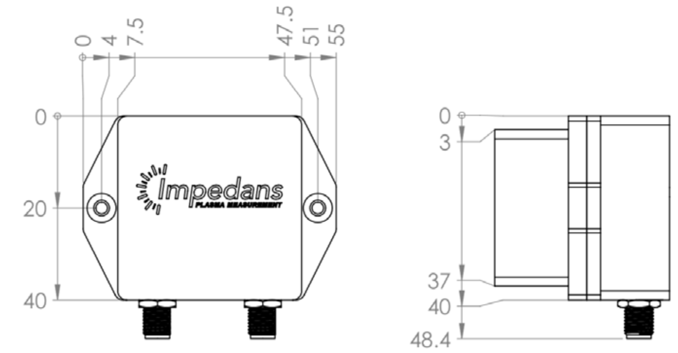
Moduli RF Spectrometer

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



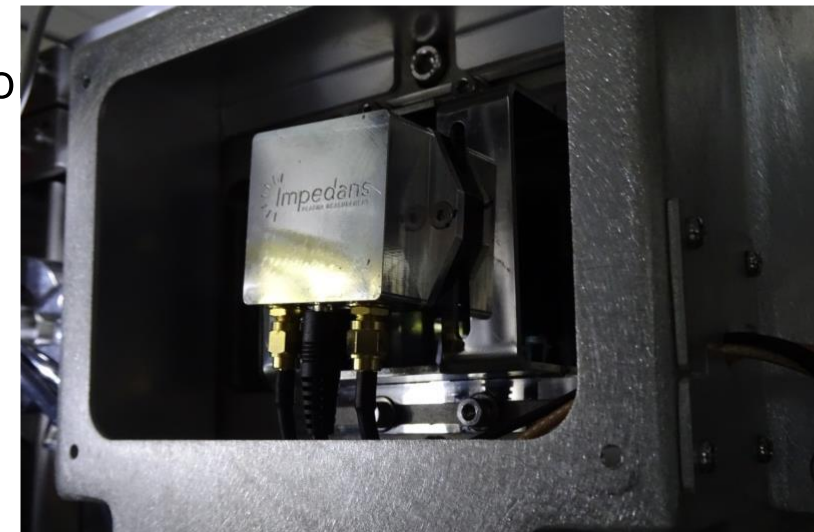
The Moduli "RF Spectrometer" is an RF antenna that can be mounted outside the chamber window to monitor the plasma directly. It can be programmed as a VI probe, monitoring the harmonic spectrum, or as an event detector to detect arcs and monitor pulses.

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 detectio
- ✓ Gas flow issue detection
- ✓ Chamber clean endpoint
- ✓ Chamber etch endpoint
- ✓ Fault fingerprinting



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The Moduli RF Spectrometer

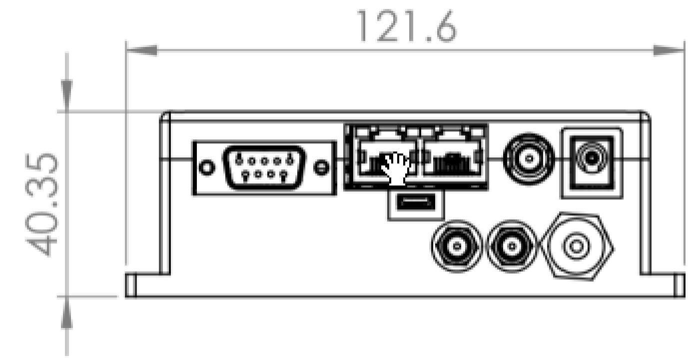
Non-invasive fault detection and chamber health monitoring

Non-invasive

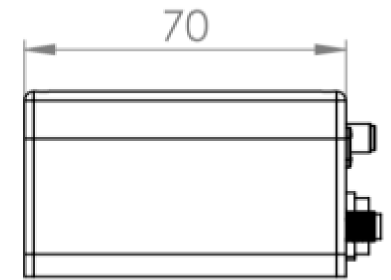
- ✓ Can be installed on a plasma chamber window or close to the matchbox fan externally
- ✓ Can be installed inside a match box, but not in-line, so it's entirely non-intrusive
- ✓ Many APIs for easy tool integration
- ✓ Special antennas available for modern, shielded tools (100x sensitive, or Opto-RF)

