

# Calculate Optical Parameters of Ions BEAM From Plasma Source

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## ABSTRACT

The research explains some of optical parameters of charged particles that emitted from plasma source. The study included theoretical analysis using matrices representation to calculate the focal length, lens power, focusing factor and displacement (the bandwidth envelope) for Horizontal plane. Results showed the increasing in focusing factor causes decreasing in focal length, the opposite action appears with lens power. Furthermore the increasing in focusing factor causes decreasing in Horizontal displacement (beam envelope).

## الخلاصة

يوضح البحث بعض من المعلمات البصرية للجزيئات المشحونة التي بعثت من مصدر البلازما. شملت الدراسة التحليل النظري باستخدام تمثيل المصفوفات لحساب البعد البؤري، قوة العدسة، معامل التنبير والازاحة (عرض الحزمة) للمستوى الأفقي. أظهرت النتائج ان الزيادة في معامل التنبير تسبب تناقص في البعد البؤري، يظهر العكس مع قوة العدسة. اضافة الى ذلك، زيادة معامل التنبير تسبب تناقص في الازاحة الافقية ( عرض الحزمة).

## INTRODUCTION

An ion beam transport system consists of focusing, deflection and often additional energy or momentum selection elements. Most often these devices are magnetic elements. To provide focusing in transverse plane quadrupole is used [1]. Focusing systems of most facilities of particle-beam technology are mean for focus of beam. While focusing a system of linear beam should provide transport of particle beams through extended channels with minimum beam-current loss [2].

New types of focusing systems, like quadruple lenses and other, that use of bend, gradient and focusing contributed to the successful development of plasma physics and accelerators [3]. Major operation importance for heavy ion beam applications to high energy density physics and fusion is the axial compression and transverse focusing of the charge bunch to a small spot size at the target [4].

Applying the formalism of geometric optics the quadruple magnetic lens can be described as a thin focusing lens, like in magnetic ion optics the focal lengths and the position of the principal planes can be deduced from the matrix elements of the transverse transport matrix for horizontal and vertical plane. The current research aims to study the focal length of quadrupole magnet system to get the best values that leading to minimum band width or best focusing which is achieved in more control on beam transport systems.

## MATERIALS AND METHODS

The emitting plasma surface area has a concave form, which relies on the plasma density and the force of the accelerating electric field at the plasma surface. The concave shape of the meniscus and the aperture in the source electrode produce a transverse electric field component that results in a converging beam [5]. The ion optical elements used in the beam line are, generally

speaking, different types of lenses and drift spaces. The beam behavior and the transformation properties can be described in an analogous way to light optics. As in light optics, a space in which a beam propagates without any forces acting on beam particles, i.e. a field free region is called drift space. In this space, beam particles maintain their direction of motion, i.e. a divergent or parallel beam remains divergent or parallel [6]. Like to the characteristics of light, particle beams have attend to spread out due to an inherent beam divergence. To keep the particle beam together and to generate specifically desired beam properties at selected points along the beam transport line, focusing devices are required [7]. The most suitable device that provides a material free aperture and the desired focusing field is called a quadrupole magnetic lens [8, 9]. Two parameters terminologies applied to lenses, the power of lens and the focal lengths. The shortest focal lengths mean more powerful lenses. Focal length distinguishes more optical systems in terms of the minimum focal spot size and maximum investigation particle flux [10].

Magnetic lenses are widely used to control beams of charged particle with various energy and directions in several fields. Therefore their focal properties have been extensively studied theoretically and also experimentally [11]. A magnetic lens consists of electromagnets arranged in a quadrupole, sextuple, or higher format; the electromagnetic coils usually are placed at the peaks of a square. From this configuration a customized magnetic field can be formed to manipulate the particle beam [12]. To create the magnetic field an electric current is passed through the coil. It is strong in the plane of the coil, and gets weak away from it. A charged particle from the axis faces a strong Lorentz force than a particle closer to the axis (assuming in same velocity). This gives rise to the focusing action. [13]. Quadrupole a four pole magnet used to focus beams. The strength of the field is

proportional to the distance from the center. Focuses in one plane while in the other defocusing. A quadrupole is a magnetic element that has four poles, two norths and two souths. They are symmetrically arranged around the center of the magnet. There is no magnetic field along the central axis [14]. Consequently two different types of quadrupole have to be used, first type in (x-y) plane and the other is the same thing rotated through (90 degree). When arranged correctly a series of quadrupole can lead to net focusing in both planes [15]. Its field, concentrated between the four magnetic poles. If the polarity was reversed, the forces will have opposite sign. This force is proportional to the distance from the axis (linear focusing) and proportional to the field and length of the quadrupole. In order to keep the beam confined in both transverse planes, it is necessary to have a sequence of quadrupoles with alternate polarity [16]. Orbit vector of the quadrupole magnet converts  $\mathbf{u}_i = (x_i, x_i')$  to  $\mathbf{u}_f = (x_f, x_f')$ . We can write the operation [10]:

$$u_f = A_F u_i \tag{1}$$

if  $A_F$  is taken as:

$$A_F = \begin{bmatrix} \cos(L\sqrt{k}) & \sin(L\sqrt{k})/\sqrt{k} \\ -\sqrt{k} \sin(L\sqrt{k}) & \cos(L\sqrt{k}) \end{bmatrix} \tag{2}$$

Where F is focusing direction.

