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SUBJECT: Trapping of Energetic Ions by  
Neutralization of a Polarized Beam

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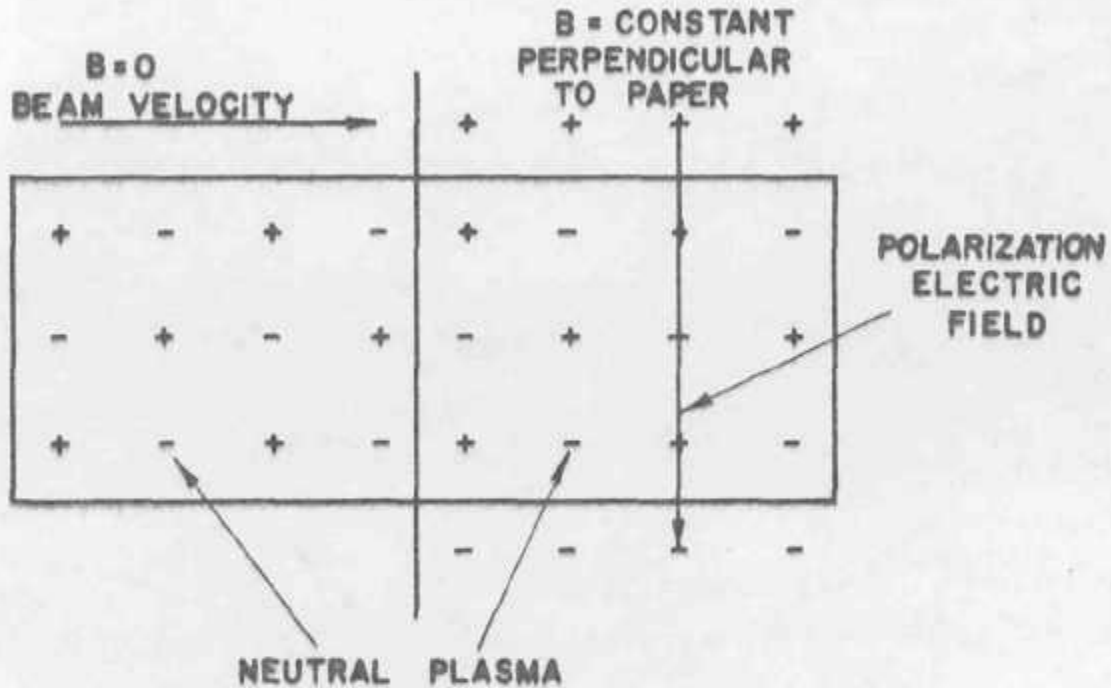
TRAPPING OF ENERGETIC IONS BY  
NEUTRALIZATION OF A POLARIZED BEAM

INTRODUCTION

<sup>1</sup>Recent experiments at the Massachusetts Institute of Technology have shown that a positive ion beam with a density exceeding  $10^8$  ions/cm<sup>3</sup> will neutralize its space charge by trapping electrons within the beam. This trapping of electrons converts the ion beam to a neutral plasma suitable for injection and polarization experiments in a cross magnetic field. The ion energy used in these experiments appears to be about 500 volts. The beam moves readily across the magnetic field due to polarization of positive and negative charges. If at a strategic place polarization could be stopped, then the ions would be trapped and stored in the magnetic field. It will be necessary to use higher energy ions with a greater density and still have the beam neutralized by trapped electrons to create a "hot" plasma. If it should prove difficult to trap electrons at higher energy, it should be easy to inject them along with the beam at the proper velocity. Studies of this system are now underway in propulsion experiments.

Experimentally, the MIT people have shown that when an energetic plasma beam of the type described is allowed to enter a magnetic field, polarization of ions and electrons occurs if the density of the beam is great enough. When the plasma beam enters the magnetic field the  $V \times B$  force field acts on the ions and electrons bending them in opposite directions. The result of this charge separation is the development of an electrostatic force which grows in magnitude until it approaches or equals

the force of the magnetic field. When the two forces are approximately equal, then the plasma beam is free to move unrestrained by the magnetic field. <sup>2</sup>The following sketch taken from an MIT report illustrates the effect of polarization of such a beam.