Communication Protocols

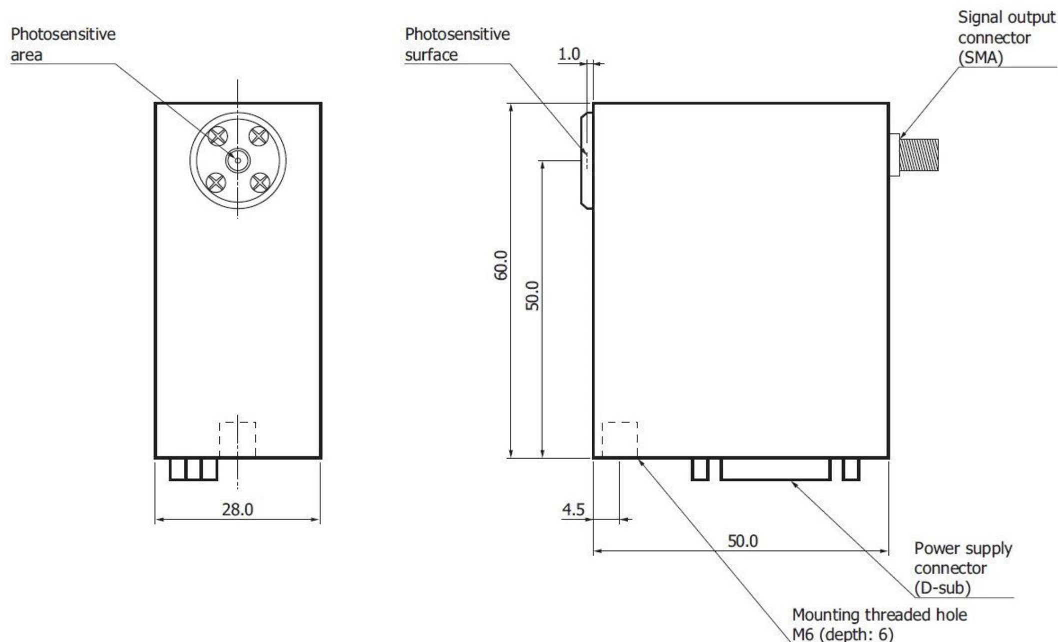
- ✓ USB
- ✓ Ethernet
- ✓ EtherCAT
- ✓ RS232
- ✓ Full APIs available for all.
- ✓ LabView interface also available
- ✓ Smart Phone display available
- ✓ Fully field upgradable

