Structural health monitoring on racing sailboats

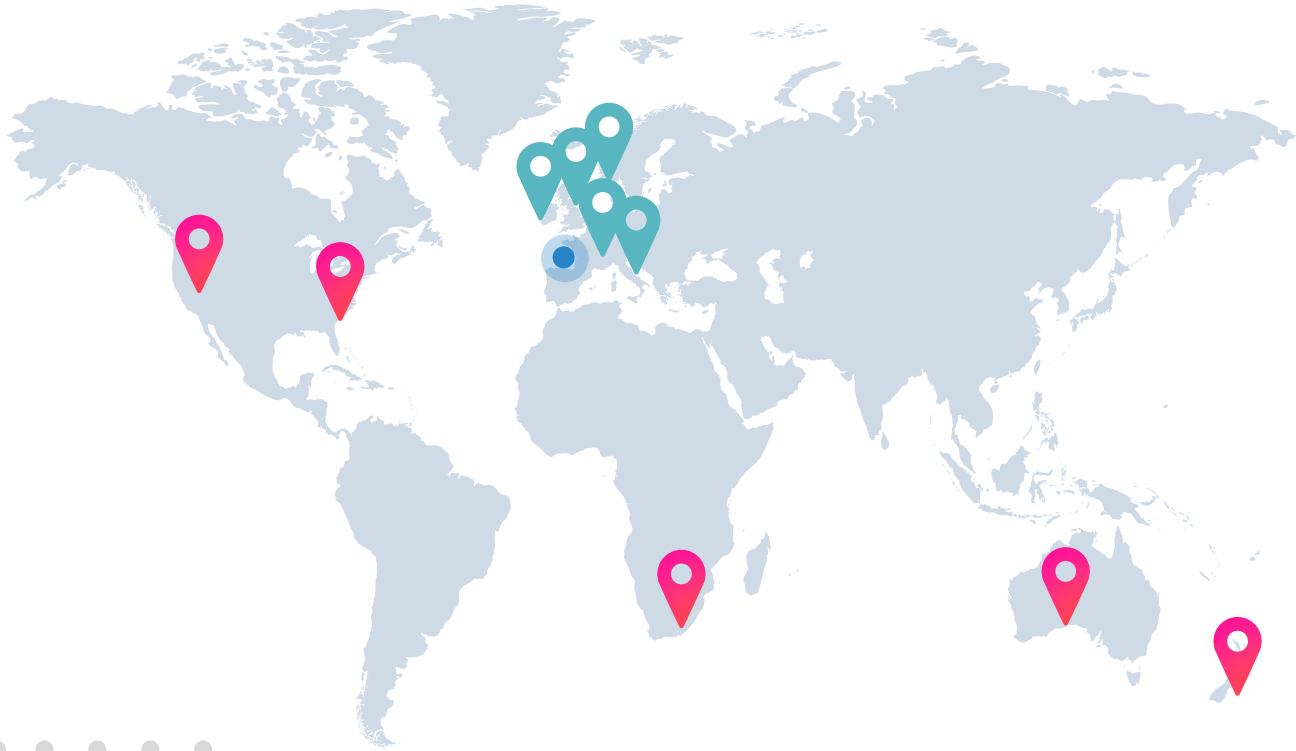
By Romain GUYARD

EPIC Online Technology Meeting on Optical Fiber Sensing for Structural Health Monitoring
November 7th 2022

Content

Key figures.

Turnover	~€2M
Employees	21
Hiring in 2022	+10
R&D employees	70%
Projects abroad	50%



Our services.

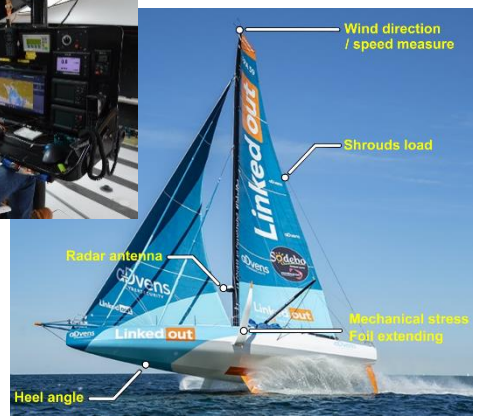
Our activity is based on 3 areas of expertise:

Integration of on-board electronics, instrumentation and **fiber optic** measurements, **custom engineering** in computer science and robotics.

INTEGRATION

Installation of all the electronic systems on board:

- navigation unit
- autopilot
- on-board communication
- energy supply system...



