Using the Luna ODiSI: High-Density Strain and Temperature Data Improves Testing and Process Monitoring

Aida Rahim, PhD
Senior Applications Engineer

Presenter

- PhD Mechanical Engineering from MIT
- Part of the Luna team since 2011
- Projects:
  - New sensor design, testing, and validation
  - Temperature monitoring of battery packs
  - Embedding sensors in composites for structural testing
- Supports:
  - Customer training and applications
  - Product testing

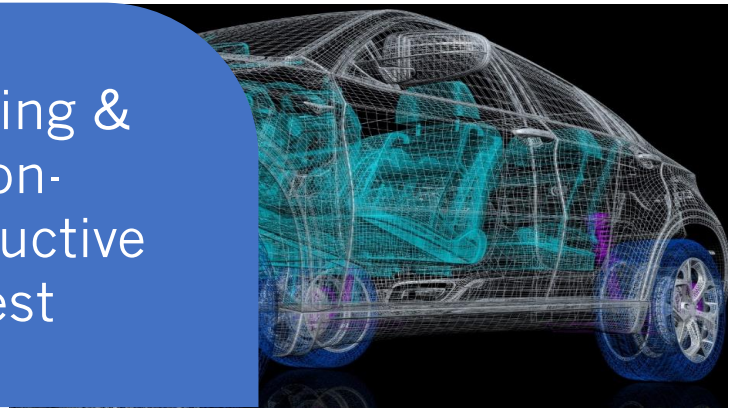
Aida Rahim
Senior Applications Engineer

Luna Innovations

- Founded 1990
- NASDAQ: LUNA
- Fiber-optic-based sensing, measurement, testing and control products for:
  - Aerospace & Defense
  - Automotive
  - Communications
  - Infrastructure
  - Process control
  - Security
  - Silicon photonics
  - Transportation

Mission: Enhance the safety, security and connectivity of people…

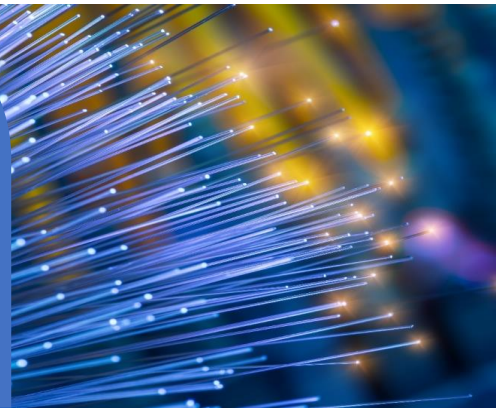
Sensing & Non-Destructive Test



Aerospace, Automotive, Infrastructure Safety & Security, Process Control

- Enabling next generation designs in aerospace and automotive through through better measurement
- Protecting infrastructure and perimeters through smarter sensors and systems
- Enhancing process control & non-destructive testing (NDT) with Terahertz technology

Comms Test & Photonic Controls



Communications and Defense

- Enabling next generation high speed optical networking through faster, better measurements
- Enhancing optical systems and instruments through high quality, precise control of light

Luna Innovations Portfolio

Sensing

Measurement Systems and Sensors

ODiSI

T-Ray

HYPERION

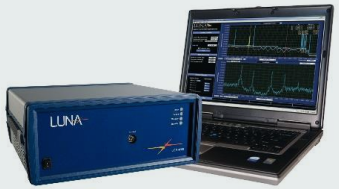
Sensors

Photonic Test, Measurement & Control

Optical Measurement and Control Systems

Luna 6415

OVA



OBR

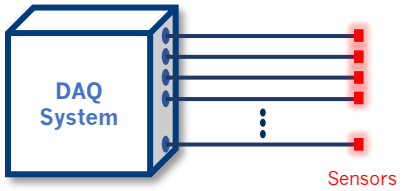
Polarization Measurement and Control

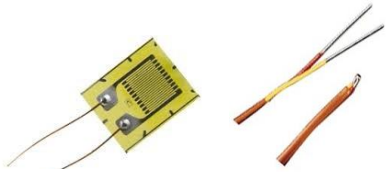
Lasers, Filters, Polarization Modules, Delay Lines, Detectors, etc.

https://lunainc.com/events/learn-luna-explainer-webinar-series

Standard Electrical Sensing

Multiple Copper Wires Per Sensor

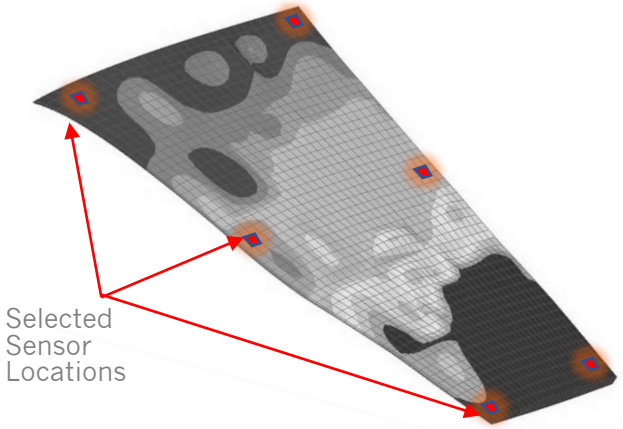




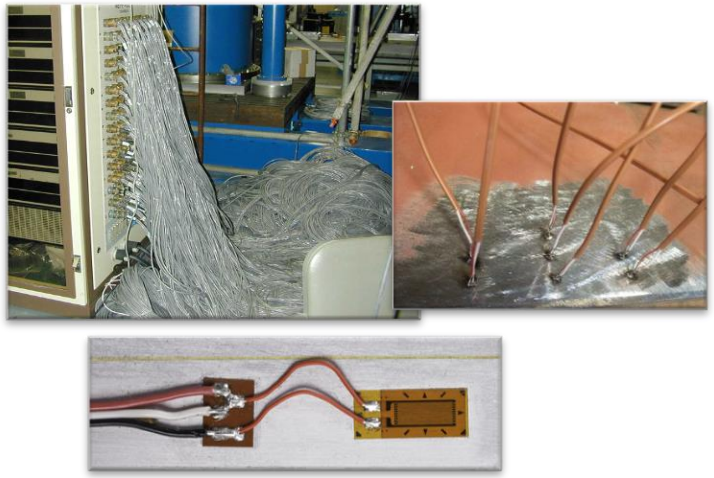
Foil strain gages, thermocouples, RTDs, etc.

- 2-3+ wires per sensor
- Multiple DAQs
- Low resolution
- Bulky, metallic wiring

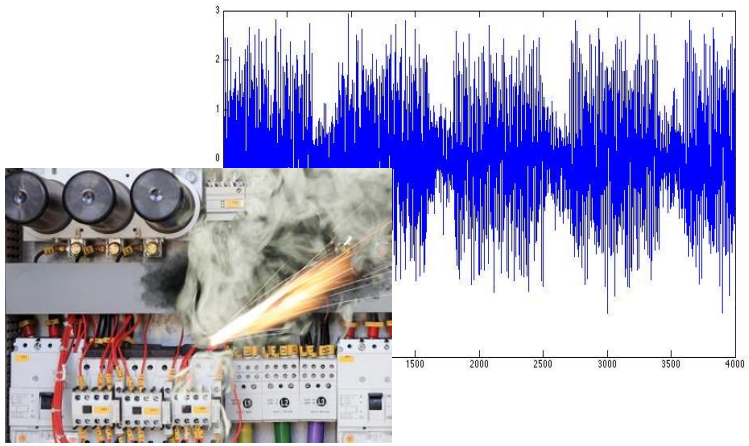
Limited Data (Low Sensor Count)



Bulky Sensors and Cabling

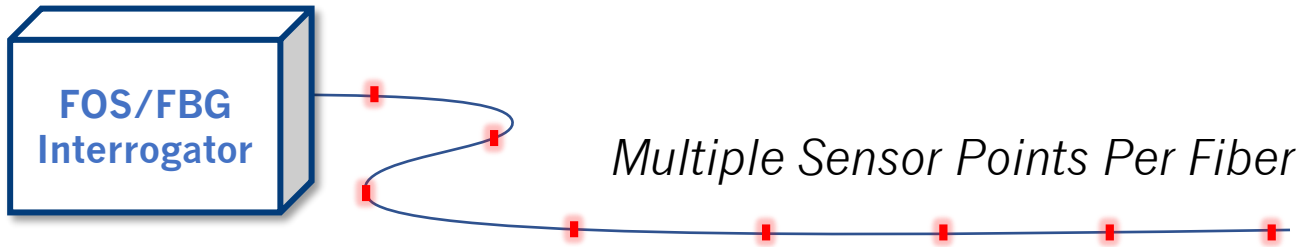


Susceptible to Electromagnetic Interference



Fiber Optic Sensing

High-Speed Distributed Sensing



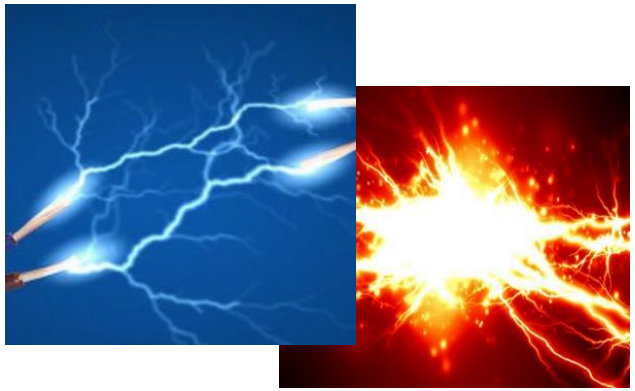
- Single optical fiber
- Static and dynamic measurements
- Long range (km's)
- Easy to install

High-Definition Distributed Sensing

- Single optical fiber
- 1000's of sensors
- Ultra-high spatial resolution
- Easy to install

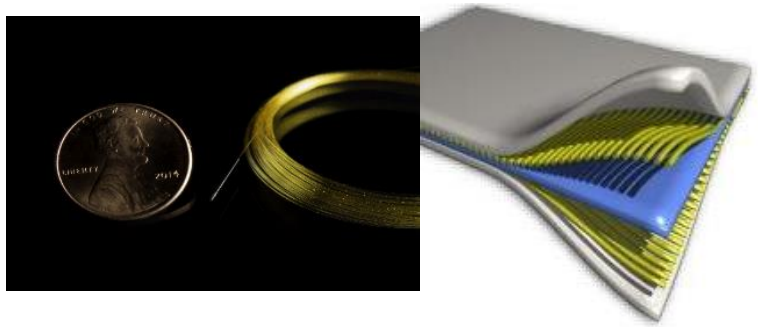
Fiber Optic Sensor Advantages

Works in harshest environments



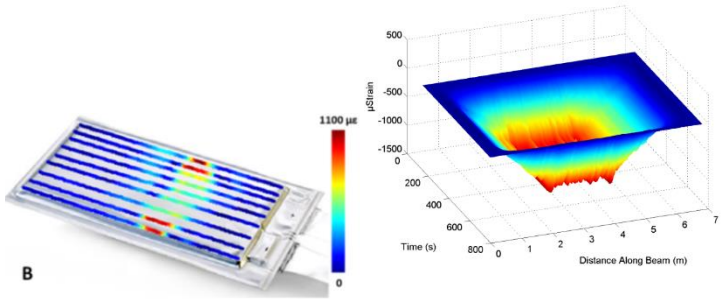
- Passive
- Immune to EMI
- Chemically inert
- Intrinsically safe

Can measure *where* you need data



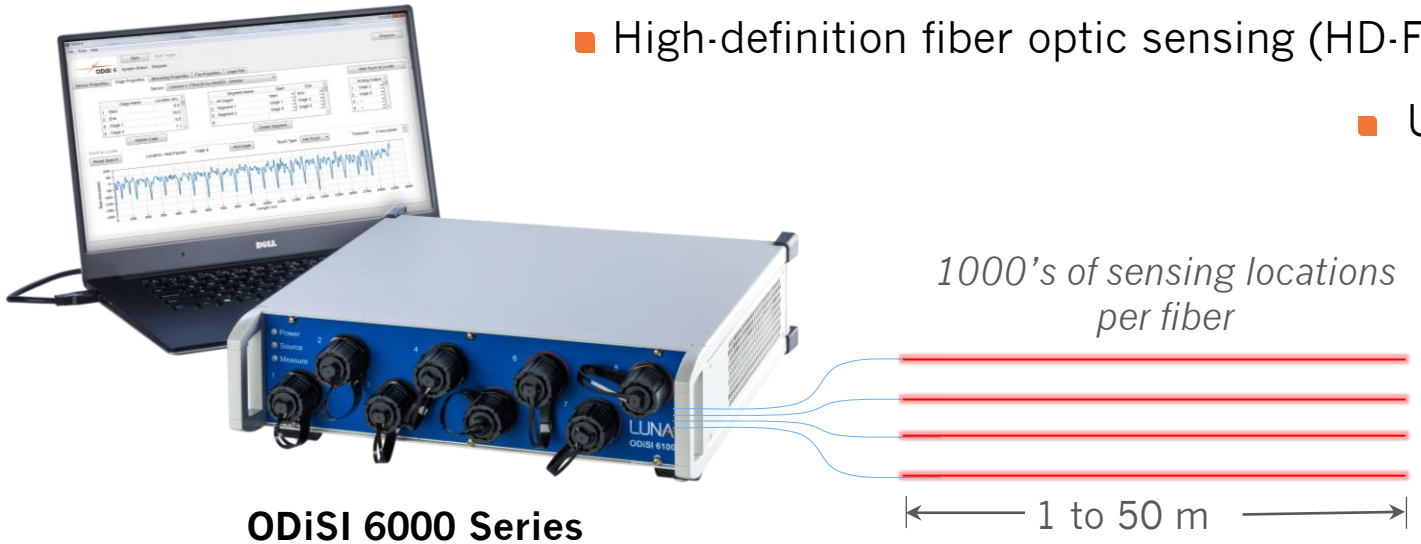
- Very small, low profile (easy to embed)
- Lightweight
- Flexible
- Distributed

Provides more data, more insight



- High-definition mapping of strain/temperature
- Distributed sensing over large areas

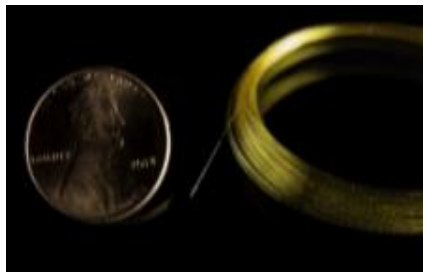
Optical Distributed Sensor Interrogator (ODiSI)



ODiSI 6000 Series

- High-definition fiber optic sensing (HD-FOS) for strain and temperature
  - Ultra-high spatial resolution
    - Gage pitch (spacing) down to 0.65mm
    - >1,500 sensor locations per meter of fiber
  - Multi-channel system
    - 1, 2, 4 or 8 HD-FOS sensor channels
    - Sensors up to 50 m in length each
  - NIST-traceable strain measurements
  - Network connectivity with IEEE 1588 PTP
  - Easy-to-use software
    - Sensor/gage configuration and management
    - Acquisition and data logging
    - Real-time 2D and 3D visualization software

Sensors

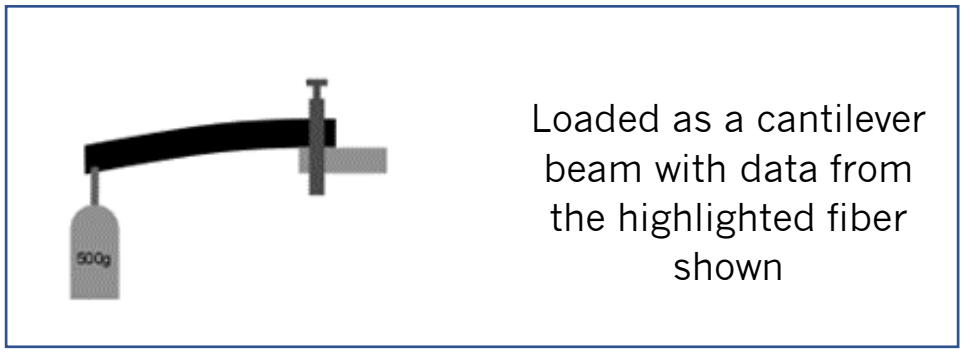


- **Light, flexible fiber (155 µm)**
- **Static and quasi-static applications**
- **Strain and temperature**

