EPFL

Optimization of a negative oxygen ion beam

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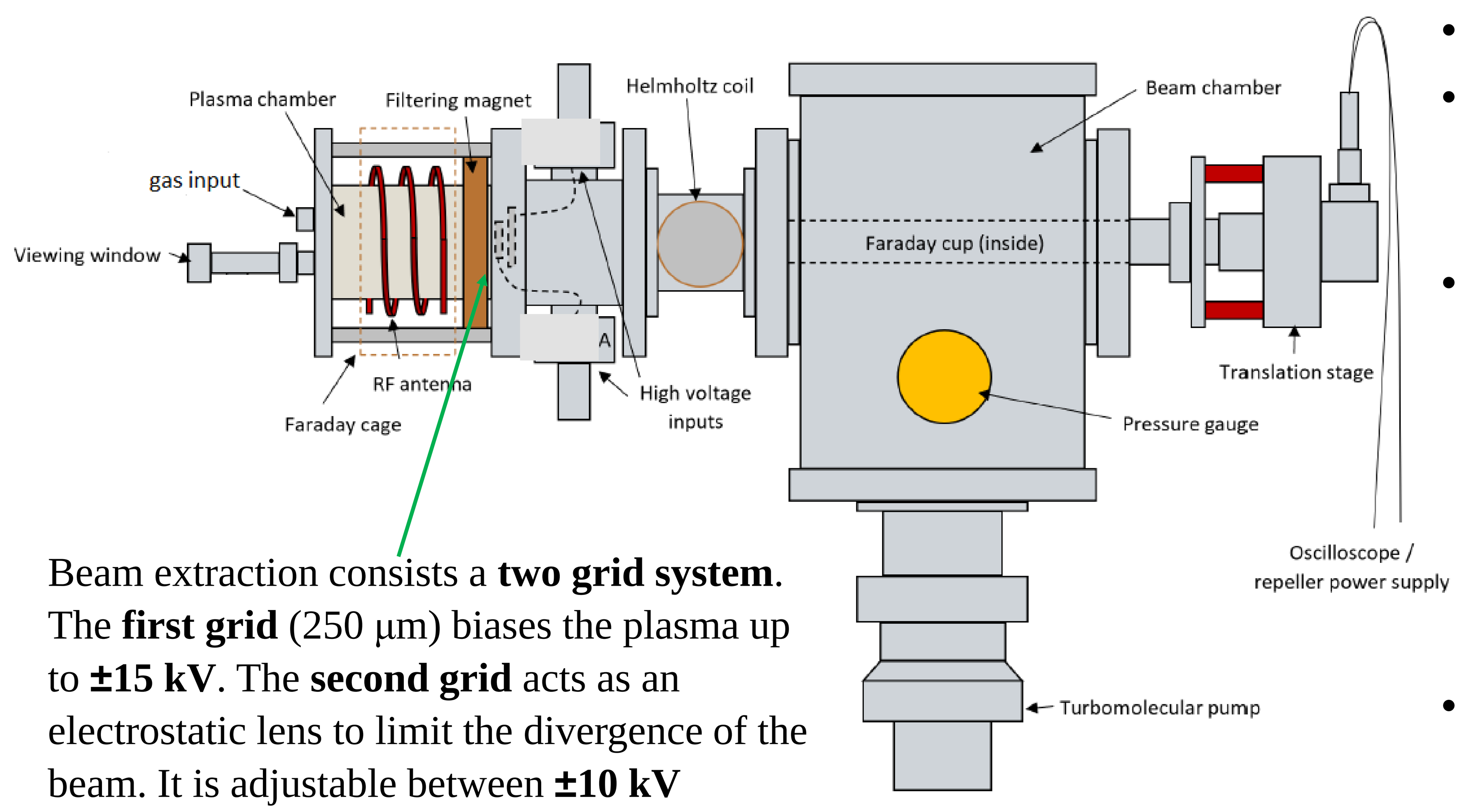
Overview

- A new negative oxygen ion source is under development for application on Secondary Ion Mass Spectroscopy (SIMS). SIMS analysis relies on measurements of secondary ions generated by the sputtering of a sample with primary ion beams (i.e. O-, O_2-, etc) [1].
- Radio frequency plasmas have been shown to be a successful primary stage to generate ion beams for SIMS instruments [2]. High spatial resolution on the target requires a highly collimated beam (<1cm) with high current density (>1uA) [3]. In addition, stability and reproducibility are important for the resulting measurements.
- The current source under development utilizes inductively coupled plasmas, and can produce positive or negative ion beams.

