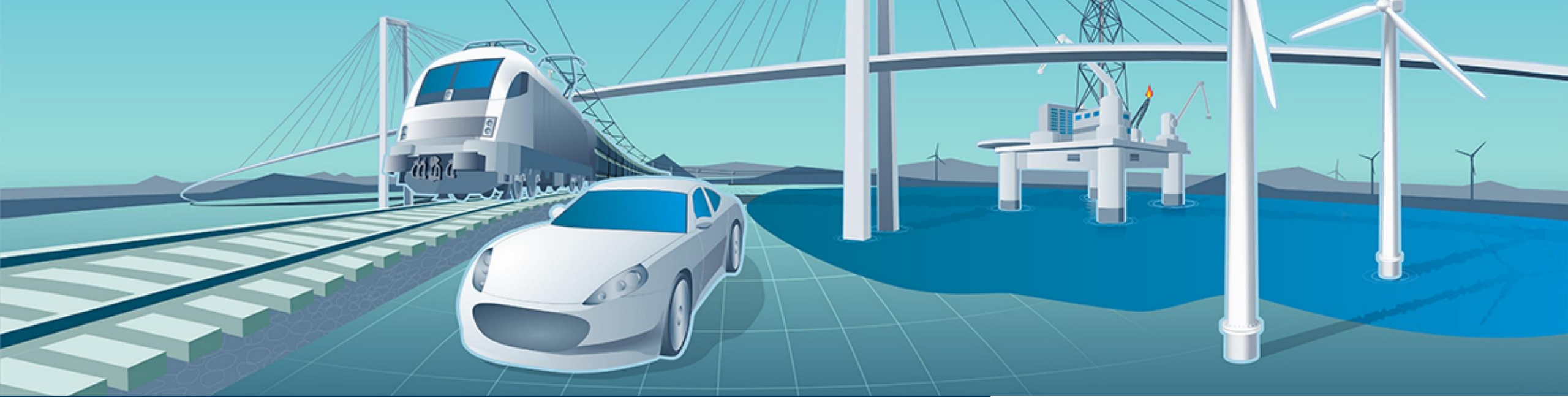




HBK Technology Days – Virtual Seminar Series

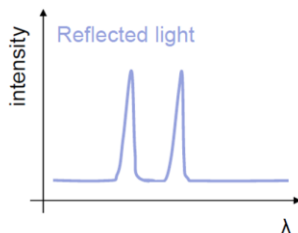
Tuesday, November 15, 2022

Fiber Bragg Grating (FBG) explained

▲ Multiplexing



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



Optical Sensor Technology and Applications for Civil Structures

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

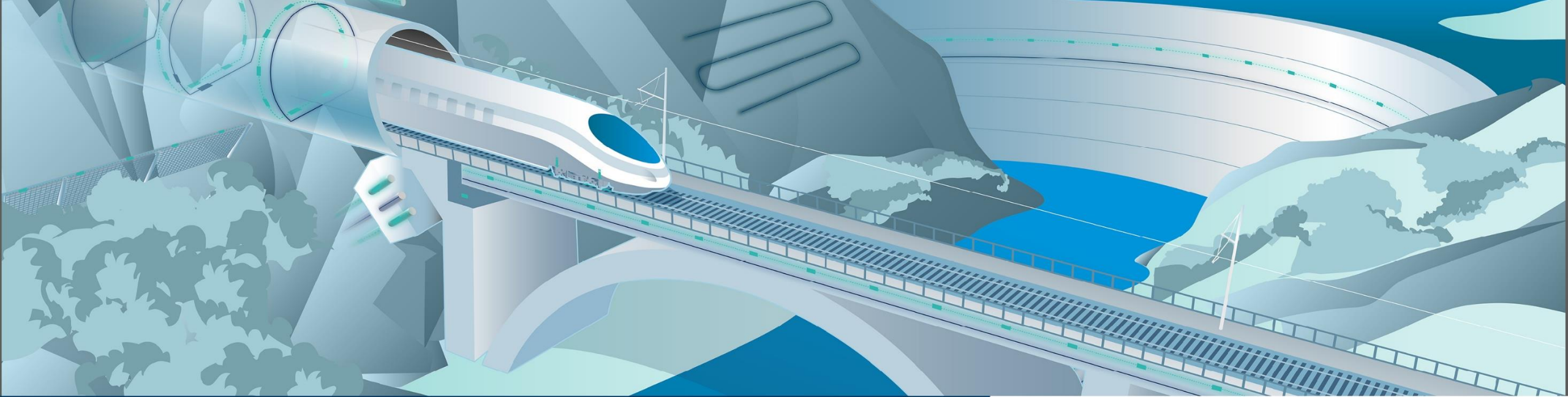
Optical Sensor Technology and Applications for Civil Structures

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

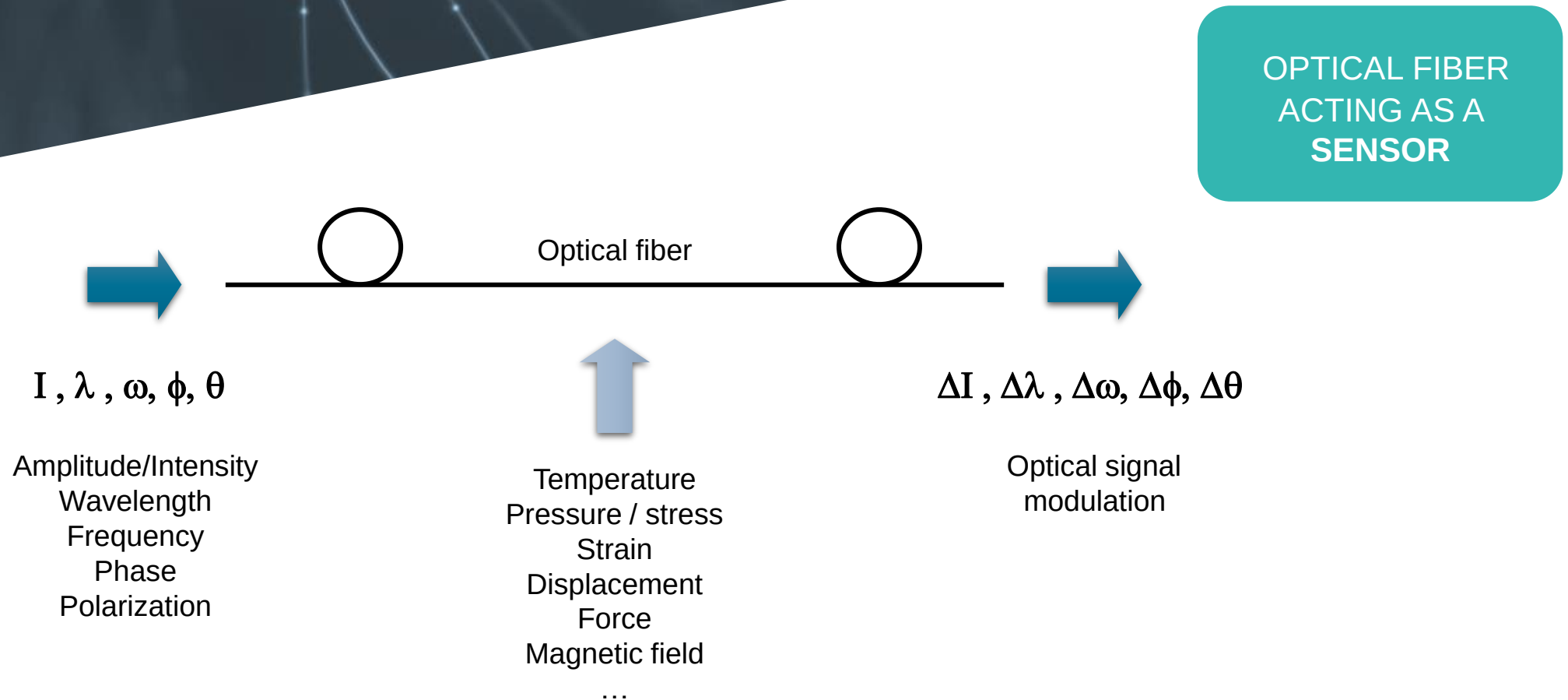
The background is a dark blue-grey gradient. It features a complex network of thin, glowing white lines that represent fiber optic cables. These lines are interconnected at various points, creating a web-like structure. Some of these connection points are highlighted with small, bright white dots or nodes. The lines and nodes are more concentrated in the upper left and center, with some lines extending towards the bottom right. The overall effect is a sense of dynamic connectivity and technological infrastructure.

**Optical
Fiber**

is connecting today's world

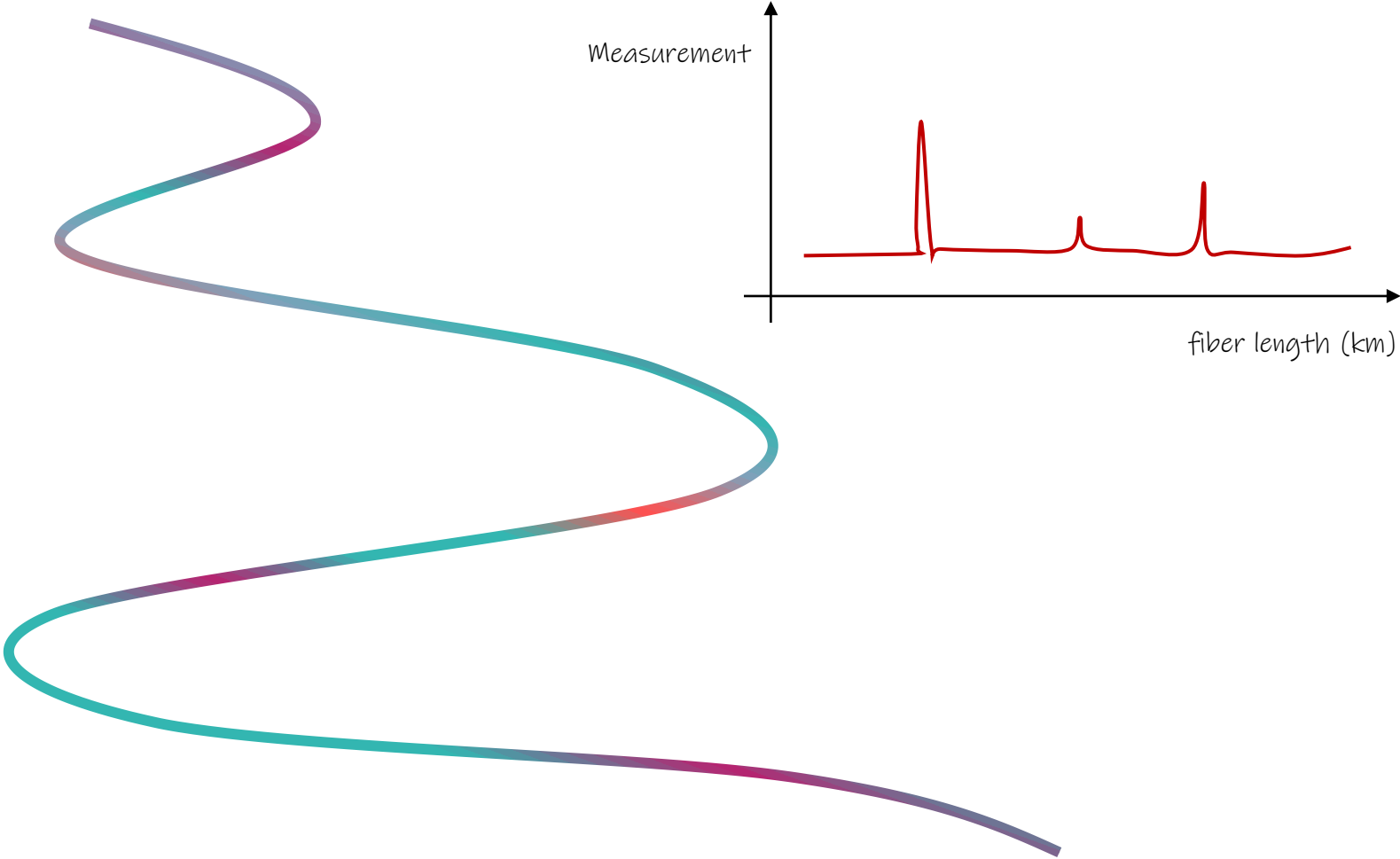
Optical Fiber

But is also being used in a different way!



