

A photograph of a Moduli RF Spectrometer device, which is a small, rectangular, metallic instrument mounted inside a larger, textured metal enclosure. The device has a prominent logo on its top surface that reads "Impedans" with "PLASMA MEASUREMENTS" underneath. The device is connected to various cables and components within the enclosure.

# Moduli RF Spectrometer

Non-invasive fault detection and chamber health monitoring

<https://impedans.com/moduli-rf-spectrometer>

# The Moduli RF Spectrometer

Measure the harmonic spectrum emitted by the plasma for many applications

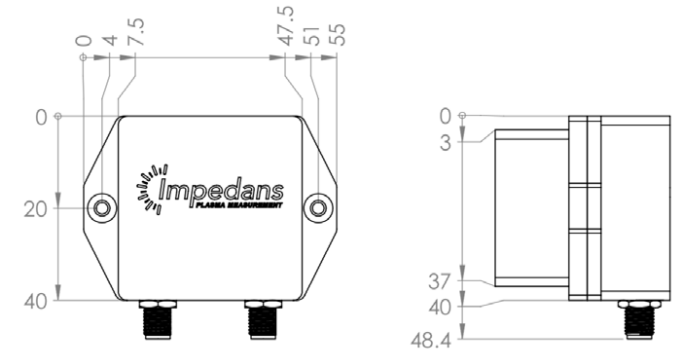
The Moduli "RF Spectrometer" is an RF antenna that can be mounted outside the chamber window to monitor the plasma directly. It can be programmed as a VI probe, monitoring the harmonic spectrum, or as an event detector to detect arcs and monitor pulses.

## Parameters Measured:

- ✓ E-field and B-field leakage from a plasma chamber (uncalibrated)
- ✓ In VI probe mode, it can measure the harmonic spectrum, phase and harmonic phase in addition to E and B field channels
- ✓ In event detect mode, it has the same features as the Alfven

## Moduli Applications (VI Mode)

- ✓ The following have been demonstrated in the field with this sensor
- ✓ Wafer misplacement detection
- ✓ Gas flow issue detection
- ✓ Chamber clean endpoint
- ✓ Chamber etch endpoint
- ✓ Fault fingerprinting



# The Moduli RF Spectrometer

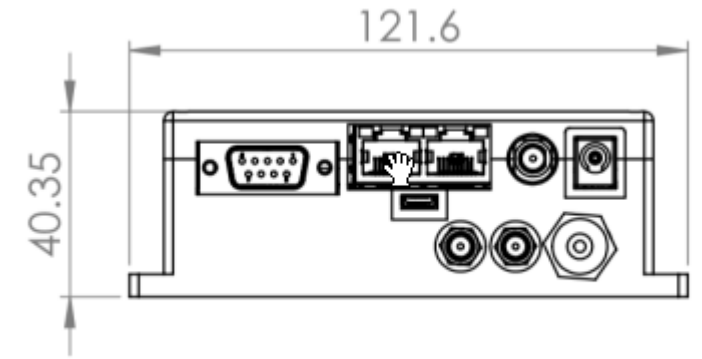
Non-invasive fault detection and chamber health monitoring

## Non-invasive

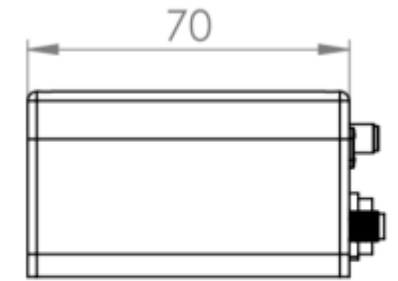
- ✓ Can be installed on a plasma chamber window or close to the matchbox fan externally
- ✓ Can be installed inside a match box, but not in-line, so it's entirely non-intrusive
- ✓ Many APIs for easy tool integration
- ✓ Special antennas available for modern, shielded tools (100x sensitive, or Opto-RF)

## Communication Protocols

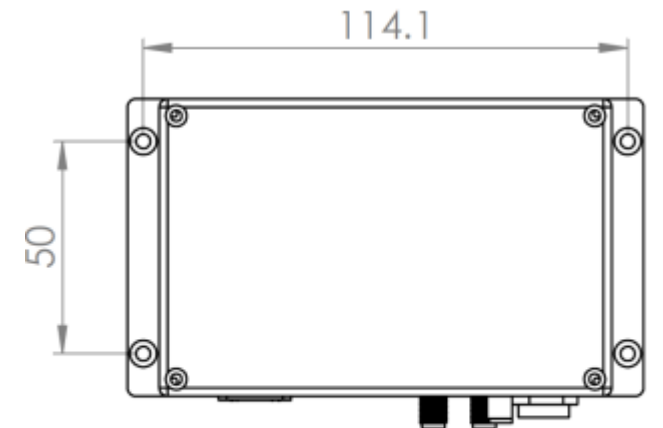
- ✓ USB
- ✓ Ethernet
- ✓ EtherCAT
- ✓ RS232
- ✓ Full APIs available for all.
- ✓ LabView interface also available
- ✓ Smart Phone display available
- ✓ Fully field upgradable



