Design for Two Electrodes Electrostatic Mirror by using the Bimurzaev Technique

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Received in: 27 January 2013 , Accepted in: 19 May 2013

Abstract

This paper describes theoretical modeling of electrostatic mirror based on two cylindrical electrodes, A computational investigation has been carried out on the design and properties of the electrostatic mirror. we suggest a mathematical expression to represent the axial potential of an electrostatic mirror. The beam path by using the Bimurzaev technique have been investigated as a mirror trajectory with the aid of Runge – Kutta method. the electrode shape of mirror two electrode has been determined by using package SIMION computer program .

The spherical and chromatic aberrations coefficients of mirror has been computed and normalized in terms of the focal length. The choice of the mirror depends on the operational requirements, i.e. each optical element in optical system at low spherical aberration or low chromatic aberration. Computations have shown that the suggested potential gave rise to mirror when the mirror applied by using the Bimurzaev technique is deduced by having the following parameters:
$C_s=-7.49*10^{-7}$ mm, $C_c=-2.15*10^{-4}$ mm, $f_R=4.7*10^{-3}$mm, L=6mm, C=1volt, D=500 volt.

Keywords: Electrostatic mirror, Bimurzaev technique, Aberrations, SIMION computer program.

Introduction

The electron mirror can correct the spherical and chromatic aberrations of the accelerating field of an immersion objective lens[1]. The resolution and sensitivity of the electrostatic electron microscope with the mirror objective lens free of spherical and axial chromatic aberrations are higher than those of a similar microscope with an electron lens[2]. Electrostatic mirrors have previously been utilized for the deflection or energy analysis of beams of ion or electrons. The Electrostatic ion mirrors was first studied in 1949[3]. An electrostatic mirror aberration corrector is installed after the image forming objective lens. A double deflection 458 beam separator is used to bend the direction of electrons from the source to the objective lens and from the objective lens to the mirror aberration corrector [4]. The paperconsider focusing of charged particles in the two-electrode electromagnetic mirror with rotational symmetry whose cylindrical electrodes also act as magnetic electrodes [5].

Theory

The potential distribution function U(z) along the optical axis (z) of an electromagnetic mirror:

$$U(z) = C * \sec h(z) + D * \tanh(z) \qquad (1)$$

The constants C, D affects the properties of the suggested potential and the mirror lengths controlled by using a specific values of the constant D.
SIMION program used to simulate electrostatic and static magnetic device for accelerating, transporting and otherwise manipulating beams of charged particles . For the purposes of this article, only electrostatic fields were modeled[6]. The shape of the electrodes for electrostatic mirror determine from the solution of Laplace's equation [7].

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

The paraxial-ray equation in rotationally symmetric field is given by[7]:

$$\frac{\partial^2 r}{\partial z^2} + \frac{U'(z)}{2U(z)}\frac{\partial r}{\partial z} + \frac{U''(z)}{4U(z)} r = 0 \qquad (3)$$

In this research with the aid 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 when the ray of charge particle is incident and the second one is applied infinite magnification condition when the ray of charge particle is reflected. By applying this technique we get :

First condition I(1)=1 $I'(1) = 0$

$$\frac{\partial^2 I}{\partial z^2} + \frac{U'(z)}{2U(z)}\frac{\partial I}{\partial z} + \frac{U''(z)}{4U(z)} I = 0 \qquad (4a)$$

Second condition $R(\infty) = 0$ $R'(\infty) = 1$

$$\frac{\partial^2 R}{\partial z^2} + \frac{U'(z)}{2U(z)}\frac{\partial R}{\partial z} + \frac{U''(z)}{4U(z)} R = 0 \qquad (4b)$$

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

The coefficients of spherical aberration **Cs** and chromatic aberration **Cc** referred to the image side and expressed in the following form [8].

$$Cs=\frac{U^{-1/2}}{16r'^{4}}\int_{zo}^{zi}\left\{\left[\frac{5}{4}\left(\frac{U''(z)}{U(z)}\right)^{2}+\frac{5}{24}\left(\frac{U'(z)}{U(z)}\right)^{4}\right]r^{4}(z)+\frac{14}{3}\left(\frac{U'(z)}{U(z)}\right)^{3}\right.$$

$$\left.r'(z)r^{3}(z)-\frac{3}{2}\left(\frac{U'(z)}{U(z)}\right)^{2}r'^{2}(z)r^{2}(z)\ \right\}\mathrm{U}^{1/2}\,(\mathrm{z})\,\mathrm{dz} \qquad (5)$$

$$Cc=\frac{U^{1/2}(z\ \ )}{r'^{2}}\int_{zo}^{zi}\left[\frac{1}{2}\frac{U'(z)}{U(z)}r'(z)r(z)+\frac{U''(z)}{4U(z)}r^{2}\right]U^{-1/2}(z)dz \qquad (6)$$

A computer program for computing the beam trajectory , the optical properties[9] and electrode shape by using SIMION computer program [6].

