Computer-Aided-Design of low aberration electrostatic Immersion lens

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Abstract

A computerized investigation has been carried out to design an immersion lens with low aberration operating under zero magnification condition using inverse problem. The aberration is highly dependent on the shape of electrodes, for a preassigned electron beam trajectory the paraxial-ray-equation is solved to determine the electrostatic potential and field distribution.

From the knowledge of the potential and its first and second derivative the electron optical properties were computed, the electrode geometry was determined from the solution of Laplace equation.

A- INTRODUCTION

Electrostatic lenses are the principal components in the overwhelming majority of electron optical devices, both electrostatic and magnetic lenses are used to focus charge particles.

The electrostatic lenses may be classified according to the number of their electrodes, in classical texts of electron optics electrostatic lenses were classified into groups according to the relationships between their electrode potentials [1].

The immersion lenses having the two different constant potential at both the object and image sides in this case the lens is accelerating if the velocity v2 of an ion or electron leaving the region of the lens is greater than the velocity v1 when entering this region and the lens is decelerating when $v2<v1$.

Throughout the published literature the inverse problem optimization method has been given little attention to determine the electrodes shape of electrostatic lenses.

B- DESIGN CONSIDRATION

The present work has been mainly concentrated on the design of two-electrode type electrostatic electron lenses operated under zero magnification condition using the inverse problem.

The trajectory of an ion or electron beam through an axially symmetric electrostatic lens field, in term of the axial potential Φ and its first and second derivatives Φ' and Φ'' respectively is given by the following equation[2].

$$\partial 2r/\partial z2 + \partial r/\partial z \,.\, \Phi' /2 \Phi + \Phi''/ 4\Phi \,.\, r = 0 \quad \ldots\ldots\ldots\ldots(a)$$

where r is the radial displacement of the beam for the optical axis z, and the primes denote a derivative with respect to z.

The starting point is assigning the electron beam trajectory using a polynomial given in the following equation:

$$r(z) = \sum_{i=0}^{n} a_i z^i \qquad \text{……………………………………….(b)}$$

The parameter a can be chosen such that the trajectory given by r(z) satisfies the initial conditions imposed by the required type of magnification in the charged particle .

To find the axial potential distribution Φ(z) satisfying the given trajectory function r(z) , the paraxial ray equation (equ. a) is solved by using the fourth-order Runge-Kutta method to determine the axial potential Φ(z) , field Φ'(z) and the second derivative Φ"(z) distribution [3].

The spherical aberration coefficient (Cs) and chromatic aberration coefficient (Cc) calculated from the following formula [1][4][5].

$$C_S = \frac{\Phi_0^{-1/2}}{16 r_0'^4} \int_{z_0}^{z_i} \left[\left(\frac{5}{4}\left(\frac{\Phi''(z)}{\Phi(z)}\right)^2 + \frac{5}{24}\left(\frac{\Phi'(z)}{\Phi(z)}\right)4 \right) r^4(z) + \frac{14}{3}\left(\frac{\Phi'(z)}{\Phi(z)}\right)^3 r'(z) r^3(z) - \frac{3}{2}\left(\frac{\Phi'(z)}{\Phi(z)}\right)^2 r'^2(z) r^2(z) \right] \Phi^{1/2}(z)\,dz \qquad \text{…..(c)}$$

$$C_C = \frac{\Phi_0^{1/2}}{r_0^2} \int_{z0}^{z_i} \left[\left(\frac{\Phi'(z)}{2\Phi(z)} \right) r'(z) + \left(\frac{\Phi''(z)}{4\Phi(z)} \right) r(z) \right] \frac{r(z)}{\Phi^{1/2}(z)}\,dz \qquad \text{……………………..…..(d)}$$

C- COMPUTER PROGRAMS

A computer programs written by Munro(1975) and then modified by Ahmad(1993) has been used to determine the trajectory of the charged particles using Runge-Kutta method.

