



Study of the Efficiency of the Magnetic Deflector at Various Operation Conditions

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Abstract

The efficiency of the magnetic deflector for variation operation condition was investigated. The design appears that the possibility of finding the constant characteristics of the deflector which lead to stability in the properties of the electron beam at the image plane despite the change in the properties of the electron source as: the initial beam divergence and the energy. The relation between the value of applied magnetic field on the magnetic deflector and the properties of the electron beam was studied. also the distribution of different value of the energy of the electron beam was studied. The calculation was carried out for different values of the divergence angle. The result showed that the increases in divergence angle dose not result change in the nature of the distribution of energy of the electron beam at image plane, and one can find constant dimensions of the electron beam at image plane even though the electron beams energy was altered, and this results can be achieved by choosing the appropriate values of magnetic field to be applied to the deflector. The calculations showed that the non-linear relation between the amount of the magnetic field and values of the kinetic energy electron beam.

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1. Introduction

In dynamics charged particle, also known as charged particle optics, charged particles (such as electrons, protons, and ions) are manipulated in an electric and/or magnetic field. Electromagnetic fields' ability to deflect charged particles has important and wide-ranging effects on a range of technologies, engineering, biological sciences, and the physical sciences. [1]. A magnetic sector deflector, consisting of two coils that act as a circular lens, can be used to deflect an electron beam. Because an electron beam's form can be preserved after deflection, magnetic sector deflectors are suitable for separating source electrons from reflected electron [2]. Lithography machines, cathode ray tubes, electron accelerators, scanning electron microscopes, electron-beam manufacturing techniques, and a few other analytical instruments all use the most common and conventional type of deflection. [3] Within a magnetic sector, the strength of the magnetic deflection field remains constant. Nonetheless, simultaneous

deflection and focus of electrons with a broad range of energies is possible by permitting the deflection field strength to rise in the path of incoming electrons [4]. A magnetic sector is one type of mass analyzer that uses a static magnetic field to deflect particles in this way along a roughly circular arc. It is defined by the deflection angle and the radius. For theory and context, particularly with regard to design elements of attention [5-7]. The single-pole detector generates a strong magnetic field that surrounds the specimen and radiates out from the pole-piece. This field is crucial for looking at a range of objects [8]. The storage volume's magnetic field is extremely strong [9-10]. The incident particle's imperfect orthogonality with regard to the magnetic field direction will result in a helicoidally trajectory, with the radius depending on the orthogonal component and the pitch on the parallel component. [11]. that this is satisfied in neutron storage tests in a magnetic cup and a storage ring [12]. While it is evident that the permanent magnet deflector construction can accommodate

many pole configurations, the magnetic deflection approach provides important insights into the dynamics and strength of the magnetic moments of these particles [13]. Some accelerators replace some arc dipoles with super bends, which are magnets that provide a similar beam deflection but a greater magnetic flux. [13]. This work aims to study effect of the operation conditions on the magnetic deflector, efficiency in a manner that ensures that it achieves its stability on the properties of electron beam after leaving the deflector, despite changing the initial properties of the electron beam. Where is the relationship between the magnetic field of deflector and the energy of electron beam was studied to achieve a stable system which gives fixed properties of electron beam. To ensure the efficiency of the stability and the nature of the behavior of the deflector, differential initial angles of the electron beam was taken into account and the calculation was carried out.

2. Materials and Methods

Where the virtual laboratory in the field of charged particle SIMION 8.1 was used to obtain the appropriate design for the deflector by writing the special code in the geometry file and after calling the program's geometry file, it determines the type of charged particles, their energy and the initial angle of launch of the charged particles. SIMION simulation consists of a number of different pieces as shown in diagram 1. The magnetic deflector was designed with the aim of controlling the electron beam and changing its path with 90° to ensuring the stability of the properties of magnetic deflector (MD) despite the change of the properties of the primary electron beam. The designed was completed by using the [15]. As shown in figure (1), the geometrical dimensions of the system were shown in table 1, the efficiency of deflection system was studied for electron beam of different values of kinetic energy 10, 30, 50 and 70 KeV, also the calculation was retaking different divergence angles $\alpha = 0.5^\circ, 0.7^\circ$ and 1° of electron beam in order to ensure the stability of the properties of electron beam.

