Design and Study the Optical Properties of Electrostatic Mirror By using Bimurzaev Technique

Intehaa A. Mohammed
Dept.of Physics/College of Education for Pure Science(Ibn -Al Haitham)/University of Baghdad

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Abstract

In this research a computational simulation has been carried out on the design and properties of the electrostatic mirror and a mathematical expression has been suggested to represent the axial potential of an electrostatic mirror. The electron beam path using the Bimurzaev technique had been investigated as mirror trajectory with the aid of Runge – Kutta method. The spherical and chromatic aberration coefficients of mirror has computed and normalized in terms of the focal length. The choice of the mirror depends on the operational requirements.

The Electrode shape of mirror two electrodes has been determined by using package SIMION computer program.

Computations have shown that the suggested potentials give good result for low value spherical and chromatic aberration Cs/Fr= - 8.05, Cc/Fr=- 9.1, L=8mm, A=500volt, which give a good indicator for designing the mirrors

Key words: electrostatic mirror, Bimurzaev technique, chromatic aberration, spherical aberration, SIMION computer program

Introduction

Electron mirror is used to correct the chromatic and spherical aberration of lenses, this idea are back to the middle of twentieth century [1]. An electron mirror is creating when an electrode with sufficiently high negative potential is placed in the path of an electron beam. The negative electrode forms a potential hill that decelerates the incident electrons. The electrons lose their kinetic energy before reaching the electrode and are back to re–accelerated in the reverse direction. [2].

An electron mirror are capable of introducing chromatic and spherical aberrations of arbitrary sign . hence, we can utilize mirrors to compensate for the corresponding aberrations of round lenses [3] Unlike a light optics mirror, where the reflection occurs at the physical surface, the electron mirror represents a "soft" mirror, which allows the electrons to penetrate into the inhomogeneous reflection medium formed by the electrostatic potential[4] by introducing a reflection in the electron path using an electron mirror, the electron beam direction reverses and the electron velocity changes sign , thus the Scherzer theorem no longer applies [5]. The mirror field is usually confined between two electrodes a negative (mirror) electrode and a positive electrode (anode) which may be aground potential. The electrode can be shaped to provide the desired focusing effects along with reversing effect.[6] In ion mirror there is one hard reflecting point, this surface does not necessarily coincide with either the physical location of the turn around point of the ion mirror or a physical electrode surface [7]. The field inside a parabolic mirror (reflection) is curved along the axis and according to the Laplace equation it also has a curvature in a radial (or transverse) direction [8]. Electron mirror is made in various geometries according to their function in an electron optical instrument . They can be made in the form of two or three concentric cylindrical electrodes at different potentials for reducing aberration [9].

Theoretical consideration

The inverse problem is important method in the design of electrostatic mirror by suggesting an axial electrostatic potential distribution using potential function.

$$U(z) = C + (A * (\tanh(z))) \text{---------------------------------}(1)$$

Where U(z) is the axial potential along the optical axis z. the constant C,A are affects the properties of this suggested potential.

The equation of motion of charge particle in the electrostatic field or paraxial ray equation is given by [10]

$$\frac{d^2R}{dz^2} + \frac{U'}{2U}\frac{dR}{dz} + \frac{U''}{4U}R = 0 \text{----------------}(2)$$

Where U' and U" are the first and second derivatives of the axial potential U respectively. R represents the radial displacement of the beam form the axis z and the primes denote a derivative with respect to z.

This research with The aid of Bimurzaev Technique and modified on it for solving electrostatic mirror trajectory by applying this trajectory equation twice at the first one applied is zero magnification condition representing the incident beam on the mirror before reflecting and the second one is applied infinite magnification condition representing the reflecting beam from the mirror.

The second condition is very important because the optical properties are computed from it.

