

ELECTRON BEAM FOCUSING USING AN OCTUPOLE

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Abstract: In this paper, the focusing capabilities of a novel MEMS octupole element are described and evaluated. The device consists of eight silicon electrodes permanently joined to a glass insulator, designed to recreate the electrostatic field of an Einzel lens while enabling real-time aberration correction and beam deflection. The beam spot quality and focusing performance will be investigated using a CMOS camera detector. The use of the octupole electrode as an electron beam focusing element is to simplify the composition of the electron optical column of a MEMS scanning electron microscope. Here the theoretical discussion on the focusing capabilities of the setup is presented using results of computer simulations.

Introduction

Our long-term goal is to develop a miniature electron microscope. Traditional silicon-to-silicon bonding hinders rapid testing of multiple configurations due to assembly errors and long processing times. To bypass this, we proposed a novel prototyping platform using a DLP 3D-printed polymer resin holder and a dedicated PCB for precise component alignment. While the complete microscope system is presented in another work, this poster focuses specifically on electron beam simulations of a multifunctional silicon octupole.

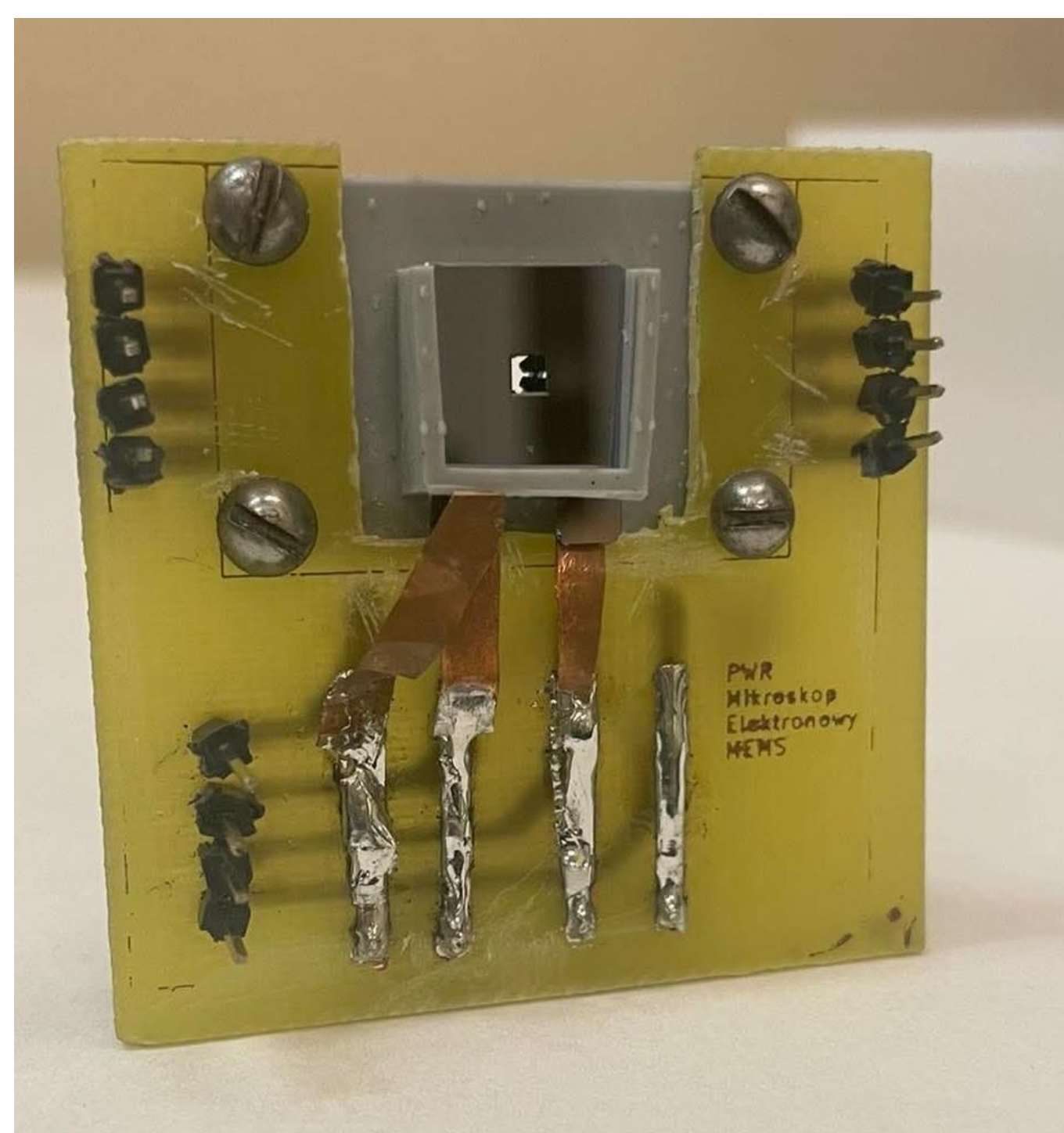


Figure 1. Modular 3D-printed testing platform.

