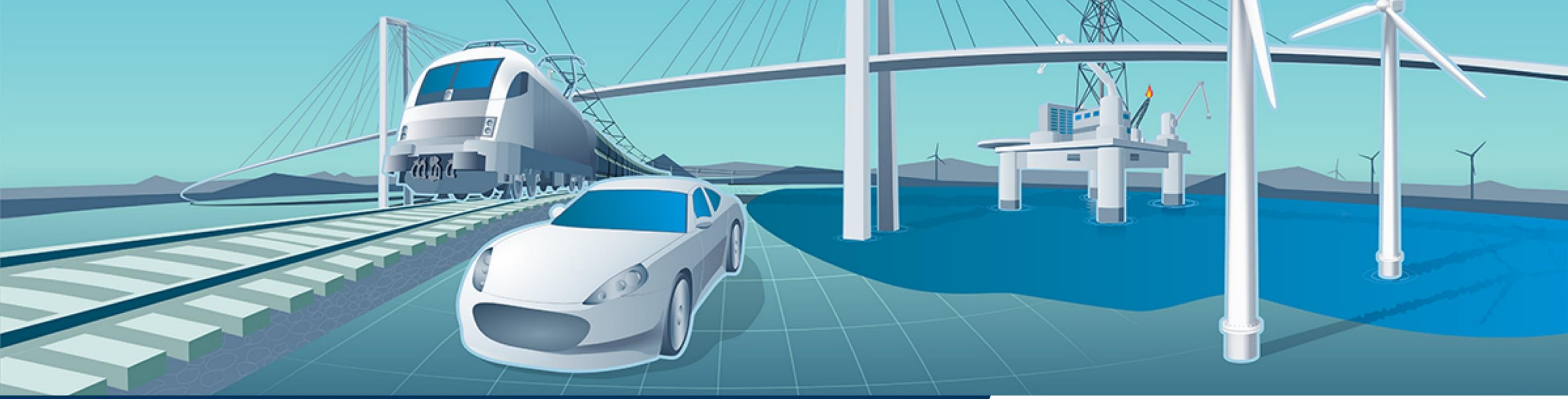
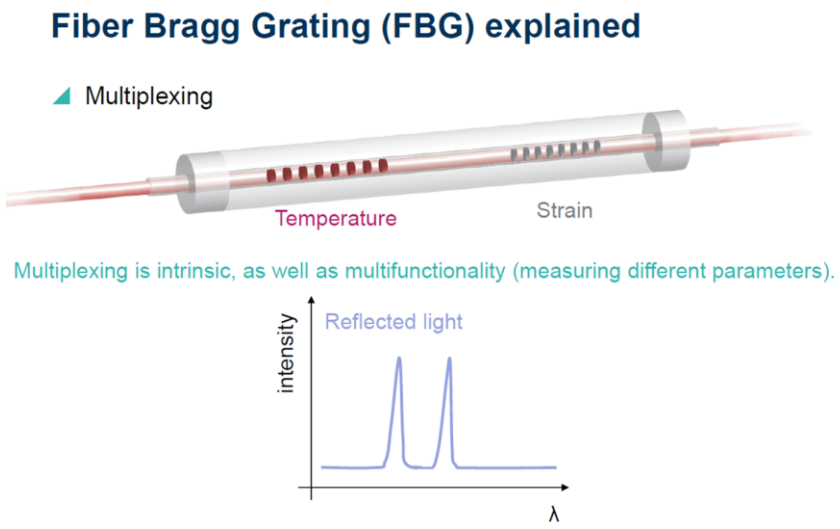


HBK Technology Days – Virtual Seminar Series

Tuesday, November 15, 2022



Optical Sensor Technology and Applications for Civil Structures

Presented by Cristina Barbosa,
Product Manager Optical Business,
HBK FiberSensing

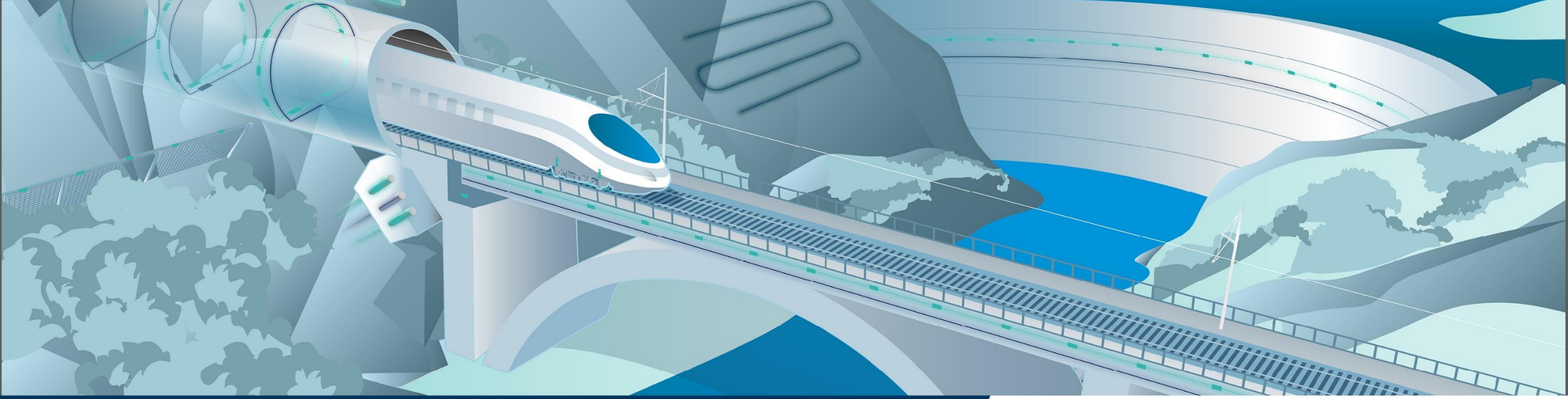
Optical Sensor Technology and Applications for Civil Structures

Abstract

Structural Health Monitoring systems aim to control the integrity of a structure throughout its service life so that planned maintenance and serviceability extension safely maximize this asset profitability. Monitoring systems are expected to reliably operate through long periods and to resist extreme events. The use of optical sensors based on Fiber Bragg Grating technology is becoming an interesting choice for Structural Monitoring Systems. In this presentation you will learn about the technology, product possibilities and current state of the art. The main challenges we are facing when monitoring civil structures will be identified and we will show how using optical technology can support on overcoming them with concrete application examples.

About the presenter, Cristina Barbosa, Product Manager Optical Business, HBK FiberSensing

Cristina Barbosa is the Product Manager for HBK Optical Business since 2015, but her work with Fiber Bragg Grating technology started more than 15 years ago, soon after graduating from the Faculty of Engineering of Porto University as a Civil Engineer. Since then, she has been working in FiberSensing, currently HBK FiberSensing, taking different responsibilities from application engineering to sales, with an important support to marketing activities.



HBK Technology Days – Virtual Seminar Series

Tuesday, November 15, 2022

Machine Learning for Structural Health Monitoring, from Data-Driven to Physics-Informed

Presented by Prof. Elizabeth Cross,
Dynamics Research Group, University of Sheffield

Optical Sensor Technology

APPLICATIONS FOR CIVIL STRUCTURES

Cristina Barbosa

15.11.2022

2022 HBK Technology Days Session 3: Structural Health Monitoring - Bridges and Sensors

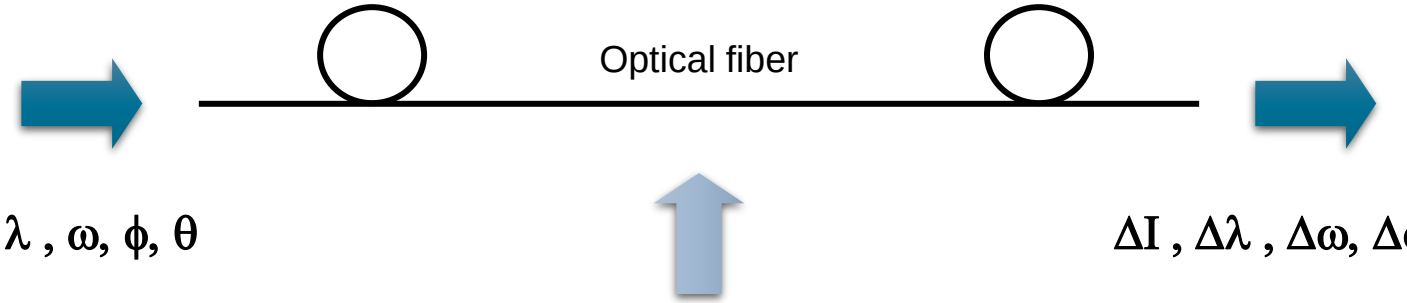
Optical Sensor Technology


Optical
Fiber
is connecting today’s world

Optical Fiber

But is also being used in a different way!

OPTICAL FIBER ACTING AS A **SENSOR**



$I , \lambda , \omega, \phi, \theta$

Amplitude/Intensity
Wavelength
Frequency
Phase
Polarization

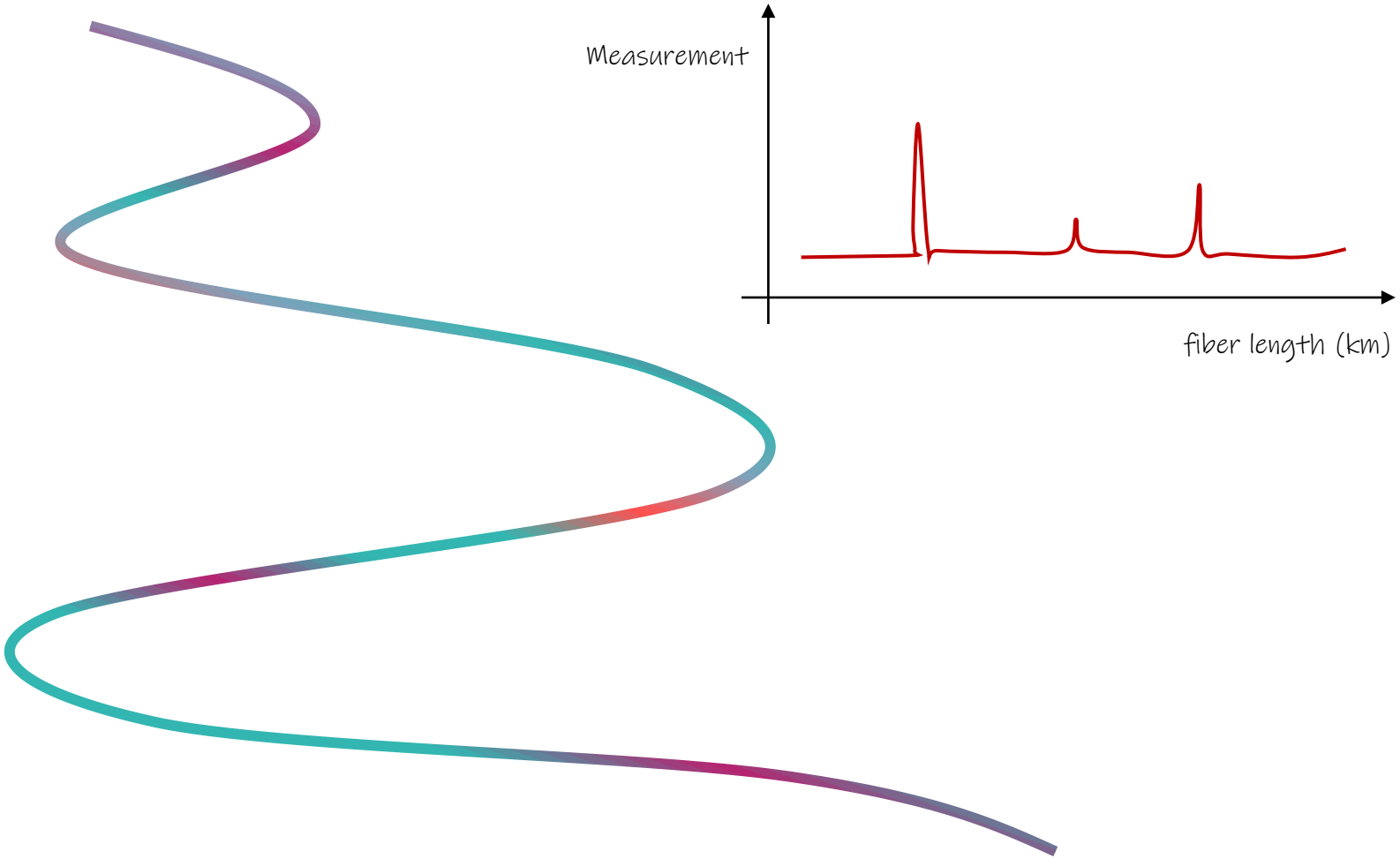
Temperature
Pressure / stress
Strain
Displacement
Force
Magnetic field
…