FIBER OPTICS

Supply of valuable data for boat design as well as real-time structural monitoring and performance :

- Structure monitoring system design and setting
- Installation on site
- Fiber optic components supplying
- R&D processes in the fiber optic sensors field

ENGINEERING

Development of some homemade electronic systems for :

- high frequency acquisition
- data supervision
- automatic piloting
- control of boats in flight

Exocet Blue

Data acquisition

Exocet Silver

Pilot & on-board calculator

Exocet Gold

Flight controller

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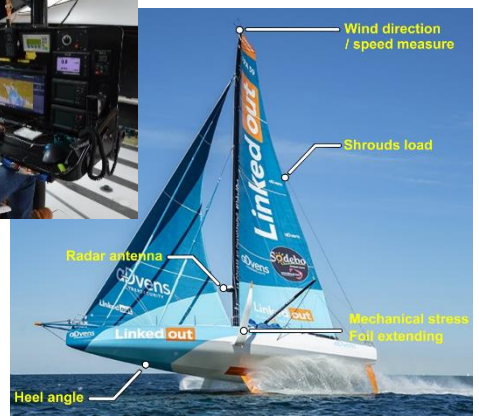

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A few applications

AC75 Americas Cup

Ultims

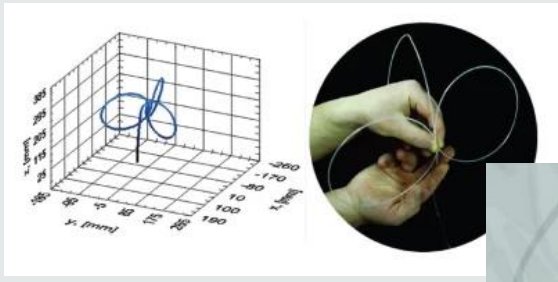
Skorpios Swan 125

IMOCA

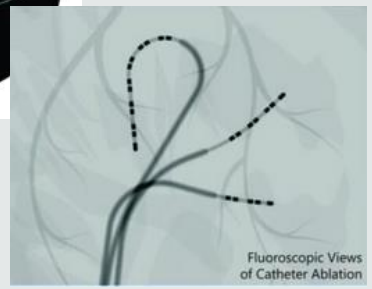
Why SHM ?

