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ARTICLE

Effects of Diameter between Electrodes on Properties of Electrostatic Quadrupole Deflector

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Abstract: This study investigates the impact of varying the electrostatic quadrupole deflector diameter (EQDD) on the image when charged particles undergo deflection. A comparison is made between aberration figures, the kinetic energy of the electron beam, and the flight time concerning different EQDD values. The results showed that the most effective image is created at the image plane when the EQDD is double the radius of the electrostatic quadrupole deflector electrode (r).

Keywords: Charge particle, Electrostatic quadrupole deflector, SIMION 8.1.

1. Introduction

Electrostatic deflectors (ED) are used to modify the direction of charged particle beams. ED is a vital element in various instruments and systems, such as surface science equipment, particle accelerators, electricity storage rings, and some kinds of electron microscopes [1]. A standard ED consists of pairs of plates symmetrically positioned around the optical axis. These come in variousshape, ranging from simple rectangular parallel plates to alternative configurations with tilted or arcuate surfaces, such as cylindrical, solid, and spherical shapes [2]. An electrostatic quadrupole deflector comprises four poles of equal size, evenly from each other. In this configuration, every two poles facing each other have the same voltage. This deflector uses a DC quadrupole field to bend a charged particle beam up to ninety degrees. The bending effect can be controlled by adjusting the voltages (+V and -V) on opposing rods, allowing for a switch between on and off states for ninety-degree bending. The electrostatic quadrupole deflector can be used with other forms of deflectors, depending on the application. When all the electrodes are parallel to the direction of travel of charged particles, a difference between the quadrupole electrostatic lens and the quadrupole electrostatic deflectors appears. The electrodes function as a lens by either collecting or scattering charged particles. Conversely, when the electrodes are perpendicular to the direction of travel, theyact as a deflector [3]. Charged particle optics researchers use computer simulations to develop the optimal optical systems underideal operational conditions [4]. Many experimental and theoretical studies have been conducted to depict the electrostatic quadrupole deflectors [5-13]. In this work, the influence coefficients of the electrostatic quadrupole deflectors, the spacing between the sides of electrodes of electrostatic quadrupole deflectors, as well as time of flight and its result on the kinetic energy distributions of the charged beam radius ofthe image plane beam are studied utilizing simulation software system SIMION 8.1. The geometric dimensions of this technology are listed. SIMION 8.1, a charged particle optics simulator, isused to design and simulate electrostatic quadrupole deflector structures. The geometry of the deflector is represented by assigning symbols for geometric shapes in a geometric report for each design.

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Subsequently, the type of charged particle can be determined by specifying the particle's charge and mass. In this paper, an electron with a kinetic energy of 1000 eV was selected. Simion8.1 is allowed to choose the voltages for each pole.

2. Computational Methods

An electrostatic quadrupole deflector bends a charged electron beam ninety-degree employing a DC quadrupole electrical field. The bending can be toggled on and off by adjusting the voltages (+V and -V) on opposing rods for ninety-degree bending. The EQDD was fabricated in three different sizes (30, 40, and 50 mm), as shown in Fig. 1. The geometrical parameters of the system are listed in Table 1. To analyze and compare the characteristics of the electrostatic quadrupole deflector systems, a simulator in charged particle optics, SIMION 8.1, was employed [4]. The geometric configurations are represented by written geometry files for each design.

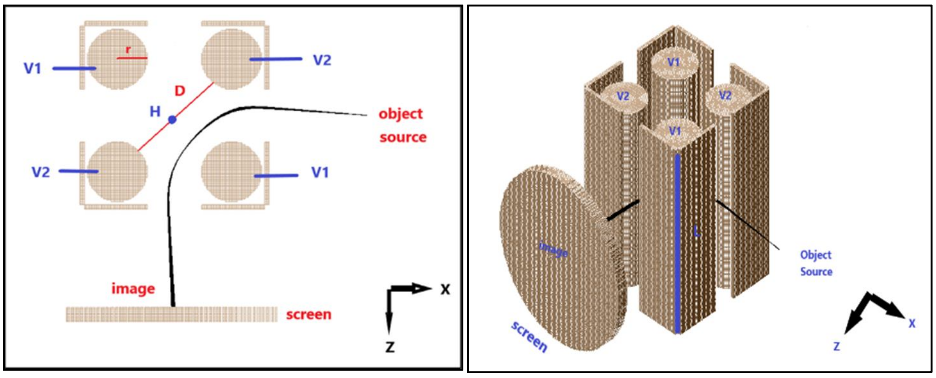

FIG. 1. Electrostatic quadrupole deflectors.

TABLE 1. Geometrical parameters of the electrostatic system.

Electrode Length (L)	80mm
The distance between the object source(o) and the center of the quadrupole deflector (H)	110 mm
The distance between the image(i) and the center of the quadrupole deflector (H)	110 mm
Electrode radius (r)	20mm
kinetic energy	1000 eV

One of the vital steps in the design of the electrostatic quadrupole deflector is to determine the voltage applied to the electrodes V1 and V2. This is achieved by testing a wide range of voltage values elected to achieve the desiredspecifications, namely, altering the direction of the charged particle accelerator beams by ninety degrees compared to the initial direction and producing the best image of the charged particle beam. The voltage settings for the electrostatic quadrupole deflector are listed in Table 2.

