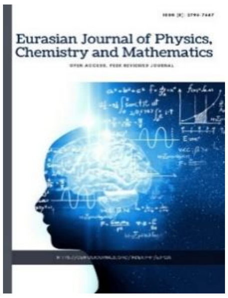

Study the Effective Length of Quadrupole Magnet on Some Parameters of Ion Optical System from Plasma Source

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ABSTRACT

This study used a MATLAB program to investigate the impact of effective length (L mm) on the quadrupole magnet lens primary parameters, where values are selected (from 50 mm to 1000 mm), to determine the power of lens, focal length and displacement of both (horizontal and vertical) planes, respectively. Theoretical analysis was done as part of the study. Results indicated that the effective length was growing decreased the system's horizontal and vertical focal length, while for the power lens, increasing the effective length leads to an increase in its value for both the horizontal and vertical axes. Additionally, the longer effective length led to on a horizontal plane, a decreasing horizontal displacement (beam envelope), the opposite happens for the vertical axes

Keywords: Focusing lenses, Ion optical, A quadrupole magnet, Ion beam and magnetic lenses

1. Introduction

The beam steering and focusing mechanism is provided by beam transport systems and particle accelerators, which are the most noticeable. For any application, it is expected that a beam of charged particles would move along a desired beam transport line, in the case of circular accelerators in a closed orbit, in close alignment with the route that is specified by design. These systems fundamental components are a series of electromagnetic components through which a beam of charged particles travels [1]. There are many different kinds of electromagnetic devices, such as magnets. These devices employ magnetic fields to deflect particles in accordance with the equilibrium between the centrifugal force and the Lorentz force. The interaction with electromagnetic forces is what mostly determines a charged particle's motion. Most particle-beam installations' focusing devices actually designed to focus the beam, therefore is, achieving a point-focused beam with an extremely tiny beam cross section [2,3]. There are many devices to focus the beam like alternating gradient focusing, sector-shaped magnets with edge focusing, quadruple lenses, and other techniques. With consistently rising energies, plasma physics was created and successfully advanced by enhancing performance qualities [4,5,6]

2. Ion Optical System

The plasma electrode, which is the front plate of the ion source and the pole puller, which generates the required electric field to speed up the ions beam, beside that source of ion beam make up the ion optical system. The particles beam intensity relies on a rough estimate of the charged particle flow striking the plasma electrode aperture then releasing plasma. The form of the surface area is concave and is dependent according to the plasma density and the plasma surface electric field. [3,7]. Drift space is the same as field free zone in light optics. Similar to how a beam that is diverging or parallel remains that way, beam particles in this area maintain their direction of travel [8]. Such focusing lenses deflect ion beam at an angle proportional to the distance of the ray from the center of the lens, which is their distinguishing feature a charge particle of beams that are parallel can be focusing to a spot with use of such a lens focusing devices are necessary to maintain the particle beam cohesion and provide the appropriate advantages of beam at precise locations throughout the beam transport line [9]. A quadrupole magnetic lens is the most practical tool that provides the necessary gap and field of focus [10, 11]. The lens power and the focal lengths are two metrics that are used to describe lenses. Stronger lenses equate to shorter focal lengths. Lens power is the reciprocal of focal length. It describes various optical systems in terms of the smallest attainable focusing point and flow of particles [7]

3. Quadrupole Magnet Lenses

In several disciplines, magnetic lenses are frequently employed to control charged particle beams of varying energies and orientations. Therefore, substantial theoretical and practical researches has been done on their focused qualities. A circularly shaped coil act as the simplest magnetic lens, allowing the beam to flow through it ideally along its axis [1, 12]. A magnetic element with two north poles and two south poles is called a quadrupole as shown in Figure 1[13]. They are placed symmetrically throughout the magnet core and be there along the middle axis no magnetic field [14,2]. The particle beam is focused using these magnets. A particle beam passing through a quadrupole magnet experiences no force because all of the field lines in the center of the quadrupole cancel each other out[15,16]. The orbital axis u_i = (x_i, $x_{i'}$) is changed in the vector u_f =(x_f, $x_{f'}$) by the quadrupole magnet lens. the u_f components are linear fusions of the ui component parts. The process may be expressed using the notation for matrices $u_f = A_f.u_i$ if A_f is regarded like [1]: .

$$A_f = \begin{vmatrix} \cos(L\sqrt{k}) & \sin(L\sqrt{k}/\sqrt{k}) \\ -\sqrt{k}\sin(L\sqrt{k}) & \cos(L\sqrt{k}) \end{vmatrix} \qquad (1)$$

