Constructing an Electron Focusing Lens

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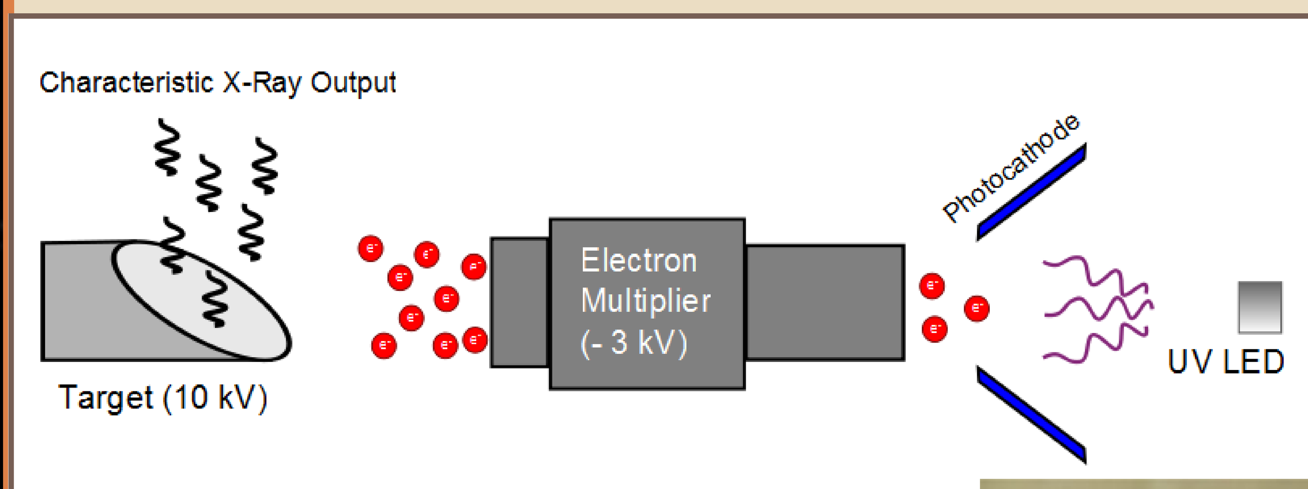
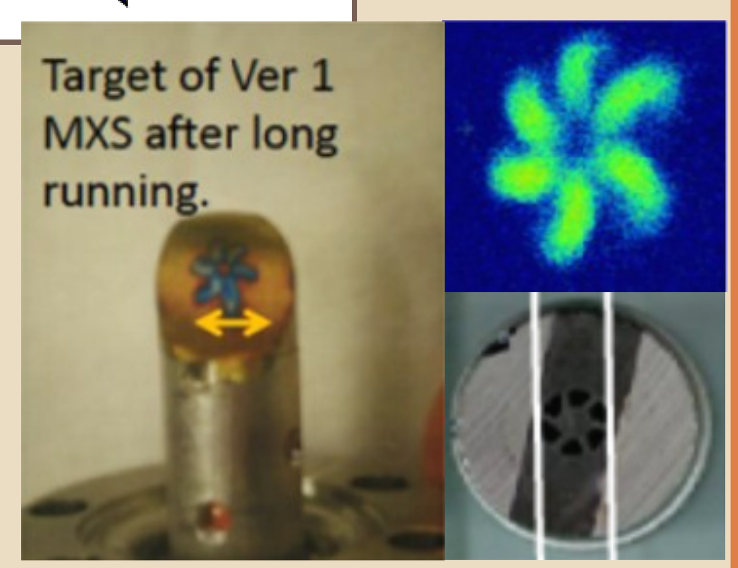
Introduction

MXS stands for Modulated X-ray Source, a device which Goddard Space Flight Center (GSFC) hopes to use for various applications including **instrument calibration** and **long-range X-ray communication.** Currently the MXS exists in the lab, where it can transmit audio signals short range. The



