Sonca Nguyen
Project Summary
Summer 2004

Design of an EXB Probe

Introduction

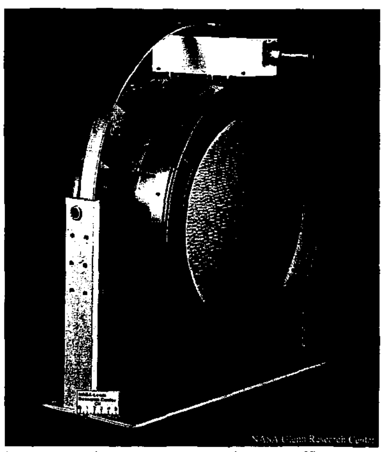
Current chemical propulsion technology cannot address the needs of some deep space missions. The amount of chemical propellant required to accomplish certain NASA's planned missions is too immense such that the spacecraft will never be able to lift off. To address this concern, electric propulsion systems have been chosen as the primary propulsion systems for some NASA's future missions, including DAWN and JIMO.

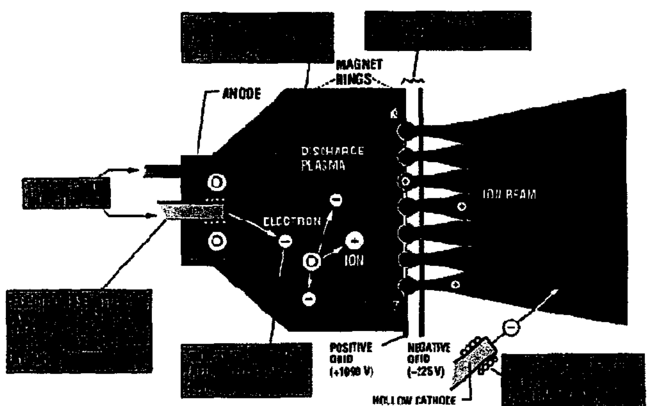
The HiPEP (High Power Electric Propulsion) engine being developed at NASA Glenn Research Center is a proposed engine for the JIMO mission, which will visit three of Jupiter's icy moons. Optimizing thruster's lifetime and efficiency are the two foci for the engineers on the Ion Team. One qualitative study of the engine's efficiency can be accomplished by examining the ratio of doubly- to singly-charged ions in the ion beam of the engine. Thrust efficiency directly relates to this ratio. The bulk of this project is to redesign and build an EXB probe to obtain this qualitative measurement. Once this probe is built, it can be installed in a vacuum tank (VF 65 in building 301) behind the exit plane of the HiPEP engine to collect data.

Background on Ion Thruster

In order to understand the usefulness of an ExB probe, one must understand how an ion thruster works. Figure 1a shows an ion thruster built at NASA Glenn and Figure 1b below shows a schematic of an ion thruster.

Some of the main features of an ion thruster include the hollow cathode, discharge chamber, grids, and the neutralizer. Gas such as Xenon or Argon is injected into the discharge chamber. The electrons produced by the hollow cathode bombard with the neutral gas atoms, ionizing the gas in the chamber into plasma. In this plasma, two species of electrons and ions coexist. At the end of the discharge chamber is a screen grid and accelerating grid, which are at a very low potential. The ions accelerate towards the grids and create an ion beam at the exit plane of the engine, thus thrust is obtained.





Courtesy of the Deep Space 1 web site.

Figure 1 (a) Ion engine built at NASA GRC (b)Schematic of ion engine. *Courtesy of NASA-GRC*

ExB Probe Theory

The ExB probe is one application of the Lorentz force. When a particle is in both an electric field and a magnetic field, it experiences a force known as Lorentz force,

$$F = eq(E + uXB) \qquad \text{Equation 1}$$

where F is the force
E is the electric field
u is the velocity of the particles
B is the magnetic field
e is charge of an electron
q is the charge.

