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Design and Studying the Effect of Inner Bore Diameter of Unipolar Lens

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ABSTRACT

This work investigated the development of magnetic and optical properties and the invention of a previously unused lens. Many new designs have been suggested for a unipolar magnetic lens based on changing the width of the inner bore and fixing the other geometrical parameters of the lens to improve the performance of unipolar magnetic lenses. The investigation of a study of each design included the calculation of its axial magnetic field the magnetization of the lens in addition to the magnetic flux density using Finite Element Method (FEM). It was found that the best magnetizing properties, the highest value of magnetic flux and the lowest value of bandwidth of the axial magnetic field strength have been obtained when the width of the inner cavity was (55 mm). The effect of current density on the optical properties has been also studied, and it was found that the optical properties have been improved also, and the chromatic and spherical aberration values have decreased significantly. Thus, the lens (55 mm) was chosen as the best design among the proposed designs.

KEYWORDS: Spherical aberration coefficients; Magnetic lens; Chromatic aberration coefficients; Magnetic properties; Optical properties.

INTRODUCTION

The magnetic lens is very important in many scientific applications such as scanning electron microscopes and transmitting electron microscopes (SEM, TEM), respectively [1], implantation systems [2], well as ion and electron beam printing systems, if the performance of the lens was not good, so cannot be produced. The best operating conditions include acceleration voltage, excitation mode of operation and characteristics, well appropriate lens shape and size. Coil lenses affect performance, in order to design the magnetic lens all must be configured [3]. Studied the effect of position and geometry of coil on the magnetic flux lines and the shape of flux density distribution by designing and studying the local properties of the magnet lens by Alaa Ahmed [4]. In 2006, Abdullah and Al-Khashab studied; a single piece magnetization lens, magnetic pole, electronic lens, and using a different coil, so it was found that choosing an appropriate type of coil geometry to improve the performance of the magnetic unipolar lens for an equal value of current density [5]. In 2010, Al-Khashab and al-Hijaz, designed magnetic targets and electrostatic lenses with deflection coefficients was carried out [6]. In 2012, A. Al-bbatat and Z. Al-Rubaye potatoes and spring performed a theoretical study using the optimal synthesis method to simulate and magnetic symmetric pole piece design. The objective focal characteristics of double pole piece magnetic lenses [7]. In 2013, Ahmed studied two types of electron lenses to obtain a preferred composite lens configuration; and found that the lens with iron isolation achieved better optical performance [8]. In 2015, Abdullah focused on the impact of the current density and lens dimensions on the design of Iron-free magnetic lenses. There was a magnetic field measured for different values of current density. In addition, it was radial and helical deflection coefficients. It has been calculated [9]. Al-Shahat et al., explored objective characteristics of the unipolar magnetic lens with different shapes for the column parts where the results indicate a spherical lens is the best Precision [10]. In 2017, Abbas and Sahi studied objective focal characteristics of symmetrical dual lens widgetstyle magnetic electronic lenses using EOD program [11]. In 2018, Noaman presented some critical geometric properties of the lens and the coefficient of spherical aberration [12]. In the design of the present work, the development of the proposed design for the unipolar magnetic lens is based on examining the impact of the inner bore diameter on the magnetic and optical properties to investigate the possibility of improving the performance of the unipolar magnetic lens using the Magnetic Electron Lenses Optical Properties (MELOP) [13].

THEORETICAL CONSIDERATIONS

In this work, magnetic and optical properties of designed lenses have been studied, in order to reach the best design among the proposed lenses, and these properties will be explained in the following sections.

Flux Density Distribution Models

Equations of paraxial ray reveals that there is no way to determine electron beam trajectory without knowing the axial magnetic field distribution (B_z). mathematical models are used to explain the axial flux density distribution in the following subsection of some of these models [14].

1. Glaser's bell-shaped model:

axial distribution of magnetic field (B_z) is given by [15].

$$B_z \frac{B_m}{1+(z/a)^2} \tag{1}$$

where: B_z axial distribution of magnetic field, B_m maximum magnetic flux density, z optical axis, a half-width at half maximum.