$\Delta I , \Delta\lambda , \Delta\omega, \Delta\phi, \Delta\theta$

Optical signal modulation

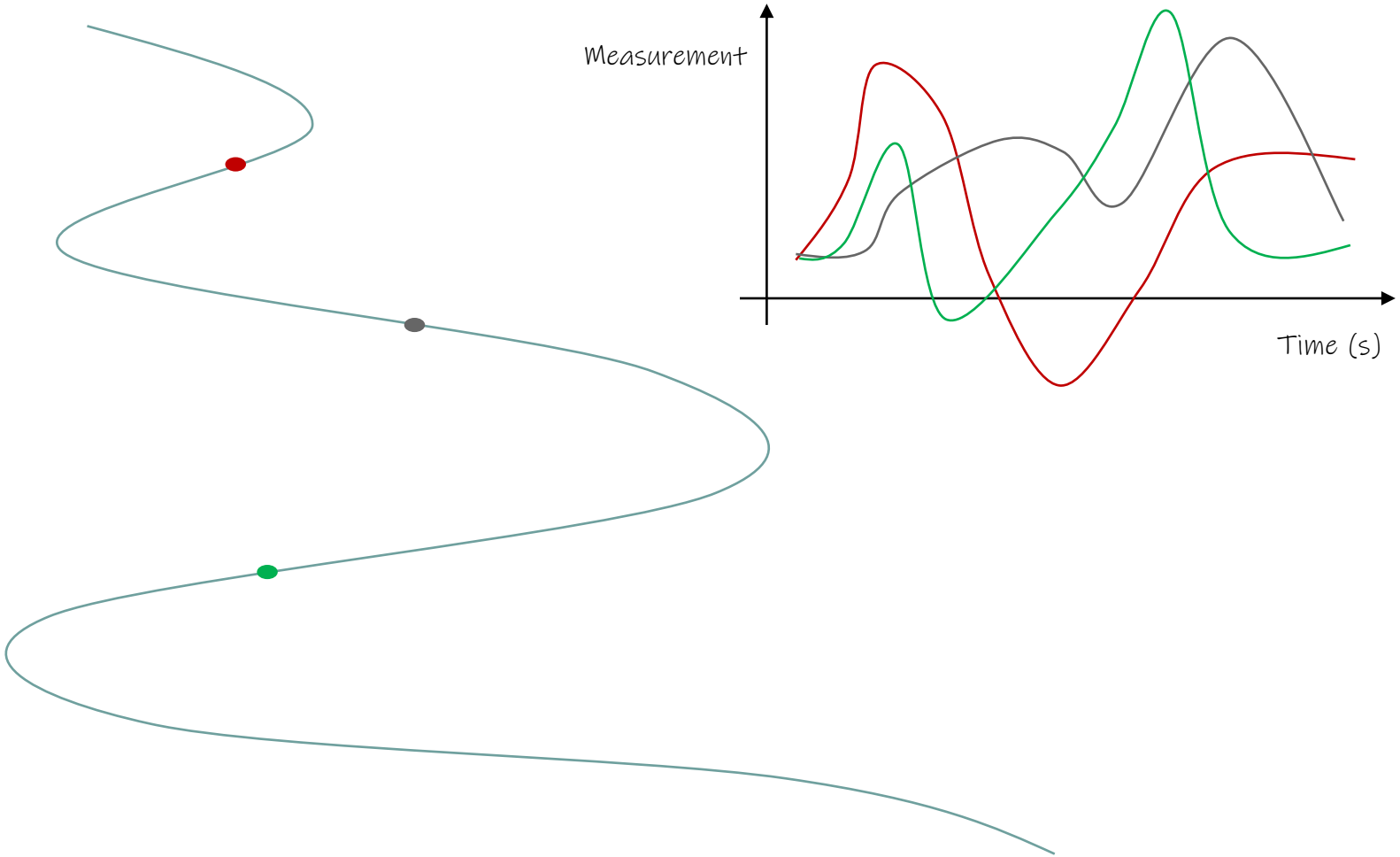
Optical Fiber as Sensor

DISTRIBUTED SENSING



Optical sensors and transducers

POINT SENSING



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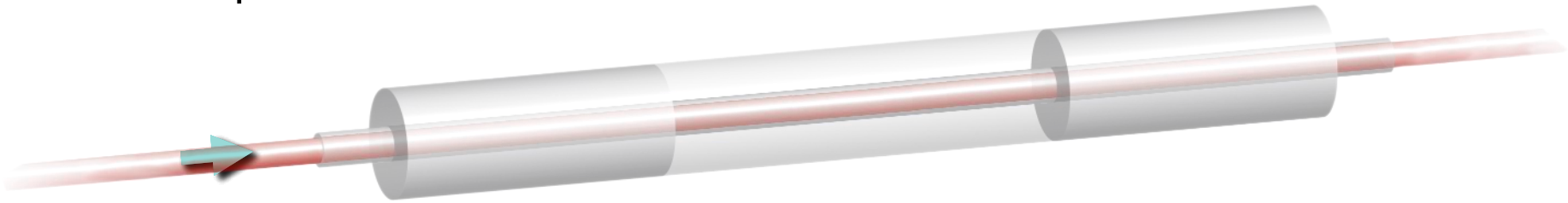
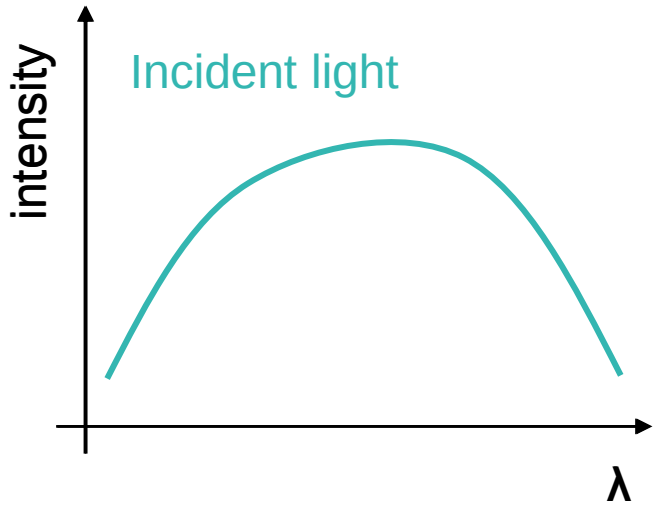
Fiber Bragg Grating (FBG) explained

- Optical fiber





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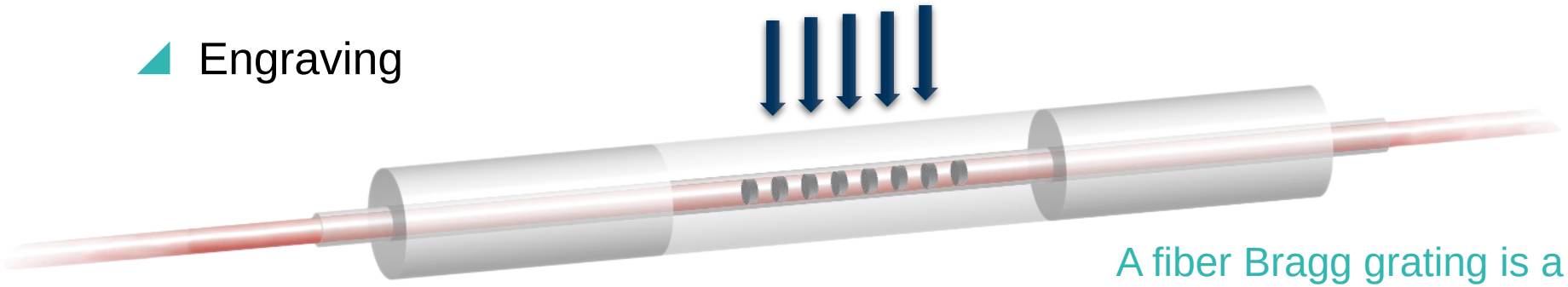
Fiber Bragg Grating (FBG) explained

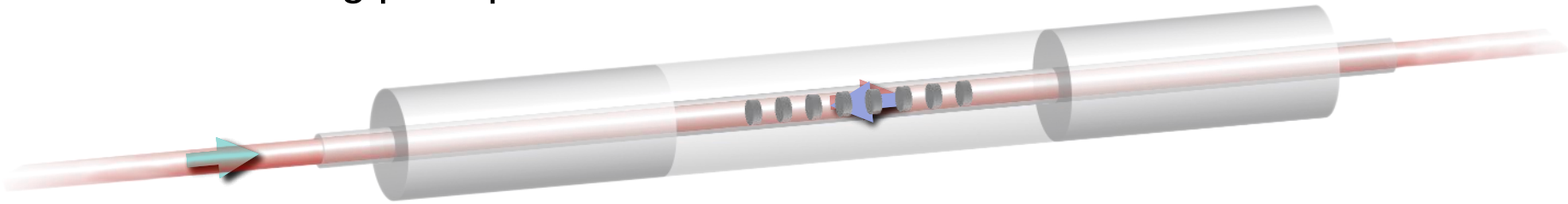
- Engraving

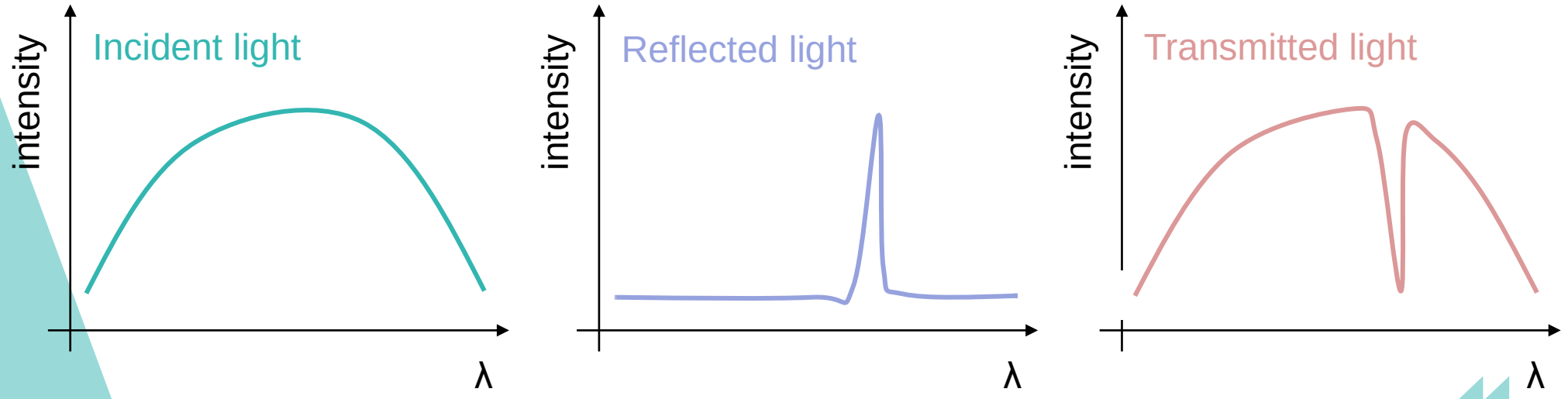


A fiber Bragg grating is a periodic microstructure that is inscribed inside the core of an optical fiber using laser light.

Fiber Bragg Grating (FBG) explained

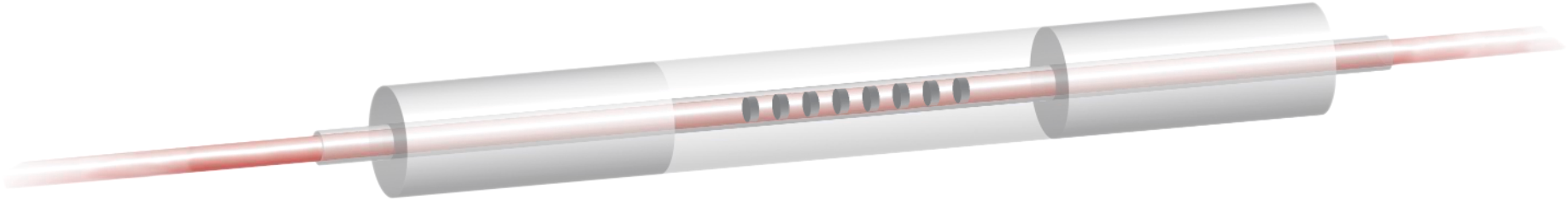
- Working principle



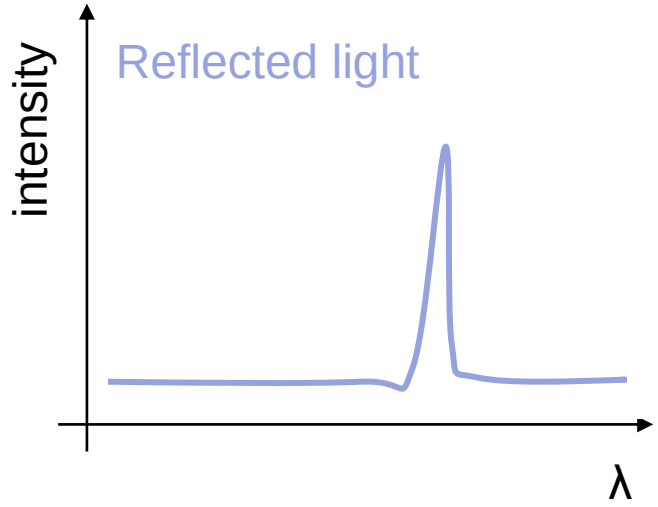


Fiber Bragg Grating (FBG) explained

- Strain Measurement



The wavelength of the reflected peak changes when strain is applied to the fiber.



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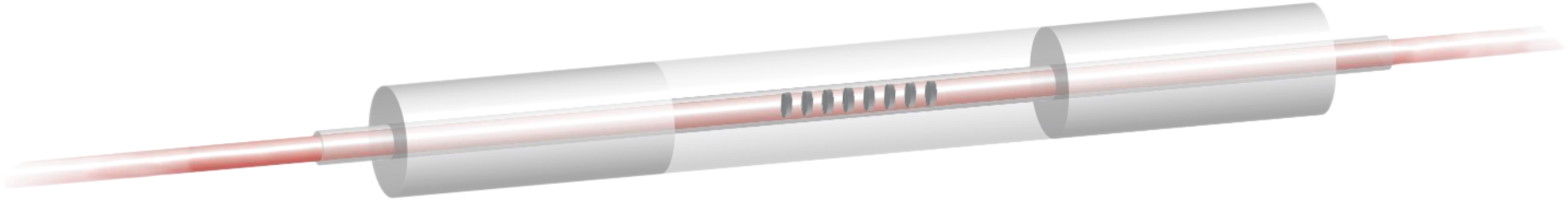

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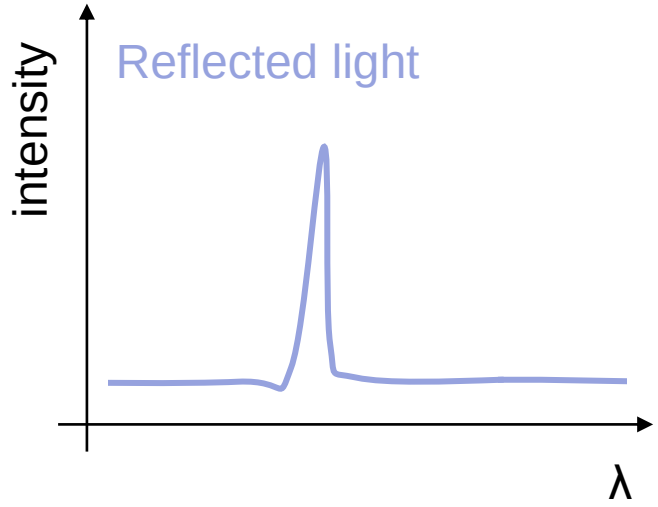

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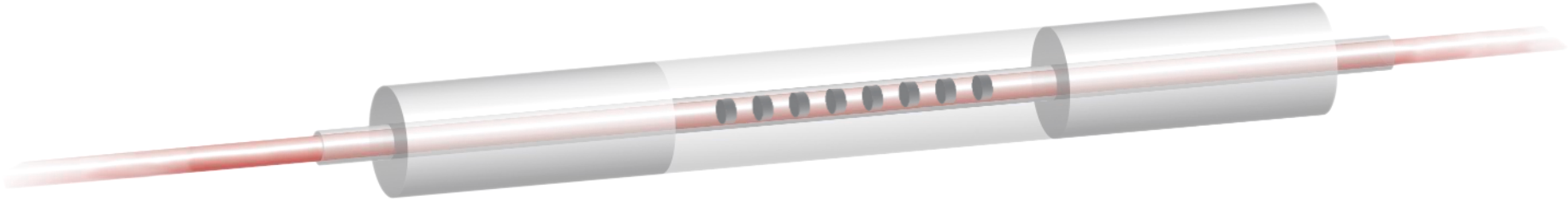