This relationship implies that a particle with a certain velocity in a magnetic field will deflect in a direction perpendicular to both. An electric field can be applied such that it can re-deflect the particle back to its original path. Alternately, the electric and magnetic fields can be adjusted in an ExB probe such that the particles entering the collimator must stay in a predicted manner, un-deflected from its original path. Figure 2 below is a schematic of the ExB probe.

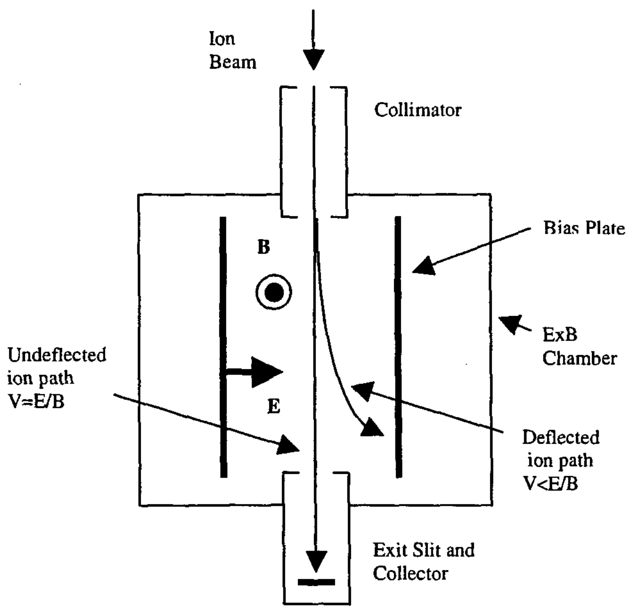


Figure 2. ExB Probe. *Courtesy of Aaron Snyder, NASA-GRC*

The main components of an ExB probe are the collimator, electrodes, magnets, and the collector. An electric field is obtained when a bias voltage is applied to the two electrodes. The main function of the collimator is to focus the beam of the ion and the collector's function is to measure the current of ions which have not been deflected.

By varying the bias voltage, thus electric field, the ion currents can be measured from the collector. Plot such as the one in Figure 4 can be obtained from the ExB probe. It is a curve of relative ion currents versus the bias plate potential. Typically, two peaks appear on the graph and it is known that the first peak is from low energy ions and the second peak is from high energy ions based on the relation in Equation 1.

