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STUDY OF THE PLASMA RF ABSORPTION USING A NOISE GENERATOR

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Abstract: The study of the rf field-ionized gas interaction represents an important tool for plasma diagnosis (e.g. [1-5]). A simple and practical method aimed to investigate the spatial distribution of the rf field absorption by a plasma column in a wide frequency band is presented. The method is based on the measurement of the amplitude variation of the rf field harmonics components due to a plasma layer. As a signal source is used a noise generator which generates a broadband rf field. The effect of the plasma on the rf field amplitude at different frequencies for various experimental conditions is observed by means of a spectrum analyzer. This method has been tested using a dc electrical discharge as a plasma source. It is described a modified version of the experimental setup intended to investigate the excitation of the rf harmonics in plasmas.

Experimental setup: The block diagram of the experimental setup is shown in Fig. 1. Experimental setup contains two main components, the plasma source (discharge tube, vacuum system and dc supply circuit) and rf measurement chain, respectively. The discharge tube consists of a Pyrex glass tube, 65 mm in diameter, having two plate electrodes made of aluminium, which are separated by 400 mm. The two electrodes are connected to a HV dc power supply by means of the ballast resistor R=57kΩ. Two RF chokes, L1 and L2, block RF currents flowing through the discharge tube dc supply circuit. RF choke L_2 may be removed from the circuit by connecting terminals X and Y. The discharge tube was connected to a vacuum system and can be filled with various gas mixtures. The preliminary tests have been performed using air at low pressure. A linear active Pirani gauge Boc Edwards APGX-M has been used to measure pressure in the system. By means of a microcontroller based circuit the pressure can be varied in the range 10^{-2} -5 mbar and can be kept constant during the experiments. The complete rf chain contains the following components: noise generator, rf-wideband amplifier, rf-switch, band pass filter (BPF), rf-probes, rf-buffer and a spectrum analyzer. Basically, the described method requires only noise generator, rf-probes, rf-buffer and the spectrum analyzer, the rest of the components being used for various versions of the

experiments explained below. The noise generator operates as a rf signal source. Initially, a homemade noise generator providing noise voltage in the range from 100kHz to about 70MHz has been used. Recently, in order to extend the frequency band investigated, that device has been replaced by a Unaohm NG500 [6] noise generator having the main characteristics: output level = 80 dBmV/MHz, frequency band = 5-2300MHz, output impedance = 75Ω. The rf probes consist of two sections of a split metallic cylinder (diameter=65mm, length=20mm) surrounding the discharge tube. The rf probes achieve the capacitive coupling between the rf field and discharge plasma. In this purpose one of the metallic sections is used to apply the rf signal to the plasma, while the other is used to collect the rf signal traveling through the plasma.

