LANGMUIR PROBE COMPLEX IMPEDANCE IN THE ION PLASMA FREQUENCY RANGE IN A MAGNETIZED PLASMA

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ABSTRACT

A Langmuir probe at the tip of a coaxial line is plugged into a toroidal, magnetized discharge plasma column. The probe complex impedance is investigated as a function of frequency, in the ion plasma frequency range, by means of a network analyzer. The probe reflection coefficient at the end of a coaxial line shows properties akin to a resonant circuit, with different characteristics depending whether the probe is biased at or above the plasma potential. Experimental results are shown and interpreted in terms of the probe sheath and radiation properties in a magnetized plasma.

The probe tip of a cylindrical Langmuir probe plugged into a magnetized plasma can be used as an antenna radiating at, or around, characteristic plasma waves frequencies. By investigating the probe impedance as a function of frequencies [1], information can be obtained on the plasma properties while the usual (I, V) characteristics in B-fields [2] are affected by electron diffusion across B field in not straightforward ways [3].
The experiment is conducted in the "ToriX" laboratory plasma. It is a discharge plasma confined in a toroidal DC magnetic field of 0.056 Tesla intensity ; the plasma major radius is 0.6 m and minor radius 0.1 m. Plasma density is 5.10^{15} m^{-3}, electron temperature 1,5 eV, in a gas of ionized Argon.
The probe is made of a standard RF coaxial line ; at the tip of it, the outer isolating and ground sheaths have been removed, only the copper central conductor (0.5 mm diameter and 15 mm length) is in contact to the plasma.

The electrical bias and RF probe insertion circuit is shown in figure 1.

