University of Zawia Journal of Engineering Sciences and Technology (UZJEST)
Volume 4, Issue 2, (2026), pp 150-160, ISSN 3006-2764

Magnetohydrodynamic (MHD) Analysis and Numerical Simulation of Intersecting High-Current Plasma Beams

Sayf Elgamoudi Elgriw [1], Hossam Gabbar [*2]

[1] Department of Nuclear Engineering, Faculty of Engineering, University of Tripoli, Tripoli, Libya
[2] Department of Energy and Nuclear Engineering, Ontario Tech University, Oshawa, Canada
*Corresponding author email: Hossam.Gaber@ontariotechu.ca

Received: 01-08-2026 | Accepted: 02-10-2026 | Available online: 06-10-2026 | DOI:10.26629/uzjest.2026.12

ABSTRACT

This paper investigates the physics of four intersecting high-current plasma beams through analytical modelling and numerical simulations. The study aims to develop analytical models of the intersecting beams based on magnetohydrodynamic (MHD) theory and implement these models in MATLAB-based computer code. Numerical simulations have been performed to examine the radial profiles of plasma parameters in symmetrical high-current plasma beams with a *z*-pinch configuration. Additional simulations have been conducted to evaluate the stability of the beams as they converge at a common intersection point, referred to as the focal region. The results of this study provided a basis for the design of an experimental setup for a new fusion concept proposed by HOPE Innovations Inc.

Keywords: Nuclear fusion, magnetic confinement, magnetohydrodynamic, plasma beams, plasma simulation, *z*-pinch configuration

التحليل الهيدروديناميكي المغناطيسي والمحاكاة العددية لحزم البلازما المتقاطعة ذات التيار العالي

سيف القمودي [*1]، حسام جابر [2]

[1] قسم الهندسة النووية، كلية الهندسة، جامعة طرابلس، طرابلس، ليبيا
[2] قسم الطاقة والهندسة النووية ، جامعة أونتاريو التقنية، كندا

ملخـــــص البحـــــث

تتناول هذه الورقة البحثية فيزياء أربع حزم بلازما متقاطعة ذات تيار عالٍ، وذلك من خلال النمذجة التحليلية والمحاكاة العددية. وتهدف الدراسة إلى تطوير نماذج تحليلية للحزم المتقاطعة استنادًا إلى نظرية الهيدروديناميكا المغناطيسية (**MHD**)، وتطبيق هذه النماذج في برنامج حاسوبي قائم على **MATLAB**. وقد أُجريت محاكاة عددية لدراسة التوزيعات الشعاعية لخصائص البلازما في حزم بلازما متناظرة ذات تيار عالٍ بتكوين انضغاط ***z***. كما أُجريت محاكاة إضافية لتقييم استقرار الحزم عند تقاربها في نقطة تقاطع مشتركة، تُعرف بمنطقة التركيز. وقد وفرت نتائج هذه الدراسة أساسًا لتصميم إعداد تجريبي لمفهوم اندماج نووي جديد اقترحته شركة **HOPE Innovations Inc** الكندية.

الكلمات الدالة: الاندماج النووي، الحصر المغناطيسي، الهيدروديناميكا المغناطيسية، حزم البلازما، محاكاة البلازما، تكوين الانضغاط

"Articles published in *Univ Zawia J Eng Sci Technol* are licensed under a Creative Commons Attribution-NonCommercial 4.0 International License."

1. Introduction

There is a continuous effort to develop clean energy technologies that can meet the rapidly growing global demand for energy while maintaining low CO_2 emissions. One of the most promising energy technologies is fusion energy, which has the potential to provide a clean and sustainable source of power while reducing dependence on fossil fuels and other intermittent renewable energy sources such as wind and solar energy. A Canadian startup company, HOPE Innovations Inc. [1], has developed the theoretical foundation for a new fusion energy system. Based in Markham, Canada, HOPE Innovations Inc. specializes in the development of power generation systems based on its patent-pending fusion technology [2].

HOPE has proposed a novel approach for generating fusion energy by magnetically confining and igniting nuclear fuel within a dense focal region. The fuel is delivered to the focal region using high-current plasma beams, with optional assistance from high-energy lasers [3]. This confinement concept is based on a multiple-beam configuration arranged symmetrically in three-dimensional space. It is expected that a minimum of four plasma beams is required to achieve and maintain this symmetry. In this context, symmetry means that all high-current plasma beams are identical except for their orientations in 3D space, with equal angular spacing between adjacent beams. This beam configuration is expected to improve plasma confinement and stability in the focal region. Such plasma stability can only be achieved if the vector sum of the opposing electromagnetic forces acting at the focal point is equal to zero.

The validation of the new fusion technology proposed by HOPE requires the development of analytical models and the performance of computer simulations to analyse the behaviour of four intersecting plasma beams and investigate the force interactions in the focal region. The four plasma beams are symmetrically arranged in 3D space using a tetrahedral configuration. This configuration is believed to have favourable effects on plasma stability and confinement in the focal region. Analytical models and numerical simulations of the four intersecting plasma beams have been carried out at the Energy Safety and Control Lab at Ontario Tech University (ESCL-UOIT) in collaboration with Atomic Energy of Canada Limited - Chalk River Laboratories (AECL-CRL).