References

[1] https://doi.org/10.2533/chimia.2022.26
[2] https://doi.org/10.1557/mrs.2014.53
[3] https://doi.org/10.1116/1.2366617

Experimental Setup



Beam extraction consists a **two grid system**. The **first grid** (250 μm) biases the plasma up to **±15 kV**. The **second grid** acts as an electrostatic lens to limit the divergence of the beam. It is adjustable between **±10 kV** according to the plasma boundary curvature to maximize the beam current.

- **Gas flow rate** 0.01-0.05 sccm
- A **filter magnetic field** is applied at the beam exit to limit electrons in the extraction region.
- **Faraday cup** located 12 cm away from the plasma source with a collector of 8 mm in diameter. It's mounted on a translation stage to measure 2D beam profile. A stainless plate biased at -50 V suppresses secondary-electrons, and collector current is measured via an oscilloscope.
- Distinguishing electron and negative ion beam from measured current on the Faraday cup can be done with the **Helmholtz coil section**.

Conclusion

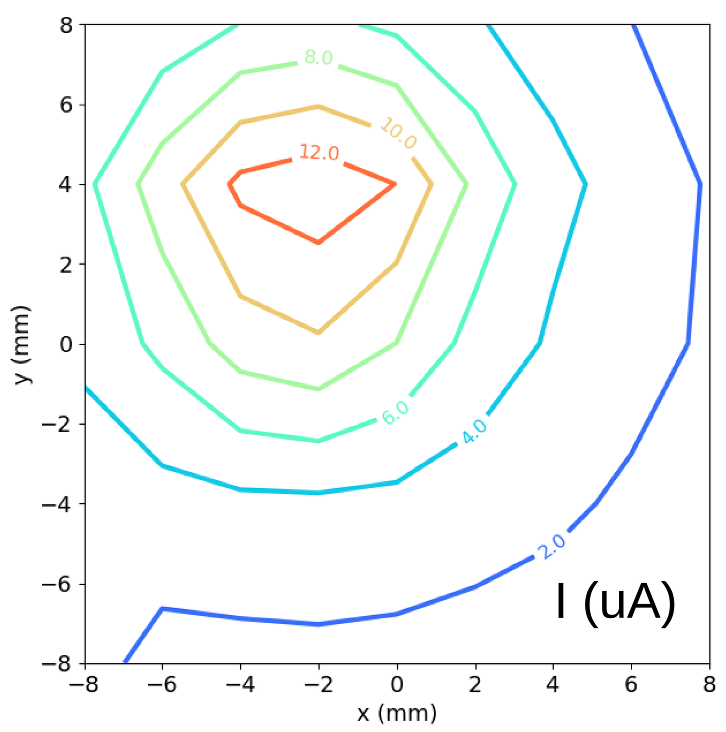
- Positive beam extracted from the source is generally 10 times stronger than negative beam.
- A smaller plasma chamber produces a positive beam 5 times stronger, and a negative beam 10 times stronger.
- Filter magnetic field has a strong effect on the extracted negative ion beam.
- A decrease in beam current has been observed after the source is in use for 10 min. This is likely related to heating of the system.
- Heating of the magnet pole pieces reduces its permeability. Reduction in B may cause a reduction in current.
- Between 13 and 40MHz, frequency applied on the antenna did not show a significant impact on the extracted positive beam.

