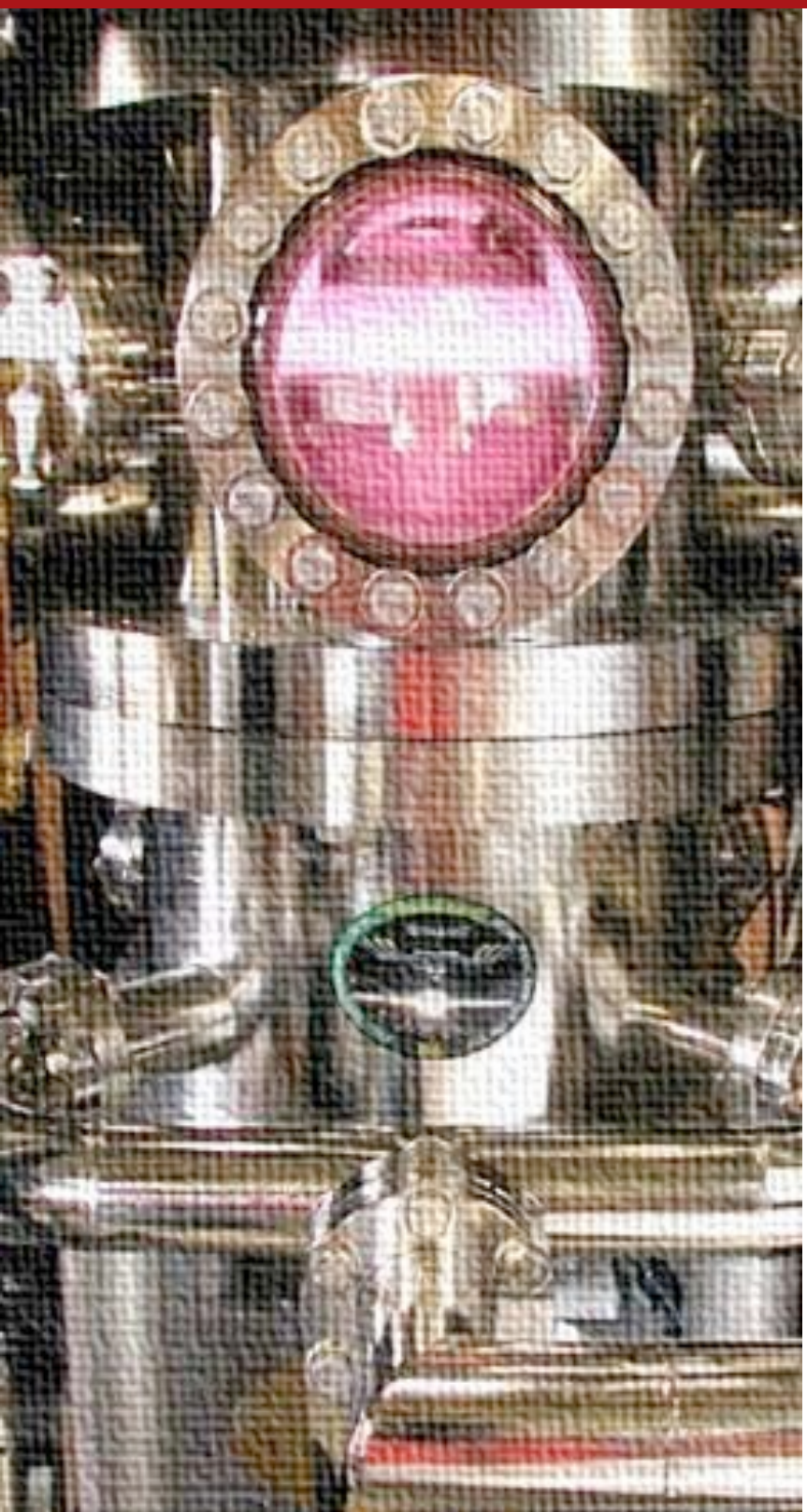
Impedans
PLASMA MEASUREMENT

LANGMUIR PROBE SYSTEM

FOR YOUR GENERAL PLASMA MEASURMENT NEEDS



Langmuir Probe System™

Radio-frequency compensated Langmuir probe

Compatible Plasma Power Types

DC, Pulsed DC, RF, Pulsed RF, Microwave, Pulsed Microwave, Atmospheric

Interchangeable Probe Heads

Single Probe, Double Probe, Spherical Probe, Planar Probe, Mach Probe

Langmuir Probe System

The Langmuir Probe is one of the most widely used plasma measurement instruments. It is used to measure the characteristics of the plasma bulk region. The Impedans Langmuir Probe System measures the key plasma parameters such as plasma potential, charged particle densities and the electron temperature using the most advanced theoretical models available. Langmuir probe measurements provide the user with fundamental insights into the physical phenomena that govern plasma behavior.

Key Features

- Interchangeable single, double, spherical, planar and Mach probe head options.
- Time averaged, time trend, synchronised pulse profile and triggered fast-sweep modes.
- Automated tip cleaning function using plasma electron bombardment.
- Integrated linear drive mechanism to automatically profile spatial plasma uniformity.
- Integrated RF compensation and DC reference probe.
- Compatible with DC, Pulsed DC, RF, Pulsed RF, Microwave and other plasma excitation methods.
- Sampling rate of 80 MS/s giving a base time resolution of 12.5ns.

Key Benefits

- Multiple, interchangeable probe head types in a single system, lowering the cost of ownership.
- Algorithms that work from high vacuum to atmospheric pressure.
- Intuitive and user friendly interface.
- Saves time and improves productivity through sophisticated automation features.
- Robust and durable design to survive in extreme plasma environments.
- Custom probe options including right angle elbows and flexible probe shafts.
- Provides measurements for fundamental research, process development and model validation.

Low Cost of Ownership