The spherical aberration coefficient Cs and the chromatic aberration coefficient Cc are computed by using the aberration integral formula given in equation (c) and (d). The integration was performed using Simpson rule.

The shape of the electrodes forming a specific electrostatic lens has been determine with the aid of the computer program in Fortran 77 language using the following formula:

Y(r,z) = Φ(0,z) - r^2. Φ"(0,z) /4 ……… (e)

Where Y(r,z) is the off-axis potential, Φ(0,z) is the axial potential function whose number of inflection points are counted. The radial displacement r approaches infinity at each inflection point where Φ"(0,z) =0, this equation can be written in the following form :

r = 2((Φ(z) - Y(r,z)) / Φ"(z))^0.5 …....(f)

Equation (f) has been used to determine the electrode profile [7].

D- RESULT AND DISCUSSION

The axial potential and field distribution obtained from the solution of the paraxial ray equation are plotted in figure (1).

Figure (2) shows the relative spherical and chromatic aberration as a function of the voltage ratio (v2/v1), this figure indicates that the relative aberration coefficients increase with increasing the voltage ratio.

The electrode profile shown in figure (3) indicates that they are symmetric with respect to the center of the lens, thus the lens can be called symmetrical.

The relative inner radius Rin/L of the central hole in each electrode is 0.0117 to allow passage for the accelerated charge particles beam. A three dimensional diagram of the two electrode immersion lens shown in figure (4).

The trajectory of the charged particles under zero magnification condition shown in figure (5).

E- CONCLUSION

It is well know that the aberration of electrostatic lenses is

higher than those of magnetic lenses, however the present work has shown that a careful of the electrodes geometry for a preassigned trajectory can produce electrodes lenses of very low relative aberration coefficients.

The analytical models of the potential for the immersion lens, which have been, put forward in the present work give favorable values for the aberrations when compared with published references [3].

Therefore, it is clear that the inverse problem optimization method is an excellent procedure for determining the geometry and the configuration of electrostatic lenses specifically operated for preassigned electron beam trajectory.

F- REFERENCES

1- Nagy A. and Szilagyi M. (1974) " introduction to the theory of space charge optics (Macmillan Press: London).

2- Kirstein P.P., kino G. S. and waters W. E. (1967) " space charge flow"(MaGrawHill: new York, London).

3- Szilagy M. (1988)" Electron and ion optics" (Plenum Press: New York, London).

4- Szilagy M. and M. P. H. (1995)" Synthesis of focusing and deflection columns" J. Vac. Sci. Tech. B13,975-982.

5- Scheinfein, M. and Galantai, A. (1986)" Multiobjective optimization techniques for design of electrostatic charged particles lens Optik, 74, 154-164.

6- Szilagyi M., and Szep J. (1988)" Optimum design of electrostatic lenses" J. Vac. Sci. Tech. B6, 953-957.

7- Al-ani S. K. (1996)"A computational study of space charge effect on the design of electrostatic lens" Ph.D. thesis, Al-Nahrain University, Baghdad, Iraq.