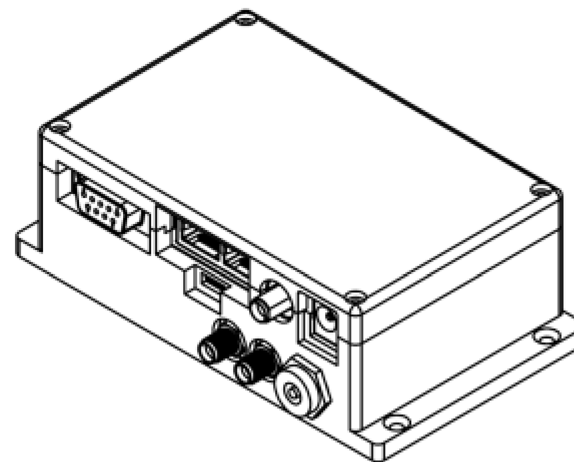


Front View



Side View





Isometric View

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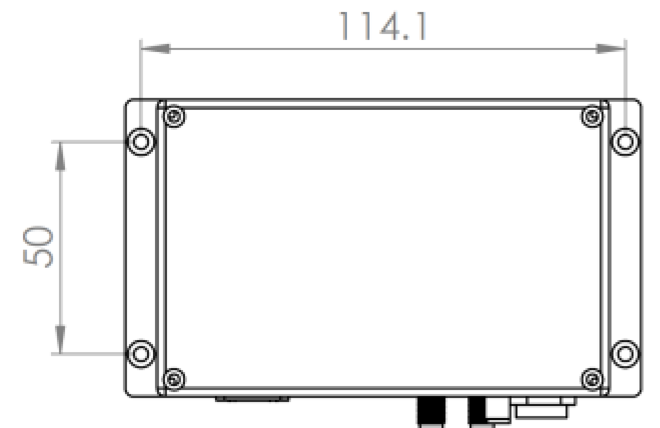
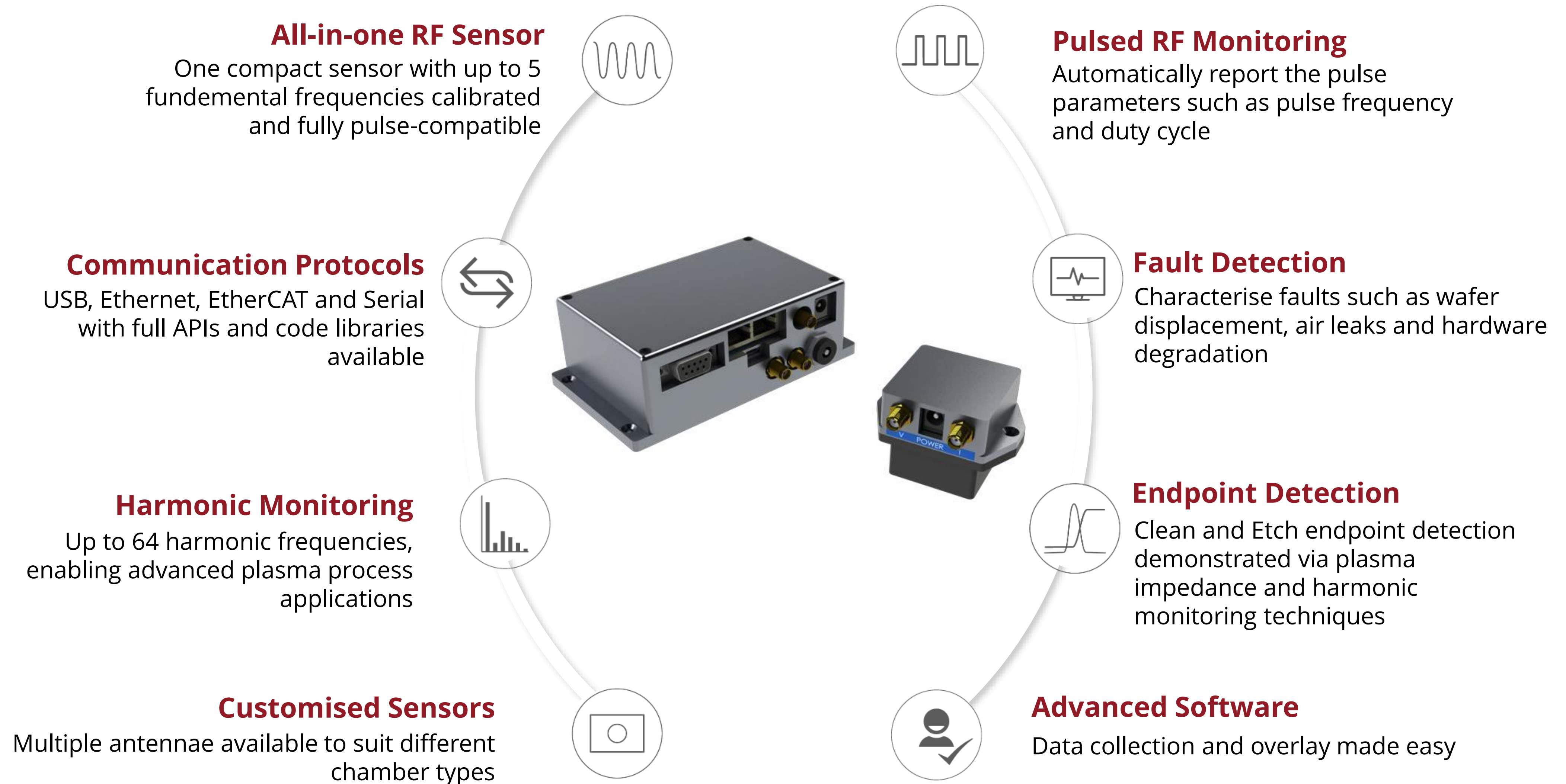


