QUIESCENT PLASMA MACHINE FOR PLASMA INVESTIGATION

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1 - INTRODUCTION

The excitation of plasma waves by particle beam interaction with plasmas has been investigated in several experiments. However most of them were made in small plasma tubes where boundary effects play an important role on the experimental results. A large volume quiescent plasma device is being developed at INPE to study Langmuir waves and turbulence generated by electron beams ($E_b \leq 500\,eV$) interacting with plasma. This new quiescent plasma machine was designed to allow the performance of several experiments specially those related with laboratory space plasma simulation experiments. Current-driven instabilities and related phenomena such as double-layers along magnetic field lines are some of the many experiments planned for this machine. Production of large volume plasmas can also be a useful tool for test and calibration of rocket and satellite boarded plasma detectors. The low density and cold plasmas obtained in this conditions have similar characteristics of some ionospheric layers and the solar atmosphere.

2 - MACHINE DESCRIPTION

The quiescent plasma machine is constructed of a non magnetic stainless steel ($304L$) vacuum vessel with 60 cm diameter and 120 cm length. An Edwards vacuum system with a 2000 l/s diffusion pump and 40 m^3/h mechanical pump is used to obtain a final background pressure of 4.0×10^{-7} mbar, as measured by an ion gauge. Plasma is produced by a system of three independent magnetic multi-dipole thermionic discharges. For each system there is an electrically insulated magnetic multi-dipole cage of permanent magnets. They are assembled in line cusp configuration to produce a surface magnetic confinement of the three plasmas and the average surface field measured by hall probes is 150 Gauss. The magnets are vacuum insulated from the discharge in thin metal wall alluminum tubes. A schematic view of this quiescent plasma device is shown in Fig.1.

The thermionic discharge is produced by heated tungsten filaments ($T \simeq 900\,°C$ covered with barium oxide (BaO) to increase electron emission from the filament cathodes. There are 24 filaments ($l = 15$ cm and $d = 0.1$ mm) for each discharge system. They are assembled in three ceramic supported double ring structures, wich also insulate the cathodes from the magnetic cage. The filaments are positioned inside the surface magnetic field in order to increase primary electron confinement and consequently the gas ionization rate.

The electron beam is generated using the double plasma configuration scheme in wich the target and source plasma are separated by the grid system shown on Fig.1. The grids are

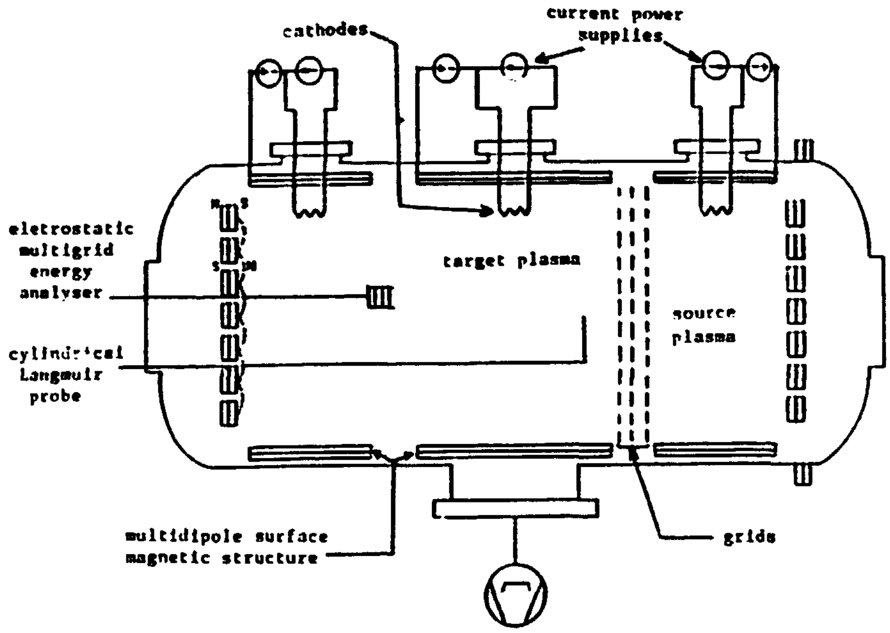


Figura 1. Schematic view of the quiescent plasma machine.

insulated by macor ceramic spacers and the distance between them is of about 1 cm. Each one of the three grids has 65% of transparency for the beam particles. This is an important limitation factor on the total beam current that can be extracted from the source plasma.