Security and safety purposes

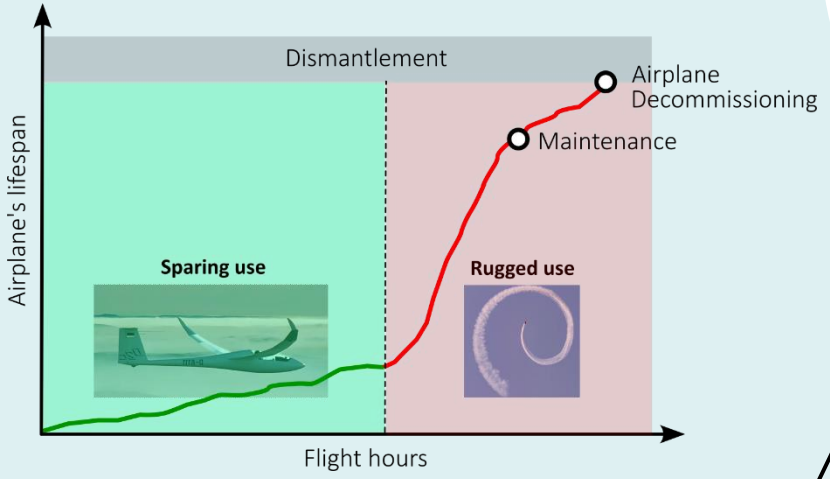
Input data for complex operations



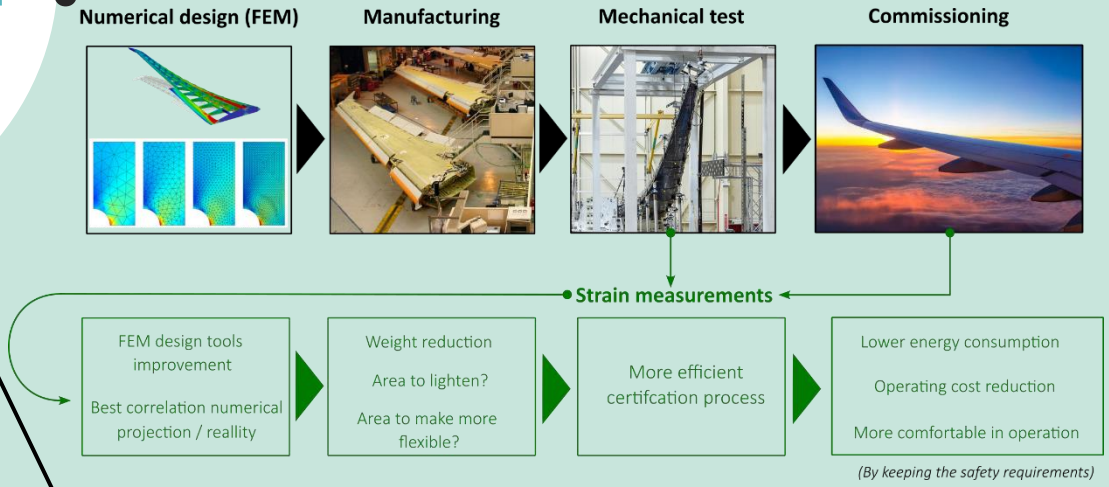
Ex : 3D shape sensing



Equipment management



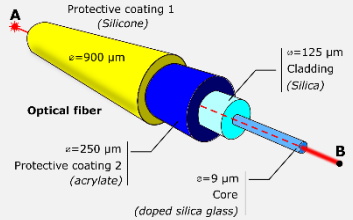
Structure improvement

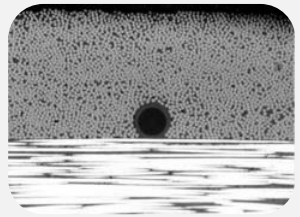


Why optical fiber ?

Highly compact

- Easily integrable
- Lightweight





Suitable for harsh environnment

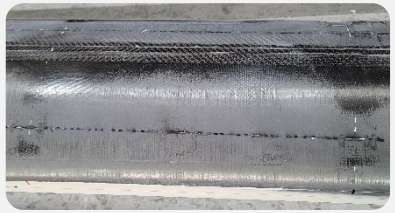
- No corrosion
- Electromagnetic Immunity

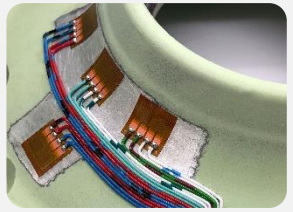
High-precision measurements

10 µm lengthening of 1 m long bar

Usable in a series

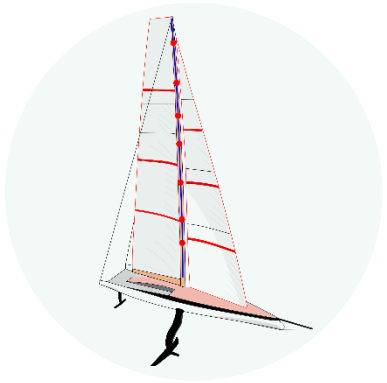
- Less cables
- Cost-effective

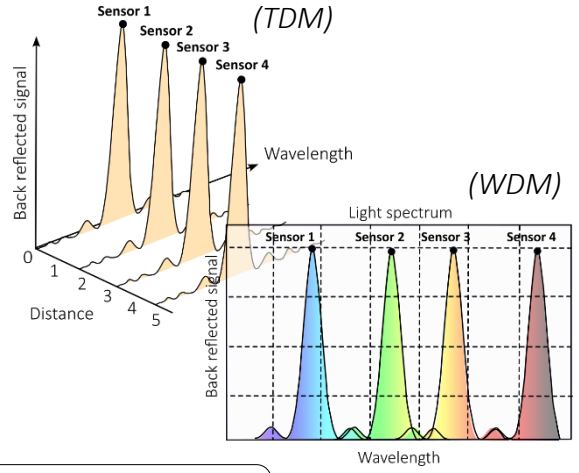




Which fiber optic technologies ?

- No ideal fiber optic technology for structures health monitoring applications
- Selection depends on numereous parameters *(structure size, goal, sampling, etc…)*

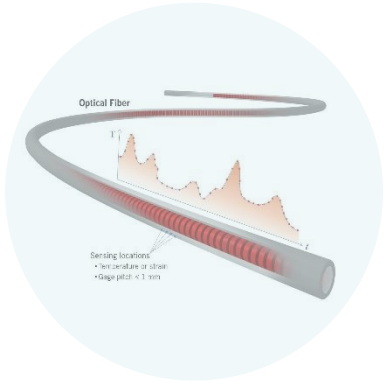


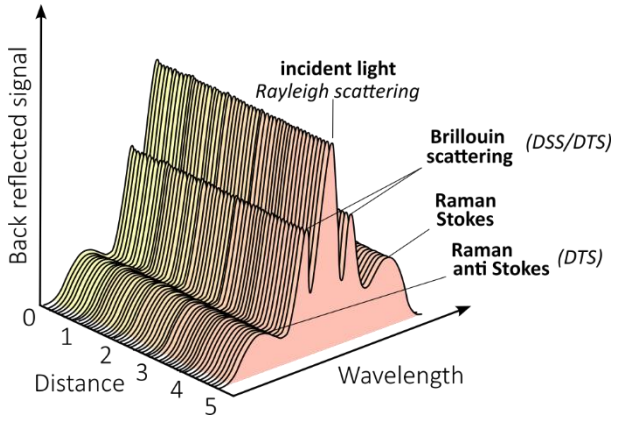


Quasi-distributed
Discrete measures along the optical fiber

Principle : Consist of some isolated sensors in a series *(Fiber Bragg gratings, Fabry-Perot cavity …)*