Plan View

Key Features



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Technical Specifications

Parameters Measured	Range
Frequency Range (Fundamental) - choose 5 from the frequency range	$40\ kHz \rightarrow 400\ kHz$ $350\ kHz \rightarrow 100\ MHz$
Harmonic Frequency range	$40\ kHz \rightarrow 2\ MHz$ $350\ kHz \rightarrow 500\ MHz$
# Harmonic Frequencies	$< 15\ per\ fundamental\ (64\ max.), < 32\ simultaneously$
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	$\pm 180^{\circ}$
Phase Resolution	0.02°resolution
Harmonic Phase Range & Resolution	$\pm 180^{\circ}$ with 0.02°resolution

- ✓ To arrange a technical discussion, contact support@impedans.com

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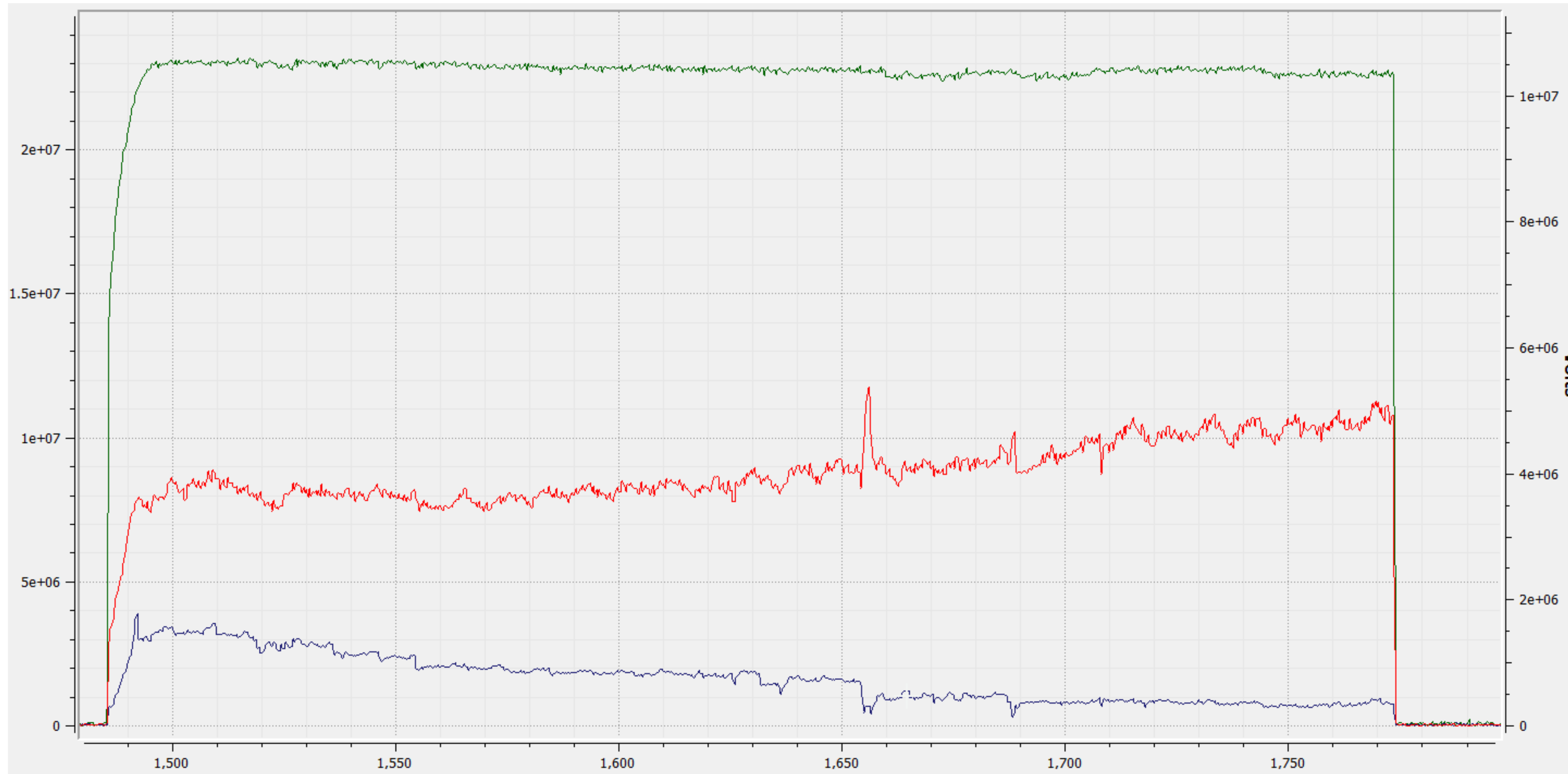
Example Data: Channel amplitudes vs time