The computational modelling and simulation of four intersecting plasma beams were performed in this study using an analytical magnetohydrodynamics (MHD) model [4]. The model is based on the *z*-pinch plasma configuration [5] and is used to solve the force balance equation together with a set of equations known as Maxwell's equations. Solving these equations results in radial profiles of different plasma parameters within the plasma beams. The complete MHD model is then simulated numerically using a MATLAB-based computer code. This code can simulate several key plasma parameters within the beams in different coordinate systems such as radial, polar, cylindrical and spherical systems. The code can also be used to examine the stability of four intersecting plasma beams by evaluating the electromagnetic forces acting in the focal region. The results obtained from this code will be used as a benchmark for validating the concept of intersecting high-current plasma beams proposed by HOPE.

This paper is outlined as follows. Section 2 is a brief overview on the methodology used in this work. Section 3 describes the analytical MHD model of a single plasma beam with a *z*-pinch configuration. A description of the MHD code used in this study is given in Section 4. Section 5 discusses the major results of the MHD simulations. A short summery and conclusions are presented in Section 6.

2. Methodology

In order to develop analytical models and to perform numerical simulations for the four-plasma beam configuration, a number of assumptions need to be taken into account:

- All plasma beams are assumed to be cylindrically shaped and identical in their dimensions and parameters.
- The plasma beams are arranged in a tetrahedral configuration such that any two beams intersecting in the focal region form an identical angle of 109.5°.
- All plasma beams pass through the focal region and continue on the other side.
- The plasma region at the focal point is assumed to be spherically shaped.
- The focal region is assumed to be subject only to a force balance between magnetic forces and dynamic pressure, due to the interaction of four plasma beams at the focal region.

This study consists of two parts: analytical modelling and numerical simulations. The analytical part of this study starts by assuming a generic magnetic field distribution inside a plasma beam with a z-pinch configuration. Using this assumption, the MHD model solves the force balance equation between the gradient of the plasma pressure (∇p) and the Lorentz force induced by the magnetic field. Solving this equation yields the radial distribution of the plasma pressure (p). By obtaining the pressure profile, the radial profiles of other key plasma parameters (such as plasma density n and temperature T) can be derived as well.

The computational part of this study uses the analytical MHD model developed for a single plasma beam and solves the governing equations numerically. The radial profiles of plasma parameters obtained from the analytical model are first imported into an MHD code written in MATLAB to simulate the behaviour of a single plasma beam. These profiles are then converted to polar coordinates (r, θ) and subsequently transformed into cylindrical coordinates (r, θ, z) to closely resemble the actual shape of the plasma beam. After generating the 3D cylindrical model of the plasma beam, the focal region (also referred to as the in-sphere) is extracted from the 3D model for further analysis.

The MHD code simulates the total force acting on the focal region by first identifying the vector components of Lorentz force density (i.e., the Lorentz force per unit volume) within the in-sphere and converting them from cylindrical to spherical coordinates (r, θ, φ). Using one plasma beam in-sphere as a reference, the code creates three additional identical in-spheres for the other plasma beams and rotates them in 3D space to arrange all four in-spheres in a tetrahedral configuration. Finally, the MHD code superimposes the four in-spheres of Lorentz force density to produce the total in-sphere. It should be noted that the in-sphere of Lorentz force for each individual plasma beam, as well as the total in-sphere of Lorentz force, is calculated by simply integrating the in-sphere of Lorentz force density over the volume of the spherical focal region.

3. MHD Model

An analytical MHD model for a single beam has been developed using the z-pinch configuration. z-pinch plasmas are subject to the internal balance between the pressure gradient of plasma and the Lorentz force induced by the magnetic field. A single fluid model is often used to analyse the plasma equilibrium. For pure hydrogen plasmas, where ion charge number is $Z = 1$, the force balance equation between the pressure and the magnetic forces can be written as [6]:

$$\nabla p = \boldsymbol{J} \times \boldsymbol{B} \tag{1}$$

where p is the plasma pressure which may be assumed to be isotropic. Substituting Ampère's law

$$\nabla \times \boldsymbol{B} = \mu_0 \boldsymbol{J} \tag{2}$$

into the force balance equation (Equation 1) yields:

$$\nabla p = \frac{1}{\mu_0}(\nabla \times \boldsymbol{B}) \times \boldsymbol{B} \tag{3}$$

The above equation can be reduced to:

$$\nabla p = \frac{1}{\mu_0}\left[(\boldsymbol{B} \cdot \nabla)\boldsymbol{B} - \nabla\left(\frac{B^2}{2}\right)\right] \tag{4}$$

where the vector identity

$$\nabla(\boldsymbol{A} \cdot \boldsymbol{B}) = \boldsymbol{A} \times (\nabla \times \boldsymbol{B}) + \boldsymbol{B} \times (\nabla \times \boldsymbol{A}) + (\boldsymbol{B} \cdot \nabla)\boldsymbol{A} + (\boldsymbol{A} \cdot \nabla)\boldsymbol{B} \tag{5}$$

has been used. Equation 4 can be rearranged as:

$$\nabla\left(p + \frac{B^2}{2\mu_0}\right) = \frac{1}{\mu_0}(\boldsymbol{B} \cdot \nabla)\boldsymbol{B} \tag{6}$$

