Light Ion High Voltage Repeller

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Background

- Ultra-high Vacuum (UHV) describes vacuums with pressures between 10^{-9} and 10^{-12} torr
- For comparison, the pressure at the International Space Station is $\sim 10^{-9}$ torr, while the lunar surface is $\sim 10^{-11}$
- 10^{-9} torr corresponds to about 25 million particles per cm^3, 10^{-11} torr is closer to 250,000.
- Such low particle densities allow for ion beam/dissociation experiments to work
- Powerful ultrafast lasers are used to dissociate ions and spectrometers are used to tag ions in time for momentum imaging

Experimental Setup

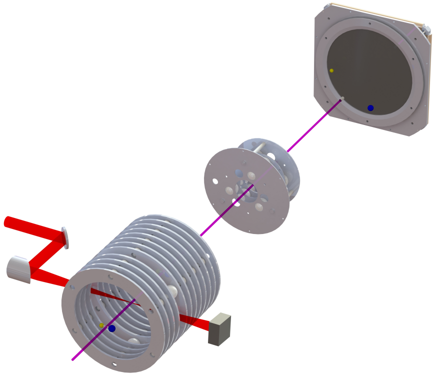


Figure: The setup of the experiment within the vacuum chamber. Visible is the spectrometer and where the laser intersects the ions, as well as the placement of the repeller and the detector

The Problem

- Despite the benefits of UHV, the background gases still very present
- Laser is able to ionize gases such as H_2 and H_2O, creating lots of light ions ($\frac{m}{q} = 1, 2$)
- Background ions cause noise on detector, possibly creating dead times in the detector, resulting in loss of data

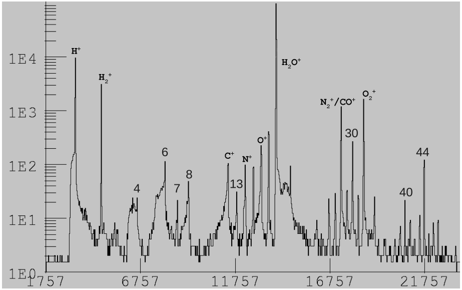


Figure: A spectrum taken of the background ions

Solutions

- Increase the energy of the ion beam so that the interesting ions arrive before the background
  - Isn't a perfect solution, since increasing the energy causes a loss of resolution for imaging
- Actively remove background ions using a pulsed high voltage

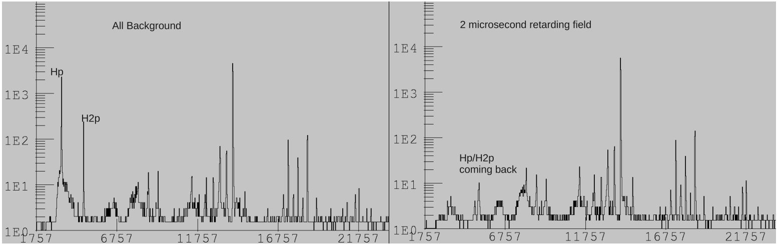


Figure: Background spectra taken as a proof of concept

Modeling Explained

- Used SimIon
- Simulated vacuum chamber and spectrometer, inserted charged rings into file
- Looked at multiple arrangements of rings to find one that could achieve a high central potential with the minimal potential gradient

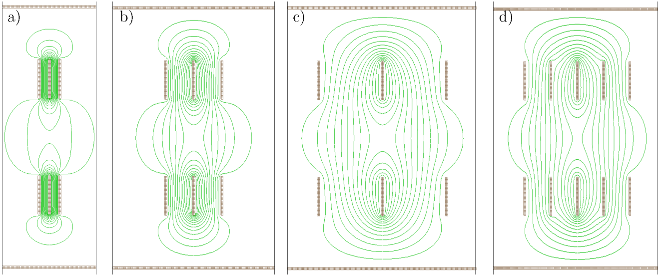


Figure: Three ring arrangements: a) 3mm apart, b) 10mm, c) 20mm, and a five ring arrangement (d) with 10mm spacing

Modeling Explained

- Used the five ring arrangement
- Simulated an ion beam passing through the repeller to check possible focus issues
- Did simulations to test for situations involving a beam moving along the central axis and one that is purposely aimed off axis
- Varied ratio of E/qV, where E is the kinetic energy of the ion beam, q is the charge of the ion, and V is the voltage placed on the center ring
- Also did simulations to find the relationship between the voltage on the central ring and the potential at the center of the repeller