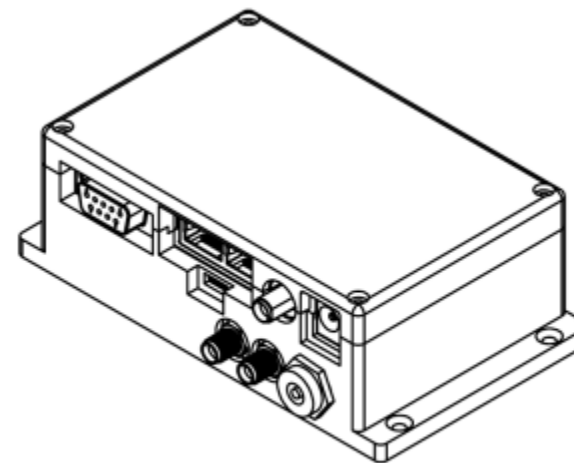
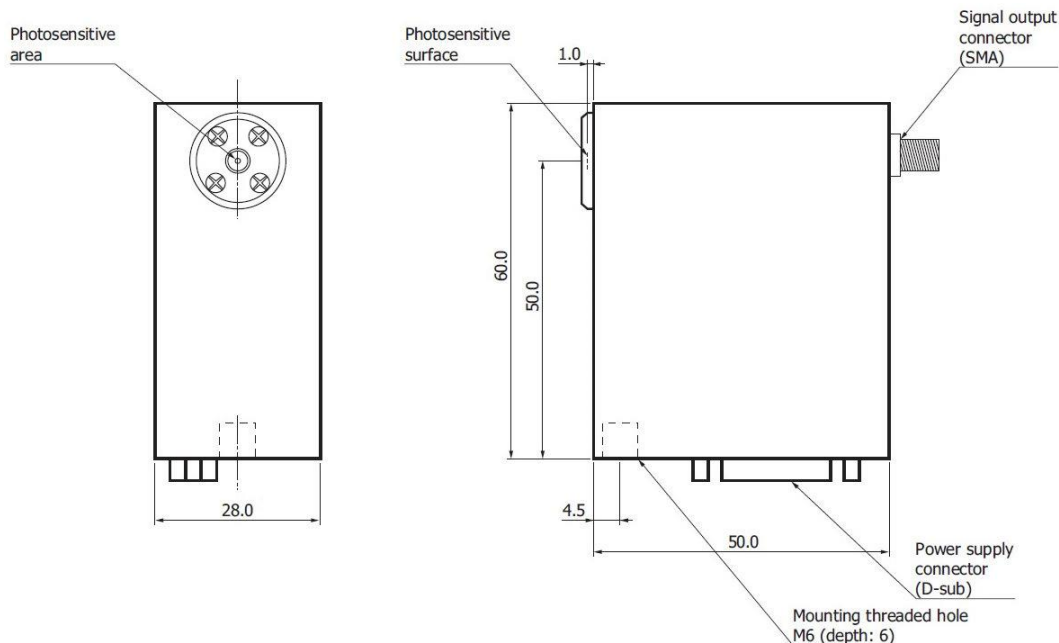
Front View



