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Scientific Detectors

# A Direct Comparison of a Resistive Glass and Stacked-Ring Reflectron

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# Overview

**Purpose**: To determine the suitability of a reflectron made of resistive glass as a replacement for a traditional reflectron comprised of metal rings and a separate resistor divider network.

**Methods**: Two reflectrons with the same basic geometry are substituted into an orthogonal time of flight (TOF) system and the spectra are directly compared.  The electric field and the resistance uniformity of resistive glass samples are measured to evaluate the uniformity of the field within the glass reflectron.  The performance of the TOF system is compared to a SIMION model.

**Results**: The resistive glass reflectron performs as well or better in the test system, indicating that the glass reflectron is a viable one-piece replacement for the stacked ring assembly.

# Introduction

Resistive glass is lead-silicate glass that has been reduced in a hydrogen atmosphere to make its surface a semiconductor. Structures and assemblies made from resistive glass can be used as ion optics such as ion guides, drift tubes, and reflectron lenses. These elements offer significantly simpler construction than their traditional metal analogues due to the dramatic reduction in the number of components and the absence of the need for a separate divider network to provide the appropriate voltages.

While there have been a number of researchers evaluating ion optics constructed of resistive glass, there is little published performance data. Our approach is to evaluate the glass reflectron by directly substituting it into a simple orthogonal TOF system and comparing the observed performance to that measured with a traditional stacked-electrode reflectron. We also compare the performance of both reflectron lenses to SIMION computer simulations of the TOF system.

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# Reflectron Lens

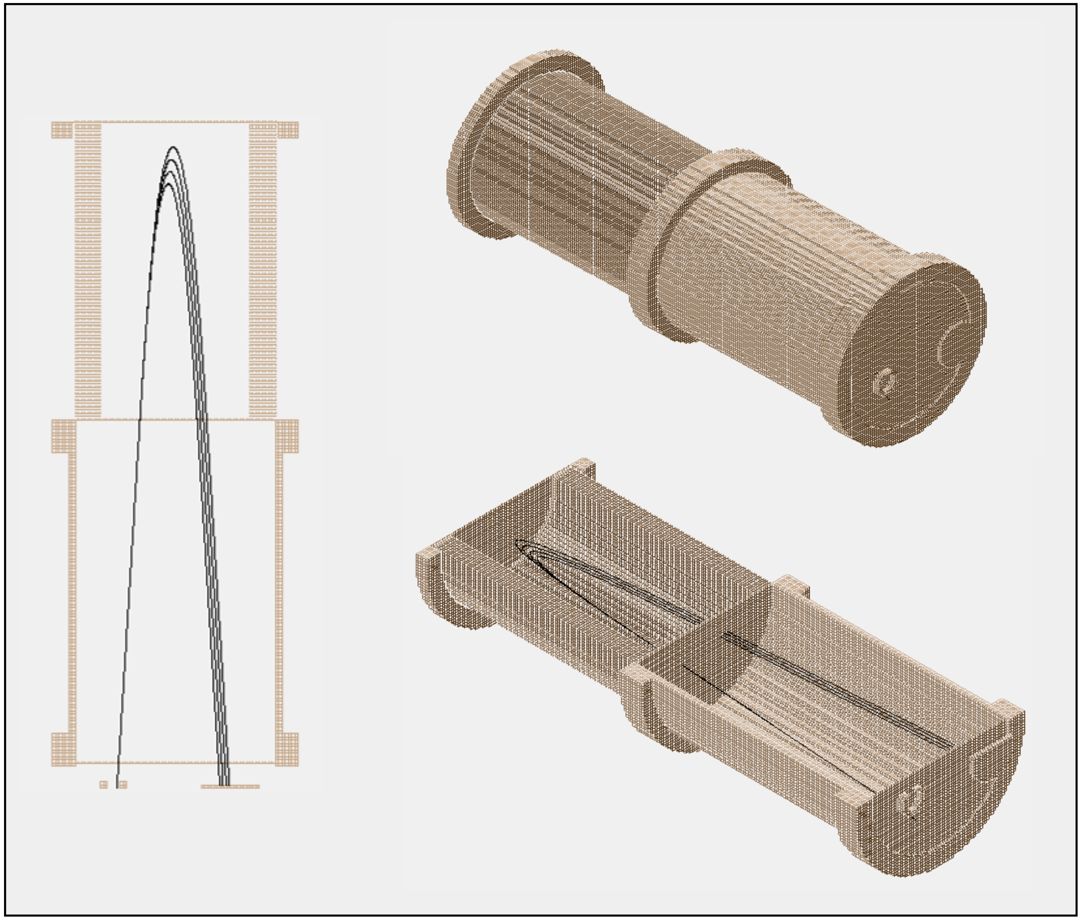


**Figure 1:** A reflectron uses a static electric field to reverse the direction of energetic ions, increasing their flight times and improving the resolution of a mass spectrometer by helping ions with different initial kinetic energies reach the detector at the same time.