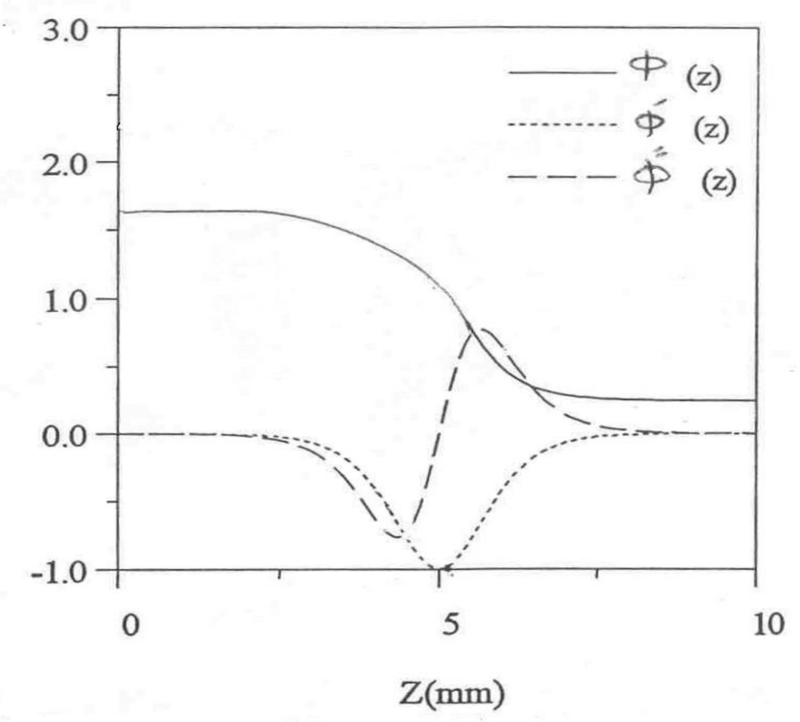

Figure –1- The axial potential distribution Φ(z) and its first and second derivatives Φ'(z) and Φ''(z) respectively.

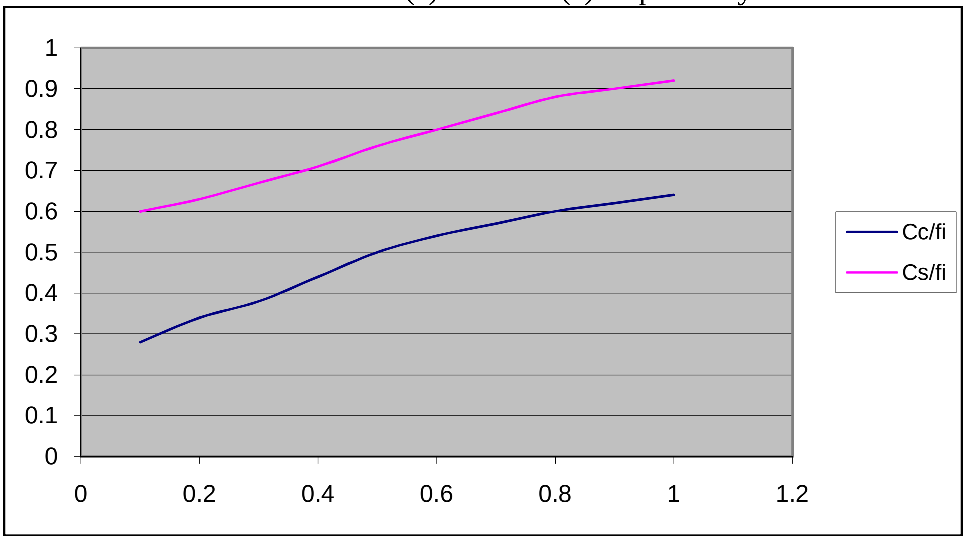

Figure –2- The spherical and chromatic aberration coefficients Cs/fi and Cc/fi as a function of voltage ratio v2/v1.