Future work

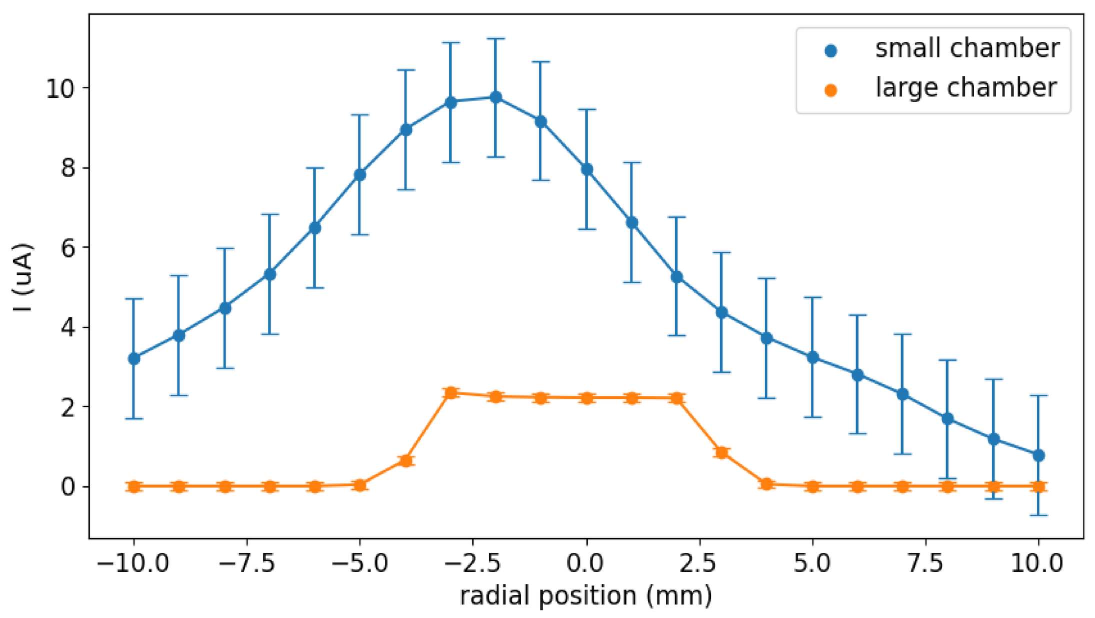
- Change magnet material.
- Change plasma boundary material.
- Implement cooling to the system.
- Utilizing a novel antenna instead of the current solenoid antenna.
- Investigate using an axial magnetic field aim to enhance plasma density.