Example of Voltage data from the Moduli at 13.56 MHz and its 3rd and 5th harmonics

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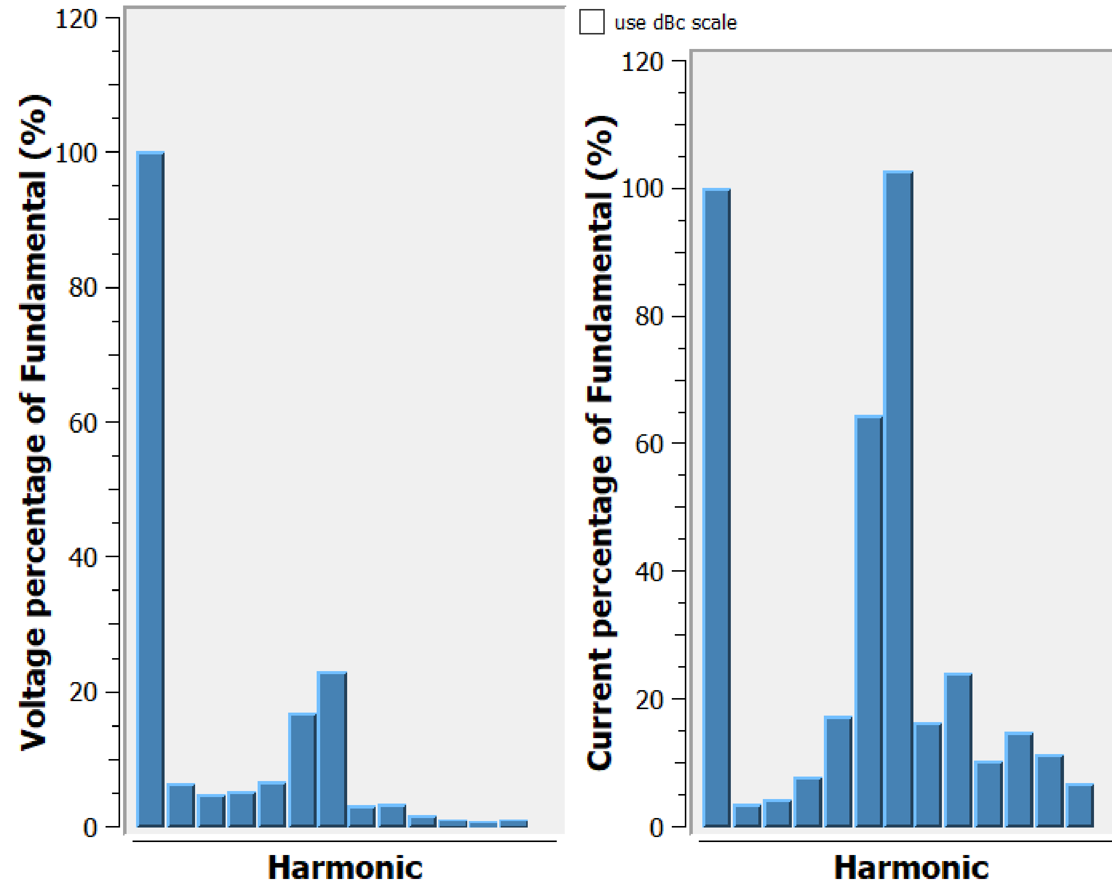
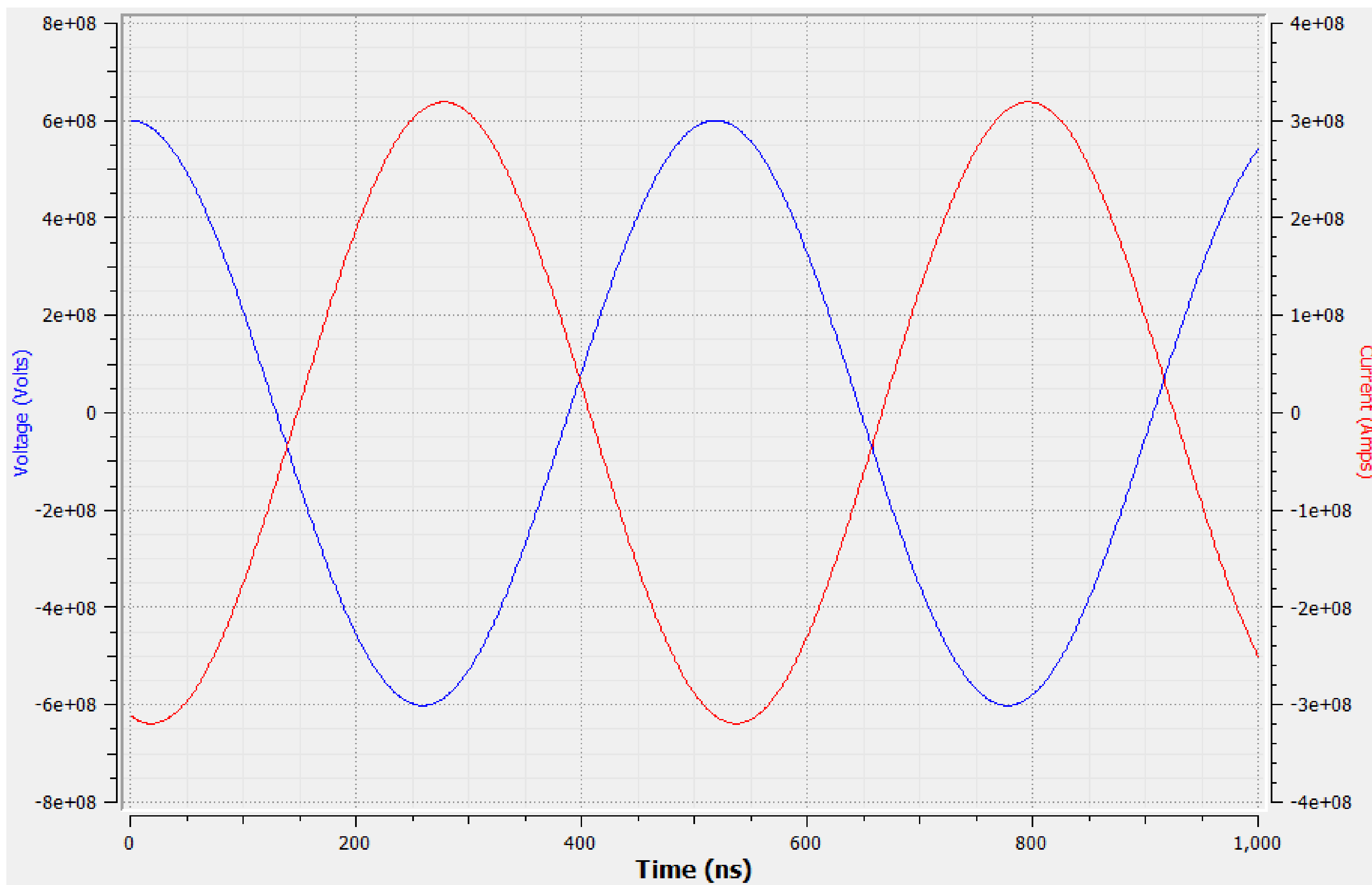
Example Data: Harmonic Profiles