TABLE 2. Voltage electrostatic quadrupole deflector in three deferent EQDD.

quadrupole deflector diameter (D)	V1(volt)	V2(volt)
30mm	500	-400
40mm	600	-500
50mm	500	-800

3. Result and Discussion

The first step involves generating an image of a beam as it passes through the EQDD. The simulation was performed using three different quadrupole deflector diameters (30, 40, and 50 mm) and two different incidence angles(α = 1.0 and α = 0.8) relative to the coordinate axis. The voltages V1 and V2 were adjusted to provide Δx and Δy, resulting in an image on the screen. The Δx and Δy values are listed in Table 3. To depict all three cases in a single drawing, as shown in Fig. 2, an electron beam with a kinetic energy of 1000 eV was used. It was observed that the most effective on-screen imagewas producedwhen the EQDD was twicelarger than the radius of the electrostatic quadrupole deflectors electrode (r). The equipotential surface distribution of the EQDD of 30, 40, and 50 mm is shown in Fig. 3.

TABLE 3. EQDD was taken in three different diameters (30, 40, and 50 mm) atα = 1.0 and α = 0.8.

Quadrupole deflector diameter (D)	Angle (α)	Δx(mm)	Δy(mm)
30mm	1.0	1.3	3.85
30 mm	0.8	1.057	3
40mm	1.0	1.03	3.85
40mm	0.8	0.857	3.1
50mm	1.0	0.75	3.8
50mm	0.8	0.595	3.1

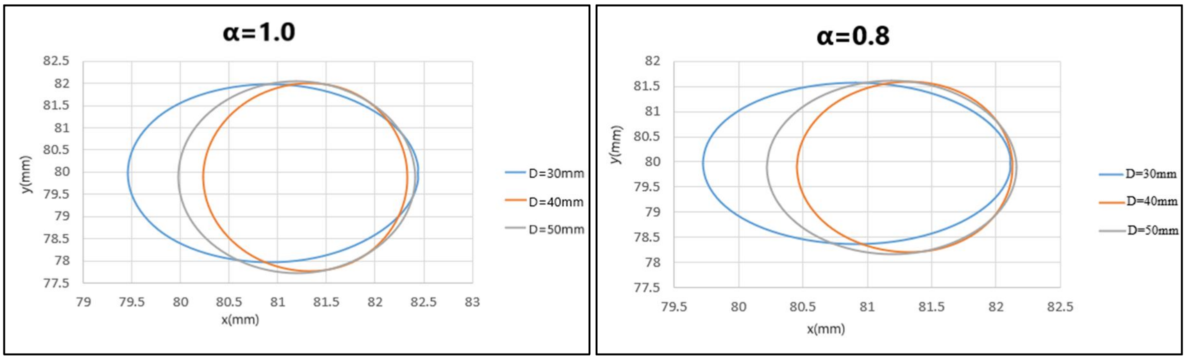

FIG. 2. Deflector with radial dimensions of 30, 40, and 50 mm at angles α = 1.0 and α = 0.8.

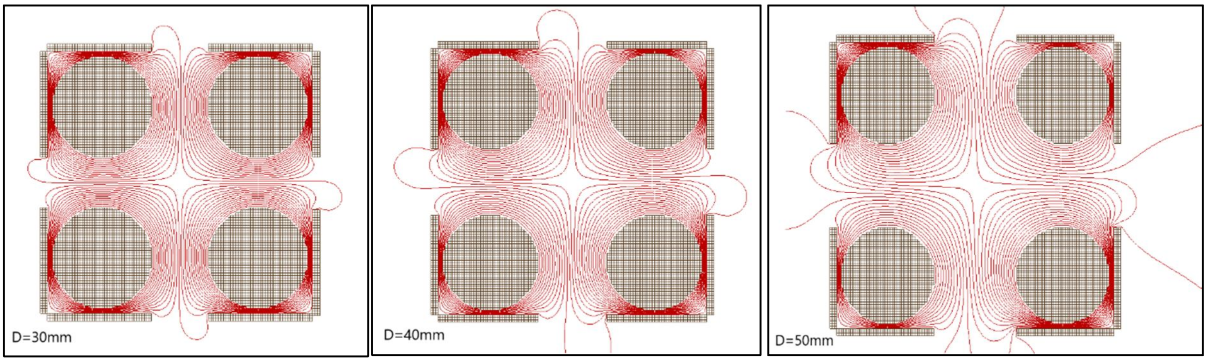

FIG. 3. The equipotential surface distribution of the EQDD 30, 40, and 50 mm.

The kinetic energy distribution of an electron beam was calculated for the EQDD diameters of 30, 40, and 50 mm at α values of 1.0 and 0.8. The results are shown in Fig. 4. The findings indicate that the kinetic energy of electron beams is more stable when using anEQDD diameter of 50 mm at α = 0.8. In general, across all cases, the difference in kinetic energy is very small and can be neglected.

