Computer Aided Design of Three Electrode Electrostatic Unipotential Lens

Dr. Samir Khudhir Al-ani[1], Nada Abdulfatah Khattab[2]

[1]Professor, Baghdad University-College of Science for Women-Physics Department

[2]Baghdad University-College of Science for Women-Physics Department

Abstract: ***The present work has been concerted on the simulation of focusing electron beam by finding the optimum design of an electrostatic uni potential lens with optimum low values of spherical and chromatic aberration coefficient. Computational theoretical investigation has chivied in the field of non-relativistic charged particles optics with the aid of the personal computer and numerical method under the absence of space - charge, the potential field distribution of un potential lens have been represented by using some of analysis functions, the paraxial ray equation have been solved for proposed fields to determine the trajectory of the electron beams in the lens. The spherical and chromatic aberration coefficients computed from the axial potential distribution and its first and second derivative the electrodes shape of the low aberration un potential lens has been determined in two and three dimension, its benefited from the optimum design for the three electrode un potential lens have a low a aberration values so it is possible to use this lens in making an optical system which can be used in focusing of charge particles.***

1. Introduction

Electron and ion optics is the theory and practices of production, control, and utilization of charged-particle beams can only be controlled (accelerated, focused)

Different symmetries may be utilized for electron such as lenses, deflector, accelerator,….etc .[1].

Aberration can be defined as, if an electron path leaving an object points a finite distance from the axis with particular direction and electron velocity intersects the Gaussian image plane at a point displaced from the Gaussian image point, this displacement is defined as the aberration[2]. The aberration can arise for a number of reasons. However, the two most aberrations of electron-optical systems are spherical and chromatic aberration.

The present work been mainly concentrated on the design of the three electrode type electrostatic electron lenses, trajectory of electron beam through an axially symmetric electrostatic lens ,Progress in the calculation of electron optical properties in recent years have been reviewed by uni potential lenses have three electrodes , the distinctive feature of lenses is that they have the same constant potential V_1 at both the object and the image side ,the central electrode is at different potential V_2 therefore they are used when only focusing is required but the beam energy must be retained

The electrostatic lenses may be classified according to the number of their electrodes, in classical texts of electron optics electrostatics lenses were classifiable into groups according to the relationships between their electrode , the trajectory of electron beam through an axially electrostatic lens [3], progress in the calculation of electron optical properties in recent years have reviewed by [4] and [5] the electrode shape of the electrostatic lens determined from the solution of Laplace equation and the results showed low values of spherical aberration and chromatic aberration, which are considered good design[6].

2. Theory II

The present computational investigation is aimed to design electrostatic lens using analytic expression that would describe the axial potential distribution of lens with electron optically acceptable aberrations. The following expression is suggested to represent the potential distribution along the optical axis of lens[7]:

$$V(z) = V1[1 + D\exp(\pm z^2)] \text{ ---------------(1)}$$

Where V1 is the voltage applied on the outer electrodes, D is a constant affecting the value of voltage applied on the central electrodes. The paraxial-ray equation in rotationally symmetric field is given by(2) [8].

$$r''(z) + r'(z)\frac{V'(z)}{2V(z)} + r(z)\frac{V''(z)}{4V(z)} = 0 \text{ --(2)}$$

where r is the radial displacement of the beam from the optical axis z, and the primes denoted a derivate with respect to z.

The spherical aberration is one of the most important geometrical aberrations and can be defined as follows: the beam passing within the lens area at a considerable distance from the axis are more refracted than the paraxial beams so that they intersect closer to the image plane, the spherical and chromatic aberrations are dominant in an electrostatic lens [9].
The spherical and chromatic aberration coefficients are denoted by Cs and Cc respectively, the spherical aberration coefficient Cso and the chromatic aberration coefficient Cco referred to the object plane, and we can compute from the standard formulae [**10].**

.

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

$$\left. r'(z) r^3(z) - \frac{3}{2}\left(\frac{V'(z)}{V(Z)}\right)^2 r'^2(z) r^2(z) \right\} V^{1/2}(z)\, dz \text{ ----(3)}$$

ISSN (Online): 2319-7064
Index Copernicus Value (2016): 79.57 | Impact Factor (2015): 6.391

$$Cc_o = \frac{V^{1/2}(z_o)}{r_o'^2} \int_{zo}^{zi} \left[\frac{1}{2} \frac{V'(Z)}{V(z)} r'(z) r(z) + \frac{V''(Z)}{4V(z)} r^2 \right] V^{-1/2}(z) dz --- (4)$$

In the image space , the spherical aberration coefficient **Csi** and chromatic aberration coefficient Cci is expressed in a similar form of equations (3) and (4) the integration was performed using Simpson rule[11].