Results and Discussion

A potential distribution function has been suggested to represent an electrostatic mirror by equation (1) is shown in figure (1a) with its first $U'(Z)$ and second $U''(Z)$ derivative where C (voltage applied in first electrode)=1volt , D (voltage applied in second electrode) =500 volt and mirror length is 6 mm**.** The values of the constant D for each mirror lengths can be shown in table (1). The second derivatives of the potential has one infliction point, hence the mirror has two justified electrodes.

. Three dimensional two electrodes forming an electrostatic mirror is shown in figure (1b)Two-element electrostatic mirror systems. which consist of cylindrical electrodes, were designed by using the SIMION programs.

The beam path along the electrostatic mirror field using Bimurzaev technique under the accelerating mode of operation has been considered and using equation (4a,b). Examples for trajectories of the electrostatic mirror along lengths L=6, 10, 14 and 18 of the mirror are given in figure (2). It is noted that D constant decreases when mirrors length increases the result can be shown in table (1).

From figure (2) it is noted that the electrostatic mirror focal length fR is directly proportional with D for all mirror length. The mirror focal length can be determined from the ray of charge particle is reflected, from the result it is noted that the mirror focal length has a positive sign that means the mirror type is convergence. For example,in figure (3) it can be shown that the value s of the mirror focal length proportional directly with D where increasing the values of D deducing decreasing in the mirror focal length.

Figure (4) shows the variation between Cs/fR and Cc/fR as a function of the mirror focal length fR, the Cs/fR and Cc/fR increase with the increase of fR and Cs/fR less than Cc/fR .

Figure (5) shows the spherical and chromatic aberration Coefficients have been Computed for electrostatic two electrode electrostatic mirror with length L=6, 10,14 and 18mm using the equations (5), (6). The Cs and Cc decrease when the values of D increase too. It is seen that Cs and Cc have a minimum values at D= 500 volt and L=6mm at this value of constant D, the value of Cs is equal to ($-7.49*10^{-7}$)mm and the value of Cc is equal to ($-2.15*10^{-4}$)mm, as shown in the table (2). Finally figure (6) shows the relative spherical and chromatic aberration coefficients Cs/fR and Cc/fR respectively as a function of the electrostatic mirror length, the increase in the mirror length causes a decrease in both Cs/fR and Cc/fR .

Conclusion

The results of investigations show that the two-electrode the electrostatic mirror has better characteristics with regard to the mathematical expression for the axial potential and the electron beam to produce the trajectories are successful and gave rise to good result from the electron – optical point of view. The electrostatic mirror is useful for studying surfaces of specimens by using the Bimurzaev technique are considered as mirror trajectories. From the negative sign of the spherical and chromatic aberration, we can use such lenses to correct aberration. The computational simulations were carried out by using the commercially available SIMION program, which addresses interactive methods for simulating a broad variety of general ion optics jobs.

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Table No. (1): Shows the values of D (mm) for each values of mirror lengths, C=1volt

D (volt)	500	270	180	130
Mirror length (mm)	6	10	14	18

Table No. (2) :Shows the best optical properties of the electrostatic mirror, C=1volt

L(mm)	D (volt)	Cs(mm)*10^{-2}	Cc(mm)*10^{-2}
6	500	-0.0000749	-0.0215
10	270	-0.86	-1.05
14	180	-2.05	-1.44
18	130	-3.4	-1.7