Advantages :
- Precise localisation of the measure
- Cost-effective and embarkable interrogator unit
- Suitable to monitor medium structures *(from 1m to 100 m)*

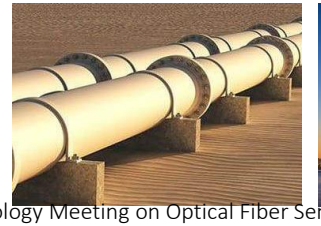




Distributed
Continuous measures along the optical fiber

Principle : Use the optical scattering phenomena wthin optical fibers

Advantages :
- Usable with existing optical fibers
- Cost-effective for the big structures *(>100 m)*
- Efficient to monitor civil engineering structures *(pipeline, submarine cable…)*



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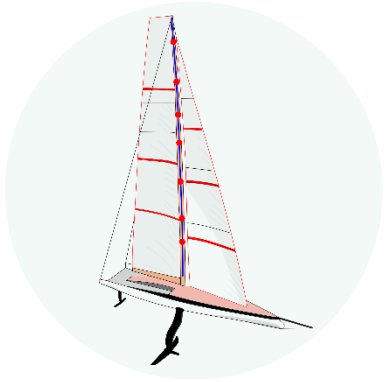
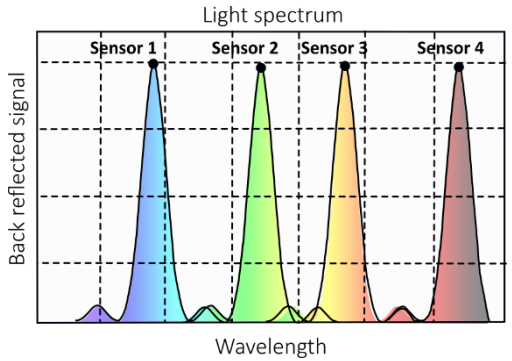


Fiber Bragg gratings – wavelength division multiplexing



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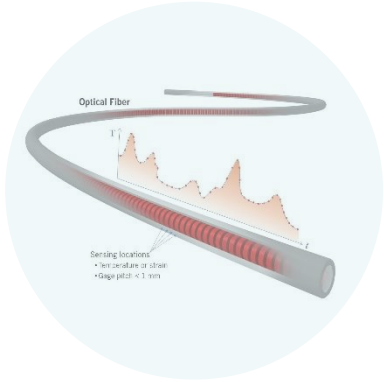