Side View



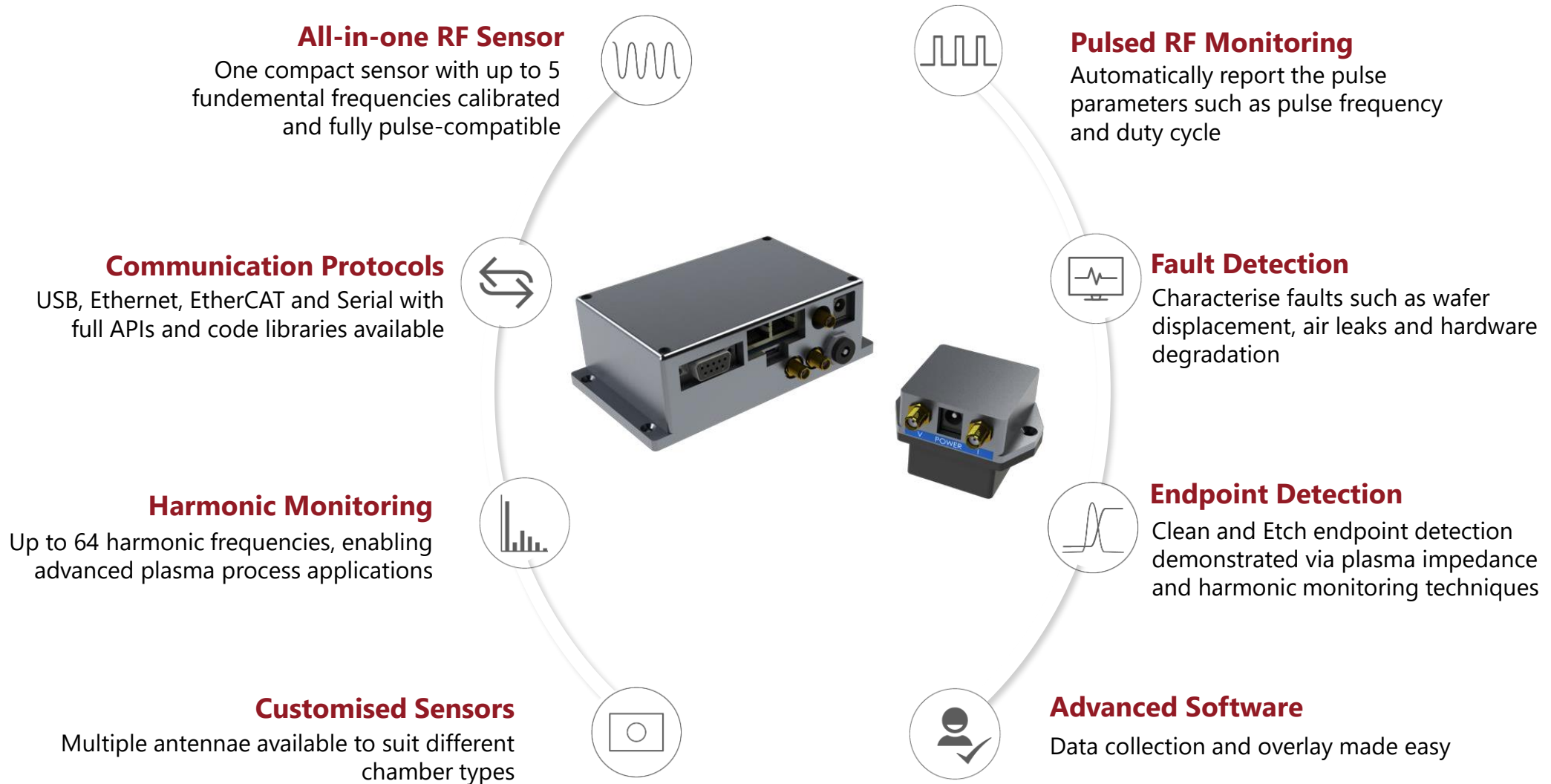
Plan View



Isometric View

Impec

# Key Features

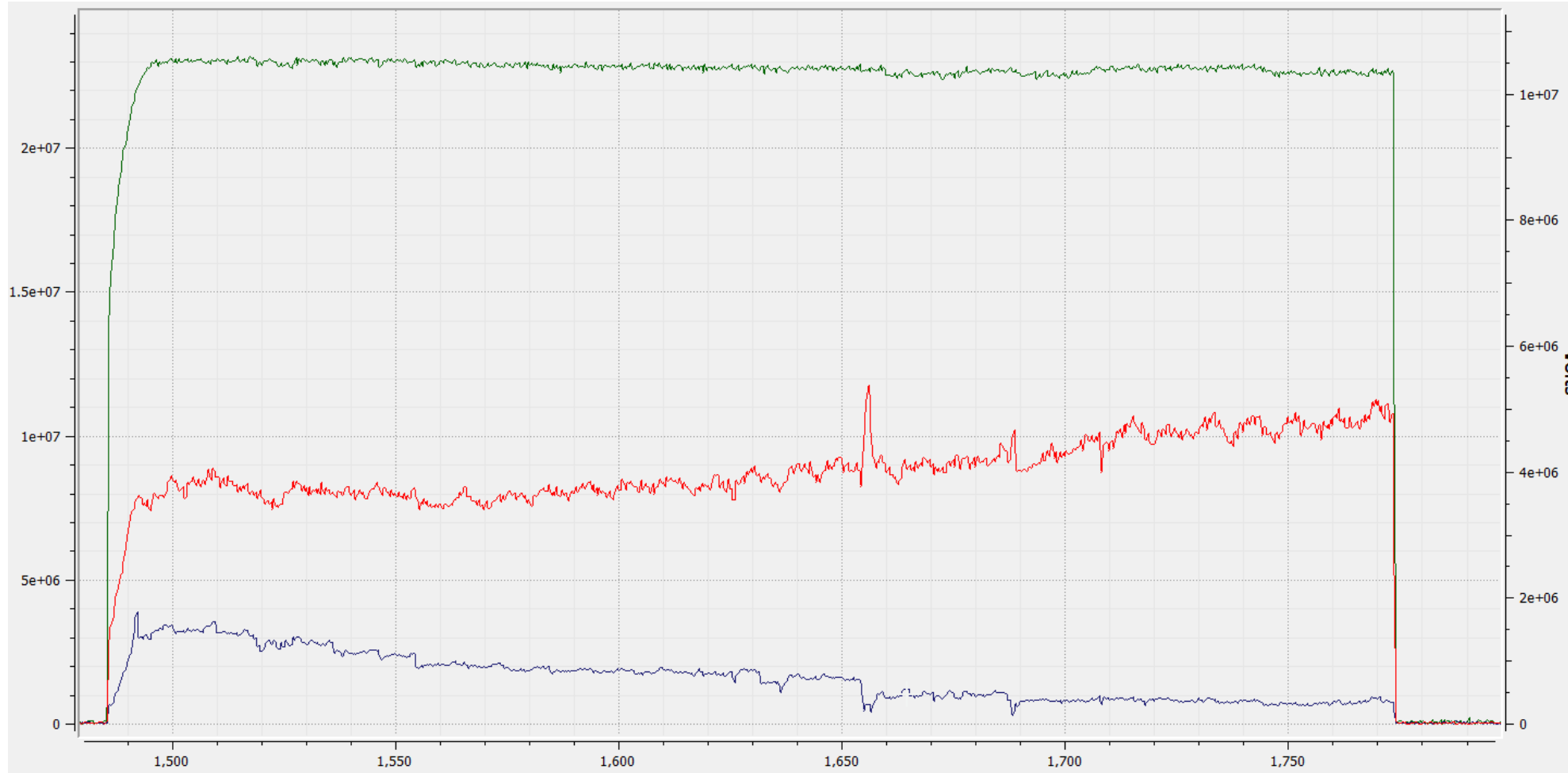


# Technical Specifications

Parameters Measured	Range
Frequency Range (Fundamental) - choose 5 from the frequency range	40 kHz → 400 kHz 350 kHz → 100 MHz
Harmonic Frequency range	40 kHz → 2 MHz 350 kHz → 500 MHz
# Harmonic Frequencies	< 15 <i>per fundamental</i> (64 max.), < 32 <i>simultaneously</i>
Output Parameters at each frequency	V & I [UNCALIBRATED]. phase, harmonic phase
Pulsed RF Profiling	1 microsecond time resolution