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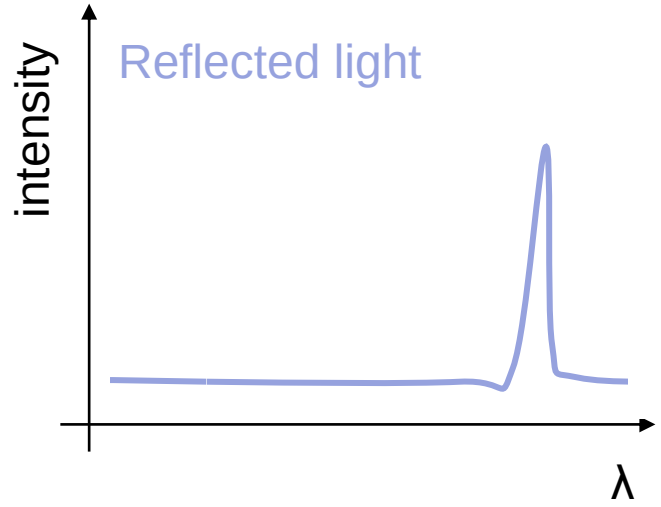

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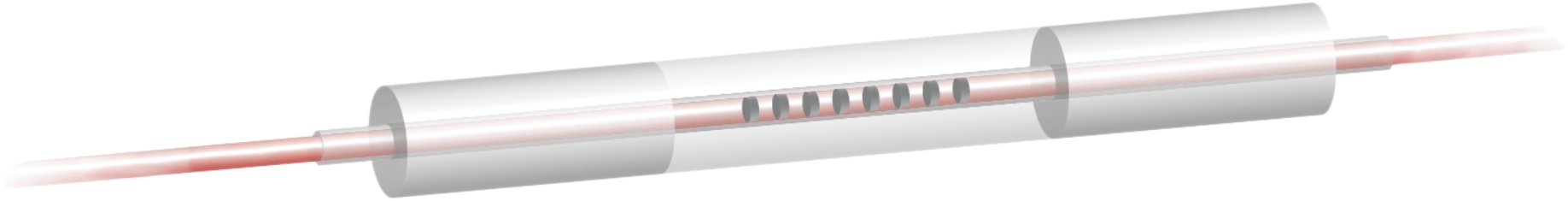

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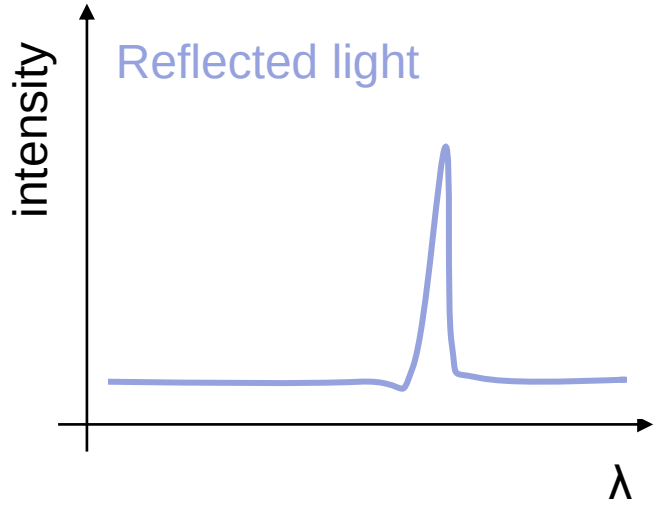
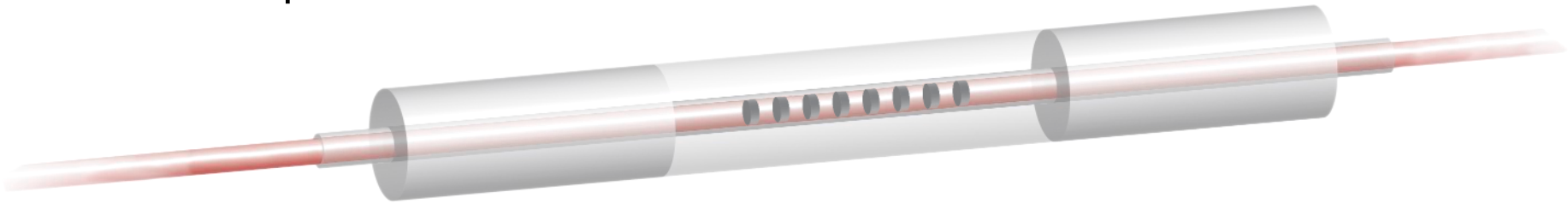


Fiber Bragg Grating (FBG) explained

- Temperature Measurement



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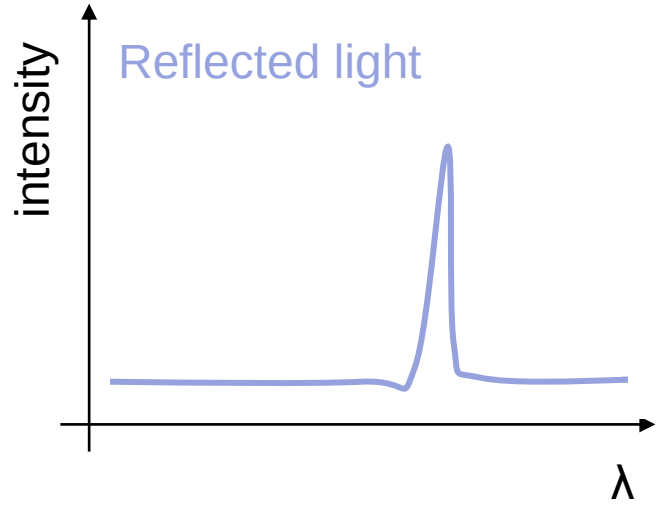

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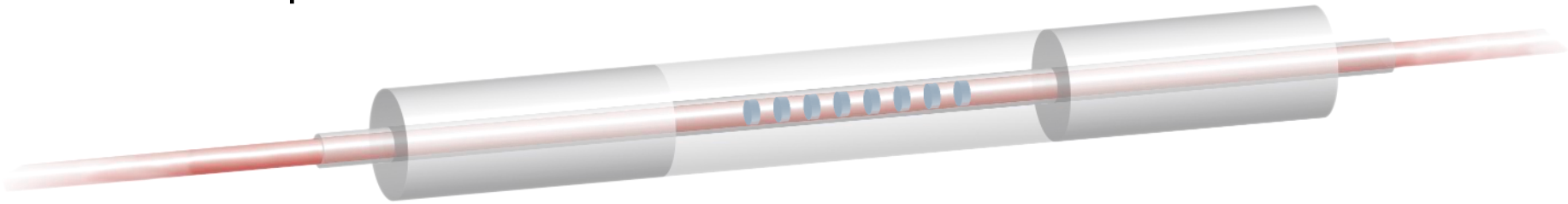

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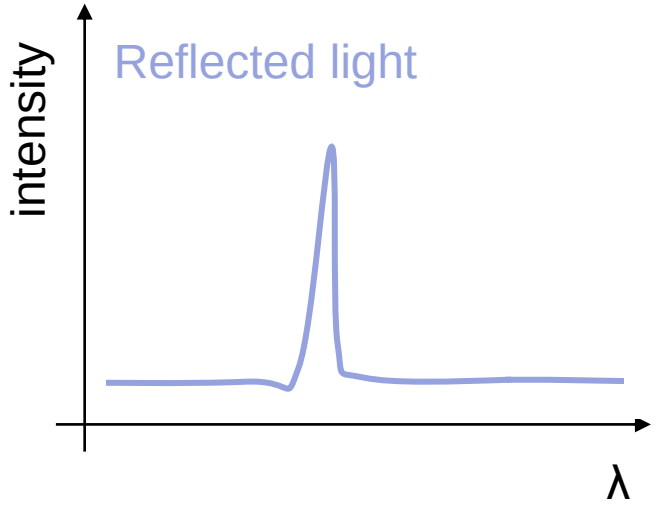

Fiber Bragg Grating (FBG) explained

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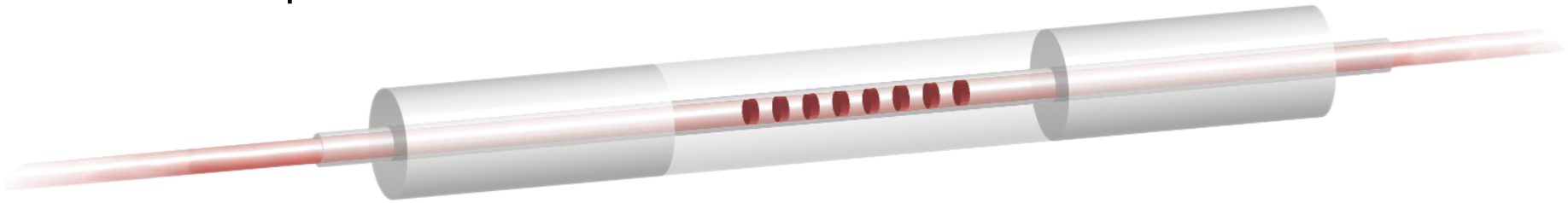

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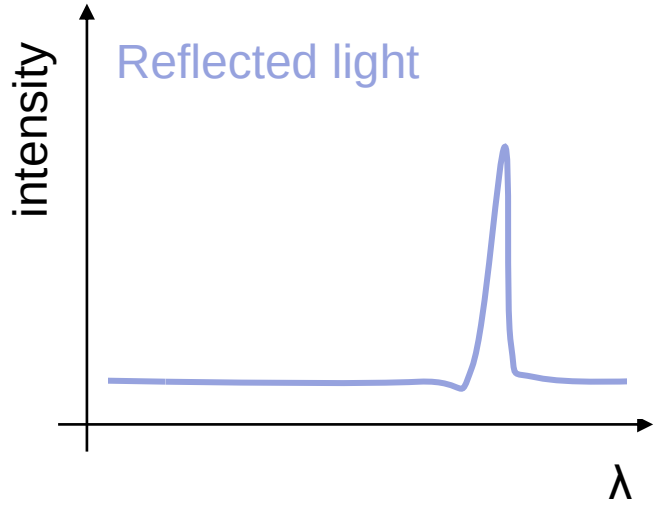
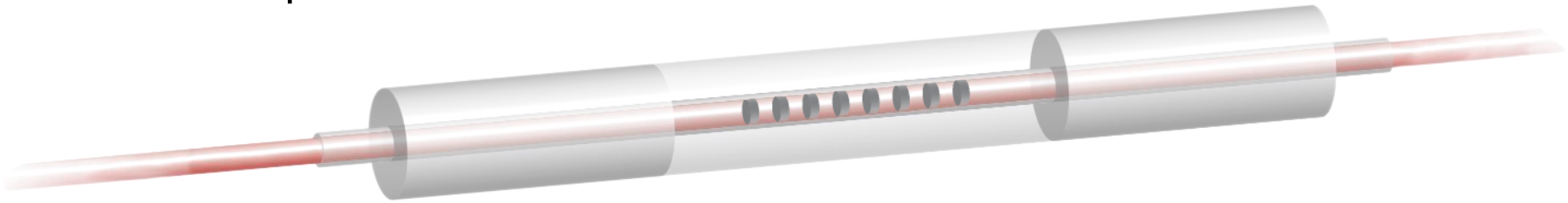


Fiber Bragg Grating (FBG) explained

- Temperature Measurement



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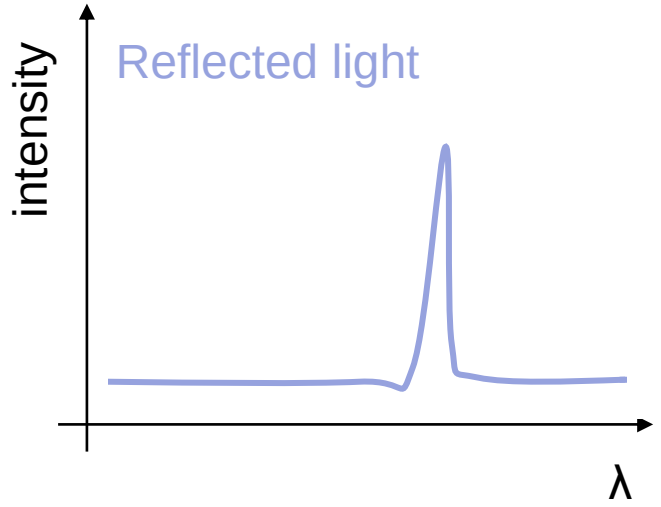
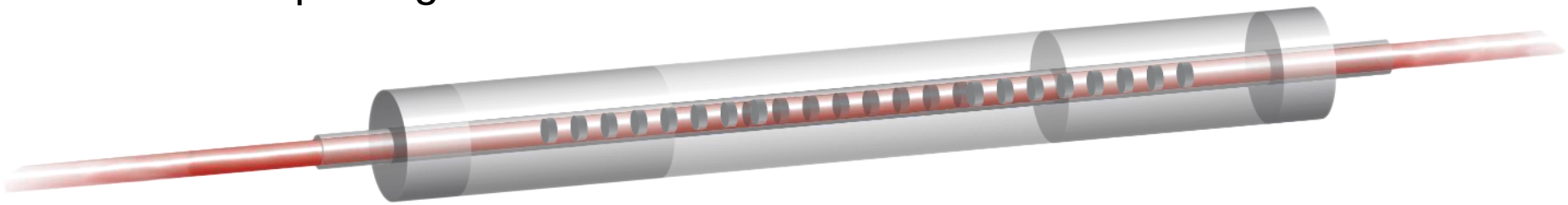
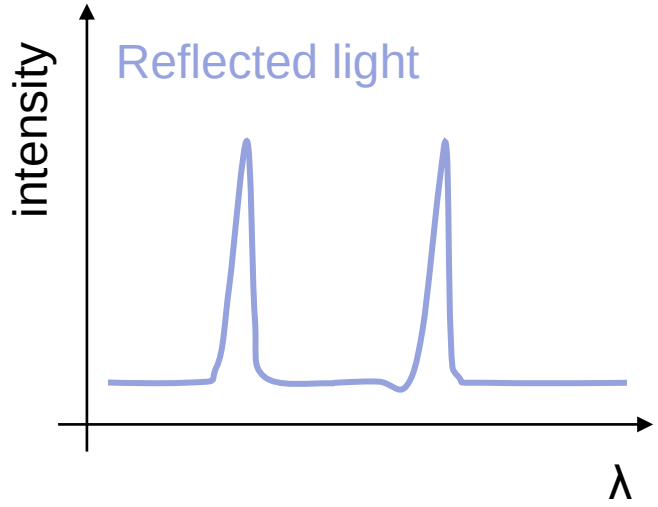


Fiber Bragg Grating (FBG) explained

- Multiplexing



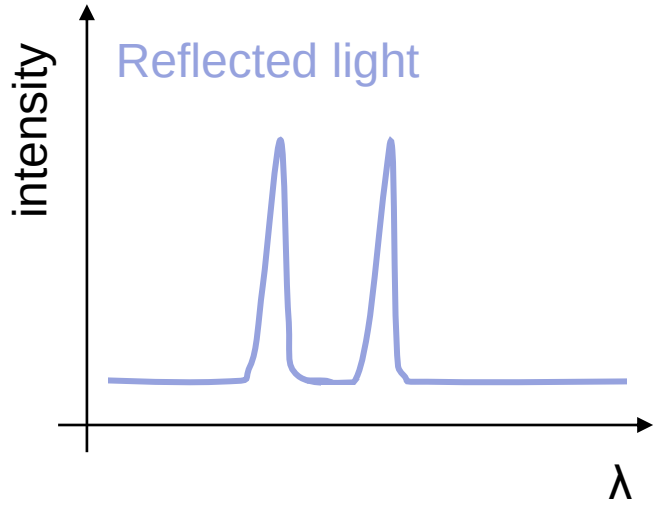
Over the same fiber we can inscribe many FBGs getting several reflections at different wavelengths.