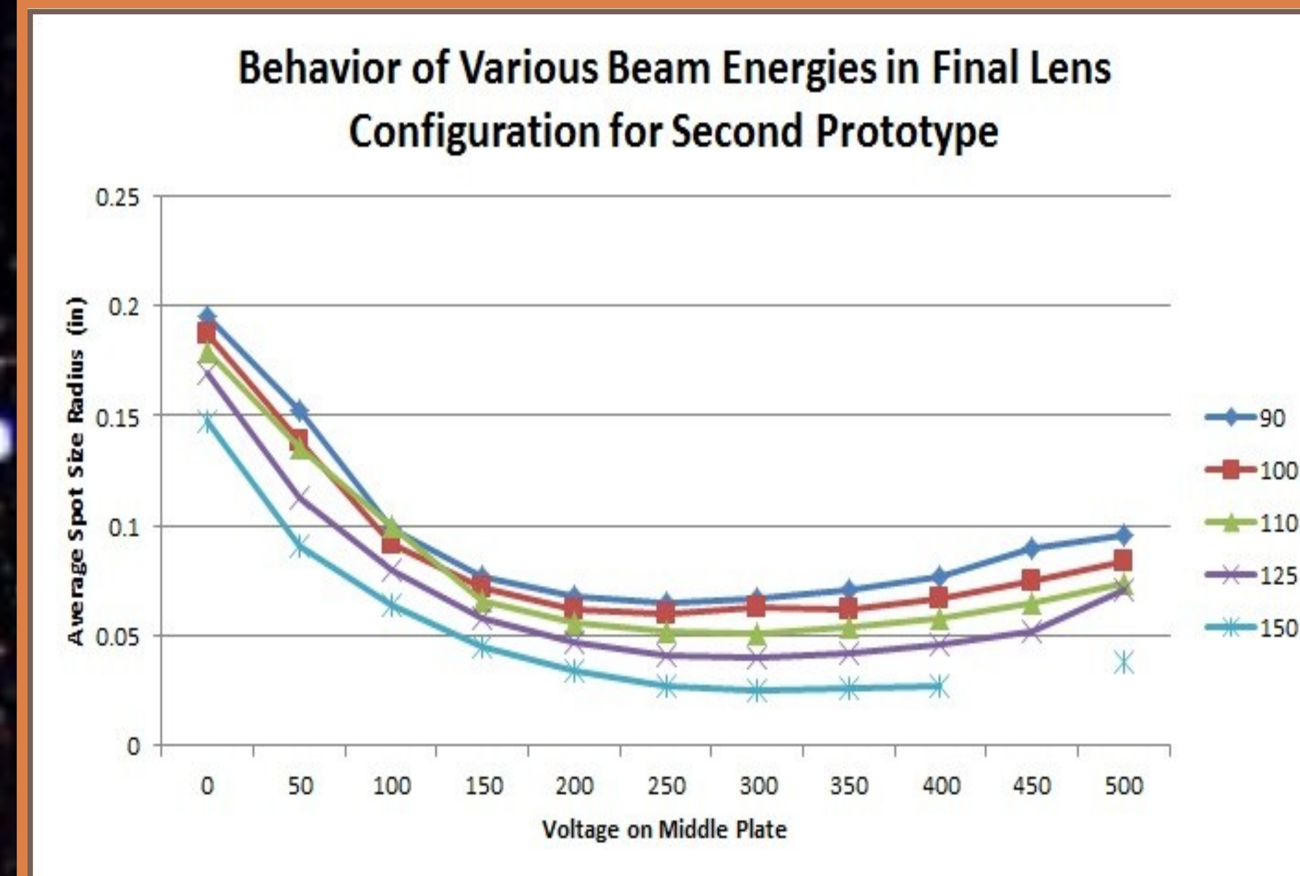


MXS uses ultraviolet light to produce electrons which are multiplied and accelerated into a high voltage target to produce X-rays. This can pulse the **X-ray output as fast as the driver can modulate the ultraviolet LED** with no moving parts, which makes the MXS perfect for spaceflight.