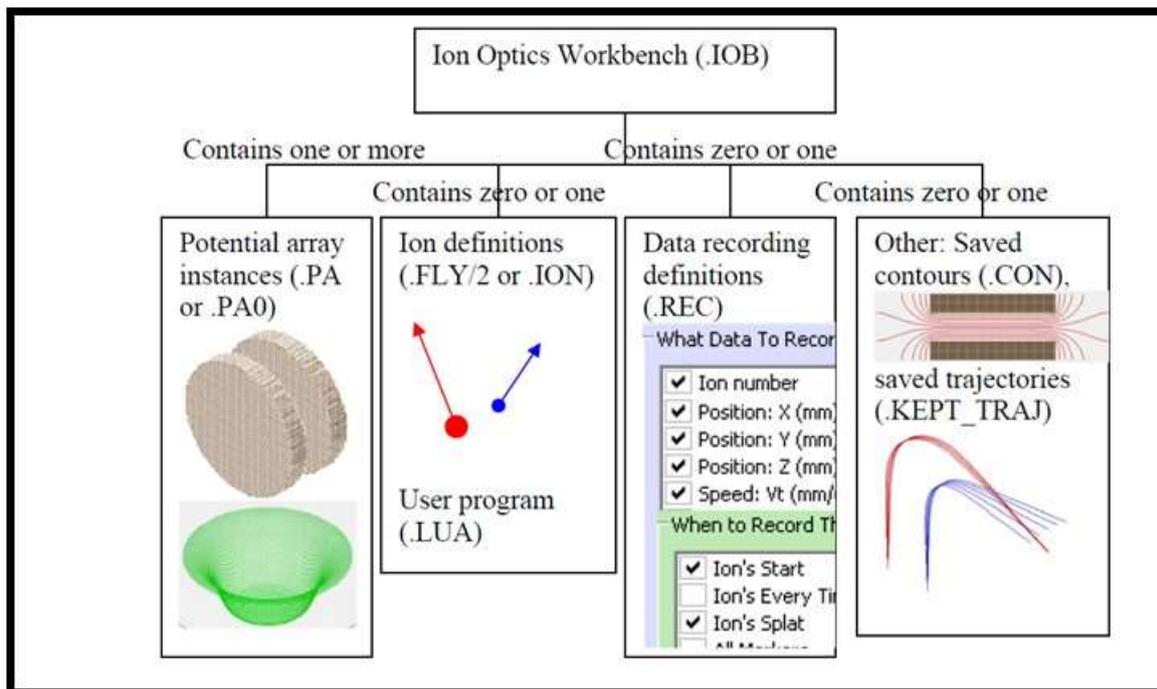


Diagram 1. SIMION simulation workbench

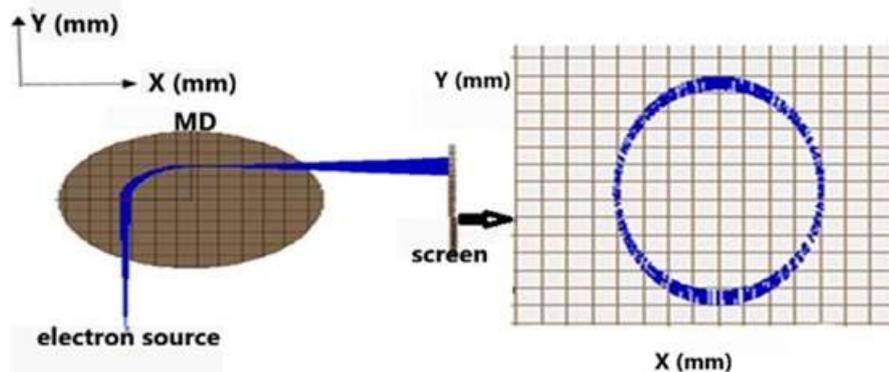


Figure 1. Two-dimensional view of the electron beam passing through magnetic deflection system and hit the screen.

Table 1. Geometrical parameters of the magnetic system.

Distance between electron source and MD	150 mm
Distance between screen and MD	249 mm
Kinetic energy	50 KeV
Angel of electron beam (α)	1.0 °

3. Result and discussion

The properties of magnetic deflector were studied for different values of energy for electron beam, where

different energies were taken to electron beam 10, 30, 50 and 70 KeV, and for constant initial electron beam angle (divergence angle) $\alpha = 0.5^\circ$ and the result of electron beam shape of image plan and its dimension was indicated in figure (2). This figure shows through the results that despite the change of energy of electron beam, but the shape and dimension of beam has been preserved. The calculations indicate that stability of properties for magnetic deflector, and difference between electron beam and another is only the shift of beam toward Y, where the Y values is increased by increasing the electron energy.

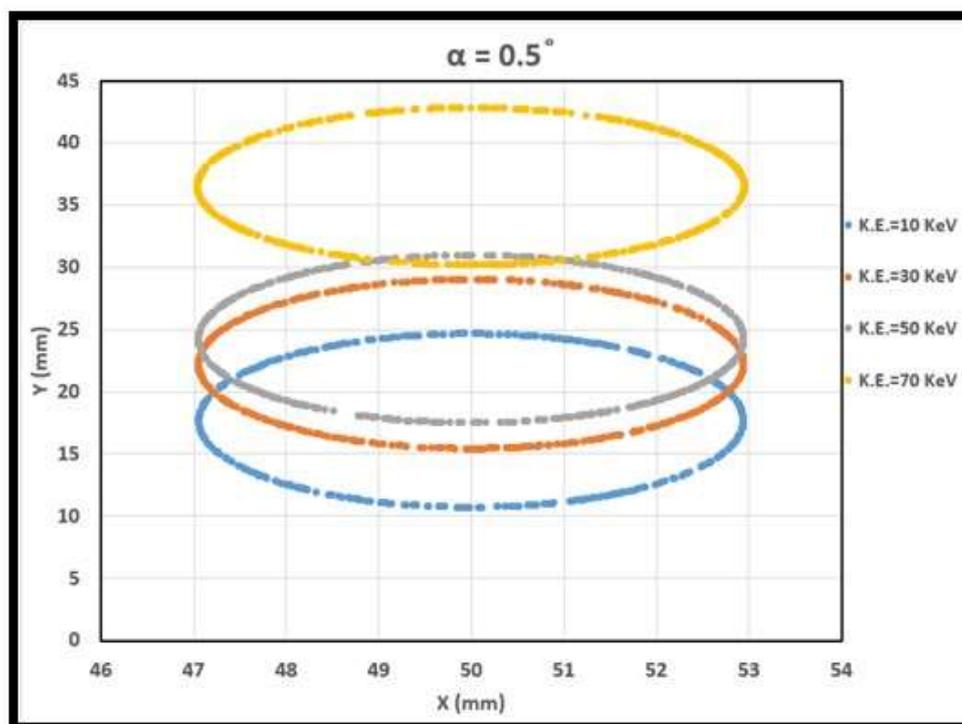


Figure 2. A comparison between the aberration figures of electron beam shape at angle $\alpha = 0.5^\circ$ for different value of energy”.

