

Ain Sams University
University College for Girls
physics Department

STUDY OF PINCH DYNAMIC AND STABILITY OF PLASMA SHEATH

*presented
by*

Walid Hasanein Gaber Mohamed

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Prof. Dr. AIDA EL-BIALY
Physics Department
University College for Girls
Ain Shams University

Prof. Dr. Mohamed Masoud
Plasma Physics Department
Atomic Energy Authority

Assistant Prof . Ali Basuni Bisara
Plasma Physics Department
Atomic Energy Authority

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Supervisors

1. **prof. Dr. A. El-Biely**
Physics Department
Faculty of Girls
Ain sams University

2. **prof. Dr. M.M. Masoud**
Plasma physics Department
Atomic Energy Authority

3. **Assistent prof . Dr. A.B. Beshara**
Plasma physics Department
Atomic Energy Authority

Signature

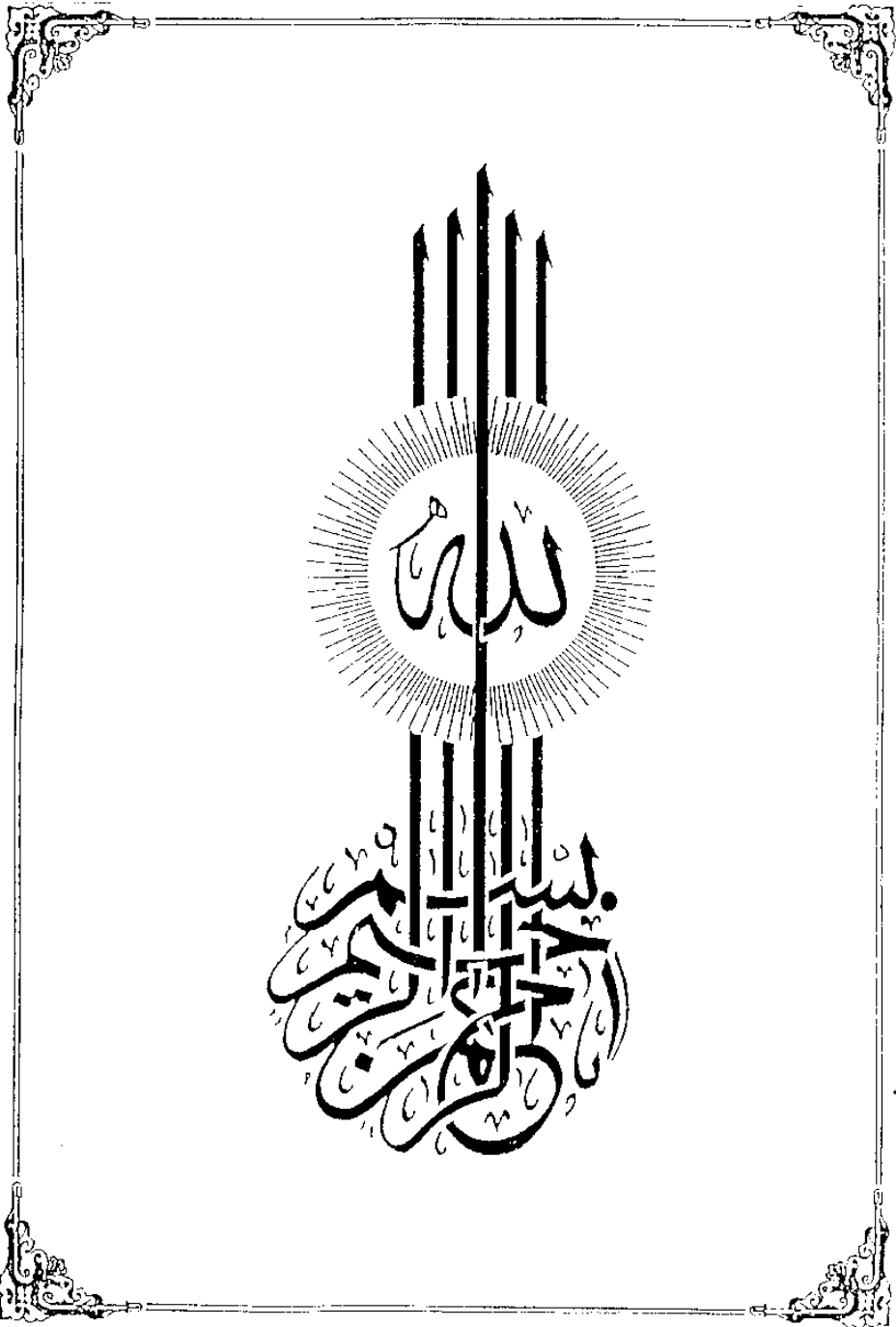
A. B. El-Biely

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M. M. Masoud

A. B. Beshara

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W.H.



