CREATING NEGATIVE ION BEAMS FROM NEUTRAL GASES USING A NEGATIVE HYDROGEN ION SOURCE

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Overview

- Negative ion beams are valuable for applications that utilize tandem accelerators for ion injection (i.e., university research centers and ion implantation in semiconductor devices) [1]
- Typical method for negative ion production [2]: **Y^+ + Metallic Vapour (abundance of electrons) → Y^0 + Metallic Vapour → Y^- + Metallic Vapour**
- Problems are encountered when using Alkali or other metallic vapour for charge exchange as it can contaminate vacuum surfaces of the apparatus or silicon wafers in the case of ion implantation [2]
- Following an example set by Doupé and Litherland [3], we take a negative ion beam incident on neutral vapour for a single step charge exchange eliminating the need for metallic vapour and avoiding contamination: **$Y^- + X^0 \rightarrow Y^0 + X^-$**
- Newly produced X^- and remaining Y^- are accelerated by an in-vacuo electrostatic accelerator to an energy range of 10-20 keV and separated by a 1:500 resolution mass spectrometer
- Non-metallic neutral gases are inserted into a gas cell at the upstream portion of the electrostatic accelerator and bombarded with H^- beams from D-Pace's TRIUMF Licenced H^- ion source [4] of up to 15 mA over an energy range of 10-30 keV
- The neutral gases studied thus far are H_2 and O_2 with plans to study H^- beams incident on He, CO_2 and CH_4

