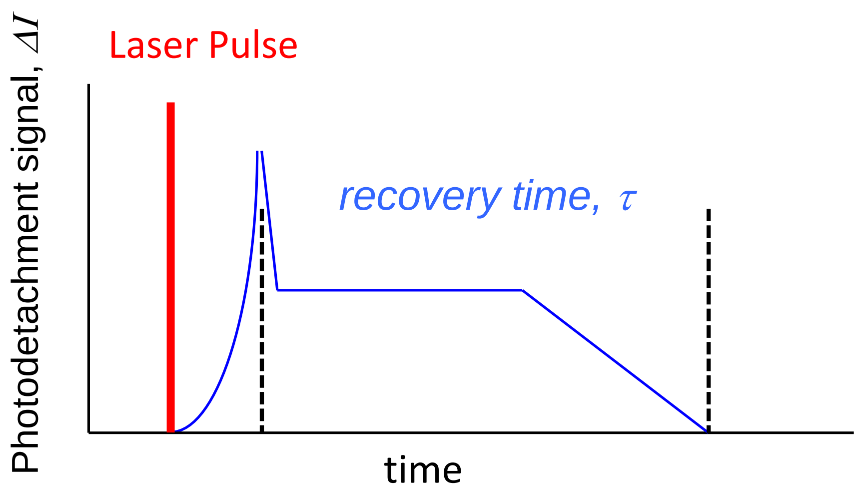


H^- Flow Measurement

Directional Photodetachment Langmuir Probe (DPLP)







$$v_{flow} = (v_A - v_C) / 2$$

v_{flow}: flow velocity

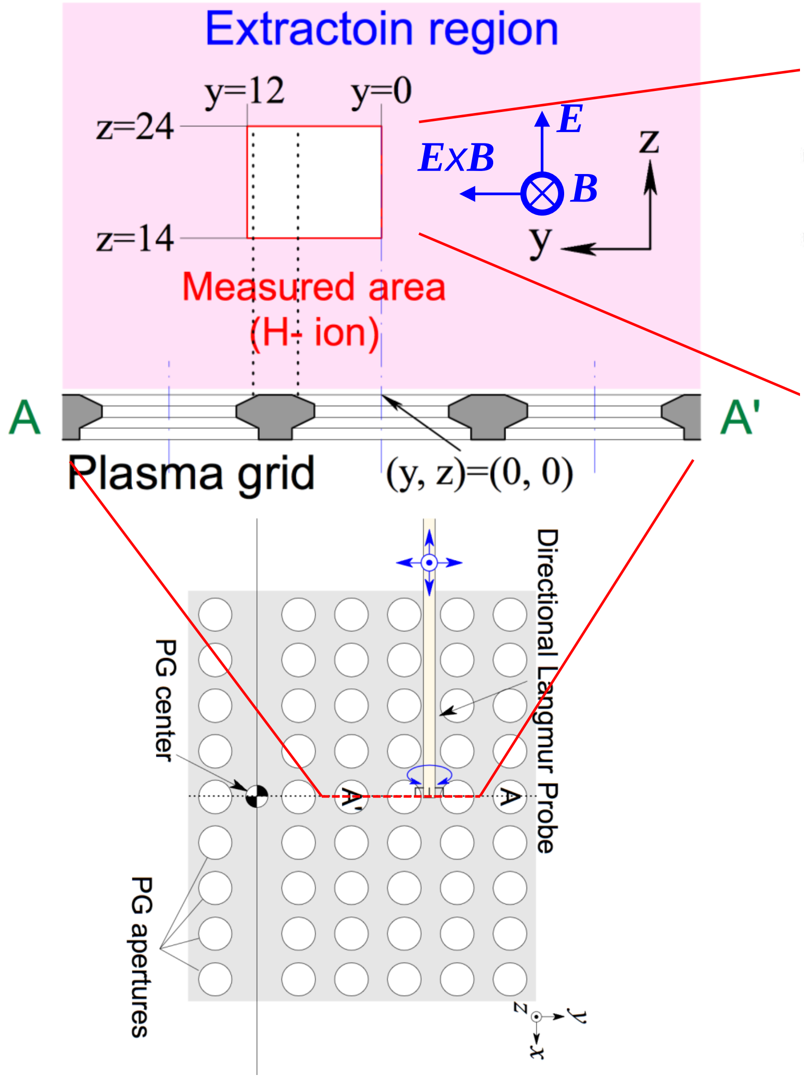
Using a shade of center stem, flow velocity of H^- ions is enable to estimate.