2. Related bell-shaped curves:

In particular, in the case $n=\frac{3}{2}$, the field of a single turn, $n=2$, and $n=\infty$

for which the distribution becomes Gaussian given by [16].

$$B_z \frac{B_m}{\left(1+{z^2}/{a^2}\right)^n} \tag{2}$$

Spherical-Aberration

The spherical aberration of the most important aberrations that occur in the lens because it affects the quality of the image formed by this lens given by [17].

$$C_s = \frac{e}{128\, m\, V_r}\int_{z_o}^{z_i}\left(\frac{3\, e}{mV_r}B_z^4 r_\alpha^4(z) + 8\, B_z^{2'} r_\alpha^4 - 8\, B_z^2 r_\alpha^2(z) {r'}_\alpha^2\right)dz \tag{3}$$

Where: e the charge of the electron, m the mass, V_r the relatively corrected acceleration voltage, B_z the magnetic flux density of the distribution, r_α solution of the axial ray equation, the spherical aberration an important role in determining the relation power of electron microscope given by [15].

$$\delta = 0.61(c_S\lambda^3)^{1/4} \tag{4}$$

Chromatic-Aberration

The aberration that depend on the difference in the speed of electrons emitted from the source given by [18].

$$C_c = (e/8mV_r)\int_{z_0}^{z} B^2(z)h^2(z)dz \tag{5}$$

PRACTICAL PART

In the current work, the finite element method was used to study the magnetic and optical properties of proposed lenses that lead to the upper limit of axial magnetic flux density and the minimum deflection coefficients. One of the objectives of this study is to design a lens that operates with little effort.

Suggested designs

Six innovative designs were made for unipolar lenses using a prototype design, as shown in Figure 1 which shows a cross section, and Figure 2 which shows three-dimensionality when its geometry data is entered into the EOD program. This lens is equipped with a coil of cross-sectional dimensions (30 mm x 20mm) and several turns (750 t).

Then make other designs after changing the inner bore diameter of the prototype design (W) with values (35, 39, 43, 47, 51, and 55 mm).

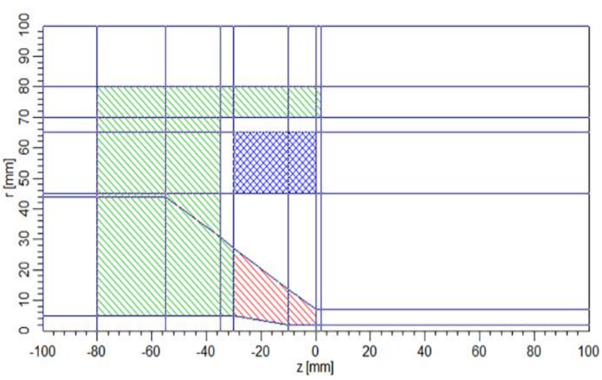

Figure 1. Cross-section of a magnetic unipolar lens prototype [19].

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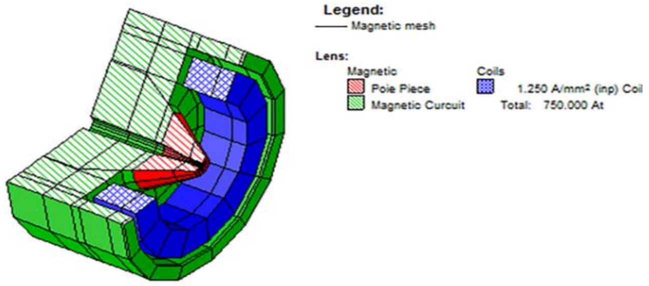

Figure 2. 3-D of a magnetic unipolar prototype lens [19].

RESULTS AND DISCUSSION

The effect of changing the inner bore diameter design prototype and the other five proposed designs was studied and compared to magnetic and optical properties, in following

Magnetic properties of designed lenses

The effect of (6) different values of the inner bore diameter of the proposed lens was studied shown in Figure 3.

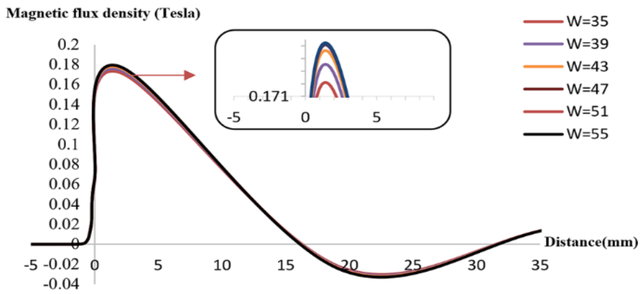

Figure 3. The distribution of axial magnetic flux density (B_z) as a function of the distance (Z) of the designed lenses.

We notice from the figure that the best value for magnetic flux density distribution is 55mm. Although we obtained a clear difference in the value of (Bz) for the above clear curves, this has not enough to distinguish the value of the best lens among studied values, presence of other properties that have not been studied such as the optical properties of the magnetic lens, which we will study and discuss in detail. In the items below, however, it can be said that this result can be taken as a preliminary indication.