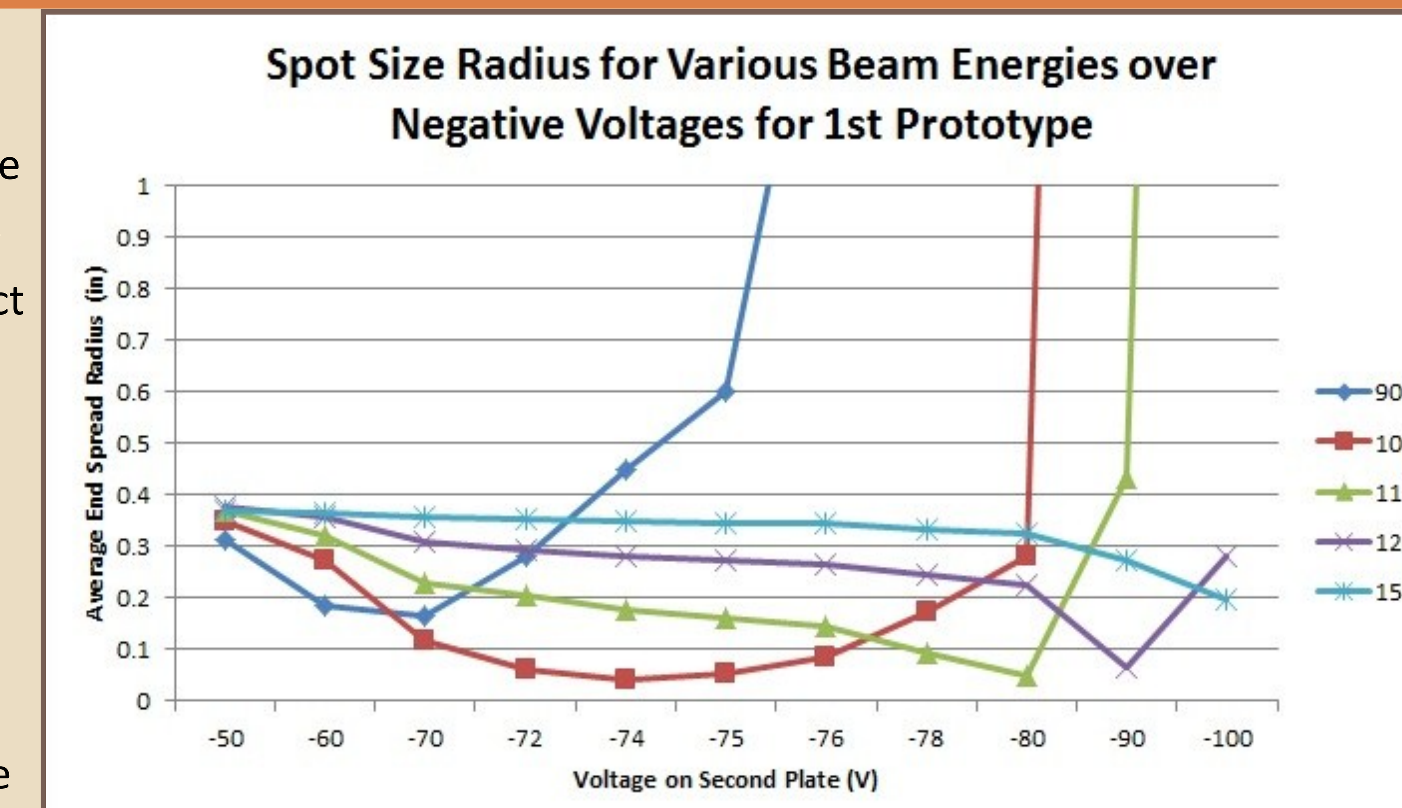
Currently, the X-ray detector only **receives 1/6 of the emitted X-rays** because the electrons are not focused before they hit the target. Images to the right show the target with the impact pattern, the charged couple device (CCD) capture of the X-rays, and the output of the multiplier visually display the spread problem. Our goal is to

Our team will model an existing X-ray source and develop an electrostatic lens in order to create a more focused hit on the target, creating better X-ray transmissions. To validate our model, we will create the MXS with electrostatic lens, using a detector to determine the electron beam or x-ray behavior.