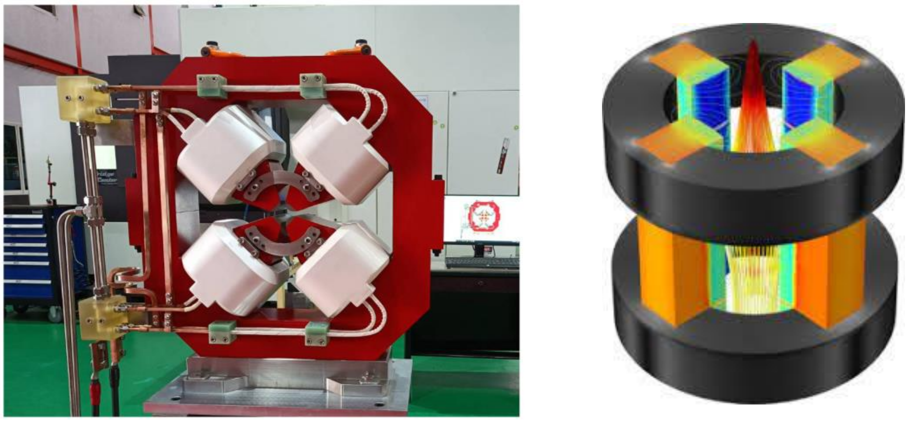
When the quadrupole magnet poles are turned 90°, the lens causes it defocuses in the opposite direction, then:

$$A_D = \begin{vmatrix} \cosh(L\sqrt{K}) & \sinh(L\sqrt{k}) \\ -\sqrt{k}\sinh(L\sqrt{k}) & \cosh(L\sqrt{K}) \end{vmatrix} \qquad (2)$$

The specifics L stood for the quadrupole magnet effective length and k for the factor of strength focusing creating small amount of (kL) and preserving the first limit of the series Taylor for the sine and cosine results in the thin lens approximation, then the matrix becomes the form [9,15,17]:

$$A_q = \begin{bmatrix} 1 & 0 \\ -1/f & 1 \end{bmatrix} \qquad (3)$$

Where f is the focal length and (1/f=kL) which represents the value of P (power of lens).



(a) (b)

Figure 1: (a) Quadruple magnet (b) Illustration of the beam inside the gap of a quadruple magnet

4. Results and Discussion

The primary factors that control the behavior of a charge particle ray traversing a set of quadruple magnets are the effective length (L) and focusing factor for strength (k), whose product offers us the magnetic lens's reversed focal length. As a result, any change in the value of any of them gives a different lens. A computer program made specifically for this study was used to calculate the impact of quadrpole magnet lenses acting such as focusing or defocusing items in the both of planes (see table 1)

Table(1): Various Effective Length values (L mm) with the Focal Length (F mm), Lens Power (P mm^{-1}), and Displacement(X, Y) mm

L mm	F_x mm	F_y mm	P_x mm^{-1}	P_y mm^{-1}	X mm	Y mm
50	2.91	12.20	0.34	0.08	17.87	8.79
100	2.38	9.89	0.42	0.10	16.62	9.73
150	1.89	7.63	0.53	0.13	15.72	10.12
200	1.19	4.99	0.84	0.20	14.80	10.63
250	1.02	3.87	0.98	0.25	13.64	10.98
300	0.81	3.23	1.23	0.31	12.83	11.20
350	0.66	2.98	1.52	0.36	12.11	11.53
400	0.60	2.67	1.66	0.37	11.97	11.84
450	0.56	2.39	1.79	0.42	11.23	11.97
500	0.53	2.09	1.89	0.48	10.82	12.23
550	0.48	1.88	2.08	0.53	10.08	12.89
600	0.41	1.63	2.44	0.61	9.63	13.19
650	0.38	1.40	2.63	0.71	8.97	13.86
700	0.33	1.31	3.03	0.76	8.11	14.08
750	0.30	1.22	3.33	0.82	7.74	14.96
800	0.28	1.09	3.57	0.92	6.77	15.60
850	0.26	0.98	3.85	1.02	5.64	16.13
900	0.23	0.87	4.35	1.15	4.45	17.24
950	0.19	0.73	5.26	1.37	4.01	17.96
1000	0.16	0.64	6.25	1.56	3.87	18.14

Whenever there is an increase in the better focus is attained for high values of L, showing that the quadruple magnet is a thin lens with good focusing properties, while lowered focal lengths refers to the strongest lenses [1]. As the effective length increases, we notice an decrease in the focal length values of the lens for both axes, as shown in Figure (2). .