In-Pulse Parameter Monitoring	Up to 2 points in the pulse [standard software], arbitrary number of points using API
Pulsed RF Range	10 Hz to 100 kHz
Extra Features	RF Waveform Reconstruction
V channel range	Arbitrary [adjustable gain]
I channel range	Arbitrary [adjustable gain]
Phase Range	±180°
Phase Resolution	0.02° resolution
Harmonic Phase Range & Resolution	±180° with 0.02° resolution

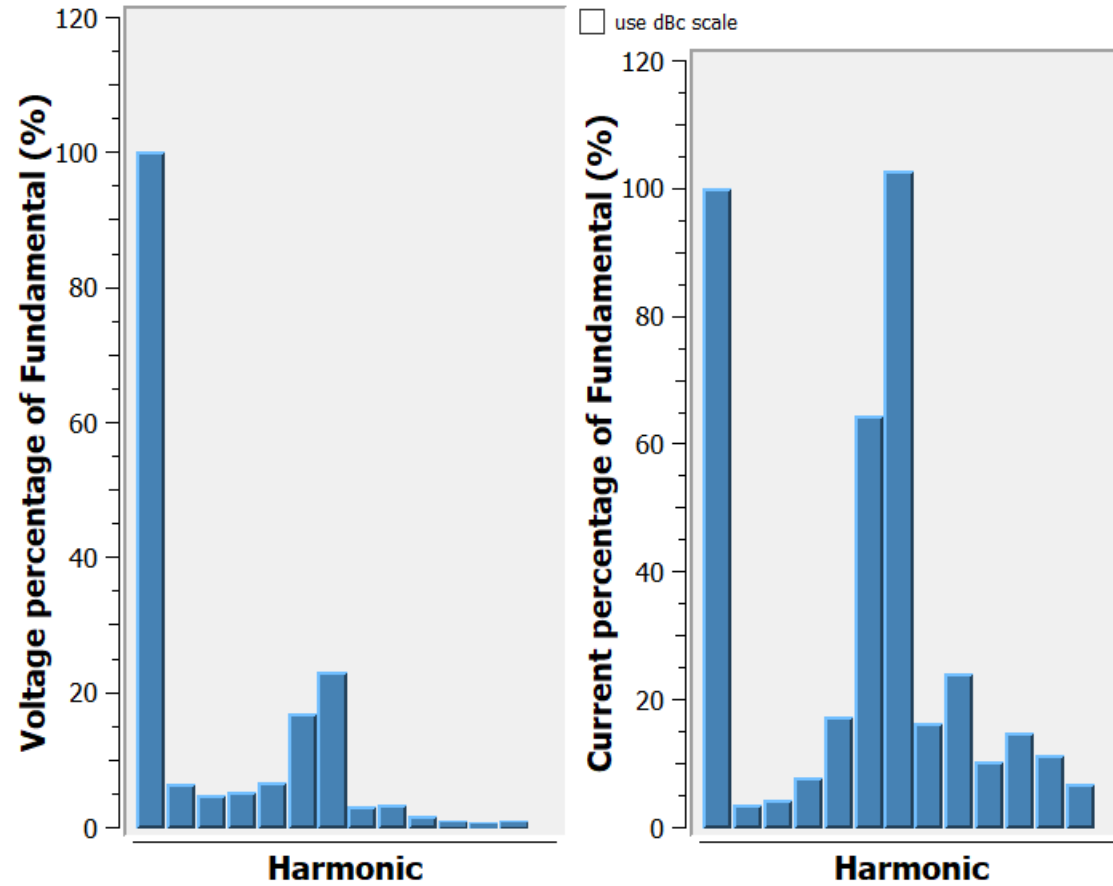
✓ To arrange a technical discussion, contact [support@impedans.com](mailto:support@impedans.com)