Octupole fabrication

- 200 μm n-type silicon
- Tapered electrode gaps from 100 to 500 μm , with a 1.0 mm central aperture and a 2.0 mm through-hole
- Pre-etching: Si substrate etched in 10M KOH (80°C, 20 min) to form <50 μm membranes
- Glass Cavity: Glass masked and etched in HF (90 min) to create a central cavity
- Activation: Oxide removed in BHF; boiling in hydrogen peroxide (20 min)
- Anodic Bonding: Components bonded at 450°C under 1.5–1.7 kV
- Isolation: Membrane removed via KOH etching to separate the electrodes
- Exposure: Glass back-etched in HF to create a through-hole and expose the electrodes

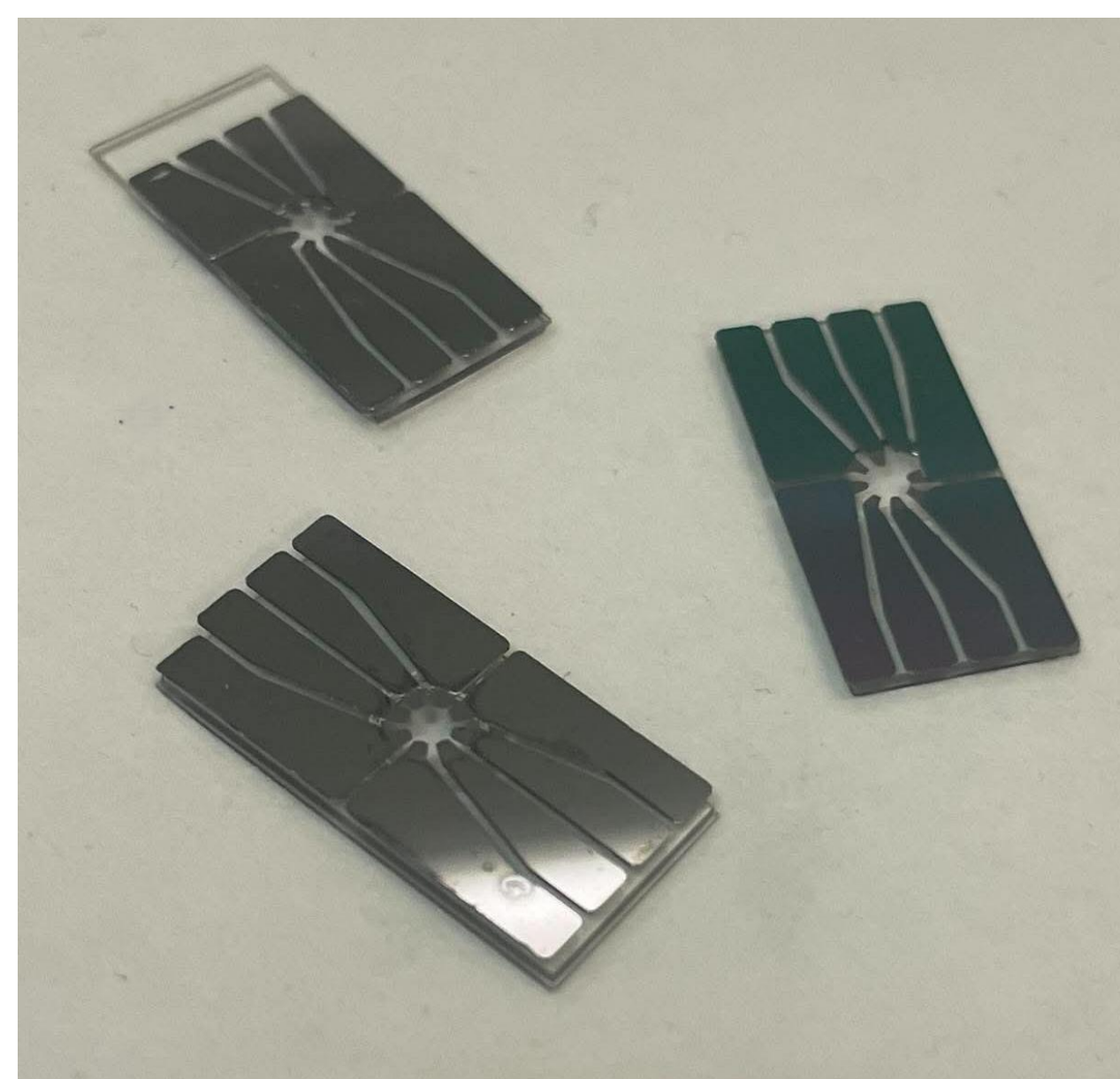


Figure 2. Fabricated octupole chips after anodic bonding of silicon electrodes to the glass substrate.