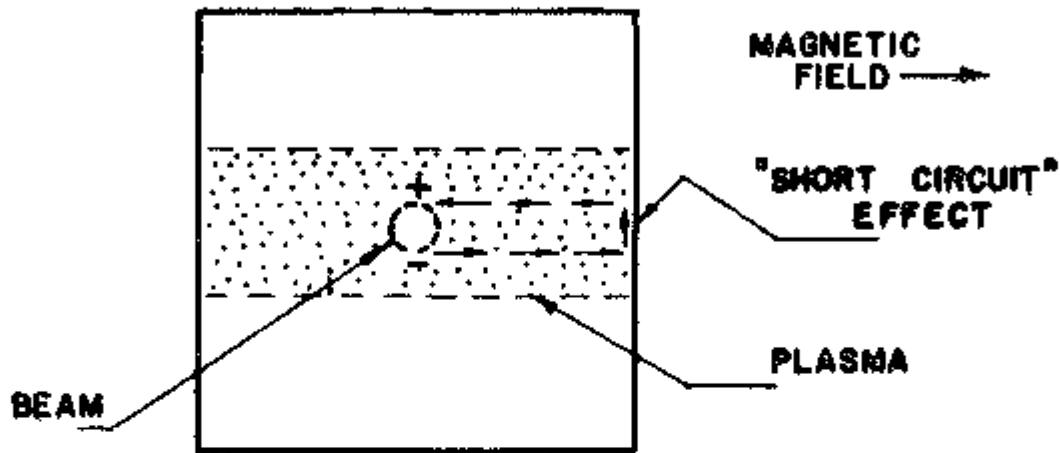


Proposed Trapping Method

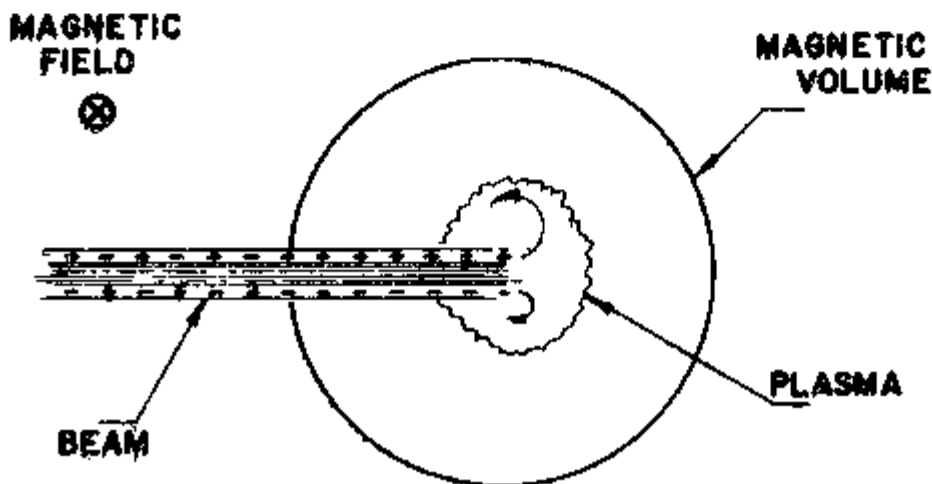
The purpose of this note is to show how a polarized plasma beam may be trapped in a magnetic field if a plasma is present in the magnetic volume.

<sup>3</sup>In the experiments described above no attempt was made to provide a plasma for the beam to pass through nor was the energy of the beam enough to do any appreciable ionization of the residual gas in the volume. Consider now the case when a plasma beam enters a region in a magnetic field that contains a plasma. The  $V \times B$  force field will as before cause the ions and electrons to bend in opposite directions. The electrostatic field does not form, however, since it is neutralized by the plasma present in the volume.

In the absence of a strong competing electric force the  $V \times B$  force will predominate and the charged particles will move into orbital paths and be trapped. The sketch below illustrates how a plasma that is present in a magnetic field can neutralize a polarized beam that enters it.



In an actual thermonuclear device the neutralizing plasma should have its greatest density near the center of the system. This plasma could be formed by various means such as PIG discharges, arcs, RF discharges, or perhaps by ionization of the residual gas by the incoming beam. The polarized beam passes through the magnetic field until it reaches a plasma region sufficiently dense to neutralize it at which point it is trapped.



<sup>4</sup>Neutralization of the polarized beam is quite similar to the "short circuit" effect postulated by Simon when ions diffuse across a magnetic field. It is likely that very little plasma will be needed to neutralize the beam when a uniform magnetic field is used. In fact, penetration of the beam into the plasma may be quite small due to the great conductivity of a plasma parallel to magnetic lines of force. <sup>5</sup>The situation is quite different, however, when a containing magnetic field is used and the number of available charges in any area is reduced by a decrease in the "short circuit" effect. Penetration of the plasma under conditions of good containment should be effective. Thus, the most fruitful use of a polarized beam may be to "feed" a thermonuclear plasma.

There are, of course, many variations to this system. Some obvious experiments are listed in the attachment.

SOME POSSIBLE EXPERIMENTS

1. In a mirror geometry. With a constant plasma density check trapping rate as mirror ratio is changed.
2. Injection method for compression studies. Injection could continue during entire compression cycle if desired.
3. Cross beam experiments. For example, one beam down axis of machine, the other across the magnetic field.
4. Two beams from opposite directions colliding in center a la Bostick.
5. Injection of any ion either separately or together. The use of molecular ions would provide two trapping mechanisms.



REFERENCES

1. Quarterly Progress Report No. 51, October 15, 1958, Massachusetts Institute of Technology.
2. ibid.
3. Allis, W. P., private communication.
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5. Simon, A., The Influence of End Mirrors, High Density and Long Tube Length on Radial Diffusion, ORNL-1960 Special.