Automation of Plasma Diagnostics at Polytechnic University of Puerto Rico

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ABSTRACT

This work presents an ongoing effort to develop an automatic measurement system for plasma diagnostics at the Plasma Engineering Laboratory of Polytechnic University of Puerto Rico, along with an example of its operation. The system intends to be used with electrostatic probes such as Single and Double Langmuir probes, emissive probe, ion and electron energy analyzers, and others. The automatic measurement system includes automatic positioning of probes inside the plasma chamber, automatic voltage sweep of probes for each position, and automatic analysis of the probe I-V characteristic. Measurement results obtained from this automatic measurement system during a particular experiment are shown and compared with a traditional method, producing satisfactory results.

INTRODUCTION

As part of the infrastructure for research of the Plasma Engineering Laboratory at Polytechnic University of Puerto Rico, a set of tools to perform plasma diagnostics is under development. One of the methods to perform diagnostics is using electrostatic probes. Electrostatic probes allow for temperature and density of plasma, plasma potential, velocity of particles, and other parameters to be known [5]. Knowing those parameters allows in turn to study the behavior of plasmas in a macro or micro level, and to be able to control instabilities, confinement, production losses, etc. Diagnostics of plasma parameters also allows to control parameters, such as temperature and density of plasma, which may be required to be in certain levels for a particular material processing [9], [1], [6] or development of simulation tools to enhance the study of plasma devices [9]. All these applications motivated the ongoing development of a plasma measurement system at the Plasma Engineering Laboratory of Polytechnic University of Puerto Rico (PUPR), in order to enable the use of electrostatic probes to perform plasma diagnostics [8]. One of the goals of this endeavor is to achieve the automatic operation of a number of electrostatic probes, currently used in the Plasma Engineering Laboratory. A system was develop using various software tools with the following functionalities: position an electrostatic probe, collect the V-I characteristic of the probes being used, analyze these characteristics using one or more algorithms, and store the results for posterior study, all of these tasks in an automatic fashion. In this work the current state of these automatic measurements system is reported, explaining the principles and scope of its operation and showing some of the results obtained at this point.

DESCRIPTION OF THE AUTOMATIC MEASUREMENT SYSTEM

PUPR ELECTRON CYCLOTRON DEVICE

The Plasma Engineering Laboratory is developed around a plasma device originally developed for fusion study; which relies on the Electron Cyclotron Resonance (ECR) principle to produce plasma. It will be referred to as PUPR Mirror-Cusp plasma machine or PUPR-MC. The device (shown in Figure 1) is the largest of its type in Latin America; some of its features are ideal for research in various areas of physics and engineering.

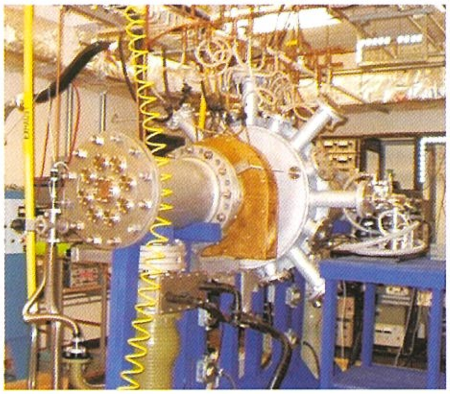

Figure 1: *Polytechnic University of Puerto Rico ECR Device.*

Among these features are: large size of chamber (allows for the introduction of large samples for plasma treatment); large number of ports around the chamber (allow the introduction of a number of probes at the same time), and its wide range of temperatures and densities (reported as from 0.1 eV to 30 KeV, and from 10^4 to 10^{11} cm^{-3}) [6]. Controllability is also a very desirable feature of this device. By adjusting the magnetic confinement current, the superheating microwave power, the operation mode (Mirror or Spindle Cusp) and the amount and type of gas injected into the plasma chamber, the characteristics of the produced plasma can be controlled. The laboratory is equipped with various in-house built probes: Single and Double Langmuir probes, a magnetic field (Hall effect) probe, an ion/electron energy analyzer, and others which are being developed for this automatic measurement system.