Simulation

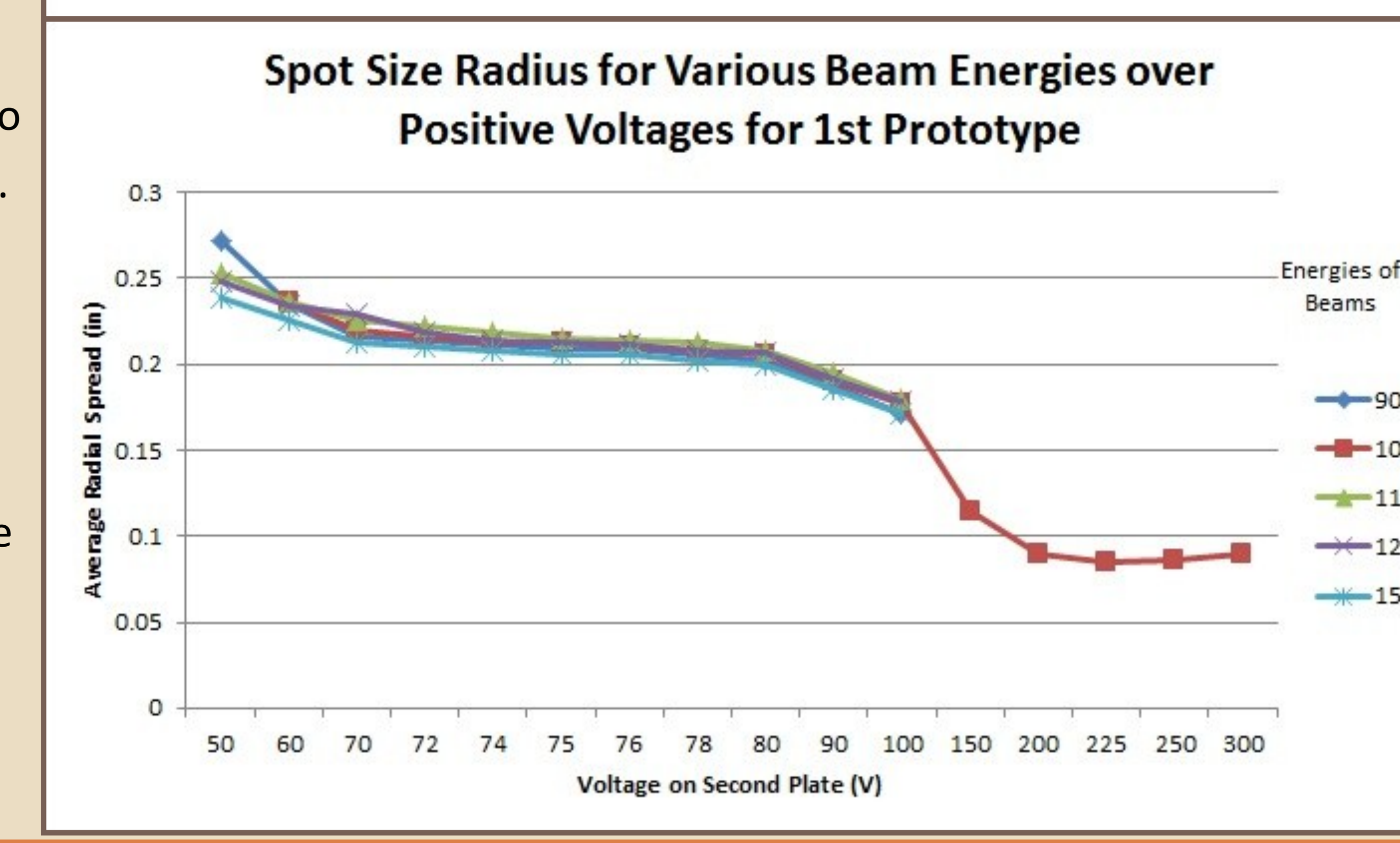


Using SIMION, an ion and electric potential simulation program, we were able to create potential arrays that depict the shapes of the electrostatic lens, outer housing, and the electron target and then send a beam of electrons through it to see how small the spot size would be on the target.