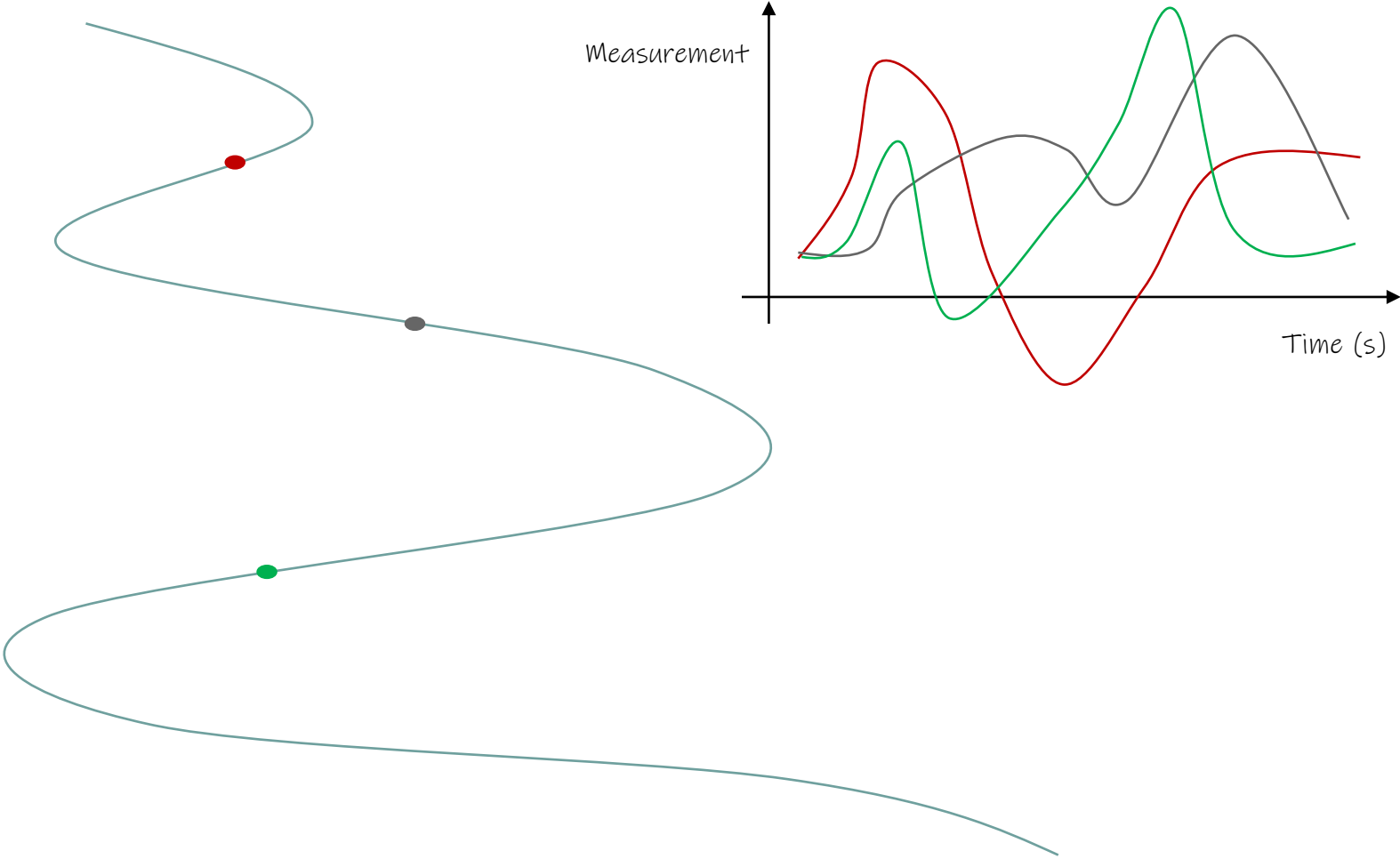
Optical Fiber as Sensor

DISTRIBUTED SENSING



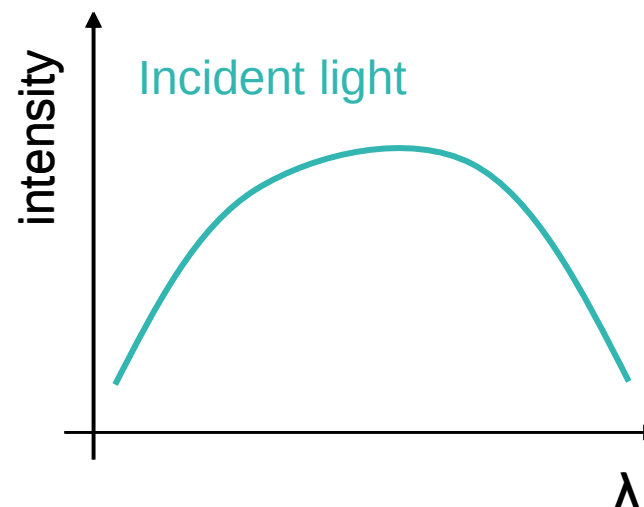
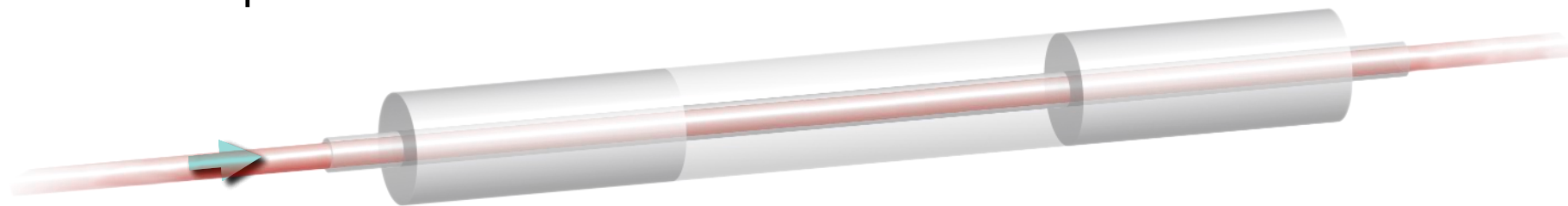
Optical sensors and transducers

POINT SENSING



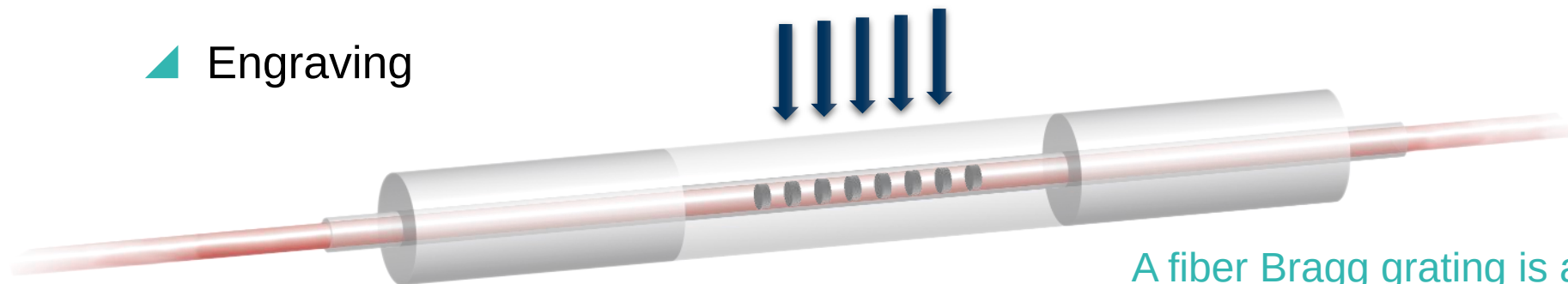
Fiber Bragg Grating (FBG) explained

▲ Optical fiber



Fiber Bragg Grating (FBG) explained

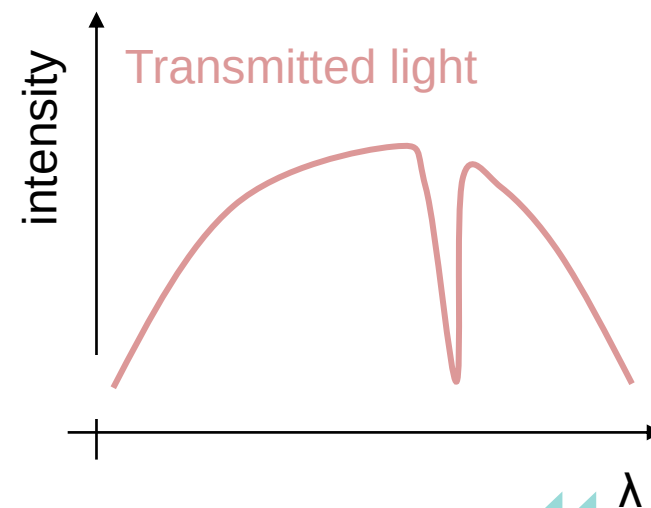
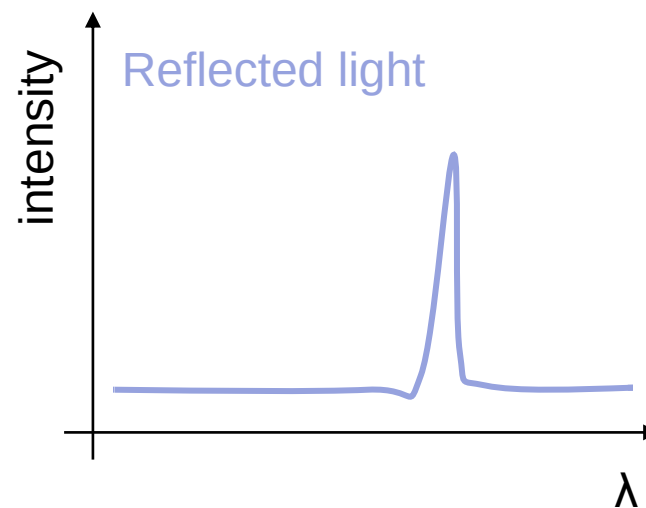
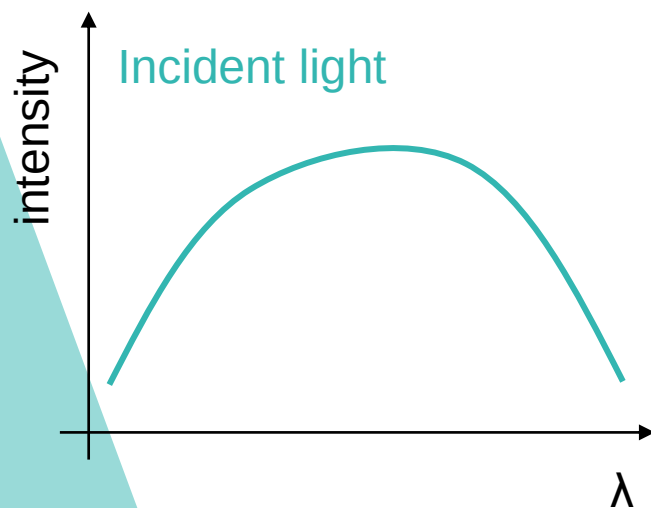
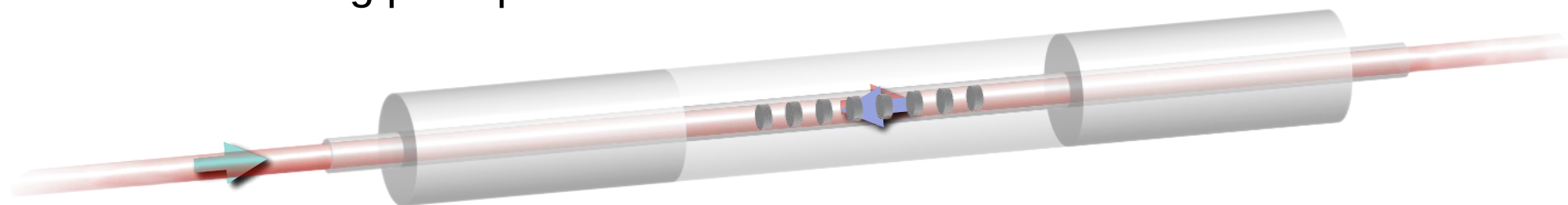
▲ Engraving