Experimental Setup

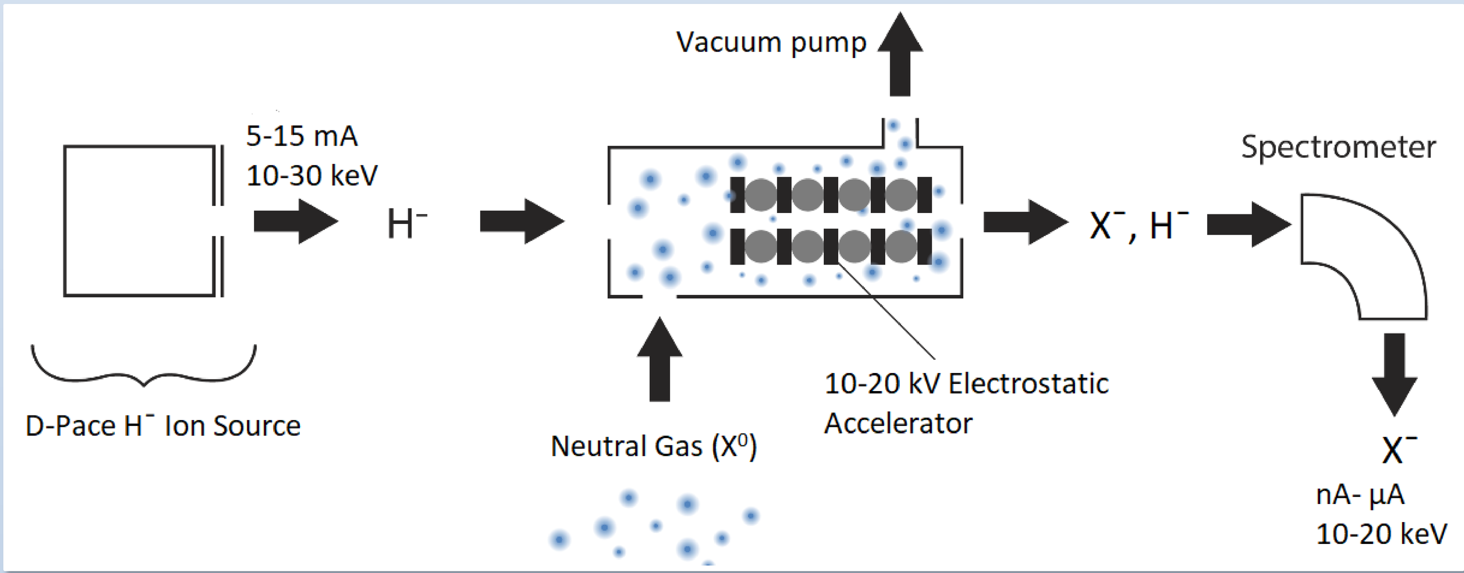

Figure 1: General apparatus diagram

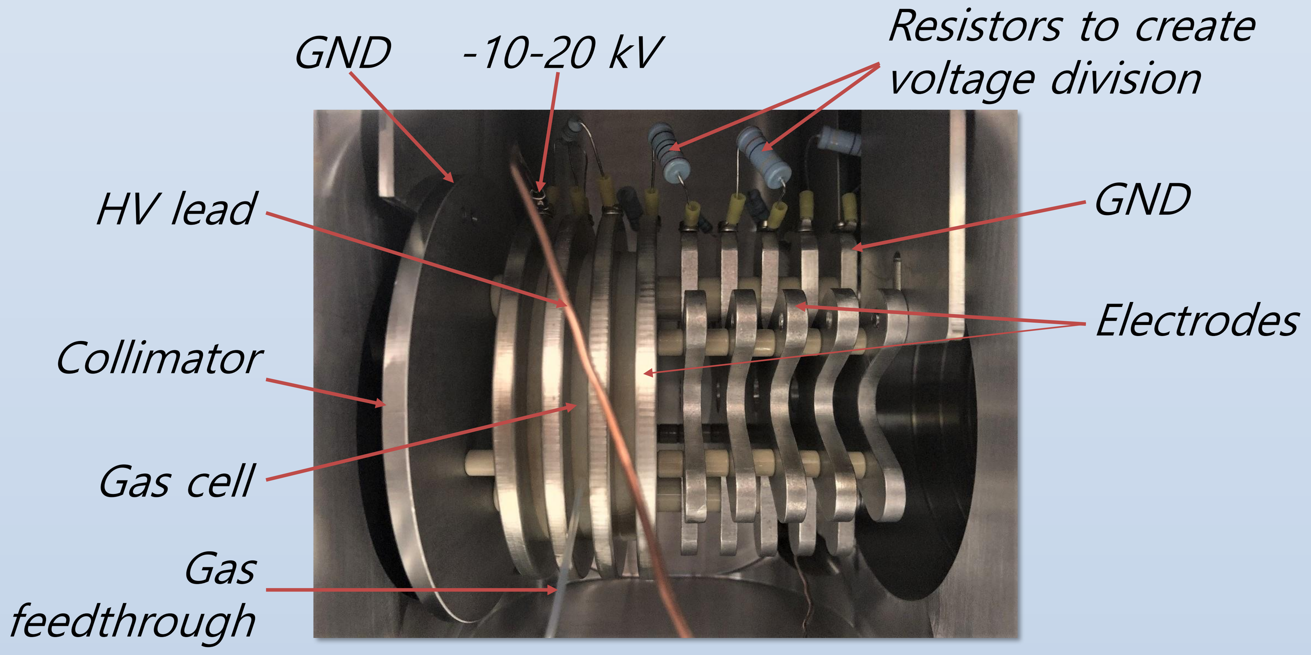

Figure 2: Gas cell/electrostatic accelerator unit

Results: H_2

Beam currents are measured from a Faraday cup after the mass spectrometer

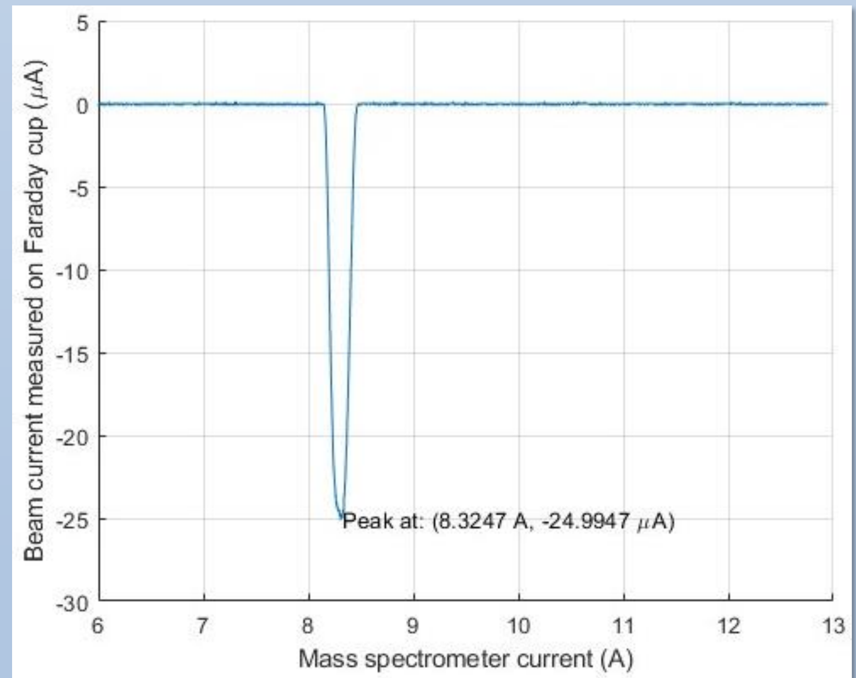

Figure 3: Incident 30 keV (E_{H^-}) H^- beam detected with 8.3 A of current (I_{H^-}) on mass spectrometer