The most important aberrations in an electron-optical system are spherical and chromatic aberration The spherical aberration coefficient Cs and chromatic aberration cofficient Cc referred to the image side are calculated from the following equations [11].

$$C_S = \frac{U^{-1/2}}{16R'^4}\int_{Zo}^{Zi}\left(\frac{5}{4}\left(\frac{U''}{U}\right)^2 + \frac{5}{24}\left(\frac{U'}{U}\right)^4 + \frac{14}{3}\left(\frac{U'}{U}\right)^3\frac{R'}{R} - \frac{3}{2}\left(\frac{U'}{U}\right)^2\frac{R'^2}{R^2}\right)\sqrt{U}R^4 dz --------(3)$$

$$C_C = \frac{U^{1/2}}{R'^2}\int_{Zo}^{Zi}\left(\frac{U'}{2U}R'R + \frac{U''}{4U}R^2\right)U^{-1/2}dz ------------(4)$$

The shape of the electrodes forming a specific electrostatic mirror has been determind by following equation [11]

$$U(r,z) = U(z) - U''(z)\frac{r^2}{4} --------------(5)$$

The electrode shape by using SIMION computer program ,this program used to simulate electrostatic and static magnetic device for accelerating, transporting and otherwise manipulating beams of charged particles.

Results and Discussion

A potential distribution function has been suggested to represent an electrostatic mirror by equation 1, Figure (1) shows the axial potential U(z) and its corresponding the first and second derivatives respectively based on the proposed expression given in this equation at the above value of the constant (C, A) the length of mirror in the case is L= 8mm

From figure (1) also we note that there is one inflection point in the second derivative of the potential distribution,(i.e. two electrode mirror have been used or chosen)

The beam path along the electrostatic mirror field using Bimurzaev technique under the accelerating mode of operation has been considered represented by equation (2), and trajectories of the electrostatic mirror along various lengths L=8mm, 12mm.16mm, 20mm, as shown in figure (2)

Figure (3) shows the electrostatic mirror focal length Fr is inversely proportional with (A) for all mirror length where the increase of the values of (A) causes to decrease the values of the mirror focal length , the mirror focal length can be determined from the reflect beam trajectory where the focal length of reflect beam trajectory represents the mirror focal length , from the result it is noted that the mirror focal length has a positive sign that is means the mirror type is convergence.

Figure (4) noted that the electrostatic mirror spherical and chromatic aberration Cs and Cc is directly proportional with (A) for all mirror length It is noted from this figure that the value of mirror aberration (Cs,Cc) inversely with value (A) where the increase of the value of (A) causes to decrease the value of the mirror spherical and chromatic aberration at the mirror length L=(8,12,16,20)mm.

Figure (5) noted that the increasing of the values of the (A) causes decreases the values of both Cs/Fr and Cc/Fr for all mirror length, these values are listed in table (1)

Figure (6) showed the relative spherical Cs/Fr and chromatic Cc/Fr aberration coefficient have been computed as a function of the relative mirror length L/Fr at mirror length L=8 mm where A=(500,300,275,220,175)volt.

Figure (7) showed three- dimension of the two electrode s electrostatic mirror using Bimurzaev technique when the A=500 volt at the mirror length L=8mm using Simion computer program

Conclusion

The electrostatic mirror achieved in present investigation are useful for studying surfaces of specimens using Bimurzeav technique are considered as mirror trajectories .In this research, good results have been got using the mathematical expression for excel potential and the electron beam to produce the trajectories which are successful. from results ,The obtained negative sign of spherical and chromatic aberration Cs and Cc can be used to correct the aberration

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Table No. (1) The optical properties of electrostatic mirror

L(Mirror length) (mm)	A(volt)	Cs/Fr	Cc/Fr
8	500	-8.05	-9.1
12	300	-9.08	-10.19
16	230	-8.71	-9.8
20	100	-6.59	-7.01