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

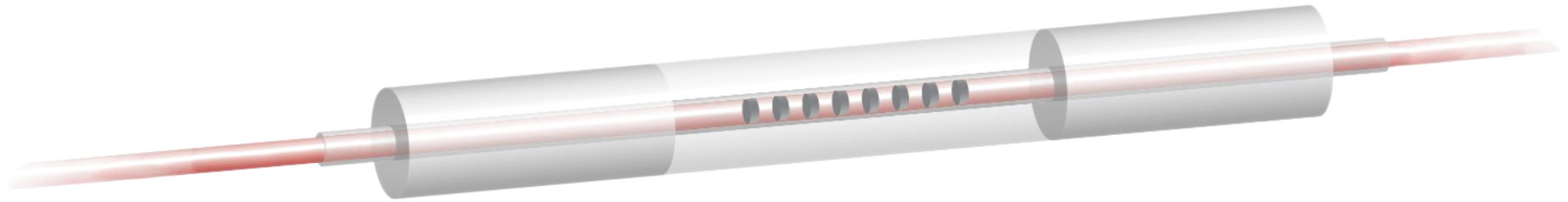
Fiber Bragg Grating (FBG) explained

Working principle

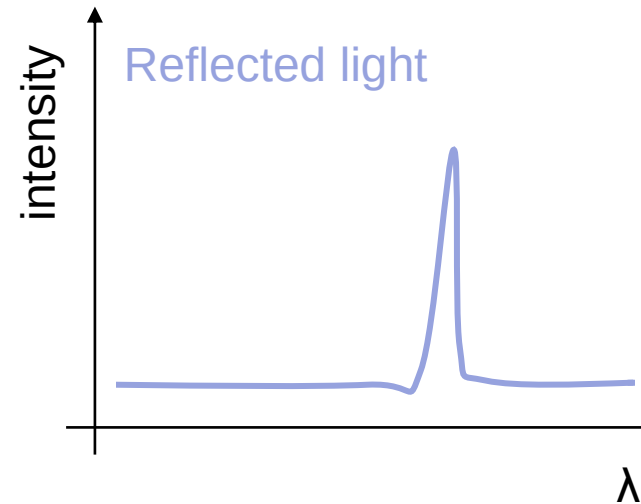


Fiber Bragg Grating (FBG) explained

Strain Measurement

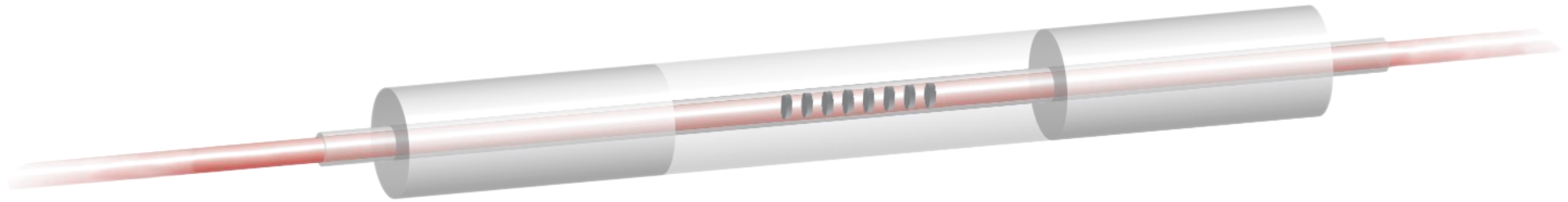


The wavelength of the reflected peak changes when strain is applied to the fiber.

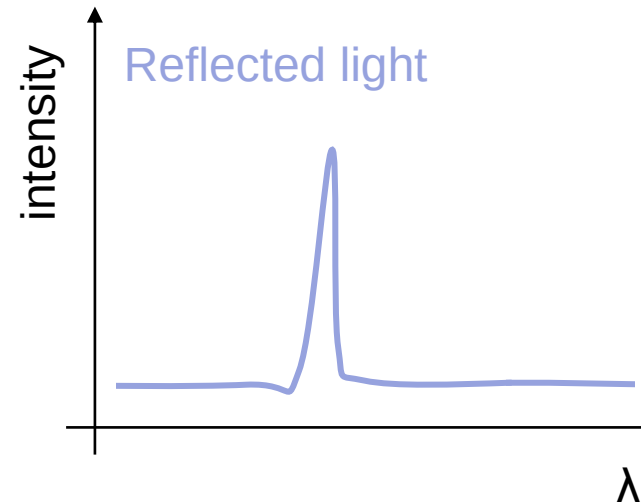


Fiber Bragg Grating (FBG) explained

Strain Measurement

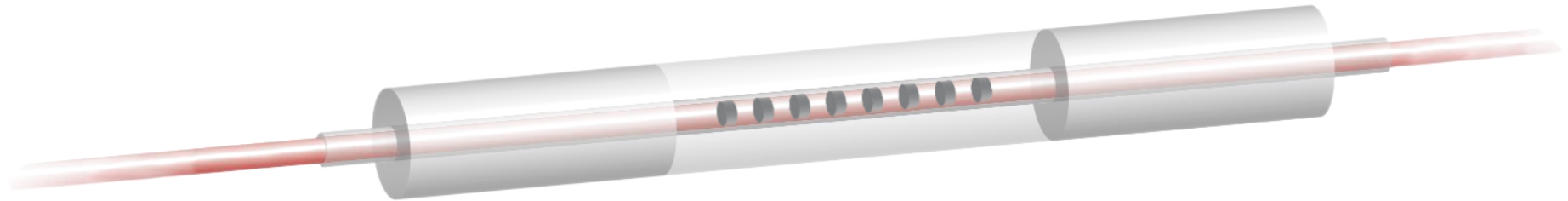


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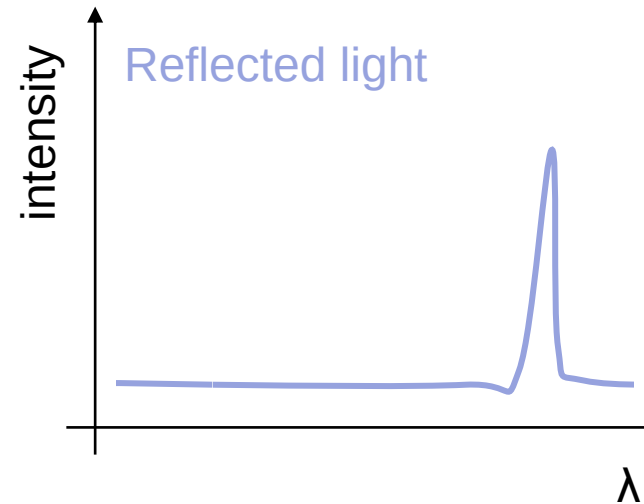


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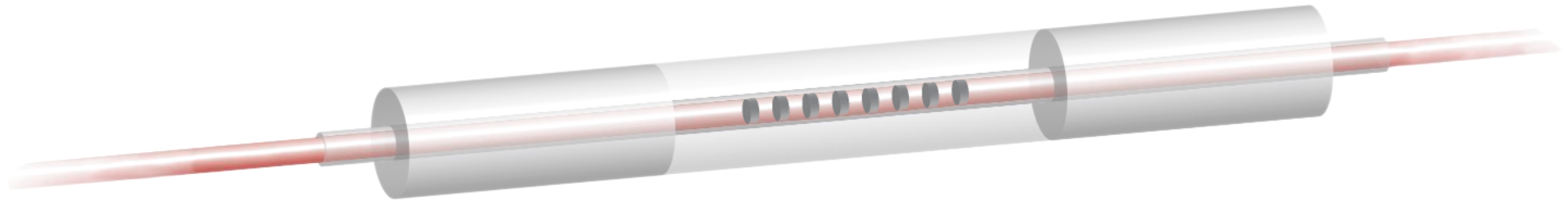


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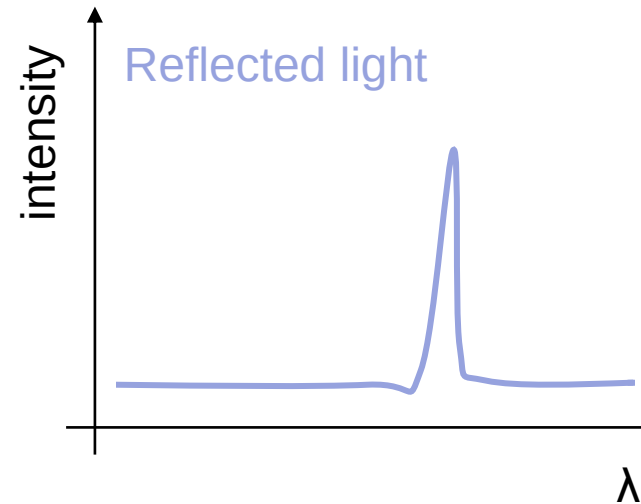


Fiber Bragg Grating (FBG) explained

Strain Measurement

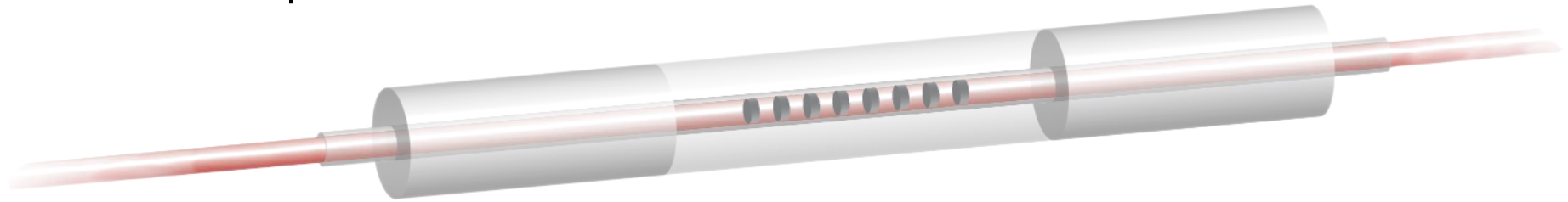


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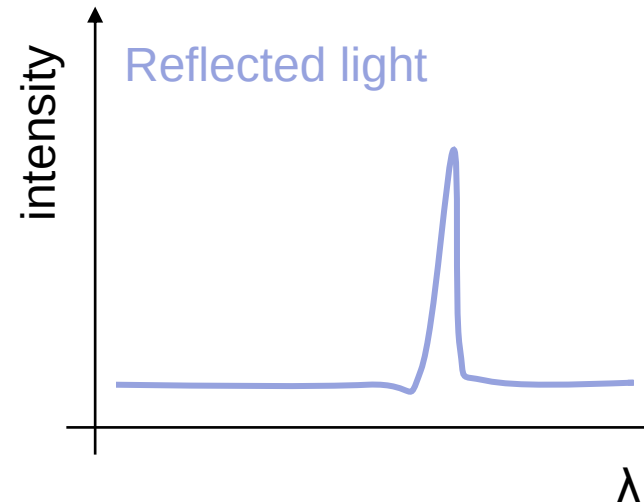


Fiber Bragg Grating (FBG) explained

▲ Temperature Measurement

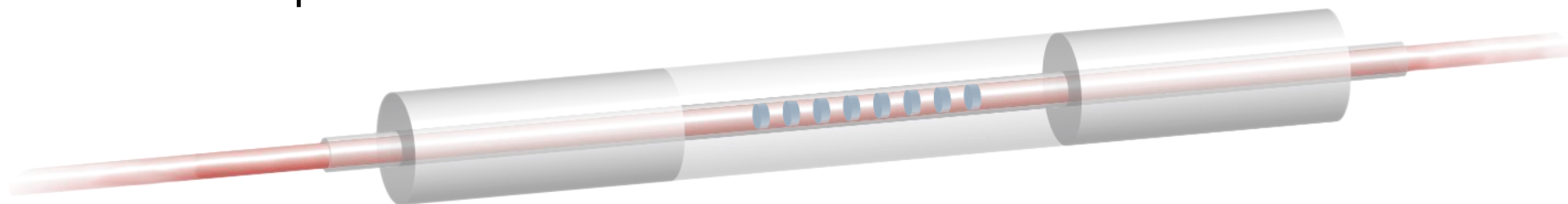


The wavelength of the reflected peak changes when temperature is applied to the fiber.

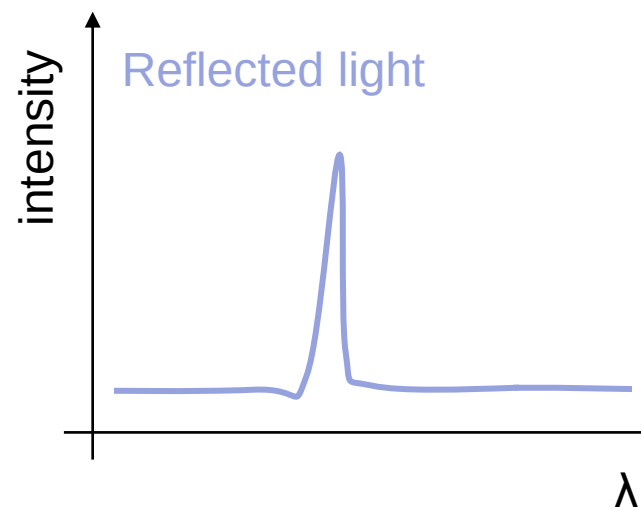


Fiber Bragg Grating (FBG) explained

▲ Temperature Measurement

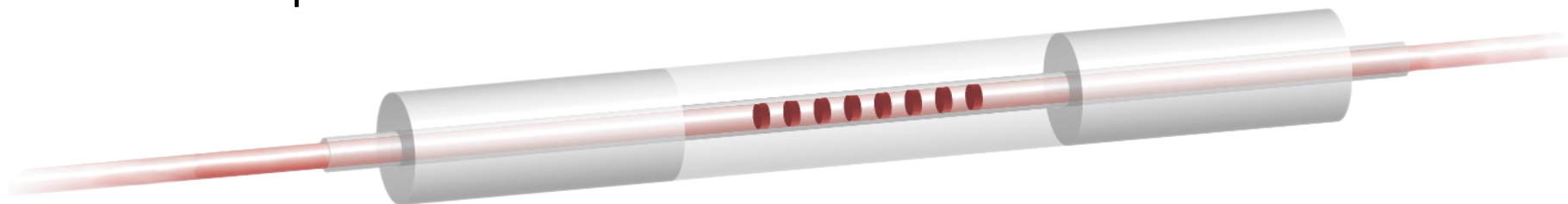


The wavelength of the reflected peak changes when temperature is applied to the fiber.