# Resistive Glass Reflectron

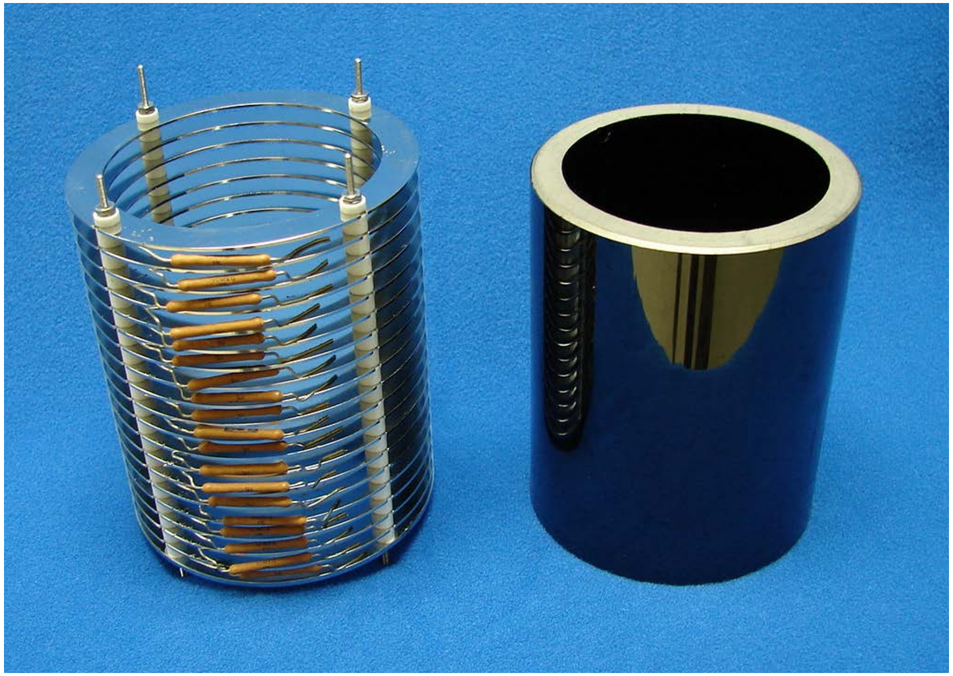


**Figure 2:** The stacked ring reflectron and resistive glass reflectron used for these tests. The stacked electrode lens consists of 127 parts that must be assembled. The resistive glass reflectron is a single piece.

**Figure 3:** Resistive Glass and Stacked Ring Reflectron shown in place on experimental apparatus. The metal and glass reflectron could be interchanged without disturbing any of the other components.

# Advantages of Resistive Glass

- One piece design
- Integral electrodes and resistive divider
- Little or no assembly
- Ultra-high vacuum compatibility
- Smooth electric fields
- Custom sizes
- Integral grids are easily added
- Good stability in vacuum
- High breakdown voltage