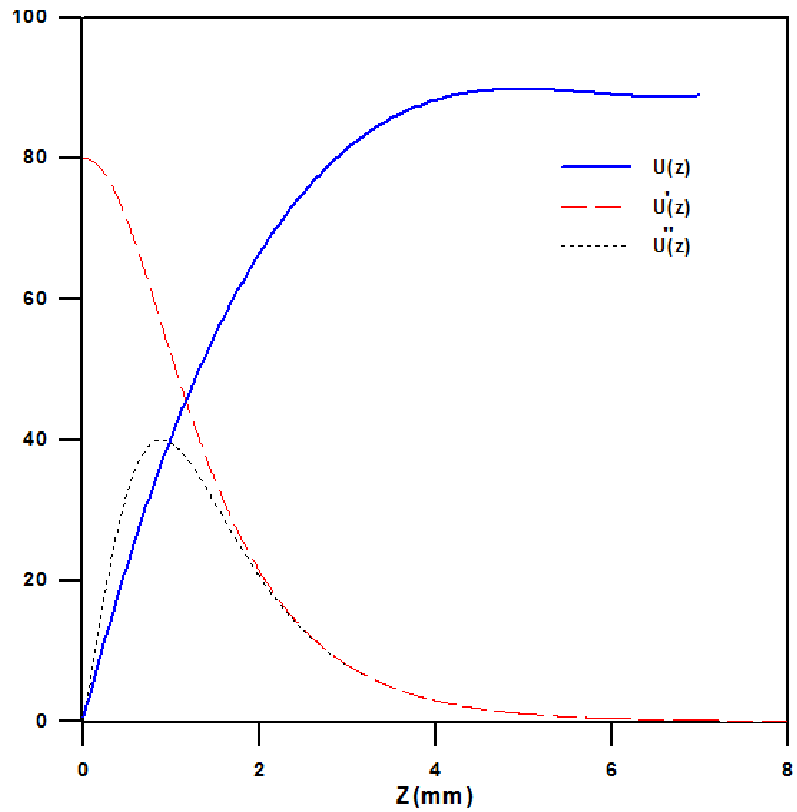
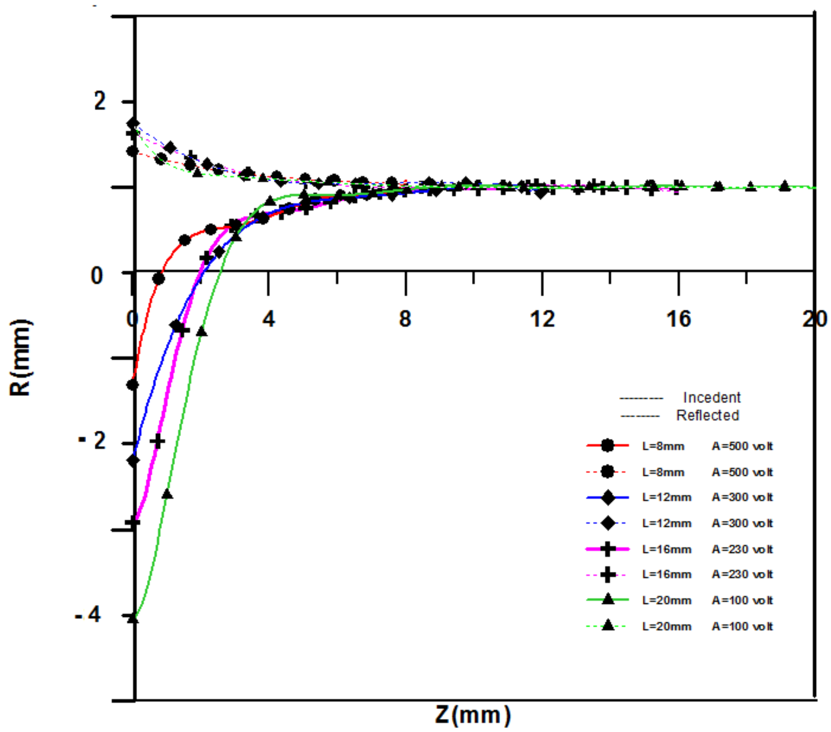


Figure No. (1) The axial potential distribution U(z) and its first and second derivatives U`(z) and U``(z) respectively of the electrostatic mirror when c=5 volt, a=300 volt and mirror length L=8mm