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

Example Data: Waveform Reconstruction



Example of the Waveform reconstruction fot the Voltage and Current channels

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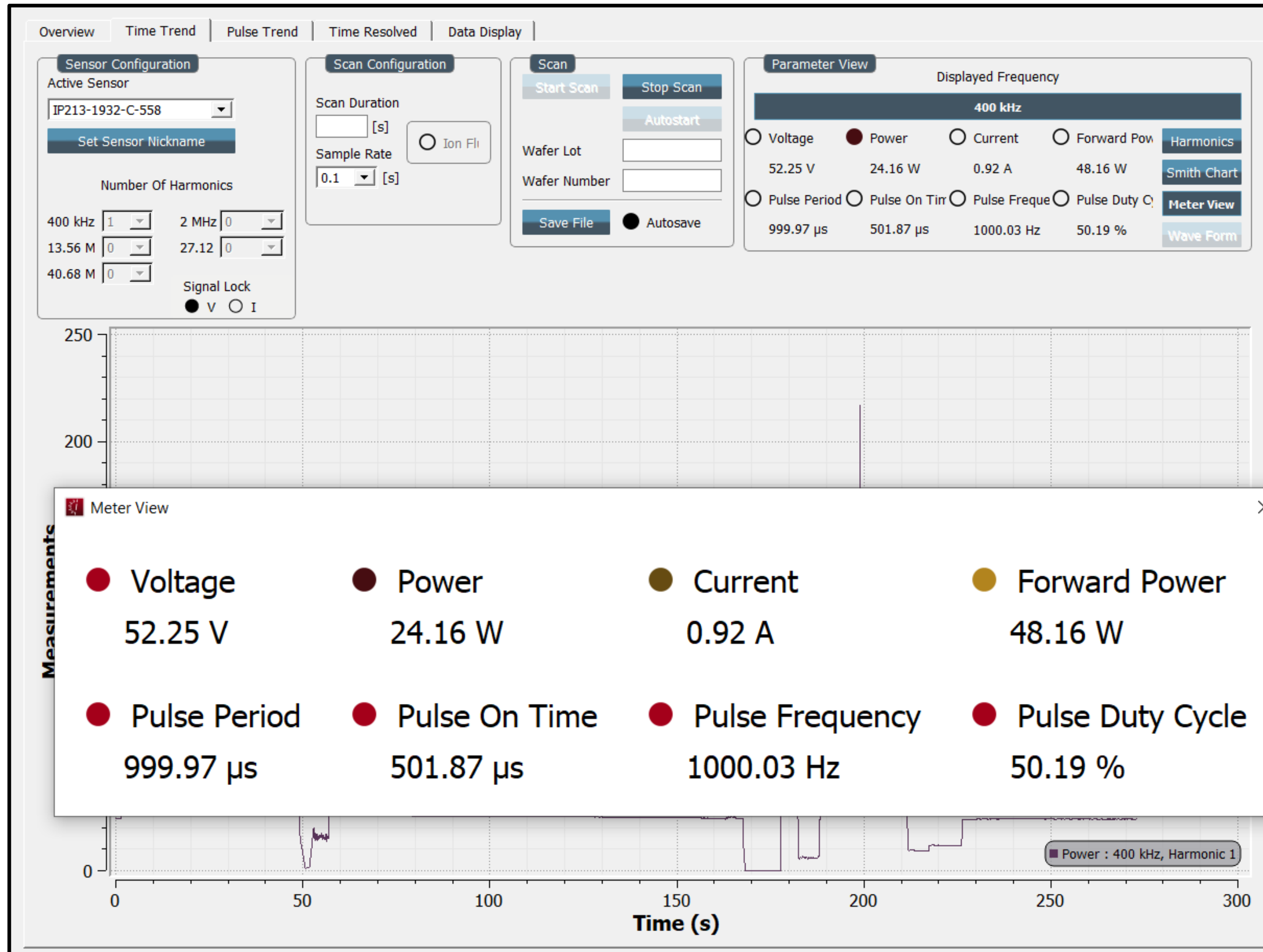
Example Data: Pulsed RF Parameters



Example of live pulse frequency and duty cycle monitoring

Moduli Applications

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Application - Clean and Etch Endpoint Detection

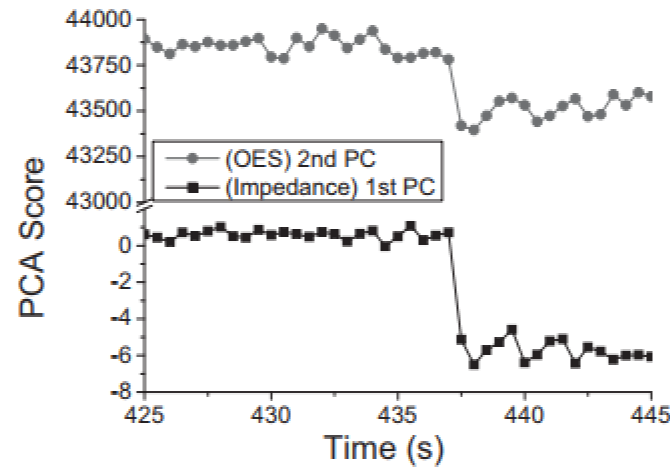
Real-Time Endpoint Detection of Small Exposed Area SiO2 Films in Plasma Etching Using Plasma Impedance Monitoring with Modified Principal Component Analysis

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

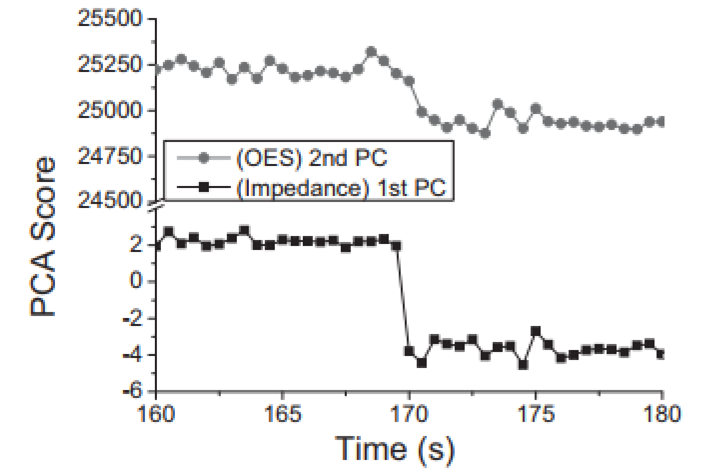
Etch endpoint was measured for various open areas, from 2% down to 0.5%