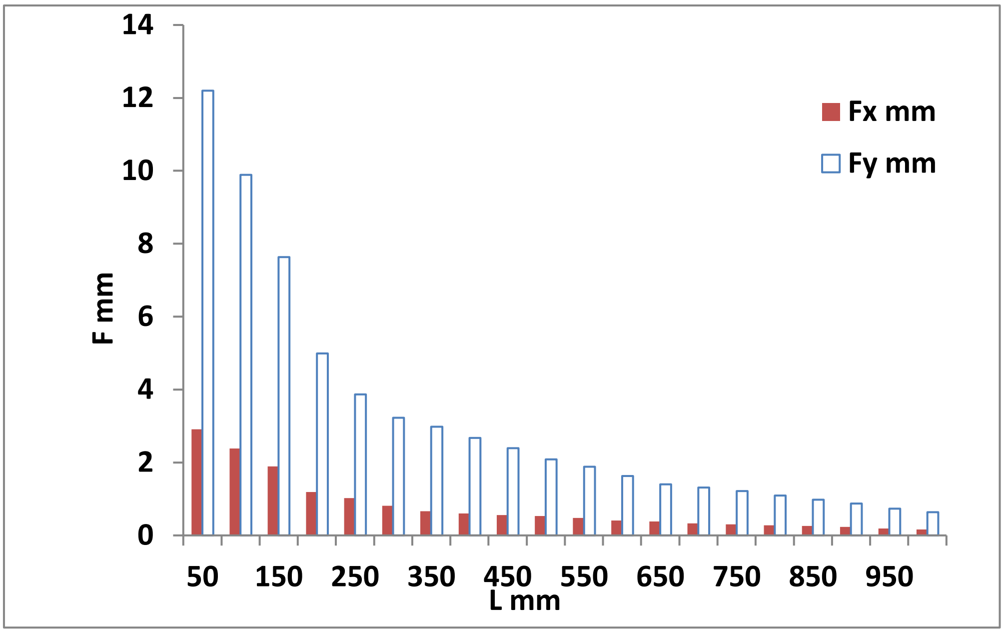


Figure 2: illustrates the relation between the focal length and the effective length for the horizontal and vertical axes

While Figure 3 shows the lens's power increases as effective length become higher because the power of a lens is inversely related to focal length. .

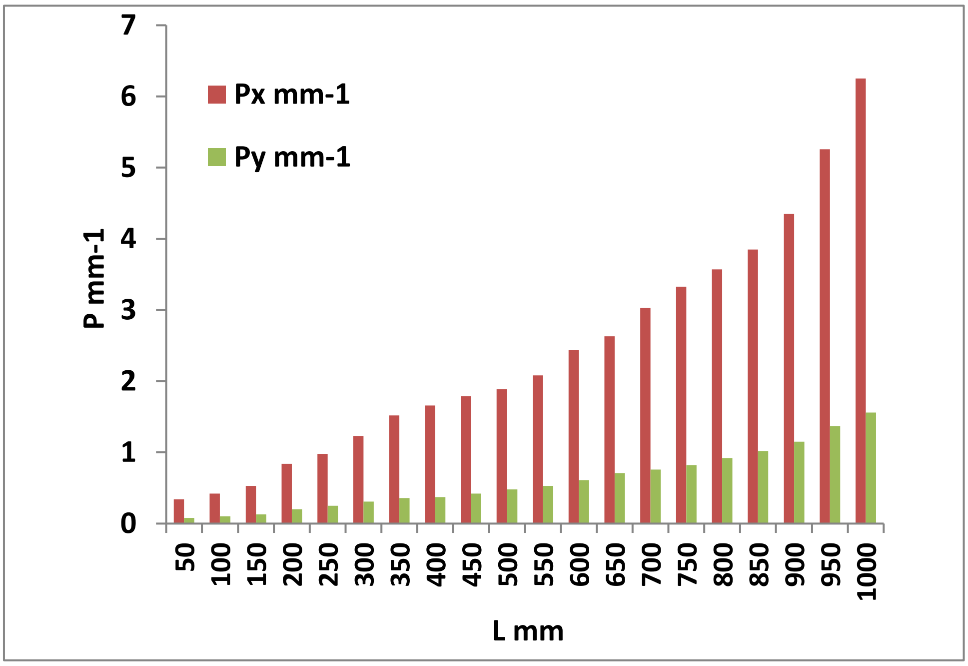


Figure 3: illustrates the relation between the lens power and the effective length for the horizontal and vertical axes

The horizontal displacement (beam envelop) increases with the increase in the focal length of lens, this means a focusing of beam in the horizontal plane as in the figure (4). In the case of vertical displacement, the opposite happens, as in Figure (5).