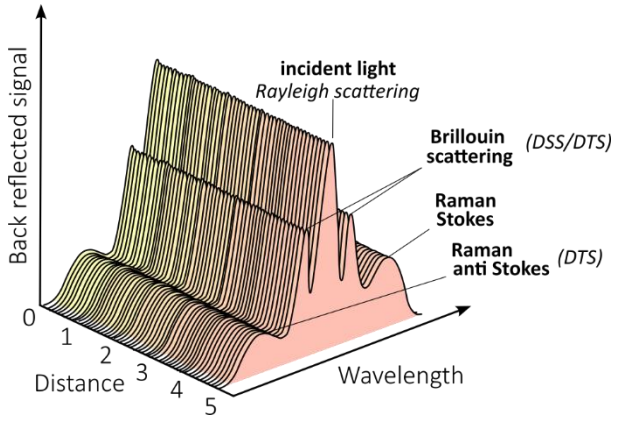

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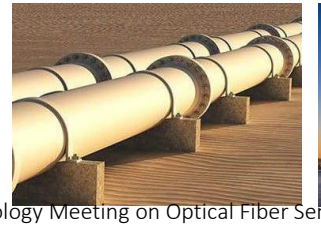
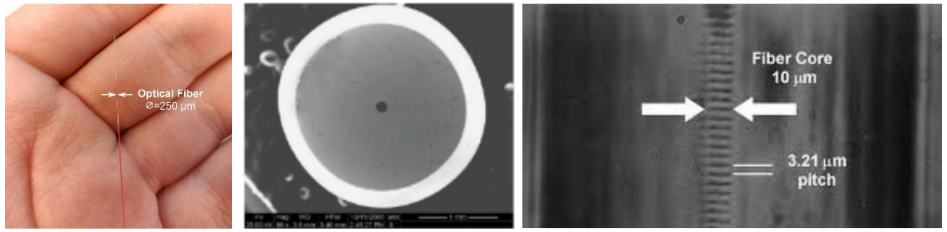
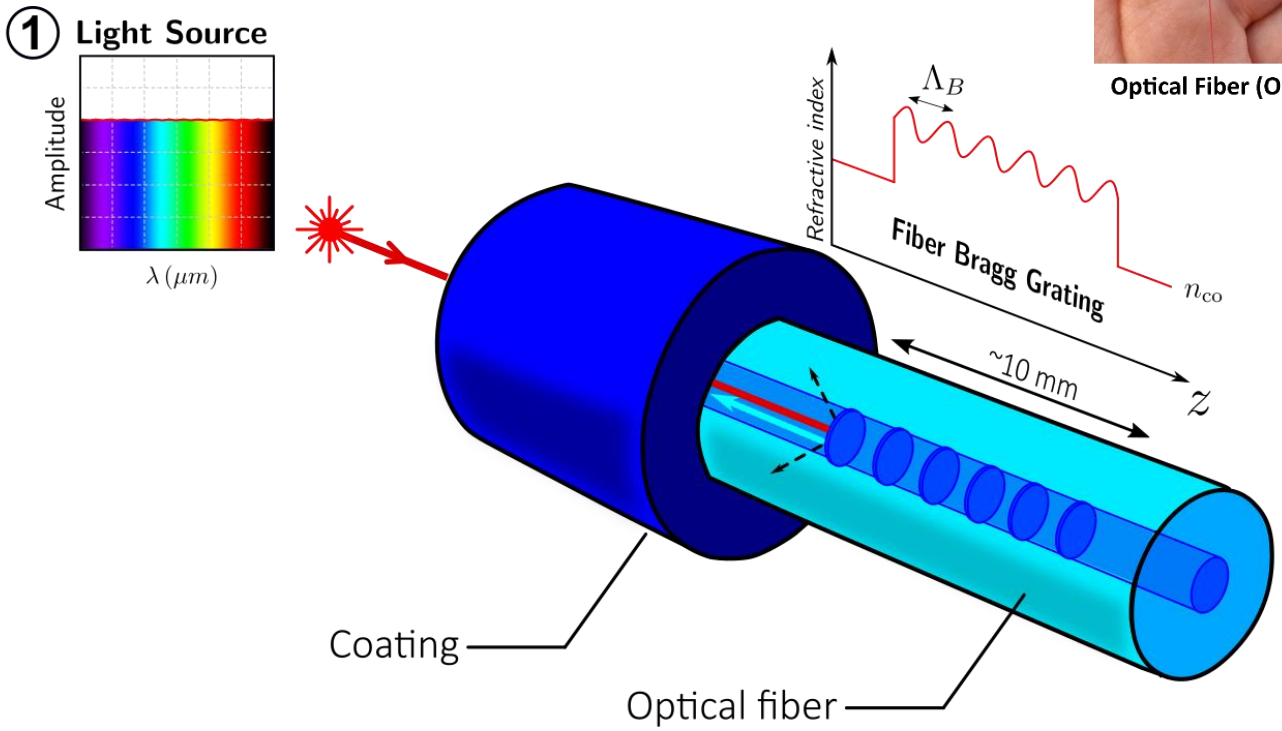


Fiber Bragg grating principle



Optical Fiber (OF) | OF Cross section | Bragg grating



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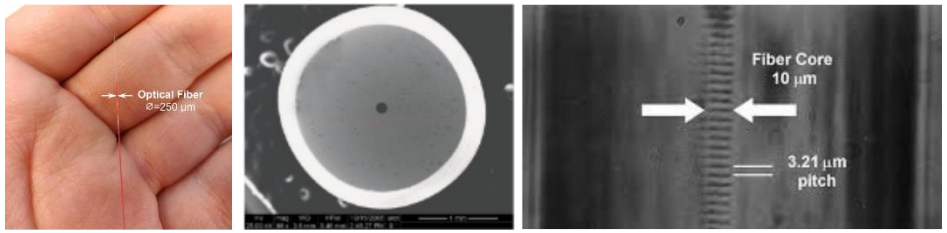