AUTOMATIC MEASUREMENT SYSTEM

The automatic measurement system is composed of various elements working together to achieve the determination of plasma parameters. The first element is the probe itself, which is inserted into the plasma chamber using a vacuum feedthrough that allows movement of the probe inside the chamber without loosing high vacuum conditions. The second element is the probe driver, a motorized mechanism that allows positioning the probe at any desired place inside the chamber. The measuring element is a Keithley 2400 source-meter [4] that allows performing a voltage sweep on the probe and at the same time provides the acquisition of the current signal being drawn from the probe. Last but not least, a workstation running National Instruments LabView 7.1 [2] where a set of libraries have been setup to run data acquisition and analysis of the different probes used in the laboratory.

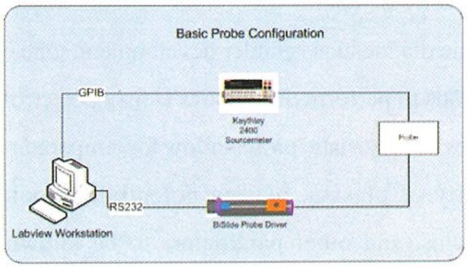

Figure 2: *Basic Probe Configuration*

PROBES

The laboratory has built various probes and analyzers to perform diagnostics and has used them in various research works [8], [7]. These probes are built using stainless steel disks as primary sensing elements. A picture of the Single Langmuir probe built at PUPR is shown in Figure 3. The measurement system is intended to be able to handle all of those probes. The basic setup is shown in Figure 2, and the probe is shown as a black box. At the moment, the Single Langmuir probe and the Double Langmuir probe are working automatically.

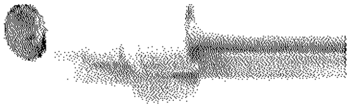

***Figure 3:** Single Langmuir Probe*

PROBE DRIVER

The probe driver is a Velmex Bslide 60 inches, motorized, linear positioning system allowing movement of probes in steps of less than one millimeter. The probe driver uses a motor controller VXM-2 enabling the positioning of two probes inside the machine. The motor controller is connected to the workstation via an RS-232 interface allowing the automatic positioning of the probe via any programming language.

KEITHLEY 2400 SOURCE-METER

Keithley 2400 source-meter is able to perform as precise, low-noise, highly stable DC power supply with a low-noise, highly repeatable, high-impedance multimeter. It has 0.012% basic accuracy with $5\frac{1}{2}$ digit resolution. At $5\frac{1}{2}$ digits, Keithley 2400 delivers 520 readings/second over the IEEE-488 bus. At $4\frac{1}{2}$ digits, it can read up to 2000 readings/second into its internal buffer. The unit has broad source and measurement ranges:

- Source voltage from 5 V to 210 V
- Measure voltage from 1 V to 211 V
- Source current from 50 pA to 1.05 A
- Measure current from 10 pA to 1.055 A
- Measure resistance from $100\mu\Omega$ to 211 MΩ
- Maximum source power is 22 W

The source-meter is setup to work as a voltage source-current meter using the autorange feature to detect currents being drawn from electrostatic probes. The meter is connected to the PC via a GPIB (IEEE-488) interface enabling control and data acquisition with minimal programming effort.

WORKSTATION AND LABVIEW

A personal computer running LabView 7.1 is connected to the system to perform data acquisition and analysis. The system is being developed as a collection of libraries, so that any student, with minimal training in LabView, is able to put together a measurement application for a probe different than the ones already in place. The scalability of the system is, hence, one of the most important features in its design. The libraries developed are then building blocks to setup programs that perform measurements of plasma parameters. Figure 4 shows block diagram of the measurement program developed using a Single Langmuir probe.

logarithm of the exponential portion of the I-V characteristic. The major advantage of this system is its imperviousness to noise in the saturation region of the I-V characteristic, a problem very often found in a plasma diagnostics environment. Density and temperature results, however, resemble those obtained from the logarithm method, which is taken as comparison method.

FUTURE WORK

As a continuation of this work, the experiment described above will be repeated for other electrostatic probes in the laboratory, and the results of these experiences will be compared. Data collected in each of these experiments will be deposited in a database, where it will be available for further analysis. Other methods to obtain information from the I-V curve will be attempted in order to gain insight about the suitability of the filtering and its limits of operation.

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