$$I_X = I_{H^-}\sqrt{\frac{E_X M_X}{E_{H^-} M_{H^-}}} \quad (1)$$

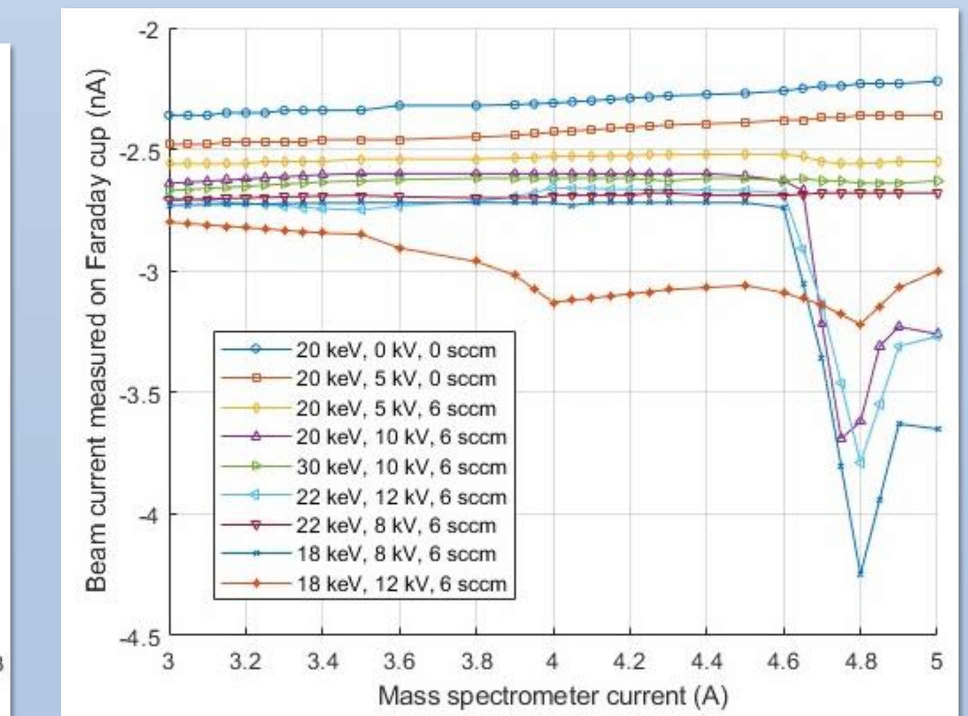

Figure 4: Varying incident beam energy, accelerator potential, gas flow with peaks only appearing when there is a 10 kV difference between incident potential and accelerator potential