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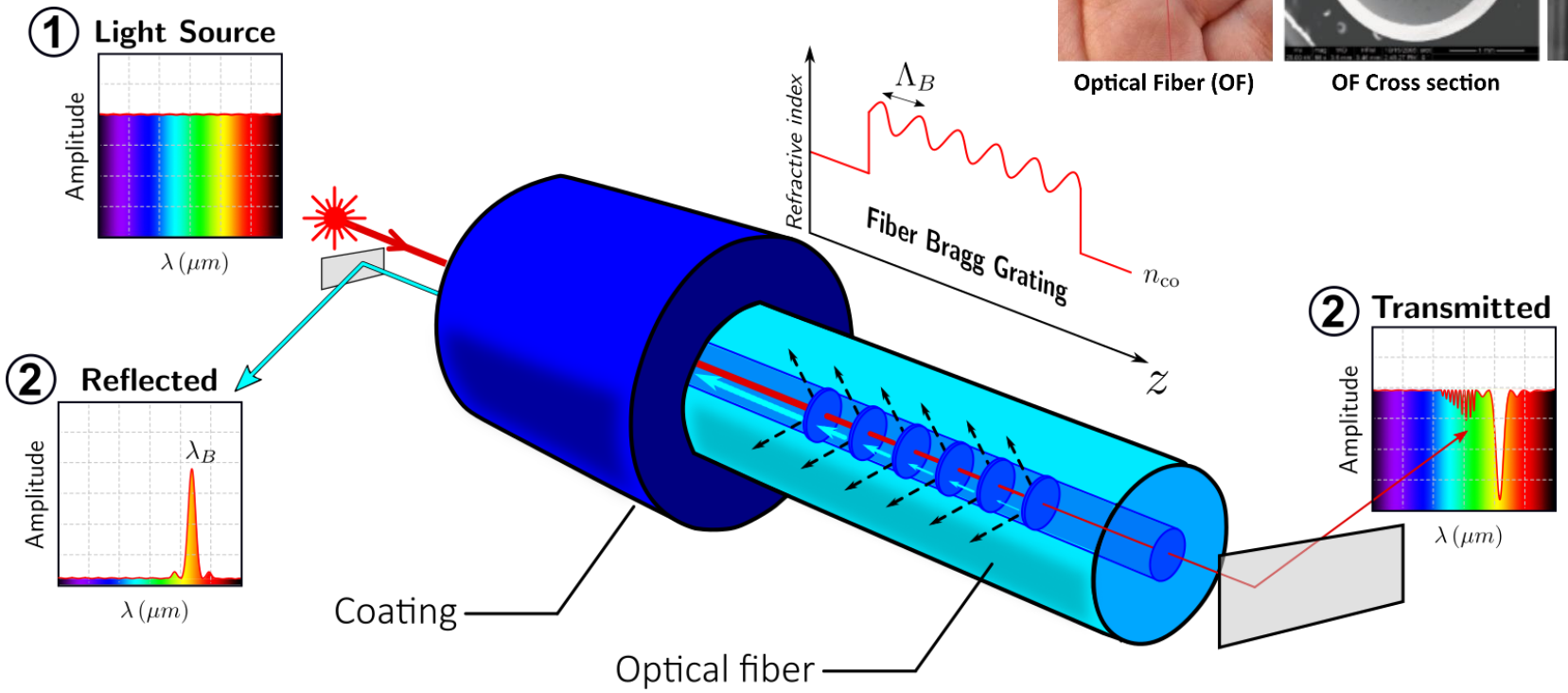
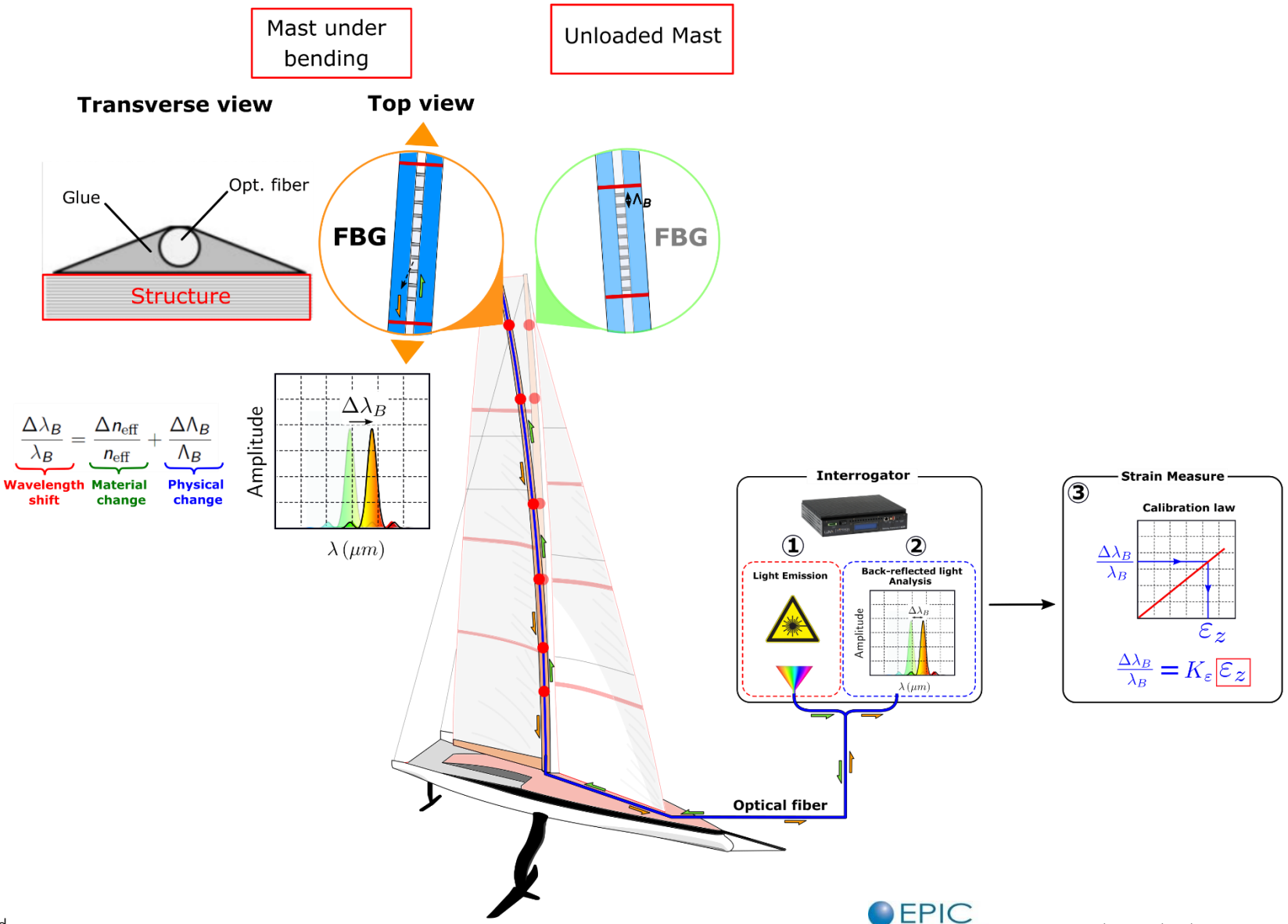