Optical properties of designed magnetic lens

To study optical properties. A comparison was made between operational properties in Figures 4-11, which shows the relationship between the values of chromatic aberration coefficient (C_c) the spherical aberration coefficient (C_s) and focal length (f_0), as a function of proportionally corrected acceleration voltage (beam voltage) (V_r) and current density (σ) respectively.

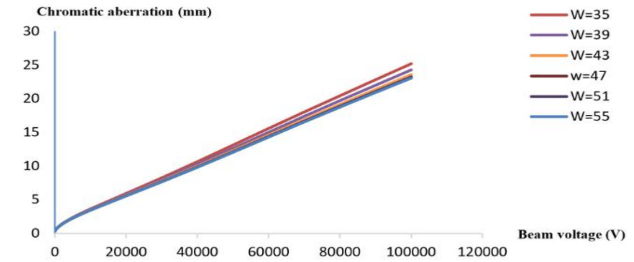

Figure 4. Comparison of chromatic aberration curves as a function of beam voltage.

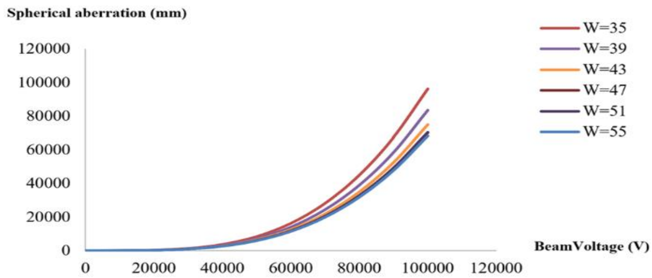

Figure 5. Comparison of spherical aberration curves as a function of beam voltage.

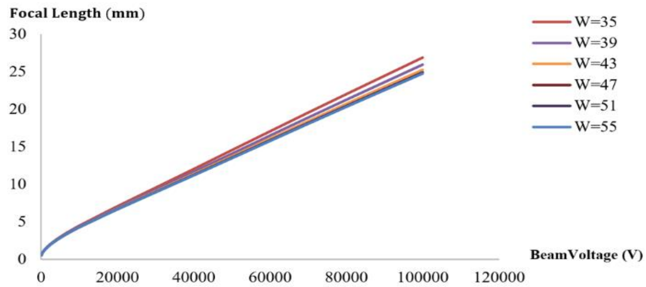

Figure 6. Comparison of focal length curves as a function of beam voltage.

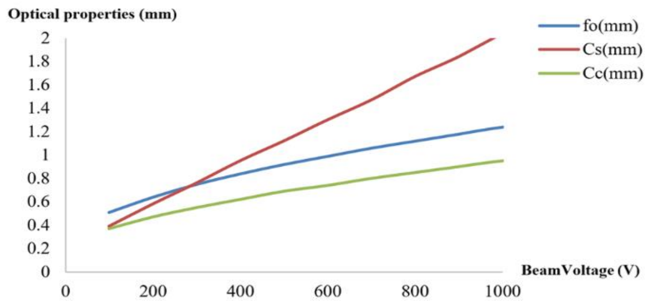

Figure 7. Comparison of optical properties as a function of beam voltage and at constant values for inner bore diameter 55mm.

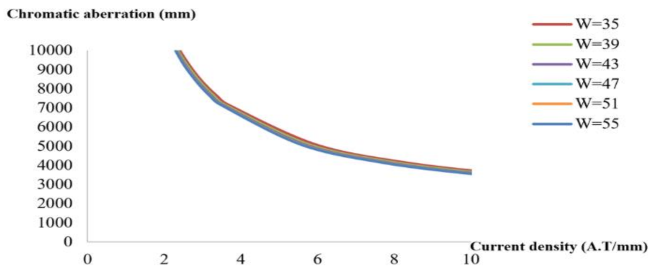

Figure 8. Comparison of chromatic aberration curves as a function of current density.

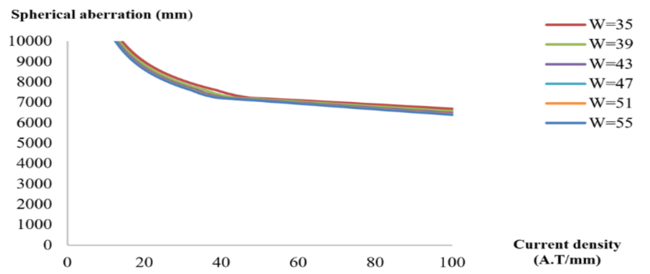

Figure 9. Comparison of spherical aberration curves as a function of current density.