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

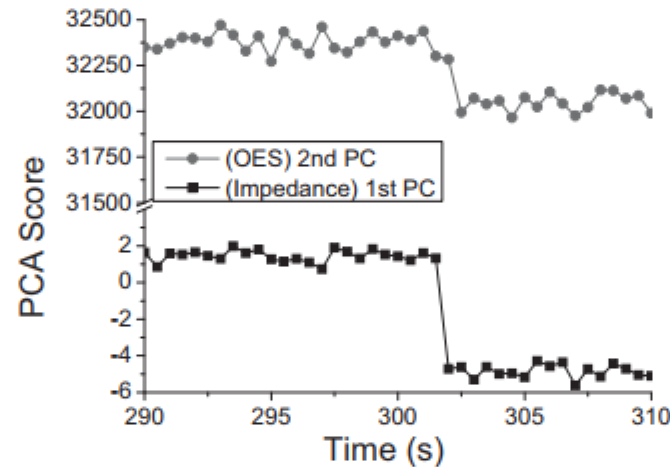
The Moduli RF Spectrometer gets equivalent data from monitoring the RF leaking from the chamber. Below 1% open area ratio etch endpoint detection has been demonstrated in the field.



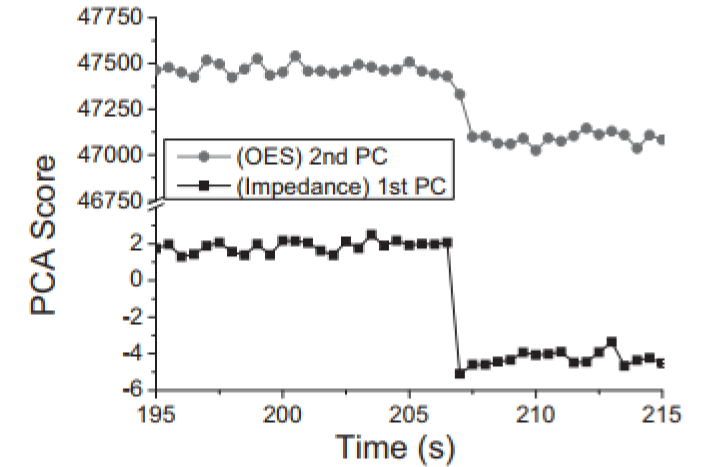
(a) 2.0% oxide area target wafer



(c) 1.0% oxide area target wafer



(b) 1.5% oxide area target wafer



(d) 0.5% oxide area target wafer

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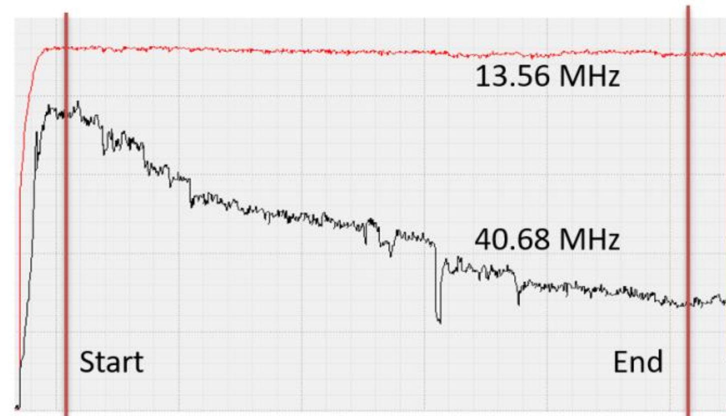
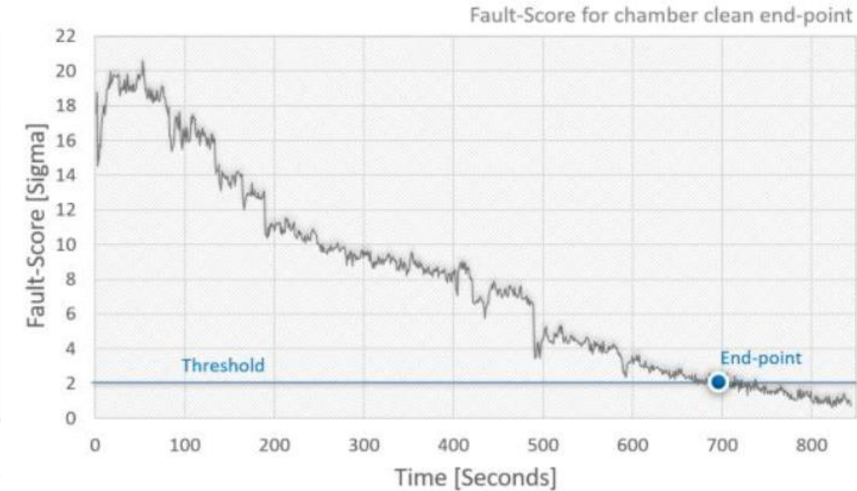
The Moduli RF Spectrometer