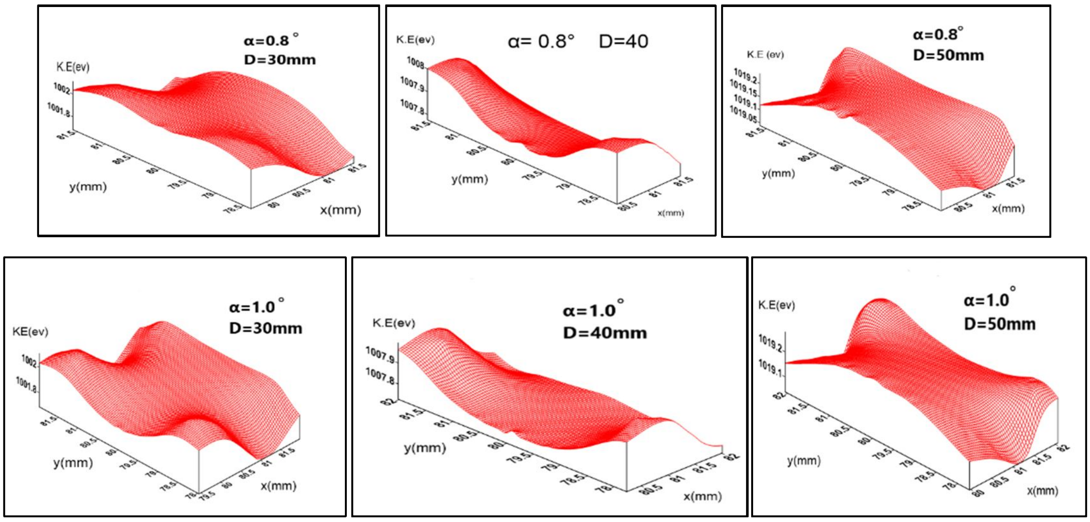

FIG. 4. Distribution of the kinetic energy of EQDD with 30, 40, and 50 mm diameters at two α (1.0, 0.8).

The time-of-flight distribution of the electron beam was calculated for EQDD diameters of 30, 40, and 50 mm,using α values of 1.0 and 0.8, as shown in Fig. 5. The analysis indicated that using a deflector for EQDD of 30 mm yieldsthe most favorable results, as it exhibitsthe least change in flight time for all charged particles passing through the deflector. This configuration produces the best picture, withcharged particles the deflector at a higher velocity compared to other cases. The behavior of the time-of-flight distribution forelectrons within the beam is summarized in Table 4.

TABLE 4. The average of time-of-flight in three different diameters (D) (30, 40, and 50 mm) at two α (1.0 and 0.8).

Deflector's diameter(D)	Angle	Average time of flight
30 mm	0.8 °	0.012253
40 mm	0.8 °	0.012971
50mm	0.8 °	0.013227
30 mm	1°	0.012253
40 mm	1°	0.01797
50 mm	1°	0.013226

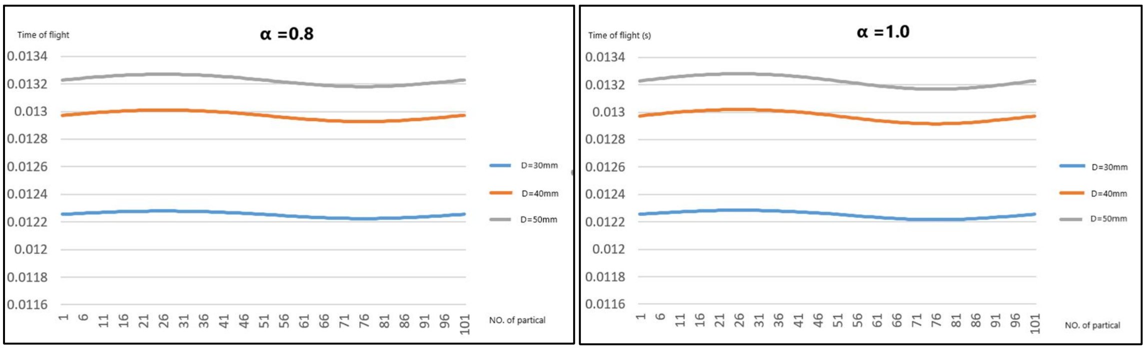

FIG 5. The time of flight to EQDD (30, 40, and 50 mm) at α = 1.0 and α = 0.8.

4. Conclusions

The charged particle optics simulator SIMION 8.1 was used to study the application of EQDD at various sizes (30, 40, and 50 mm) for angles of 1.0 and 0.8. Calculations were made to analyze the resulting image on the screen for the three different EQDD configurations.The findings showed that the EQDD of the deflector significantly influences the image formed on the screen as charged particles pass throughthe deflector. It was concluded that the best image quality is achieved when the EQDD is double the radius of the electrostatic quadrupole deflector electrode (r), minimizing aberrations. Specifically, the EQDD of 30 mm demonstrated the best in-flight time, allowing all charged particles to pass through the deflector, resulting in the highest-quality image. Furthermore, the EQDD of 50 mm at an angle of 0.8 exhibited superior kinetic energy compared to other configurations.

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