The relationship between the amount of magnetic field over the magnetic deflector and the energies of electron beam is shown in figure 3. As it appears from the results, the magnetic field must be increased as the energy of the electron beam increase in order to

maintain constant dimensions of the beam diameter in the image plane, and this increasing is non-linear and that the values of magnetic field for each energy indicated in table 2.

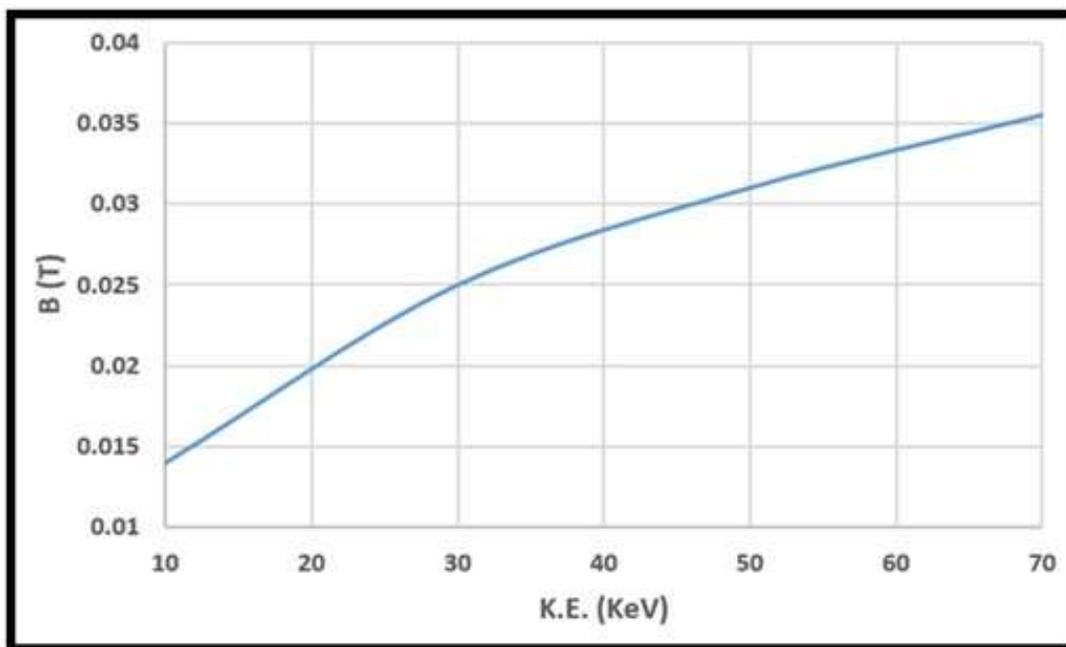


Figure 3. The relationship between applied magnetic field and the energy. of the beam for divergence angle of electron beam $\alpha = 1^\circ$.

Table 2. values of the energies of the electron beam and the corresponding magnetic field that should be applied to the deflector.

Electron beam energy (KeV)	B (T)
10	0.014
30	0.025
50	0.031
70	0.0355

The distribution of energy was studied to electron beam at the level of image for different cases of electron energy 10, 30, 50 and 70 KeV and for a fixed divergence angle of electron beam 0.5° , as shown in figure 4, the results show great stability in the distribution of the energy for electron beam, as the most part of these electrons has the same energy, which ensure the overcoming of the chromatic aberration resulting from fluctuation in electrons

energy inside the electron beam is very little where income and outcome of energy are equal. The result show that the highest loss of the energy 7.5% for beam of energy 10 KeV, 1.6% for beam of energy 30 KeV, 0.14% for beam of energy 50%, 0.07% for 70 KeV. This indicate an increase in stability of the distribution of energy reduction in energy loss as energy of the beam increases.