The above equation is called the pressure balance equation which is a nonlinear differential equation for **B**. It can be solved for **B** subject to the constraint $\nabla \cdot \mathbf{B} = 0$. When rewritten in terms of the poloidal magnetic flux function, the pressure balance equation reduces to the Grad-Shafranov equation [7]. The gradients of the plasma pressure p and the magnetic pressure ($B^2/2\mu_0$) on the left-hand side are counterbalanced by the curvature term $(\mathbf{B} \cdot \nabla)\mathbf{B}$ which results from bending the magnetic field lines.

Figure 1 shows the equilibrium in the z-pinch which can be represented by a cylindrical plasma column of radius a with cylindrical coordinates (r, θ, z). The equilibrium is treated by assuming axial symmetry. The axial plasma current has a current density distribution $J_z(r)$. The axial current $J_z(r)$ generates an azimuthal magnetic field $B_\theta(r)$. The azimuthal field is defined inside the plasma by [8]:

$$B_\theta(r) = \frac{\mu_0 I r}{2\pi a^2} \tag{7}$$

where I is the plasma current.

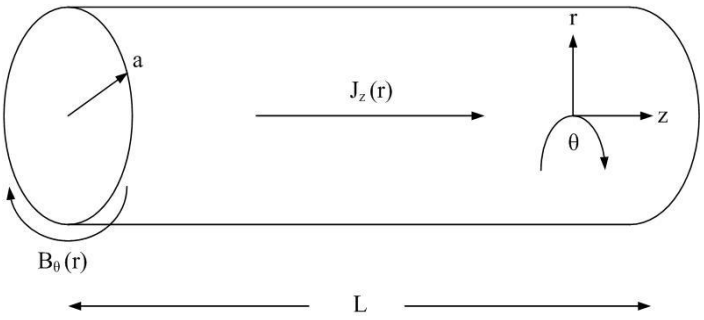


Figure 1. MHD equilibrium in a z-pinch plasma configuration

Since the current density $J_z(r)$ is related to the magnetic field by Ampere's law (Equation 2), substituting Equation 7 into Ampere's law yields:

$$J_z(r) = \frac{1}{\mu_0}\left(\frac{dB_\theta(r)}{dr} + \frac{B_\theta(r)}{r}\right) = \frac{I}{\pi a^2} = const. \tag{8}$$

which suggests that the current density is uniform across the plasma. The radial component of the pressure balance equation (Equation 6) can be expressed by:

$$\frac{\partial}{\partial r}\left(p + \frac{B_\theta^2}{2\mu_0}\right) = -\frac{1}{\mu_0}\frac{B_\theta^2}{r} \tag{9}$$

The curvature term acts only in the azimuthal direction (θ):

$$(\boldsymbol{B}\cdot\nabla\boldsymbol{B})_r = \frac{B_\theta}{r}\frac{\partial}{\partial\theta}(B_\theta \boldsymbol{e}_\theta) = -\frac{B_\theta^2}{r}\boldsymbol{e}_r \tag{10}$$

where the vector identity

$$\frac{\partial \boldsymbol{e}_r}{\partial\theta} = -\boldsymbol{e}_\theta \tag{11}$$

was substituted in Equation 10. The radial balance equation (Equation 9) can be written as:

$$\frac{\partial p}{\partial r} = -\frac{1}{2\mu_0}\frac{1}{r^2}\frac{\partial}{\partial r}(rB_\theta)^2 \tag{12}$$

Further manipulation yields:

$$\frac{\partial p}{\partial r} = -J_z B_\theta = -\frac{1}{\mu_0}\frac{B_\theta}{r}\frac{\partial}{\partial r}rB_\theta \tag{13}$$

Integrating Equation 13 from r to a and solving for p results in a parabolic profile for p [9]:

$$p(r) = \frac{\mu_0 I^2}{4\pi^2 a^4}(a^2 - r^2) = p(0)\left(\frac{a^2-r^2}{a^2}\right) \tag{14}$$

where $p(0)$ is the plasma pressure at the plasma center (i.e., $r = 0$). The plasma density and temperature are related to the pressure by:

$$p(r) = kT(r)n(r) = kT(0)\left(\frac{a^2-r^2}{a^2}\right)^{\frac{2}{3}} n(0)\left(\frac{a^2-r^2}{a^2}\right)^{\frac{1}{3}} \tag{15}$$

where k is the Boltzmann constant. Therefore, the plasma density and temperature profiles can be written as:

$$n(r) = n(0)\left(\frac{a^2-r^2}{a^2}\right)^{\frac{1}{3}} = \frac{p(0)}{kT(0)}\left(\frac{a^2-r^2}{a^2}\right)^{\frac{1}{3}} \tag{16}$$

$$T(r) = T(0)\left(\frac{a^2-r^2}{a^2}\right)^{\frac{2}{3}} \tag{17}$$

Finally, the radial profile of other important plasma parameters like thermal (v_{th}) and drift (v_d) velocities inside the plasma can be respectively defined by:

$$v_{th}(r) = \sqrt{\frac{kT(r)}{M}} \tag{18}$$

$$v_d(r) = \frac{J}{en(r)} \tag{19}$$

where M is the ion mass.