# Orthogonal TOF Spectrometer

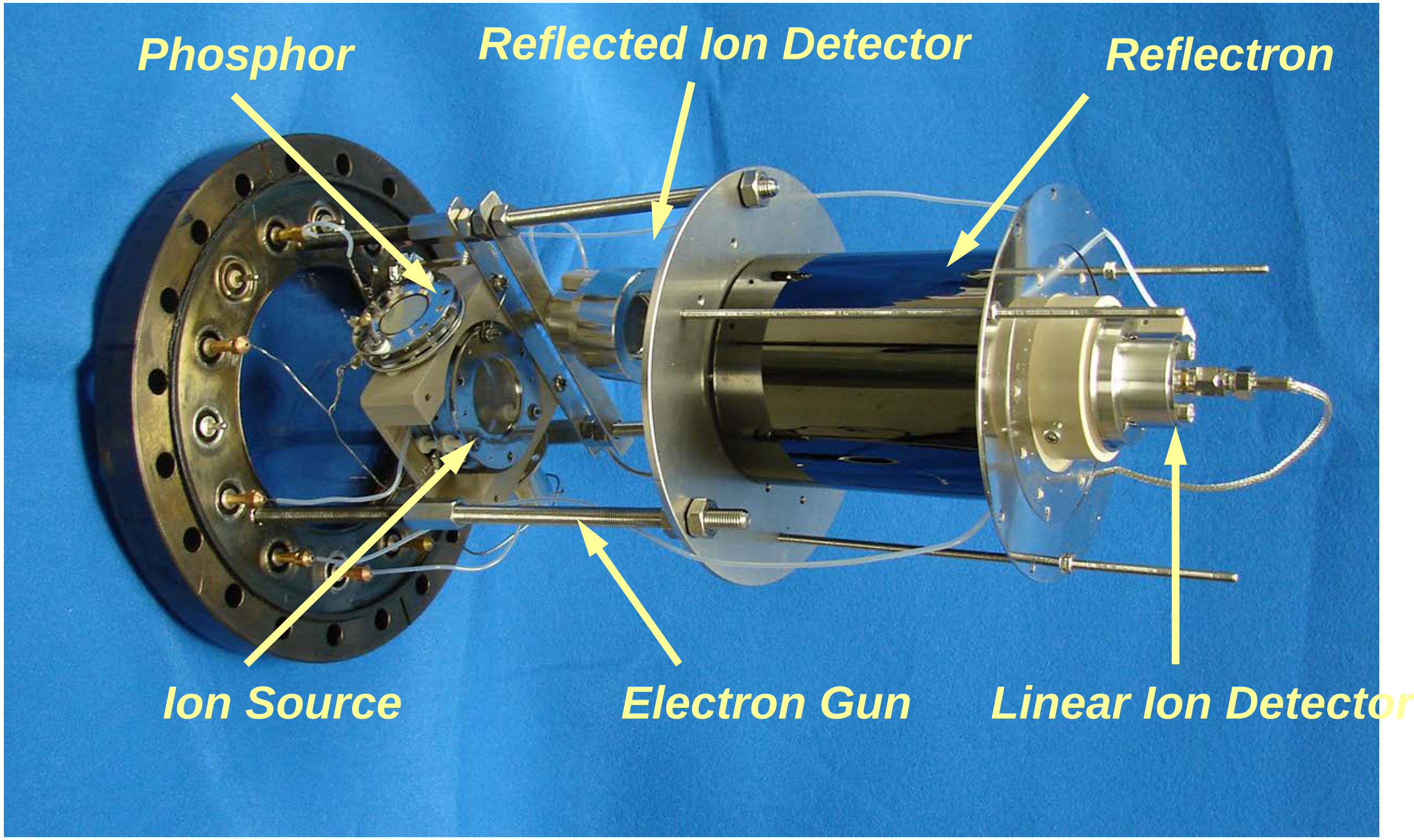


**Figure 4:** Experimental apparatus used for these measurements.

# Methods

## Simple orthogonal TOF system

- Perfluorotributylamine (PFTBA) source gas admitted into the source through a capillary tube using a variable leak valve (not shown).
- A hot filament electron-impact ionization source directs a beam of electrons through the ion source body parallel to the face of the ion pusher-plate, ionizing the source gas. A phosphor on the opposite side of the ion source is used to monitor the focused electron spot as it exits the other side.
- The pulsed pusher-plate ejects the ions out of the source towards the reflectron. The ions travel to the reflectron, where they can be detected by the linear ion detector or reflected back to the reflected ion detector.
- The peak shapes from the detectors can be analyzed on an oscilloscope triggered using the pusher plate pulse.

# Methods

**Source Details**

- Two-Stage / Wiley-McLaren[1] source with 1 cm source and acceleration grid spacing.
- PFTBA source gas
- 300V, 2 µs pulse with 10 ns rise time. Pulse rate was 50 Hz.
- All data presented here is with 600V accelerating voltage.
- Typical operating pressures were $4\times10^{-6}$ Torr.

**Spectra Details**

- TOF spectra averaged over 300 pulses.
- TOF spectra converted to mass spectra based on leading edge position of mass 69 and mass 219 peaks.
- Flight times <2µs not shown to eliminate pulser artifacts in spectra.

# Methods

## Two Reflectron Lens Assemblies

- 9.18 cm long 5.35 cm inner diameter stacked ring reflectron consisting of 20 metal electrodes and 19 resistors. Total resistance ~140 MΩ.
- 9.35 cm long 5.24 cm inner diameter resistive glass cylinder. Total resistance ~1400 MΩ.

## Substitution testing

- The same grids, grid support frames, linear detector, and mounting hardware were used with both reflectrons
- Source parameters were not changed for comparative spectra.
- Linear spectra measured periodically between reflected spectra.
- The peak width in the linear spectra differed by ≤3%.