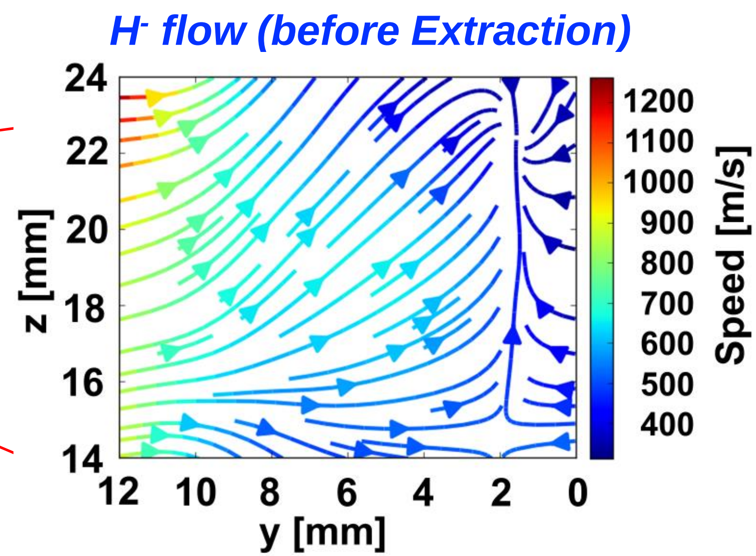
The velocity at each probe tip is evaluated by r_L / τ, where r_L and τ are radius of laser column and recovery time, respectively.

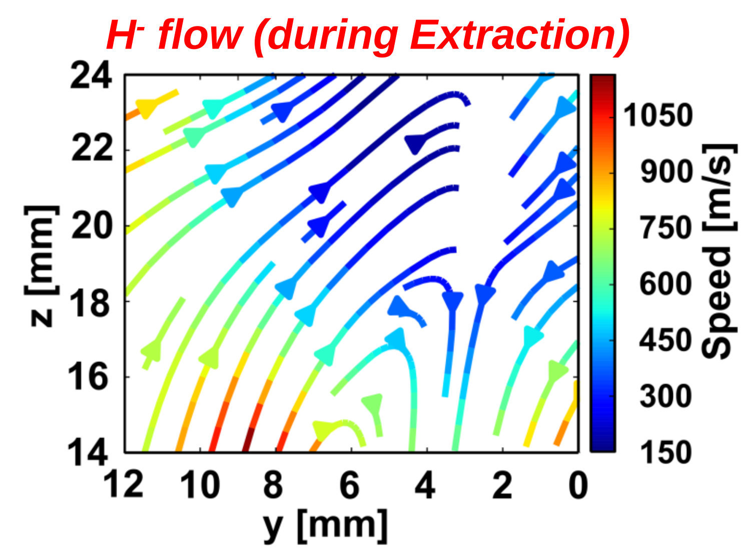
S. Geng et al., **MonPS32**: *ICIS 2015*