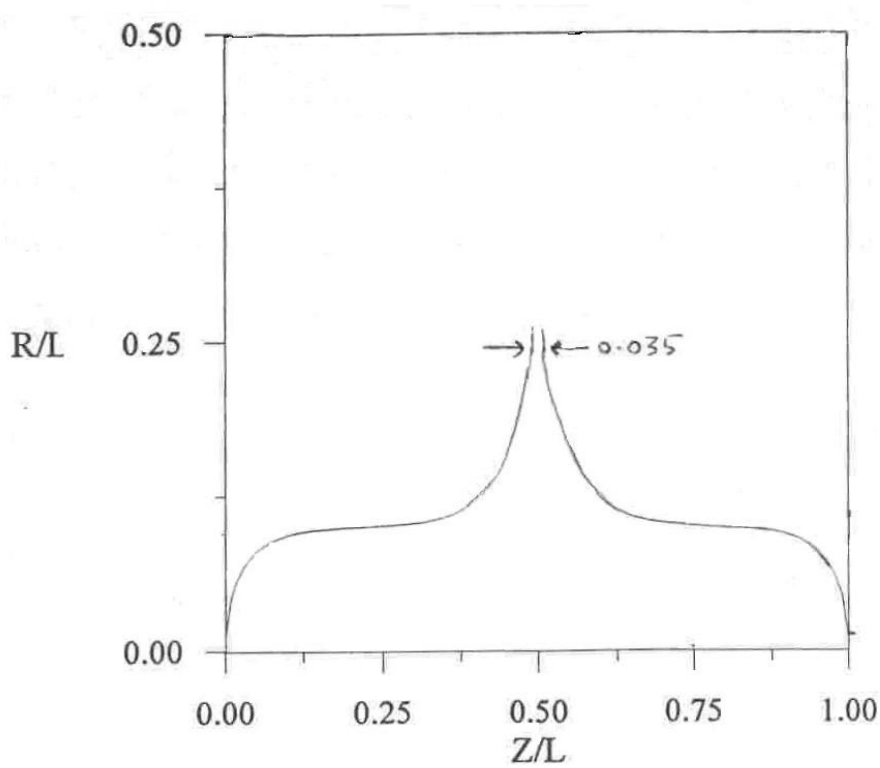

Figure-3- The two dimensional electrode-shape of immersion lens.

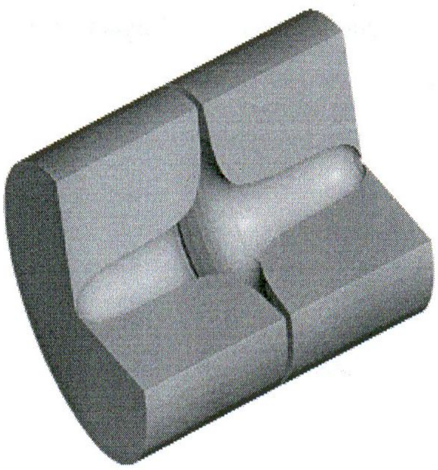

Figure –4- The three dimensional diagram of the two electrode immersion lens.

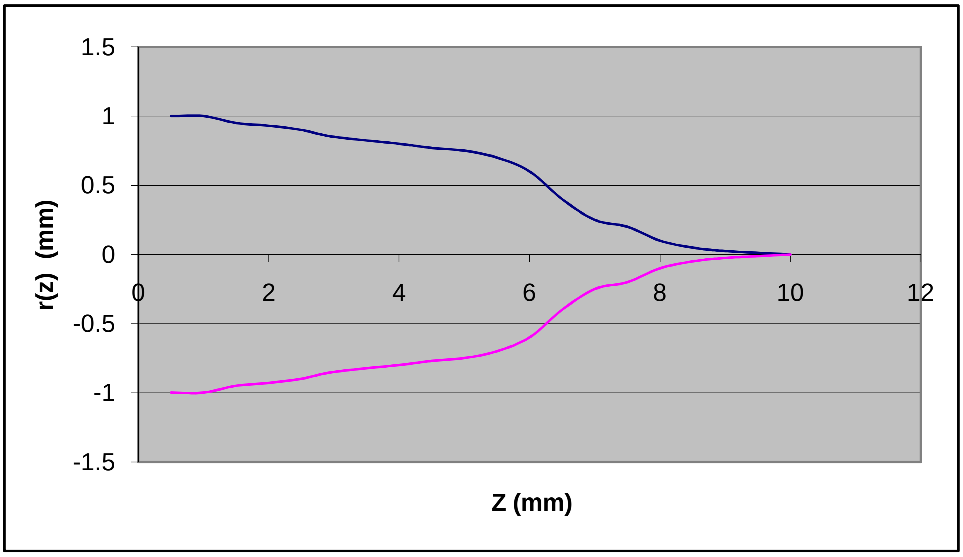

Figure-5- The beam trajectory under zero magnification condition.