The Langmuir Probe System has multiple probe head options, allowing you switch easily between single probe, double probe, spherical probe, planar probe and Mach probe functionality. Single and double probe heads are included as standard. No other system on the market has this in-built capability. This is particularly valuable when you have multiple plasma chambers, with and without grounded metallic walls. You no longer have to purchase multiple probe systems from different suppliers to meet your needs.

Expert Analysis

The Langmuir Probe System incorporates the most advanced Langmuir theory found in the published literature. At low pressure, Orbital-Motion-Limited (OML) theory is used to correct

for ion current loss due to angular momentum i.e. some ions will enter the probe sheath, orbit the probe and escape back to the plasma without being collected. At high pressure, collisions within the probe sheath slow the ions down, which also results in an artificial reduction in ion current. Allen-Boyd-Reynolds (ABR) theory is used to compensate for this effect. In the intermediate pressure regime, Impedans use a sophisticated model to weight the contributions from OML and ABR theory based on the collisionality of the sheath.

Elimination of RF Distortion

RF chokes, with high impedance at the plasma excitation frequency (and harmonics), are installed close to the probe tips so that they float at the RF plasma potential. Stainless steel protective sleeves, which surround the probe tip sections, double as RF compensation electrodes. Thus, the probe tips are tightly coupled to the RF plasma potential, eliminating RF distortion of the IV characteristic.

DC Compensation

In some scenarios, biasing of the probe tip can cause the DC level of the plasma potential to shift. This happens if the plasma has a poor ground return or if the current drawn is a significant fraction of the discharge current. A DC compensation electrode is used to monitor for shifts in the DC plasma potential and correct the IV characteristic accordingly. The form factor is that of a second probe tip, offset from the main tip, making it easier for maintenance and cleaning than some of the competing solutions on the market.