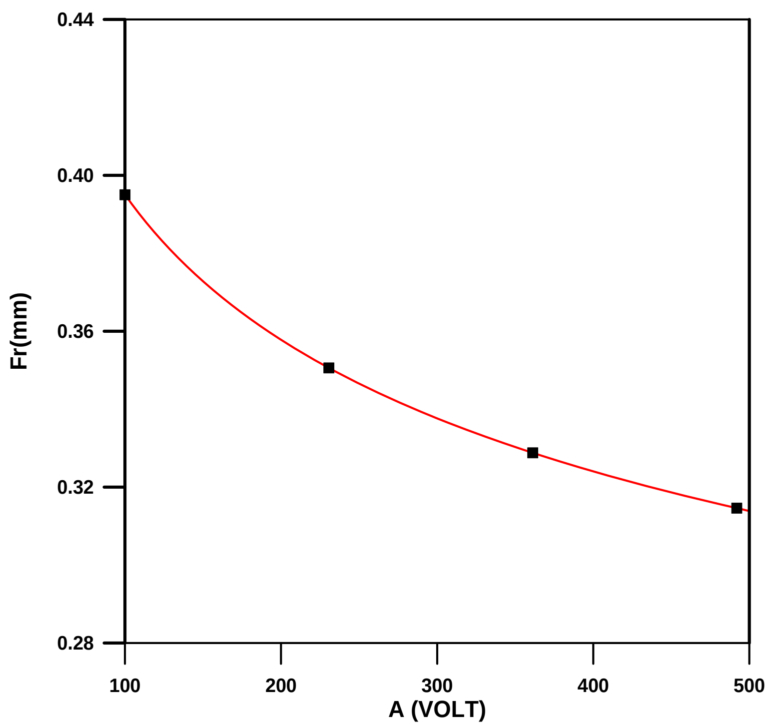
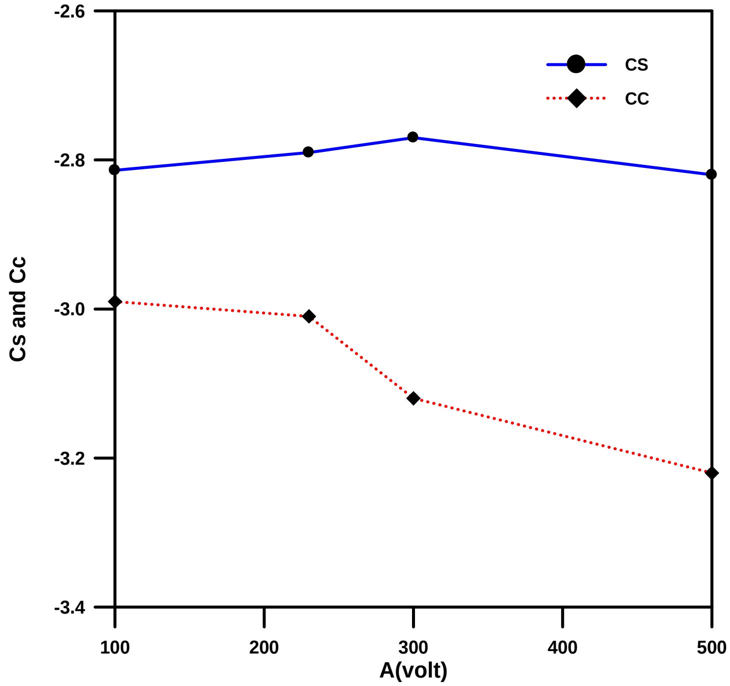