Measurement setup

■ Cathode ■ Gate ■ Octupole ■ Anode
■ CNT ■ Focus ■ Detector

Figure 3. Single Electrode Lens

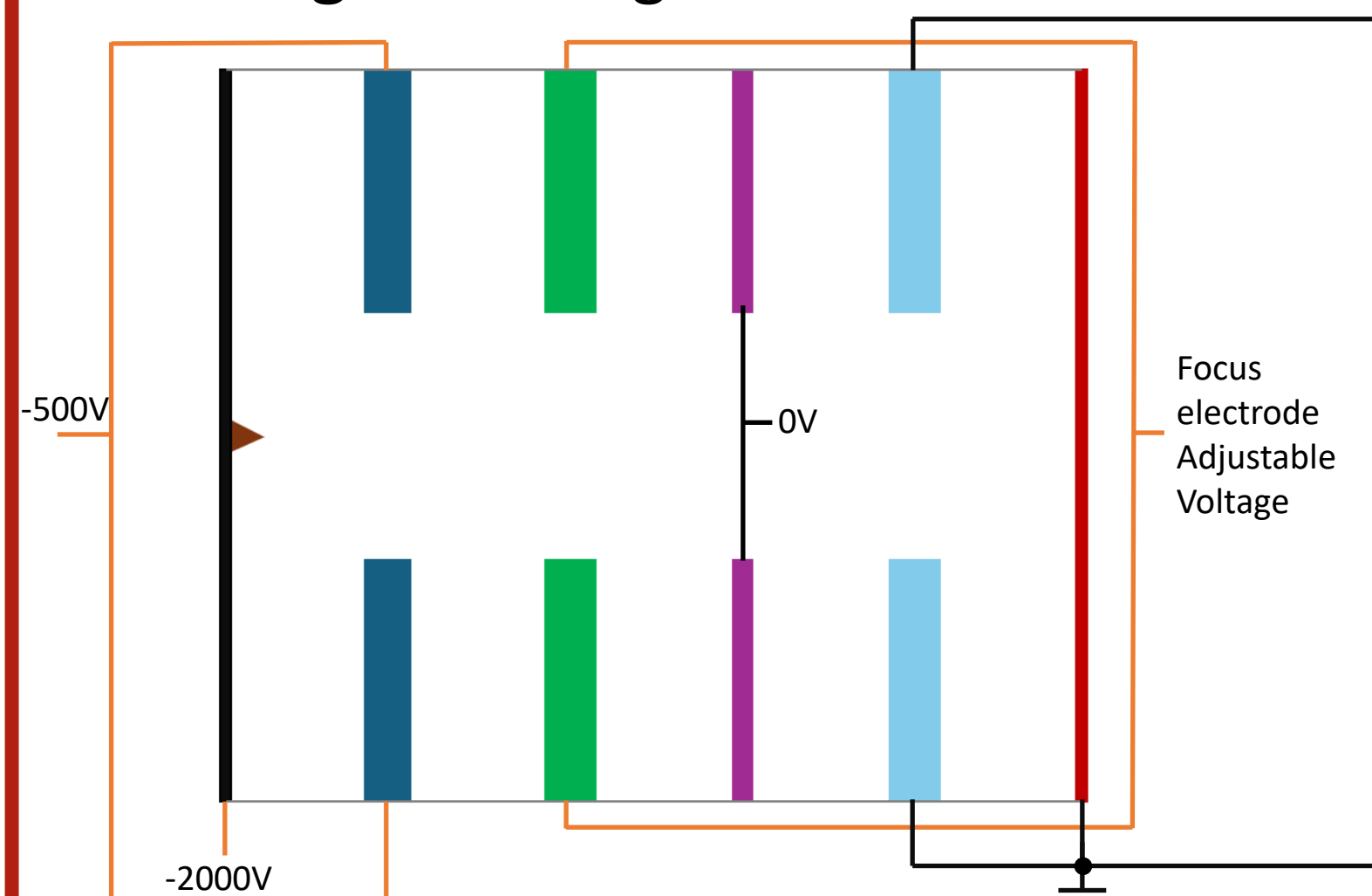
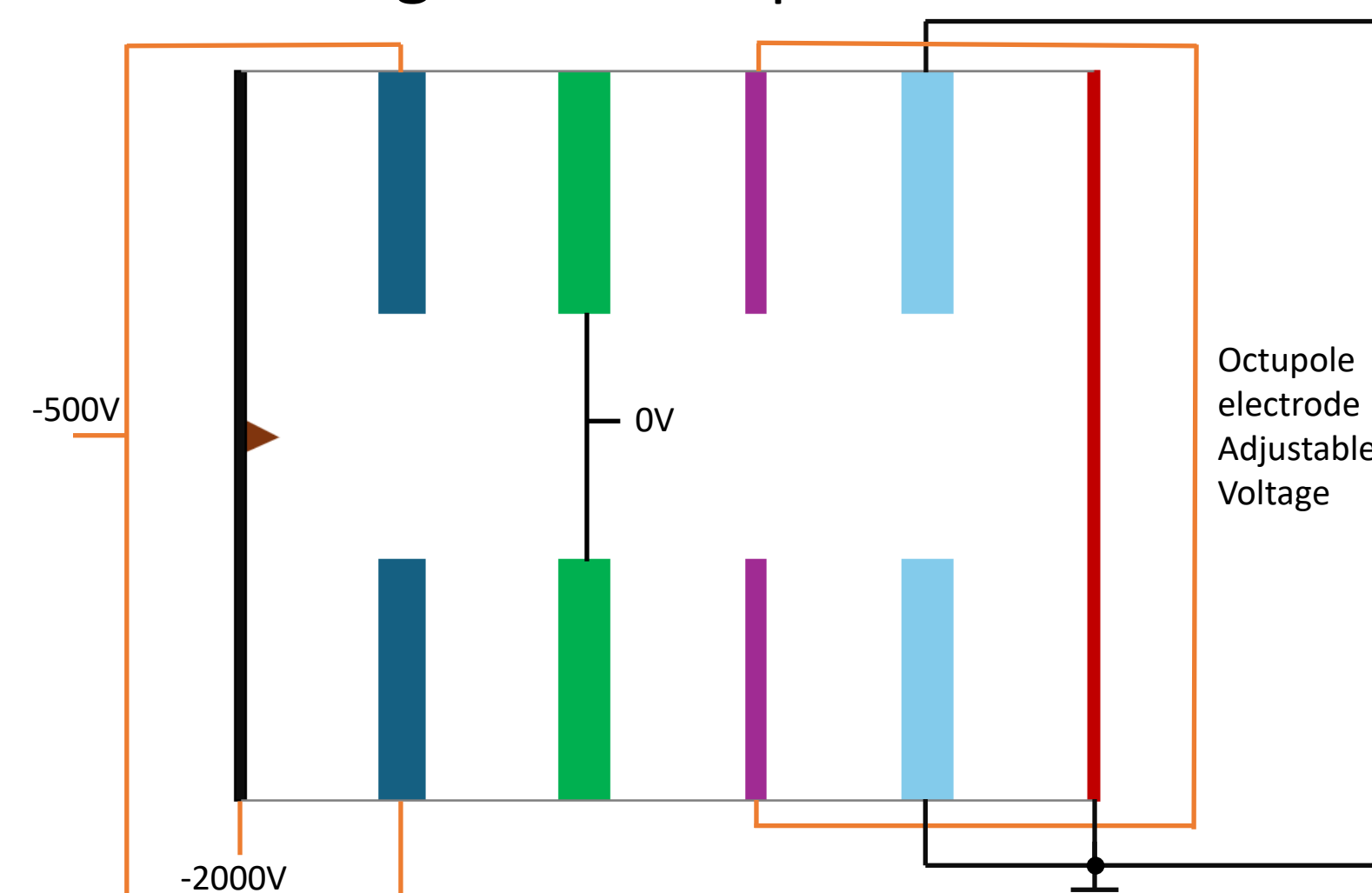


Figure 4. Octupole Lens



Summary

This work demonstrates that the novel MEMS octupole element significantly improves electron beam control over conventional single electrode lenses used up to this time. Standard focusing degrades rapidly beyond 2300 V, whereas the octupole mode ensures superior beam confinement and tighter focal spots at higher potentials (2400–2500 V). Future research will focus on the experimental testing of the fabricated chips, aberration limits, and dynamic beam deflection.