If the poles of quadrupole magnet are rotated 90°, then:

$$A_D = \begin{bmatrix} \cosh(L\sqrt{k}) & \sinh(L\sqrt{k})/\sqrt{k} \\ -\sqrt{k} \sinh(L\sqrt{k}) & \cosh(L\sqrt{k}) \end{bmatrix} \tag{3}$$

D is defocusing direction.

The two main parameters that show in Equation 3 are  $k$  and  $L$ , where  $L$  represented the effective length of quadrupole magnet (in metre) and  $k$  represented the strength focusing factor (in  $m^{-2}$ ). The thin lens approximation is done by making the ( $kL$ ) small and by keeping the first term of Taylor series for the cosine and sine. The matrix then takes the form

$$A_q = \begin{bmatrix} 1 & 0 \\ -\frac{1}{f} & 1 \end{bmatrix} \tag{4}$$

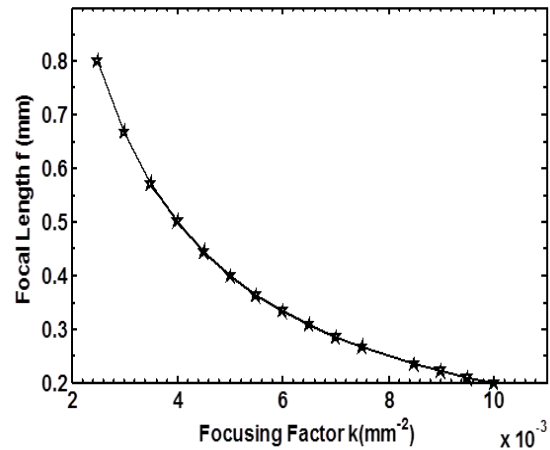
Where  $f$  is the focal length, in case of quadruple given by [7]

$$1/f = k * L \tag{5}$$

**RESULTES AND DISCUSSION**

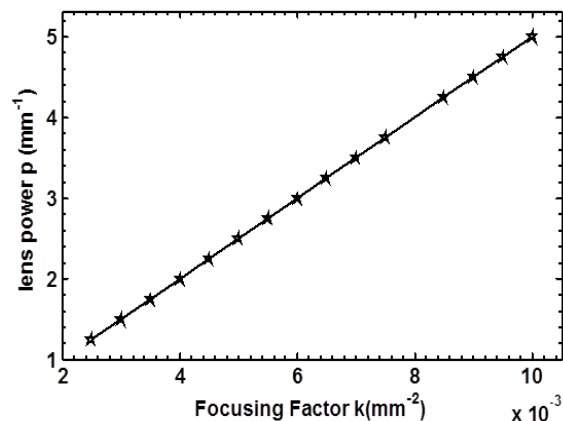
We use program of Matlab to study the effect of main parameter of quadrupole magnet lens. The main parameters effect on the behavior of charged particles beam passing through a system of quadrupole magnet can be fixed, these parameters are  $k$  (strength focusing

factor), and the effective length ( $L$ ) which the product of these two parameter gives us the inverted focal length of the lens magnetic. So any changing in the one of these parameters gives different lens which means new beam profile. In this study the action of quadrupole magnet lens as focusing or defocusing elements in horizontal plane this effect was calculated using a computer program that has been built for this purpose, we note when the increasing in focusing factor causes decreasing in focal length for horizontal plane, the opposite action appears with lens power as show in Figure 1 which illustrated the relation of focal length as a function of focusing factor.



**Figure 1:** The relation of focal length as function focusing factor

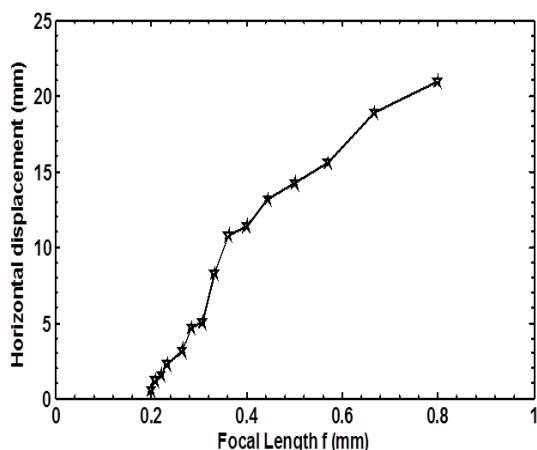
The best focus occurs for high values of focusing factor which means good focusing properties of quadruple magnet as thin lens where shorter focal lengths mean stronger lenses [3] while Figure 2 in this figure, we note that the relationship is extrusive, an increase of focusing factor value increases the power of the lens.



**Figure 2:** The relation of lens power as function focusing factor.

Figure 3 indicates the relation of horizontal displacement as a function of focal length. In form note that the horizontal displacement (beam envelop) increases with

increased focal length, that means that there is a focusing for charged particle beam in horizontal plane.



**Figure 3:** The relation of Horizontal displacement as function focal length

### CONCLUSIONS

The results have shown that quadrupole magnet acts as focusing element for the horizontal plane. The increasing in focusing factor causes decreasing in focal length for horizontal plane, the opposite action appears with lens power. Furthermore the increasing in focusing factor causes decreasing in Horizontal displacement (beam envelope) for horizontal plane.

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