Positive ion beam

2D positive ion beam profile



500W RF power 0.03 mbar

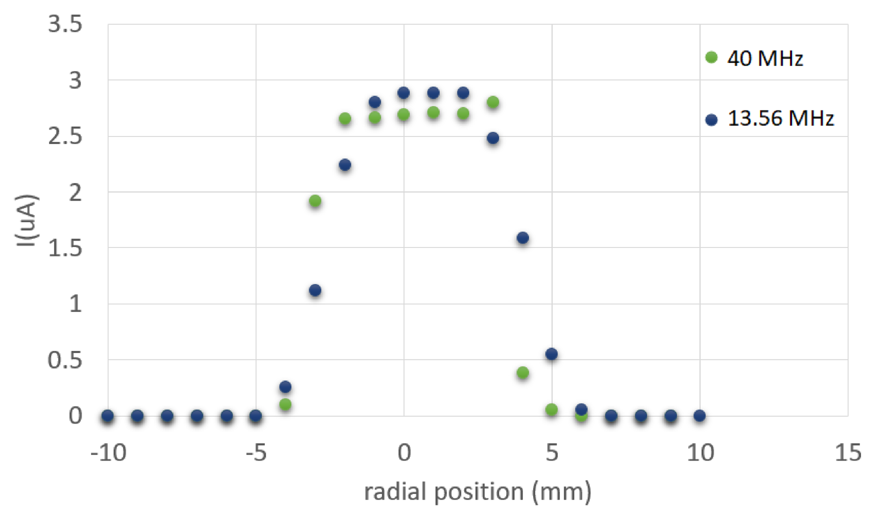


Two plasma chambers with same extraction systems

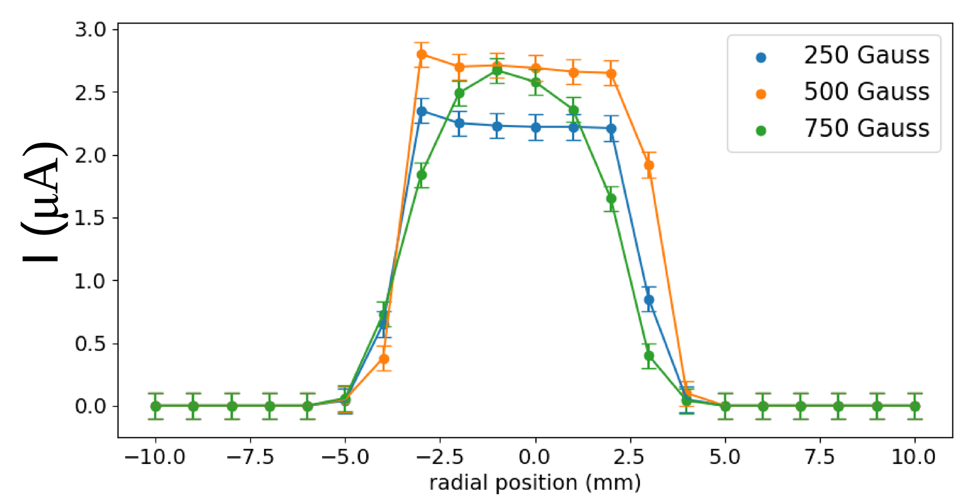
	small	large
Diameter (cm)	1.74	8.5
Length (cm)	7.4	14.4

Beam current x5 larger for small chamber

Beam profiles with different frequencies applied to the antenna but otherwise identical conditions.



filter magnet field strength

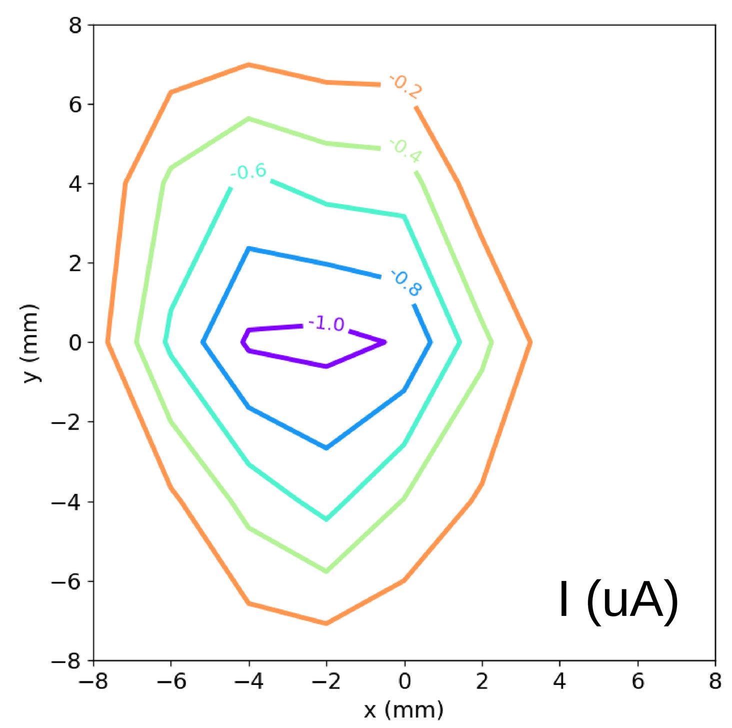


B is measured in room temperature with a gauss meter, and likely changes as the magnet pole pieces heat up => permeability decrease.

Faraday cup entry hole is 8 mm diameter => cannot measure beam profiles smaller than that. This resolution limit likely applies to the orange and blue curve on top figure, as well as the orange curve above measured in the large chamber.