4. MHD Simulation

The analytical radial profiles obtained from the MHD model in the previous section have been implemented in a computer program coded in MATLAB. The MHD code first simulates the radial profiles of key plasma parameters within a single plasma beam. It is capable of modelling 1D, 2D and 3D profiles for the following parameters: current density (J), magnetic field (B), plasma pressure (p), pressure gradient (∇p), plasma temperature (T), plasma density (n), thermal velocity (v_{th}), and drift velocity (v_d). The 2D profiles are constructed in the polar coordinates (r, θ), while the 3D profiles are generated in the cylindrical coordinate system (r, θ, z).

After generating a complete 3D cylindrical model of a single plasma beam, the MHD code extracts a spherical cut at the beam center, referred to as the plasma in-sphere. The in-sphere is assumed to have

the same radius as the plasma beam (5 mm). This extracted in-sphere is fixed in a reference plane (the *x*-*z* plane in this case) and used as the reference in-sphere. Once the vector components of the plasma parameters on the reference in-sphere are defined, they are converted from cylindrical to spherical coordinates (r, θ, φ). The MHD code then rotates the reference in-sphere to generate the in-spheres of the remaining three plasma beams. A graphical outline of the MHD code is given in Figure 2.

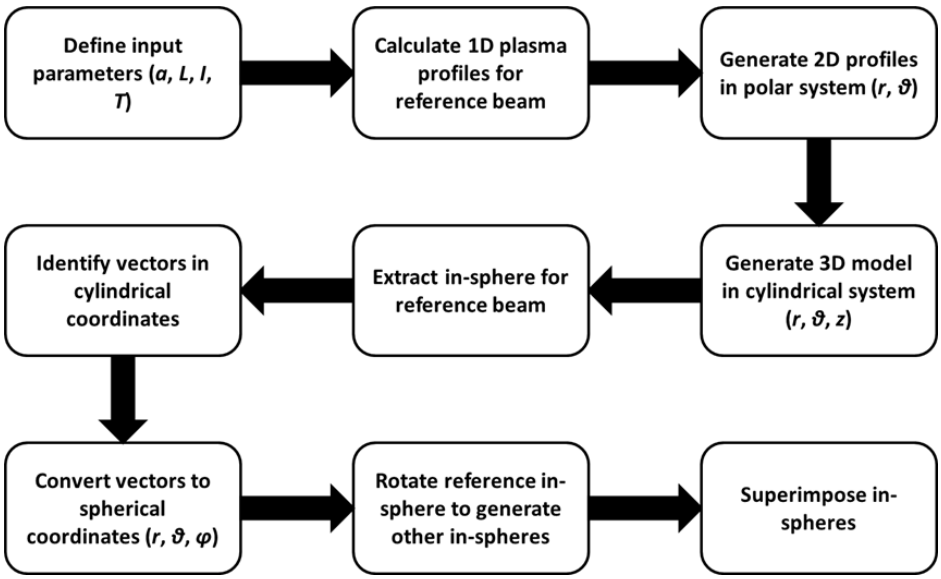


Figure 2. Graphical outline of MHD code

Figure 3 shows a 3D model of the tetrahedral configuration formed by the four intersecting plasma beams in 3D space, which is used to verify the rotation angles of the in-spheres with respect to the reference in-sphere. The 3D model indicates that the in-sphere of the second beam must be rotated by 70.5° around the *y*-axis. The third beam requires rotations of 70.5° around the *y*-axis and 120° around the *z*-axis. The fourth and the last plasma beam requires rotations of 70.5° around the *y*-axis and 240° around the *z*-axis.

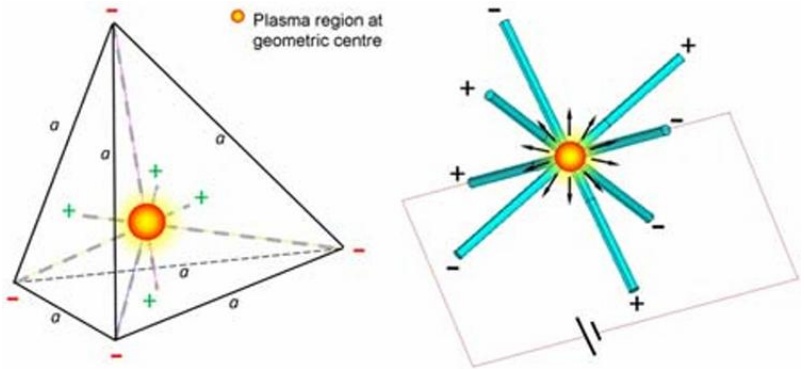


Figure 3. Tetrahedral configuration of four plasma beams in 3D space

As discussed in the previous sections, each plasma beam intersects with the others at a common focal region. The interaction occurs between the vector components of the plasma parameters expressed in spherical coordinates. To study this interaction, the self-induced Lorentz force density (i.e., $\mathbf{f} = \mathbf{J} \times \mathbf{B}$) of the plasma beams must be calculated from the vector components of **J** and **B**. Since the **J** vector acts

in the axial direction (z) and the **B** vector acts in the azimuthal direction (θ), the resultant Lorentz force density points radially inward. This inward magnetic force is counterbalanced by the outward plasma pressure gradient (∇p), leading to radial force equilibrium (refer to Equation 1).