# Linear and Reflected Specta

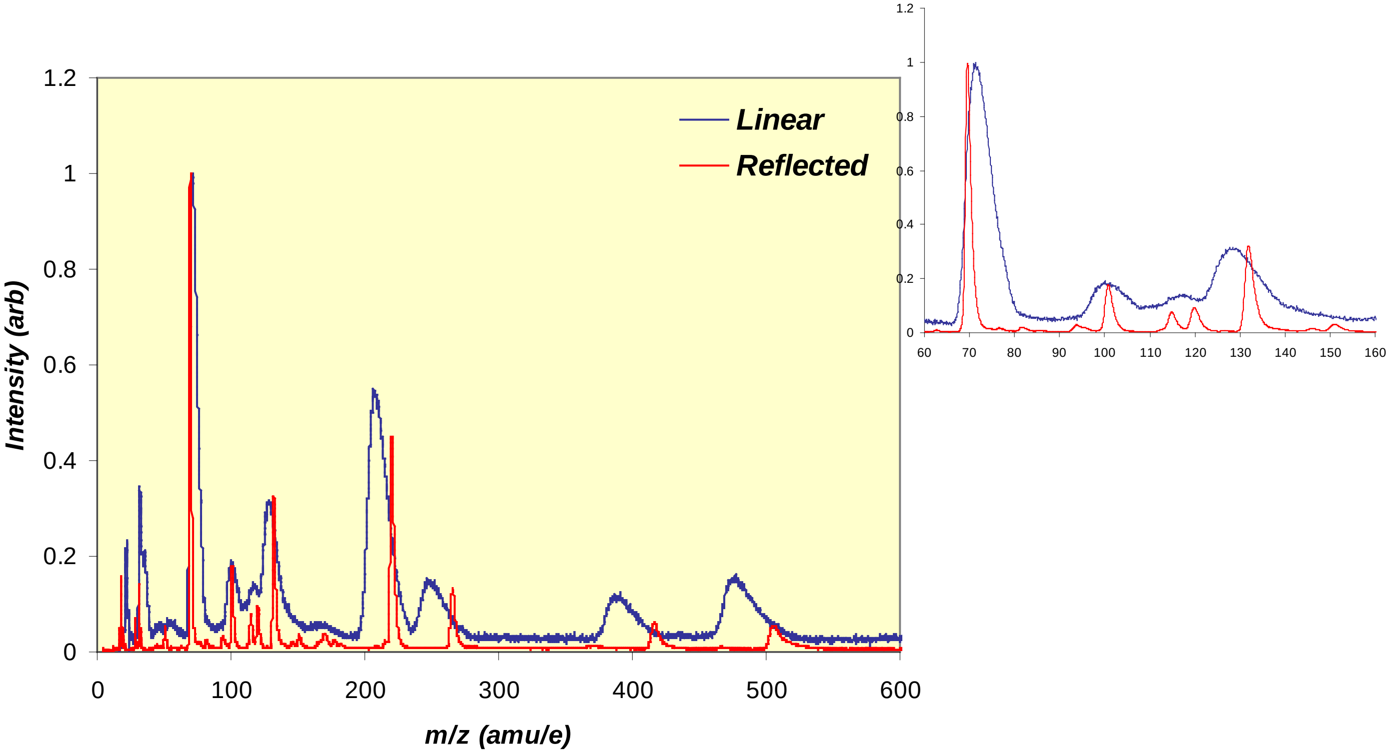


**Figure 5:** Linear and reflected spectra measured using the resistive glass reflectron demonstrating the improvement in mass resolution due to the energy focusing. The inset shows a portion of the mass spectrum, detailing peaks that are unresolved in the linear spectrum.

# Reflected Spectra

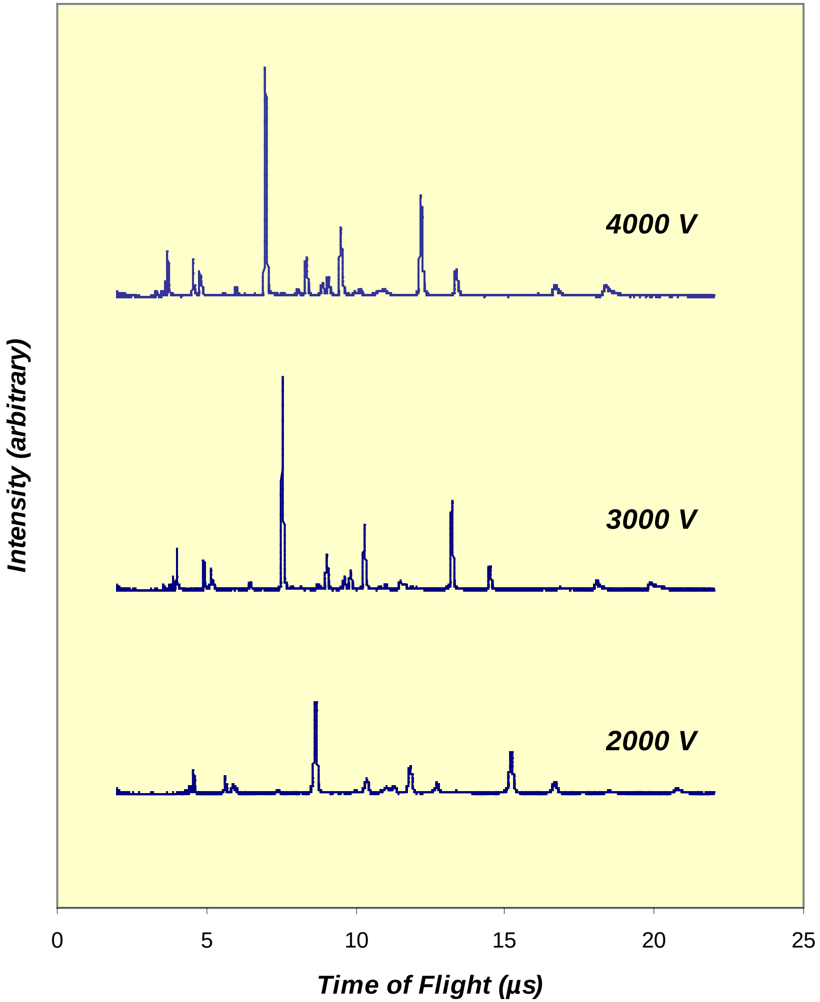


**Figure 6:** Time of flight spectra for three values of reflectron voltage, demonstrating changes in peak positions and peak widths. The change in peak width is much more noticeable for lower reflectron voltages / electric fields as can be seen in Figure 9.