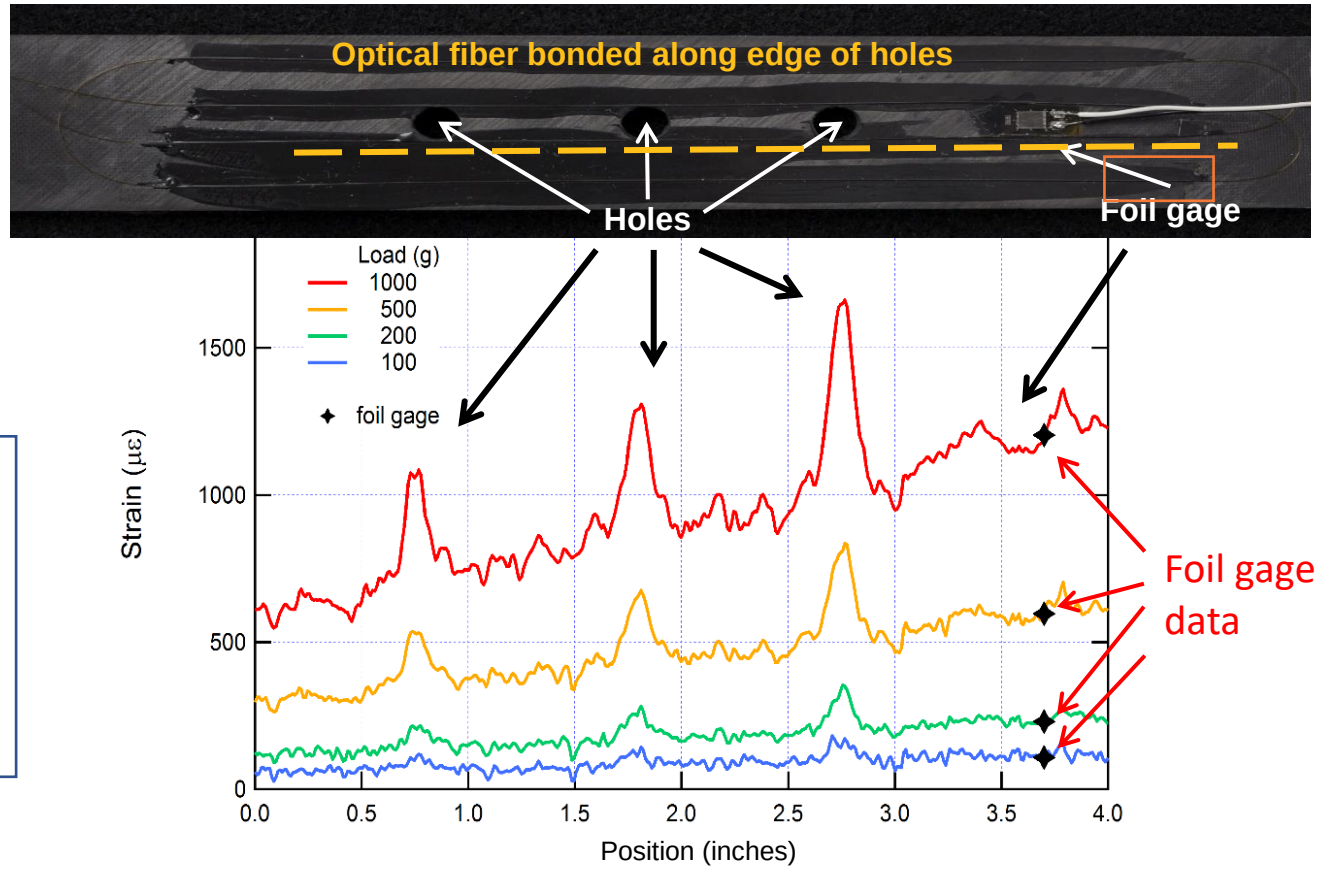
Distributed Sensors Complement Discrete Sensors

Consider a composite coupon with three holes drilled in the center

- Fiber optic sensors are installed onto the coupon along the edge of the holes
- A standard foil gage is installed onto the coupon on one end



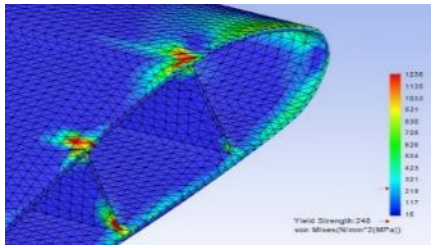
Loaded as a cantilever beam with data from the highlighted fiber shown



High-Definition Fiber Optic Sensing (HD-FOS) allows users to capture data and events that might be missed if only a few gages were available or not placed near event locations

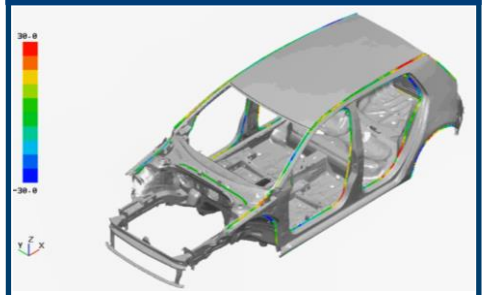
HD-FOS Addresses Key Challenges in Test and Evaluation

FEA Model Verification



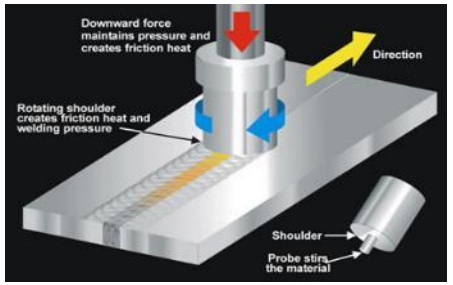
- Calibrate/verify model
- Measure complex geometries
- Comprehensive structural test data
- More complete strain data

Structural Testing



- Measure structural integrity
- Test to failure including failure mechanism
- Life cycle testing
- Fatigue testing

Material Joining & Welding

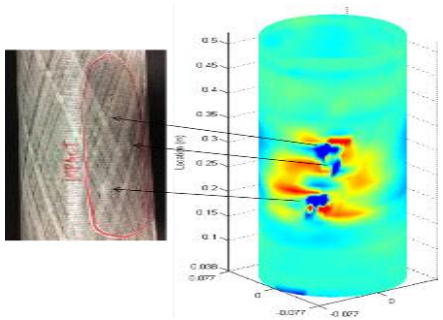


- Verify adhesive performance
- CTE mismatch effects
- Weld quality
- Weld temperature
- Post process residual strain

Manufacturing Processes

- Real-time thermal or strain mapping
- Curing temperature
- Weld temperature

Smart Parts (SHM)



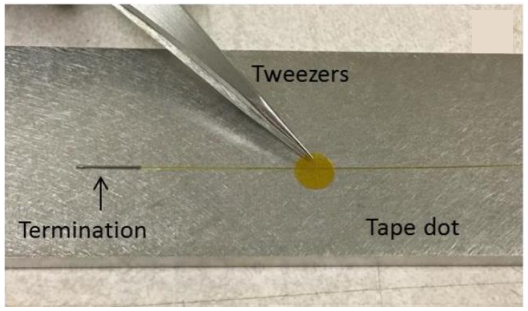
- Embedded sensing for life cycle mgt.
- Composite damage detection
- Crack propagation
- Structural integrity monitoring

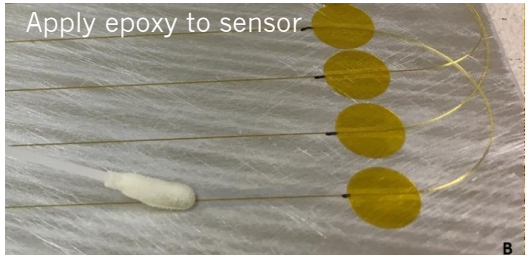
ODiSI Demonstration

Sensors

Strain Sensor

- **Prepare:** Abrade and clean the surface for bonding
- **Plan:** Identify the sensor path
- **Apply:** Lay out the sensor in its intended path
- **Bond:** Epoxy the sensor in place



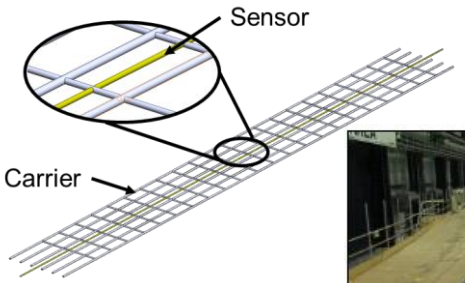


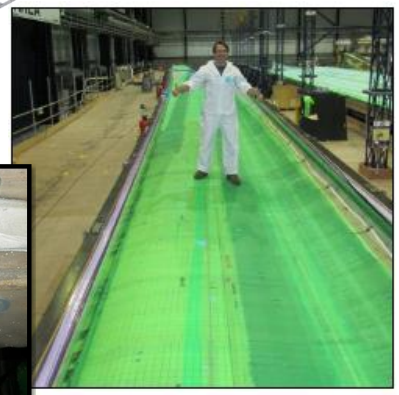
Temperature Sensor

- **Prepare:** Clean the surface
- **Plan:** Identify the sensor path
- **Apply:** Lay out the sensor in its intended path
- **Affix:** Hold down sensor to surface using tape, adhesive, or brackets

Complex Instrumented Articles

Sensor Layout and Placement





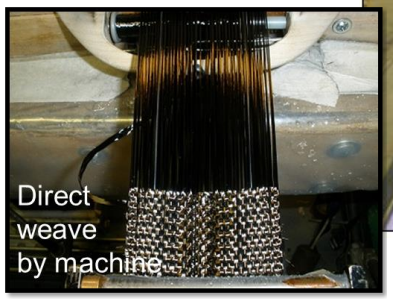
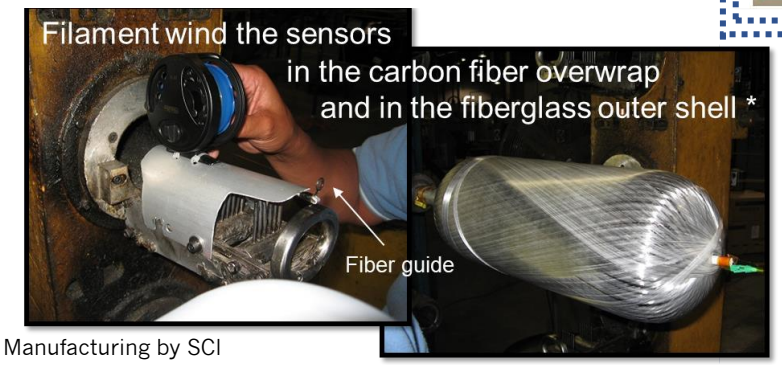
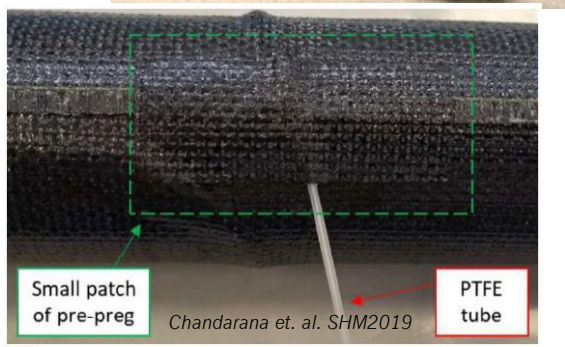


Image courtesy of Bally Ribbon Mills, 2014

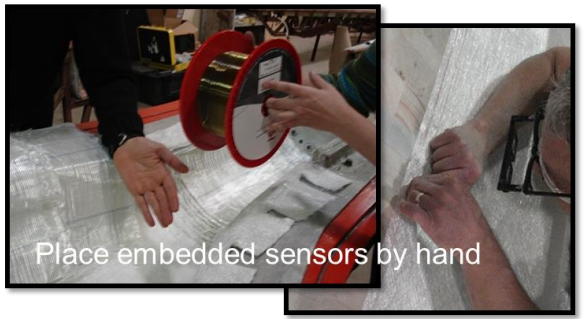


Manufacturing by SCI

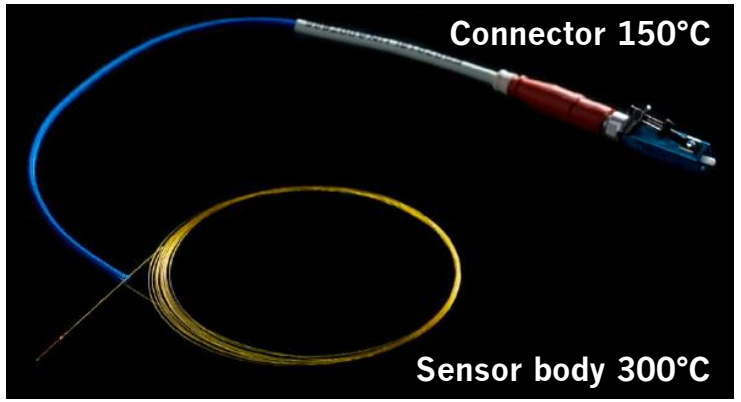
Ingress / Egress Protection



Chandarana et. al. SHM2019

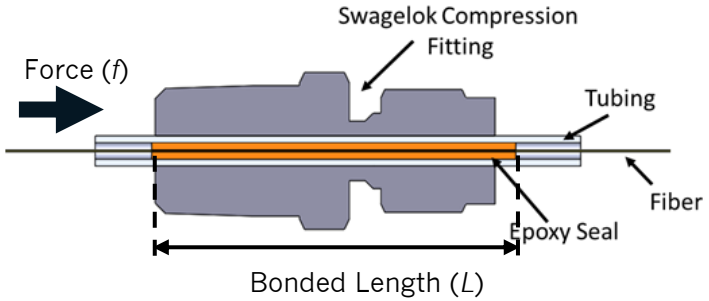


Processing Parameters – Temperature & Pressure



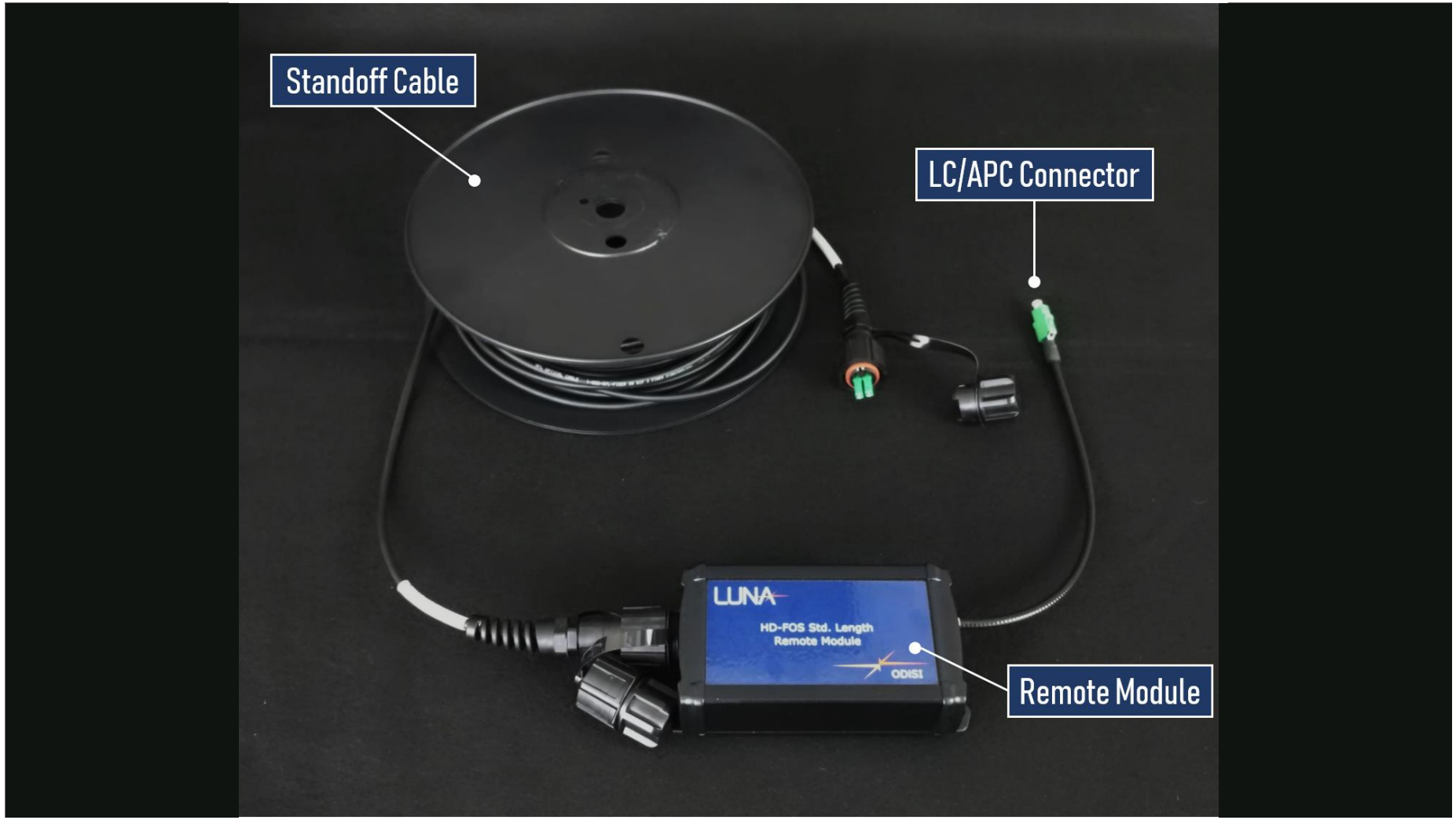
Oven feedthrough: silicone rubber stopper, glass wool