Fiber Bragg Grating (FBG) explained

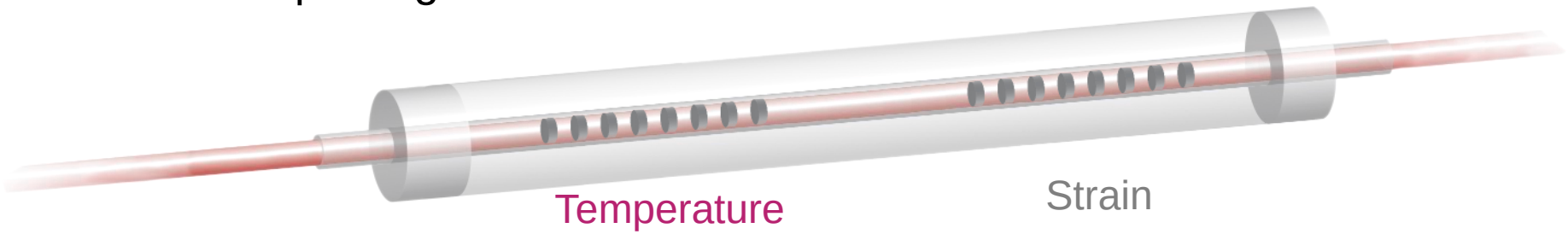
- Multiplexing

Multiplexing is intrinsic, as well as multifunctionality (measuring different parameters).



Fiber Bragg Grating (FBG) explained

- Multiplexing



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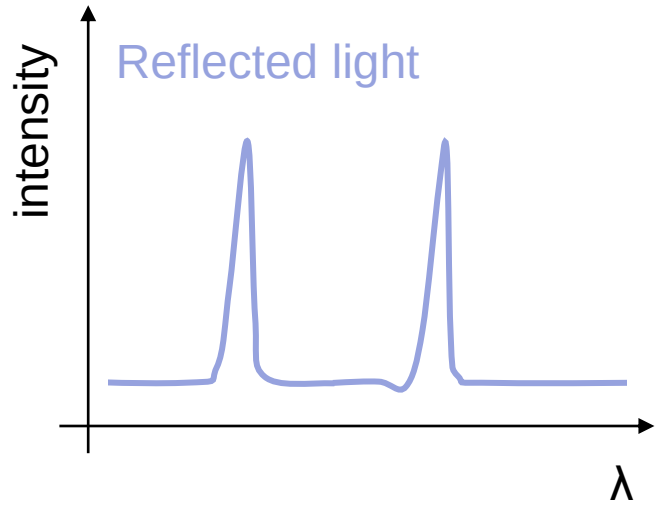
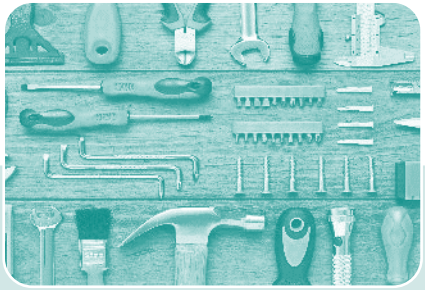


Advantages for Civil Engineering Structures



Multiplexing and multipurpose

- Easily address large sensor count with a single device
- Simplify installation with optimized cabling offered by in-series connection of sensors

Large Sensor Count

Immunity to EMI and RFI

- Reduce errors and measurement uncertainties in hazardous environments as, for example, offshore
- Simplify installation procedures and needed protection

Harsh Environments

Low losses

- Concentrate heavy measuring equipment in accessible and protected areas while sensors are spread over kilometers

Long Distances

Passive technology

- Safely measure in explosive areas or high voltage environments

Explosive or High Voltage Areas

Absolute measurements

- Ensure accuracy and long-term stability with no zero drift measurements
- Reduce or eliminate equipment calibration efforts

Long term Measurements

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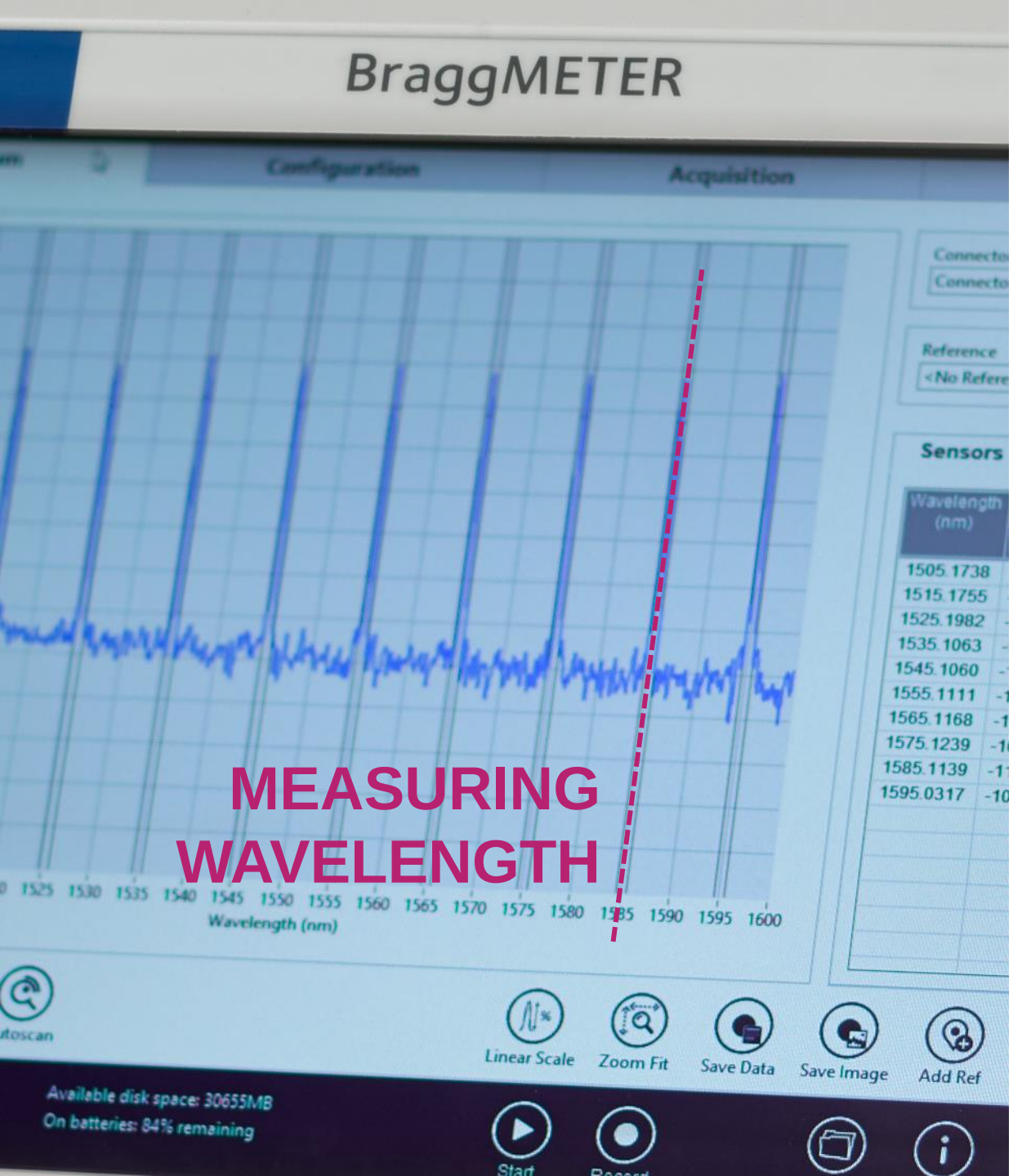
Application in Civil Engineering

Long periods of operation

Silica

Resistant



Long periods of operation

Wavelength

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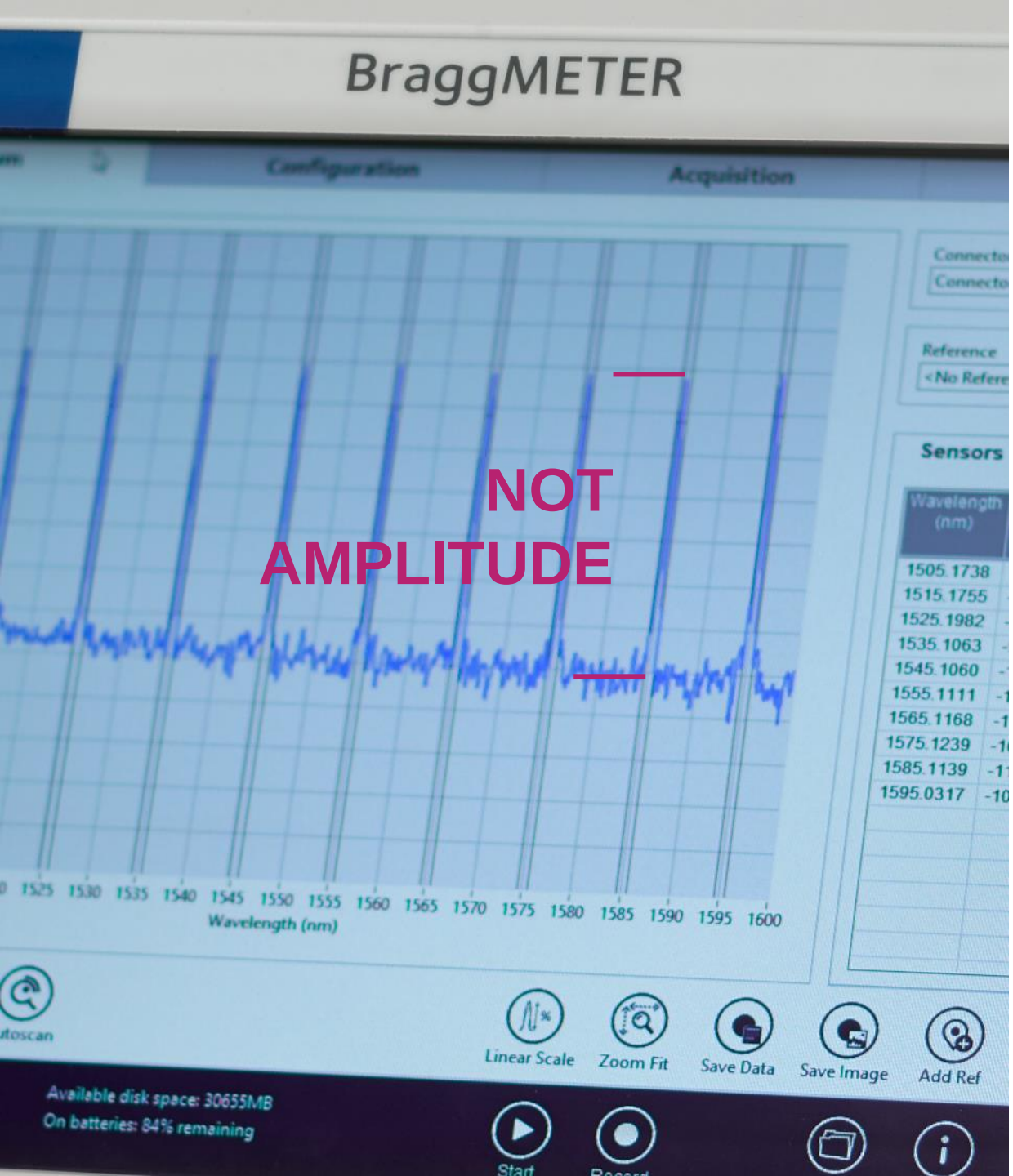

Long periods of operation

Wavelength

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Long periods of operation

Wavelength

Insensitive to losses

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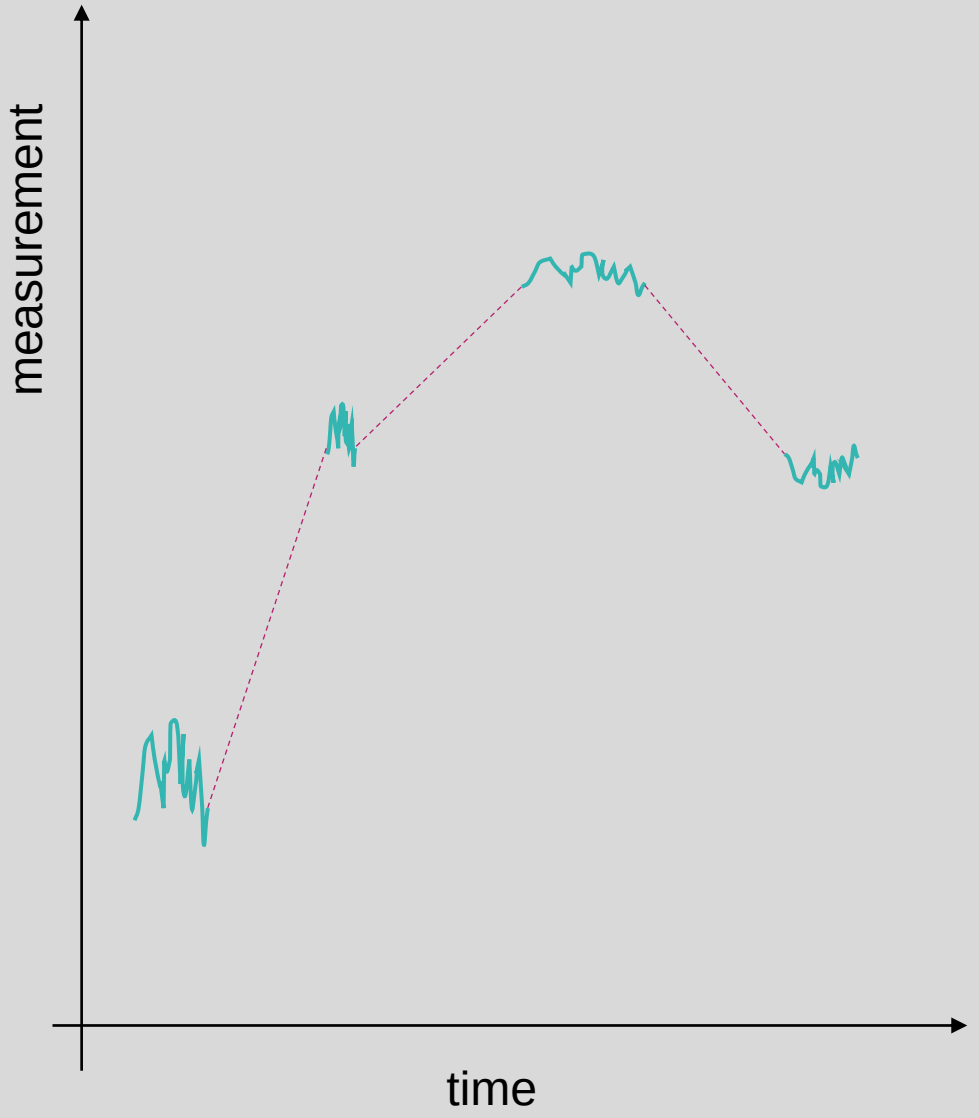