# Glass and Metal Comparison

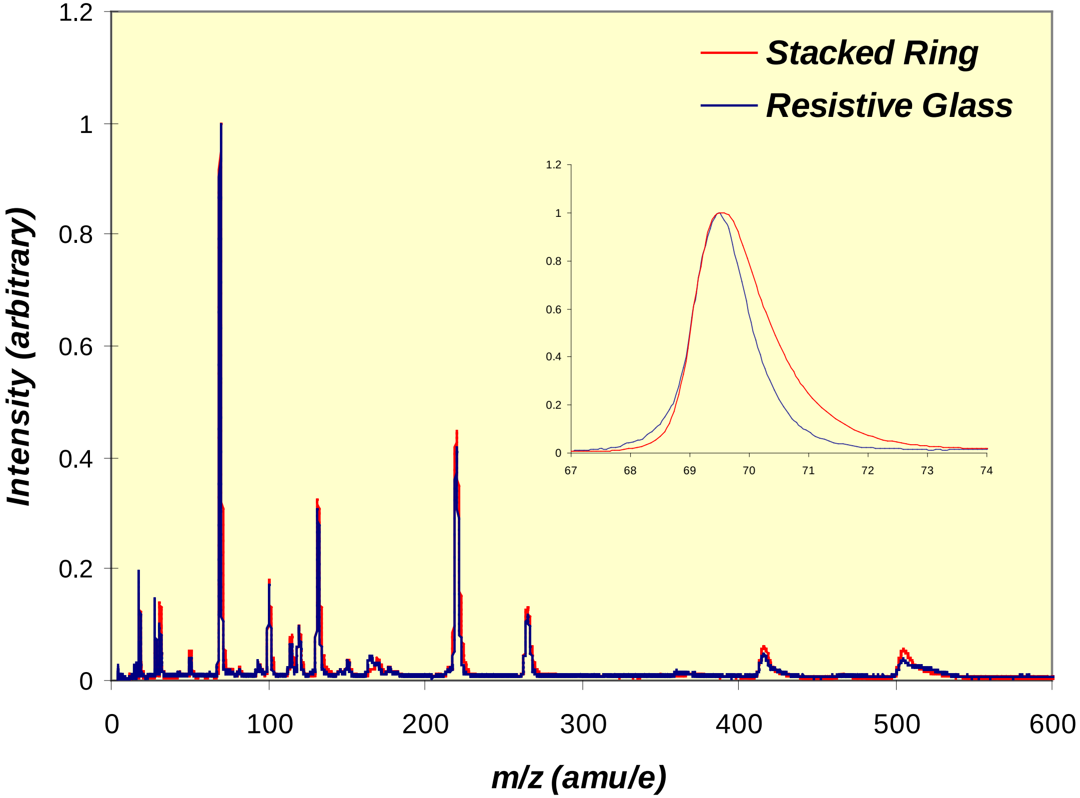


**Figure 7:** Comparative spectra for the resistive glass and stacked ring reflectrons at near-optimal mass resolution. Overall, performance is nearly identical though the glass reflectron (inset) produces narrower peaks.

# Time of Flight Values

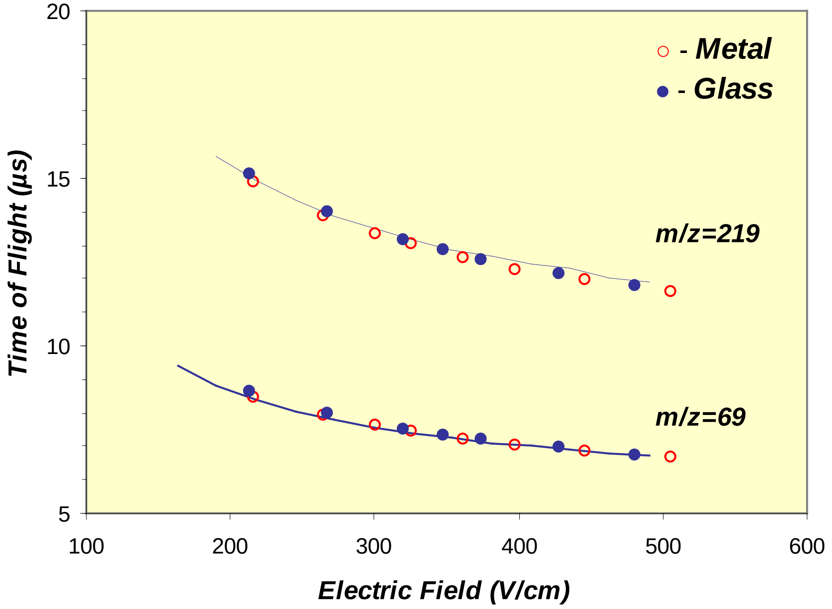


**Figure 8:** Time of flight as a function of reflectron electric field measured at two masses showing good agreement between the two reflectron lenses. The solid lines are from a SIMION simulation.