For our first prototype, our team ran simulations sweeping the number of electrodes (two or three), inner diameter, outer diameter, electrode length, and spacing between electrodes. For each variable our team considered which values gave us a smaller spot size.

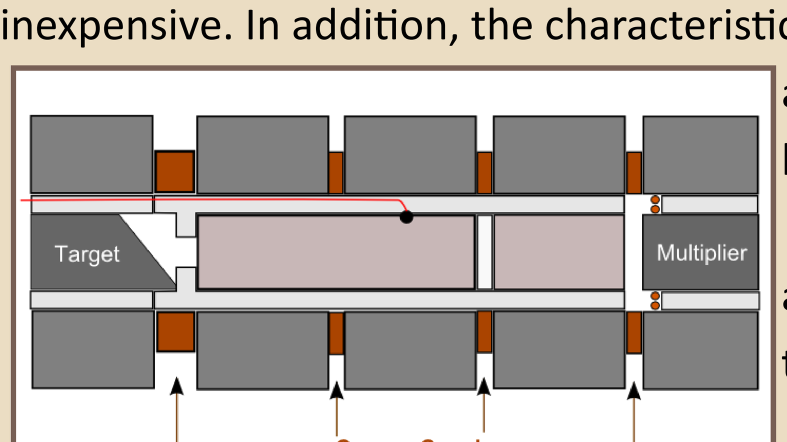
Once we had decided upon a lens, optimized for negative second plate voltages, we ran simulations with that finalized geometry with varying beam energies so we could match up our results with the simulated ones (RIGHT). We realized after we submitted the lens design that it would be better to hold the plate at positive voltages, so for our second prototype, we optimized the variables for positive second plate voltage ranges and achieved better results (bottom right graph).



Hardware

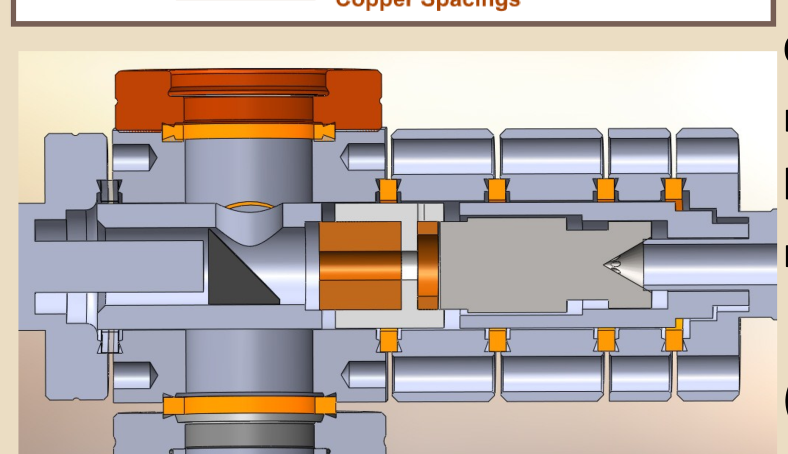
We had a several physical constraints on our lens design. The lens had to fit within a mini-CF vacuum fitting, ideally be no longer than .75", and have only one electrical feed-through to minimize custom machining.

We chose **copper 110** for our lens elements, being electrically conductive, easily machined, and relatively inexpensive. In addition, the characteristic energy required to excite electrons from copper is quite high, so any stray electrons colliding with the copper lens would be less likely to excite characteristic X-rays.



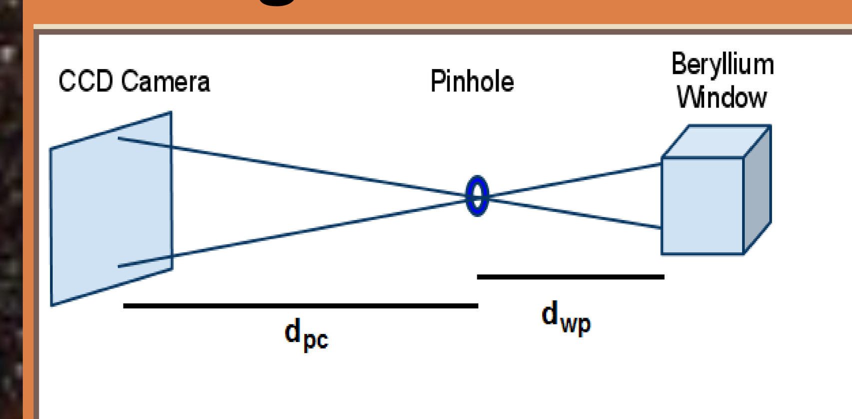
We used **MACOR**, a machinable glass ceramic, for the housing around the lens. This insures the lens is electrically isolated from the grounded mini-CF fittings.