$$\lambda_B = 2 n_{eff} \Lambda_B$$

Optical fiber implementation



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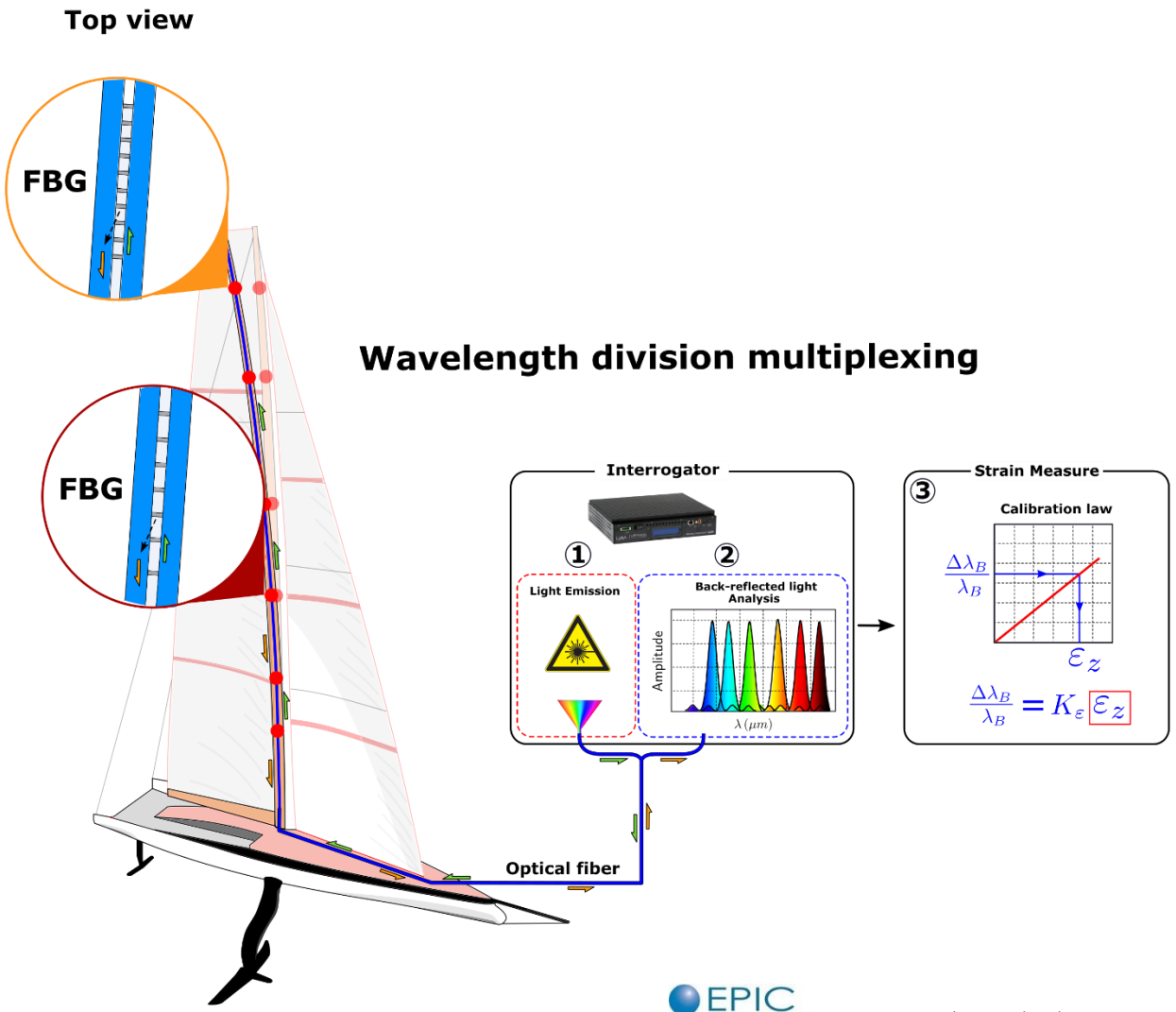
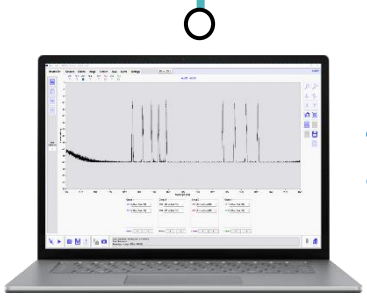