# Example Data: Channel amplitudes vs time



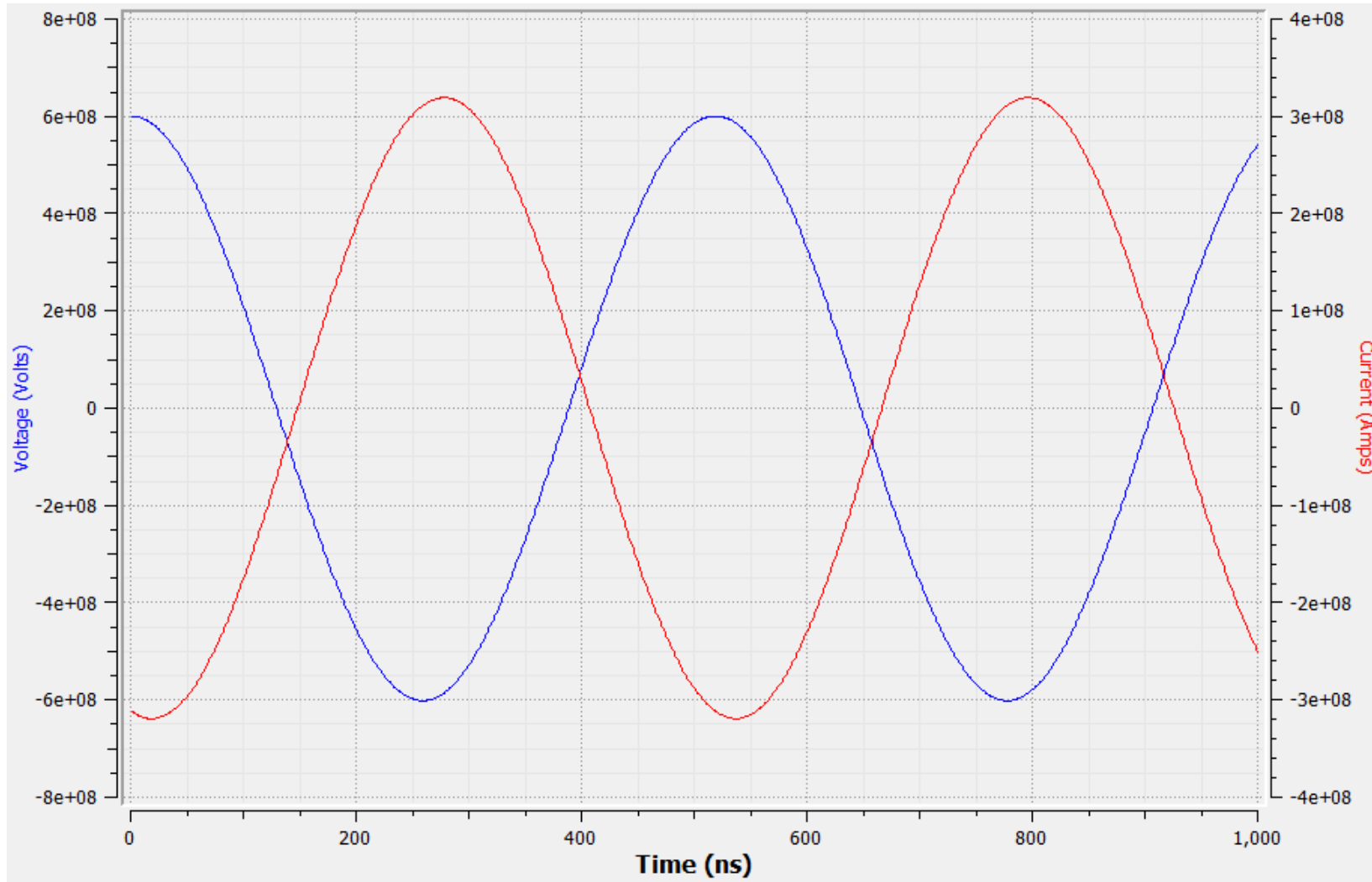
*Example of Voltage data from the Moduli at 13.56 MHz and its 3<sup>rd</sup> and 5<sup>th</sup> harmonics*

# Example Data: Harmonic Profiles



*Example of the harmonic profile for voltage and current as shown in the software*