To achieve this, the radial profiles of **J** and **B** are first calculated. The 1D and 2D profiles of the Lorentz force density are then derived from the cross product of these profiles and subsequently used to construct a reference plasma beam in the cylindrical coordinate system. Afterward, an in-sphere is generated from the reference beam and converted from cylindrical to spherical coordinates. The in-spheres of the remaining three beams can be obtained by rotating the reference in-sphere in 3D space. The common focal region can be finally constructed by superimposing all in-spheres.

The resulting focal region, represented by the superimposed in-spheres, corresponds to the total Lorentz force density (**f**) acting on the focal region by the four beams. The in-sphere of the total Lorentz force (**F**) can be generated by numerically integrating the force density in-sphere over the volume of the focal region. Figure 4 illustrates the steps for constructing the in-spheres and converting them from the cylindrical to the spherical coordinate system.

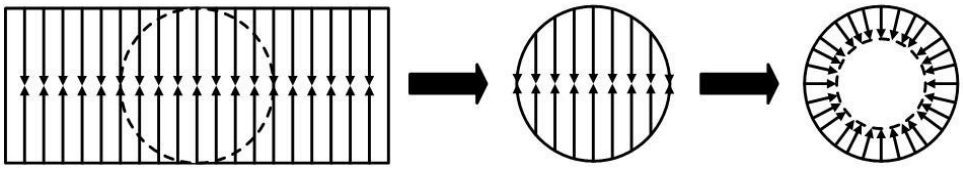


Figure 4. Extracting and converting the in-spheres from cylindrical to spherical coordinate system

5. Simulation Results

The MHD code developed in Section 4 is used to generate the radial profiles of a single plasma beam. These profiles are calculated using Equations 7, 8, 13, 14, and 16-19, which are identical for all four plasma beams. The beam parameters used in the calculations are listed in Table 1. The table summarizes some key beam parameters such as beam radius (a), beam length (L), plasma current (I) and temperature (T). The values of geometrical parameters (i.e., a and L) are selected according to the values proposed by HOPE in their previous work [3], while the remaining parameters are arbitrarily chosen based on typical plasma conditions in small to mid-sized magnetically confined fusion devices [10]. These parameters can be adjusted as required.

Table 1. Input parameters of MHD code

Parameter	Input Value
Beam radius (a)	5 mm
Beam length (L)	1 m
Plasma current (I)	100 kA
Plasma Temperature (T)	1 keV

The resulting radial profiles of plasma parameters in a single plasma beam, as calculated by the MHD code, are shown in Figure 5. The generated profiles include the magnetic field (B), current density (J), plasma pressure (p), pressure gradient (∇p), plasma temperature (T), plasma density (n), thermal velocity (v_{th}), and drift velocity (v_d). These profiles can be optimized by simply adjusting the input parameters given in Table 1. They are needed to construct the 2D polar distributions required for the 3D modelling of plasma beams.

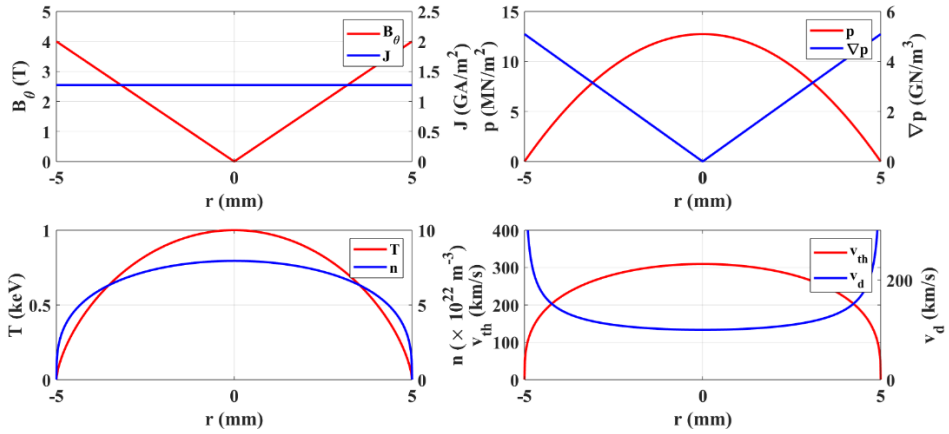


Figure 5. Radial profiles of plasma parameters in a single plasma beam

The radial profiles of the beam parameters are 1D functions that vary only in the radial direction (r). To obtain the corresponding 2D polar distributions, these profiles must be expanded into the polar coordinate system (r, θ). This can be achieved by generating the plasma parameters from their radial profiles under the assumption of no variation in the azimuthal direction (θ). Figure 6 shows the resulting 2D polar distributions of plasma parameters for a single plasma beam. The colour bar in each plot indicates the variation of the respective plasma parameter over the beam radius r.

