DIAGNOSTICS IN THE HYDROGEN PLASMA OF THE RF-DISCHARGE

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ABSTRACT

For the rf-ion source RIG 10, the profiles of plasma densities, electron temperature, and ion current density on the extraction plane, have been measured by movable double probes. The current density increases linear with the discharge power and reaches 310 mA/cm^2 at 5 kW. First beam analytic results are presented.

1. INTRODUCTION

Additional heating of fusion plasmas can be achieved by injection of intense and high energetic beams of neutral (hydrogen or deuterium) particles. The neutral beam is produced by neutralizing high energy ions by charge exchange. For this purpose, ion sources are needed, which produce an ion beam of high density (250 mA/cm^2), an even density profile (variation $\leq$ 5%) and a high proton (or deuteron) fraction.

These qualifications can be matched with the RIG 10 (Radiofrequency Ion Generator of 10 cm in diameter), which is being developed in Giessen (1)(2).

2. EXPERIMENTAL

2.1 The Design of the RIG 10 R: The mechanical structure of our ion source RIG 10 R is very simple and rigid. Fig. 1 shows the modified RIG 10 R for diagnostic investigations. The discharge vessel is made of quartz. It is air cooled at the moment, which is sufficient for discharge-powers up to 5 kW. For higher discharge powers, a water cooling system will be used.

The quartz vessel is surrounded by the rf-induction coil. The working gas (H_2) is fed into the discharge volume at the circumference of the plasma holder in the up-stream direction.

2.2 Experimental Set-up: For diagnostic measurements in the discharge, we used a radially movable double probe (Fig. 1). The radial profiles of plasma density, electron temperature, and current density were determined for discharge powers up to 5 kW.

Fig. 2 shows the extraction system, that has been built recently. The extraction electrodes (usual accel-decel-technique) are now mounted on a system, where isolators and SS-rings are electron welded vacuum tight to each other.

The presented first results in beam diagnostics were obtained using a simpler modification of the extraction system. The mass ratio in the extracted ion beam was determined by a magnetic analyzer (Fig. 3).

3. EXPERIMENTAL RESULTS

3.1 Current Density Profiles: Fig. 4 shows the obtainable current density at the surface of the extraction plane, determined by double-probe measurements (discharge chamber length 6 cm, external axial magnetic field 0.15 mT (3)). R 5% indicates the radius, were the current-density decrease is 5%. Available for extraction with a variance in the beam density profile of less than 5% is a circular plane of 7 cm in diameter.

3.1.1: Power Dependency: The ion current density increases (up to 5 kW) linear with the discharge power (Fig. 5). The slope of the current density curve depends on the discharge pressure (it is steepest at 10 μbar). At 5 kW (which remains our power limit until a water cooled vessel will be available), a current density of 310 mA/cm^2 is reached.

3.2: Extraction: The extracted current density is smaller than the probe measured current-density at the extraction plane. Investigations with an one-hole-extraction system showed, that the ratio of extracted current density/probe measured current density is between 50 and 70% (depending on the extraction geometry) (4).

A computer code for simulating the ion trajectories and extrapolating the plasma boundary has been developed (5). Fig. 6 gives a recent example of a typical result.

3.3 Beam Diagnostic: The first measurements with a magnetic mass analyzer yielded qualitatively the expected results (Fig. 7, 8). The main components of the beam are: H_1^+, H_2^+, and H_3^+. Impurities in the beam (O^+, CO_2^+, CH_3^+, HO^+, H_2O^+, H_3O^+, N_2^+) are in total less then 3%.

In a medium region of discharge pressure (4 to 10 1bar), the H_1^+-ions are dominant in the beam. If the discharge power is increased, this region becomes wider and the ratio $H_1^+/(H_2^+ + H_3^+)$ is considerably increased, too.

Quantitatively, however, these preliminary results are not yet satisfactory, as former experimental and theoretical results predicted a considerably larger ratio $H_1^+/(H_2^+ + H_3^+)$ for a rf-discharge.

But by optimizing the RIG 10 R in this respect, we are sure to reach the expected result of 80 ÷ 90% H^+-ions.

4. ACKNOWLEDGEMENT

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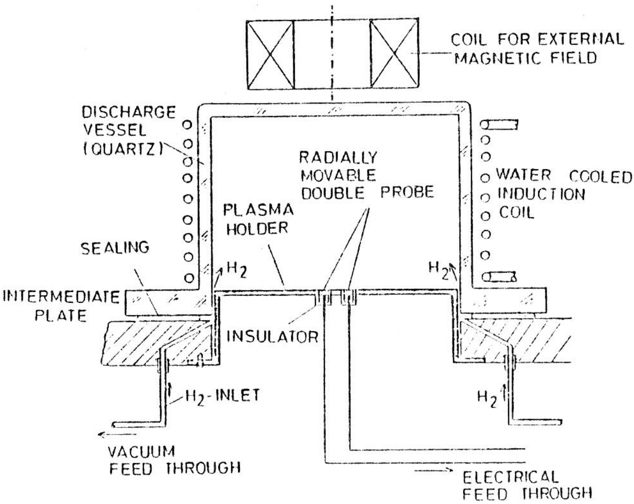

Fig. 1: Rf-ion source RIG 10 R for diagnostic measurements at high discharge powers (up to 20 kW)