The lens design is shown in the two figures to the right. The MACOR housing consists of a hollowed-out cylinder with an approximately 2 mm spacer between the lens elements. The longer lens is held at a positive voltage, while the shorter lens is grounded by means of contact with a power spring on the multiplier.

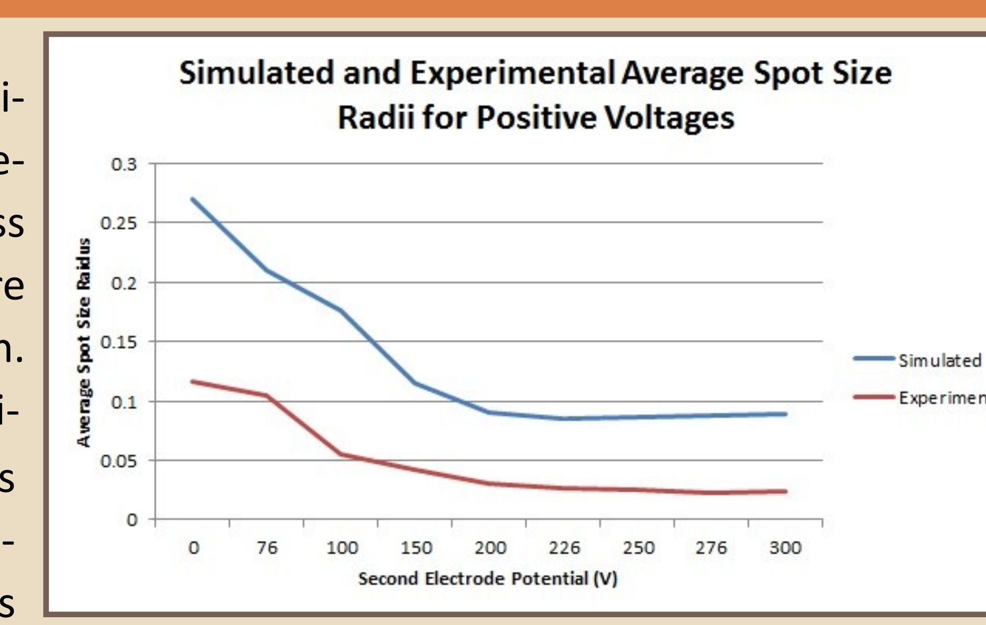


The significant difference in our next iteration of our lens (BOTTOM LEFT) is length: we were able to reduce the overall length of the lens assembly to under 0.6".

Testing and Conclusion



A pinhole image is used for our experimental testing. X-rays are emitted from the beryllium window of the MXS, which then pass through a pinhole. The image of the X-rays are then projected onto the CCD camera screen. The ratio d_{pc}:d_{wp} (LEFT) determines the magnification of the original image coming from the MXS. We had expected that negative voltages on the middle plate would provide the best focusing effects, but our testing proved the opposite. We believe this is due to the force from the second lens electrode on the electrons repelling beams of lower energies.



To compare our results with our simulations, we used MATLAB to find the maximum pixel values in order to determine the smallest and brightest spot sizes in each image. Our comparison between simulated and experimental results for the first prototype are shown in the graph to the left. What surprised our team is that the **experimental results were better than our simulations**. This could possibly be because the actual beam has a higher beam energy or less beam repulsion than we simulated. Regardless, both the experimental and simulated results show the same behavior and have the same magnitude, our team considers our simulations validated by these test results and a reasonable indication that our lens acts as we expect. Our second prototype testing results (RIGHT) show a general matching trend to the simulated.