H⁻ Flow Measurment

S. Geng *et al*., Fusion Eng. Des., http://doi.org/10.1016/j.fusengdes.2017.02.041 (to be published).





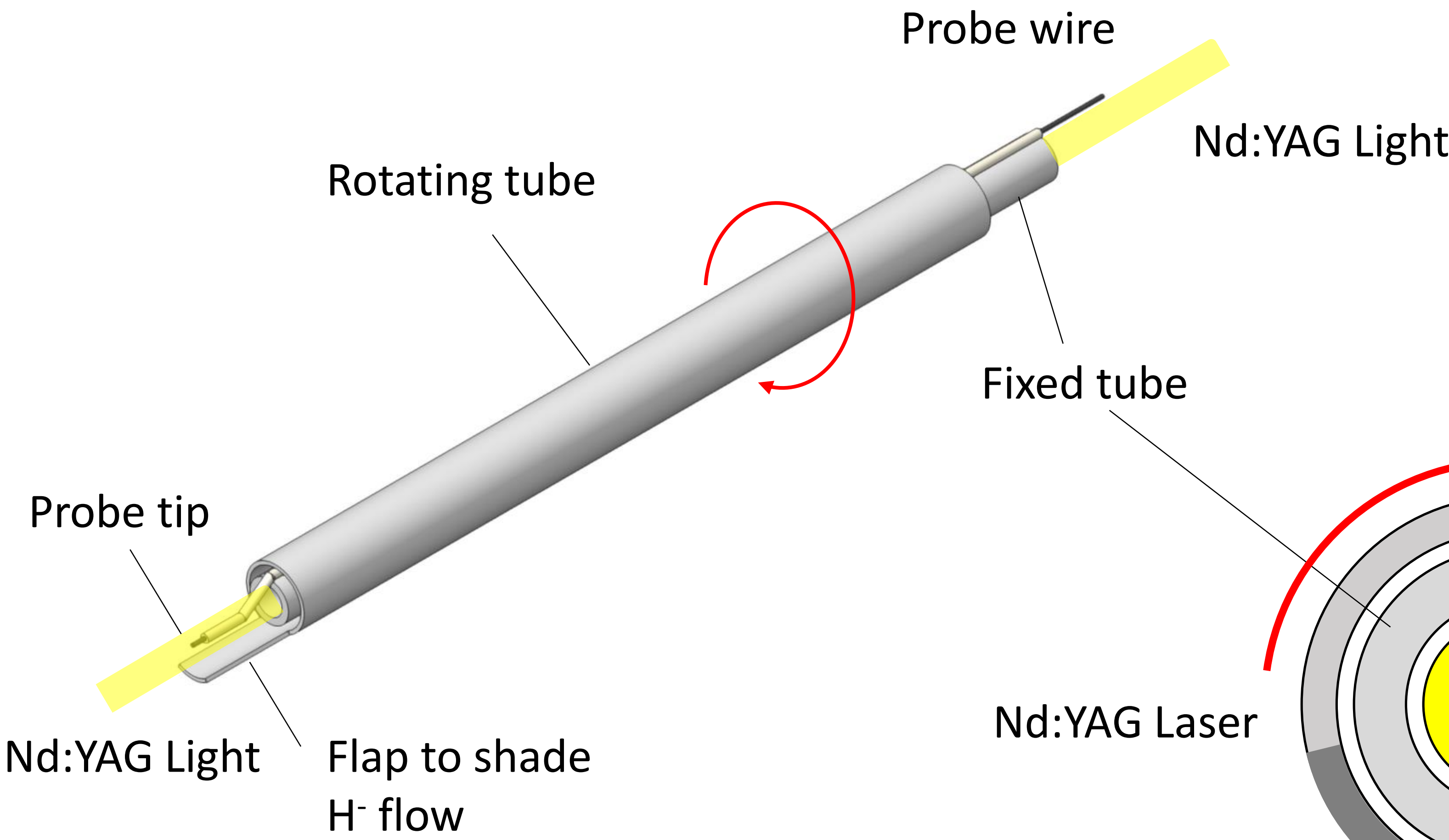


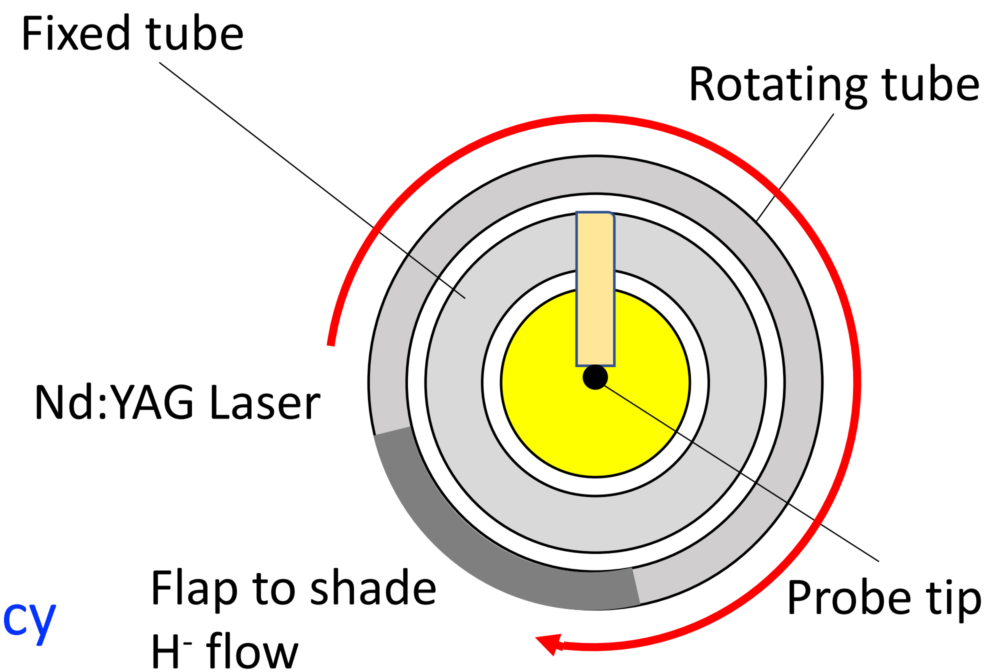
Problems of Our Present DPLP 2

Although the four-tips DPLP provides details of the flow patterns of H^- ions useful to understand the mechanism of production and the ions, there are some week points of the diagnostics;

1. The probe tips are placed certain distances, which is determined with least Laser diameter (~ϕ3 mm).
2. When the probe tips are positioned at different magnetic domains, data error becomes larger.
3. There are 4 probe tips and 4 shots of laser irradiation are needed by changing the position of the laser line-of-sight.
4. The photodetached electrons are bound with magnetic field stronger than H^- ions. There could be influence to the interpretation of flow patterns.