# Peak Widths

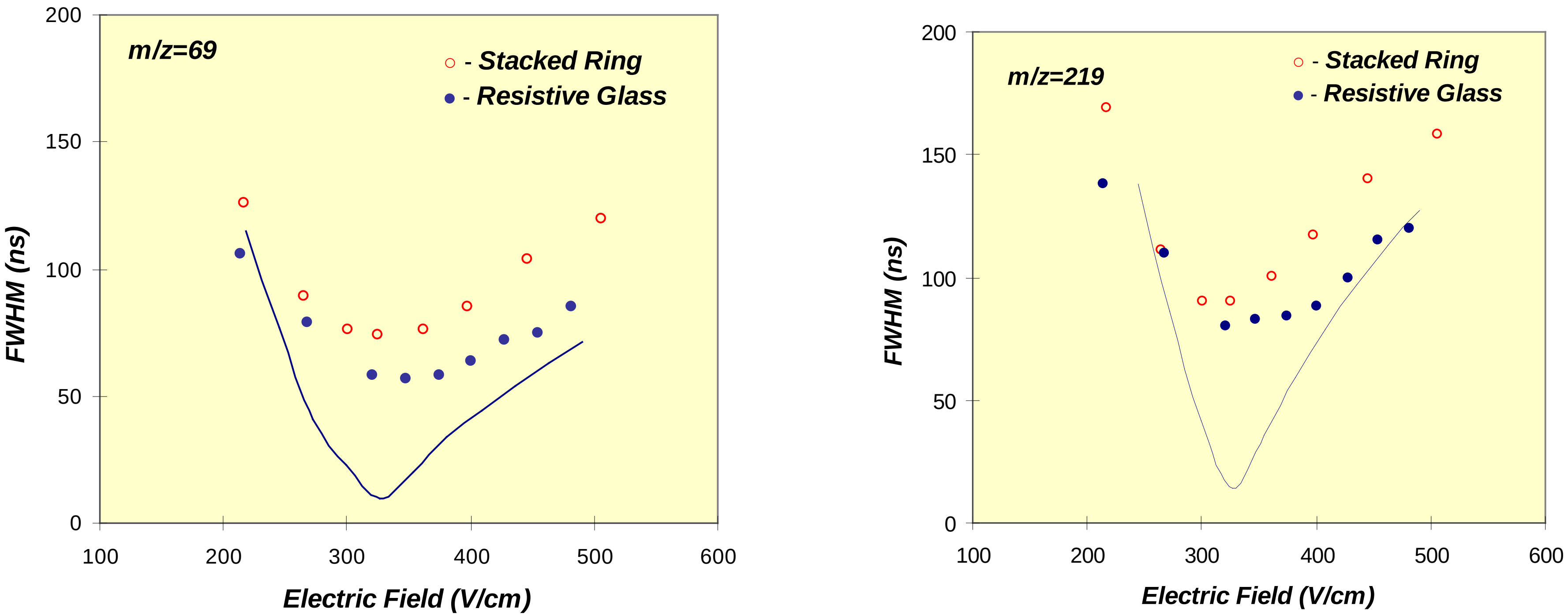


**Figure 9:** Peak full width at half maximum (FWHM) values as a function of reflectron electric field for the resistive glass and stacked ring reflectrons for two masses. Lower FWHM values represent better energy focusing. The solid line is from SIMION simulations, which only include ion initial position as a source of peak broadening.

# Analysis of Resistive Glass

We have used a Kelvin Probe to directly measure resistive glass samples in order to provide further information about the performance of resistive glass as an ion optics material. A Kelvin Probe uses a vibrating capacitor tip to make extremely sensitive measurements of the potential difference between the probe and the sample surface.  For an unbiased sample, the probe measures the work function difference or surface potential between the probe and the tip, which is a very sensitive indicator of surface charging, contamination, or local anomalies in the surface.  For samples with a bias across them, the Kelvin probe allows us to measure the electric field at a fixed distance above the sample, giving us a picture of the field and of the distribution of voltage across the sample.