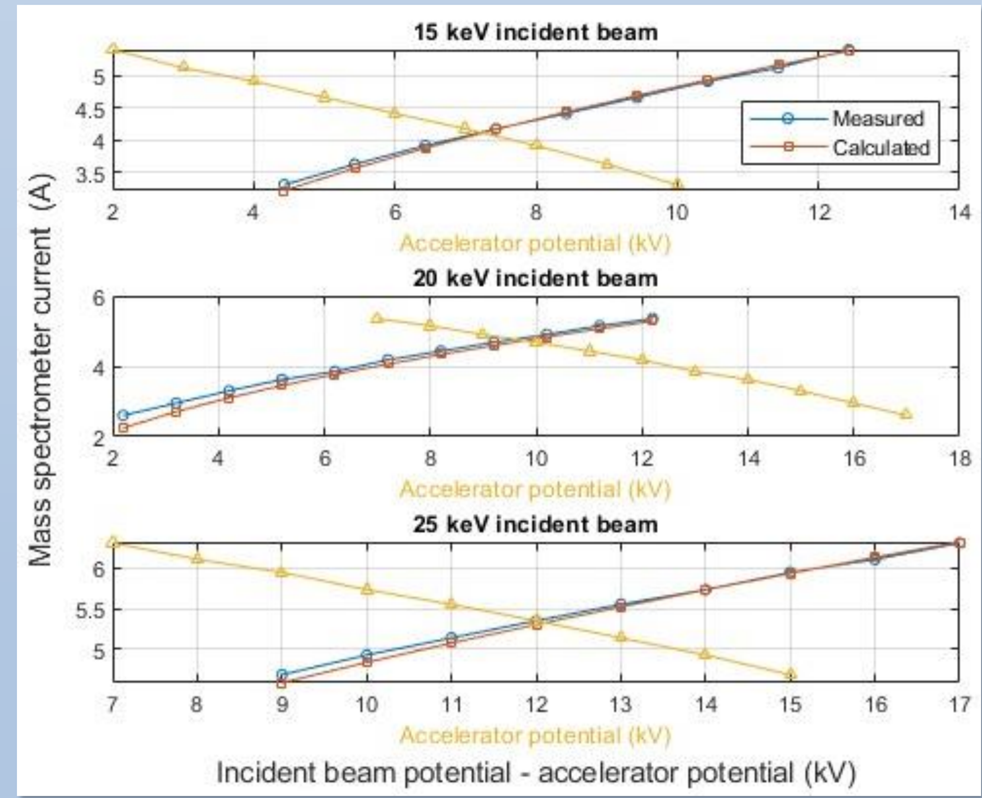

Figure 5: Calculated mass spec. current (by eqn. 1) compared to mass spec. current measured if incident beam is slowed by first electrode and neutralized – gaining e^- before mass spec.

$$H^- + H_2 \rightarrow H^0\,(E_{H^-} - E_X) + H_2 + e^- \rightarrow H^-\,(E_{H^-} - E_X) + H_2$$

Results: O_2

5-20 keV beam of O^- would be detectable at 13.5-27 A of current on the mass spec. by eqn. (1)

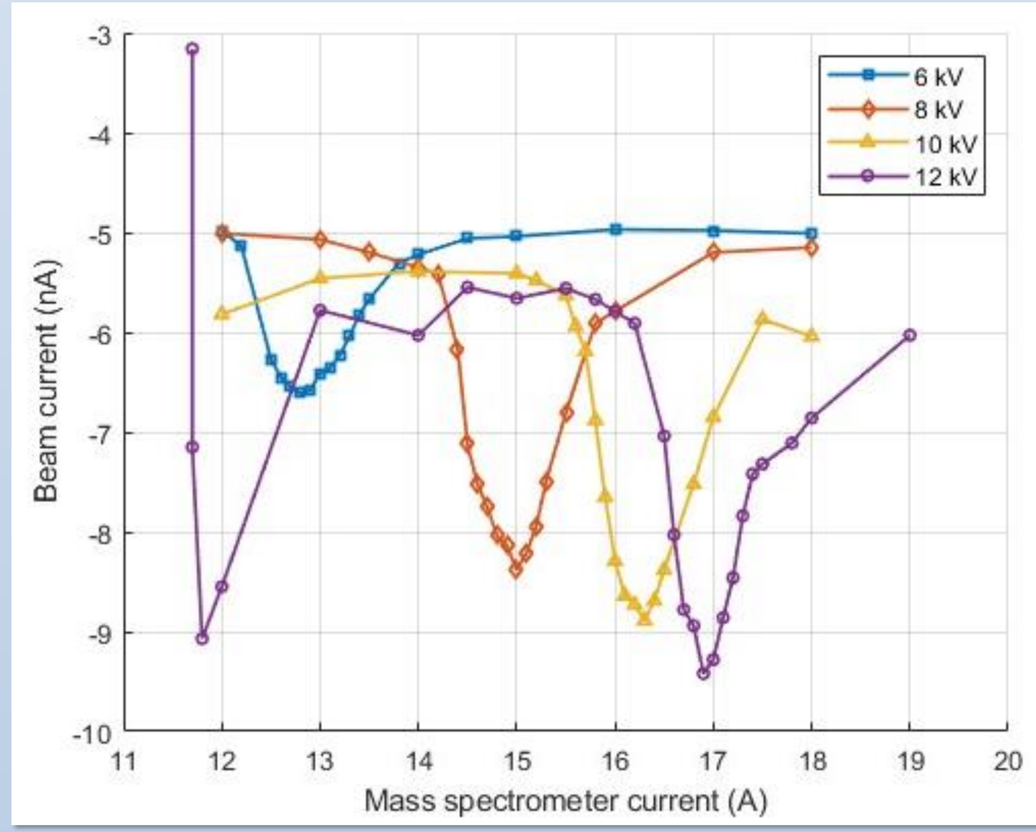

Figure 6: 30 keV H^- beam incident on 6 sccm gas flow of O_2 producing negative beam current peaks below expected mass spec. current range for O^- beams