Pressure feedthrough



System Components

System Components



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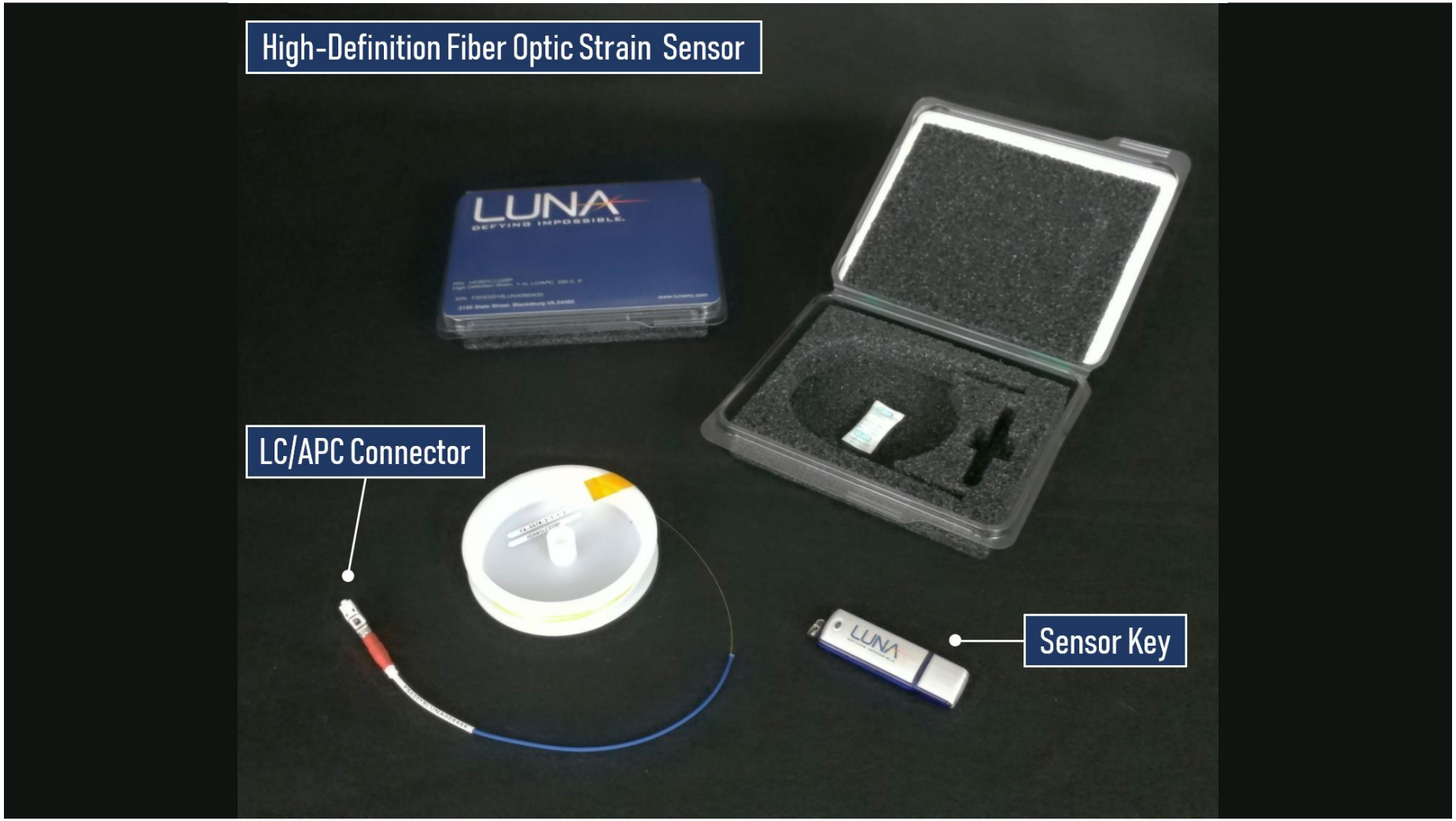

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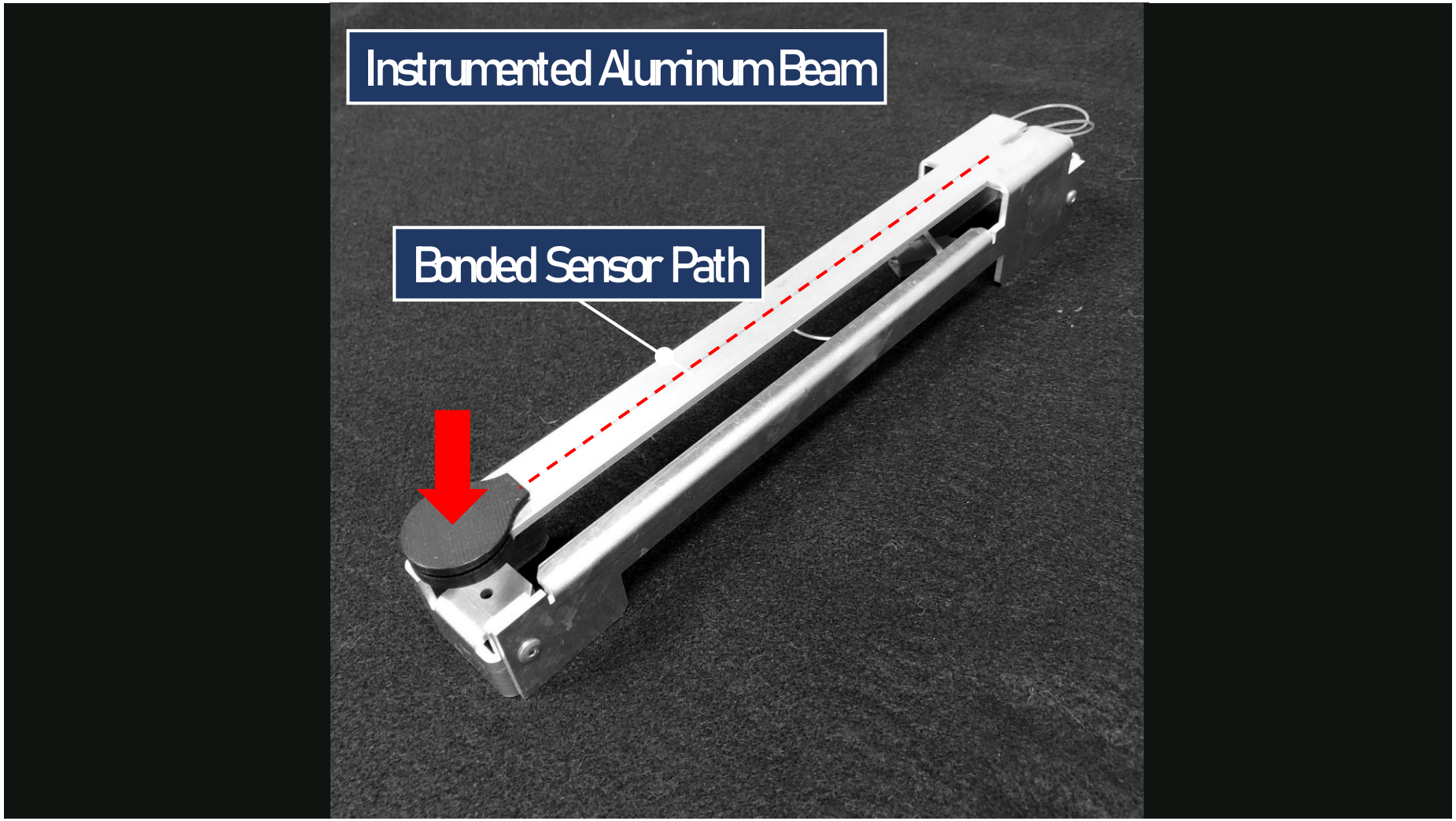
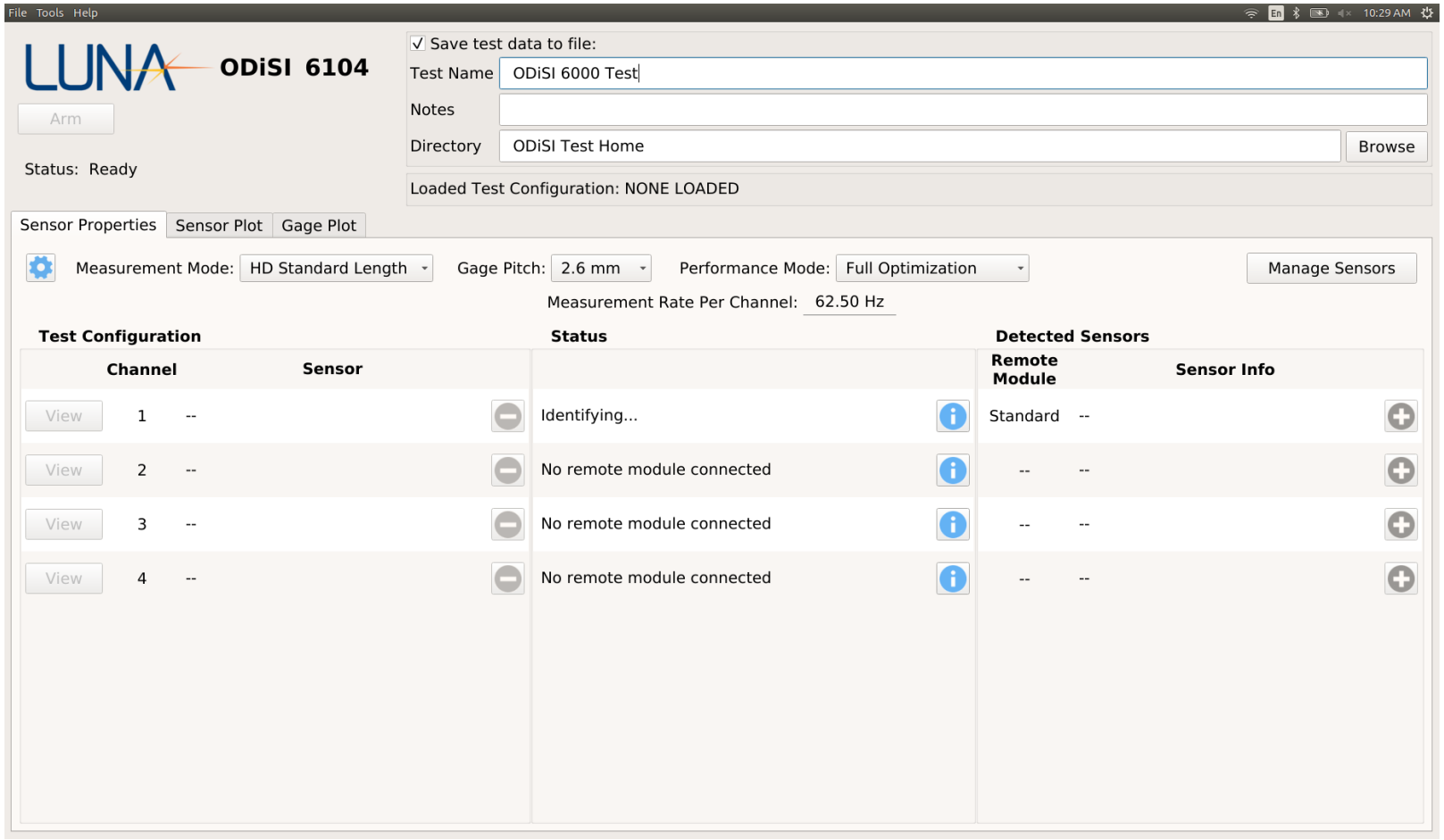


System Components

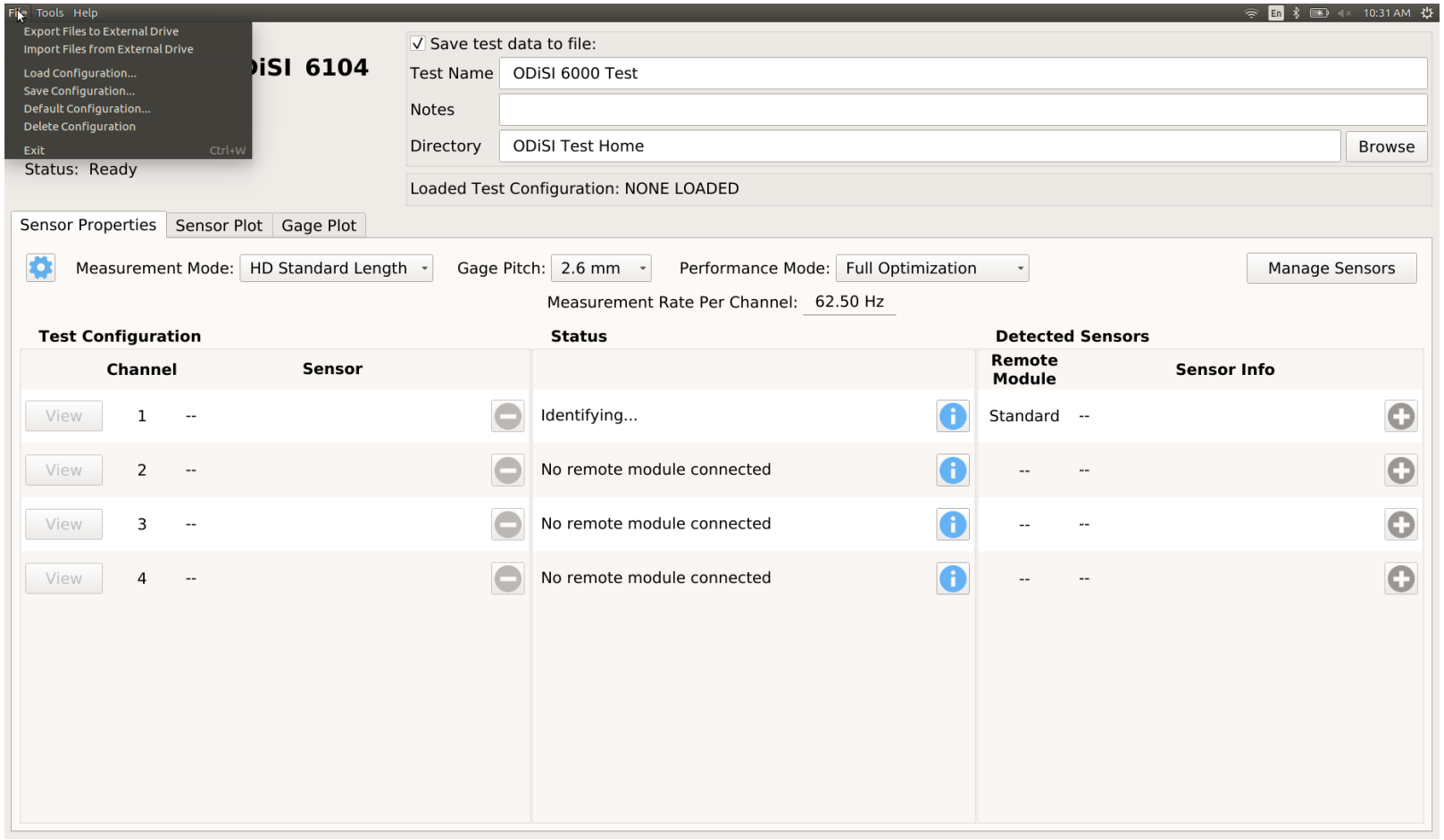
System Components

ODiSI Software – Main Interface

- Launch the software by double-clicking the “OD6” icon on the desktop
- It will take a few seconds to complete initialization
- Once the initialization is complete, the user will be able to change settings, view sensors, or collect data