Designed with Productivity in Mind

Multiple operating modes make plasma measurement in various plasma reactor types possible. A basic “Time-Averaged” mode accumulates and averages IV curves for the duration configured by the user. A “Time-Trend” mode can be used to configure short IV curve accumulation times (on a time scale of **seconds**) which is repeated at set time intervals over the process duration (up to time scales of **hours**). The “Time-Resolved” mode is for fast pulsing applications (time scales of **milliseconds** and less). The user can synchronize with the plasma pulse generator and take plasma measurements as a function of time through the pulse period. Finally, a “Trigger” mode enables short-lived, single-shot, plasmas to be measured. An external trigger is fed to the Langmuir controller, which initiates data collection when the plasma ignites. A full scan can be obtained in less than a hundred microseconds. A probe tip cleaning function allows the user to clean the probe tip without breaking vacuum. An optional automated linear drive allows data collection across the plasma volume to investigate plasma uniformity or gradients. A text based scheduling function allows you to configure multiple scans, of different types, to run at particular times.

High Speed Acquisition

The Impedans Langmuir Probe System has the highest sampling speed on the market at 80 MS/s. This gives a theoretical time resolution of 12.5 ns. However, cables and the physical probe can limit the bandwidth of the system. Sub microsecond resolution can be achieved with proper setup.

Model Options

Table 1: Langmuir Probe System – Controller Options

Model #	Product Name	Current Range
02-0241-01	Langmuir Probe | Electronics Unit	1.5 µA – 1 A
02-0045-04	Langmuir Probe | Electronics Unit	15 nA – 150 mA
02-0460-01	Langmuir Probe | Electronics Unit	1.5 nA – 15 mA
02-0502-01	Langmuir Spatial | Electronics Unit	1.5 µA – 1 A
02-0503-01	Langmuir Spatial | Electronics Unit	15 nA – 150 mA
02-0504-01	Langmuir Spatial | Electronics Unit	1.5 nA – 15 mA

Table 2: Langmuir Probe System – Rigid Probe Options

Model #	Product Name	Description
02-0144-02	Langmuir Probe | Fixed Probe 10mm | <1m	10 mm OD, rigid, alumina shaft (< 1 m length)
02-0463-01	Langmuir Probe | Fixed Probe 6.5mm | <1m	6.5 mm OD, rigid, ceramic coated stainless steel shaft (< 1 m length)

Table 3: Langmuir Probe System – Flexible Probe Options

Model #	Product Name	Description
02-0501-01	Langmuir Probe | Feedthrough for flexible shaft models	Feedthrough for flexible Langmuir Probes
02-0466-01	Langmuir Probe | Flexible 10 mm Shaft	Rigid tip section with flexible ceramic beaded cable
02-0467-01	Langmuir Probe | Flexible 6.5 mm Shaft	Rigid tip section with flexible ceramic beaded cable

Table 4: Optional Accessories

Accessory	Part number
Mach Probe	AOR[1]
Planar Probe	AOR
Spherical Probe	AOR
90^0 Elbow Kit	AOR
Elbow Extensions	AOR
Replacement Ceramic Coated Shafts	AOR
Water Cooled Probes	AOR
Customization	AOR

[1] Available on request.

Table 5: Langmuir Probe System – Linear Drive Options

Model #	Product Name	Stroke Length
02-0468-01	150mm Linear Drive	150 mm
02-0033-04	300mm Linear Drive	300 mm
02-0034-04	450mm Linear Drive	450 mm
02-0035-04	600mm Linear Drive	600 mm
02-0469-01	900mm Linear Drive	900 mm

Figure 1: Standard 300mm linear drive.