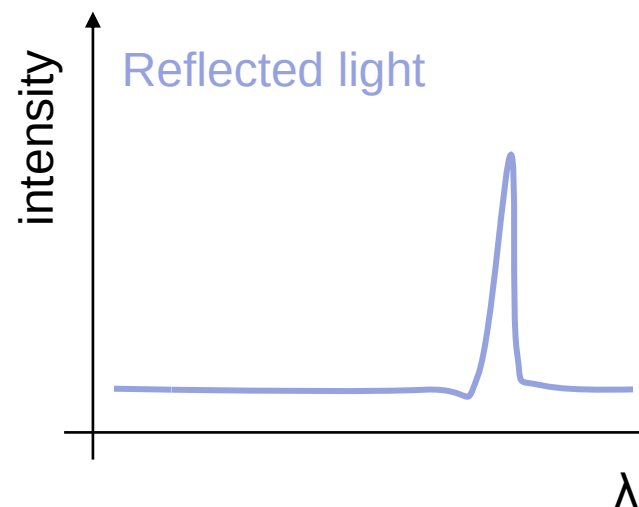


Fiber Bragg Grating (FBG) explained

▲ Temperature Measurement

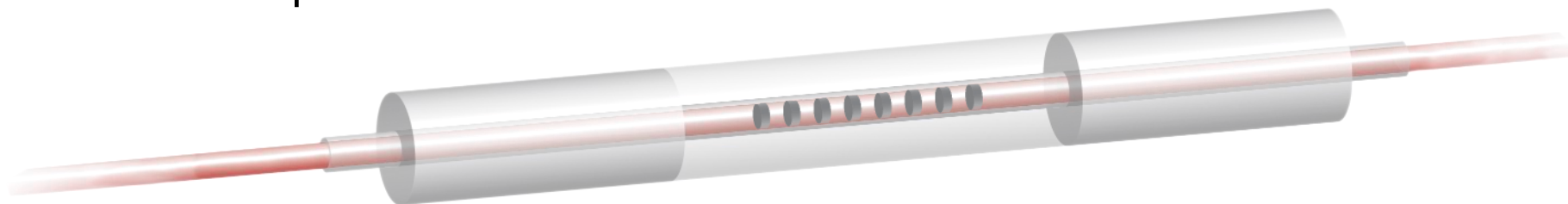


The wavelength of the reflected peak changes when temperature is applied to the fiber.

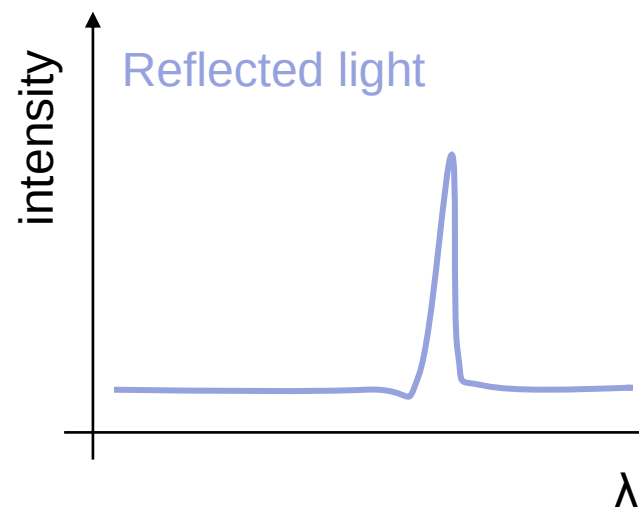


Fiber Bragg Grating (FBG) explained

▲ Temperature Measurement

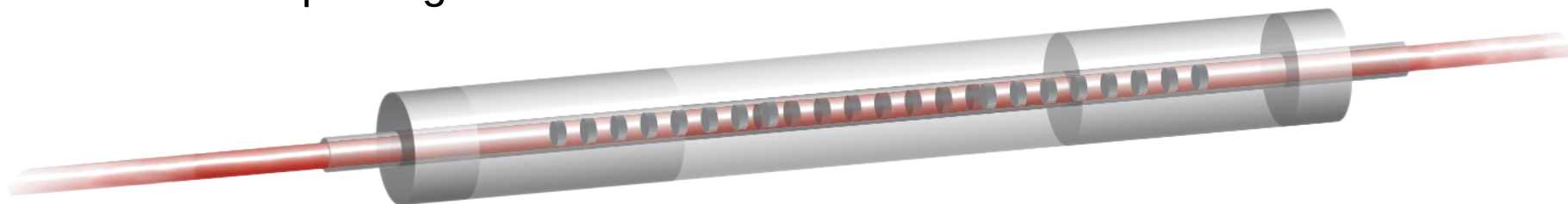


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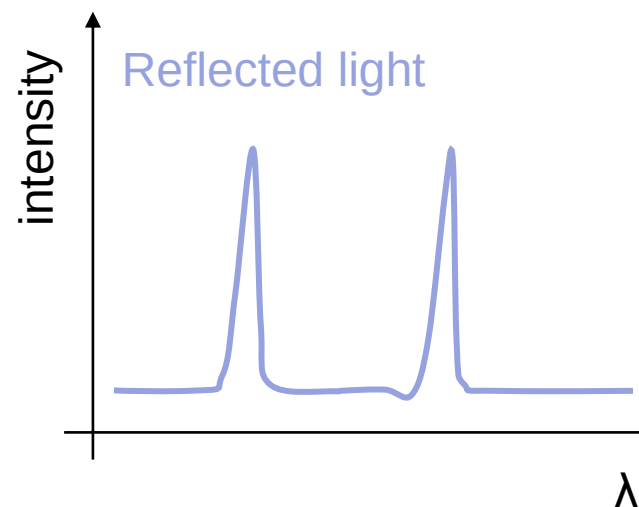