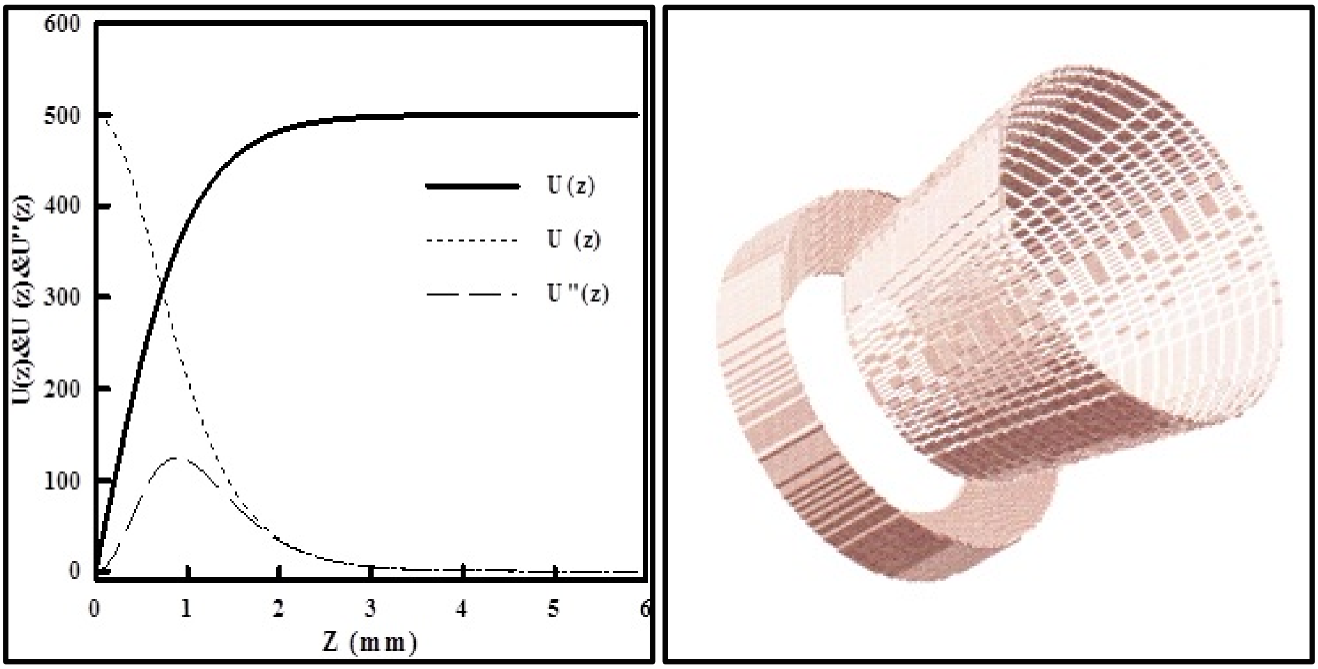

Figure No. (1a): The axial potential distribution U (z) and its first $U'(z)$ and second $U''(z)$ derivatives of two electrode Electrostatic mirror when C=1 volt, D=500 volt, mirror length=6mm. (1b) three- dimensional of two electrodes mirror with best of optical properties

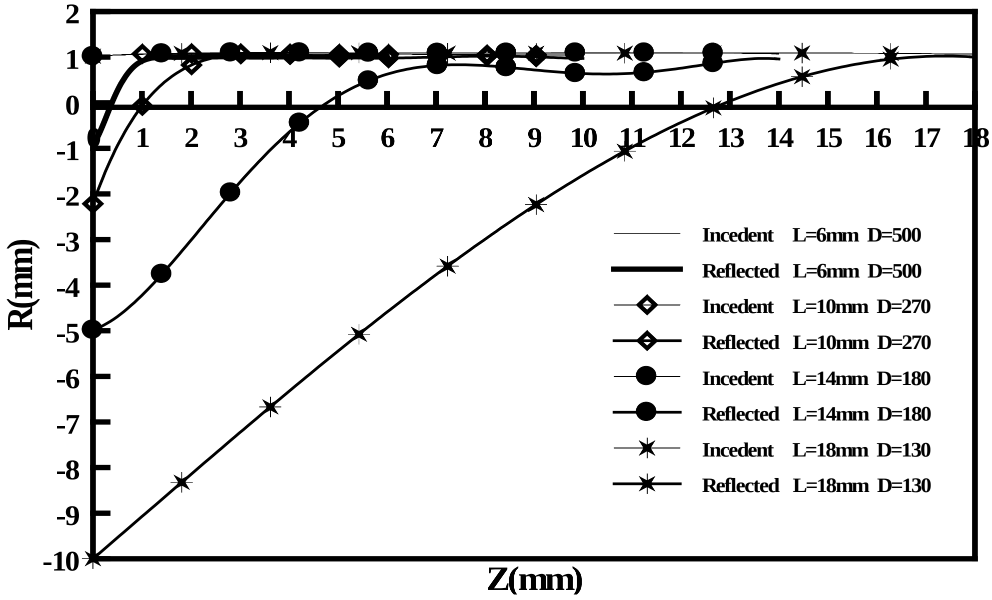

Figure No. (2): The electron beam trajectories for the electrostatic mirror along lengths L=6, 10, 14 and 18 (mm)