Table 6: Model 02-0144-02 - Probe Head Replacement Parts

Model details	Replacement parts	
02-0144-02 Langmuir Probe | Fixed Probe 10mm | <1m 	02-0470-01 Single Probe Tip Holder	
	02-0471-01 Double Probe Tip Holder	
	Reference probe tip (02-0461-01 Tungsten) (02-0462-01 Platinum)	
	Measurement probe tip (02-0505-01 Tungsten) (02-0506-01 Platinum)	
	05-0334-02 Tip Cover	

Table 7: Model 02-0463-01 - Probe Head Replacement Parts

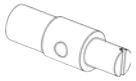
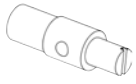
Model details	Replacement parts	
02-0463-01 Langmuir Probe | Fixed Probe 6.5mm | <1m 	05-0145-01 Single Probe Tip Cover	
	05-0144-01 Single Probe Tip Holder	
	Probe tip (Tungsten 02-0464-01) (Platinum 02-0465-01)	

Table 8: Flexible Probe

Base Feedthrough	Flexible Probe Options	Replacement parts	Image
02-0501-01 Langmuir Probe | Feedthrough for flexible shaft models 	02-0466-01 Langmuir Probe | Flexible 10 mm Shaft 	02-0470-01 Single Probe Tip Holder	
		02-0471-01 Double Probe Tip Holder	
		Reference probe tip (02-0461-01 Tungsten) (02-0462-01 Platinum)	
		Measurement probe tip (02-0505-01 Tungsten) (02-0506-01 Platinum)	
		05-0334-02 Tip Cover	
	02-0467-01 Langmuir Probe | Flexible 6.5 mm Shaft 	05-0145-01 Single Probe Tip Cover	
		05-0144-01 Single Probe Tip Holder	
		Probe tip (Tungsten 02-0464-01) (Platinum 02-0465-01)	

Parameters Reported

Table 9: Plasma parameters reported by the Langmuir Probe System

Parameter	Description	Units
V_p	Plasma Potential (DC Level)	V
V_f	Floating Potential (DC Level)	V
kT_e	Electron Temperature	eV
J_e	Electron Current Density	Am^{-2}
N_e	Electron Density	m^{-3}
J_p	Ion Current Density	Am^{-2}
N_i	Ion Density	m^{-3}
L_d	Debye Length	µm
I_{sat}	Ion Saturation Current	mA
EEPF	Electron Energy Probability Function	$m^{-3}eV^{-3/2}$
N_e (EEPF)	Electron Density from EEPF	m^{-3}
E (EEPF)	Average Energy of EEPF	eV
kT_e (EEPF)	Electron Temperature from EEPF	eV

Table 10: Langmuir Probe System graphical displays

Graph Type	Description	Mode
IV Characteristic	Current versus voltage characteristic	TA[2], TT[3], TR[4]
dI/dV	First derivative of the IV characteristic	TA, TT, TR
d^2I/dV^2	Second derivative of the IV characteristic	TA, TT, TR
EEPF	Electron energy probability function	TA, TT, TR
Parameter trend	Parameter versus time or space	TT, TR
I_{sat} trend	High speed I_{sat} trend	TT, TR

[2] Time Average Mode
[3] Time Trend Mode
[4] Time Resolved Mode

Specifications

Table 11: General Controller Specifications

Controller Environmental Specifications	
Mains voltage	100 – 200 V AC
Mains Current	1.6 A AC
Mains frequency	47 – 63 Hz
Installation category	II
Pollution degree	1
Max. relative humidity	95%, non-condensing
Max. operating temperature	55^0 C
Max. altitude	3000 meters
Protection rating	IP20 (IEC 60529)

Table 12: Controller Operating Specifications

Controller Operating Specifications	
Voltage Scan Range	-150 V to +150 V
Current Range	See table 1
Connectivity	USB 2.0
PC Operating System	Windows 2000 / XP / Vista / 7 / 8 / 10
Sampling Rate	80 MS/s
Data Acquisition Resolution	$16\ bit$
Time Resolved Step Resolution	12.5 ns
External Sync (for time resolved mode)	TTL
External Trigger (for fast-sweep)	TTL
Synchronization frequency range	1 Hz to 1 MHz
Probe Electrical Connection	Tiaxial Jack or BNC Jack