3 - PLASMA DIAGNOSTICS

The stable DC plasma generated in the thermionic discharge is suitable for simple basic plasma diagnostics. Cylindrical Langmuir probes are used to measure electron plasma density and temperature, wich are typically $10^{8}\,cm^{-3}$ and 2.0 eV, respectively. The electron distribution function is measured using a Langmuir probe controlled by a second harmonic detector circuit designed to obtain the electron distribution from two sucessives derivation of the probe characteristic curve. Fig.2 shows the energy distribution function of the plasma electrons with and without the beam. Notice the impossibility to detect the beam electrons with this method because $E_b \geq 50\,eV$ in general. However, it is possible at least to see the effect of the heating of the plasma electrons by the beam looking at the increased number of electrons in the hot tail of the distribution function.

A multigrid eletrostatic energy analyser is used to detect the electron beam generated by the source plasma. Three grids and a colector are used in this analyser to provide better accuracy on the acquired data. Fig.3 shows the characteristics curves of the analyser (a) and its derivatives (b). Curve 1 represents only the beam. Curve 2 represents the beam and the accelerated plasma bulk electrons. The beam energy of this curves was about 70 eV as can be atested by the peaks on the first derivative curves. These curves were taken with the analyser positioned 5 cm away from the grid acceleration system and it is possible to see that the beam is far from being cold.

Cylindrical RF probes are used to detect the beam excited Langmuir wave. The probes are connected to a spectrum analyser (Tektronics 7113) which contains an analog fast Fourier

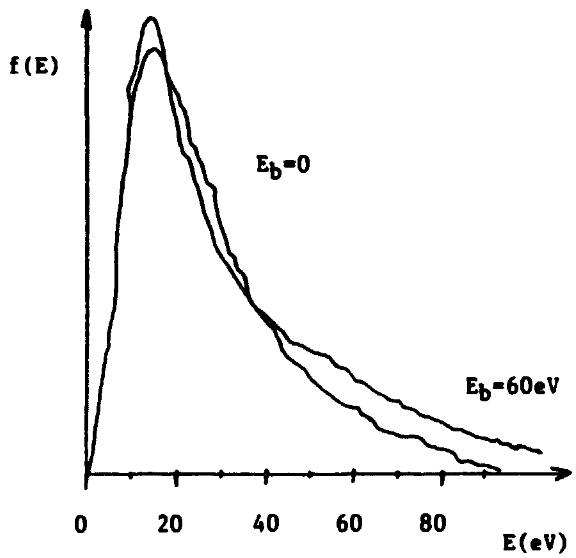


Figura 2. Electron energy distribution functions detected by an eletrostatic probe controlled by second harmonic detector.