Numerical simulations

This section outlines electron beam focusing simulations carried out using the SIMION simulation package. The primary objective was to investigate and compare the focusing characteristics achieved by an octupole lens configuration against those of a conventional focusing using single electrode focusing.

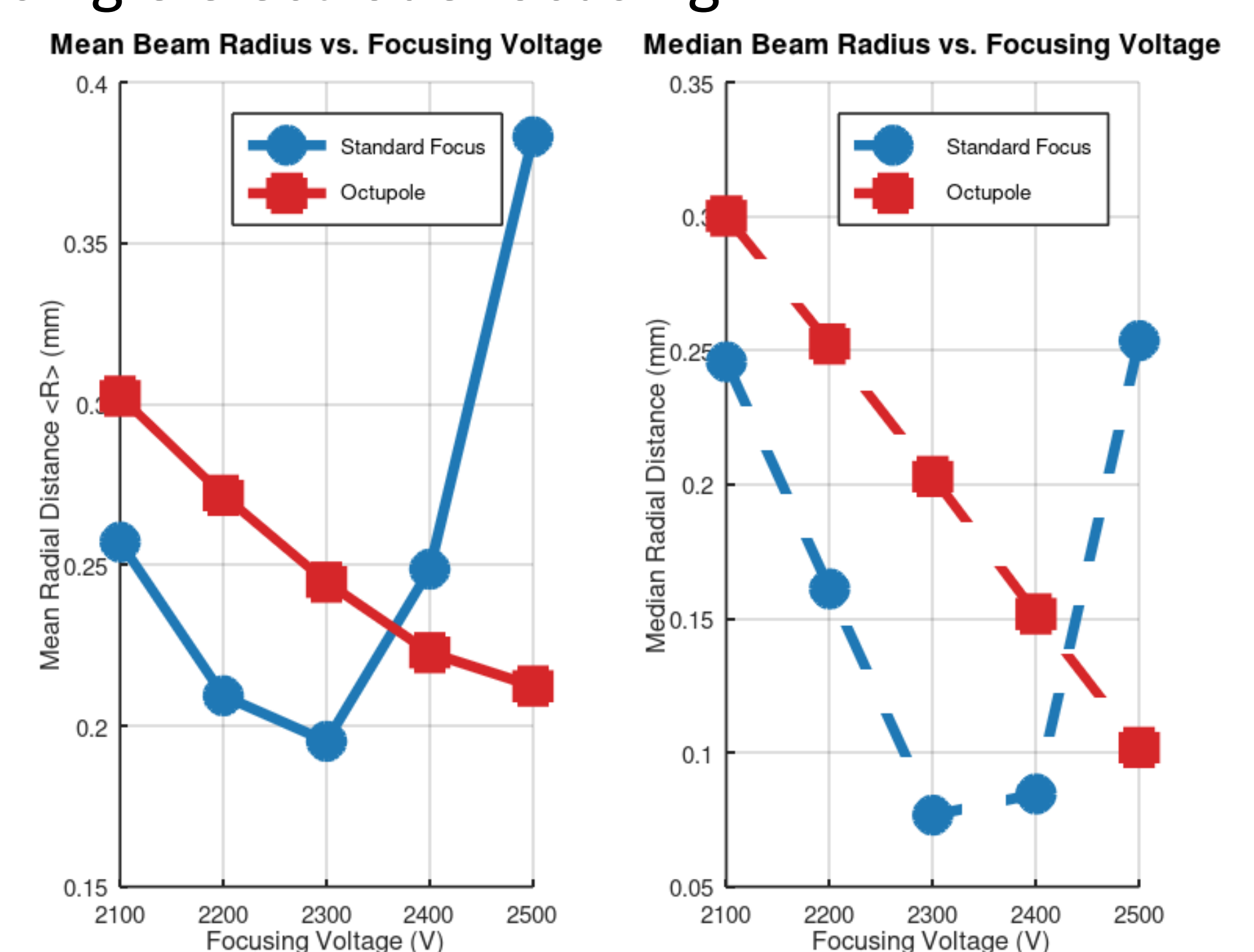


Figure 5. Beam radius comparison between single electrode focusing and octupole focusing modes for voltages 2100–2500 V. Mean (left) and median (right) radial distances show that standard focus optimizes at 2300 V and degrades rapidly, while the octupole provides superior beam confinement and continuous improvement at higher voltages (2400–2500 V).