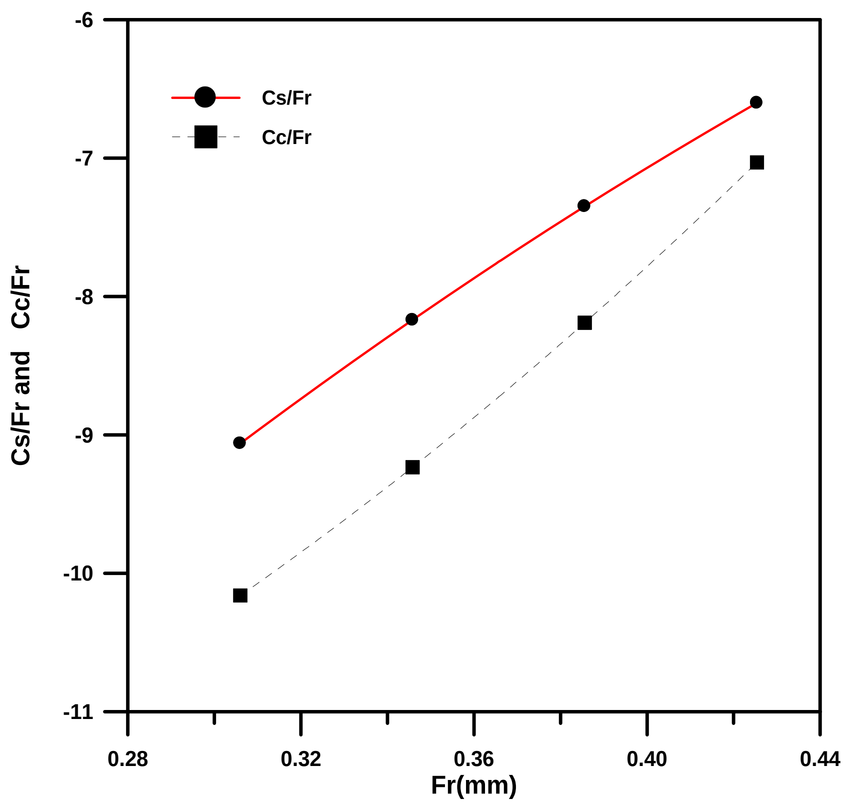
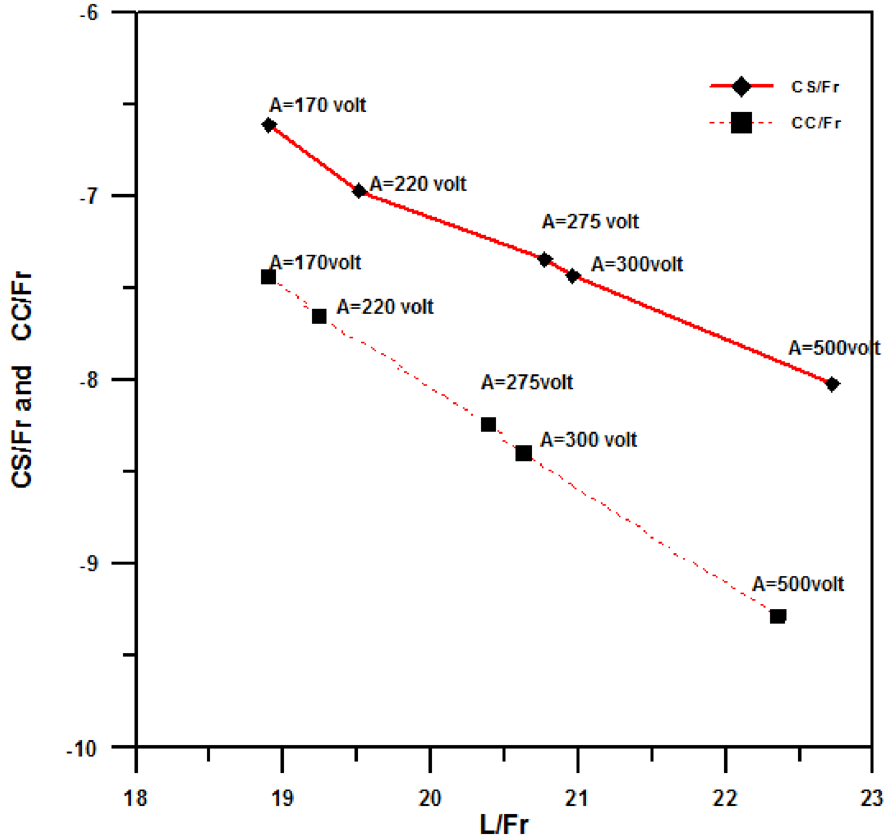