Long periods of operation

Wavelength

Referenced Measurement

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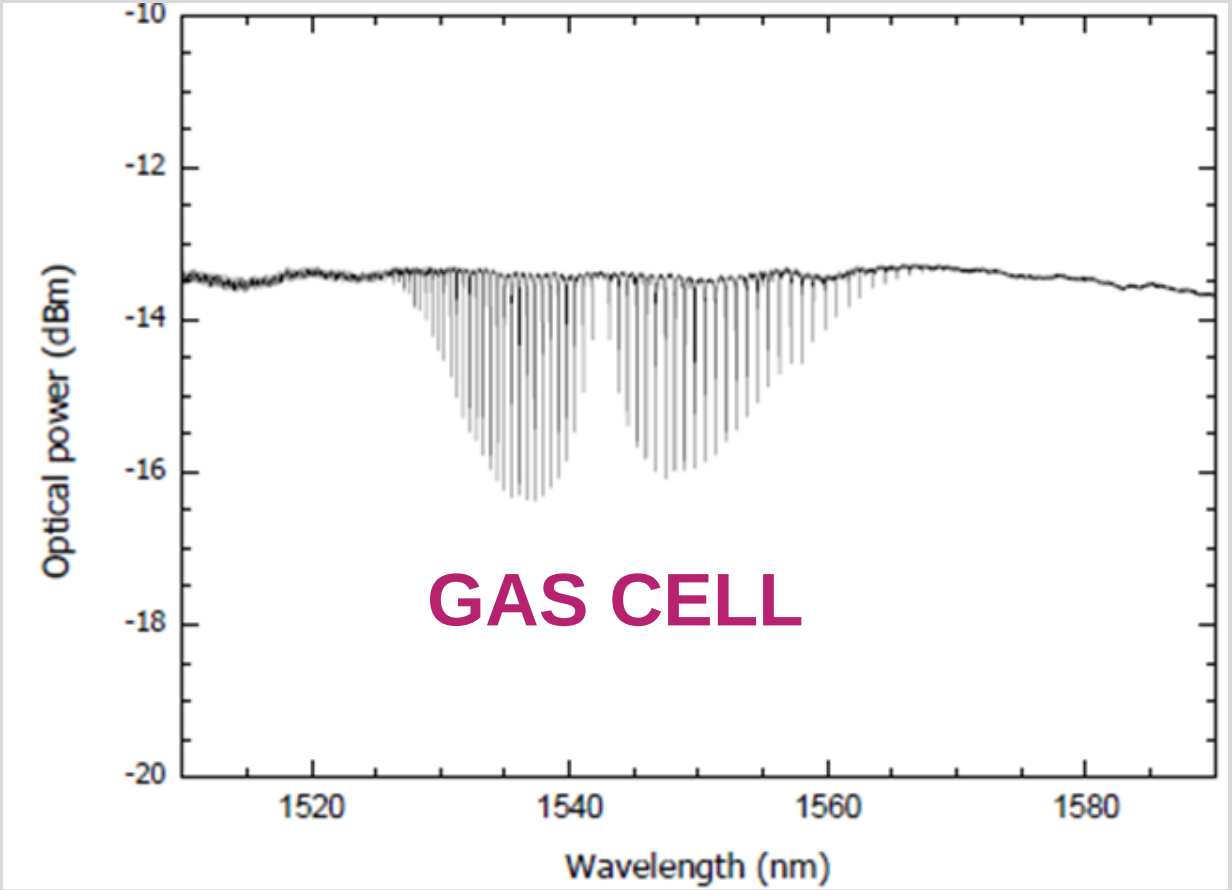
Long periods of operation



Wavelength

Built in Reference

No Drift

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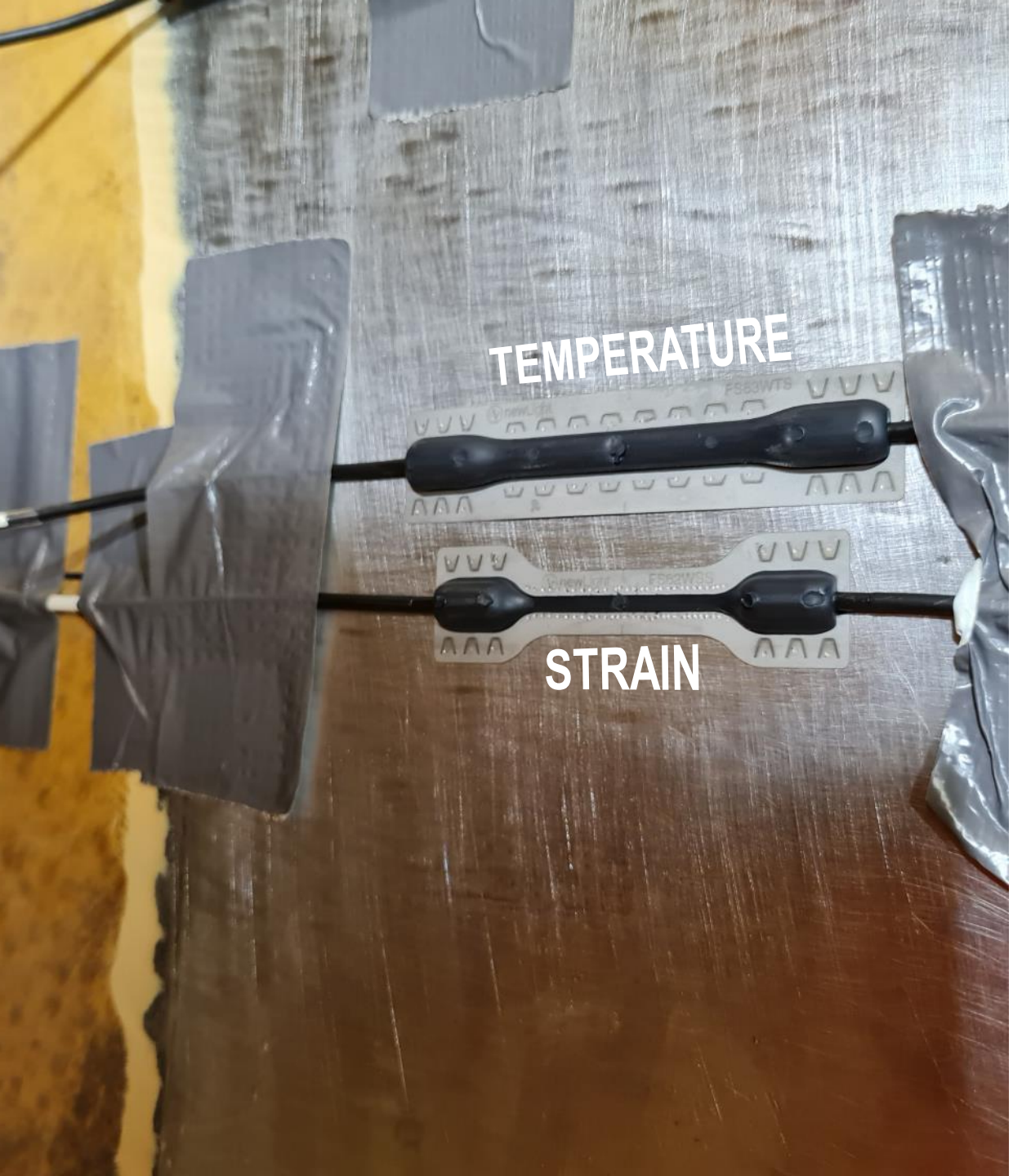

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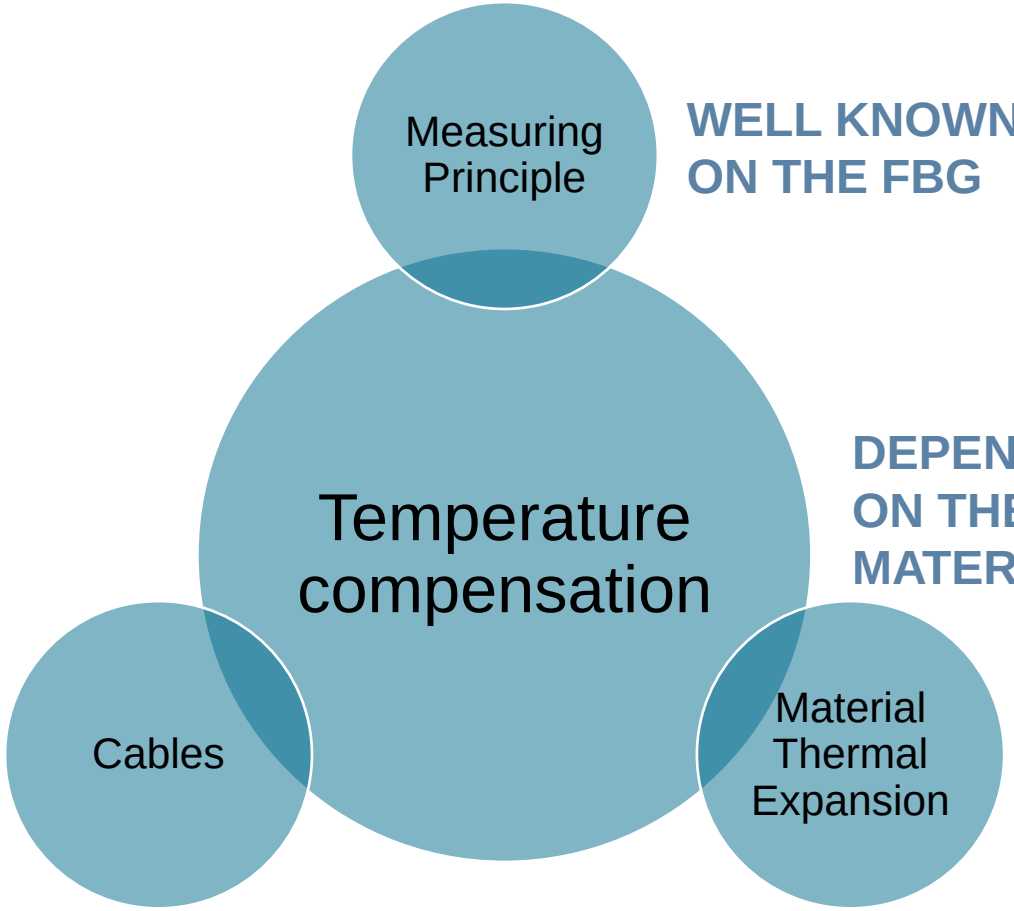

WELL KNOWN ON THE FBG

DEPENDING ON THE MATERIAL

NON-EXISTING ON OPTICAL TECHNOLOGY

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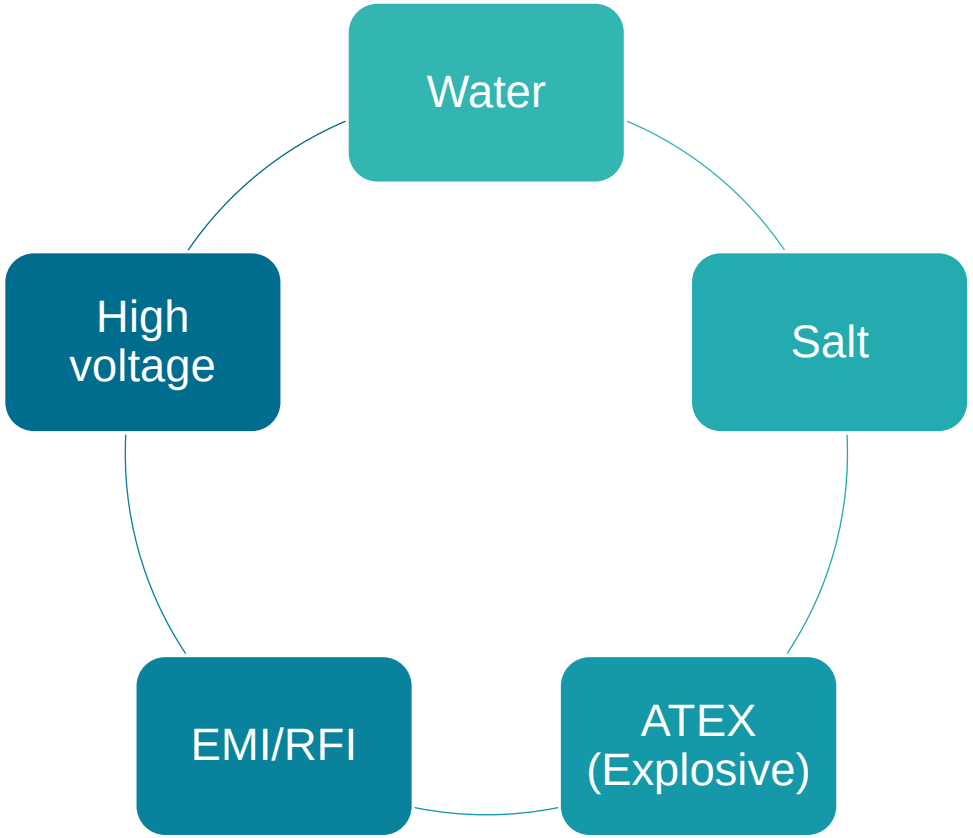
Harsh environments



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Long distances

- Long structures
- Remote locations
- No power supply

Low attenuation of optical fibers:

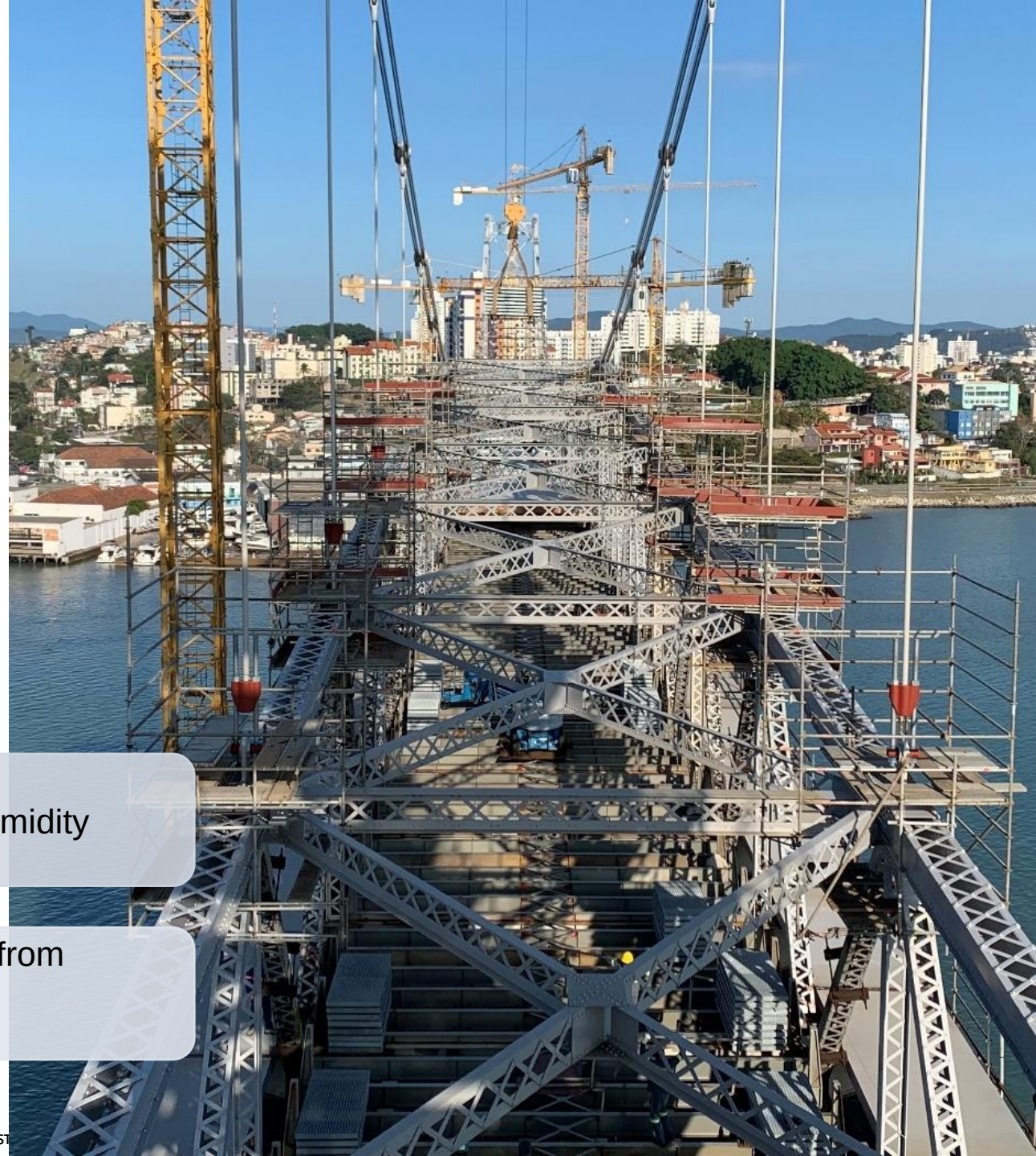
No heavy equipment on inaccessible locations

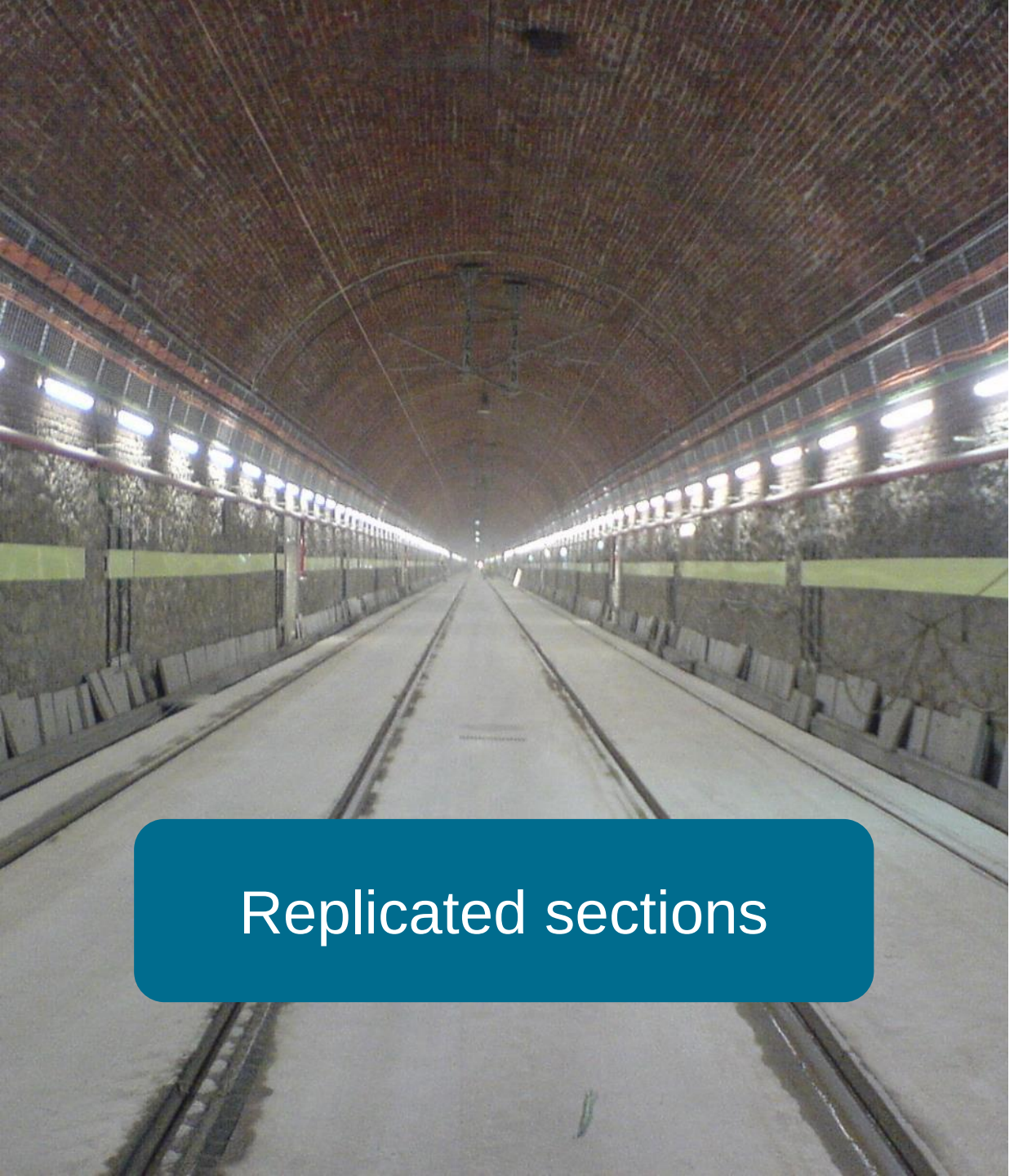
Concentration of devices on one controlled location

- Access control
- Temperature and humidity control

Scattered sensors

- Data acquisition far from sensors
- Sensors far apart





Replicated sections

Large sensor count

Multiplexing

Multifunctionality

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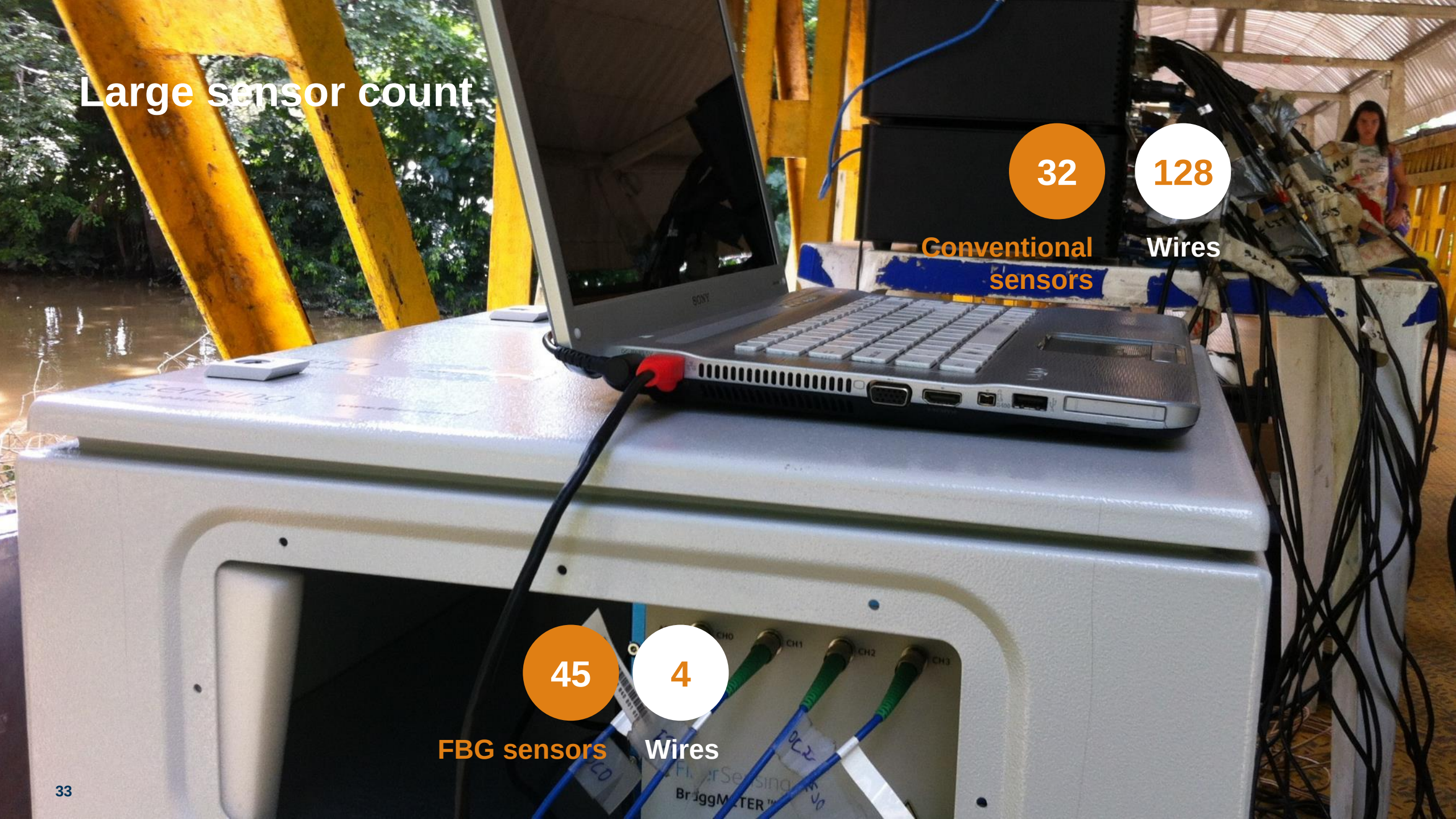
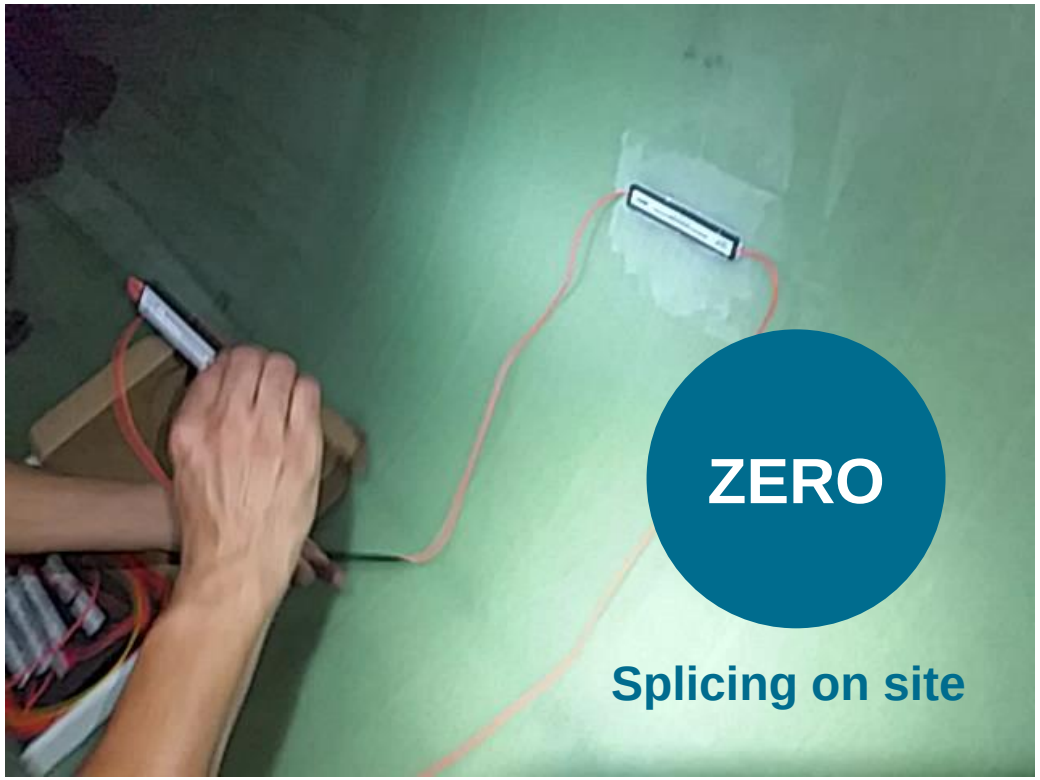
Large sensor count



Installation efficiency

Preassembled arrays of sensors



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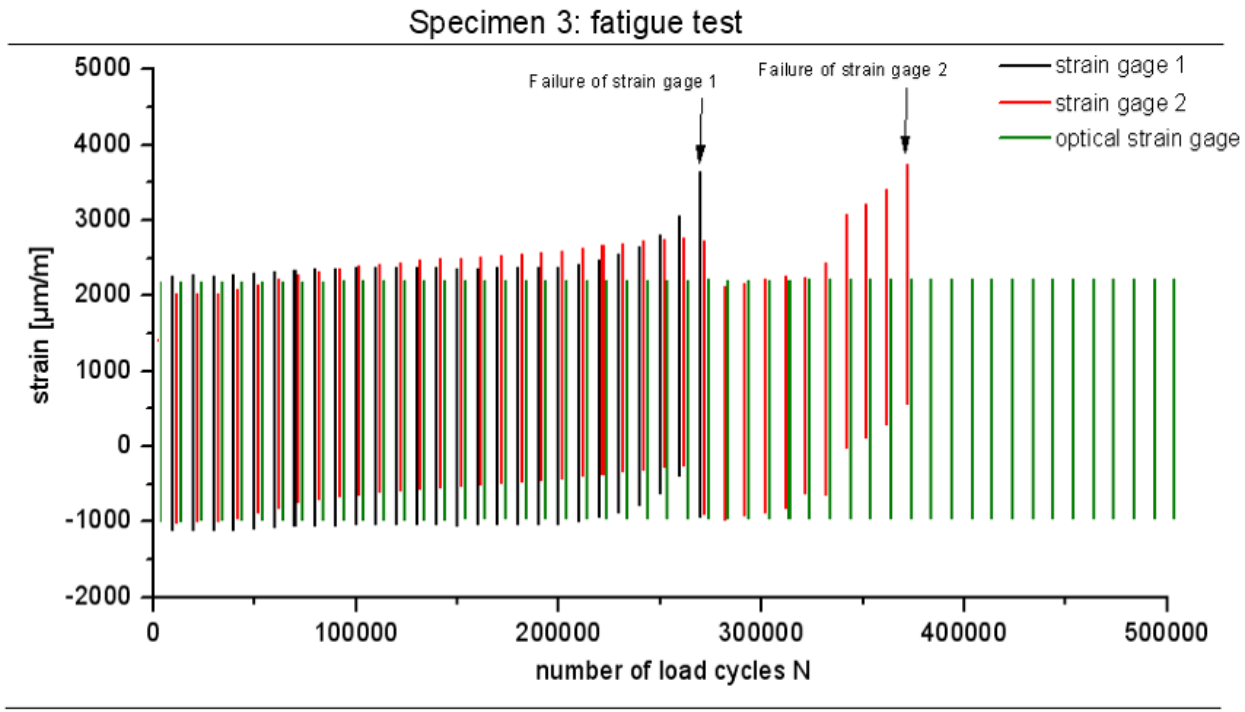
Meeting new materials