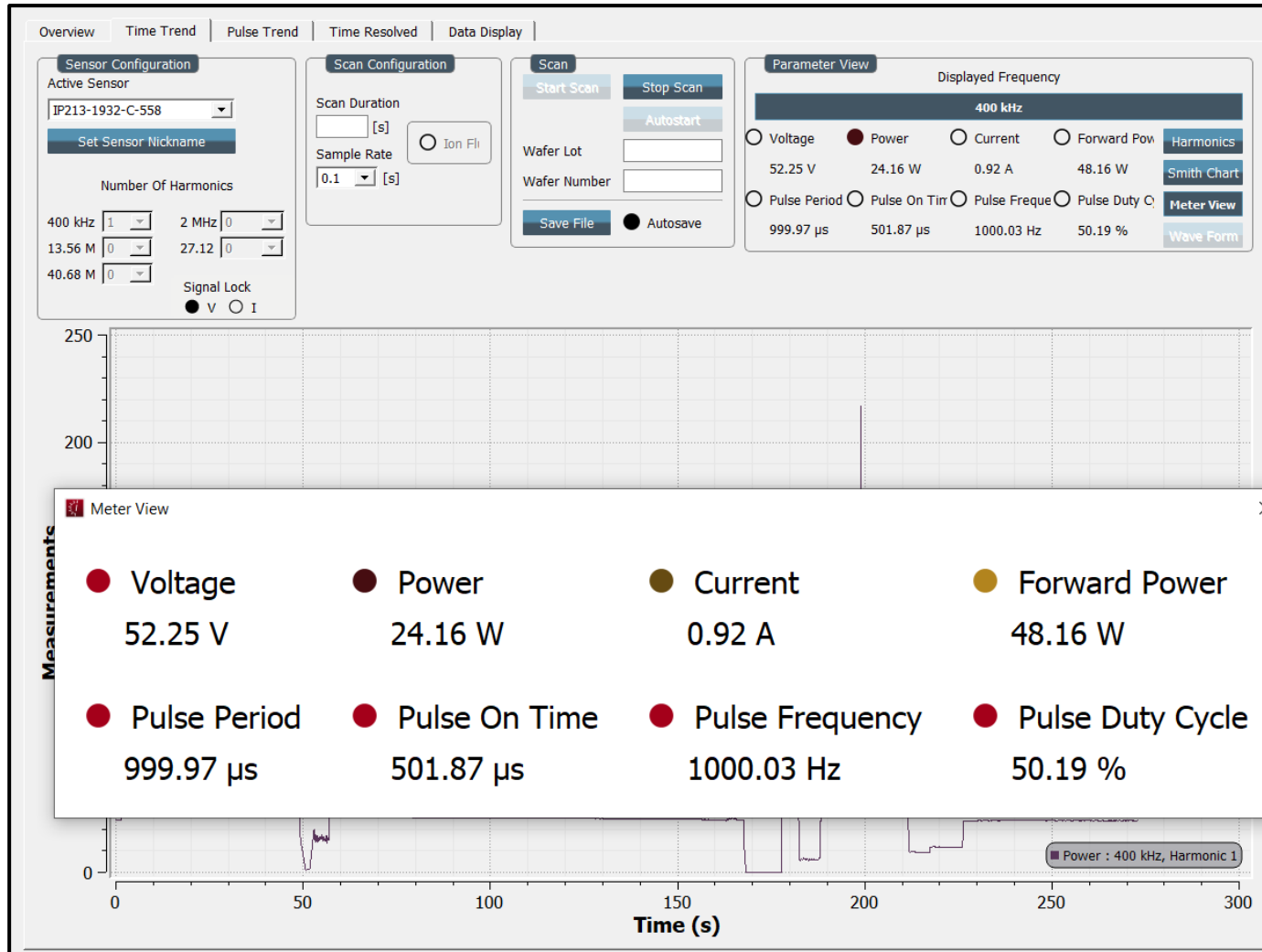
# Example Data: Waveform Reconstruction



*Example of the Waveform reconstruction for the Voltage and Current channels*



# Example Data: Pulsed RF Parameters



*Example of live pulse frequency and duty cycle monitoring*

# Moduli Applications

# Application - Clean and Etch Endpoint Detection

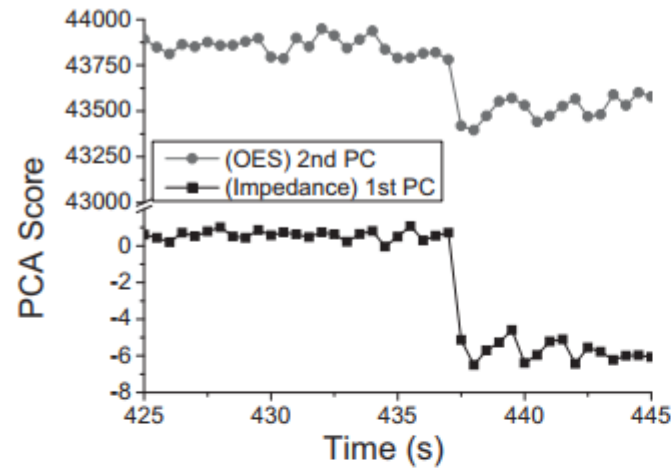
## Real-Time Endpoint Detection of Small Exposed Area SiO<sub>2</sub> Films in Plasma Etching Using Plasma Impedance Monitoring with Modified Principal Component Analysis

Principle component analysis (PCA) was used to combine all the data from an Octiv sensor vs all the optical channels from an OES.

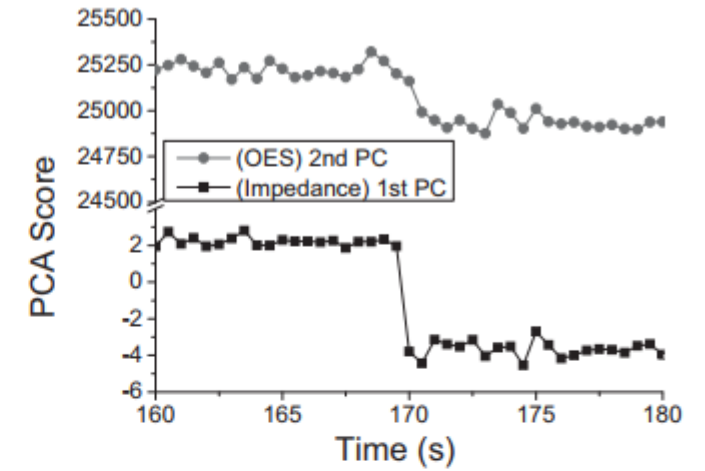
Etch endpoint was measured for various open areas, from 2% down to 0.5%

Monitoring RF had at least twice the sensitivity compared to multivariate OES techniques

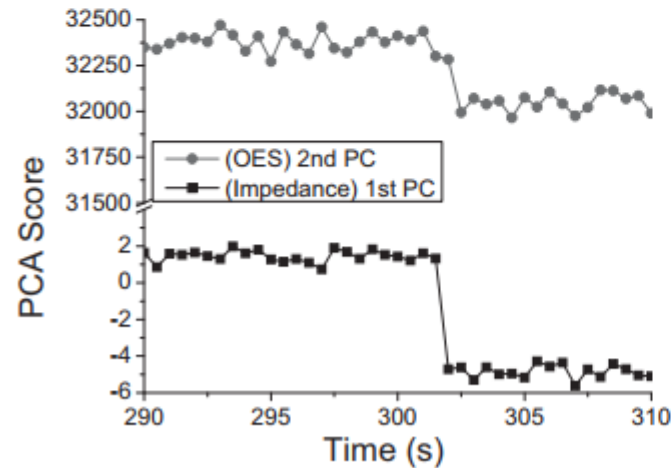
The Moduli RF Spectrometer gets equivalent data from monitoring the RF leaking from the chamber. Below 1% open area ratio etch endpoint detection has been demonstrated in the field.