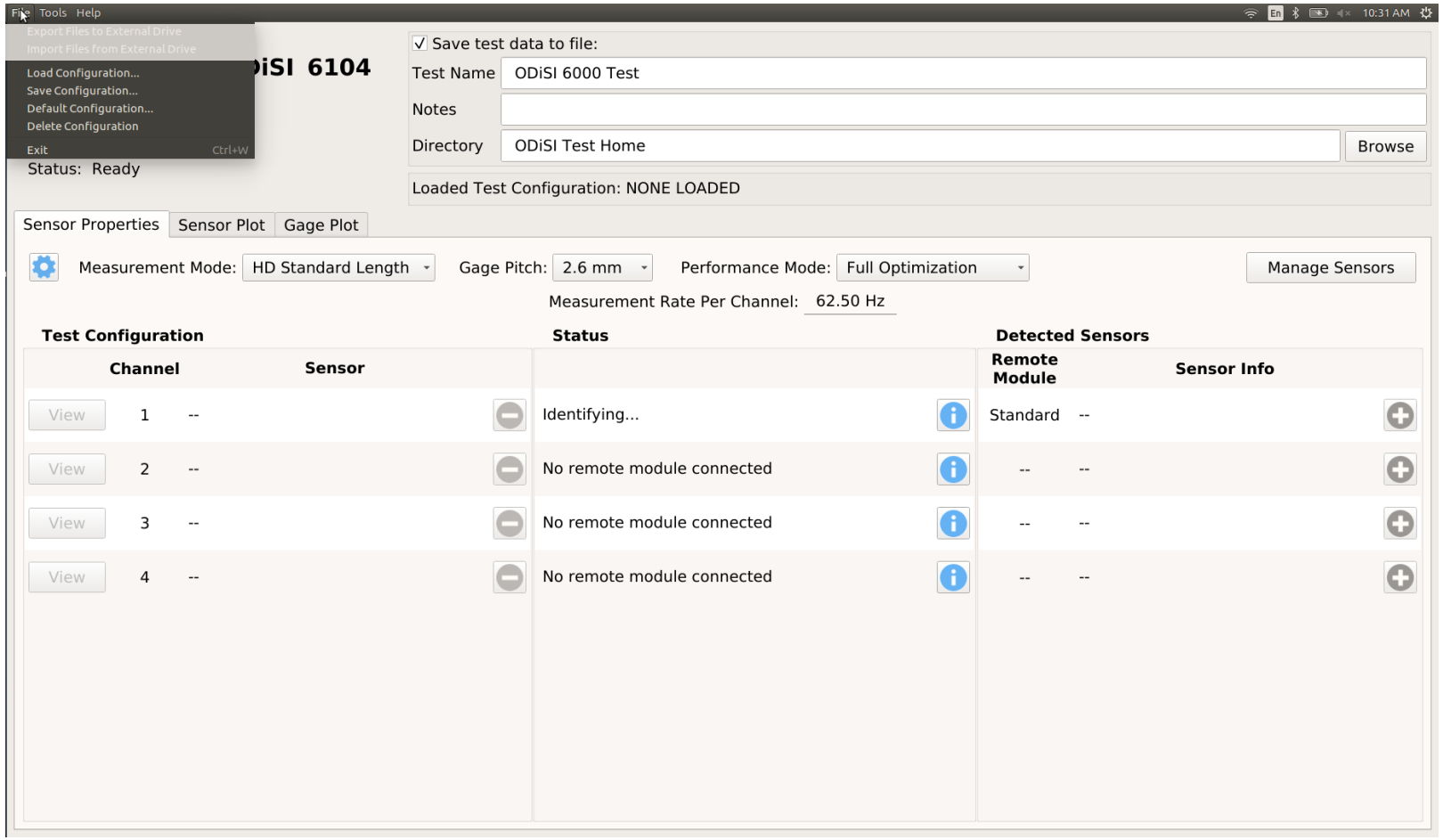


ODiSI Software – Manage Files



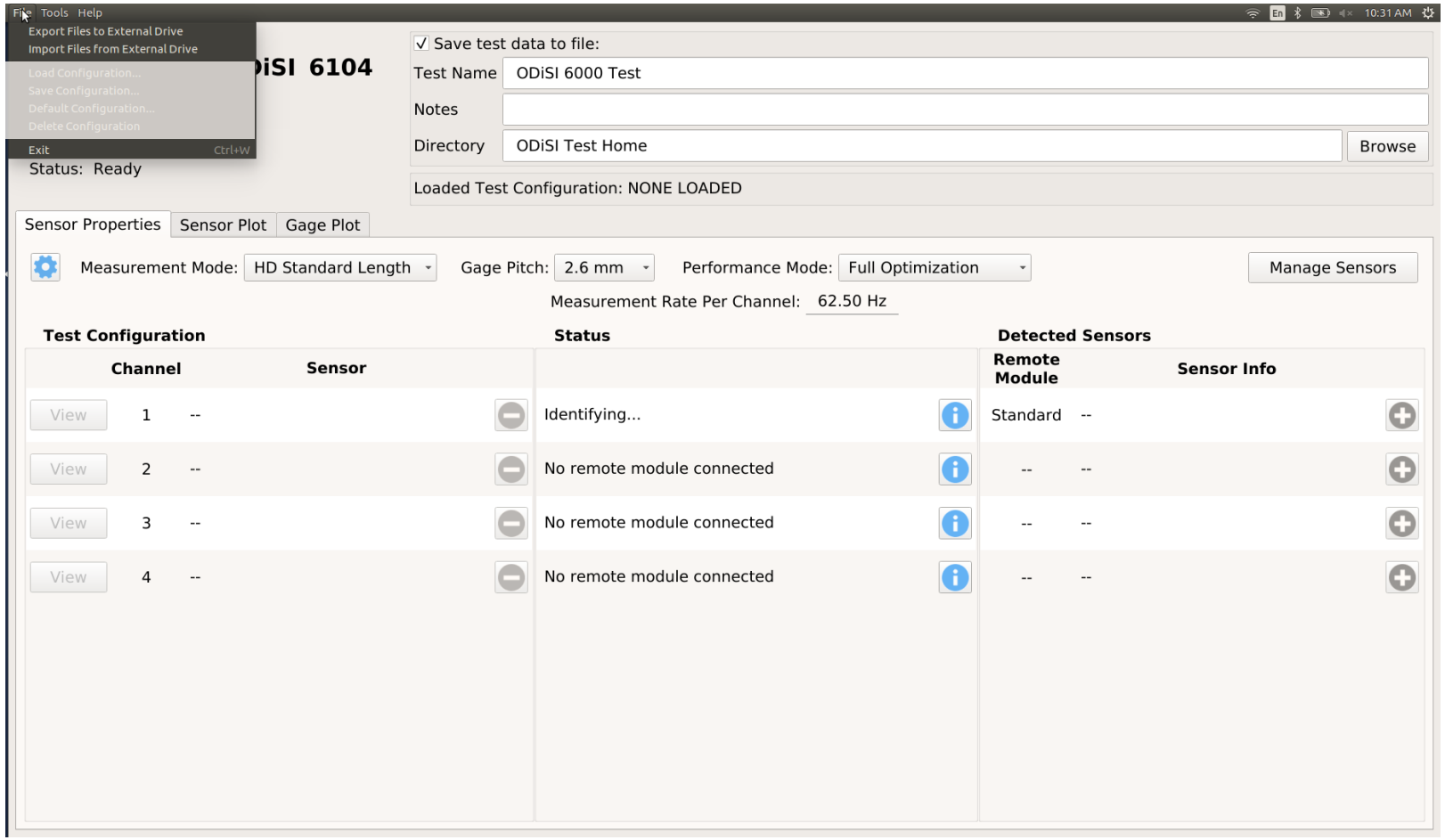
ODiSI Software – Configurations

- Save and load configurations
- Configurations remember user preferences such as operating mode or trigger options

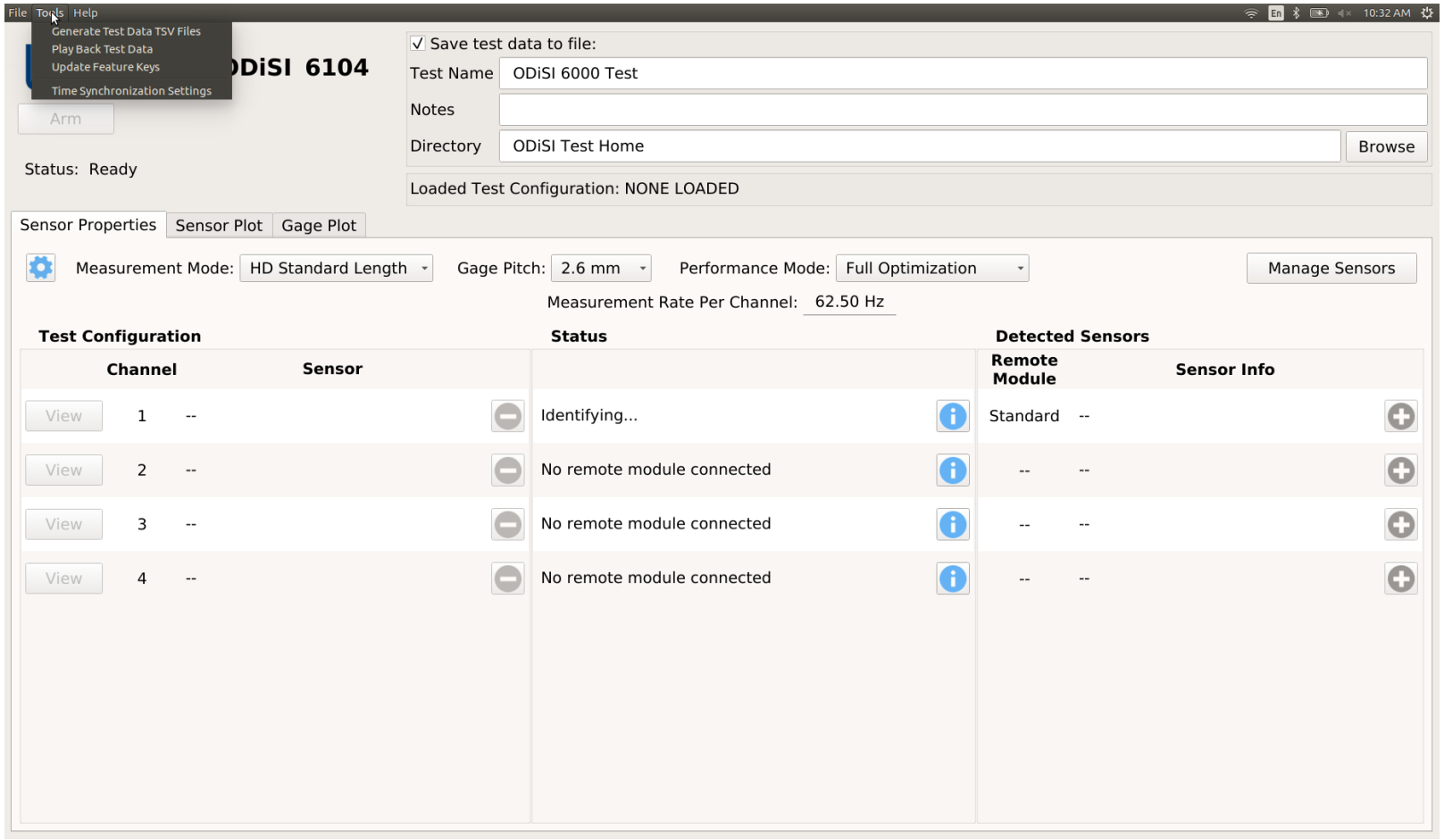


ODiSI Software – Moving Files

- Export to, or import from, an external drive (USB or CD)

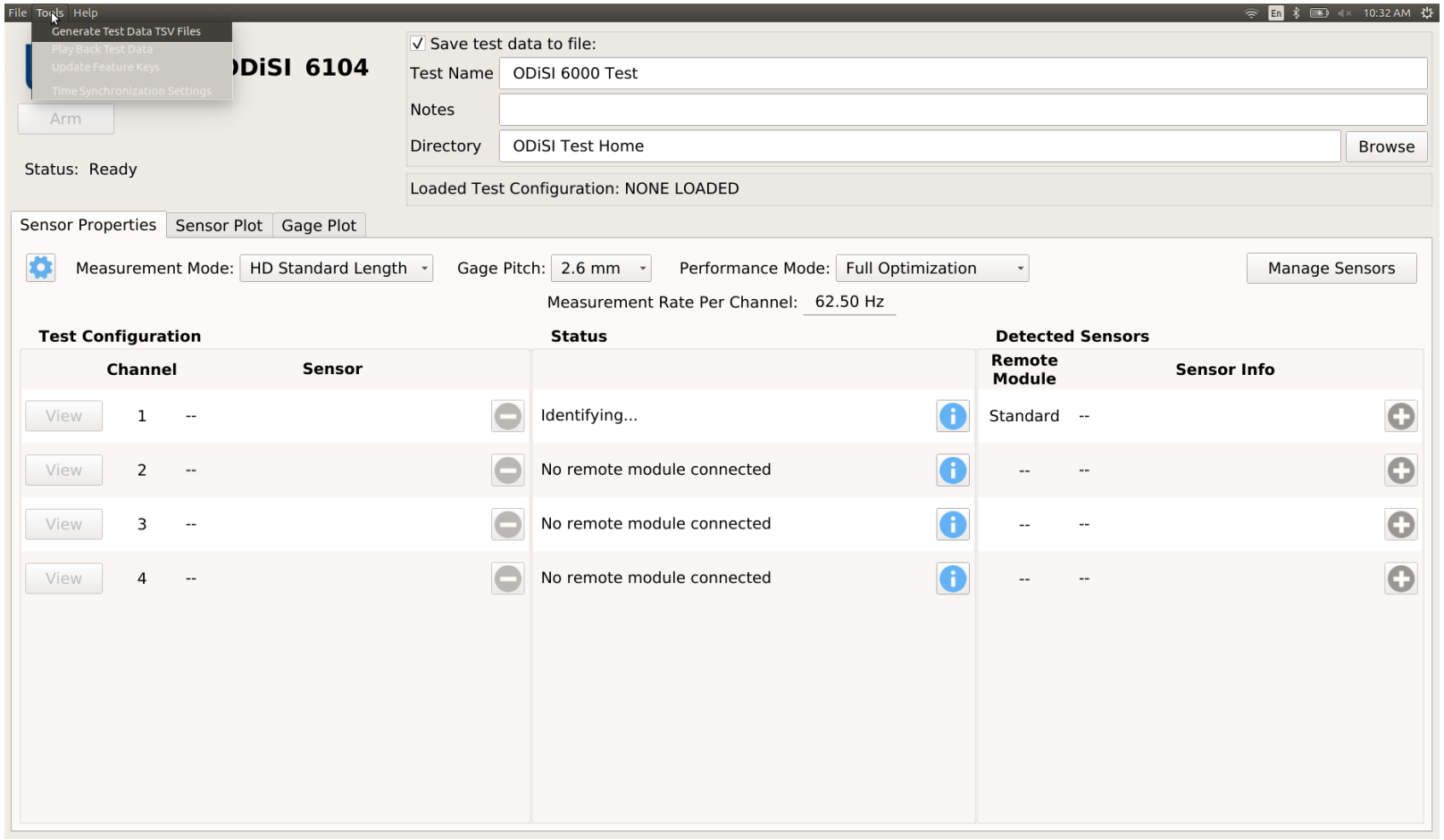


ODiSI Software – Interact with Test Data



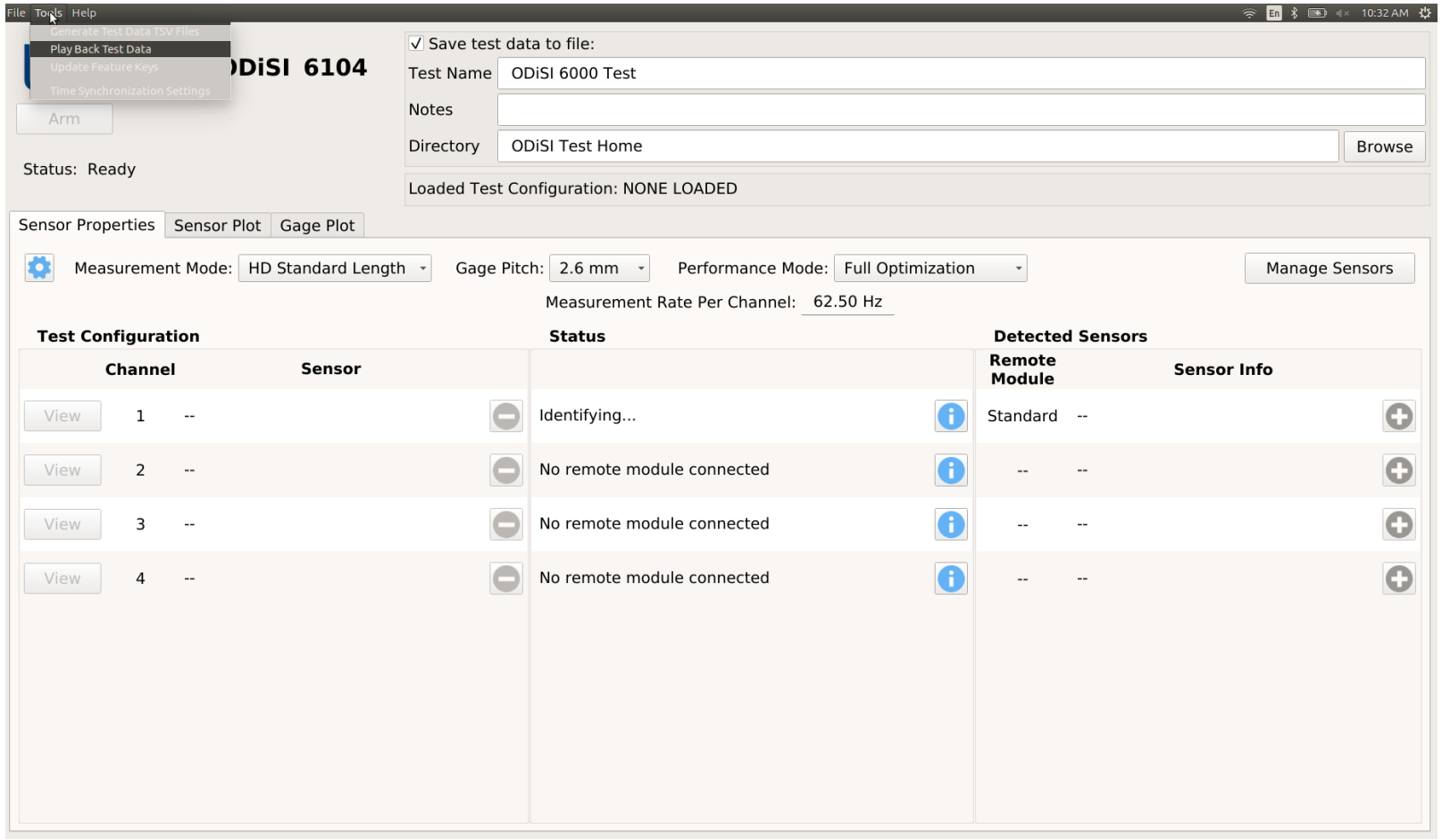
ODiSI Software – Generate Test Data TSV

- Convert measurement data from binary data files into human readable tab-delimited data files
- TSV files can be opened in Excel, Matlab, Python, LabView