Fiber Bragg Grating (FBG) explained

▲ Multiplexing



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

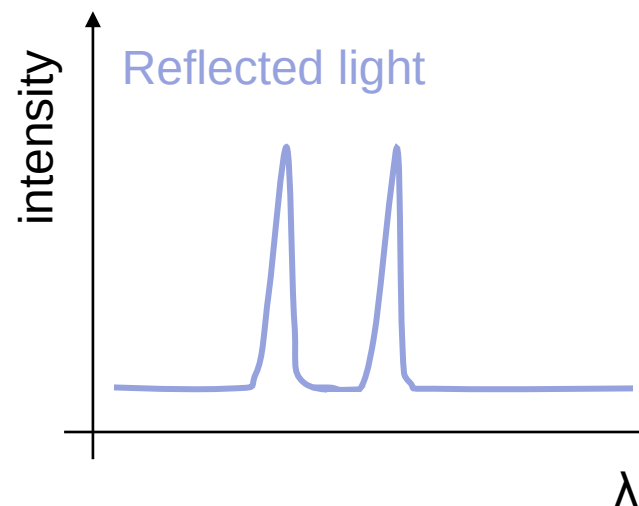


Fiber Bragg Grating (FBG) explained

▲ Multiplexing



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

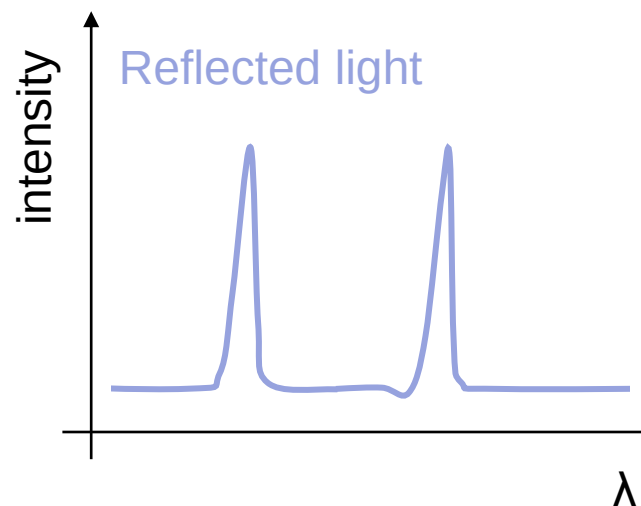


Fiber Bragg Grating (FBG) explained

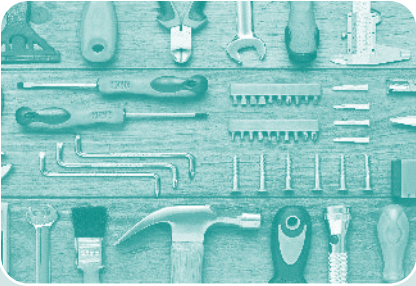
▲ Multiplexing



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



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

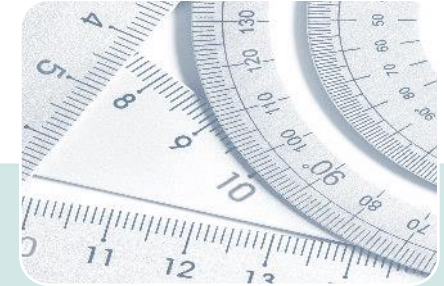
Long Distances



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

Application in Civil Engineering



**AFTER A
FEW YEARS**

Long periods of operation

Silica



Resistant

BraggMETER

Long periods of operation

Wavelength

MEASURING
WAVELENGTH



BraggMETER



Long periods of operation

Wavelength

BraggMETER

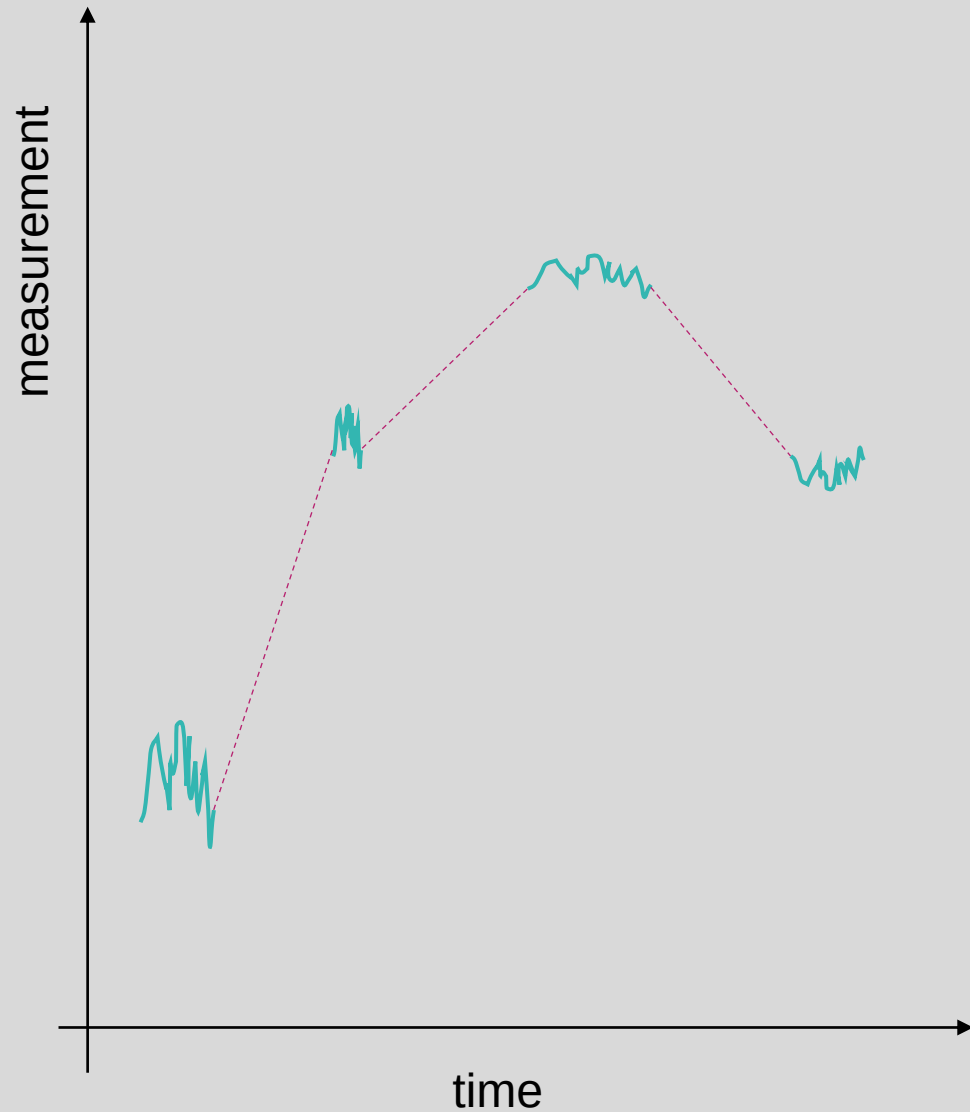


Long periods of operation

Wavelength

Insensitive
to losses

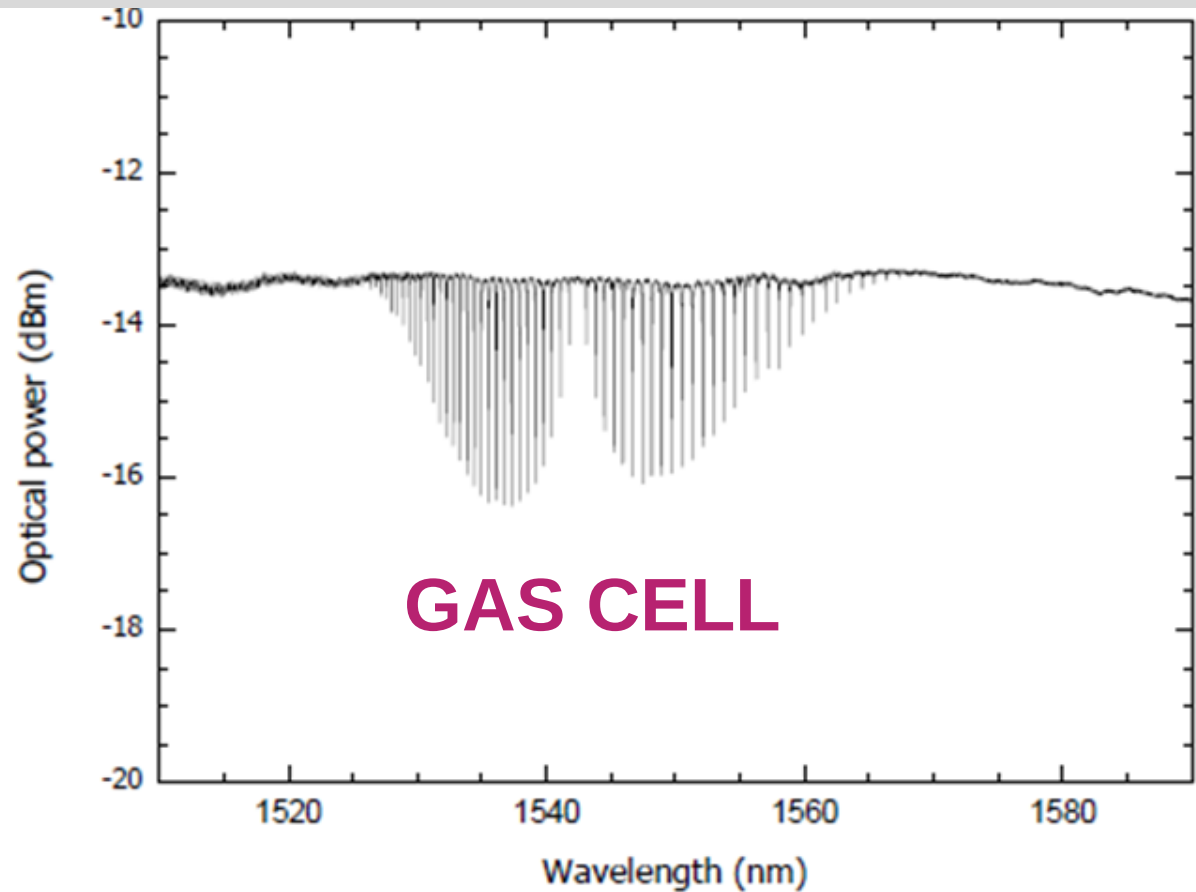
Long periods of operation



Wavelength



Referenced
Measurement

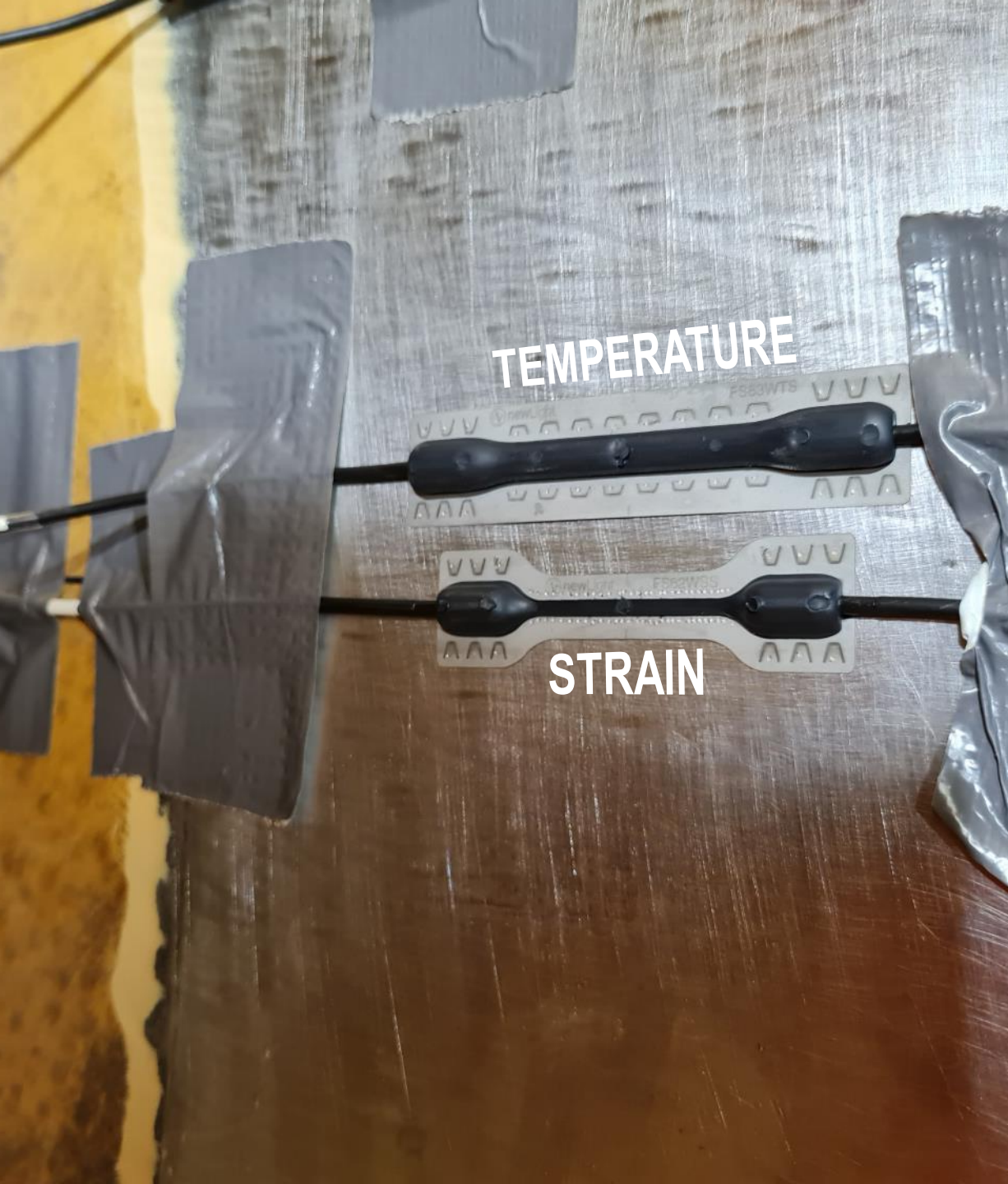


Long periods of operation

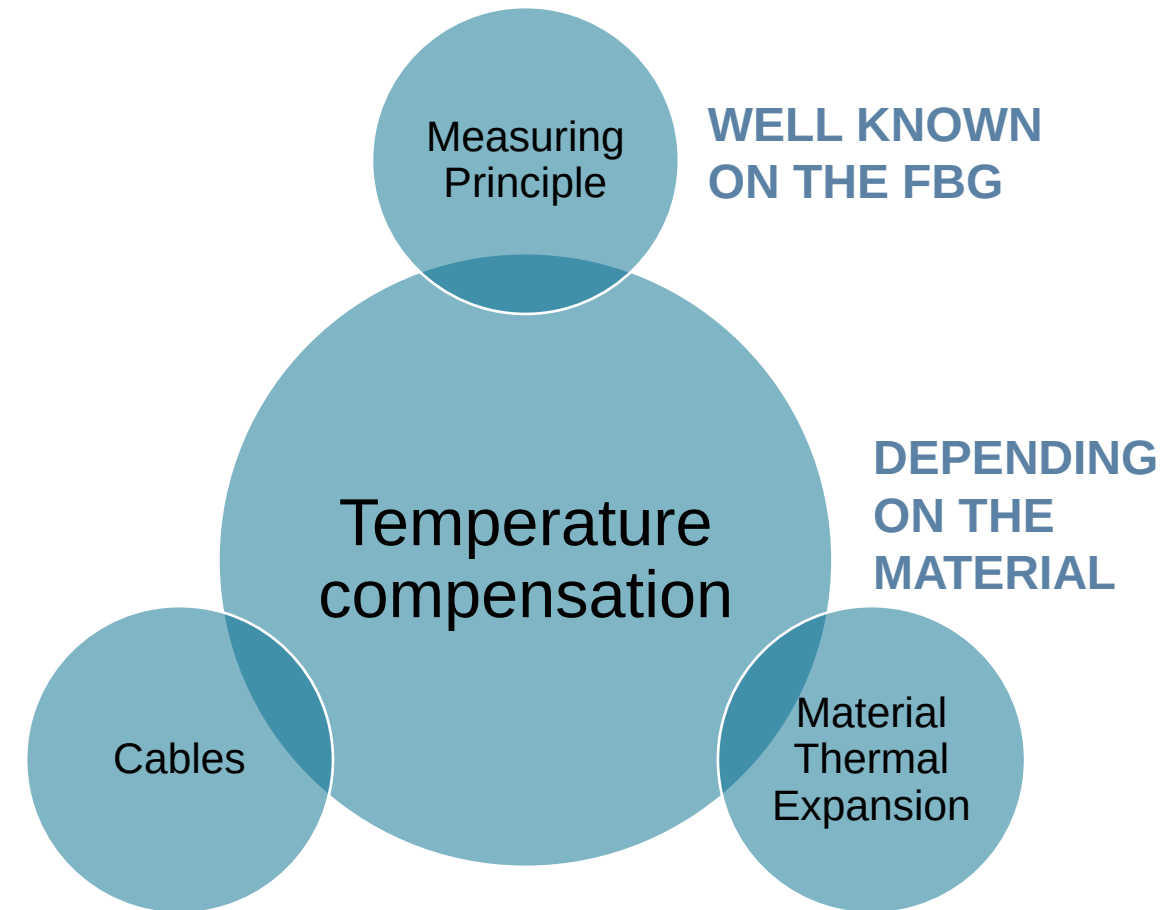
Wavelength

Built in
Reference

No Drift



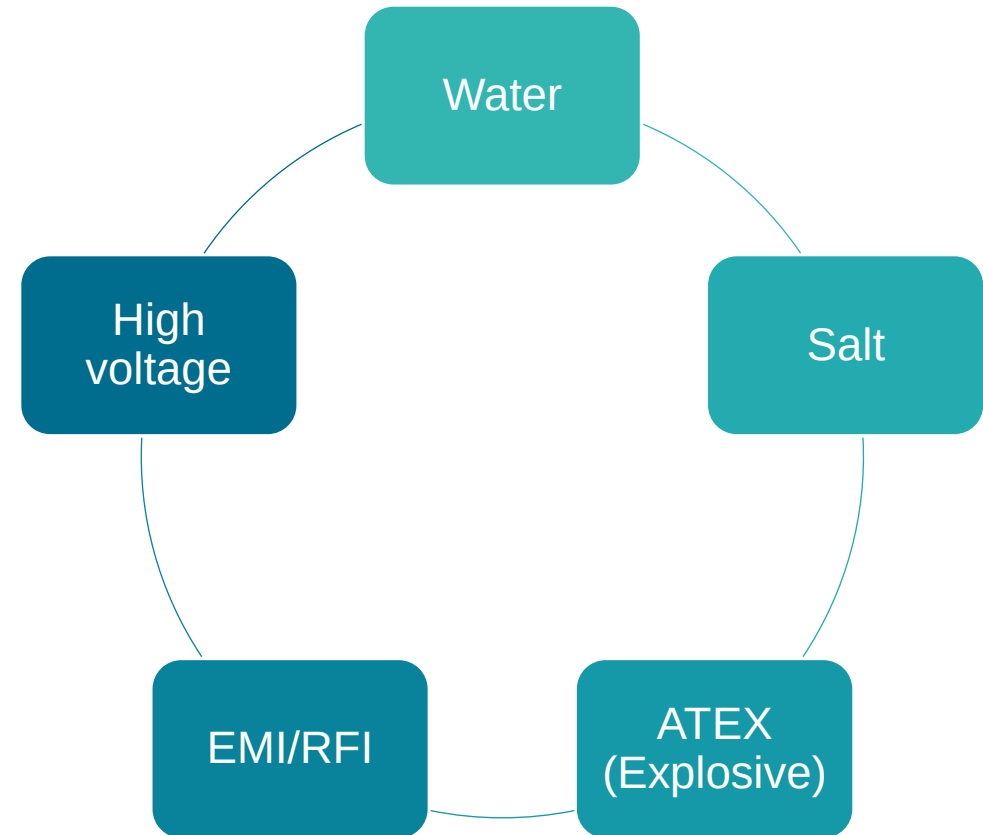
Long periods of operation



NON-EXISTING ON
OPTICAL TECHNOLOGY



Harsh environments



Long distances

- Long structures
- Remote locations
- No power supply

Low attenuation of optical fibers:

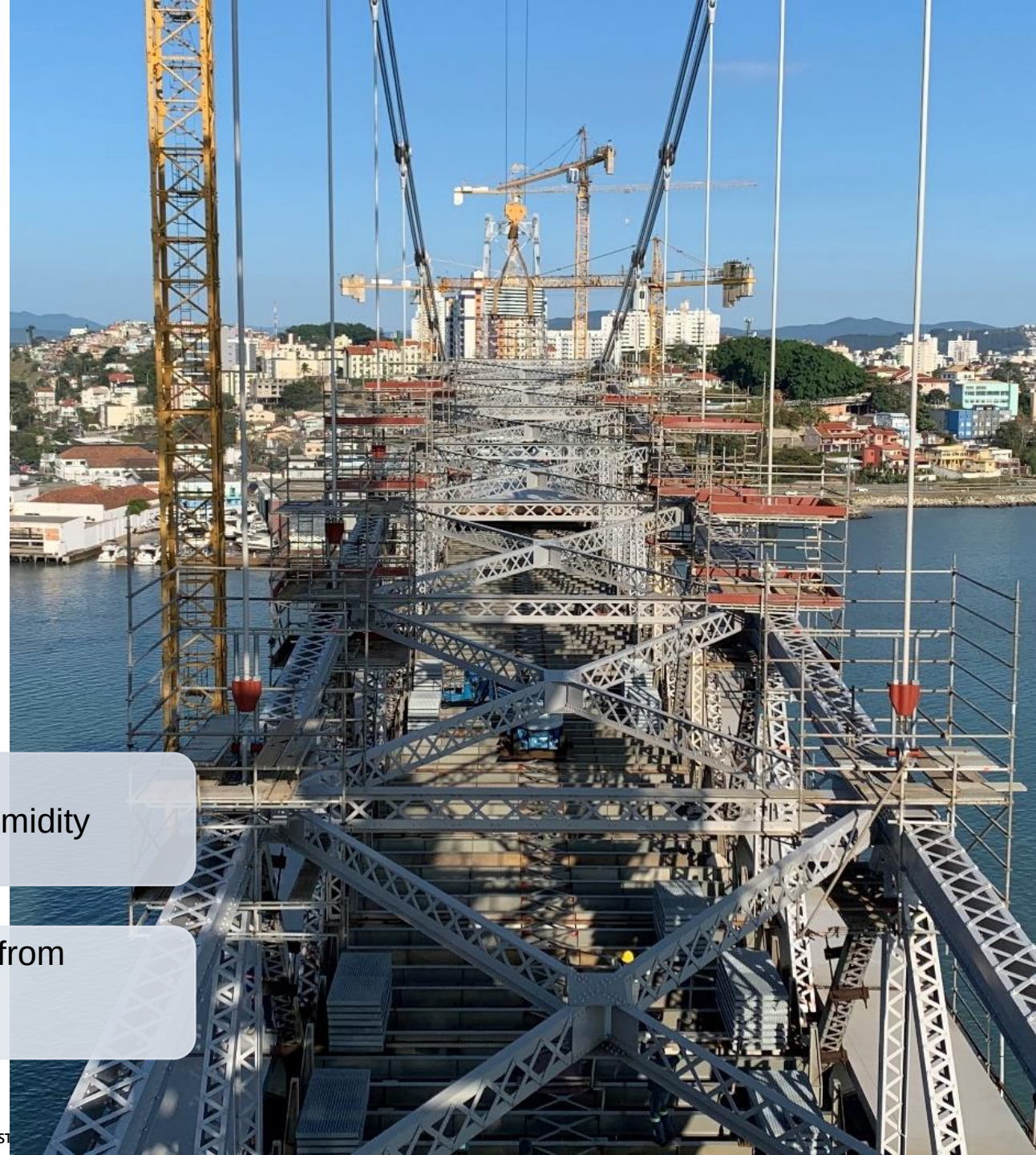
No heavy equipment on inaccessible locations

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

Large sensor count

32

Conventional
sensors

128

Wires

45

4

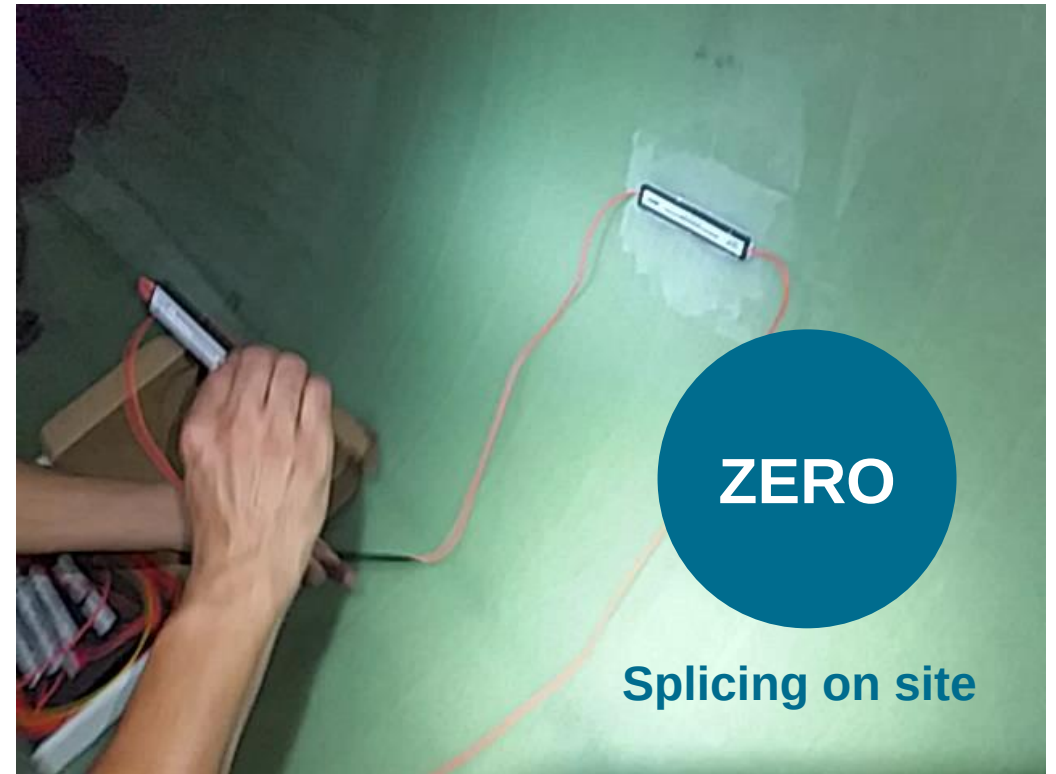
FBG sensors

Wires



Installation efficiency

Preassembled
arrays of sensors



Meeting new materials

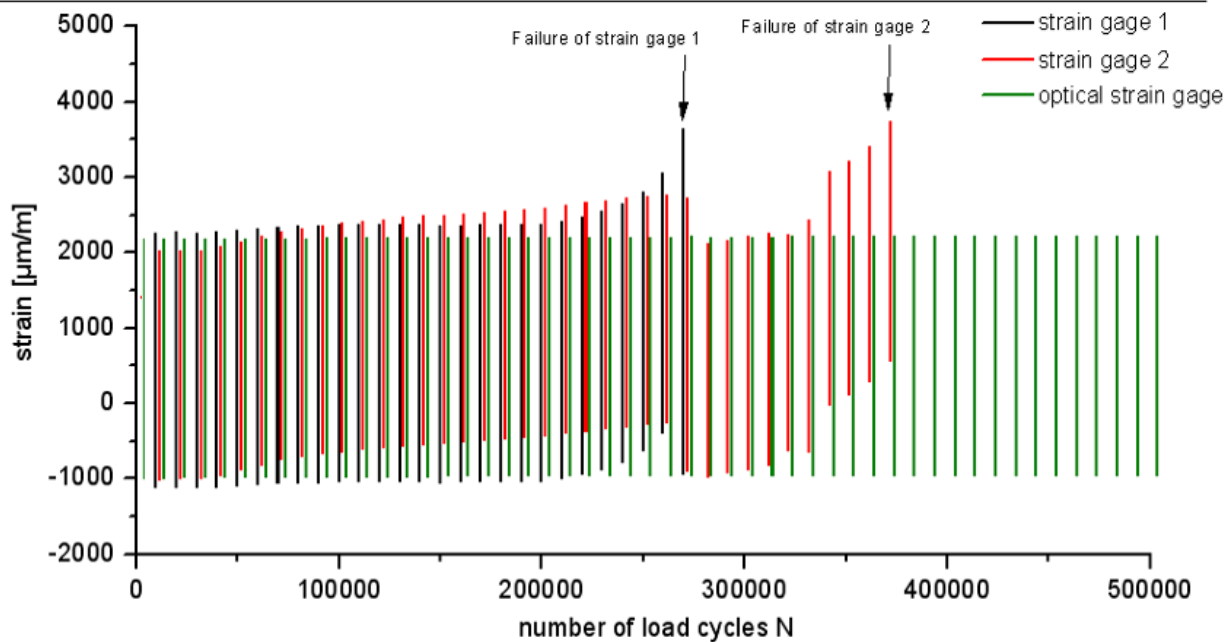
- Higher resistance

OPTICAL TECHNOLOGY

High Strain

High Fatigue

Specimen 3: fatigue test



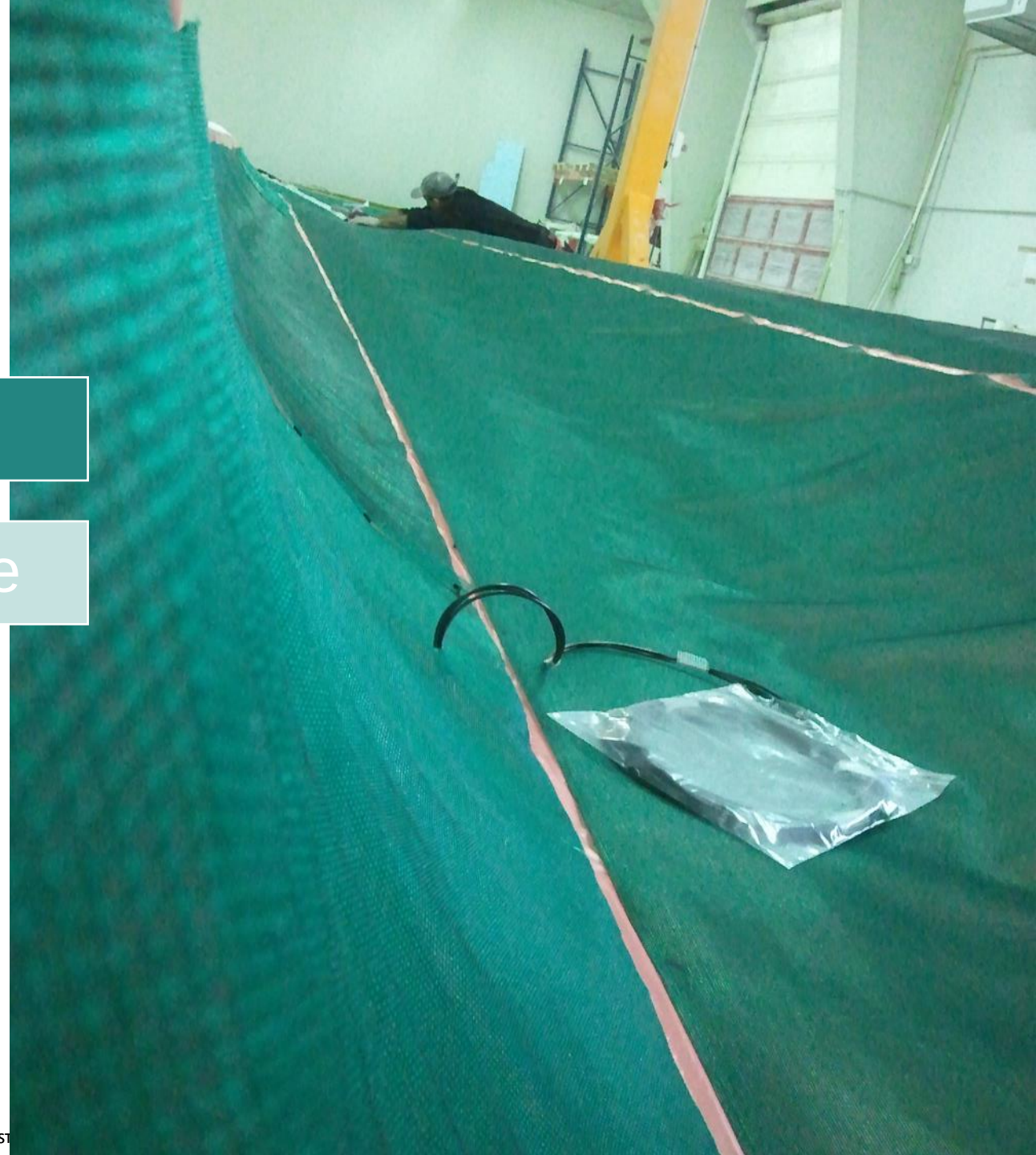
Meeting new materials

Lighter Structures

OPTICAL TECHNOLOGY

Small

Embeddable



Cost effectiveness



Examples

Peljesac Bridge

MONITORING DURING CONSTRUCTION

CROATIA
2019-2022



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

CROATIA
2019-2022

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

A close-up photograph showing a hand holding a small metal component, which is being welded to a black cable. The welding process is taking place on a metallic surface. In the background, there are some cables and a metal component with the text "newLight" and "F883WTS" visible.