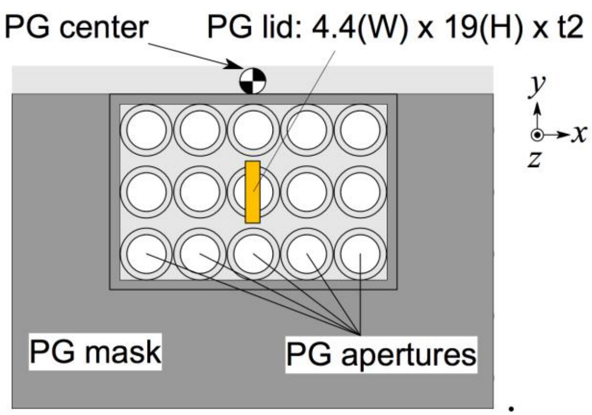
Improved DPLP

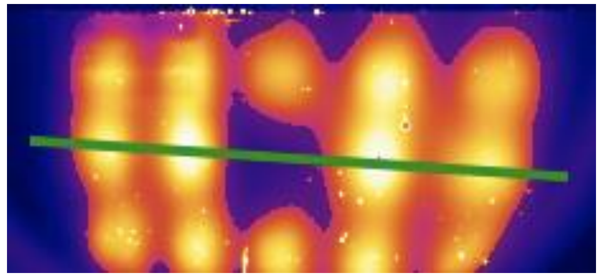




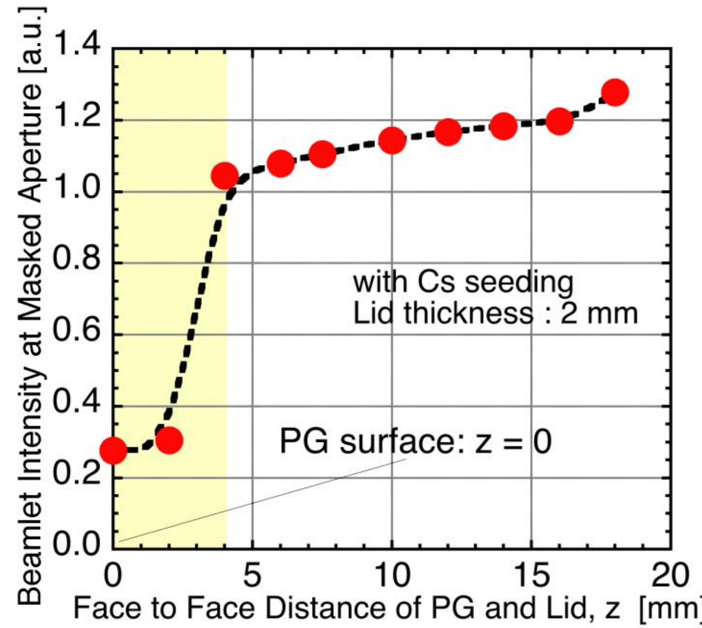
Data ambiguity and acquisition efficiency can be improved using this DPLP

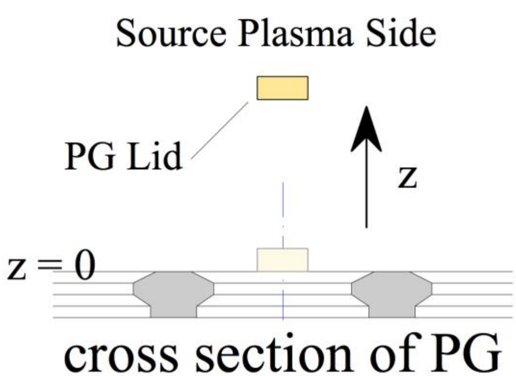
Another Method to Measure the Extraction Region of H^- Ions

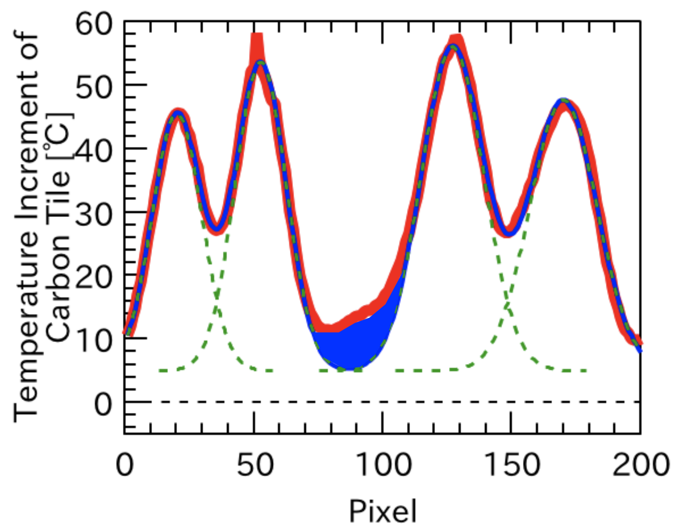




IR images of 5 x 3 beamlets on the monitor graphite tile







H. Nakano et al., in this conference

Beamlet distribution on the green line above

- PG-lid (2 mm thickness) method shows effective region of beam extraction is 4 mm from PG surface.
- This method could compliment the week points of DPLP.

Summary

- H- transport through production to extraction was measured with Directional Photodetachment Langmuir Probe (DPLP).
- D^- acceleration was unexpectedly different from H^- case. Source plasma diagnostics is required to improve the acceleration efficiency.
- Detailed H^- flow in extraction region obtained with DPLP
- Although DPLP is useful diagnostic method, it has some problems.
- To compliment the problems of DPLP, new diagnostic method (PG lid method) is developed.