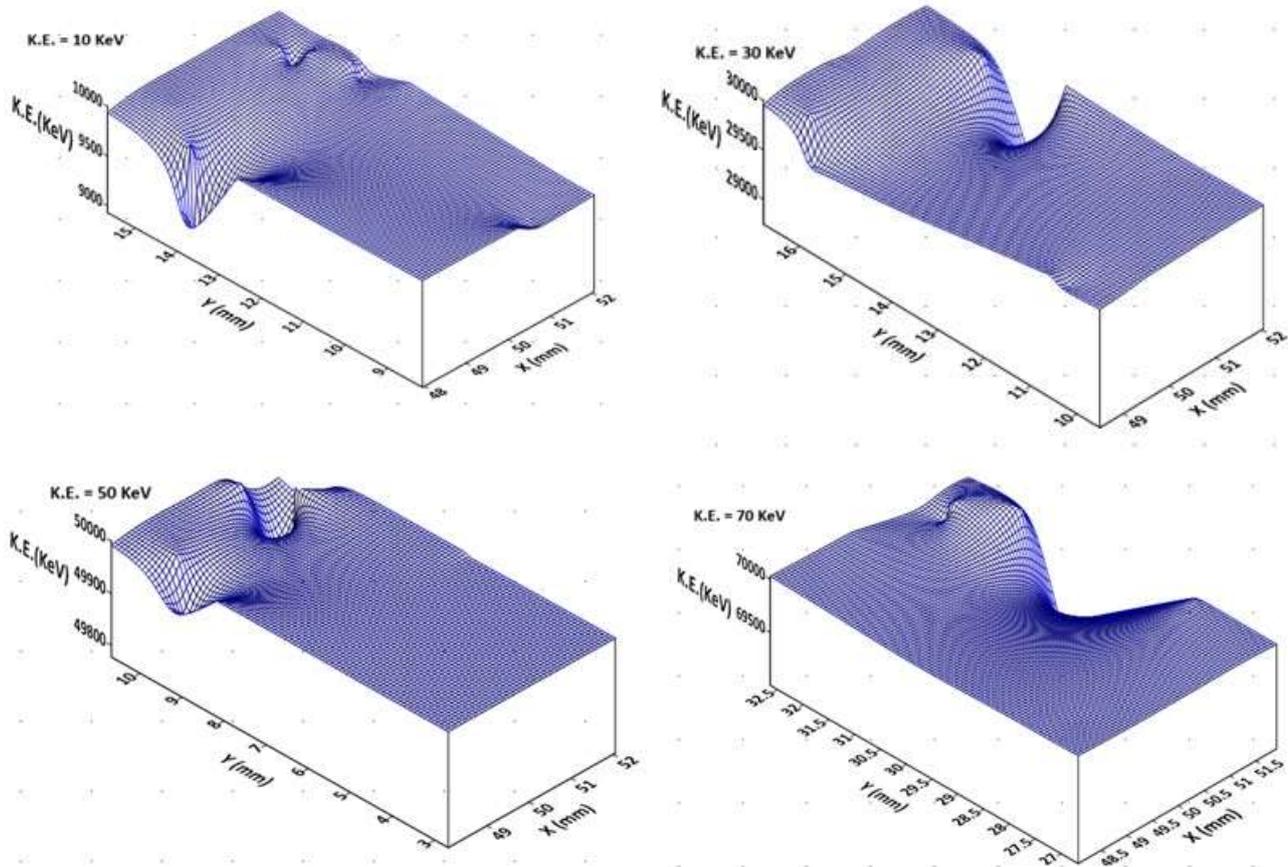
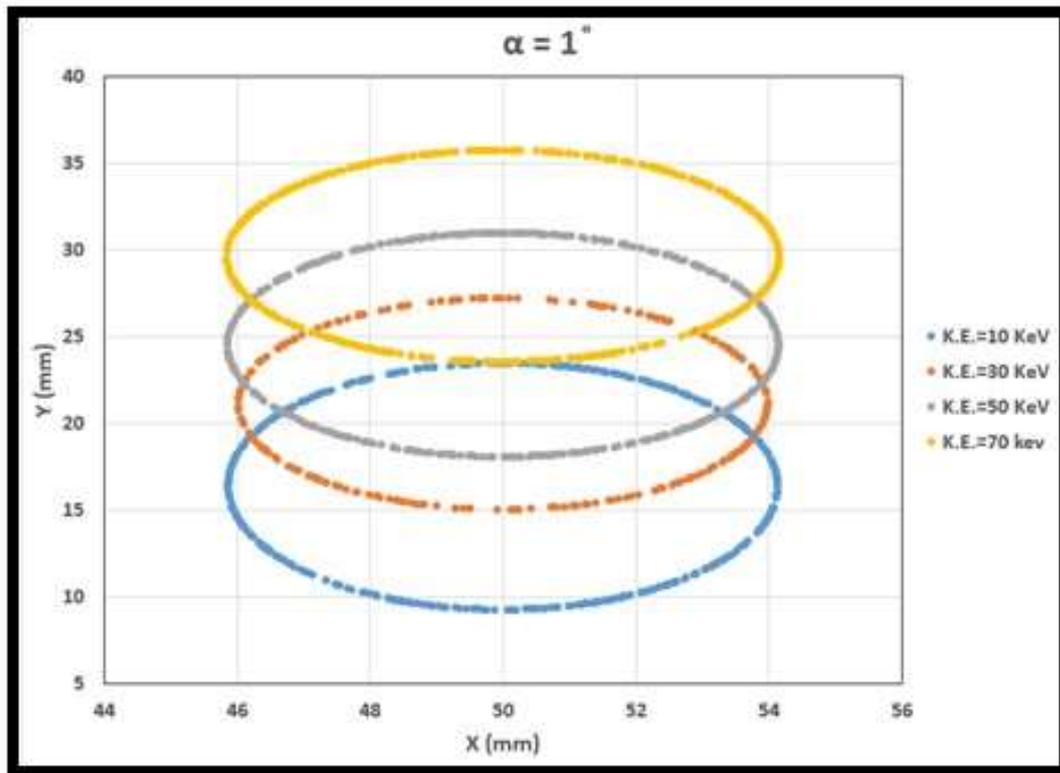