3. Results and Discussed

Figure (1) show the axial field distribution of lens that central electrode is higher voltage whose the two outside electrode. Figure (2) show the trajectory of charged particles of the electrode unipotential lens under infinite magnification condition, Figure (3), (4) shows the relative spherical and chromatic aberration as function of the voltage ratio(V1/V2), this figure indicates that the relative aberration coefficients the spherical aberration coefficient is increased, and the chromatic aberration is decreased with increasing the voltage ratio, the axial field distribution V(z) given in equation (1) for lens Figure (5) shows The electrode shape of the three – electrode unipotential lens. .

Table 1: Shows the best optical properties the electrostatic lens

Vi/Vo	Cs/f	Cc/f
10	0.001	0.2
15	0.01	0.15
20	0.08	0.13
25	0.2	0.12
30	1.43	0.122

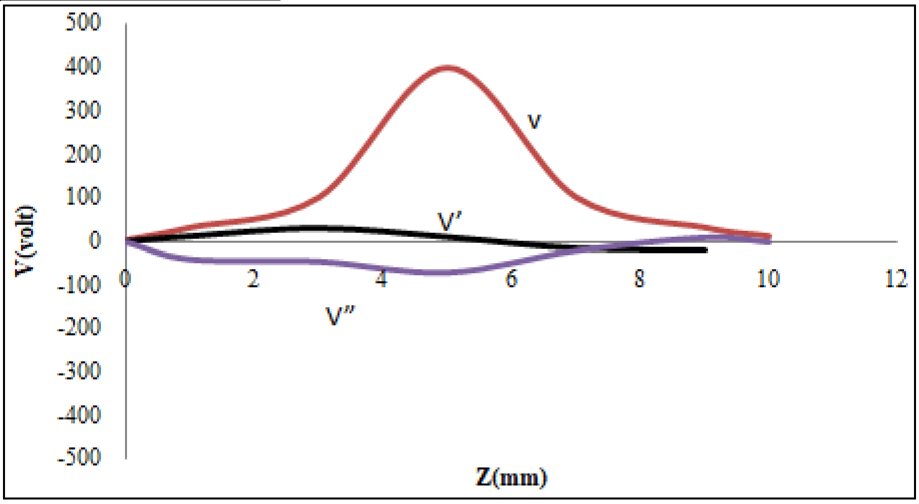

Figure 1: The axial potential distribution V and its first and second derivatives

4. Conclusion

1) It is well know that the spherical aberration coefficient is increased, and the chromatic aberration is decreased with increasing the voltage ratio Vi/Vo.
2) It appears from the present investigation that it is possible to design of electrostatic lens with small aberrations operated under different potential ratios.
3) It appears that the proposed analytic function of the axial potential field for a lens offers considerable advantage with regard to the relative spherical aberration coefficient.

Paper ID: 27121703 DOI: 10.21275/27121703

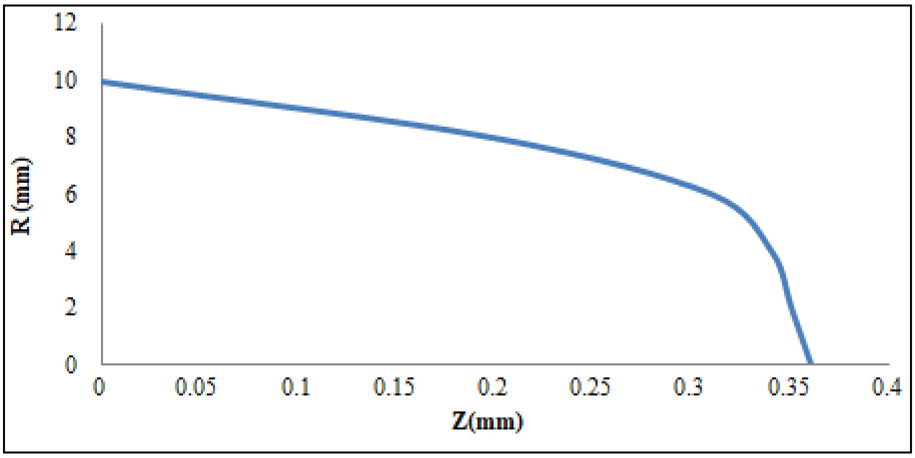

Figure 2: Represent the relation between trajectory of the three electrode unipotential lens and Z spacing under infinite magnification condition

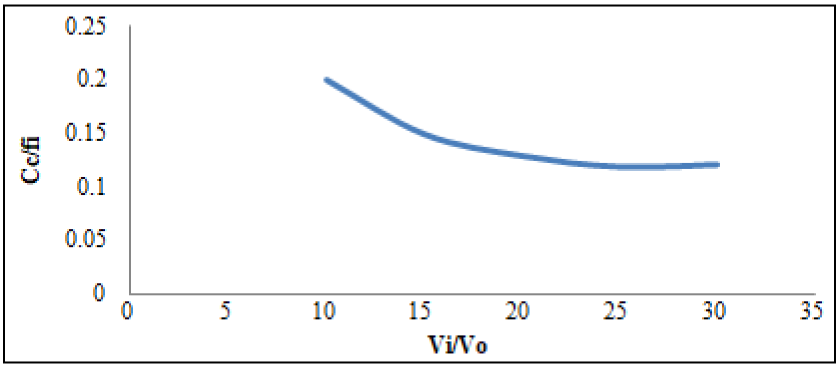

Figure 3: The relative chromatic aberration coefficient Cci/fi as function of Vi/Vo