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Physics Department
Faculty of Girls
Ain sams University

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Plasma physics Department
Atomic Energy Authority

3. ***Assistent prof . Dr. Ali Bassuni Beshara***

Plasma physics Department
Atomic Energy Authority

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SUMMARY

SUMMARY

The study of the plasma dynamics and existence of kinetic instabilities are of great importance to obtain a controlled thermonuclear fusion reaction which represent a very promising new source of energy . The linear Z-pinch is one of the oldest confinement geometries ; however its development into practical fusion system is still in its infancy . For this reason , a linear Z-pinch is designed and constructed specially in Plasma Physics Department Atomic Energy Authority , in order to study the pinch dynamic and stability of its plasma sheath

This thesis describes the design , construction and operation of the linear Z-pinch system . The electrical parameters of the system and plasma parameters are studied .The plasma temperature and density within the plasma sheath are evaluated . The internal plasma sheath current and its motion toward the discharge tube axis are also studied in this thesis .

For charging voltage 10 kV , the capacitor bank stored energy is 1kJ , maximum discharge current of 55 kA ; with rise time of 4.25 μ s flow (through a pressurized switch) between two parallel electrodes fixed at the end of the cylindrical Pyrex tube to produce a linear pinched plasma column . The total circuit has a resistance of 20 m Ω and inductance of 365 nH . The working gas (He) is allowed to flow through the discharge tube via controlling needle valve.

The diagnostic tools used in this study are miniature Rogowski coil , magnetic probe , spectroscopy , electric probe beside the ordinary measurement such as ; Rogowski coil and capacitive potential divider ; are used to investigate the essential characteristic parameters of the system . Rogowski

coil is used to measure the discharge current flows from the capacitor bank . A special design of a voltage divider system has been done which is insulated from the discharge system to avoid any high voltage hazards which may affect the oscilloscope . Miniature Rogowski coil and magnetic probe are inserted inside the discharge tube to measure the sheath current density and position beside the reversed current outside the sheath column . Spectroscopy is used to estimate plasma electron temperature by using grating monochromatic and photomultiplier tube . Electric probe is used to measure plasma electron temperature and density .

For Helium gas pressure of 0.2 Torr ; plasma inductance showed a peak values of 68 nH at $\approx 5\mu\text{s}$ while the plasma resistance reached its minimum value $\approx 4\text{ m}\Omega$. At pinch time $\approx 4\text{ }\mu\text{s}$ the plasma resistance showed a peak value of $34\text{ m}\Omega$ while the inductance has its minimum value of 5 nH .

It has been found that the plasma sheath is formed near the discharge tube walls and the plasma sheath starts to move towards the axis . The current sheath motion is monitored by magnetic probe and miniature Rogowski coils where there results are in coincidence . For Helium gas pressure of 0.2 Torr and peak discharge current of 55 kA , the current sheath velocity increases with radial position at start until it reaches a maximum value at $r = 4\text{ cm}$ then it starts to decrease due to the plasma kinetic pressure retarding forces before the pinch occurs . It has been found that the pinch occurred at $\approx 4\mu\text{s}$ with radius of 0.5 cm . This results is in agreement with plasma inductance measurement mentioned previously . The motion of the sheath has been calculated theoretically using the relation

$$\frac{d}{d\tau} \left[(1-x^2) \frac{dx}{d\tau} \right] = -\frac{\tau^2}{x} - \alpha x^{-7/3}$$

where ; $\alpha = 2 P_0 t_1^2 / r_0^2 \rho_m = 0.015$

It has been found that the experimental results are in good agreement with the theoretical calculations .

It was observed that the plasma current sheath velocity increases with time reaching a peak value of 3×10^6 cm /s at $2 \mu s$ then starts to decrease until the plasma current sheath collapse at the center at $\approx 4 \mu s$.

The plasma current sheath velocity decreases with the increases of the working gas pressure below 0.06 Torr to 0.02 Torr but at pressure greater than 0.06 Torr to 0.25 Torr, the current sheath velocity is nearly constant .

It has been found that the measured plasma sheath thickness at Helium gas pressure 0.2 Torr increased within its motion towards the axis which is mainly due to the increase of the plasma density as well as the discharge current density . The decrease of the plasma sheath thickness later is due to its collapse at the axis . It is observed that with the increase of the working gas pressure the plasma sheath thickness increases which may be due to the diffusion of charged particle ahead of it .

The plasma sheath current density decreases with pressure beginning from 320 A /cm^2 at 0.02 Torr until it reaches 120 A /cm^2 at 0.1 Torr then become approximately constant .A reverse current has been observed between the main current sheath and discharge tube wall . The reverse current density variation with pressure had the same profile as the main current sheath which indicates that the origin of reverse current may be due to the magnetic field of the original sheath and make a close loop with it .

The electron plasma temperature has been measured at 0.2 Torr on the axis of the plasma tube by using triplet line for $\lambda_1 = 5048 \text{ \AA}$ to the single line $\lambda_2 = 4713 \text{ \AA}$. The

plasma electron temperature reaches 26.5 eV then it decays to 20 eV . Double electric probe measurement shows two group of electron temperature ,the first group has 7.5 eV with density $2.2 \times 10^{14} \text{ cm}^{-3}$ while the second group has low temperature 1.75 eV with low density of $5 \times 10^{13} \text{ cm}^{-3}$ which may be due to the rest gas medium which was ionized by the sheath diffused particle and radiation .

ABSTRACT