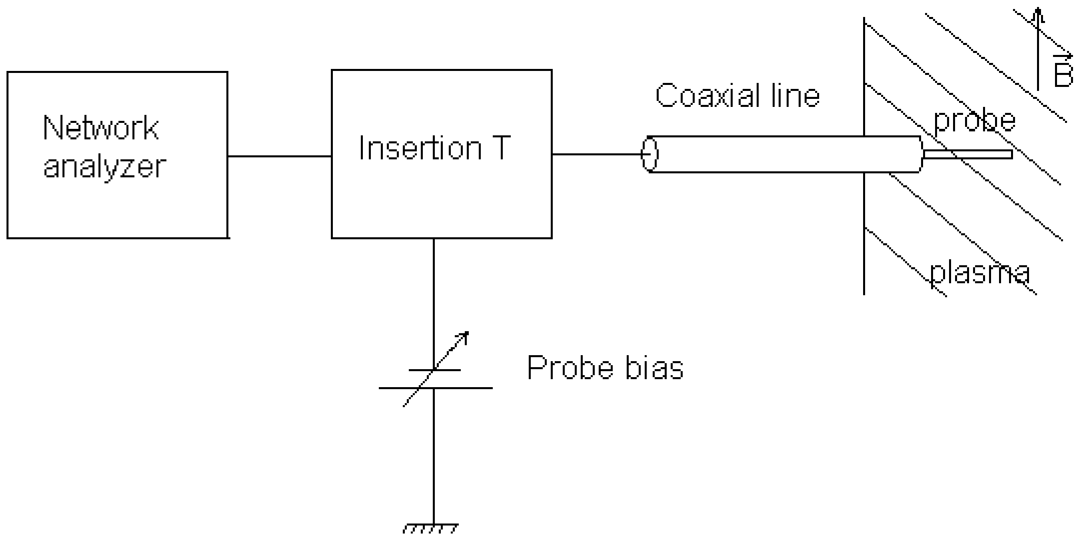

Fig. 1. Probe electrical connection circuit

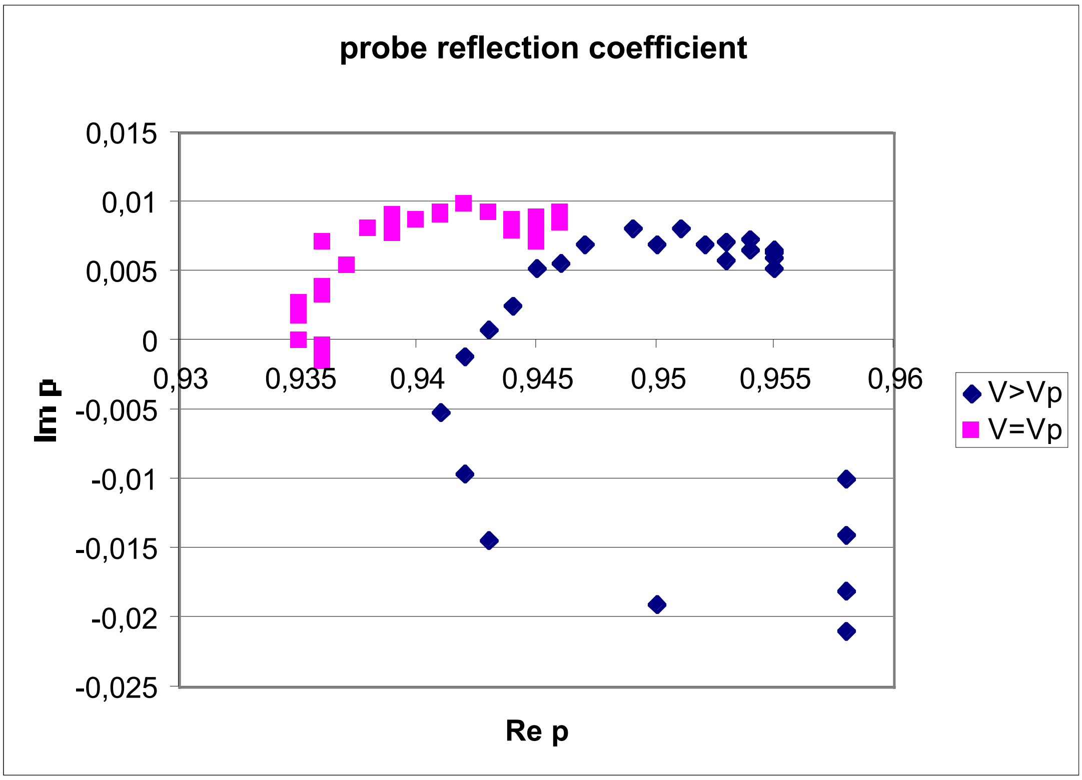

Fig. 2. Complex reflection coefficient from the plasma inserted probe

The network analyser is connected to the biased probe via a coaxial line and an insertion T. This component insulates on one hand the HF generator from the DC part of the potential, and on the other hand the DC generator from the HF part of the potential thanks to an inductance.

The frequency of the HF signal is swept from 300 KHz to 5MHz. The reflection coefficient of the all line, ρ_1, is then measured. The reflection coefficient of the probe alone, ρ, is needed. It is assumed and checked that, for the range of frequency studied, the only effect of the cables between the network analyser and the probe is to add a delay, i.e. a phase factor $\alpha(\omega)=e^{i\omega\tau}$, where τ is the cable delay time. The reflection coefficient measured when there is no plasma equals this phase factor, $\alpha(\omega)$. We get ρ by dividing the raw experimental results, $\rho_l(\omega)$, by $\alpha(\omega)$.

Two different experimental results are shown in Figure 2. Both are obtained in the same plasma but for two different probe bias : plasma potential bias (full squares) and above plasma potential (the probe is biased at a potential shifted positively from the plasma potential by an amount equal to the electron temperature ; filled rhombs).

When the probe is biased at plasma potential (squares), and as the frequency increases, the complex reflection coefficient starts from a real value while the imaginary part increases to positive values and saturates above 2 MHz. When the probe bias is above plasma potential (rhombs), the reflection coefficient real part starts from a real value, near to one (corresponding to the effect of a large real impedance) and the imaginary part takes on negative values as the frequency increases. The complex reflection coefficient follows a nearly circular path in the complex plane, rotating in the indirect direction as the frequency increases, and the imaginary part reaches positive values for frequency larger than 1.7 MHz until a maximum at the end of the 5 MHz range.

These complex reflection coefficients are similar to those given by simple circuits. At plasma potential bias, the circuit is a (LR) serial circuit made of a resistance R and an inductance of L=20 μH. The resistance is equivalent to the slope of the probe DC characteristics at plasma potential (R=1500 Ohm). At the positive probe potential bias, the equivalent circuit is a serial (RLC) circuit with a resonant frequency of 1.7 MHz. This frequency is close to the ion plasma frequency.

These features are characteristics of the magnetized plasma response to the RF probe excitation and require further analytical investigations.

AKNOWLEDGEMENTS

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