Figure No.(3) The changeability between values of the mirror focal length (Fr)mm and (A)volt when L=8,12,16,20 mm





FigureNo. (5) The changeability between Cs/Fr and Cc/Fr as a function of mirror focal length Fr (mm) for different values of (A)



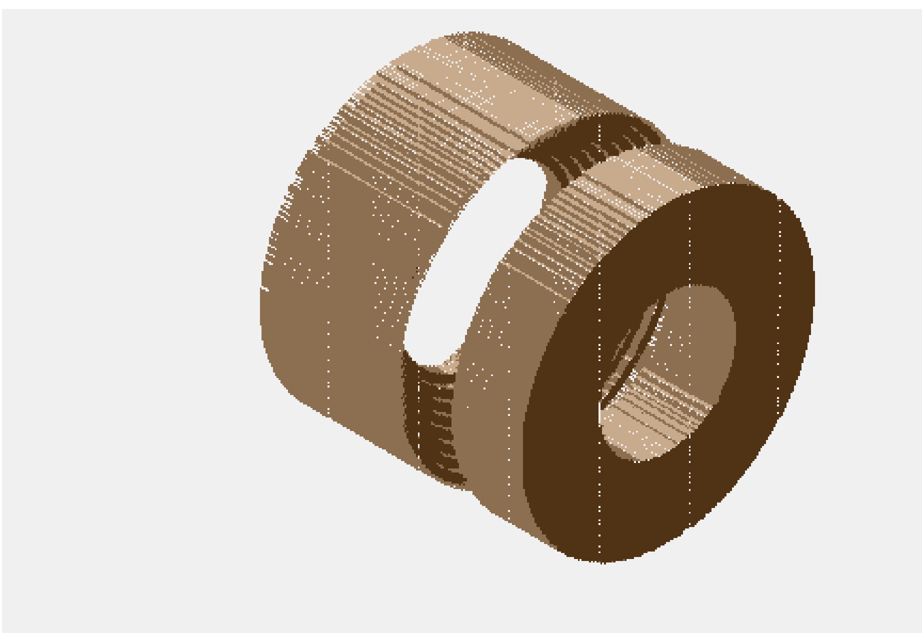


Figure No. (7) The shape of electrodes for electrostatic mirror in three-dimensions by using Simion computer program

تصميم ودراسة الخواص البصرية لمراة كهروستاتيكية باستعمال تقانه بمرزايف

انتهاء احمد محمد
قسم الفيزياء/كلية التربية للعلوم الصرفة ابن الهيثم/جامعة بغداد

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الخلاصة

تم في هذا البحث إجراء بحث حاسوبي عن تصميم وخواص المرايا الكهروستاتيكية واقتراح صيغة رياضية لتمثيل الجهد المحوري لهذه المرأة الكهروستاتيكية و تمت دراسة مسار الحزمة الالكترونية باستعمال تقانه بمرزايف على انها مسار مراتي بالاستعانه بطريقة رنج –كوتا.

تم حساب الخواص البصرية للمرايا من معاملات الزيوغ الكروية واللونية وتم تعبيرها بدلالة البعد البؤري ان اختيار المراة يعتمد على طريقة ومستلزمات التشغيل. تم ايجاد شكل اقطاب المراة ثنائية الاقطاب ورسمها من خلال استخدام برنامج سيميون

بينت الحسابات ان الجهود المقترحة اعطت نتائج جيدة قيم قليلة للزيغين الكروي واللوني فلقد حصلنا على Cs/Fr= - 8.05 Cc/Fr=- 9.1 L=8mm A=500volt والذي يعطي مؤشر جيد لتصميم المرايا

الكلمات المفتاحية :المرا يا الكهروستاتيكية ، تقنية بمرزايف، الزيوغ الكروية، الزيوغ اللونية ، برنامج سيميون