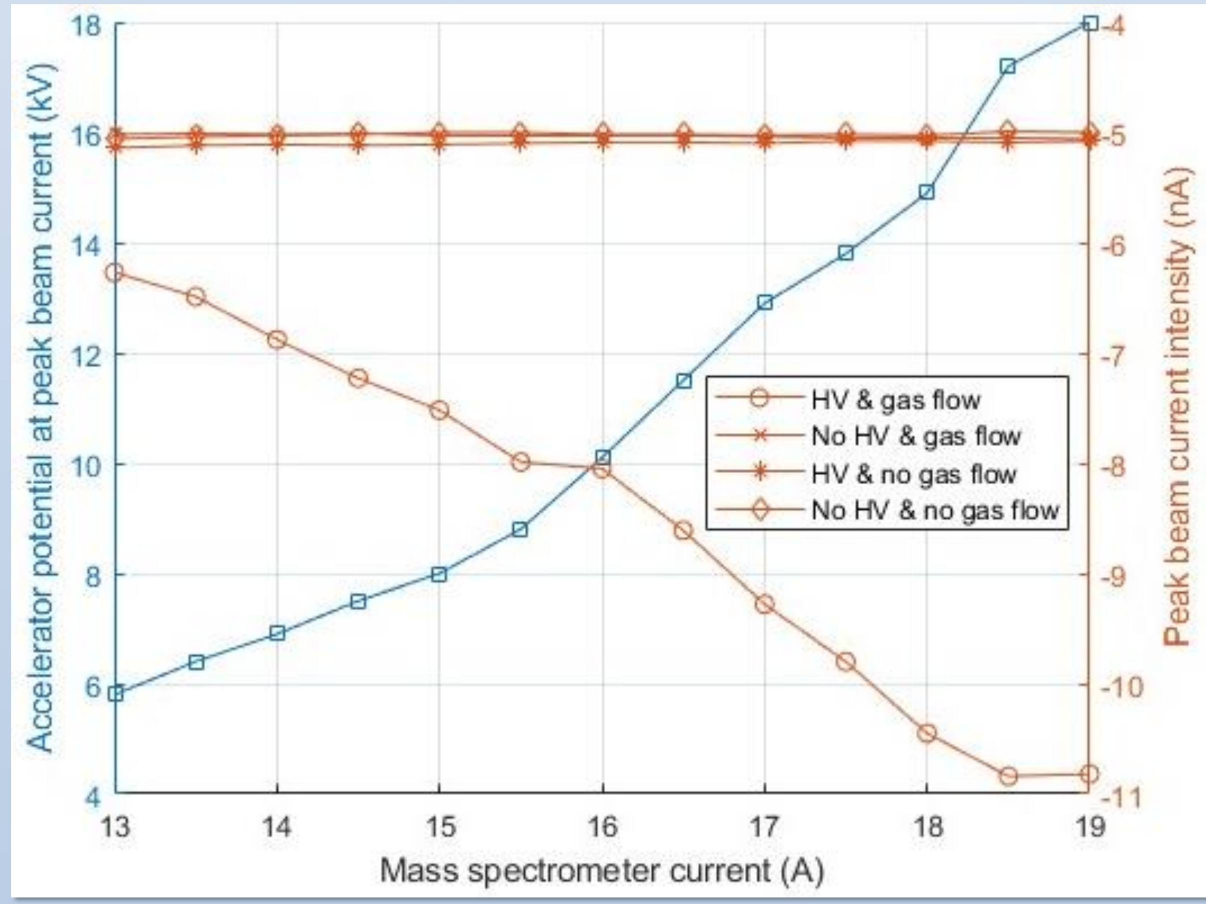

Figure 7: Increasing accelerator potential to display that a stronger magnetic field is required to detect higher energy O^- beams / Tests with no potential on the accelerator (HV) and no gas flow of O_2 were performed to assure false beam current peaks were not being recorded

Conclusions

- A secondary beam of H^- was not created from H_2 gas in the accelerator unit, instead, the incident beam of H^- was slowed and neutralized (likely from collisions with H_2), capturing an electron before the mass spectrometer
- 1.5-5.5 nA beam current peaks resembling O^- beams were recorded at increasing mass spectrometer currents for increasing accelerator potentials
- Multiple beam current peaks recorded for 12 kV acc. potential

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References

[1] Chang, S., et al. "High energy hydrogen and helium ion implanter." *2014 20th International Conference on Ion Implantation Technology (IIT).*

[2] Bacal, M., et al. "Negative Ion Sources." *Journal of Applied Physics*, vol. 129, no. 22, 2021, p. 221101.

[3] Doupé, J. P., & Litherland, A. E. "An electron-transfer gas ion source with isobar separation for Cl −." *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms*, 259(1), 217–223.

[4] Kuo, T., et al. "On the development of a 15 mA direct current H− multicusp source." *Review of Scientific Instruments*, 67(3), 1314–1316.

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