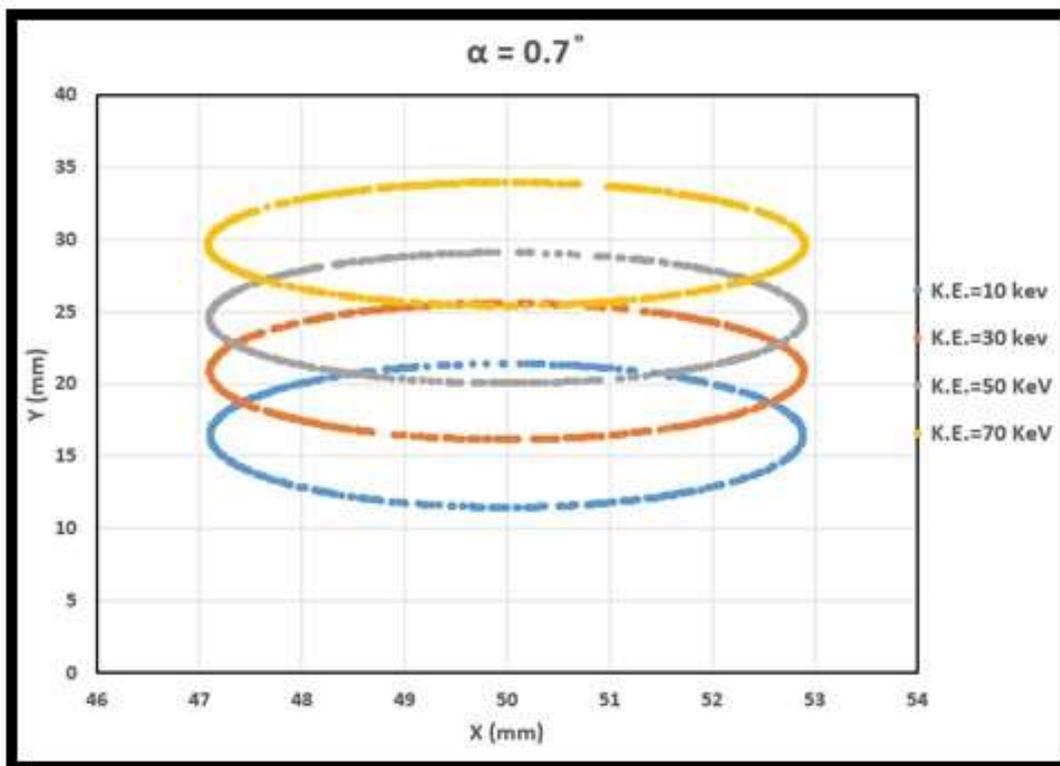
Figure 4. The electron beam's dispersion of energy for different values of the kinetic energy and constant value of the divergence angle $\alpha = 0.5^\circ$.

To insure the stability of the efficiency of the magnetic deflector despite changing the properties of the electron source, the calculation was repeated for more than one initial angle, where two additional angles were taken into account, which are $\alpha = 0.7^\circ$ and $\alpha = 1^\circ$ as shown in figure (5) and the shapes of electron beam were found in the image plane for the same energies of the electron beam in the case of $\alpha = 0.5^\circ$. The results in figure (5), show the same behavior

as in the previous case by obtaining fixed dimensions of the electron beam with displacement on an Y axis, where the only increases with the increasing in the energy of the electron, which indicates the stability of the deflector properties and is not affected by the change in the properties of electronic source properties. This behavior gives stability to the system in which this deflector will be included in its design.



(a)



(b)

Figure 5. Comparison between the electron beam shapes of the image plane for different values of the energy with divergence angles (a): (a) $\alpha = 1^\circ$, (b) $\alpha = 0.7^\circ$.

The energy distribution of the electron beam has been studied to the new angle's value, where in figures (6) and (7) the result are shown for $\alpha = 0.7^\circ$ and $\alpha = 1^\circ$, respectively the result for $\alpha = 0.7^\circ$ show that the highest loss of the energy is 1% for beam of energy 10 KeV, 0.16% for beam of energy 30 KeV, 2% for beam of energy 50%, 0.7% for 70 KeV, and for $\alpha =$

1° the highest loss of the energy is 3% for beam of energy 10 KeV, 0.5% for beam of energy 30 KeV, 0.3% for beam of energy 50 KeV, 0.4% for beam of energy 70 KeV, this very little change in the energy value for two cases indicate the stability of the distribution of energy of electron beam.