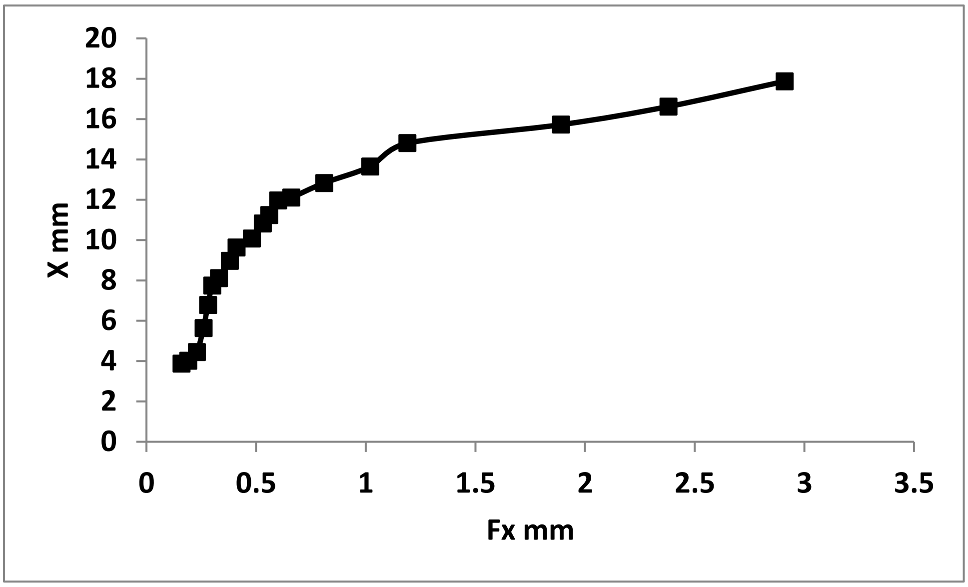


Figure 4: The relationship between the focal length of the lens and the horizontal displacement

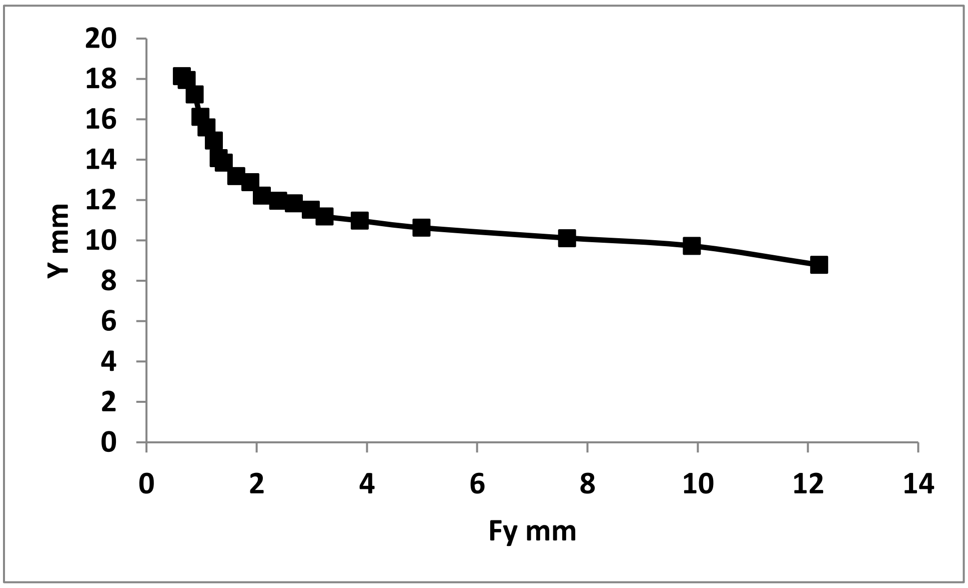


Figure 5: The relationship between the focal length of the lens and the vertical displacement

5. Conclusions

We conclude from the above, quadrupole magnets act as defocusing elements for the vertical plane and as focusing elements for the horizontal plane. For the horizontal and vertical planes, an increase in effective length results in a decrease in the focal length with lens power, the reverse effect is seen. Additionally, when effective length increases the horizontal displacement (beam envelope) decreases nevertheless, the reverse effect occurs for the vertical plane.

Acknowledgements

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