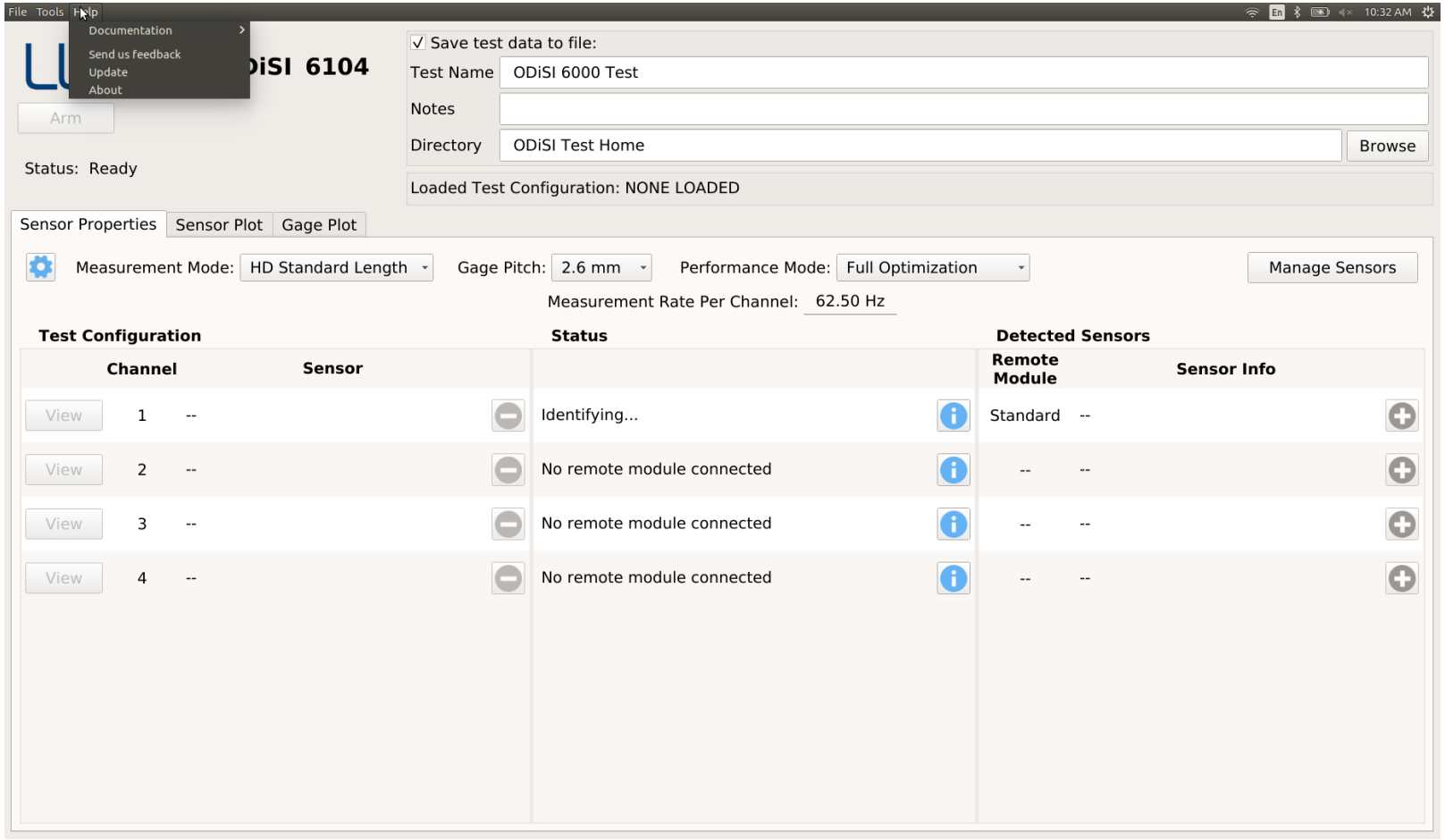
ODiSI Software – Play Back Test Data

- Run through a test that has already been completed
- Jump to any point during the data set
- Change playback speed



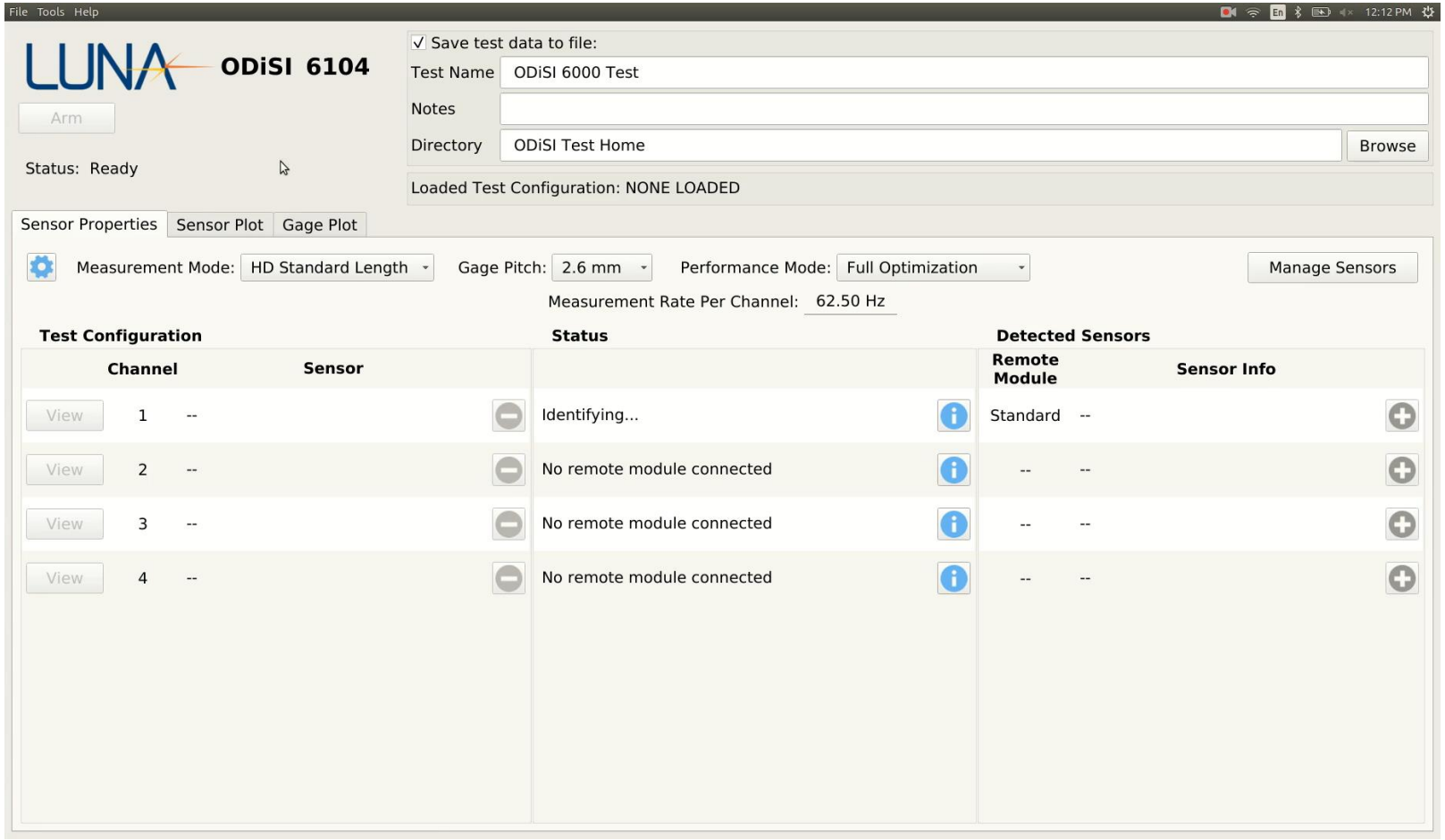
ODiSI Software – Help

- Look at new features
- Refer to User's Guides
- Send feedback to Luna



ODiSI Software – Navigate Software Main Tabs

- Gage Plot: Measurement vs Time
- Sensor Plot: Measurement vs Length
- Sensor Properties: Displays status of the system, channels, sensors, access settings



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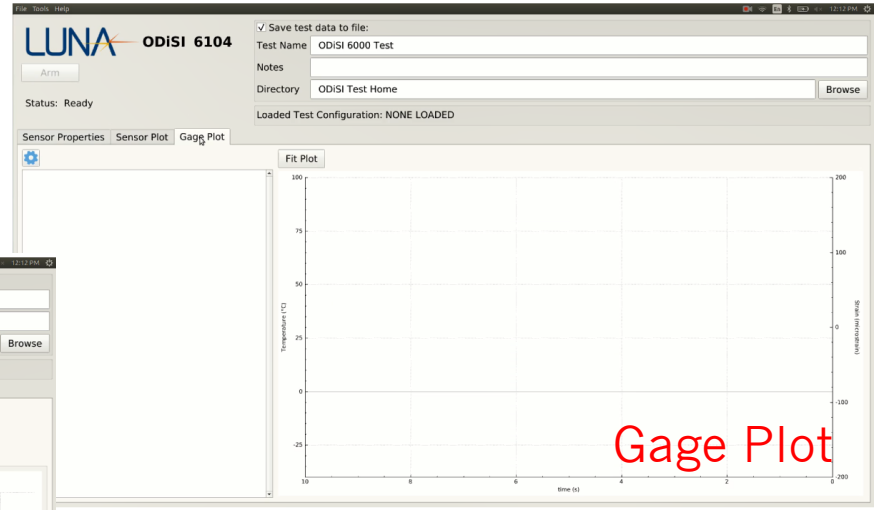
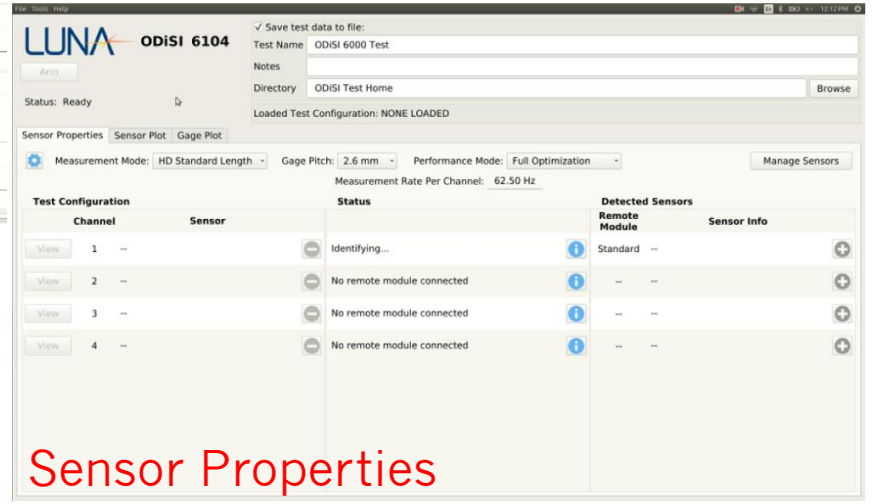
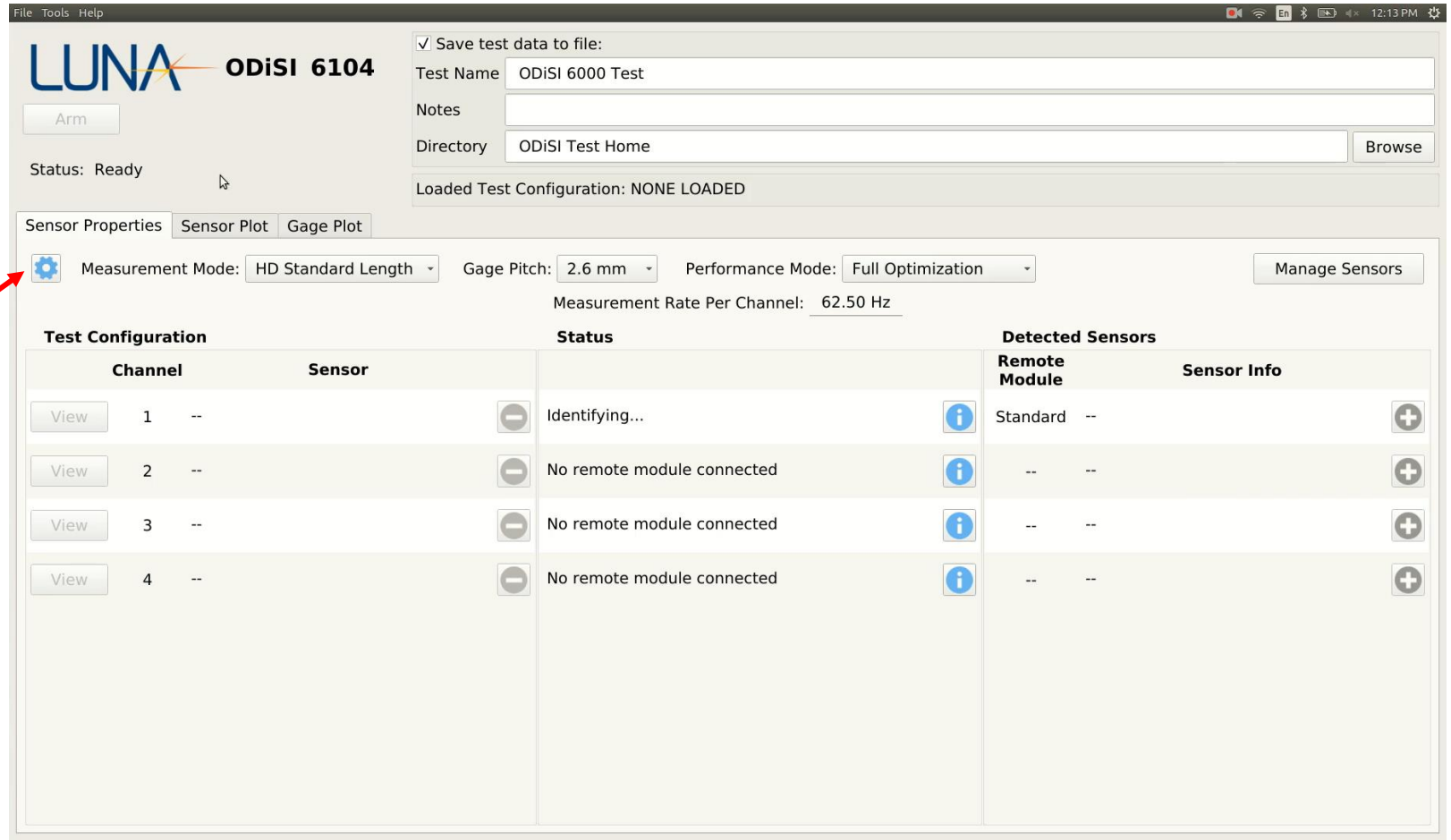