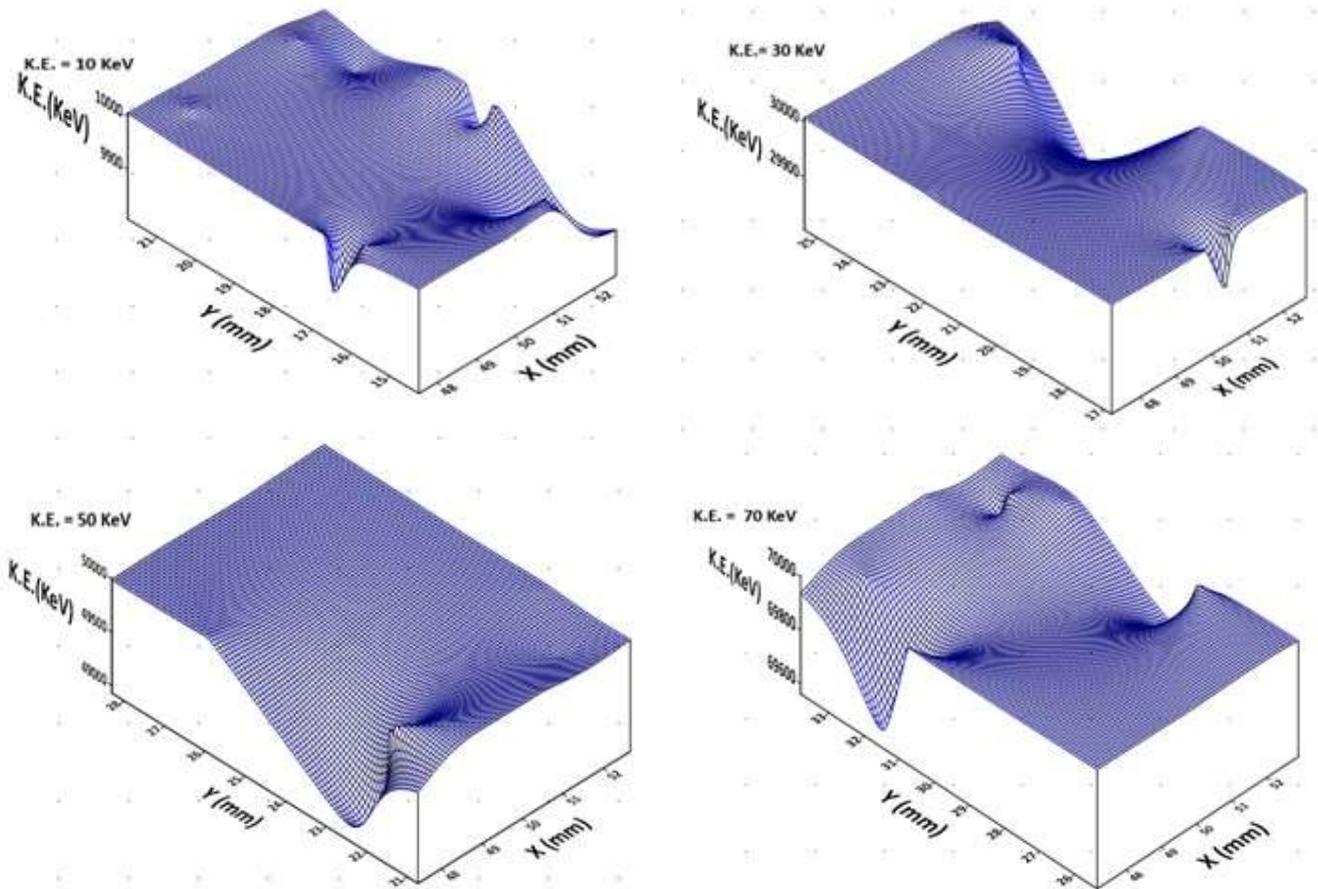


Figure 6. The distribution of the kinetic energy of the electron beam for different values of the kinetic energy and constant value of the initial angle $\alpha = 0.7^\circ$.