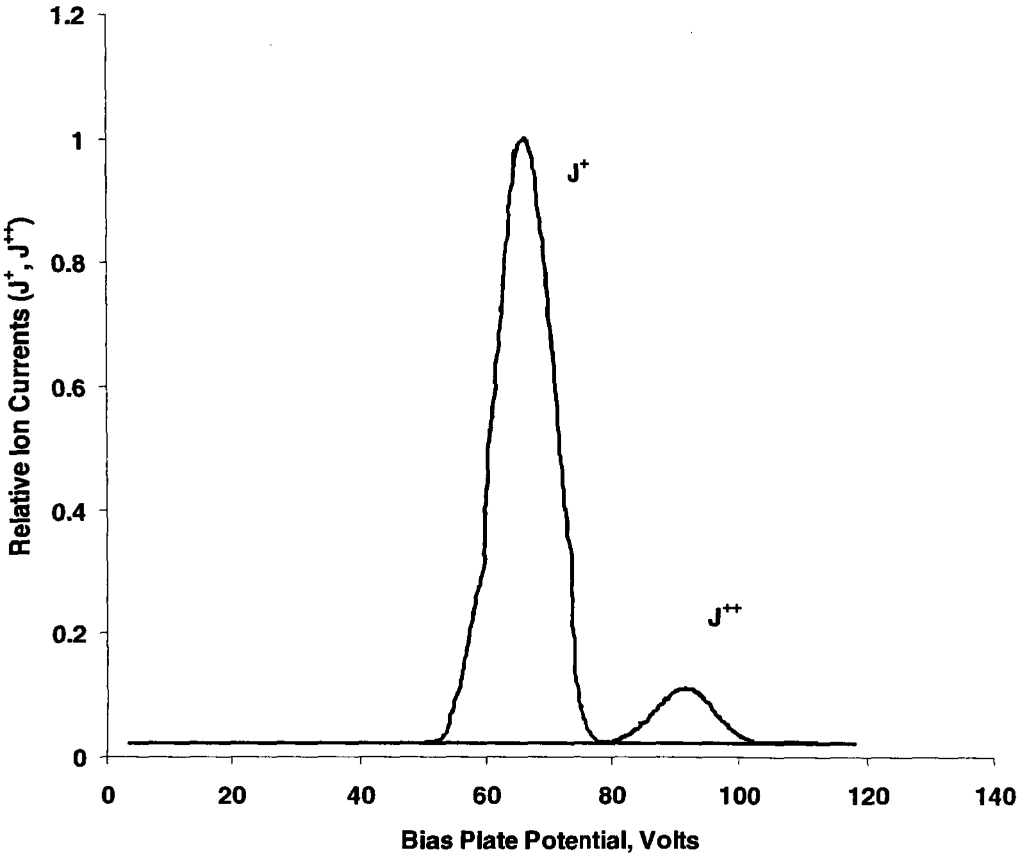


Figure 4. An example of a data collected from an ExB probe. *Courtesy of Aaron Snyder, NASA GRC*

Design Considerations

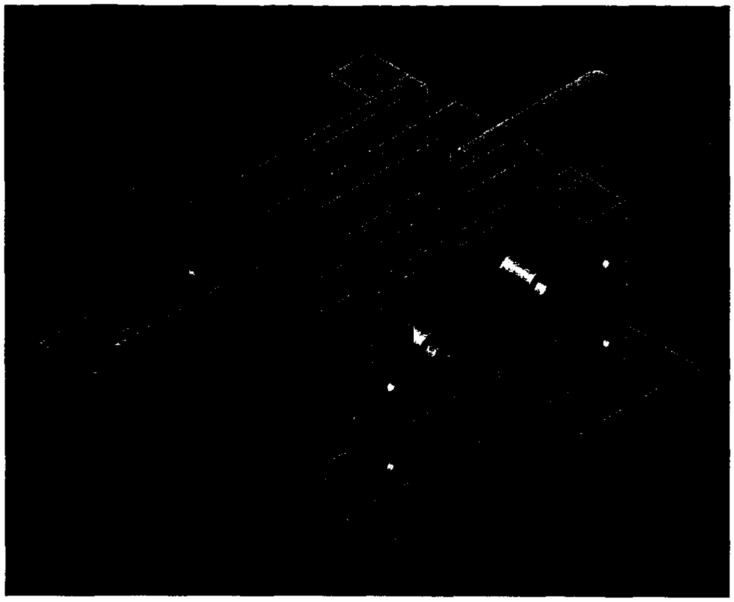
For the particles to remain on its original path, the net force exerted on it must be zero. Thus, the main design is based on this relationship:

$$E=uB$$

A few key parameters were being considered before the design of the probe including the magnetic field strength, the electric field, and the distance between the electrodes. The magnetic field strength of 0.09 Tesla is obtained from an available set of magnets. With 0.09 Tesla and a given ion energy of 6700 eV, the required range of electric field is 400-500V, and this is for a gap of 2 cm. The magnitude of the electric field and the distance between the electrodes are directly related. It is desirable to separate the electrodes at 2 cm because the electric field required is within the range of the available power supplies.

Design

The design work was done through SolidEdge. Following are some pictures illustrating the design. I have made several modifications to the existing probe to ensure proper alignment and short circuiting of the electrodes.



Conclusions

I have modified the existing ExB probe, which will be used as part of the diagnostic tools for HiPEP engine testing. The parts are currently being machined while I am setting up the test experiment using LabVIEW. Data to be obtained from this probe will be able to qualitatively characterize the thrust efficiency of the HiPEP engine.