Table 13: Langmuir Probe System Operating Ranges

Probe System – Plasma Parameter Ranges	
Floating Potential	-145 V to +145 V
Plasma Potential	-100 V to + 145 V
Plasma Density[5, 6]	10^6 to 10^{13} cm^{-3}
Ion Current Density[5, 6]	1 µA/cm^2 to 300 mA/cm^{-2}
Electron Temperature	0.1 to 15 eV
Electron Energy Probability Function	0 to 100 eV

[5] Dependent on probe head type and plasma conditions
[6] Assuming argon gas and electron temperature of 3 eV

Table 14: Probe Specifications

Probe Specifications	
Probe Length	300 mm to 1400 mm
Probe Shaft Diameter	Model dependent (see table 2)
Probe Tip Length[7]	10 mm
Probe Tip Diameter[7]	0.4 mm
Probe Tip Material Options[7]	W, Ta, Ni, Pt
Customization	90^0 elbows, water cooling, other
Max. Operating Temperature	Model 02-0144-02: Air cooled to 230^0 C Model 02-0144-02: No cooling to 125^0 C Model 02-0463-01: 900^0C Model 02-0501-01: 125^0C
# RF Compensation Frequencies	Max. 5
RF Compensation Frequency Options	400 kHz, 2 MHz, 13.56 MHz, 27.12 MHz, 40.68 MHz, 60 MHz
Air Cooling Inlet	4 mm tube push fit
Max. Compressed Air Pressure	4 Bar

Table 15: Compatible Plasma Conditions

Compatible Plasma Conditions	
Plasma Reactor Types	DC, Pulsed DC, MF, RF, Pulsed RF, Microwave, Atmospheric[8] Plasmas
Gas Chemistry	Inert to Reactive
Single Probe Pressure Range	High Vacuum to 10 Torr
Double Probe Pressure Range	High Vacuum to Atmospheric Pressure

[7] Other options available on request.
[8] Dependent on type.

Software Display

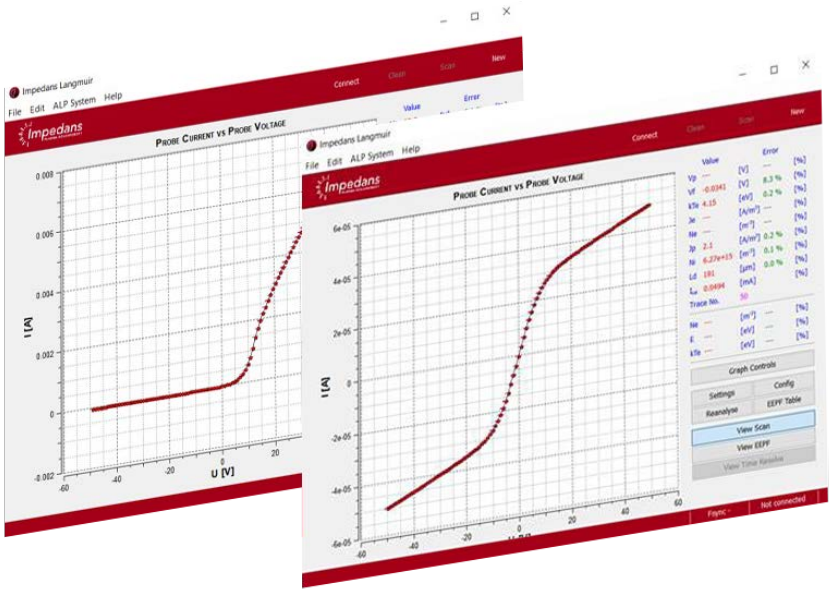


Figure 2: Typical single and double Langmuir probes IV characteristics.