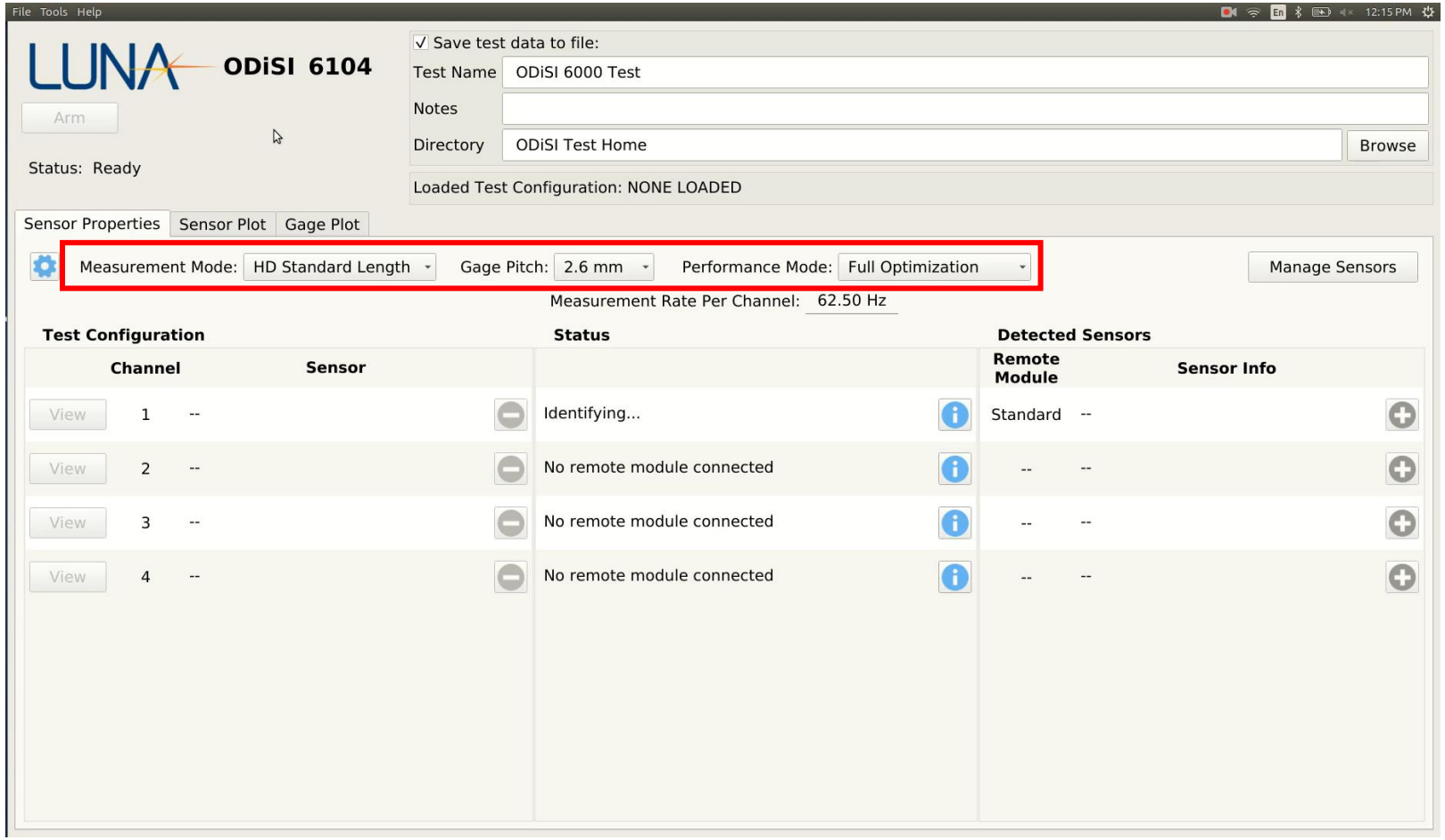
ODiSI Software – Settings

- Adjust Channel Settings, Streaming Properties, Trigger settings, Strain or Temperature settings, and Sampling Rate



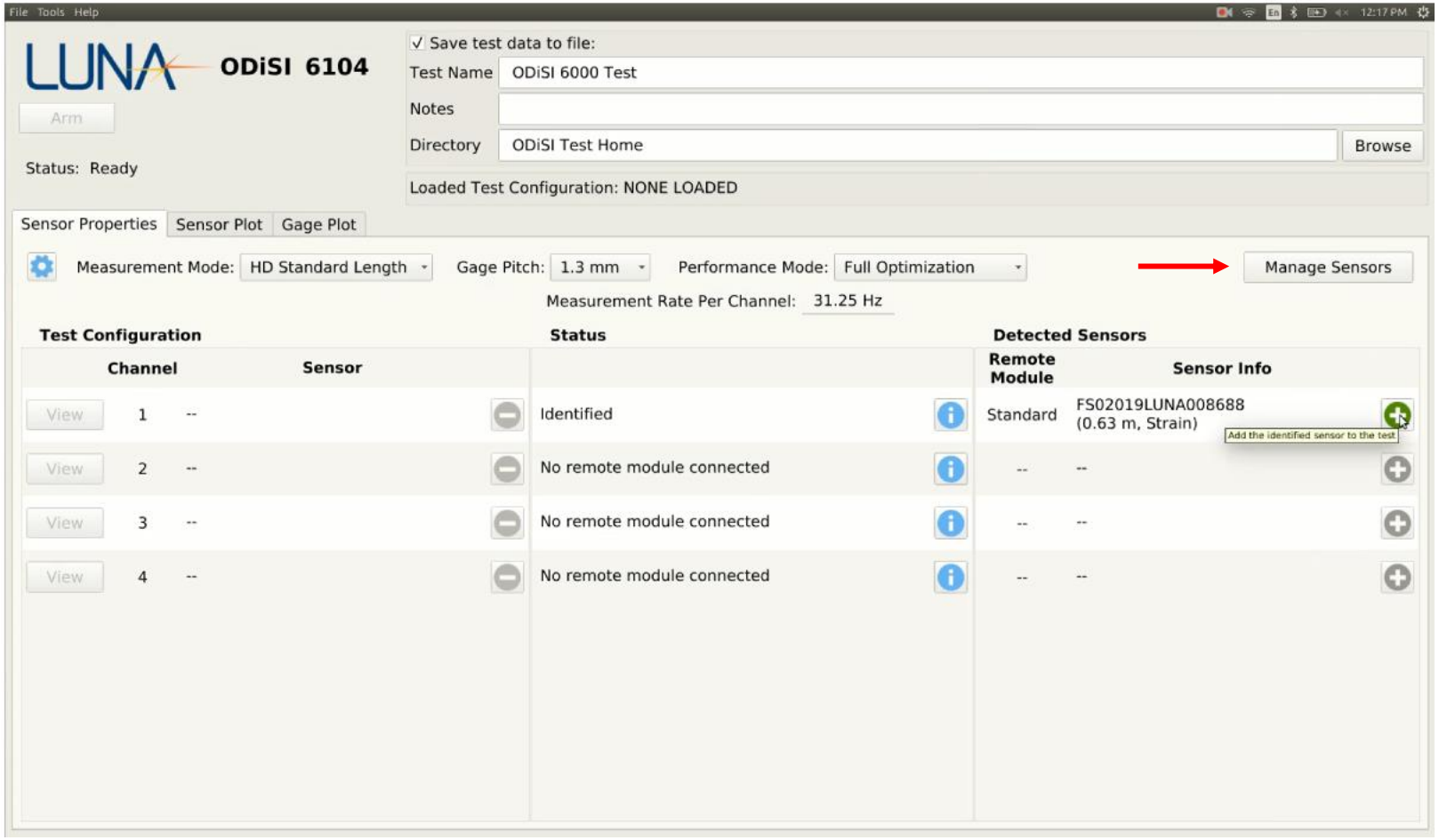
ODiSI Software – Select Operational Mode

- Measurement Mode: Standard (up to 20 m sensor) or Extended (up to 50 m sensor)
- Gage Pitch: select 0.65mm for high strain gradients
- Performance Mode:
  - Full Optimization for highest quality data
  - Maximum Rate for fastest rate



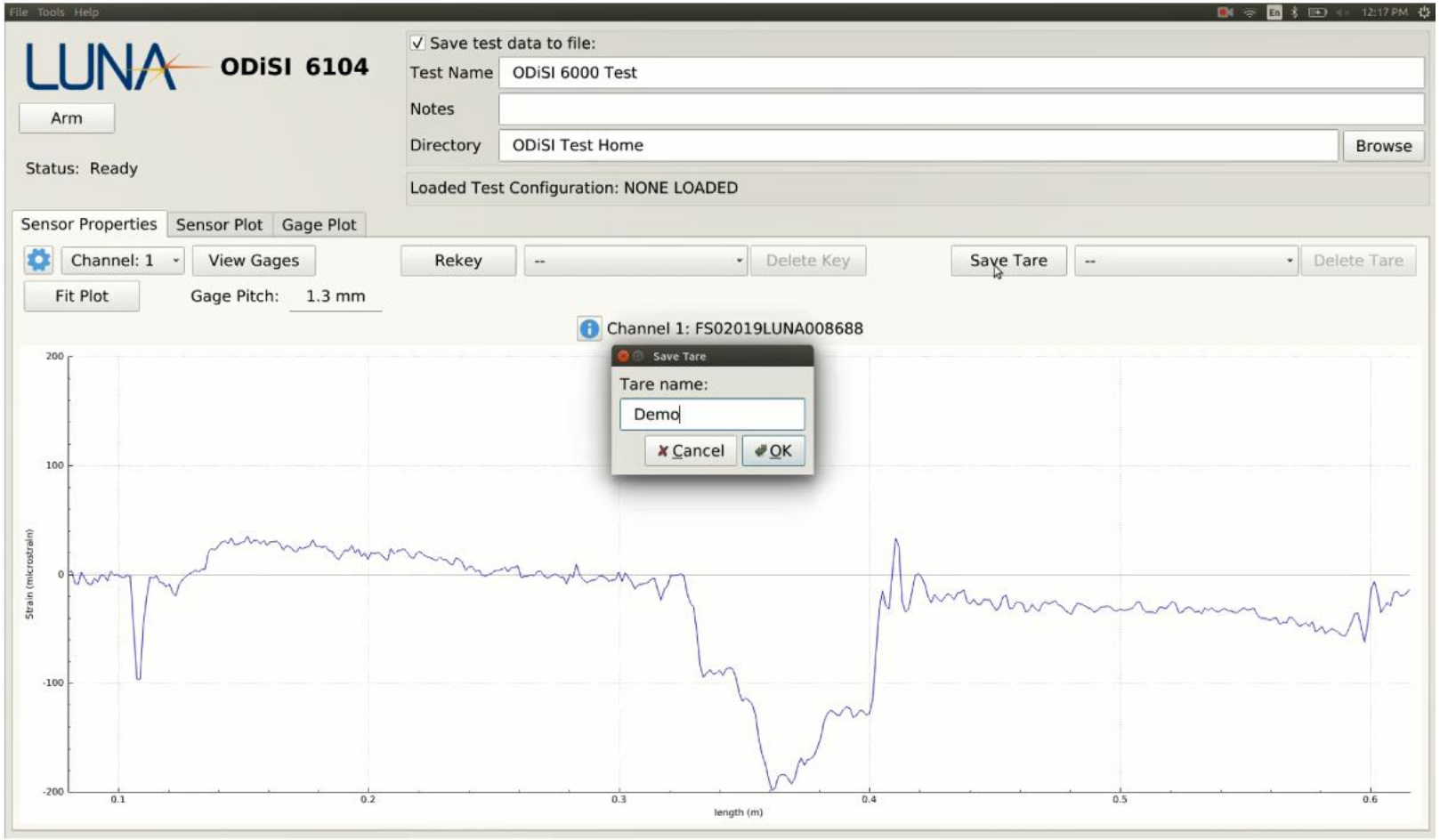
ODiSI Software – Install Sensor Key

- Each sensor has a unique key that enables the system to automatically recognize the connected fiber
- Sensor keys can be Installed, Uninstalled, Deleted, Renamed
- Once a sensor is plugged into the remote module, the system will automatically recognize the sensor



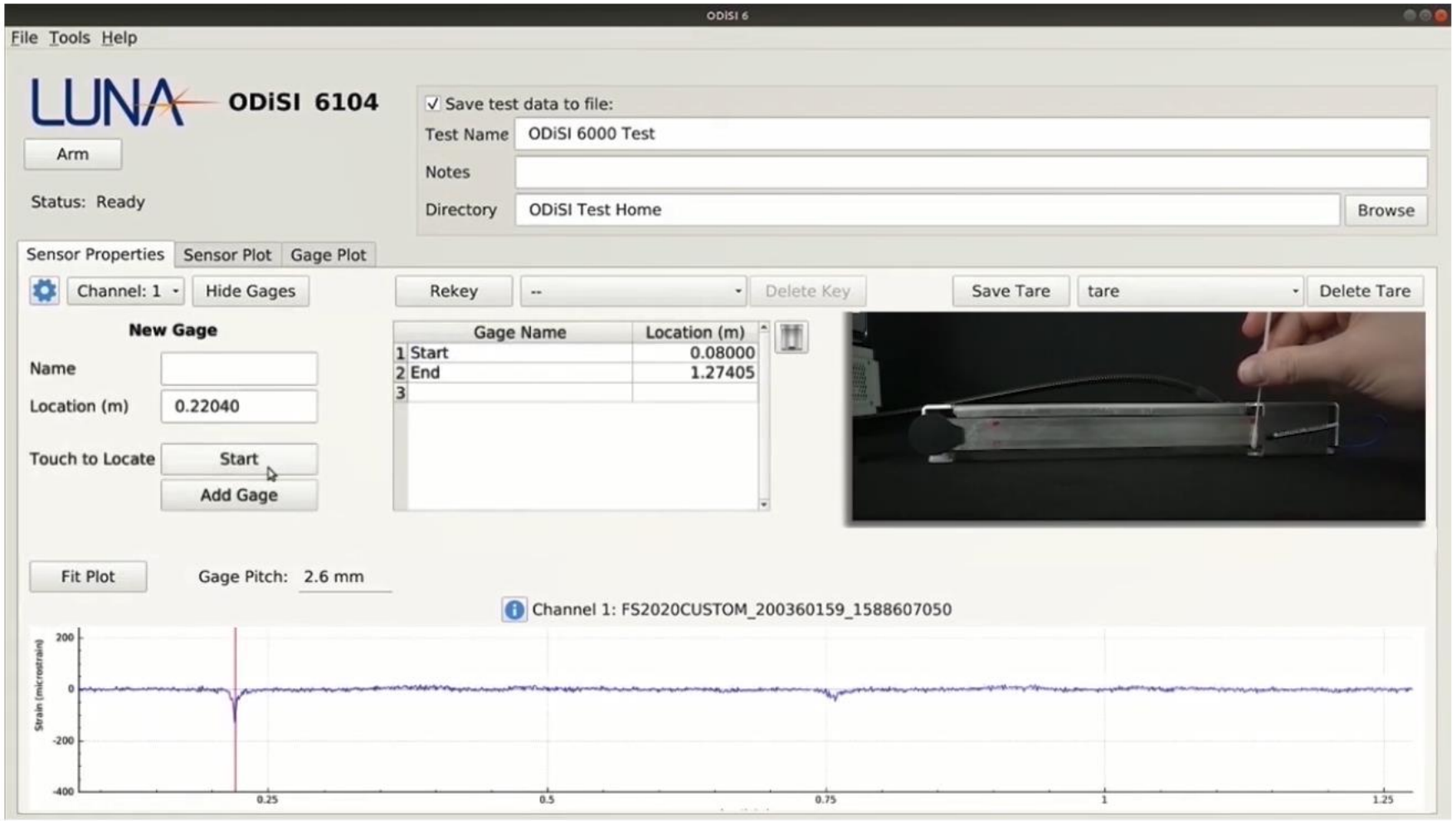
ODiSI Software – Run Test

- Tare: Zero out measurements before test start
- Arm: Prepare system for logging
- Start: Start logging data
- Select gages to display in Gage Plot



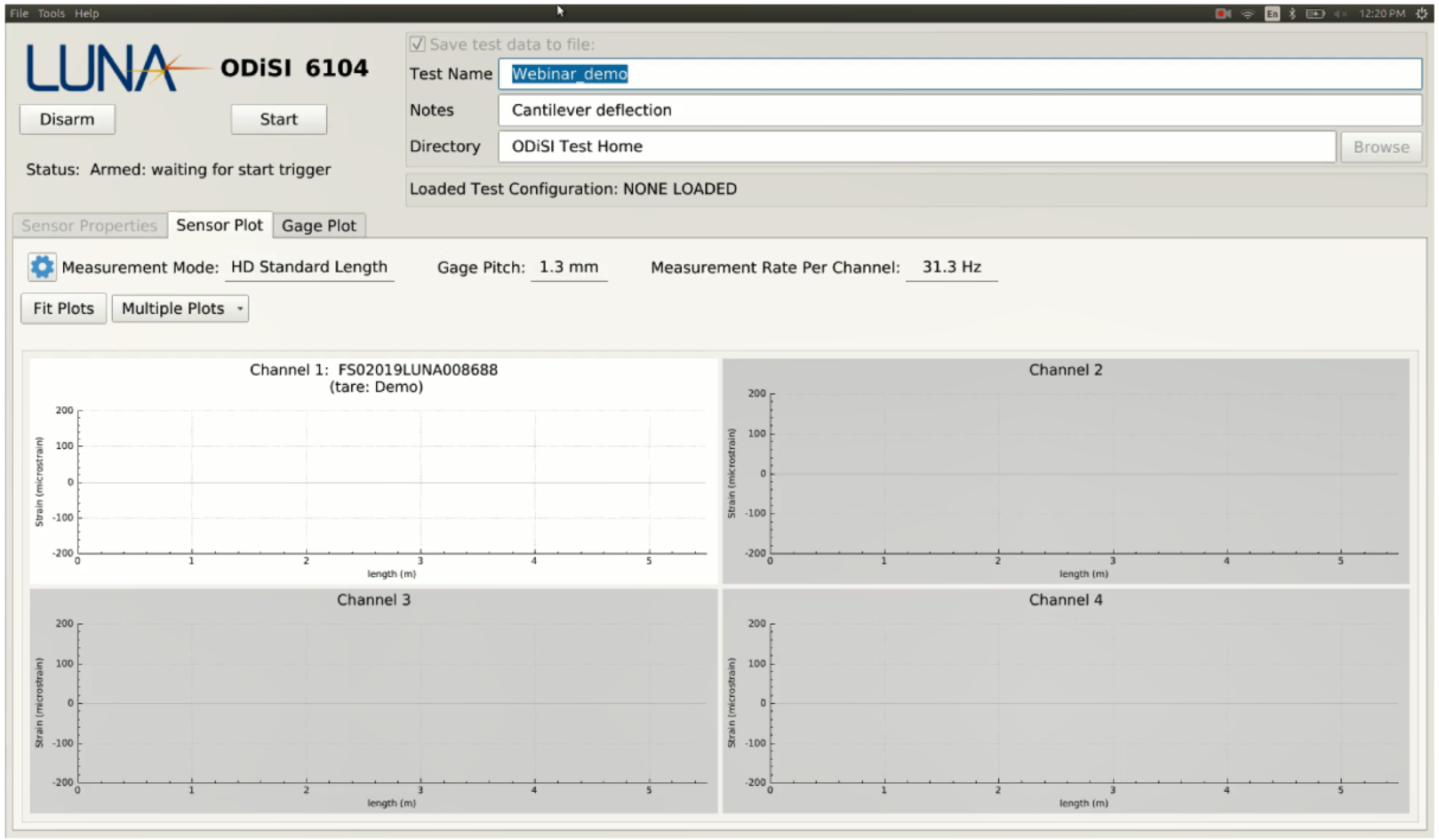
ODiSI Software – Touch-to-Locate

- Identify specific gages of interest using freeze spray or soldering iron set to low