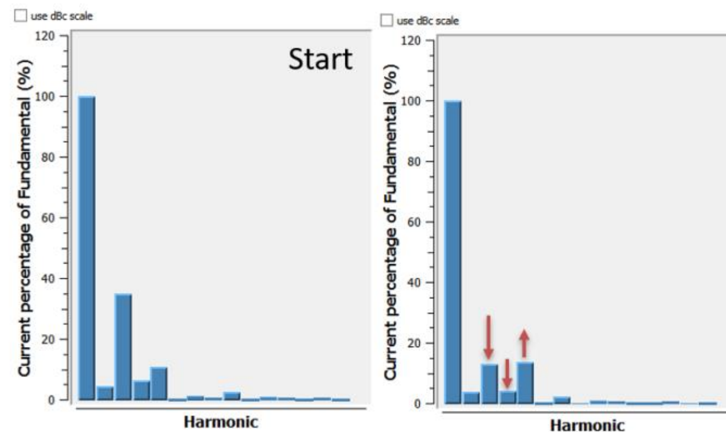
Endpoint detection that exceeds OES available from the same plasma viewport

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

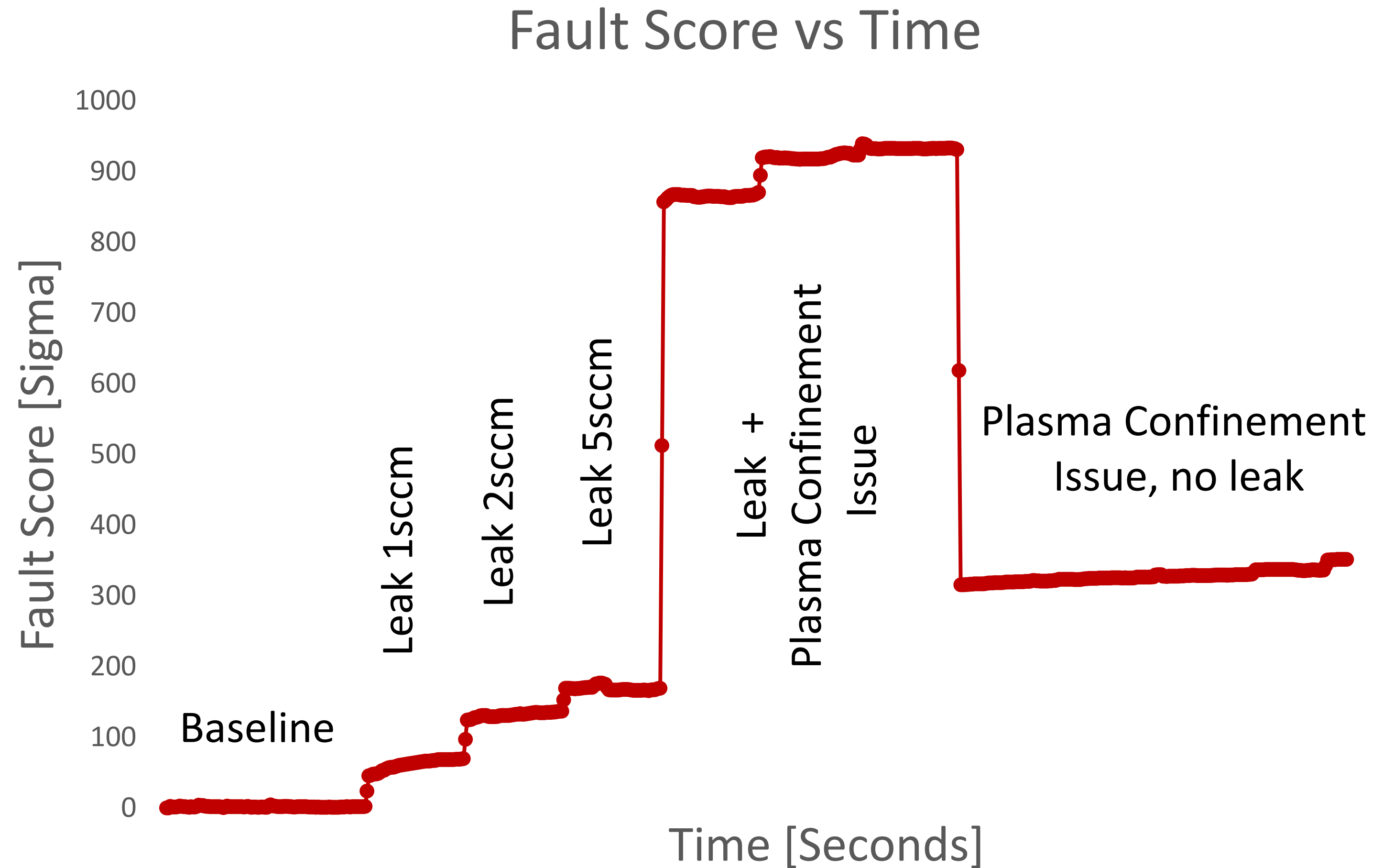
Detection of an air leak

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

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