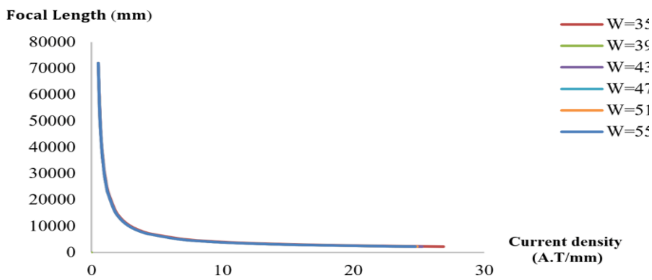

Figure 10. Comparison of focal length curves as a function of current density.

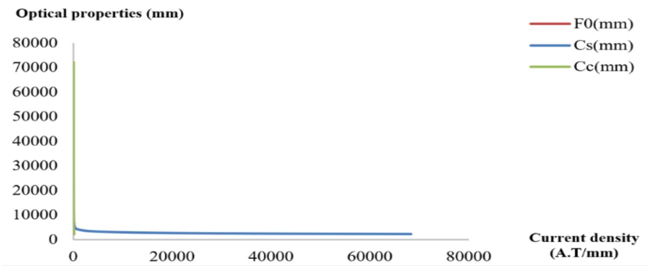

Figure 11. Comparison of optical properties as a function of current density and at constant values for inner bore diameter 55mm.

Figures 4-11 found that the best optical properties obtained for the design of proposed lenses in this research when the inner bore diameter is 55 mm, thus the lowest values of aberrations correspond to the desired objective in this study were obtained. Despite the identification of the best design, this was not sufficient to reach the desired goal, so there is a need to study another visual property to improve the possibility of distinction and preference. Therefore, it was resorted to studying the resolving power (δ) for these proposed designs, the two Figures 12 and 13 represent the values of resolving power (δ) for magnetic lenses as a function of beam voltage and current density respectively their value has been calculated from the aforementioned equation (4).

In addition, they display that the best resolving power was obtained for the proposed lens design when the inner bore diameter was 55mm and this result reinforces the previous obtained from the comparison between the values (Cc), (Cs) in Figures 4-11.

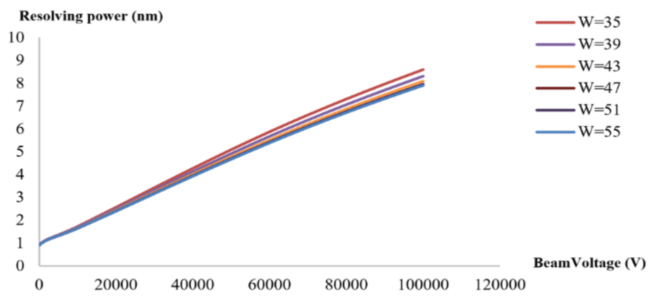

Figure 12. Comparison of resolving power curves as a function of beam voltage.

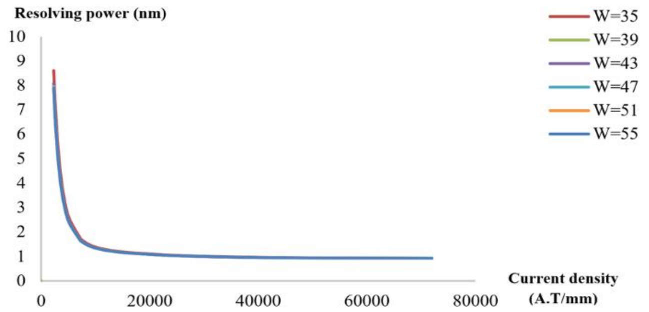

Figure 13. Comparison of resolving power curves as a function of current density.

CONCLUSIONS

The results showed that the magnetic flux density increases when the inner bore diameter. In addition, the results showed a possibility of obtaining a few chromatic and spherical aberration factors, these factors vanish with a decrease in the inner bore diameter that leads to better optical properties. Additionally, when the current density increases, the maximum flux density increases, while the skew factors decrease and resolving power (δ) improves. Under conditions of this work, it can be mentioned that the changes made in the prepared designs, in inner bore diameter (55 mm), are the most improved and effective one in most important scientific applications, which can use the results reached to create an obstacle-free design with very good optical and magnetic properties. Similar to the successful lenses previously studied, but with a different design that prevents magnetic leakage that occurs in the lenses, and another property was discovered They favor the use of unipolar lenses under low voltages., However, more studies may be required to alter magnetic lens parameters to achieve other applications. When comparing the extracted results with the theoretical results from the researches mentioned, the results of this research are good and similar to the results of those researches. Thus, we can obtain good criteria for measuring the optical parameters.

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