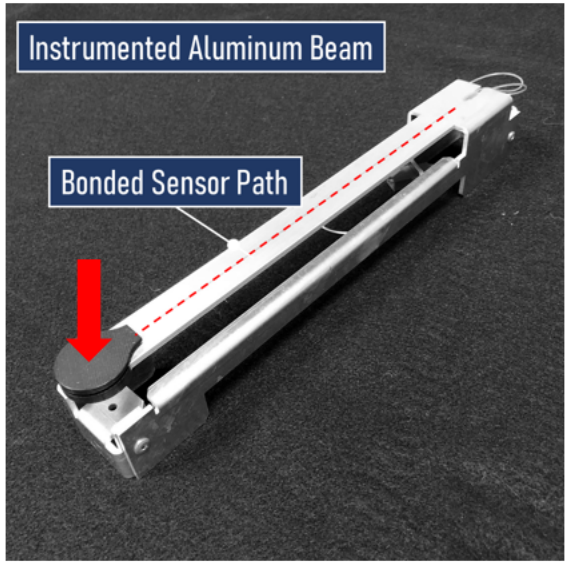
ODiSI Software – Start Test

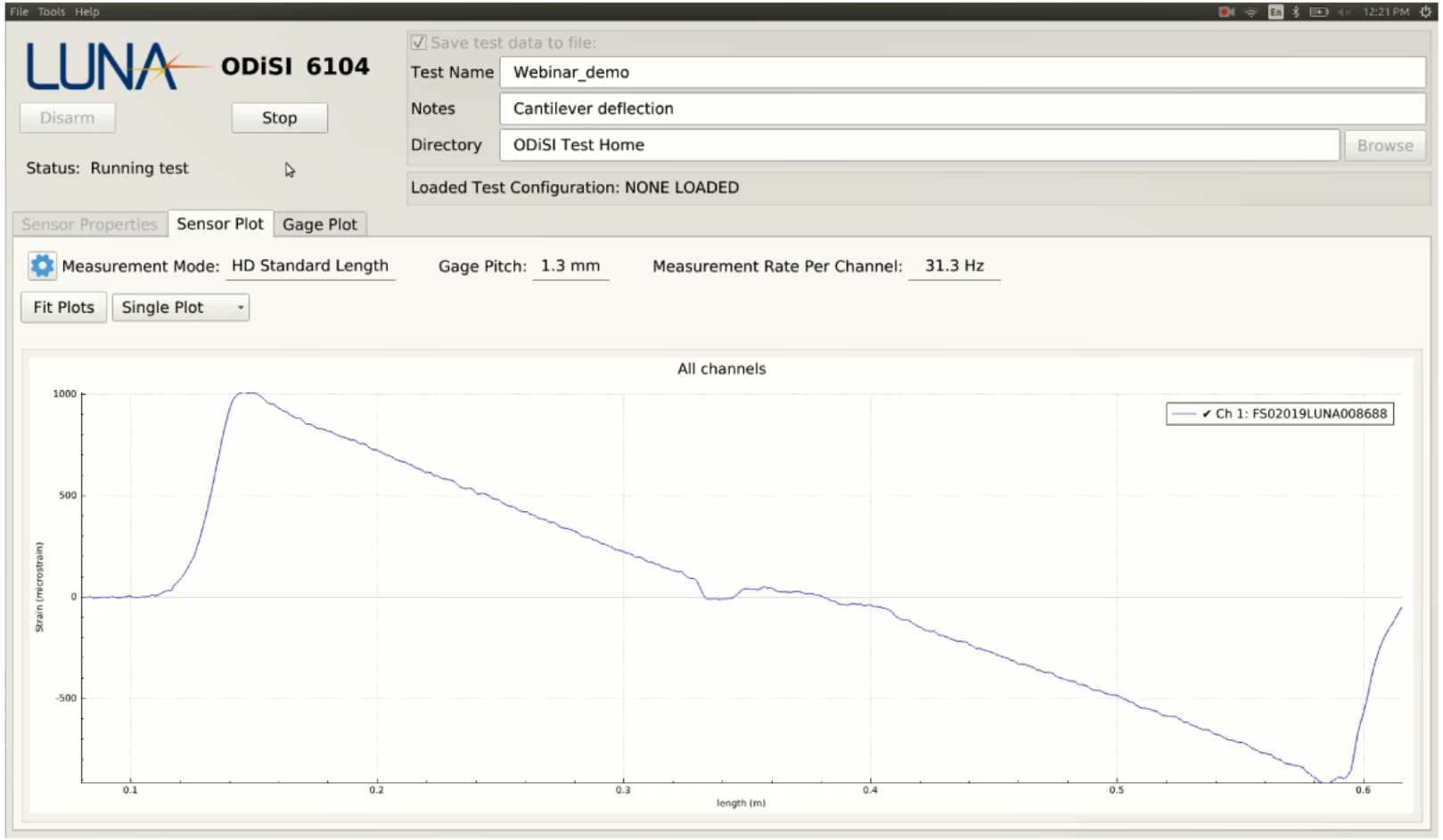
- Display Strain vs Length



ODiSI Software – Sensor Plot

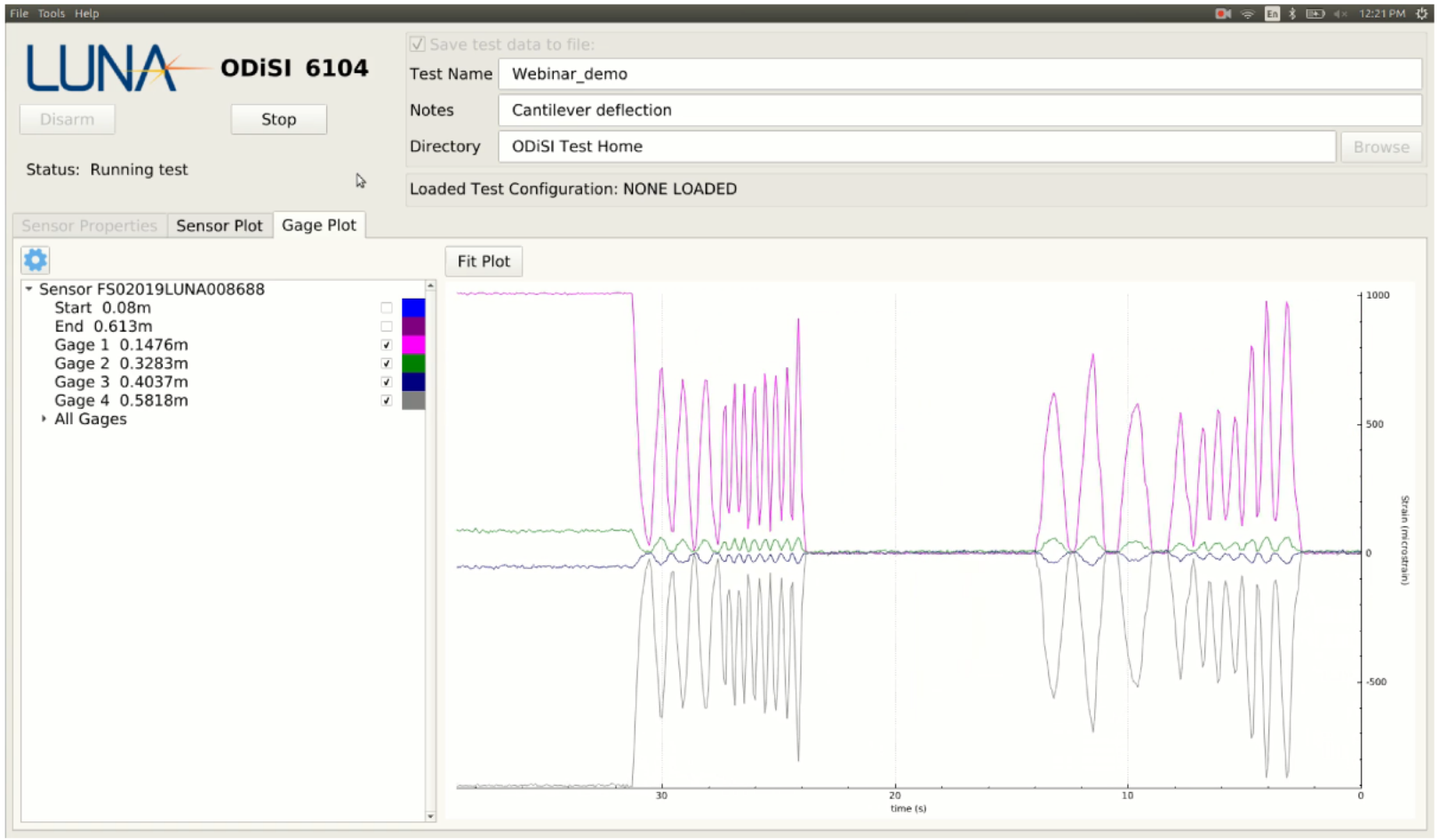
- Display Strain vs Length
- Monitor entire sensor throughout test





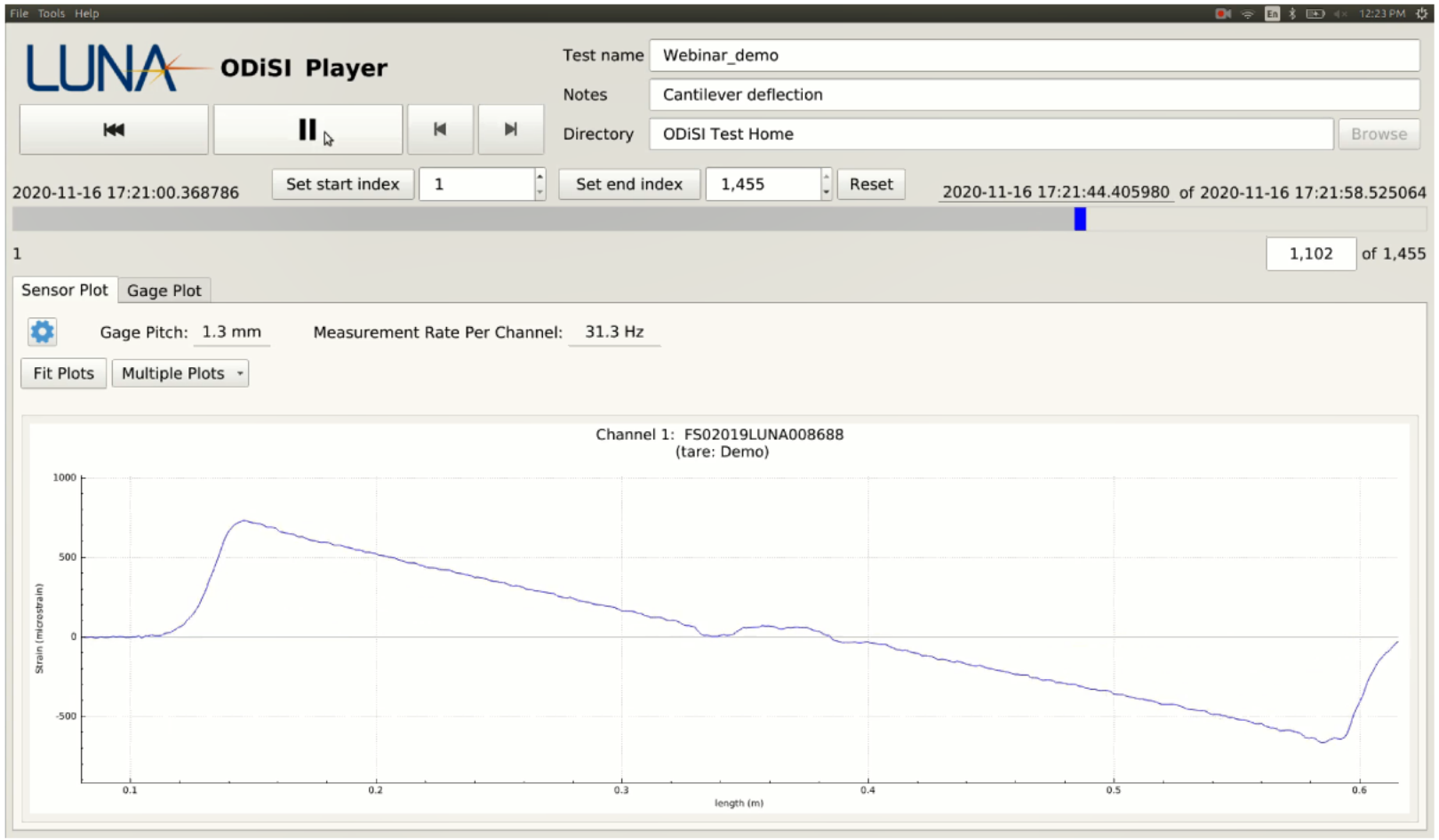
ODiSI Software – Gage Plot

- Display Strain vs Time
- Monitor individual gages over time



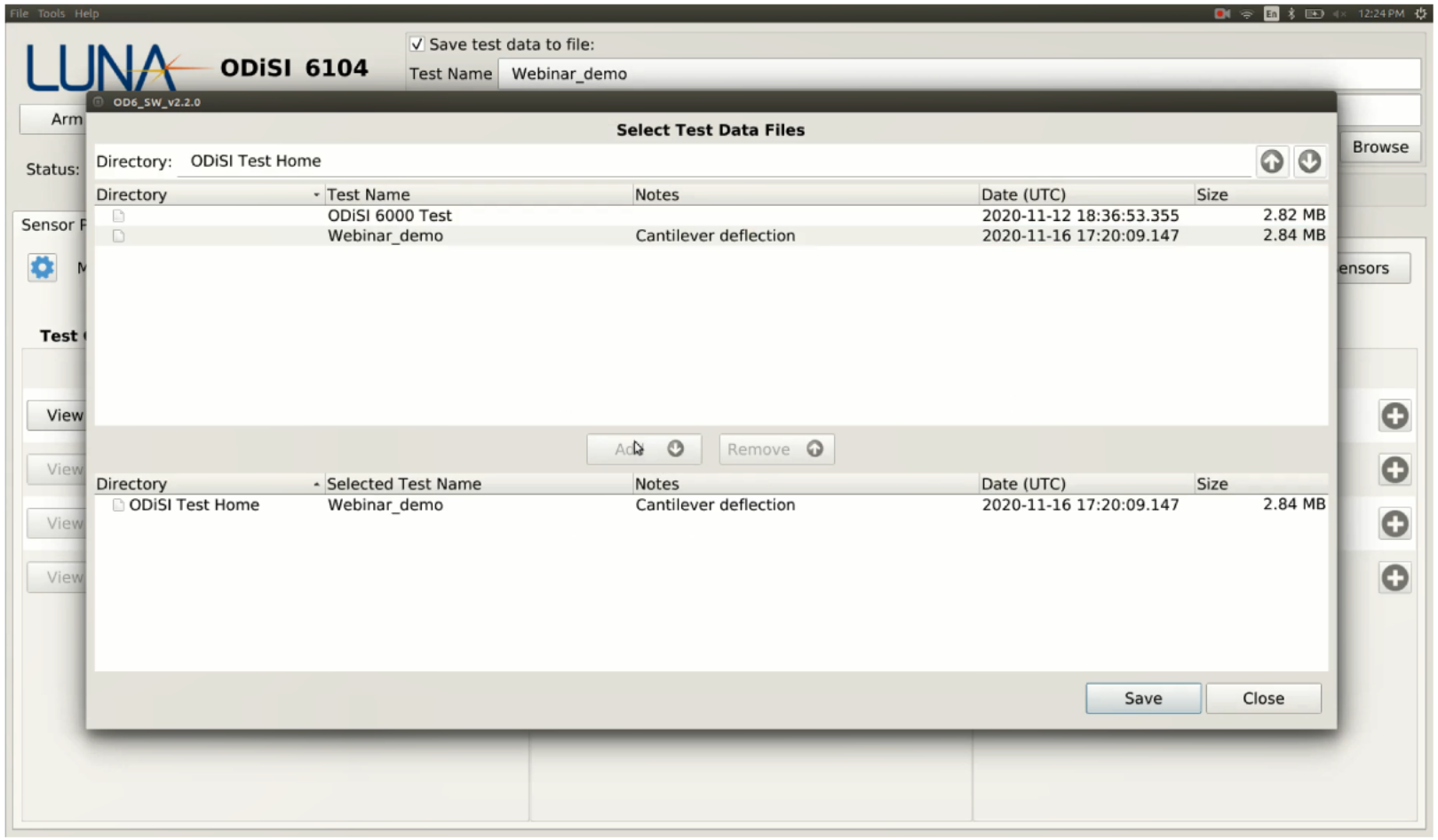
ODiSI Software – Play Back Logged Data

- Run through a test that has already been completed
- Jump to any point during the data set
- Change playback speed