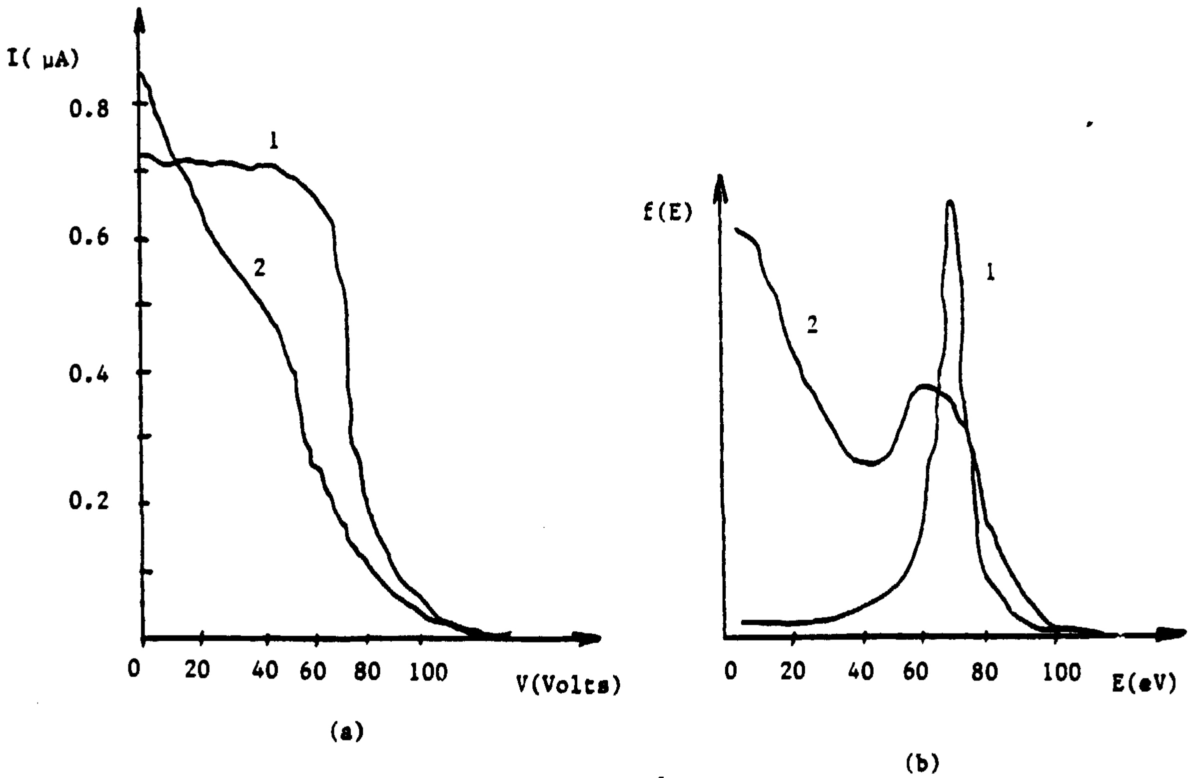
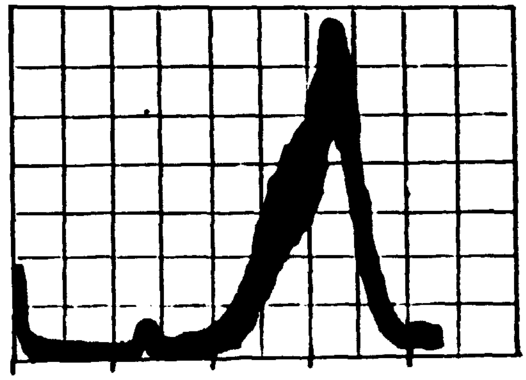


Figura 3. (a) $I \times V$ characteristic curves of the multigrid electron beam analyser. (b) Electron beam distribution functions.



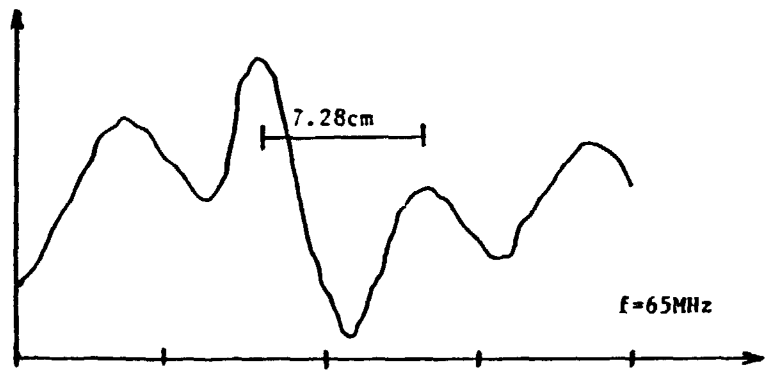


Figura 4. (a) Langmuir waves frequency spectrum. (b) Measured wavelength using an interferometric RF probe system.

transformer, to measure the wave frequency spectrum in the target plasma. They are also connected to an interferometric system capable to give wavelength measurements with 0.5 mm accuracy. Fig. 4a shows a typical spectrum of a Langmuir wave excited by a 50 eV beam. Fig. 4b shows the interferometric trace obtained by using RF probes moved by step motors. In this measurements the argon pressure was kept as low as possible ($\leq 10^{-4}$ mbar) to prevent the waves from electron-neutral collisional damping. The frequency and wavelength measured by these techniques are in good agreement with the theoretical predictions for Langmuir waves excited by beam plasma interaction.

4 - CONCLUSION

A quiescent plasma machine for plasma investigations studies was described. Based on the experimental data detected by probes and energy analysers the machine performance is good, according to the machine project design. Further experiments on strong Langmuir turbulence, double layers and field aligned current-driven instabilities are planned to be carried on in the near future.

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