Negative ion beam

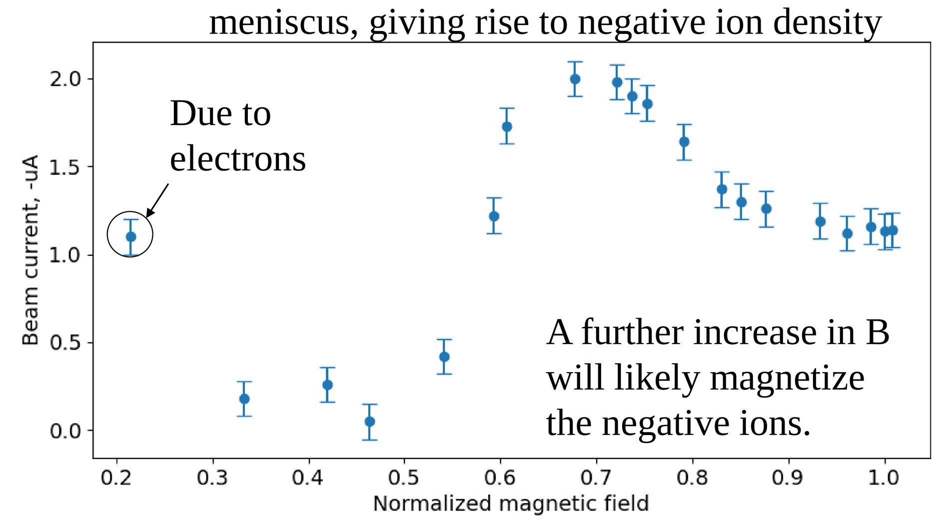
2D negative ion beam profile



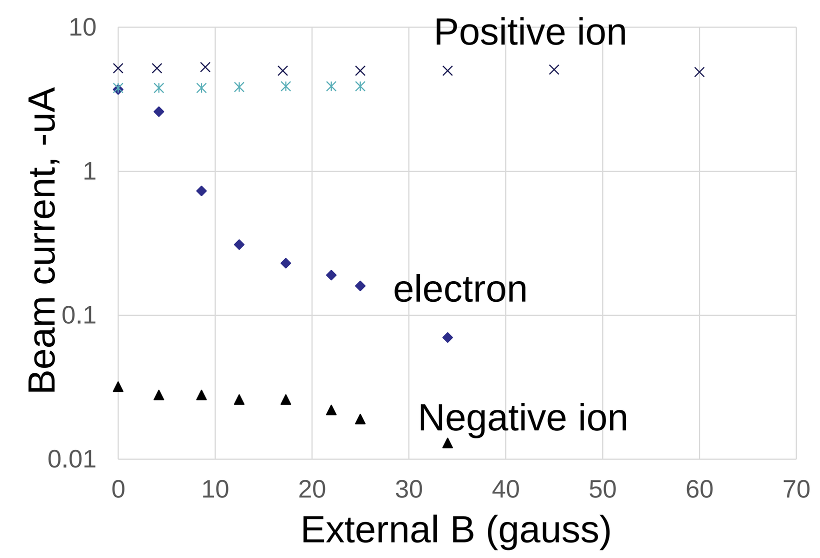
- In general, negative ion beam has 10 times smaller current than positive beam.
- This can be contricted by ratio of negative to positive ion near the meniscus at pressures between 0.01 and 0.1 mbar.

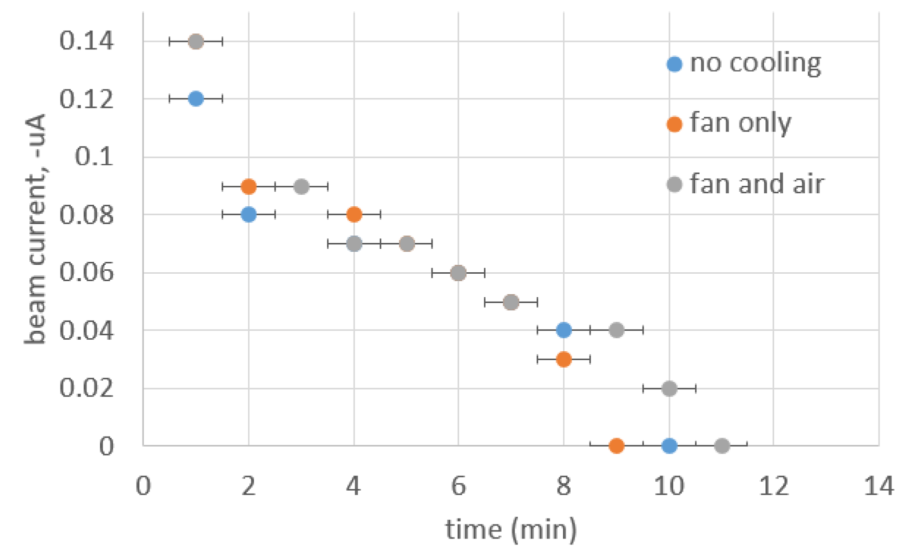
Result with small chamber varying filter B

more electrons are excluded from the meniscus, giving rise to negative ion density



Result with large chamber varying Helmholtz coil B





- Disappearance of negative ion current within 10 min.
- Likely due to heating (large chamber has limited external cooling).
- Fans and compressed air was added to cool the ceramic chamber, but did not show a significant change on the result.
- Heating applies to magnet pole pieces located wholly within the chamber; not coolable by fan or air flow.

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