# Resistive Glass Acts Like a Good Conductor

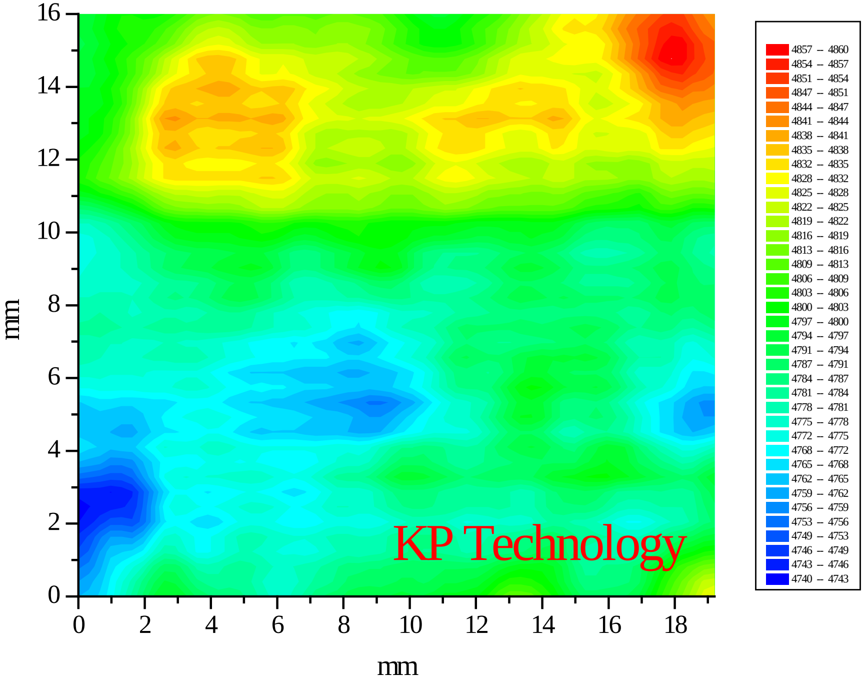


**Figure 10:** Kelvin probe measurement of an unbiased 50x50 mm resistive glass sample showing a very uniform (±0.024 eV) work function. This kind of uniformity is similar to that measured for a metal electrode, indicating that the resistive glass is a good dissipater of charge with a well-defined Fermi surface.

# Direct Measurement of a Linear Electric Field

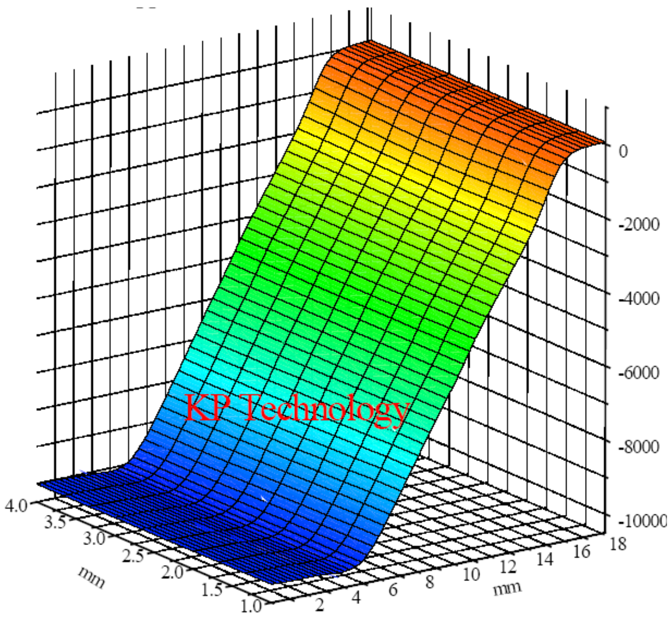
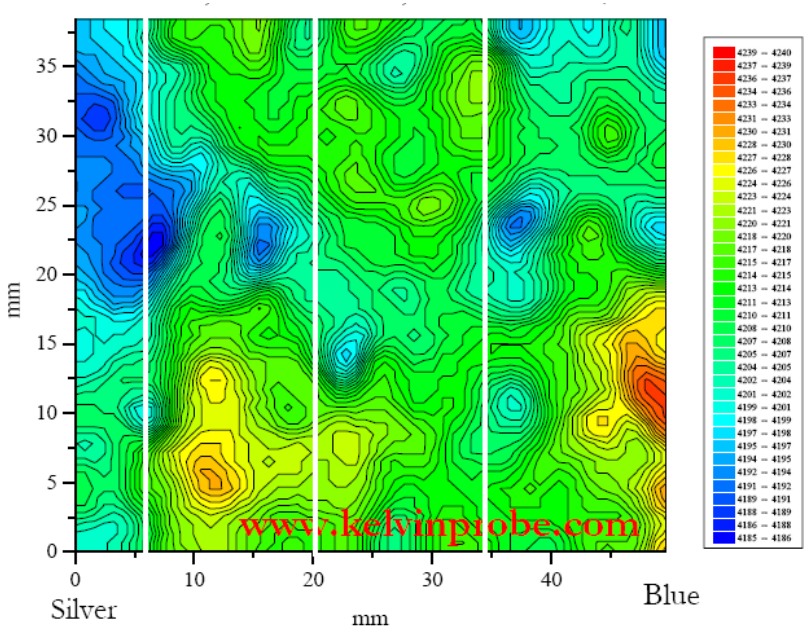


**Figure 11**: The Kelvin probe was used to measure the voltage distribution developed across the resistive glass sample shown in Figure 10 with two edges of the sample held at constant voltage. The resistive glass provides a uniform gradient with no significant anomalies. The smooth gradient indicates extremely uniform resistivity in the surface of the resistive glass.