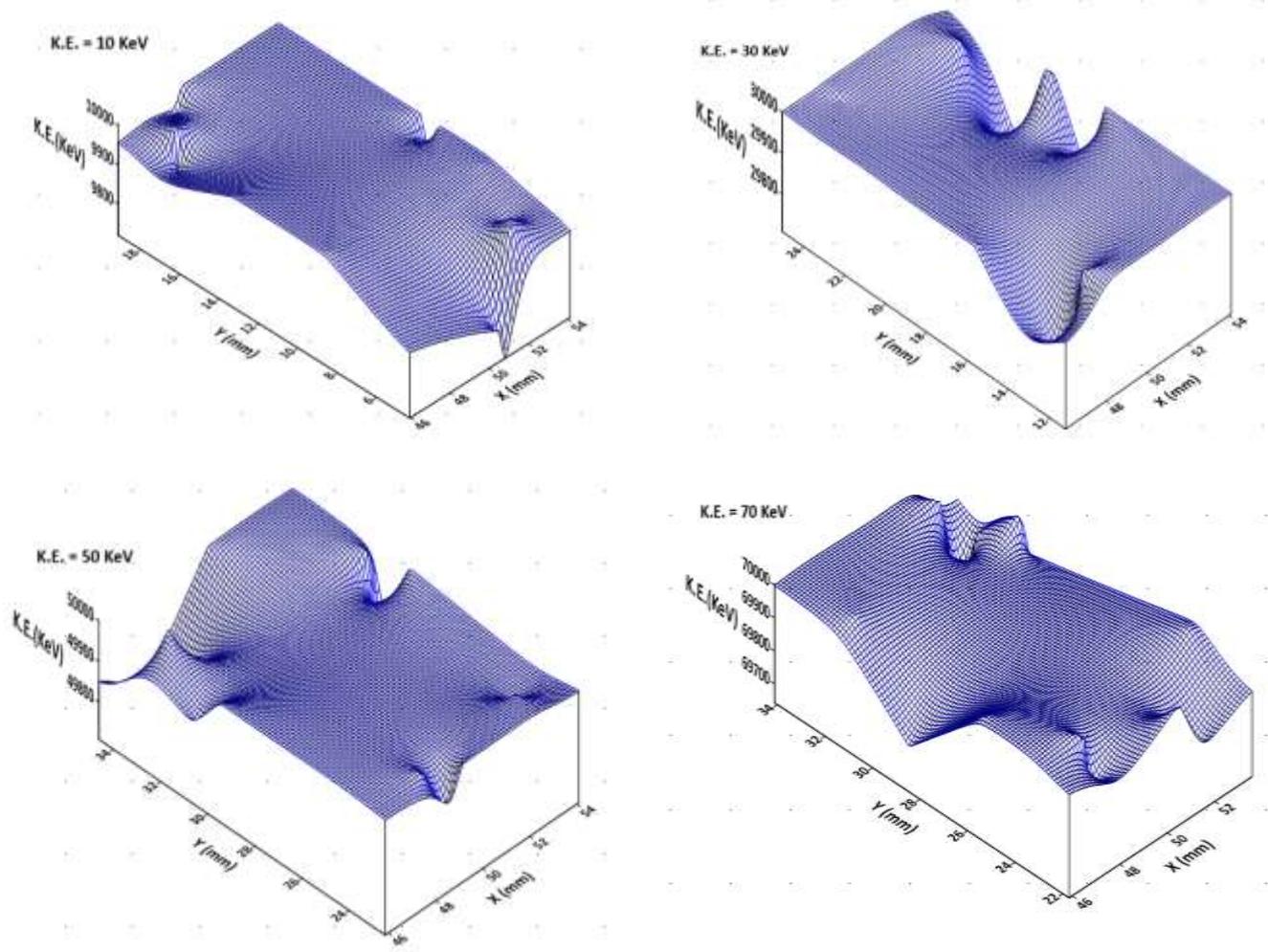


Figure 7. The distribution of the kinetic energy of the electron beam for different values of the “kinetic energy and constant value of the initial angle $\alpha = 1.0^\circ$ ”.

To investigate the effect of the increasing of the initial angle (α) of the electron beam, the comparison between the cases of $\alpha = 0.5^\circ, 0.7^\circ$ and 1° for kinetic energy of electron beams 50 KeV as the result shown in figure (8). The result shows an increasing in the dimensions or the diameter of the electron

beam as the initial angle increased. The increasing of this angle by half a degree led to doubling the dimension of the beam in the X and Y-direction by the 100% and the table 3 shows the comparison in numbers.

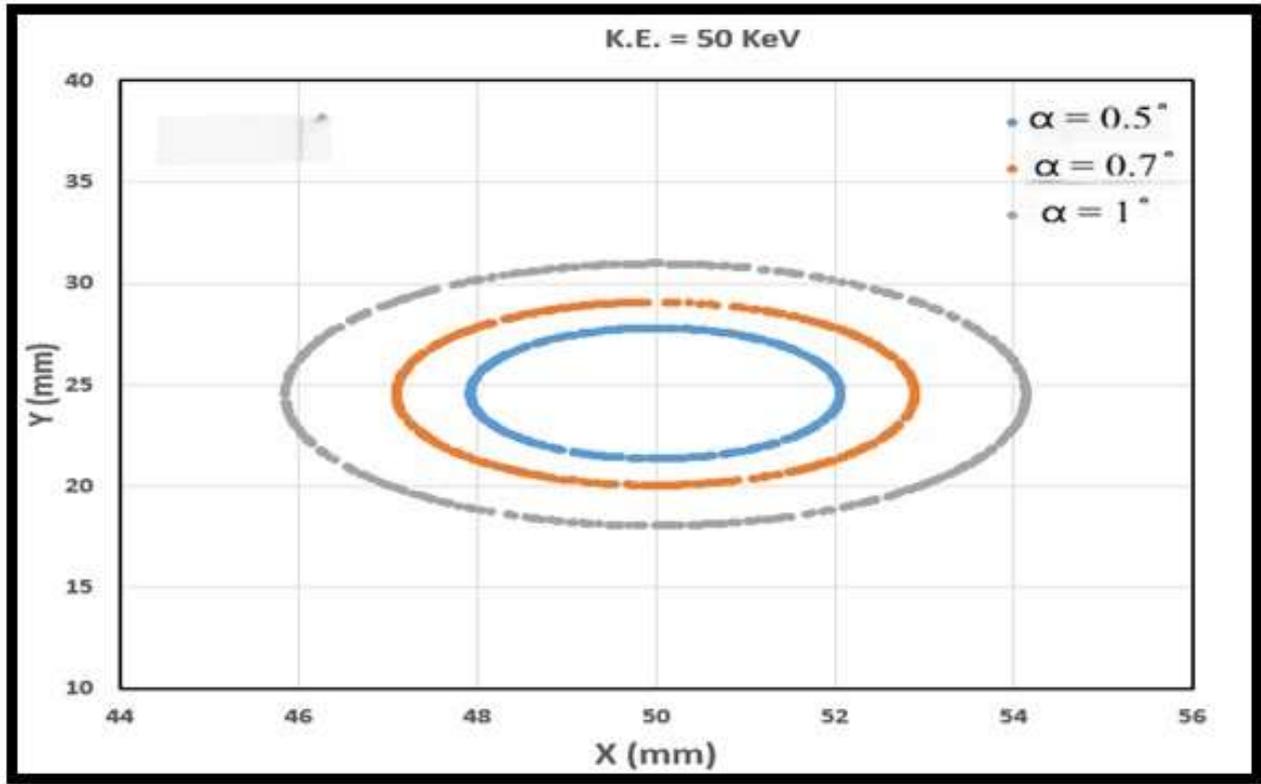


Figure 8. Comparison between the electron beam shapes (aberration figure) in the image plane for specific energy 50 KeV for three different divergence angles.

Table 3: The electron beam dimensions' characteristic at the image plane for different divergence angles (α) with energy 50 KeV.

Angel (α)	ΔY (mm)	Δx (mm)
0.5 °	6.54	4.41
0.7 °	9.15	6.06
1 °	13.26	8.46

The distribution of energy of the electron beam on the screen and the extent to which it is affected by changing the divergence angle of the electron beam was studied and its compared between different

angle $\alpha = 0.5^\circ$, 0.7° and 1° for constant energy of electron beam 50 KeV. The result was shown in figure (9), the results show great stability and homogeneity in the energy of the electrons within the beam, and that there are vary few difference between the highest and lowest energy level, it can be neglected and this difference almost disappears when the initial angle is smaller, in general the distribution of energy is constant and is not affected by changing the divergence angle of the electron beam to vary large extent.