- Higher resistance

OPTICAL TECHNOLOGY

High Strain

High Fatigue



Meeting new materials

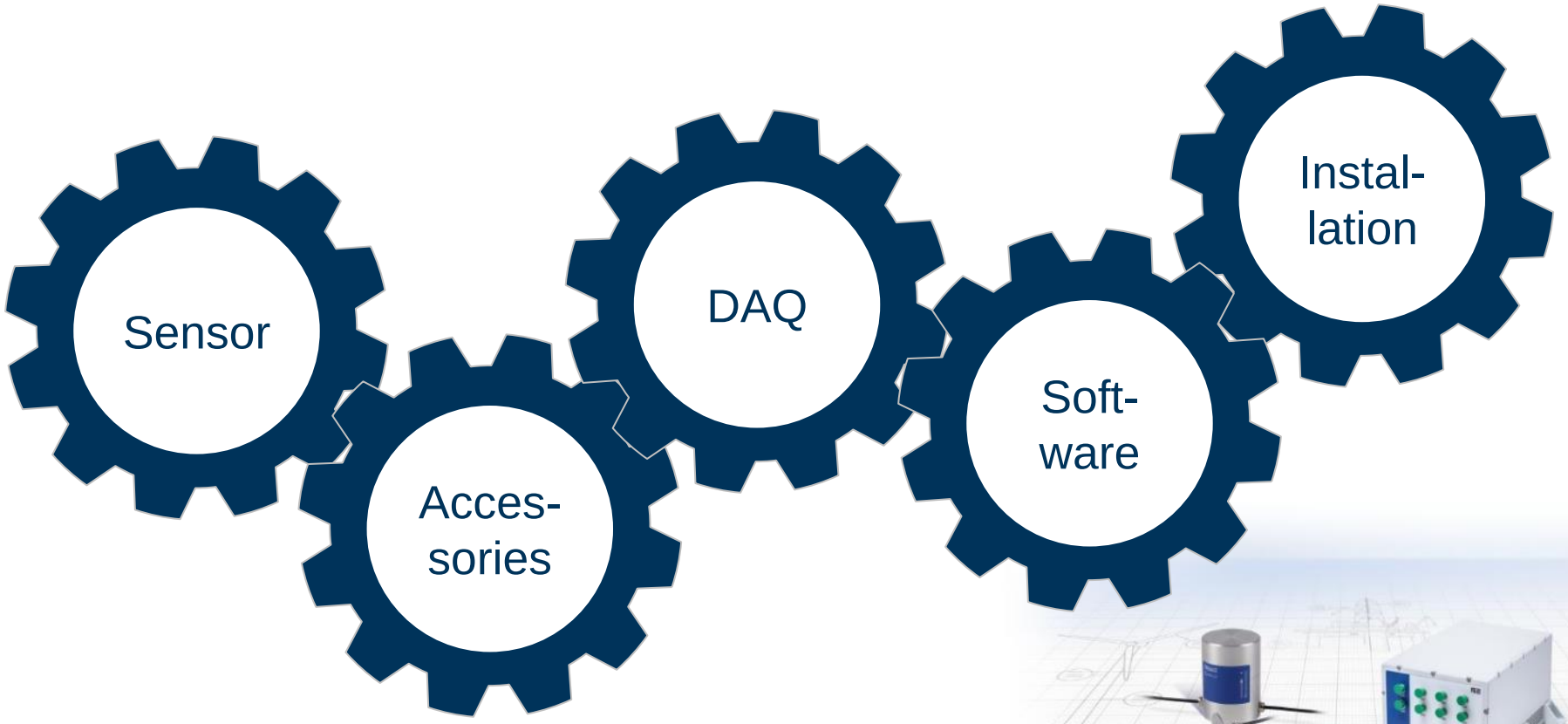
- Lighter Structures

OPTICAL TECHNOLOGY

Small

Embeddable

Cost effectiveness



FULL MEASUREMENT CHAIN

Examples

Peljesac Bridge

MONITORING DURING CONSTRUCTION

CROATIA
2019-2022

source: https://crbc-croatia.com/

source: https://crbc-croatia.com/

Peljesac Bridge

MONITORING DURING CONSTRUCTION

- High number of channels system for monitoring during construction of the piles foundations, piers and towers
- System available for continuous monitoring throughout service life
- Large sensing system
  - 321 Weldable sensors
  - 128 Rugged sensors for embedding
  - 51 accelerometers in triaxial mounting
  - 8 FS22 BraggMETER interrogators

HBK
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321
Weldable
128
Embeddable

51
Accelero-meters

Triaxial
Mounting

8
FS22

Peljesac Bridge

MONITORING DURING CONSTRUCTION

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  - 8 FS22 BraggMETER interrogators
- Hands on training
  - Tips and tricks for filed installation

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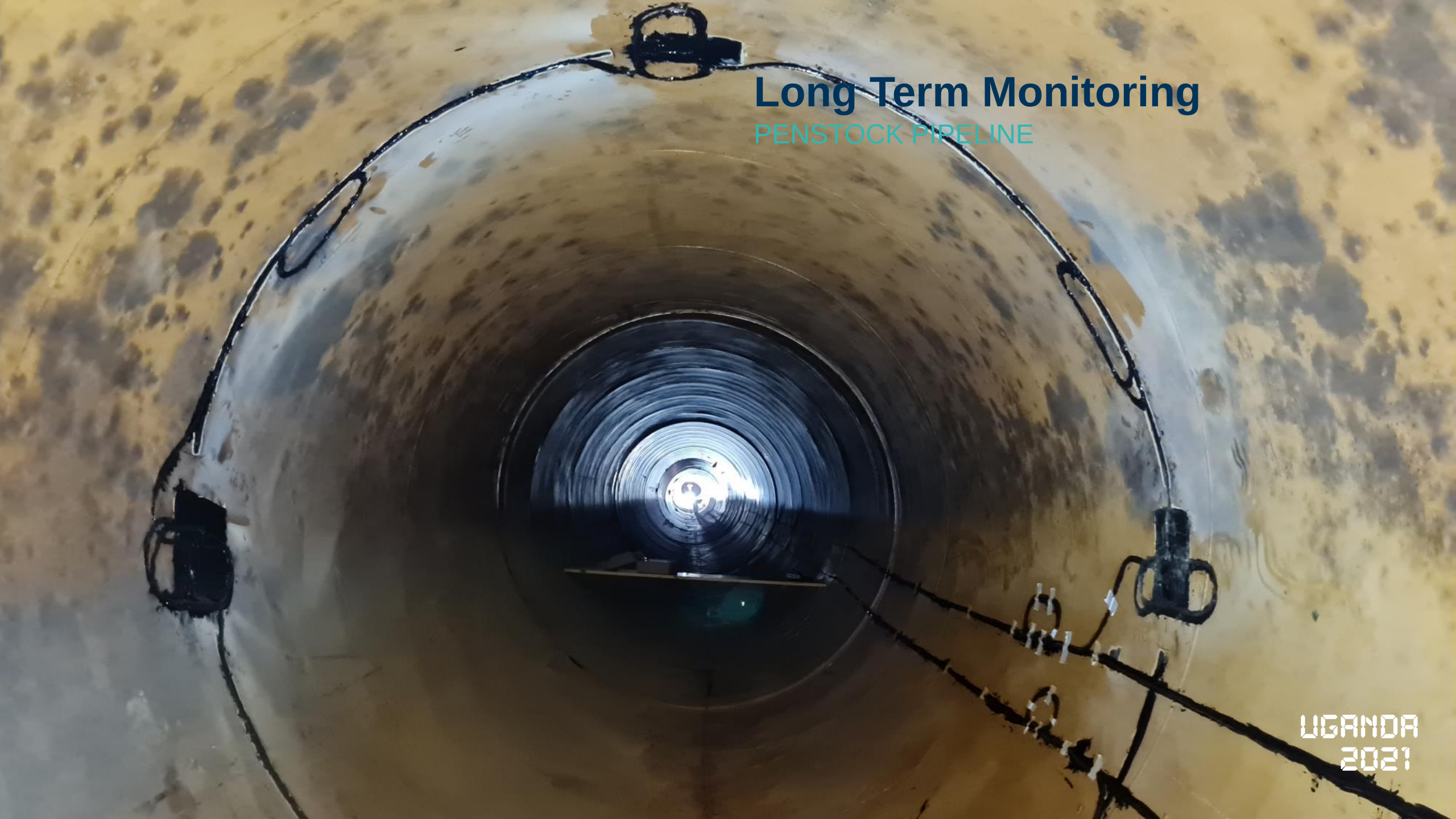
Long Term Monitoring

PENSTOCK PIPELINE

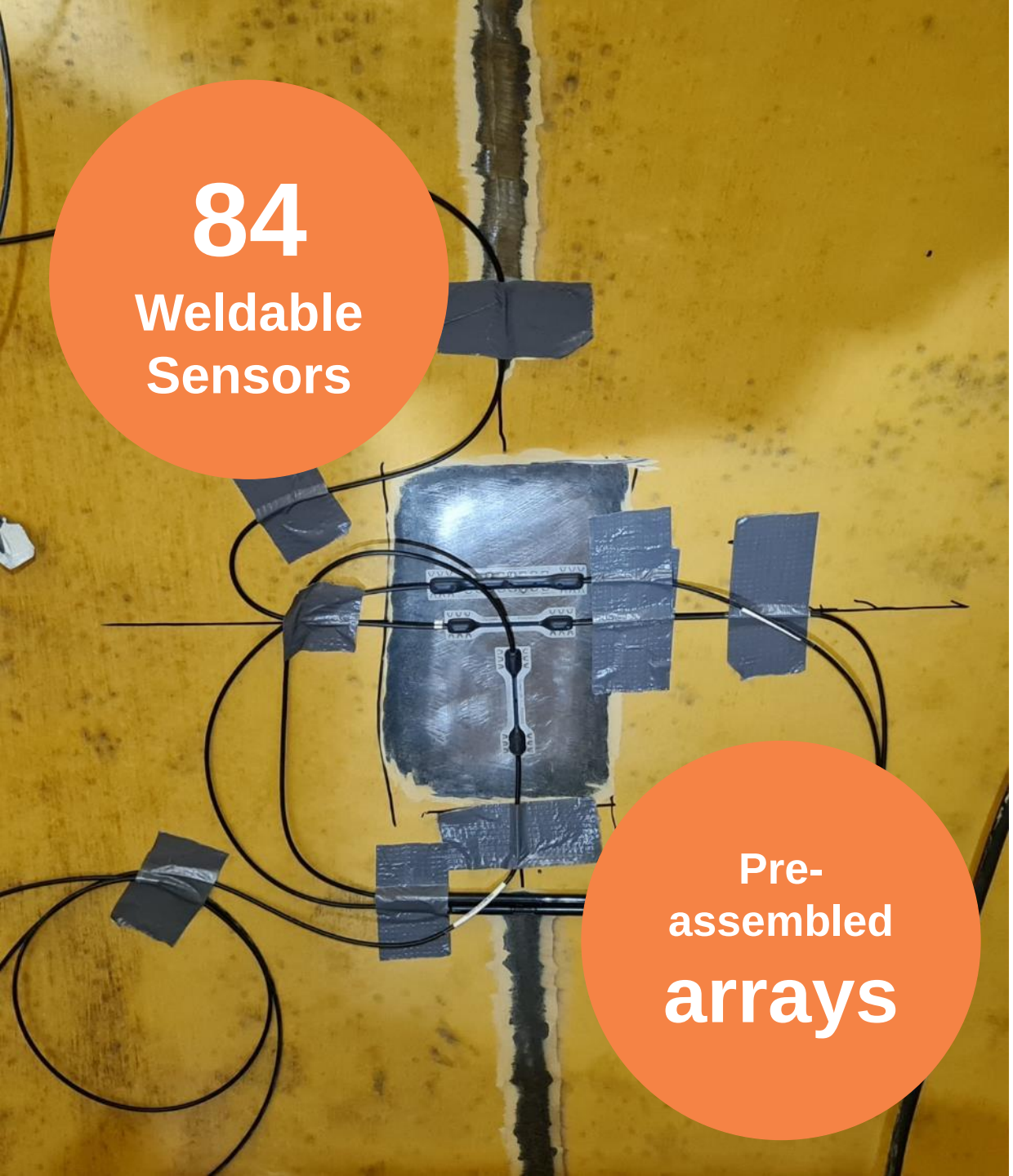


Long Term Monitoring

PENSTOCK PIPELINE

- Steel penstock water pipe with structural issues. A complete reconstruction of the penstock and power plant shut down had a too big impact on people lives
- Long term strain monitoring with sensors under water and high pressure, along several kilometers
- Full measurement chain from HBK including system architecture, installation and training