321

Weldable

A close-up photograph showing a metal component being embedded into a concrete structure. The component is a long, thin rod with a flange at one end. It is being held in place by a metal bracket. The concrete is a light gray color. The metal component has a dark, possibly painted or coated, surface.

128

Embeddable

51

Accelerometers

Triaxial
Mounting



8

FS22

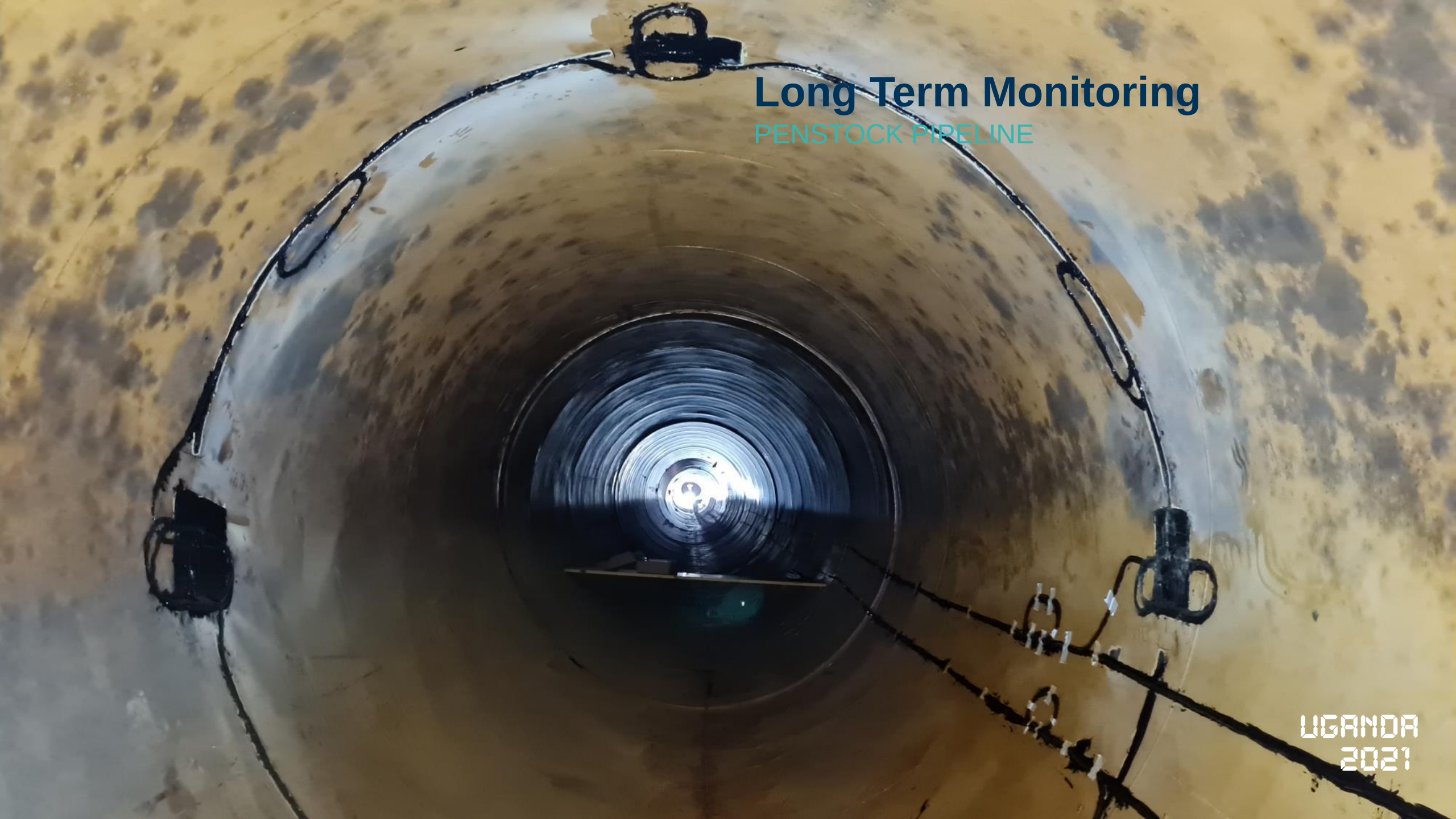


Peljesac Bridge

MONITORING DURING CONSTRUCTION

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 - 321 Weldable sensors
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 - 51 accelerometers in triaxial mounting
 - 8 FS22 BraggMETER interrogators
- ▲ Hands on training
 - Tips and tricks for field installation

Hands-on
Training



Long Term Monitoring

PENSTOCK PIPELINE

UGANDA
2021



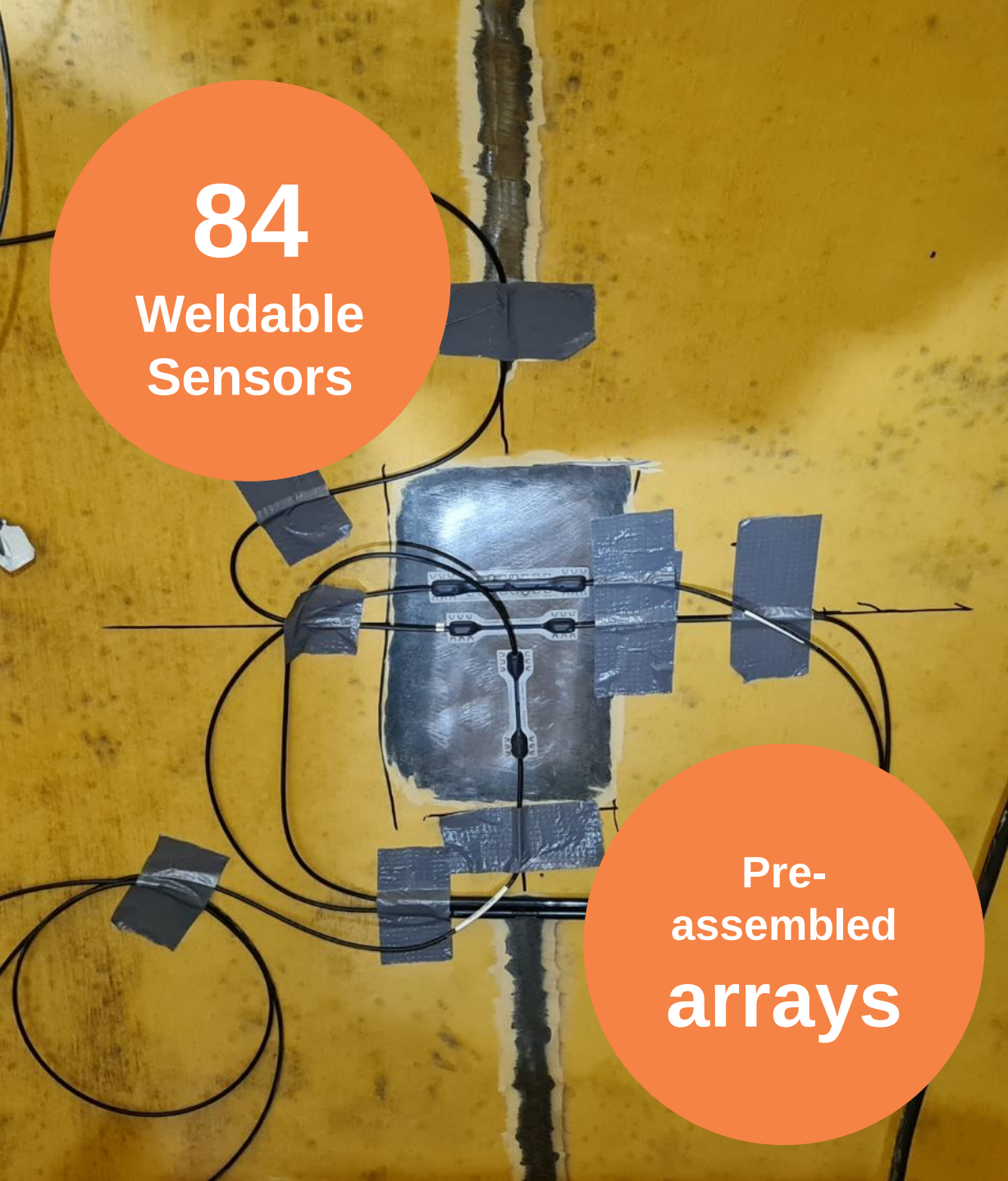
UGANDA
2021

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





84

Weldable
Sensors

Pre-
assembled
arrays

Long Term Monitoring

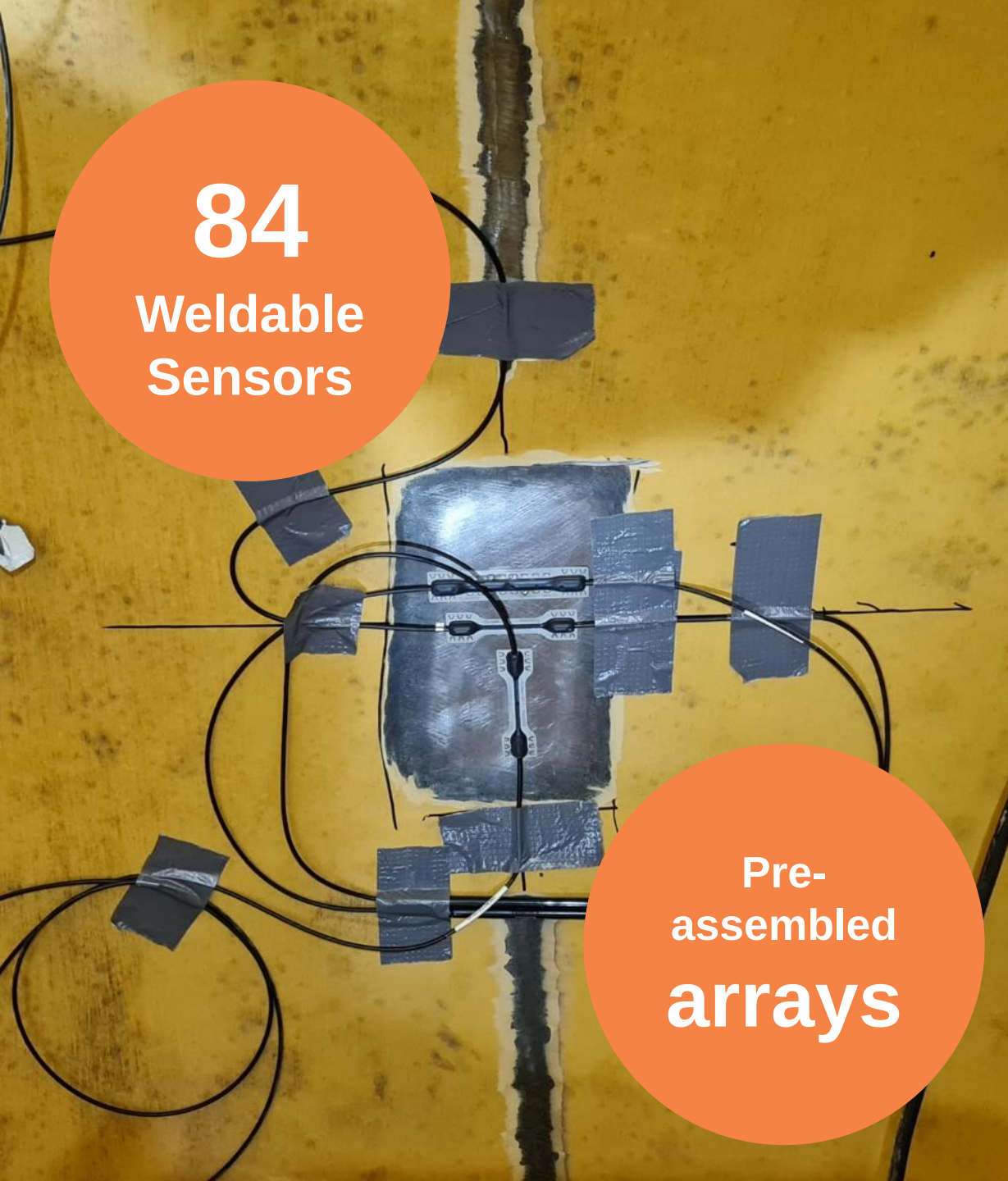
PENSTOCK PIPELINE

▲ 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



84

Weldable
Sensors

Pre-
assembled
arrays



Under-
ground
Installation



Inside



Underwater
Protection



Long Term Monitoring

PENSTOCK PIPELINE

▲ Fully optical system:

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 - Strain sensors
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▲ Installation

- Underground installation
- Inside the pipe
- Protected for underwater operation

▲ Commissioning

- Sensor network verification
- Training

Commis
-sioning

Training

A wide-angle photograph of an offshore wind farm in the North Sea. Several white three-bladed wind turbines are visible, each mounted on a tall, orange-painted monopile. The turbines are arranged in a line that recedes into the distance. The water is a deep blue, and the sky is a pale, hazy blue. A small boat is visible in the water between two of the turbines in the middle ground.