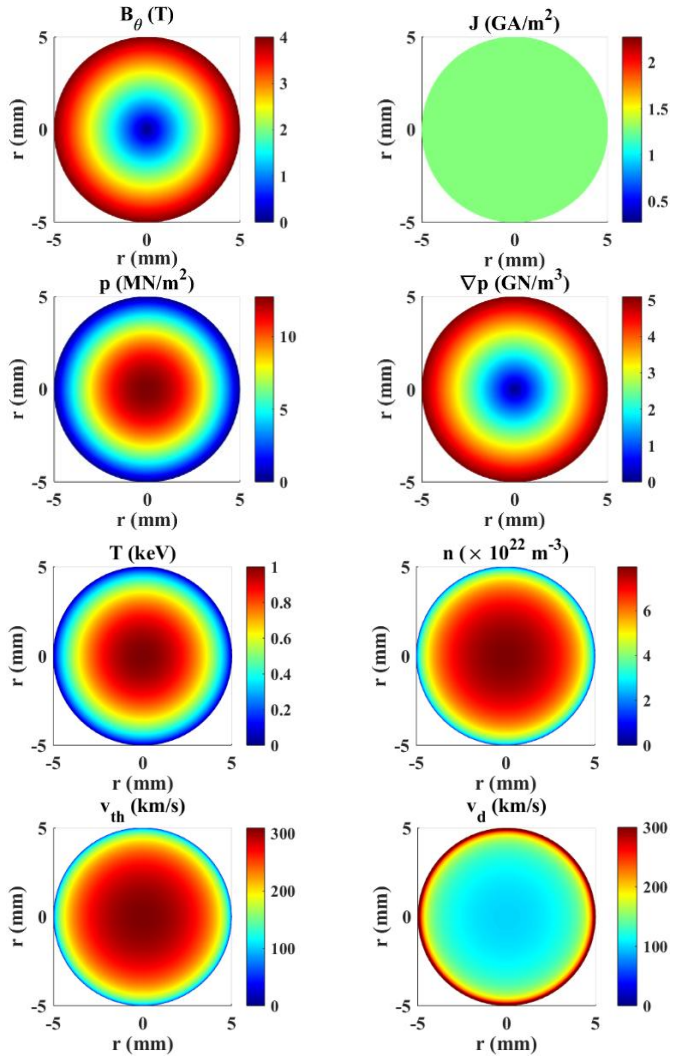


Figure 6. 2D Polar distributions of plasma parameters in a single plasma beam

The numerical values of the plasma parameters, as calculated by the MHD code, are summarized in Table 2. The table lists the minimum, maximum, and average values of each parameter and specifies whether the min/max values occur at the beam edge or at the beam center. The listed parameters are, in order, the magnetic field (B), current density (J), plasma pressure (p), pressure gradient (∇p), plasma temperature (T), plasma density (n), thermal velocity (v_{th}), and drift velocity (v_d). Again, these values can be further optimized by adjusting the values of input parameters listed in Table 1.

Table 2. Minimum, maximum and average numerical values of plasma parameters in a single plasma beam as calculated by the MHD code

Parameter	Min. Value	Max. Value	Mean. Value
Magnetic field (B)	0 (center)	4 T (edge)	2 T
Current density (J)	1.27 GA/m^2 (uniform)	1.27 GA/m^2 (uniform)	1.27 GA/m^2
Plasma pressure (p)	0 (edge)	12.73 MN/m^2 (center)	8.48 MN/m^2
Pressure gradient (∇p)	0 (center)	5.09 GN/m^3 (edge)	2.54 GN/m^3
Plasma temperature (T)	0 (edge)	1 keV (center)	0.74 keV
Plasma density (n)	0 (edge)	7.94 x 10^{22} m^{-3} (center)	6.67 x 10^{22} m^{-3}
Thermal velocity (v_{th})	0 (edge)	309.5 km/s (center)	260.1 km/s
Drift velocity (v_d)	100 km/s (center)	630.2 kms (edge)	128.35 km/s

After obtaining the 2D polar distributions of the plasma parameters in the previous step, 3D cylindrical models are generated by expanding these distributions into the cylindrical coordinate system (r, θ, z), under the assumption of axial symmetry along the z-direction. An example of a 3D model is displayed in Figure 7, representing the radially inward Lorentz force density ($\mathbf{f} = \mathbf{J} \times \mathbf{B}$) acting on the plasma beam, which is counterbalanced by the outward pressure gradient (∇p). The model is constructed using the 2D polar distribution of the pressure gradient shown in Figure 6. The model length is approximately 10 mm, corresponding to the full diameter of the focal region. It serves as a reference beam from which a reference in-sphere can be generated in 3D space.