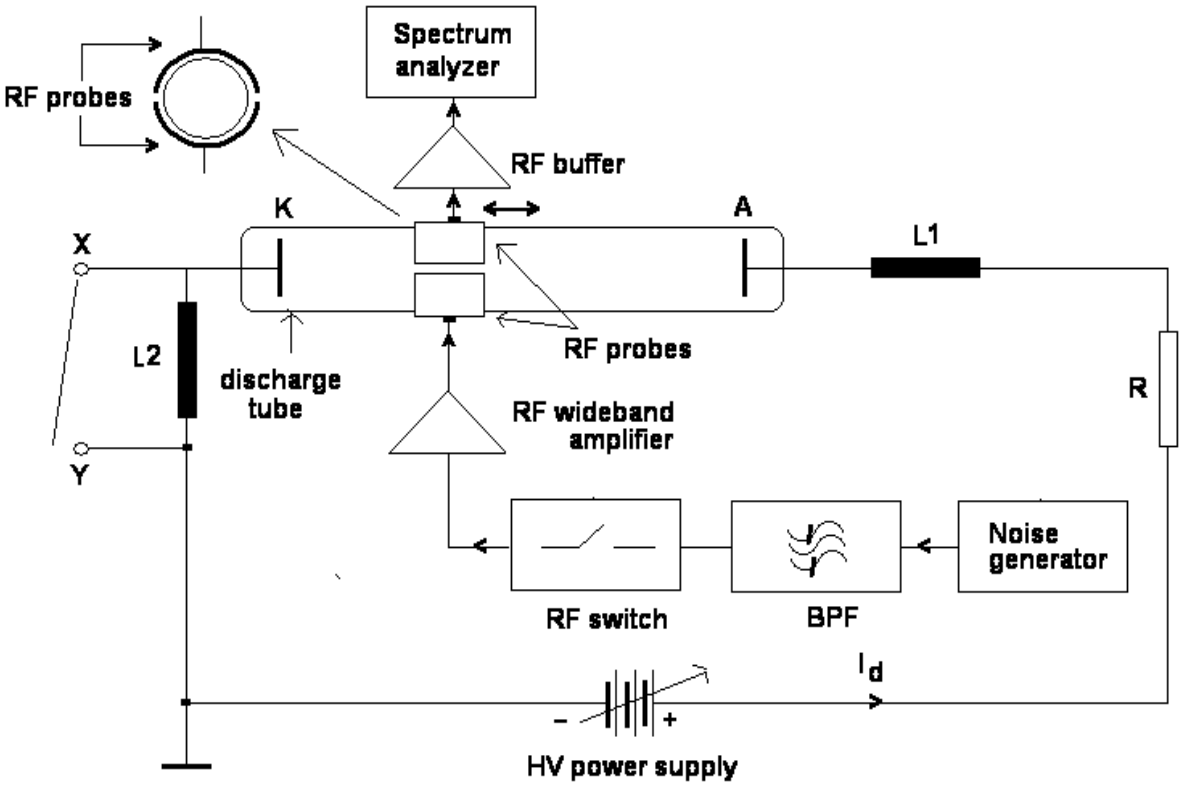

Fig. 1 Block diagram of the complete experimental setup

The rf probes can be translated along the discharge tube allowing the study of the rf absorption variation as a function of the discharge region. Frequency response of the discharge plasma is observed by means of a spectrum analyzer. We employed a Hameg HM5014 spectrum analyzer operating in a frequency band from 0.15MHz to 1050MHz. Due to the low input impedance of the spectrum analyzer the rf signal collected is firstly applied to

the input of a rf buffer unity gain amplifier. The rf buffer input and output impedance are 50kΩ and 50Ω, respectively. There are several possible improvements of the experimental setup above described. In order to employ various synchronous techniques or to study the transient effects due to the interaction plasma–rf field, the applied rf signal can be amplitude modulated using a rf switch. At present, there are a lot of electronic devices commercially available for this purpose. We tested with good results the CMOS integrated circuit HCT 4051 and GaAs PHEMT device MASWSS0006, respectively. By adding few components, the experimental setup could be used in order to investigate the excitation of the rf harmonics in plasmas due to various nonlinear effects. Usually, the nonlinear effects occur at relative high level of the applied rf field. Consequently it is necessary to increase the noise generator output rf signal level inserting a wideband rf amplifier. Also, the frequency band of the applied rf signal must be narrowed using a band pass filter (BPF). The rf signals generated by nonlinear effects occurring in plasmas are expected to be observed in the attenuation bands of the filter. Theoretically, the noise generator could be replaced by a common rf sweep generator. However, in this case, at any moment, the rf generator output signal has a well defined frequency, varying in time. In the case of a noise generator output signal contains all harmonics which are applied continuously to the plasma.

Results: The frequency spectrum of the rf field, in the presence of plasma, generated by a glow discharge obtained in the tube above described, for various experimental conditions (pressure and discharge current), as a function of rf probe position have been recorded. The major experimental results are summarized as follows:

-the presence of RF absorption dips has been observed;

-the RF absorption dips have been observed when RF probes were located over the negative glow region;

-the RF absorption dips are well defined only if RF choke L_2 is removed (X connected to Y).

As an example, in Fig. 2 is presented the spectrum corresponding to the frequency range between 10MHz and 100MHz obtained in the following experimental conditions: pressure $=2\text{x}10^{-2}$ mbar, discharge current I_d=10mA, discharge voltage U_d=3.2kV. The rf probes were located over the negative glow region. The distance between the rf probes and cathode was about 150mm. It can be seen from Fig.2 the presence of an absorption dip around 31 MHz. The position of the absorption dip depends on the discharge current I_d . Table 1 lists the frequency f_a of the absorption dip for different values of the discharge current I_d . Increasing pressure, the negative glow region becomes shorter and absorption dip vanishes.

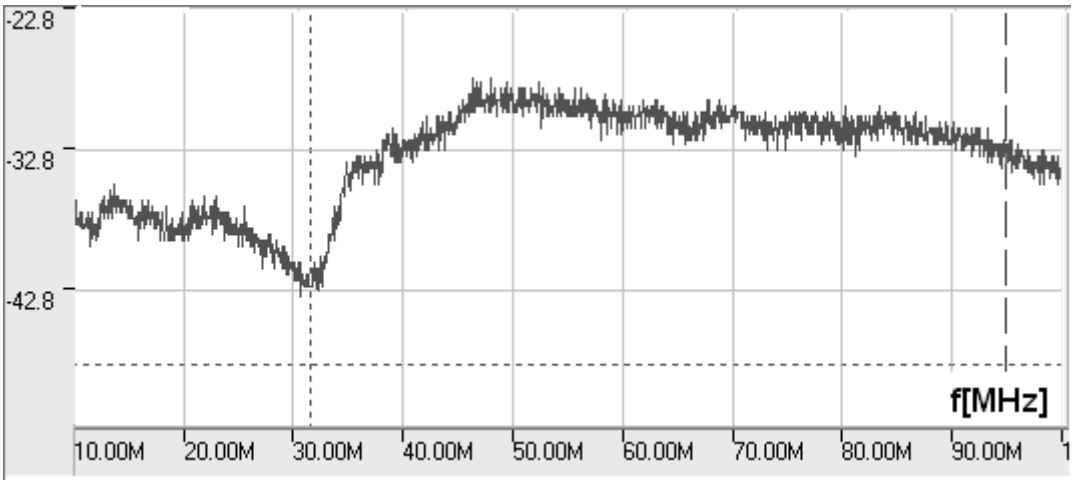

Fig. 2 RF absorption dip

Table 1

f_a [MHz]	29.7	30.8	31.2	32.2
I_d [mA]	6.8	8.5	10	12

Because the frequency of the absorption dip f_a increases with discharge current I_d, and knowing that in the negative glow region electrical current is predominantly carried by the electrons, it may be supposed that this parameter is related to the electron density.

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