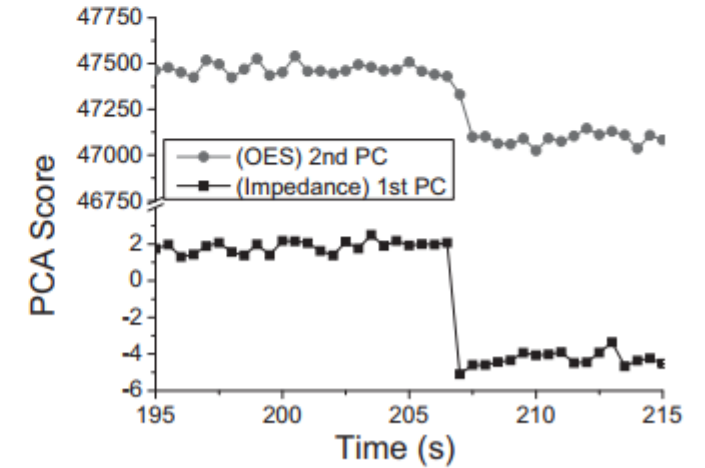
(a) 2.0% oxide area target wafer



(c) 1.0% oxide area target wafer



(b) 1.5% oxide area target wafer



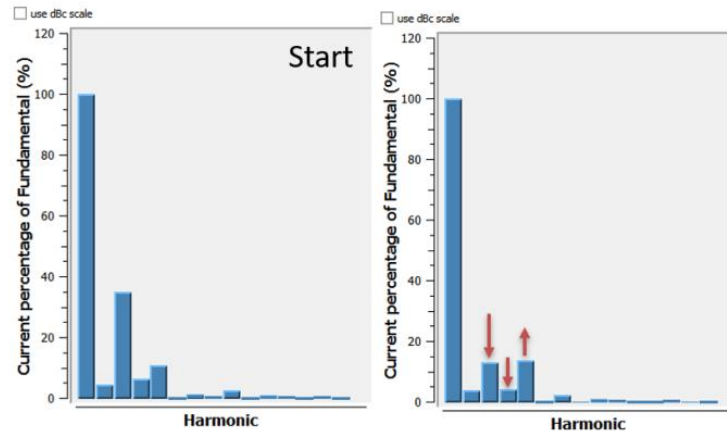
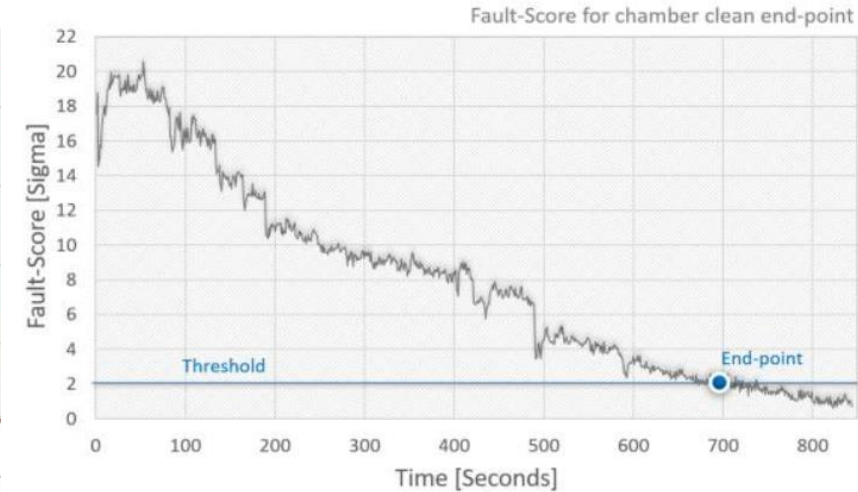
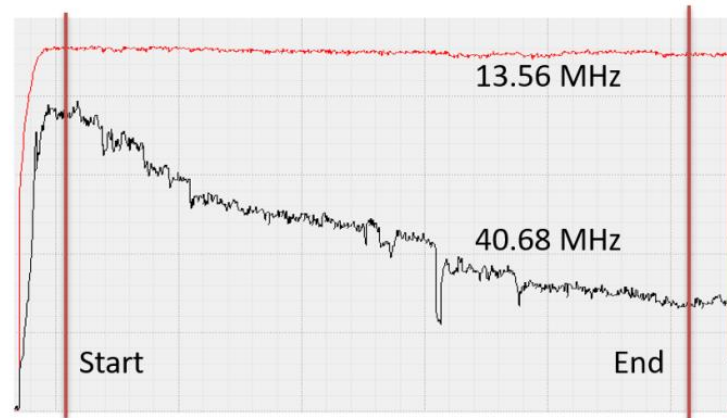
(d) 0.5% oxide area target wafer