Modeling Data

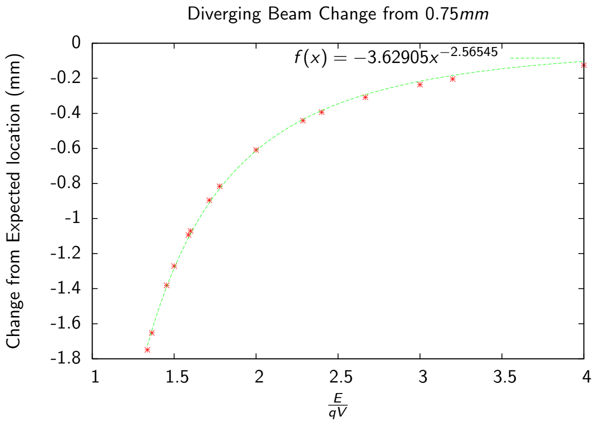


Figure: A graph showing the relation of $\frac{E}{qV}$ to distance away from the target location for a diverging ion beam. A graph like this allows for an understanding of how much the path of the ion beam will be bent based on the energy of the beam and the voltage of the spectrometer.

Modeling Data

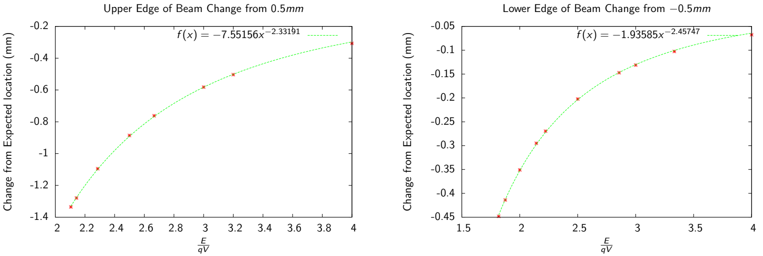


Figure: Two graphs, one corresponding to the upper edge of the ion beam (left) and the other corresponding to the lower edge. These show the relationship of $\frac{E}{qV}$ to distance away from the target location for an ion beam bent so as to be aimed at a cup roughly $7mm$ away from the central axis.

- Usual experiments take place in the realm of $\frac{E}{qV} \geq 7$
- Ion beams in simulation had moved by less than $0.1mm$ from intended target at $\frac{E}{qV} = 4$
- Very little worry of background ions returning

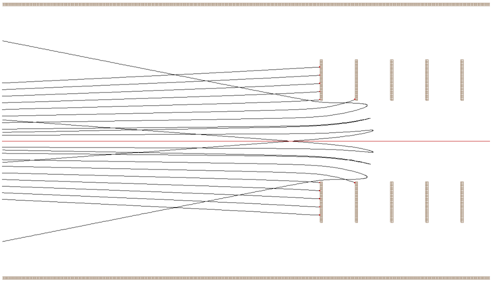
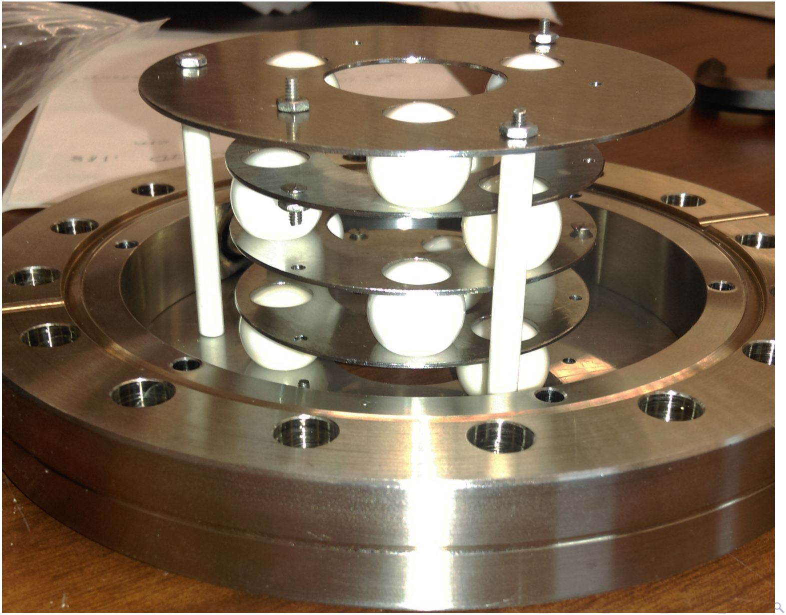


Figure: A simlulation of 18 different H^+ ions sent from near the spectrometer being repelled by the Repeller. The ions obtained a maximum energy level of $925eV$

Constructed Repeller



Repeller Details

- One of the outer rings directly attached to the walls of the vacuum, stopping anything from passing the Repeller on the outside of the rings
- Rings are roughly $1cm$ apart, spaced by ceramic balls
- Inner rings are connected to high voltage source using resistors to achieve the desired voltage
- Outer rings are hard grounded by their connection to each other and the walls of the vacuum

Real World Tests

- Real vacuum tests coming soon (hopefully)
- Will be testing:
  - speed at which the Repeller reaches maximum voltage
  - how well it blocks ions in an actual experimental setting
- Finally, it will be used to help gather data for an actual experiment before getting the blessing for full use