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INVESTIGATION OF PLASMA PARAMETERS IN A DUOPIGATRON USING A LANGMUIR PROBE

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Abstract

To design an extraction electrode system for a duopigatron ion source, the SNOW [1] computer simulation has been used. Plasma parameters such as electron and ion current density, electron and ion temperatures are used in the SNOW. We have designed and constructed a Langmuir probe to investigate the plasma parameters in a duopigatron ion source. The probe has been designed in such a way that the plasma can be sampled through the source aperture. This paper will discuss some of the source's parameters, the Langmuir probe design and the plasma parameters of the source.

Introduction

The knowledge of plasma parameters such as electron and ion density distributions, electron and ion temperatures and the plasma potential is essential in an ion source development. For example, the ionization and dissociation of neutral in a source depends on the primary and the secondary electron density distributions. These distributions are influenced by the source's parameters such as the magnetic field, arc current and voltage. Adjusting these parameters allows optimization of the source operation and increases the source's efficiency. Electron density distribution is also related to the fraction of the species that is extracted from an ion source.

The ion density distribution at the extraction aperture of the source provides information on the quality of the extracted ion beam. A beam with a large divergence angle is a result of a nonuniform ion density distribution at the extraction aperture and a poor extraction electrode design. In particular, formation and transport of a "well-behaved" high intensity ion beam becomes more difficult if the ion density distribution at the source's extraction aperture is badly nonuniform.

Plasma parameters, such as electron and ion temperatures, and plasma potential play an important role in an ion source through the following: the electron temperature is related to the ionization and dissociation phenomena in the source. The ion temperature helps in understanding the ion beam energy spread which is related to the energy resolution of an ion beam. The plasma potential answers to the instabilities that may occur in the source which can be translated to an extracted ion beam.

Experimental Description

A detailed description of the duopigatron used in this experiment has been previously published [2]. The schematic drawing of the source, electronic circuitry and the Langmuir probe arrangement for this experiment are shown in Fig. 1. The size of the ion exit aperture on the source can readily be varied by replacing the molybdenum inserts in the focusing electrode.

The Langmuir probe is a .025 mm diameter tungsten wire shielded by a 1.0 mm alumina tubing. The tip of the probe extends 2.0 mm out of the shield. The probe assembly is mounted on a 305.0 mm long and 6.35 mm diameter stainless steel rack. The rack is an integral part of a XYZ manipulator which provides for the axial translation of the probe. Three stepper motors, controlled by a microcomputer (HP 9845B), drive the XYZ manipulator unit. This unit allows the probe to travel axially 254 mm and scan a 51. mm^2 plane across its path.

The voltage on the probe is varied by a programmable (± 200 volts) power supply. This voltage and the probe's current signals are fed to a two channel oscilloscope. A typical oscilloscope trace of the probe current vs. voltage is shown in Fig. 2 such an I-V curve gives the electron temperature, electron and ion current densities and the plasma potential.

Three potentiometers on each of the stepper motor's shafts provide voltage signals corresponding to the spatial variation of the probe. This feature is used to obtain the ion density profile at a desired axial position of the probe. An X-Y plotter is used to register the ion current signal from the probe (probe is kept at negative potential) vs. the position of the probe. A typical ion density profile, using this arrangement, is shown in Fig. 3.

Experimental Results

The duopigatron ion source has produced a 13.5 mA, 30 keV beam of argon ions. Similarly, the source has been capable of producing a 19.5 mA ion current using BF_3 gas and a 32.0 mA ion current using AsH_3 gas. The total output current from the source is approximately a linear function of the arc discharge current, see Fig. 4.

The ion density profile at a 12.7 mm exit aperture was obtained using a Langmuir probe. The two curves in Fig. 5 illustrate the ion density "fall-off" from the center of the exit aperture to the wall. Depending on the operating parameters, the ion density "fall-off" is approximately 50%-70%. This mode of source operation, usually, is not acceptable since it introduces an ion beam with a high degree of nonuniformity in the ion density distribution.

In order to find more detailed information on the ion density profile at the exit aperture,

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the following experiment was carrried out. The Langmuir probe scanned the expansion cup at several axial positions The axial positions of the probe, with respect to the exit aperture, is given on the left hand side of Fig. 6. The curves on the right hand side correspond to a given position of the probe. As the probe transversed the exit aperture (toward the source) the ion density distribution became more uniform. As it can be seen from Fig. 6, the ion density "fall-off" was reduced from 80% outside the aperture to approximately 15% inside the source. It is always desirable to have better than 30% "fall-off' in the ion density distribution.