# The Moduli RF Spectrometer

Endpoint detection that exceeds OES available from the same plasma viewport

## Clean Endpoint:

- In this experiment the Antenna was mounted outside a viewport with the RF shielding removed
- The chamber cleaning process was run on a clean chamber, to get a baseline
- Deposition processes were run on the chamber
- Then, a real clean was done
- Shown in the graph is how the harmonic spectrum changed during the clean, highlighted by red arrows
- Using the baseline, Fault Score was used to show the clean endpoint (when the coated chamber returned to within 2 Sigma of a clean chamber)



# Application - Fault Detection – Air Leak Detection

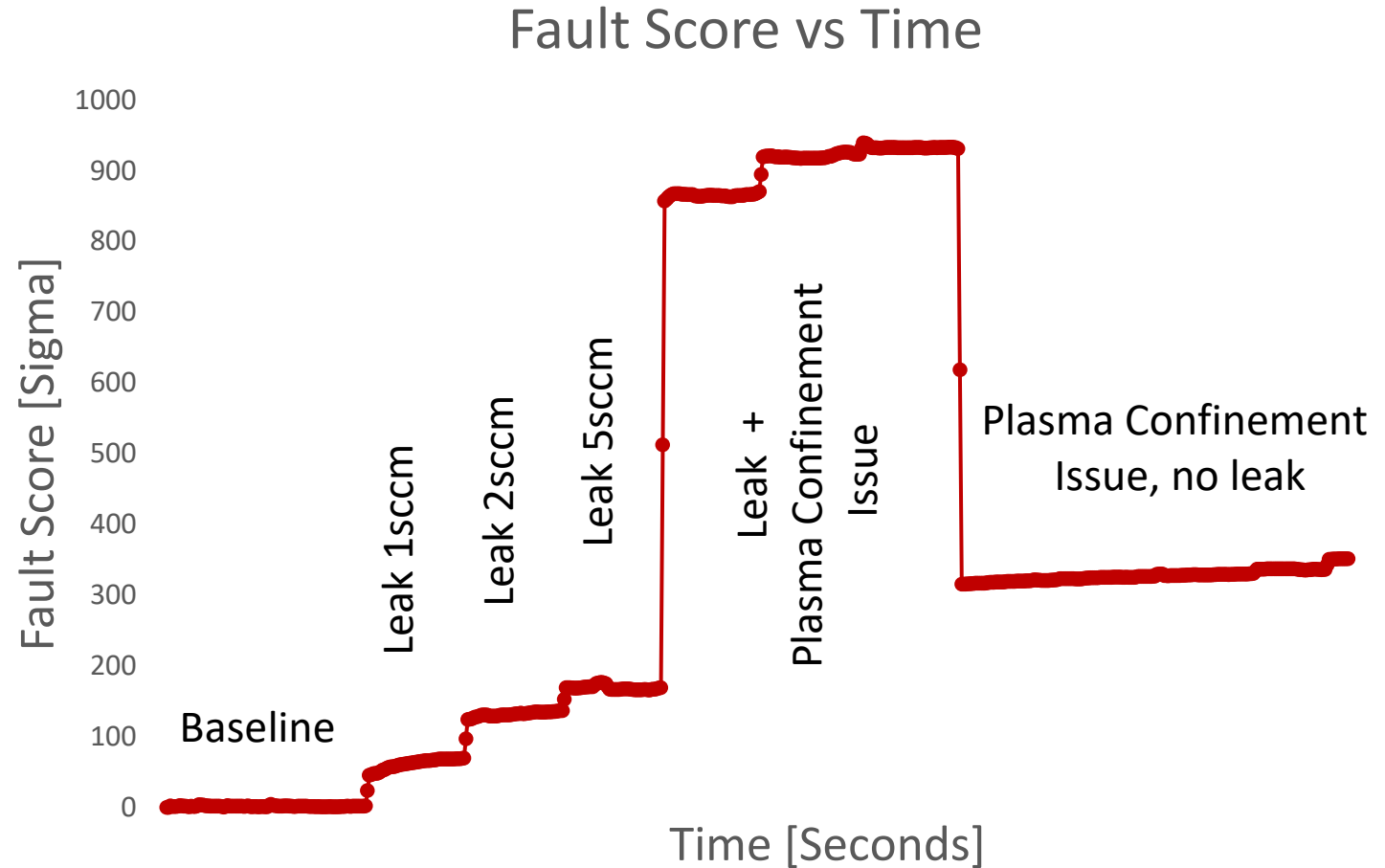
## Detection of an air leak

Real time detection of a change in gas, here due to an unwanted air leak into the chamber

Some example data is shown to the right

When a large amount of extra air was present, the plasma expanded out into the windows, hence the very large jump in the Fault Score. The extra plasma remained after the air leak was removed

This is detectable due to the change in the plasma impedance and in the plasma harmonic emissions



*Examples of the effect of the introduction of an air leak on the statistical score*

# Impedans Ltd

Chase House, City Junction Business Park, Northern Cross,  
Dublin 17, D17 AK63, Ireland

Ph: +353 1 842 8826

Fax: +353 1 871 2282

Web: [www.impedans.com](http://www.impedans.com)

Email: [support@impedans.com](mailto:support@impedans.com)