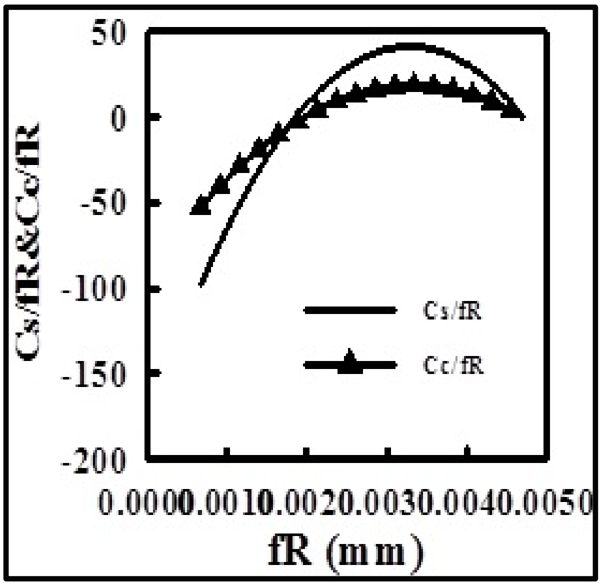

Figure No. (4):The relative spherical and chromatic aberration coefficients as a function of the fR

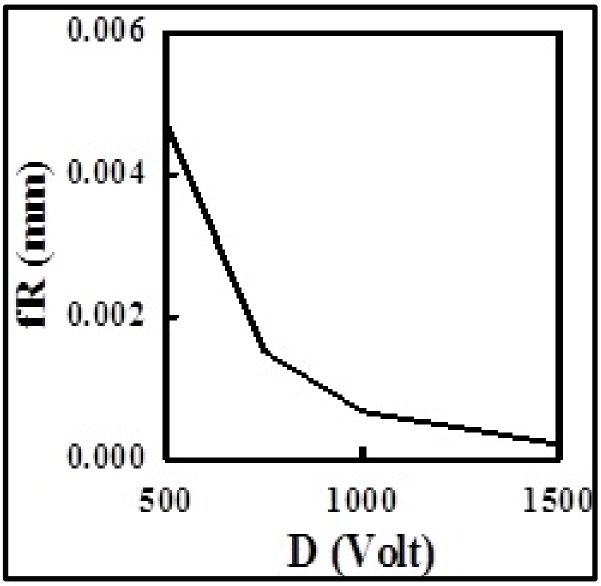

Figure No. (3): Shows the relation between the constant D and fR, where C=1 volt, L=6 mm.

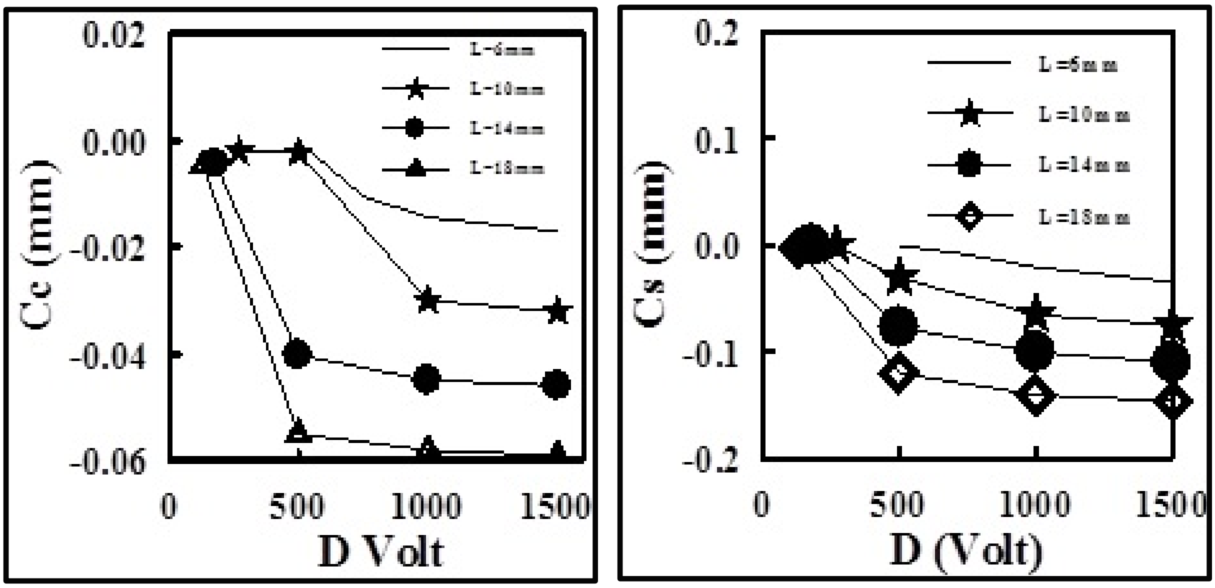

Figure No. (5):The relative spherical and chromatic aberration coefficients as a function of the constant D, where C=1 volt