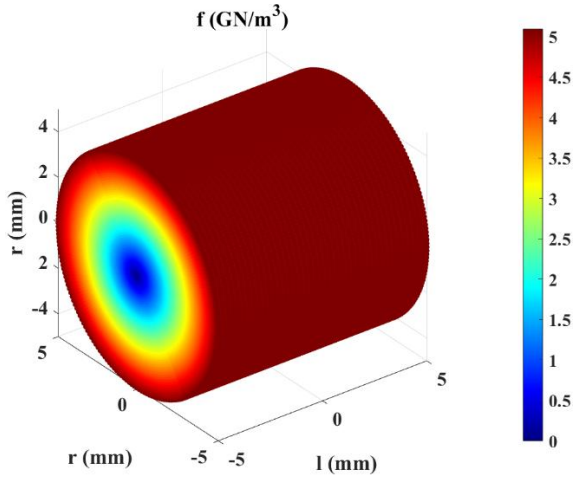


Figure 7. 3D model of Lorentz force density for a single plasma beam

Since the model shown in Figure 7 is constructed in the cylindrical coordinates (r, θ, z), the corresponding in-sphere must be converted to the spherical coordinates (r, θ, φ). However, as discussed in Section 4, the conversion from cylindrical to spherical coordinates requires identifying the directions of vector quantities. In this case, the Lorentz force density is directed radially inward in cylindrical

coordinates (refer to Figure 4). Therefore, when expressed in spherical coordinates, the force vectors must be scaled by a factor of cosθ, where θ is the local angle coordinate varying between -90° and 90°.

Figure 8(a) shows the reference in-sphere of Lorentz force density (**f**) after it was extracted and converted from cylindrical to spherical coordinates. The in-spheres of other three plasma beams are identical to the reference in-sphere, differing only in their spatial orientation in 3D space. The in-sphere of force (**F**) is obtained by numerically integrating the in-sphere of Lorentz force density over the volume of the focal region. The resulting in-sphere of Lorentz force is shown in Figure 8(b).

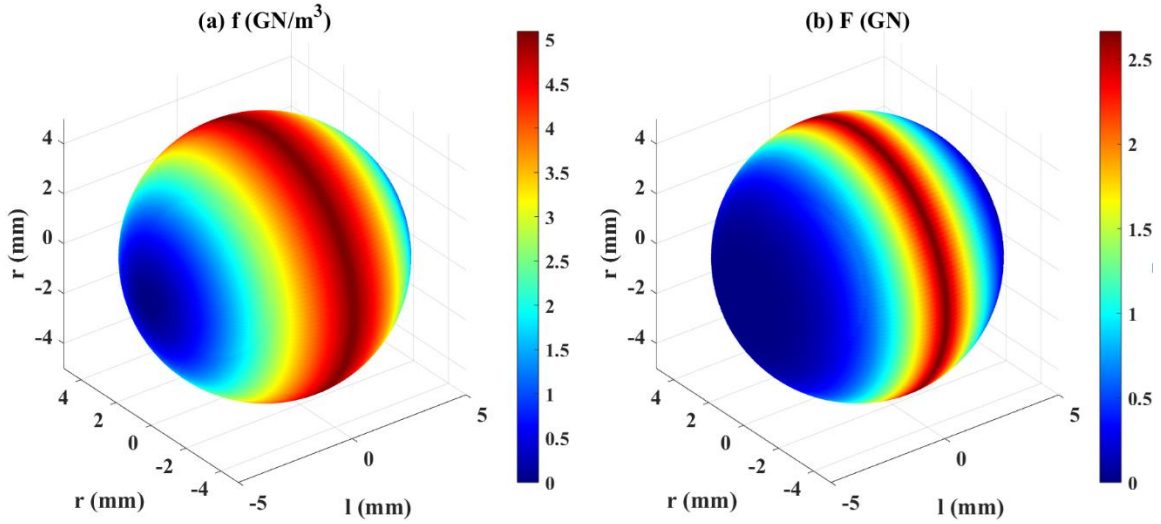


Figure 8. In-spheres of (a) Lorentz force density and (b) Lorentz force for the reference plasma beam

After generating the in-spheres of Lorentz force density and their corresponding force in-spheres for all four plasma beams, the total Lorentz force density acting on the focal region can be simulated. Since all vector components of the Lorentz force density point inward toward the center of the in-sphere, the total Lorentz force density is obtained by superimposing the four in-spheres and adding their respective vector components. The resulting in-sphere of Lorentz force density is shown in Figure 9(a). The in-sphere of total Lorentz force acting on the focal region, displayed in Figure 9(b), is then calculated by integrating the total in-sphere of Lorentz force density over the volume of the focal region.