Conclusions

It is our belief that a comprehensive investigation of the plasma parameters in an ion source is required in an ion source development. The ion density profiles which were obtained in the experiments assisted in the selection of the size and the shape of the expansion cup in our duopigatron. These profiles were instructive in the design of the extraction electrodes which could generate an ion beam with a desired divergent angle.

Acknowledgements

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References

[1] SNOW - A Digital Computer Program for the Simulation of Ion Beam Devices.

[2] E. Ghanbari et al., "Development of a High Current Ion Source for Ion Implantation", to be published in Nucl. Sci. Instr. Apr. (1985)

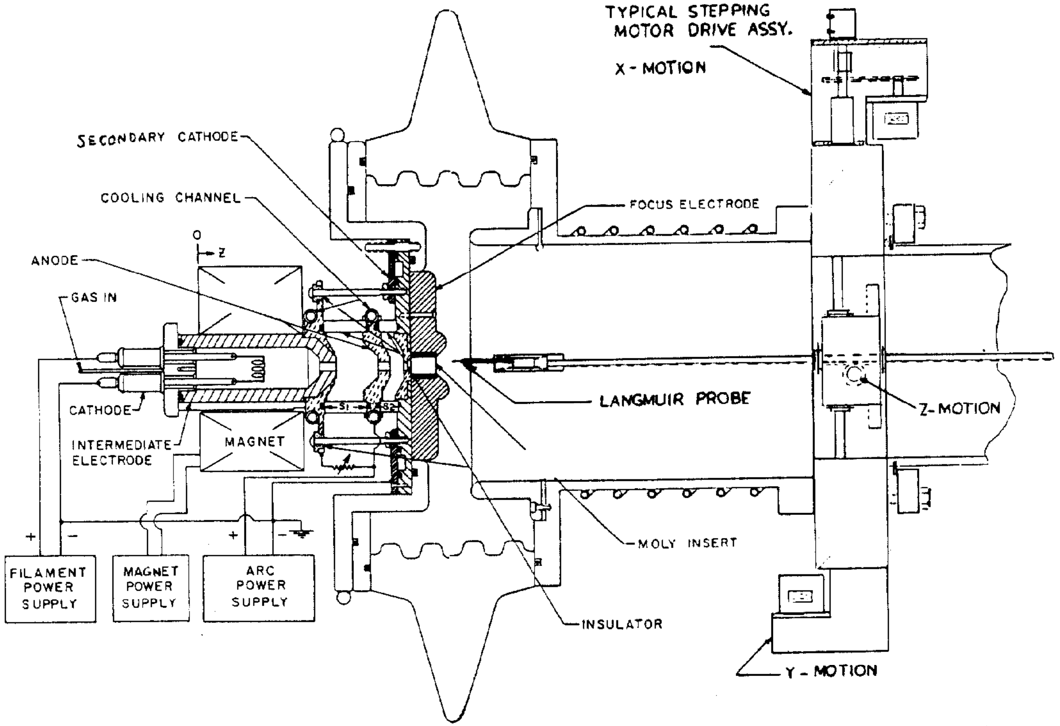

Fig. 1. Schematic drawing of the experimental arrangement to measure the plasma parameters in duopigatron ion source

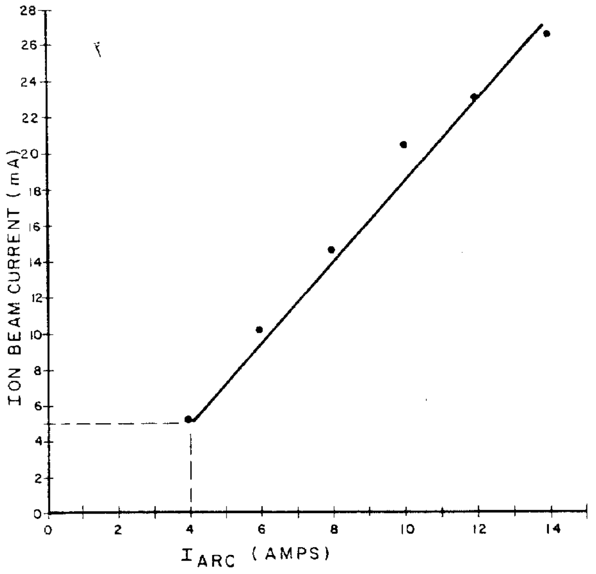

Fig. 2. Total ion beam current as a function of arc current up to a value of 14A.