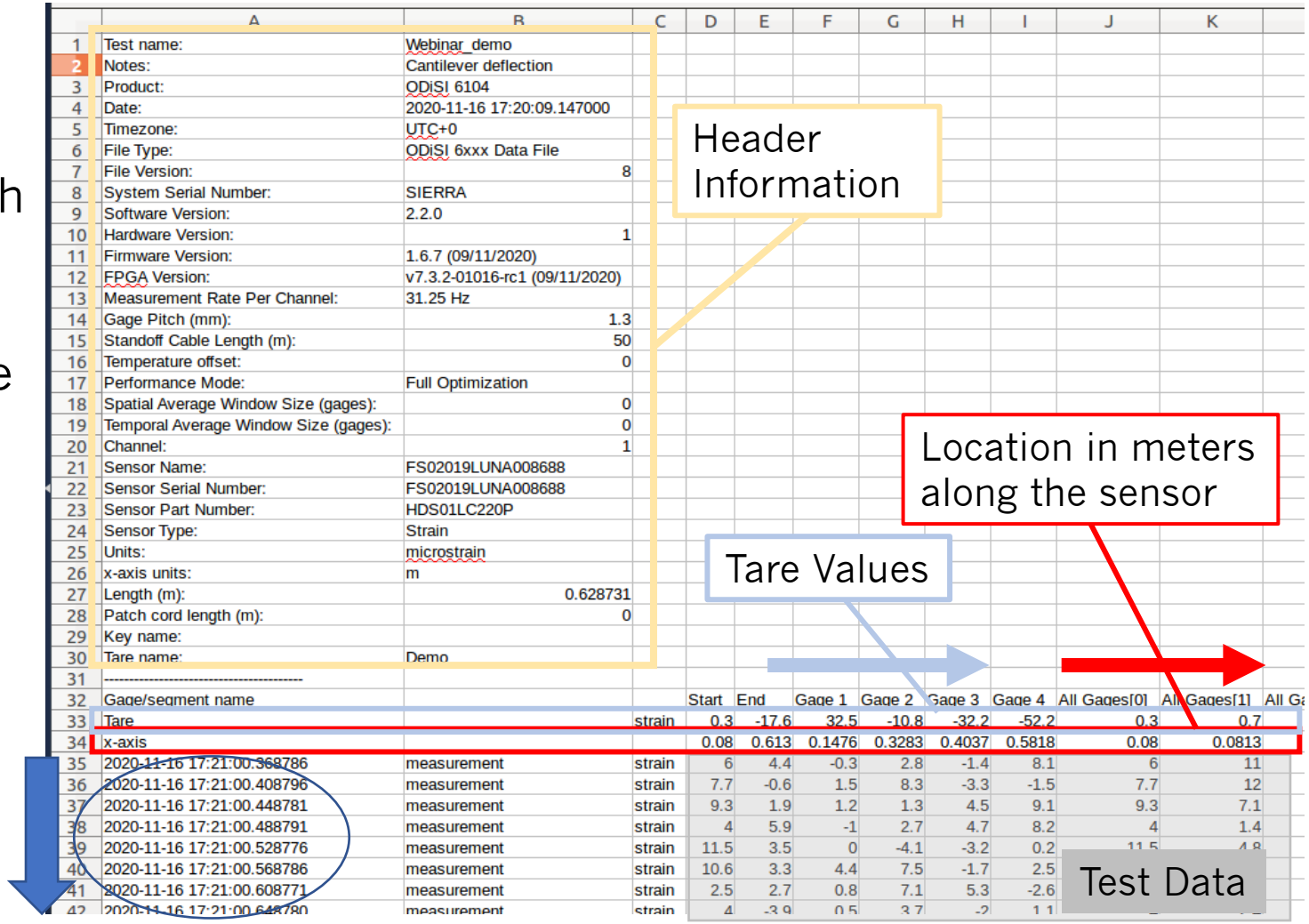
ODiSI Software – Convert to TSV

- Convert measurement data from binary data files into human readable tab-delimited data files
- TSV files can be opened in Excel, Matlab, Python, LabView



ODiSI Data Analysis

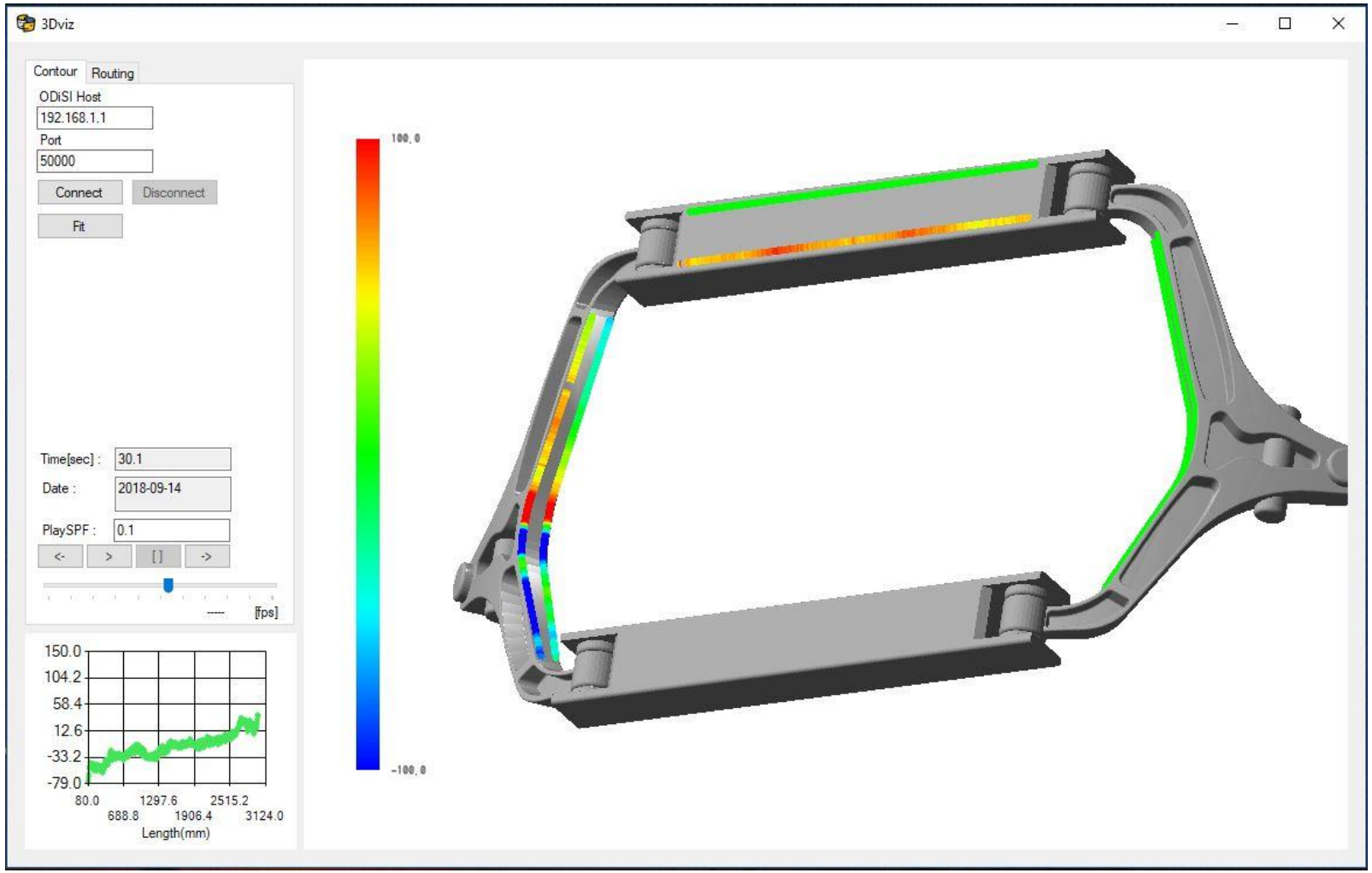
- Strain or temperature data is recorded in a 2-dimensional matrix where each row is a separate scan in time and each column is a location along the sensor
- Tab delimited data files can be read into Excel, Matlab, Python, LabView, etc.



	A	B	C	D	E	F	G	H	I	J	K
1	Test name:	Webinar_demo									
2	Notes:	Cantilever deflection									
3	Product:	ODiSI 6104									
4	Date:	2020-11-16 17:20:09.147000									
5	Timezone:	UTC+0									
6	File Type:	ODiSI 6xxx Data File									
7	File Version:	8									
8	System Serial Number:	SIERRA									
9	Software Version:	2.2.0									
10	Hardware Version:	1									
11	Firmware Version:	1.6.7 (09/11/2020)									
12	FPGA Version:	v7.3.2-01016-rc1 (09/11/2020)									
13	Measurement Rate Per Channel:	31.25 Hz									
14	Gage Pitch (mm):	1.3									
15	Standoff Cable Length (m):	50									
16	Temperature offset:	0									
17	Performance Mode:	Full Optimization									
18	Spatial Average Window Size (gages):	0									
19	Temporal Average Window Size (gages):	0									
20	Channel:	1									
21	Sensor Name:	FS02019LUNA008688									
22	Sensor Serial Number:	FS02019LUNA008688									
23	Sensor Part Number:	HDS01LC220P									
24	Sensor Type:	Strain									
25	Units:	microstrain									
26	x-axis units:	m									
27	Length (m):	0.628731									
28	Patch cord length (m):	0									
29	Key name:										
30	Tare name:	Demo									
31	----------										
32	Gage/segment name			Start	End	Gage 1	Gage 2	Gage 3	Gage 4	All Gages[0]	All Gages[1]
33	Tare		strain	0.3	-17.6	32.5	-10.8	-32.2	-52.2	0.3	0.7
34	x-axis			0.08	0.613	0.1476	0.3283	0.4037	0.5818	0.08	0.0813
35	2020-11-16 17:21:00.368786	measurement	strain	6	4.4	-0.3	2.8	-1.4	8.1	6	11
36	2020-11-16 17:21:00.408796	measurement	strain	7.7	-0.6	1.5	8.3	-3.3	-1.5	7.7	12
37	2020-11-16 17:21:00.448781	measurement	strain	9.3	1.9	1.2	1.3	4.5	9.1	9.3	7.1
38	2020-11-16 17:21:00.488791	measurement	strain	4	5.9	-1	2.7	4.7	8.2	4	1.4
39	2020-11-16 17:21:00.528776	measurement	strain	11.5	3.5	0	-4.1	-3.2	0.2	11.5	4.8
40	2020-11-16 17:21:00.568786	measurement	strain	10.6	3.3	4.4	7.5	-1.7	2.5		
41	2020-11-16 17:21:00.608771	measurement	strain	2.5	2.7	0.8	7.1	5.3	-2.6		
42	2020-11-16 17:21:00.648780	measurement	strain	4	-3.9	0.5	3.7	-2	1.1		

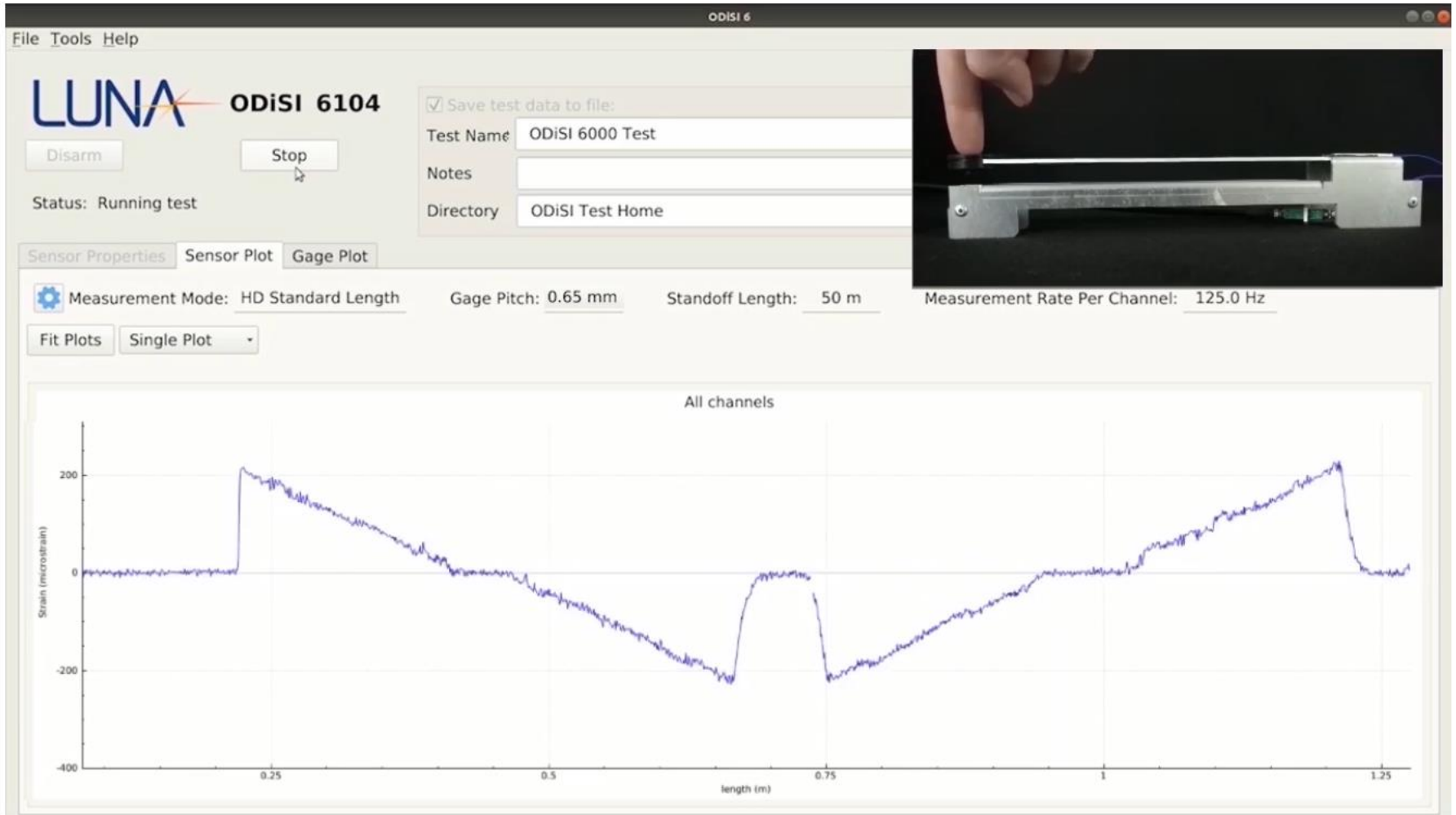
3D Data Visualization

- Display data as color map over test article image or 3D model



Summary: How to Use an ODiSI

- Install a keyed sensor onto a test article
- Use the ODiSI software to Identify gages of interest
- Select data logging parameters
- Log data during a test and/or stream to a network location
- Play back data post-test



Fiber Sensing Advantages

Luna's high-definition fiber optic sensing solution allows materials, structures and systems to be seen like never before:

- Instrument complex geometries to validate models
- Embed fiber sensors in composite structures and monitor structural health and aging
- Provide feedback control for manufacturing processes
- Create smart parts through sensor integration
- Implement predictive maintenance through embedded sensors

Learn More

- Luna's Website:
  - https://www.lunainc.com
- ODiSI 6000 web page:
  - https://lunainc.com/product/odisi-6000-series
- ODiSI 6000 Data Sheet:
  - https://lunainc.com/sites/default/files/assets/files/data-sheet/LUNA-ODiSI-6000-Data-Sheet.pdf
- ODiSI 6000 User's Guide:
  - https://lunainc.com/sites/default/files/assets/files/resource-library/ODiSI%206100%20User%20Guide.pdf

Thank you! Questions?

Q&A

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https://lunainc.com/events/learn-luna-explainer-webinar-series