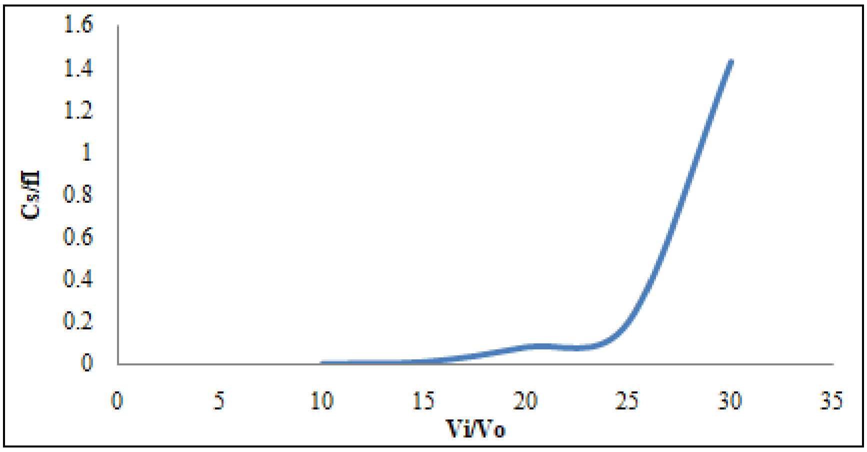

Figure 4: The relative spherical aberration coefficient Csi/fi as function of Vi/Vo

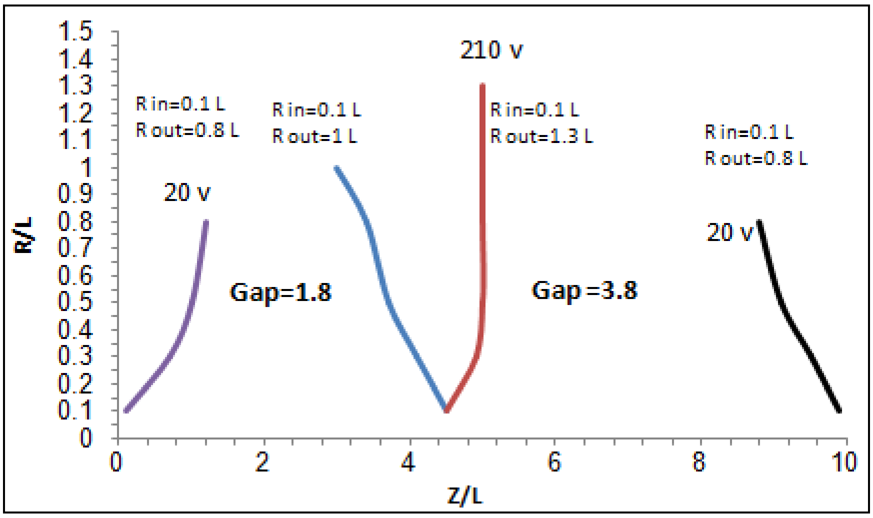

Figure 5: The electrode shape of the three- electrode unipotential lens

References

[1] AI-Obaidy , U. A. Computational Optimization of an Electron Beam Deflecting System Ph D, Thesis, AI – Nahrain University, Baghdad, Iraq. (2005)
[2] EI –Kareh, A.B. and EI- Kareh, J. C. J Electron Beam, Lenses and Optics 2, (Academic Press New York and London). (1970)
[3] Hawkes P.W (2004). Recent advances in electron optics and electron microscopy, Annales de la Fondation Louis de Broglie, 29(1), 837-855.
[4] Sise, O., UIu, M. and Dogan, M. (2007), Characterization and modeling of multi-element electrostatic lens systems.
[5] P.W. Hawkes and A. Septier ed. Septier, Lens aberration Focusing of charged partical" ,Academic press ,New York, 1967.
[6] S.Kh. Yassin, R.R.Mamoud, "Design of Immersion Electrostatic Lens Operated under Zero Magnification Condition UM Salama Science journal, University of Baghdad, Baghdad, Iraq. (2008)
[7] Polyanin, A. D. (2002). Handbook of Linear Partial Differential Equations for Engineers and Scientists. Boca Raton: Chapman & Hall/CRC Press.
[8] Hawkes P. W. and Kasper E., (1989), Principles of electron optics ,1 (Academic Press: London).
[9] Szilagyi, M. Electron and Ion Optics. Plenum Press, New York. (1988)
[10] Hawkes, P. W.(1973) Image Processing and Computer-aided Design in Electron Optics, (Academic press, London and New York).
[11] Erwin K., Herbert K, Edward J. N.(2011) Advanced Engineering Mathematics