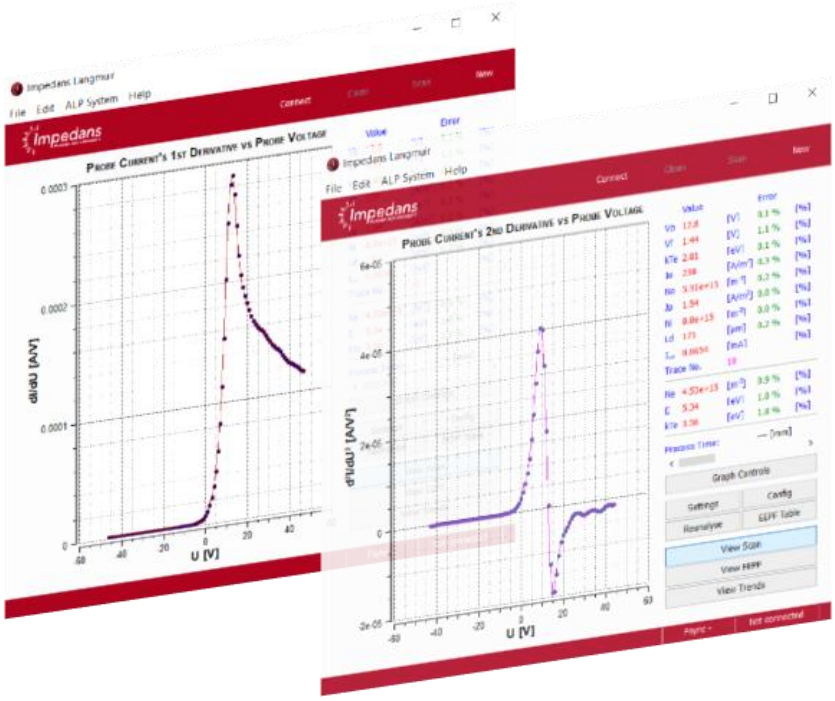


Figure 3: Example of the first and second derivative of a single Langmuir probe IV characteristic.

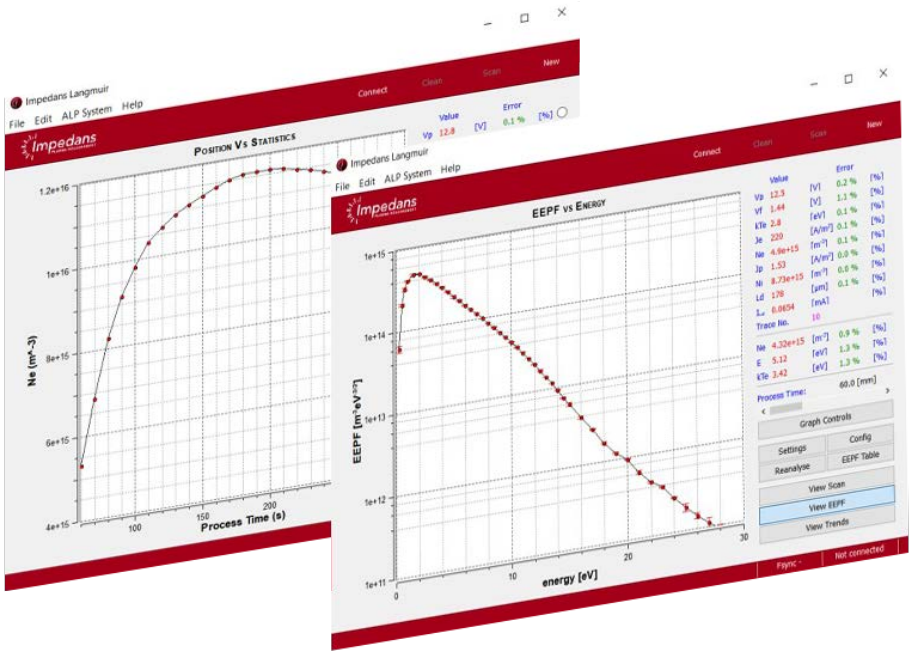


Figure 4: Example of the spatial trend of electron density and a sample EEPF calculated from the second derivative.