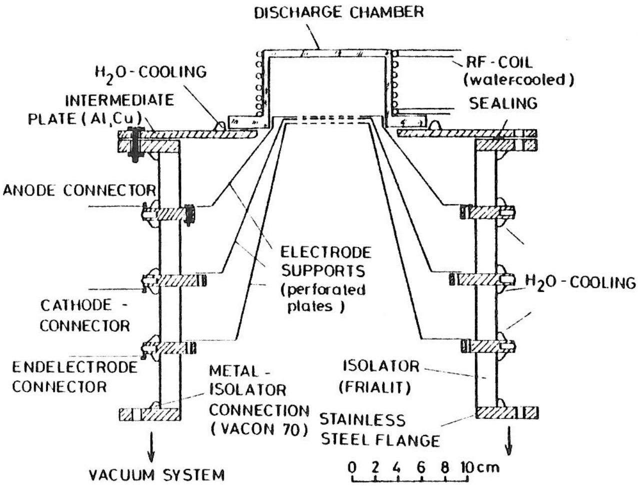

Fig. 2: Set-up of RIG 10 (rf-ion source, extraction system, and electrode support)

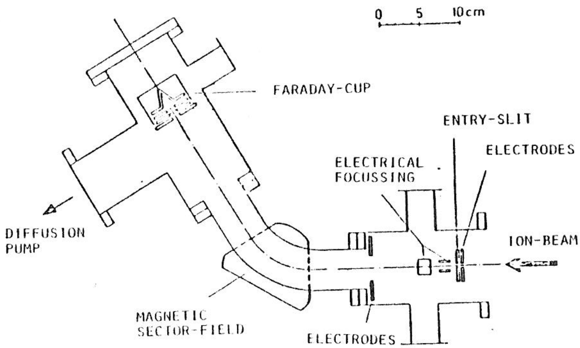

Fig. 3: The magnetic analyzer used for beam analysis

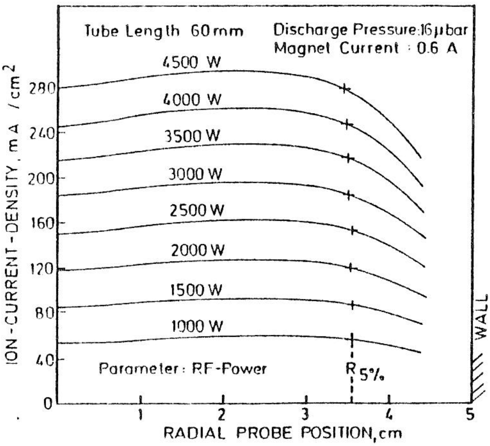

Fig. 4: Current density profile for various discharge powers (discharge chamber length at 6 cm; superimposed external magnetic field intensity: 0.15 mT)

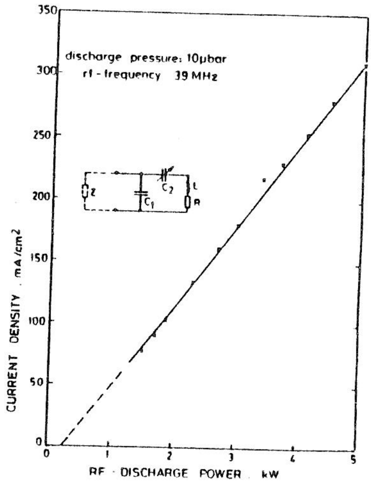

Fig. 5: The ion beam intensity increases linear with the rf-discharge power.

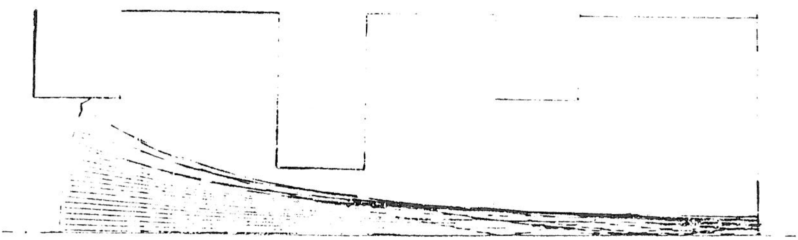

Fig. 6: Ion trajectories and plasma boundary in a single extraction hole of the RIG 10 with a net-extraction voltage of 12 kV and a current density of 250 mA/cm^2 (computer plot)

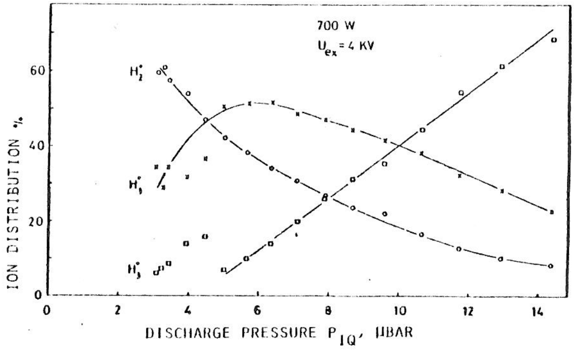

Fig. 7: Ion distribution in the beam as a function of discharge pressure

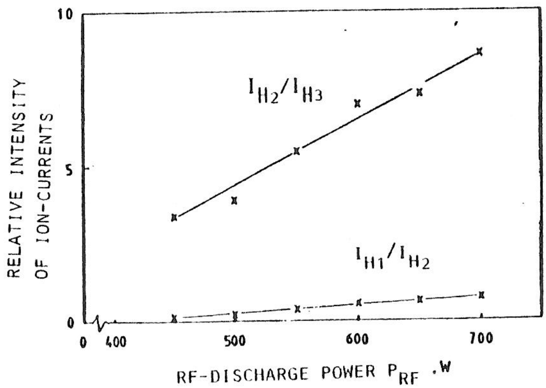

Fig. 8: Power dependency of the mass ratio in the extracted beam