Offshore Monopile Monitoring

FATIGUE AND STRUCTURAL HEALTH ASSESSMENT

NORTHERN EUROPE
2020

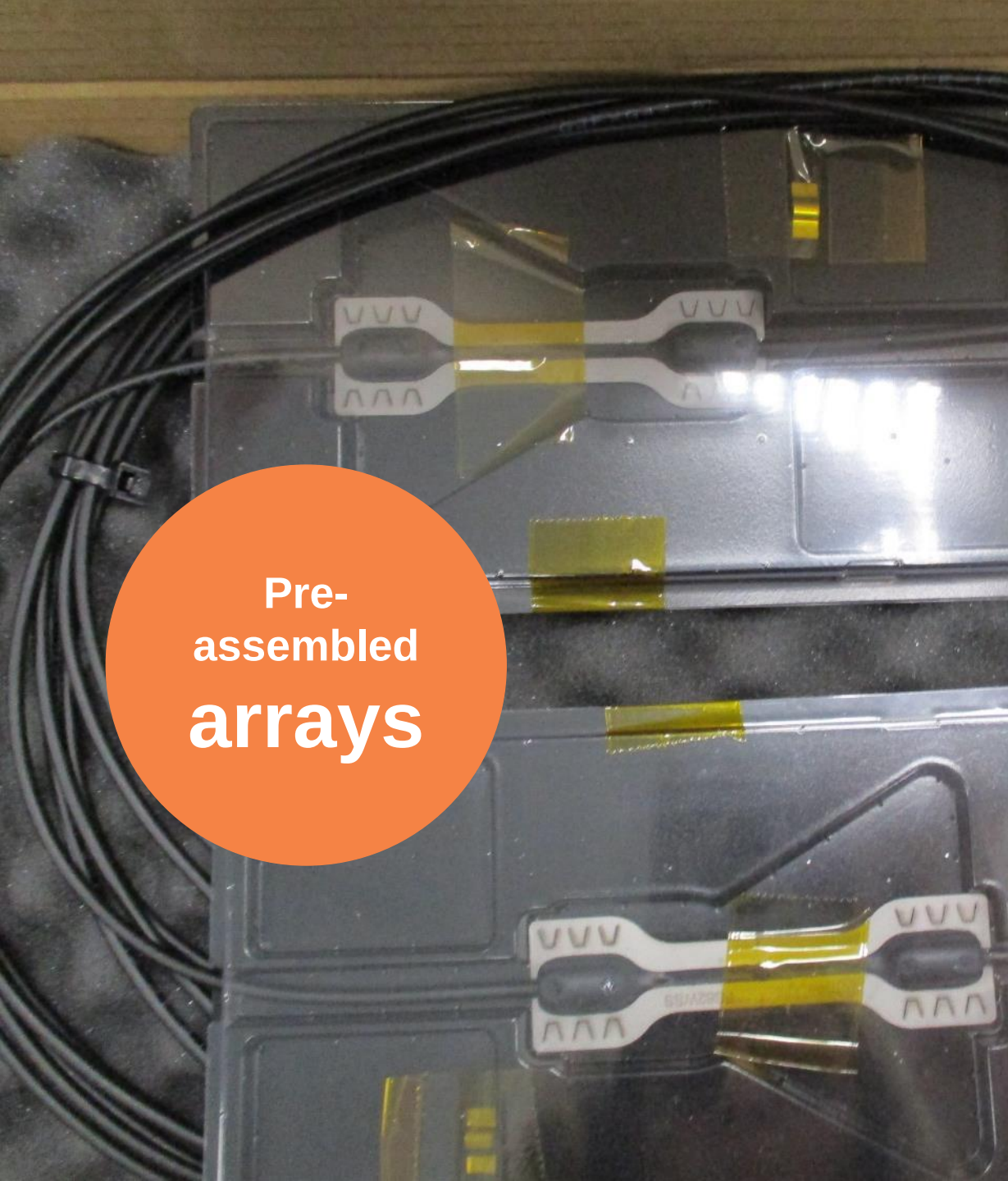


NORTHERN EUROPE
2020

Offshore Monopile Monitoring

FATIGUE AND STRUCTURAL HEALTH ASSESSMENT

- ▲ 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



Pre-
assembled
arrays

This image shows a close-up of a pre-assembled array. It features a metal plate with several fiber optic cables connected to it. The cables are bundled together and secured with yellow tape. The connectors are white and have a series of 'V' shaped slots. The background is a dark, textured surface.



Robust
Sensors

This image shows a robust sensor setup. It features a camera mounted on a stand, pointing down at a perforated metal plate. The plate is mounted on a metal frame. The background is a white wall.

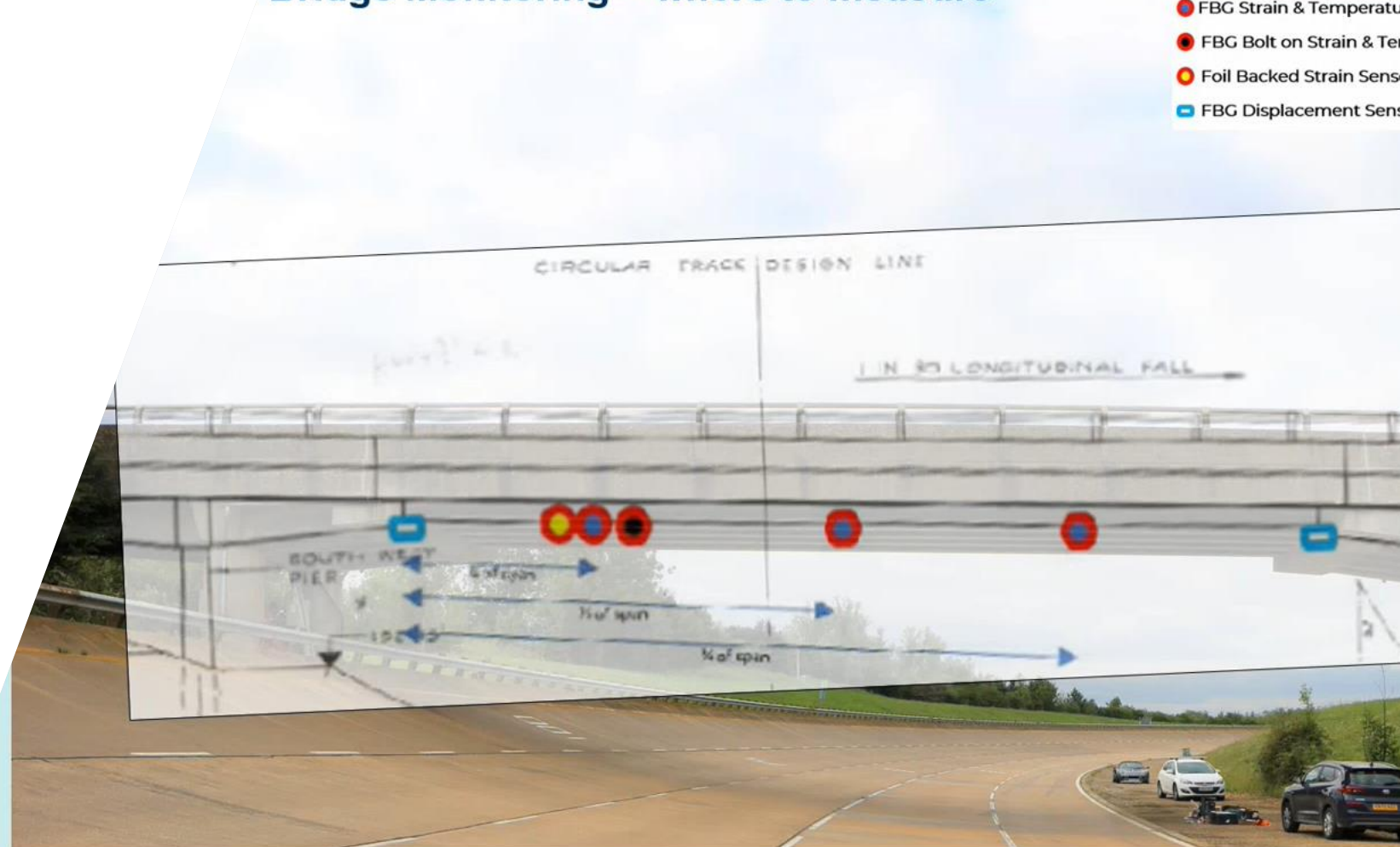
Demonstration

Demonstration

Contact HBK
for a
demonstration

Watch the
recorded
webinar

Bridge Monitoring – where to measure



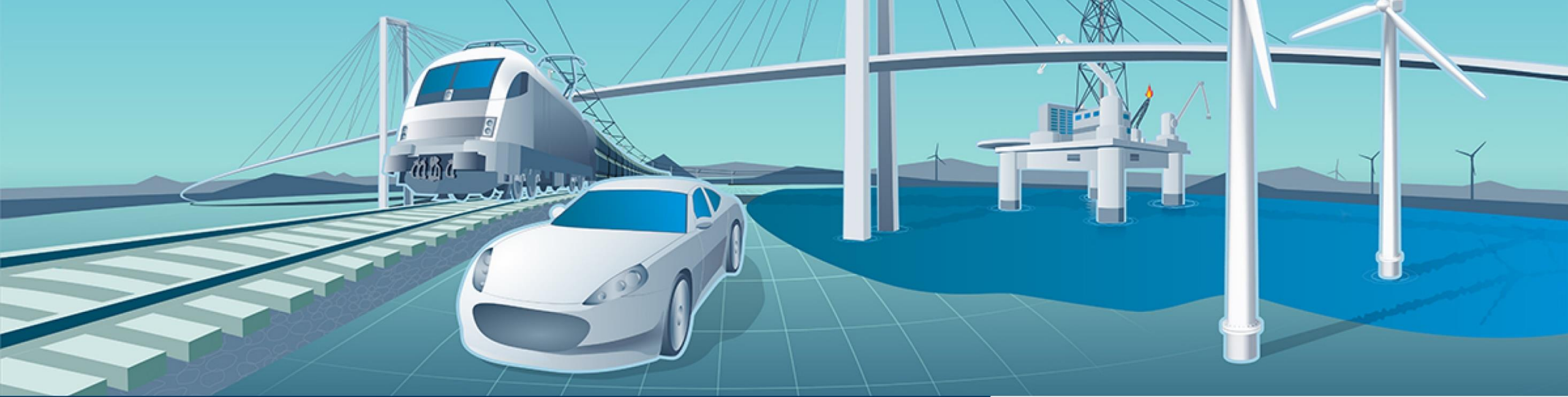
5 | <https://www.hbm.com/en/10649/tech-compared-in-bridge-monitoring/>

UNRESTRICTED

Thank You

QUESTIONS?





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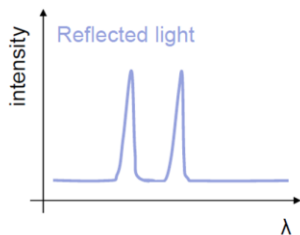
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