HBK
HOTTINGER BRÜEL & KJÆR

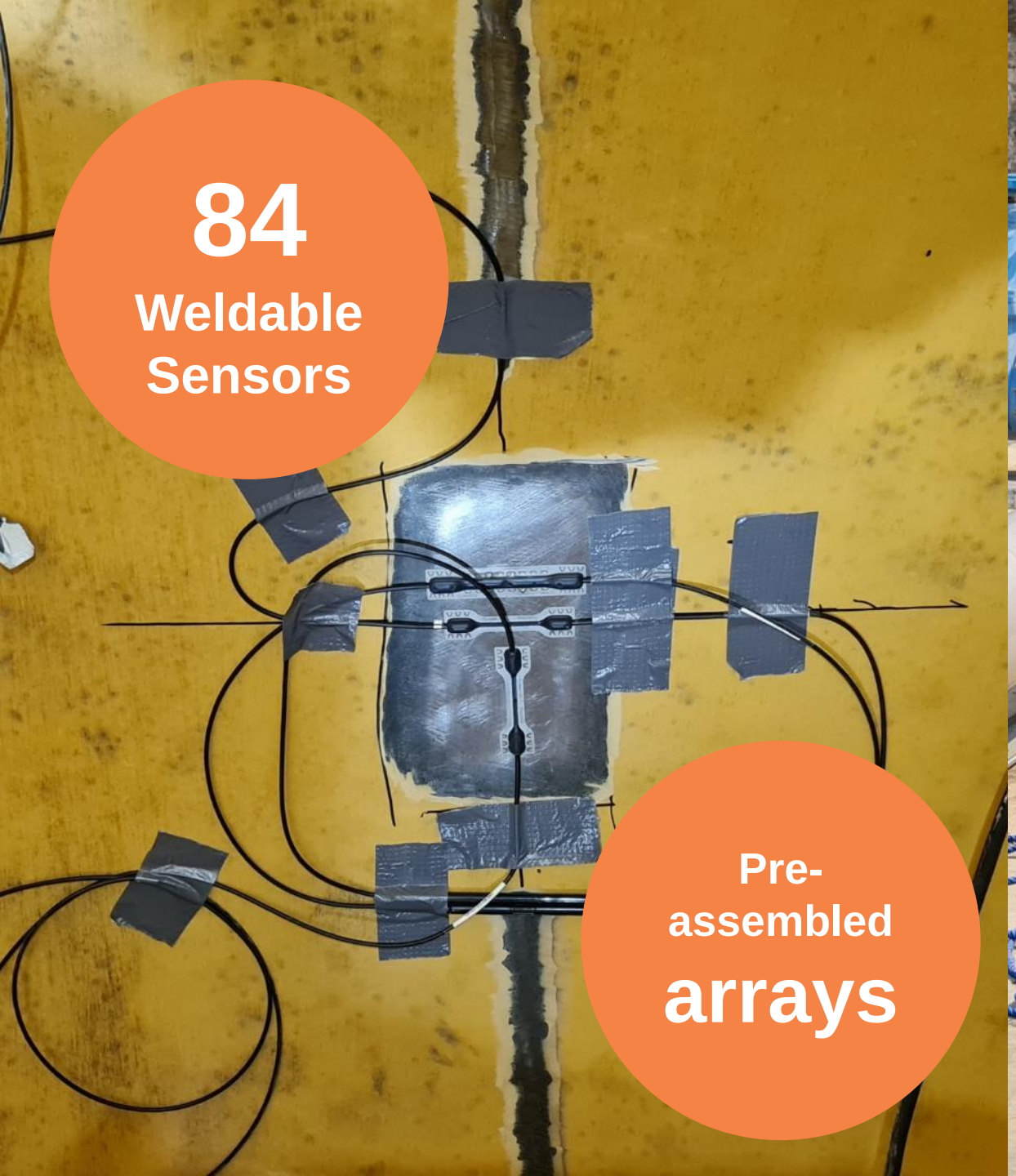


Long Term Monitoring

PENSTOCK PIPELINE

- Fully optical system:
  - FS22SI Interrogator running with catman®
  - 84 Weldable Sensors delivered in arrays
    - Strain sensors
    - Temperature sensors for compensation
- Installation
  - Underground installation
  - Inside the pipe
  - Protected for underwater operation

HBK
HOTTINGER BRÜEL & KJÆR


84
Weldable
Sensors
Pre-
assembled
arrays


Under-
ground
Installation


Inside


Underwater
Protection

Long Term Monitoring

PENSTOCK PIPELINE

- Fully optical system:
  - FS22SI Interrogator running with catman®
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    - Strain sensors
    - Temperature sensors for compensation
- Installation
  - Underground installation
  - Inside the pipe
  - Protected for underwater operation
- Commissioning
  - Sensor network verification
  - Training

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Offshore Monopile Monitoring

FATIGUE AND STRUCTURAL HEALTH ACESSMENT

NORTHEN EUROPE
2020

Offshore Monopile Monitoring

FATIGUE AND STRUCTURAL HEALTH ACESSMENT

- Map the current state and remaining lifetime of the wind turbines
- Sensors chained from factory for easy installation along the interior of monopiles
- Rugged sensors
  - less cabling
  - less weight
  - lower piling risk

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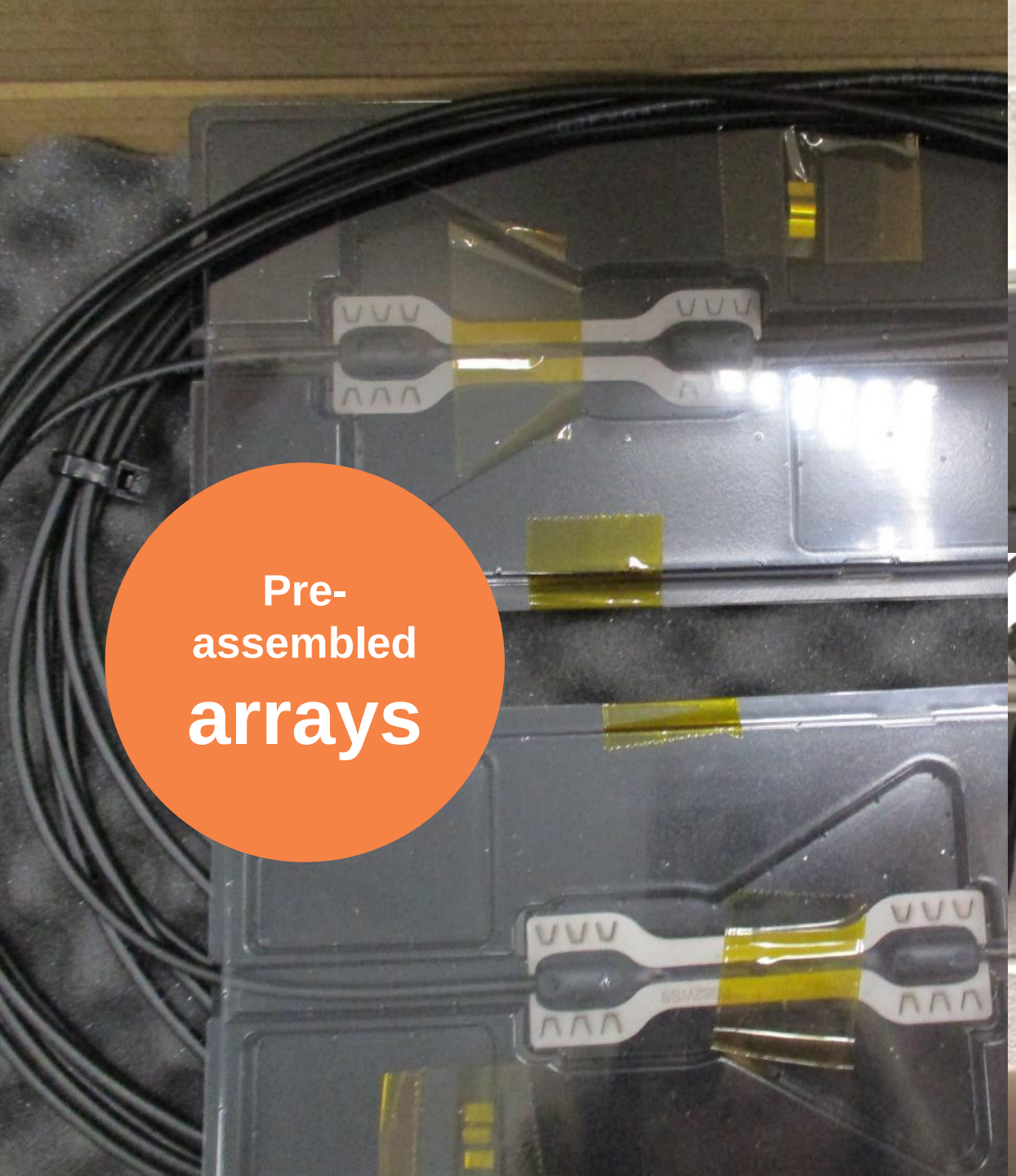

Pre-
assembled
arrays

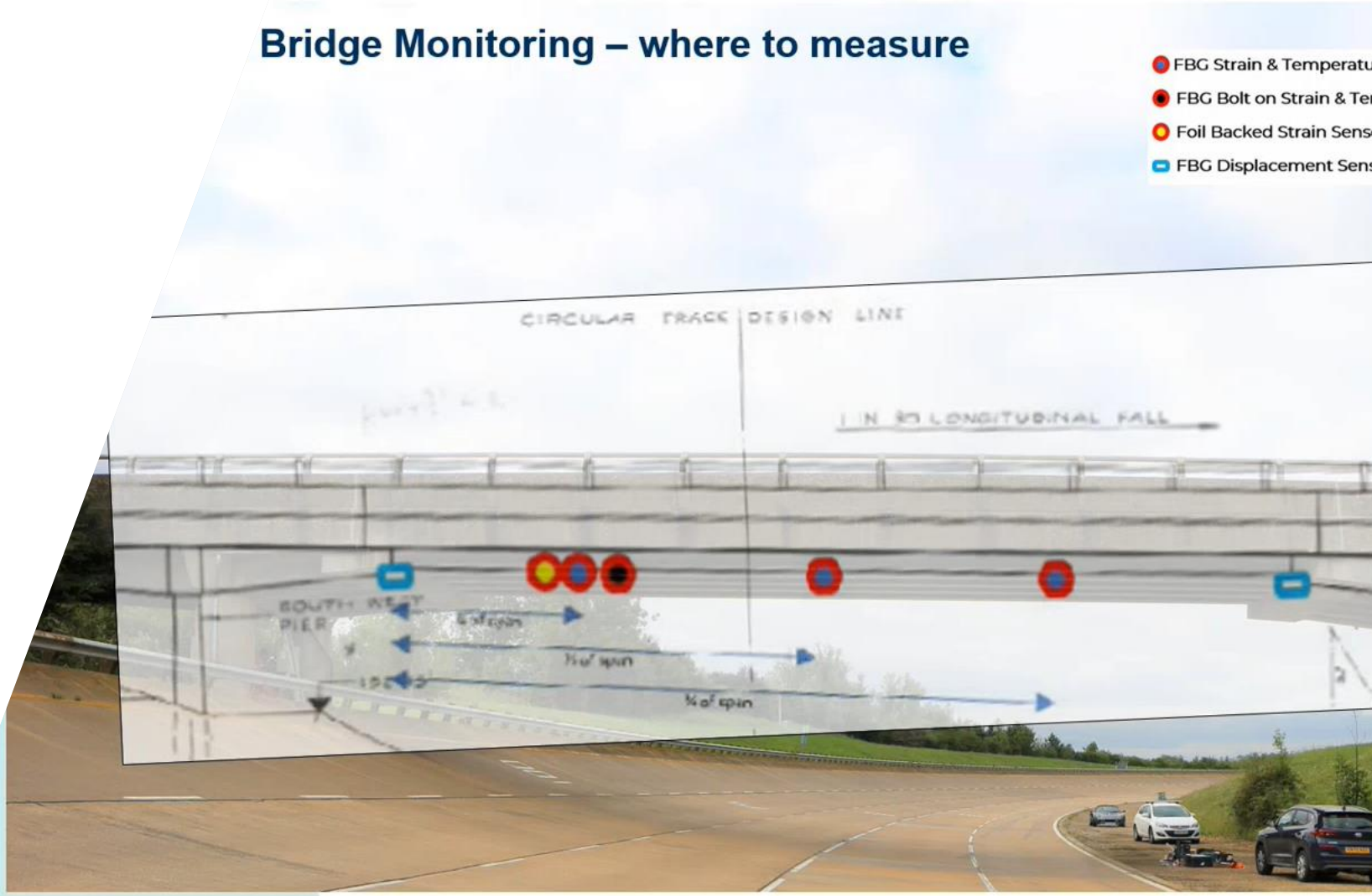

Robust
Sensors

Demonstration

Demonstration

Contact HBK for a demonstration

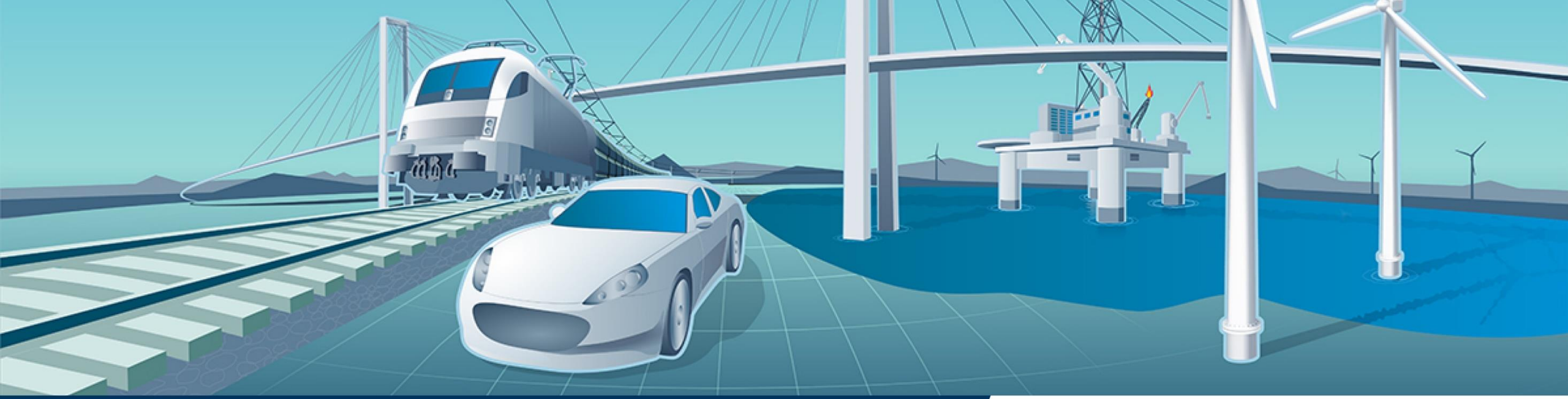
Watch the recorded webinar



https://www.hbm.com/en/10649/tech-compared-in-bridge-monitoring/

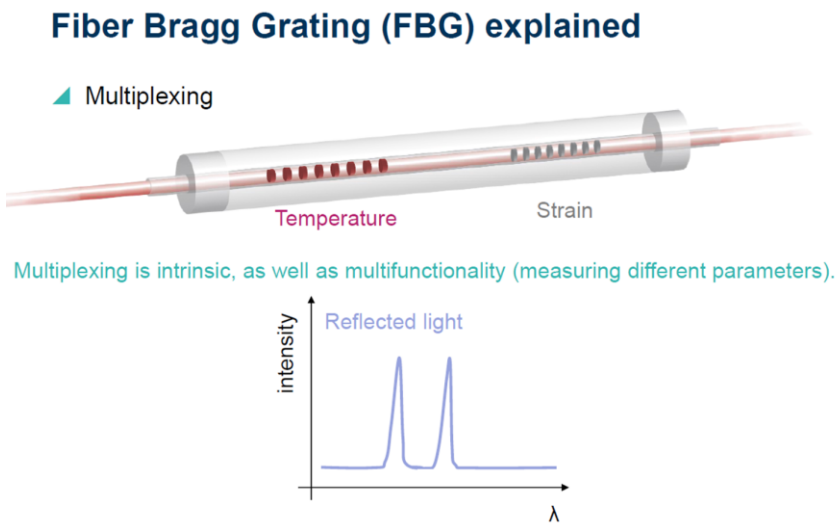
Thank You

QUESTIONS?



HBK Technology Days – Virtual Seminar Series

Tuesday, November 15, 2022



Optical Sensor Technology and Applications for Civil Structures

Presented by Cristina Barbosa,
Product Manager Optical Business,
HBK FiberSensing