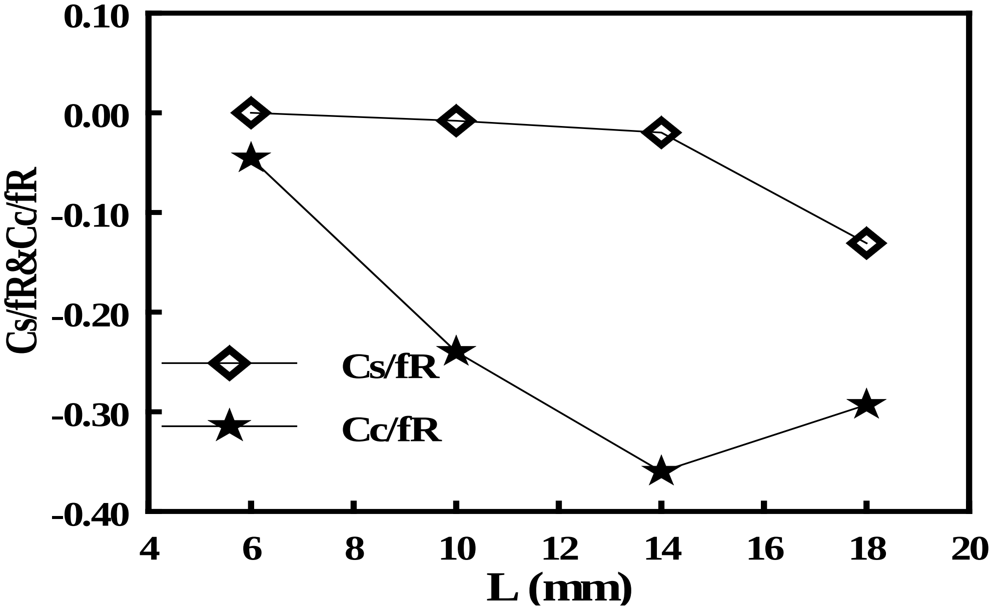

Figure No. (6):The relative spherical and chromatic aberration coefficients as a function of the electrostatic mirror length.

تصميم لمرآة كهروستاتيكية ثنائية الأقطاب بأستخدام تقنية بمرازيف

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استلم البحث في 27 كانون الثاني 2013 ، قبل البحث في 19 ايار 2013

الخلاصة

يصف البحث تصميم نظري لمرآة كهروستاتيكية ثنائية الأقطاب، اذ اجري بحث حاسوبي عن تصميم و خواص المرايا الكهروستاتيكية، بأقتراح صيغة رياضية لتمثيل الجهد المحوري لمرآة كهروستاتيكية. ودرست الحزمة باستخدام تقنية بمرازيف على أنها مسار مرآتي بالاستعانة بطريقة رنج-كوتا.

حيث وجد شكل الأقطاب للمرآة ثنائية الأقطاب باستخدام احد برنامج المحاكاة المعروفة بأسم (سيميون). حسب كل من معاملات الزيغين الكروي واللوني وتم تعبيرها بدلالة البعد البؤري. ان اختيار المرآة يعتمد على مستلزمات التشغيل وذلك فيما اذا كانت الرغبة في تشغيل المرآة في منظومة ايونية بصرية عند زيغ كروي واطئ او زيغ لوني واطئ. وبينت الحسابات ان الجهد المقترح قد اعطت عمل المرآة عندما تعمل المرآة باستخدام تقنية بمرازيف التي استنتجت لها القيم الاتية:

$Cs=-7.49*10^{-7}$ mm, $Cc=-2.15*10^{-4}$ mm, $fR==4.7*10^{-3}$mm, L=6mm, C=1volt, D=500 volt

الكلمات المفتاحية: المرايا الكهروستاتيكية، تقنية بمرازيف، الزيوغ ، برنامج المحاكاة (سيميون).