# Graded Resistance on Single Sample



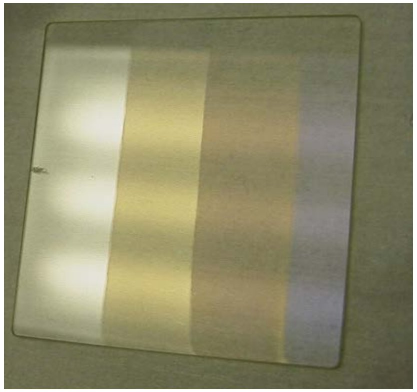


**Figure 12:** We have begun development of a process for making regions of differing resistivity on a single sample. A Kelvin probe scan of a sample with four distinct regions shows that it retains its good work function uniformity (±0.009 eV)

# Conclusions

- In a direct substitution test, a resistive glass reflectron provided equal or better performance than a traditional stacked ring reflectron.
- Kelvin probe measurements show resistive glass produces highly uniform fields and is a good dissipater of charge.
- Use of resistive glass offers an opportunity to dramatically simplify ion optics components.

# Future Work

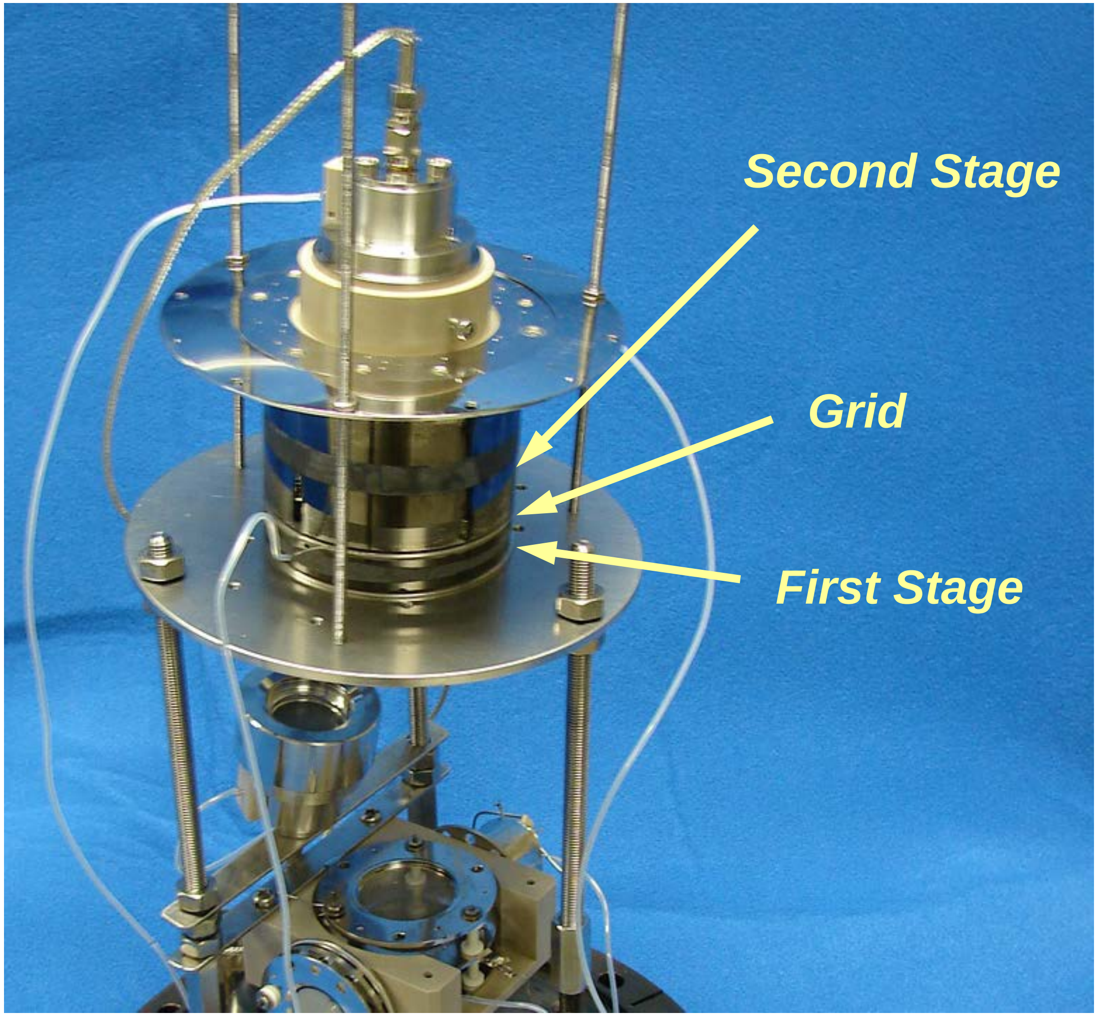


**Figure 13:** We have begun testing of two-stage reflectrons made of resistive glass. Two stage reflectrons have two distinct electric fields which, if properly chosen, can be used to give improved energy resolution for sources with broad initial kinetic energy distributions.

# Acknowledgements

We would like to thank Dr. Matt Evans of Syagen, Inc. and Dr. Eugene Moskovets of the Barnett Institute for their help with development of the reflectron lens experiment.

## References

[1] Wiley, W.C., and McLaren, I. H., Rev. Sci. Inst. **26** (1955) 1150-1157.