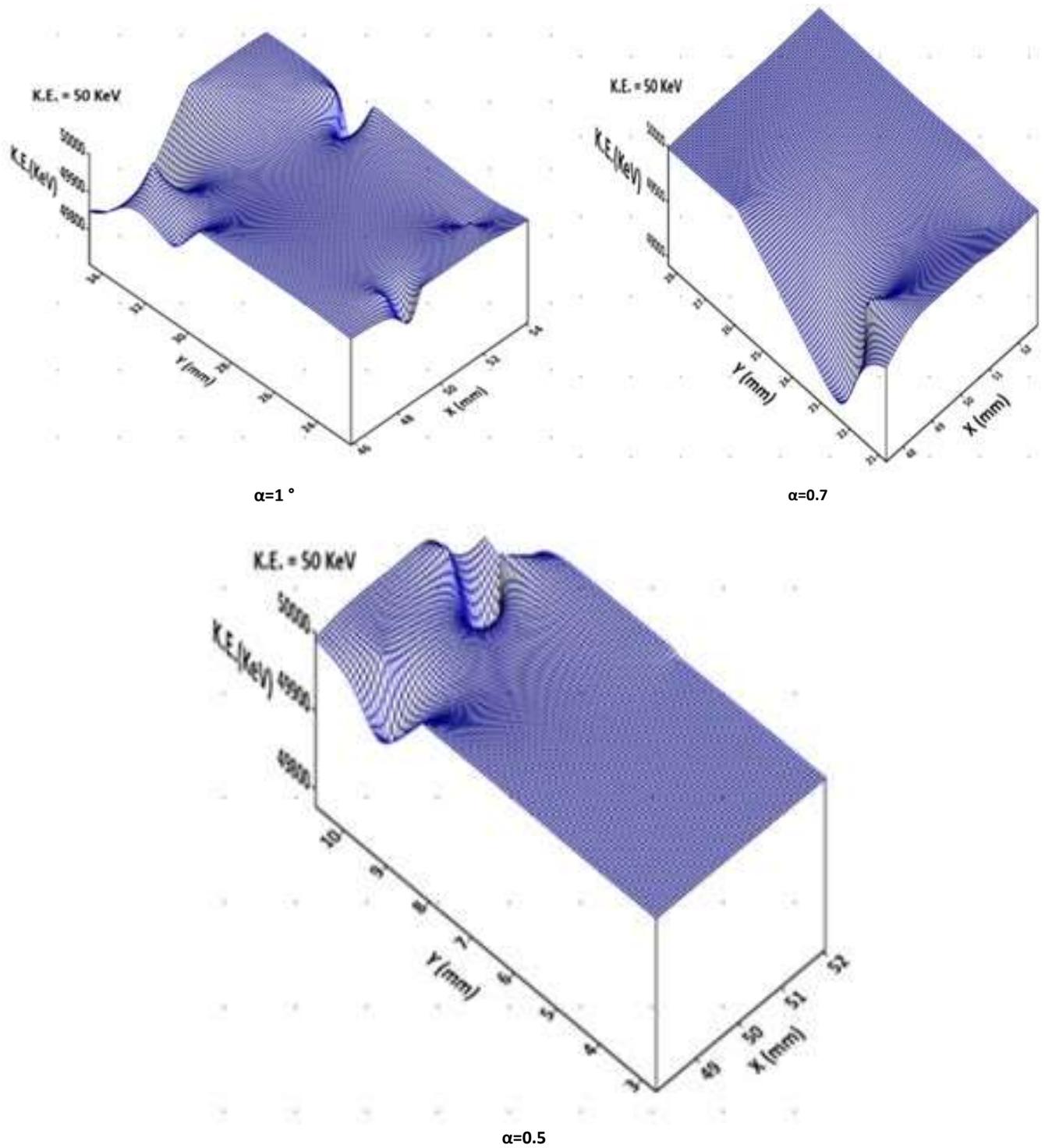


Figure 9. The distribution of the energy 50 KeV of the electron beam for various values of divergence angle.

4. Summary and Conclusions.

A magnetic deflector was designed to control and deflect the electrons at angle 90° and the characteristics of this deflector were studied. Its efficiency was investigated, and its relationship with the operational condition, including the characteristic of the electron beam like the energy and divergence angle of electron beam which is related to the nature of electron source. The results showed that the success of preserving the dimensions of the electron beam on the screen (image plane) in a constant form with displacement at Y axis only, and this can be achieved by finding the appropriate magnetic field that is compatible with each value of the kinetic energy of the electrons. The calculations showed that the nature of the relationship between the values of the magnetic field of the deflector and the energy of electron beam it was non-linear relationship. The results showed that the high stability was achieved in the distribution of energy of electrons within the electron beam for most cases, and that the difference between the highest and lowest values was very small and could be ignored. Therefore it's possible to avoid chromatic aberration due to large homogeneity of electron energy. The results also showed that there is an inverse relationship between this difference between the highest and lowest energy and the energy of electron beam, where the increasing of the energy led to little loss of energy that its already few. The result showed that increasing of the divergence electron angle does not result change in the nature of distribution energy of electron beam at the screen (in image plane) and is almost neglected, as well as the result showed that the increasing of the divergence angle of electron beam by one-half a degree led to increasing in the dimensions of the beam (diameter of the beam) by 100%.

Conflicts of interest: The authors declare no conflict of interest

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