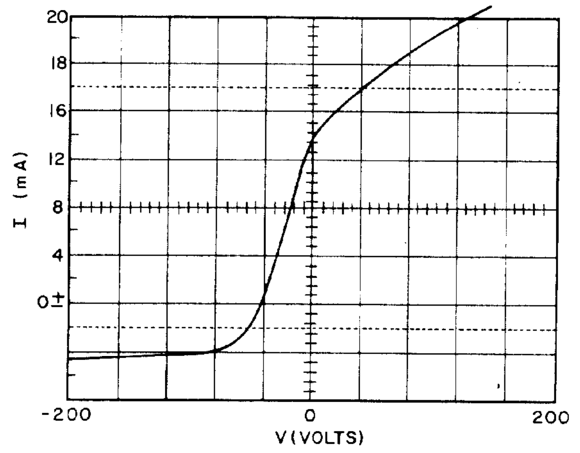

Fig. 3. Oscilloscope trace showing a typical I-V curve for determination of the plasma parameters.

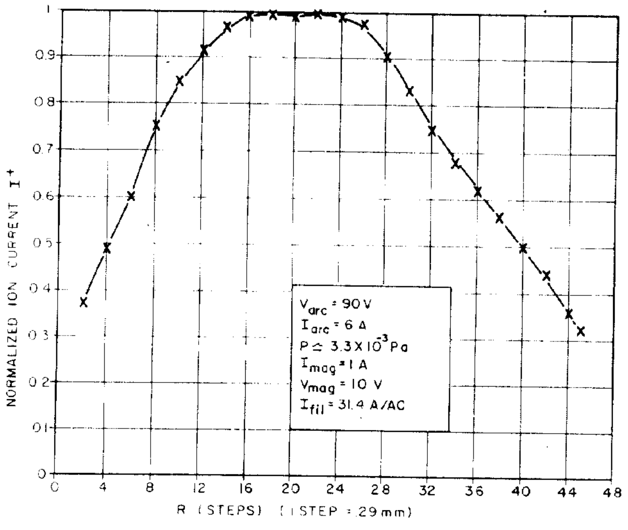

Fig. 4. A typical ion density profile across a 12.7 mm diameter extraction aperture.

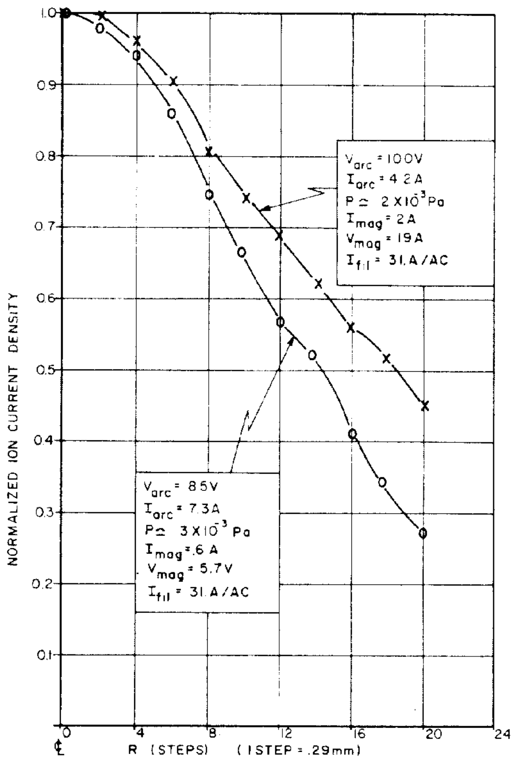

Fig. 5. Ion density profiles at the exit aperture for various operating conditions of the source.

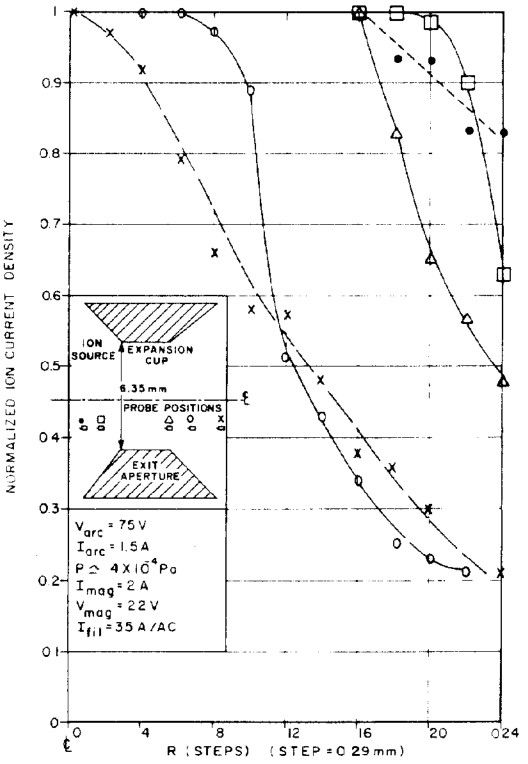

Fig. 6. Ion density profiles for various axial position of the Langmuir probe. Step 16 corresponds to the center line of the three right hand side profiles.