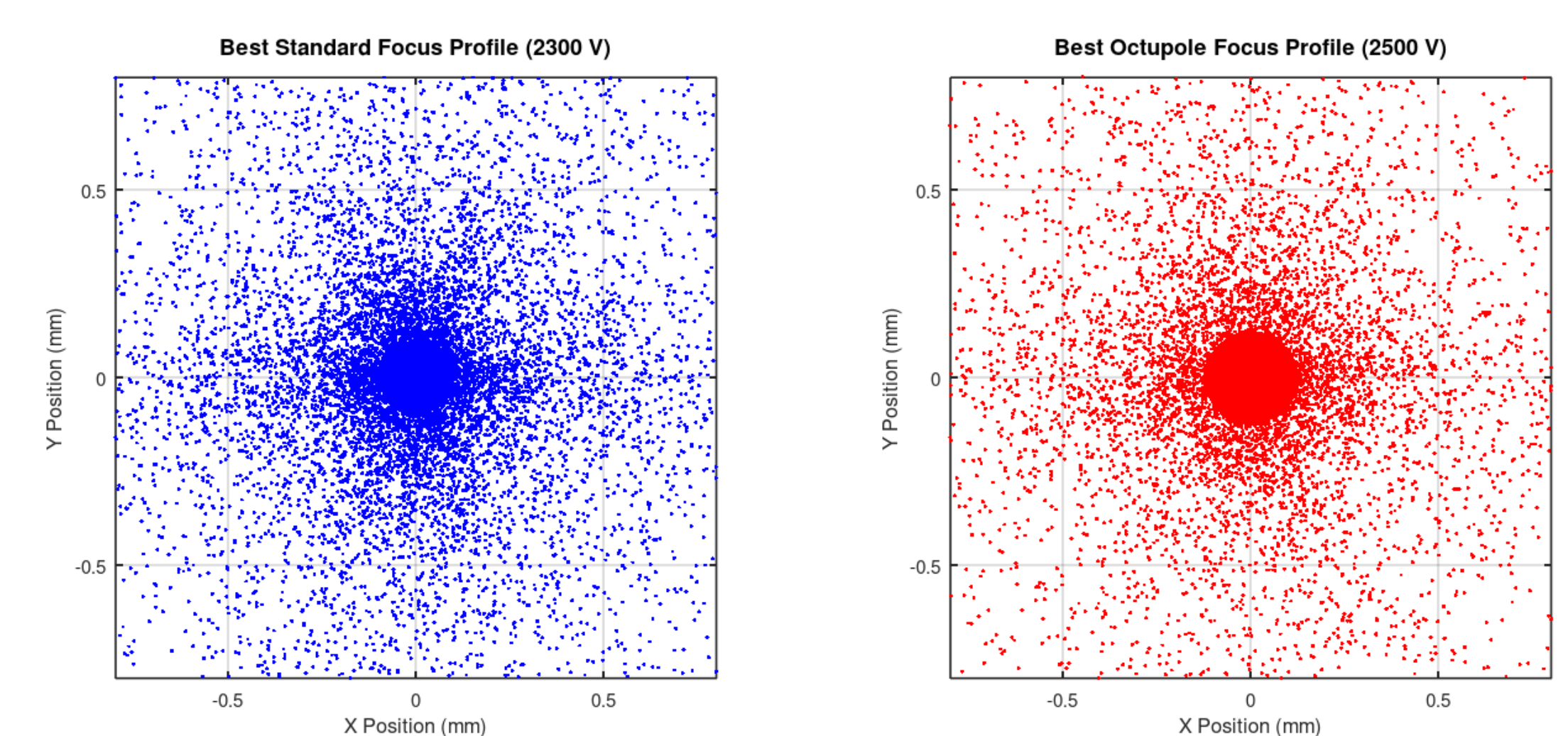


Figure 6. Spatial distribution and particle density of the beam under two different voltage configurations. The scatter plots visualize the cross-sectional shape and containment of the beam for the Focus (2300 V) and Octupole (2500 V) settings. A higher concentration of dots represents the peak intensity and core focus of the beam.

Bibliography

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