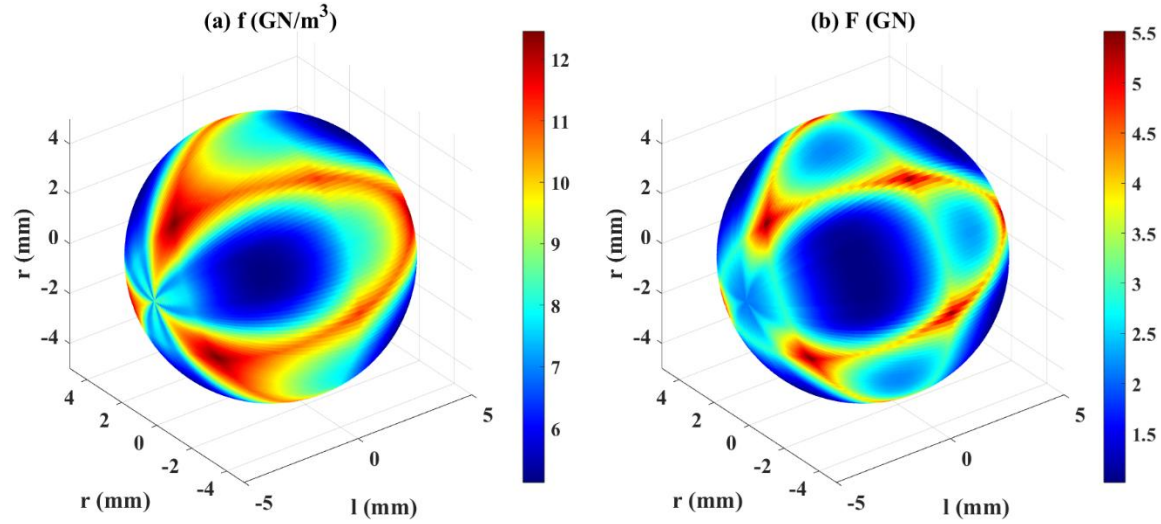


Figure 9. The in-spheres of (a) total Lorentz force density and (b) total Lorentz force acting on the focal region

It is evident from Figure 9 that the distribution of total Lorentz force acting on the in-sphere is nonuniform, indicating the presence of kink-like plasma instabilities [11] within the focal region. These instabilities can compromise both the stability and the confinement time of the plasma. These findings agree with previous work conducted on the same plasma configuration using ANSYS [3]. Several techniques have been proposed to control this kink-like perturbations at the focal region, including bombarding it with high-energy laser beams and/or introducing additional plasma beams into the existing configuration. These techniques, however, are currently being investigated.

6. Summary and Conclusions

This paper presents the analytical modelling and numerical simulation of the four intersecting plasma beam configurations proposed by HOPE Innovations Inc. An analytical MHD model of the plasma beams was developed based on the equilibrium of a z-pinch configuration. Radial profiles of the plasma parameters obtained from this model were implemented in a MATLAB code. The code calculates 1D, 2D, and 3D distributions of plasma parameters inside the beams. The 3D models were used to generate the so-called in-spheres of the plasma beams, which were used to examine the interaction between the beams in the focal region. To accurately analyze these interactions, vector quantities were transformed from cylindrical to spherical coordinate systems.

The Lorentz force density in-spheres were successfully constructed and integrated over the focal region volume to determine the total Lorentz force. The stability of the four-beam configuration was evaluated by examining the distribution and uniformity of the Lorentz force within the focal region. The results showed that the confining Lorentz force is not uniformly distributed, suggesting the presence of kink-like instabilities that could deteriorate plasma stability and confinement. Based on these findings, HOPE is working on modifying their original design to mitigate these instabilities, for example by introducing high-energy laser beams or adding supplementary plasma beams into the configuration. The results of these ongoing studies and simulations will help establish the updated design requirements for the experimental setup of the interacting plasma beam experiment.

REFERENCES

[1] HOPE Innovations Inc.: www.hopeinnovations.ca.
[2] X. Zheng, “Continuous fusion due to energy concentration through focusing of converging particle beams,” New United States Provisional Patent Application No. 61/495, 481, Mississauga, CA. 2011.
[3] F. Miao *et al*., “Fusion of multi-pinched plasma beams converging with spatial symmetry,” *Plasma Sci. Technol*., vol. 17, no. 7, pp. 552-559, 2015.
[4] J. P. Freidberg, *Ideal Magnetohydrodynamics*, 1st ed, New York. NY, USA: Plenum Press, 1987.
[5] U. Shumlak, “Z-pinch fusion,” *J. Appl. Phys*., vol. 127, no. 20, pp. 200901, 2020.
[6] D. A. Gurnett and A. Bhattacharjee, *Introduction to Plasma Physics with Space and Laboratory Applications*, 1st ed, Cambridge, UK: Cambridge University Press, 2005.
[7] V. D. Shafranov, “Plasma equilibrium in a magnetic field,” *Rev. Plasma Phys.*, vol. 2, pp. 103-151, 1966.
[8] T. J. Dolan, *Fusion Research: Principles, Experiments and Technology*, 1st ed, Oxford, UK: Pergamon Press, 1982.
[9] F. Dini *et al*., *An overview of plasma confinement in toroidal systems: in Glow Discharges and Tokamaks*, New York, USA: Nova Science Publishers, pp. 159–279, 2010.
[10] International Atomic Energy Agency, *World survey of fusion* devices, 2022. Available online: https://www-pub.iaea.org/MTCD/Publications/PDF/CRCP-FUS-001webRev.pdf.
[11] D. D. Ryutov *et al*., “Phenomenological theory of the kink instability in a slender plasma column,” *Phys. Plasmas*, vol 13, no. 3, pp. 032105, 2006.