Fiber optic sensing basic requirements

TCP / IP

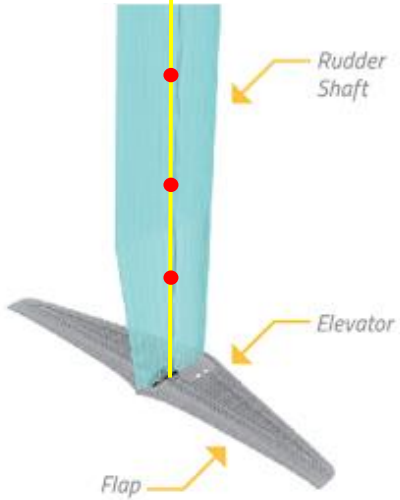
Optical fiber cable



Data logging

Alarms notifications

Structure



Fiber optic sensing basic requirements

Weight : 4,3 kg **Cons :** 35W
H x W x D : 307 x 274 x 69 mm
Freq : > 100 Hz **Precision :** < 10 µε
Sensors per channel : up to 20
Channel nb : 4, 8 or 16

1 **Interrogator** LUNA

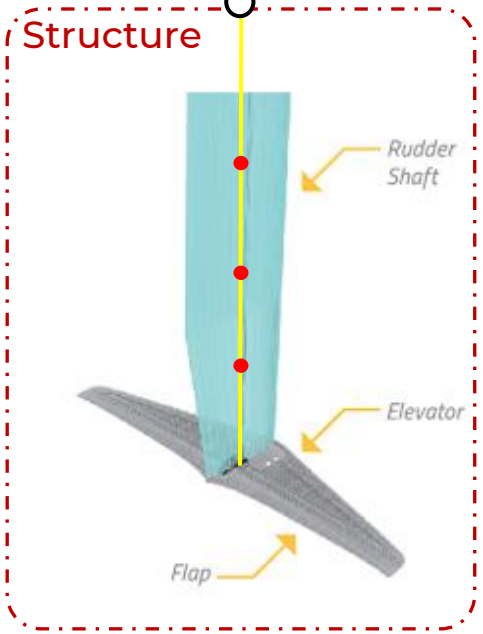
TCP / IP

Optical fiber cable

SD

Data logging

Alarms notifications



Fiber optic sensing basic requirements

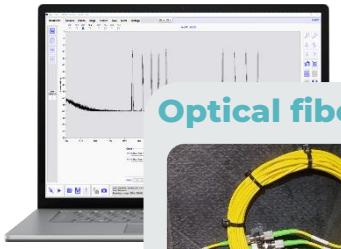
1 Interrogator

TCP / IP

Optical fiber cable

SD

Data logging

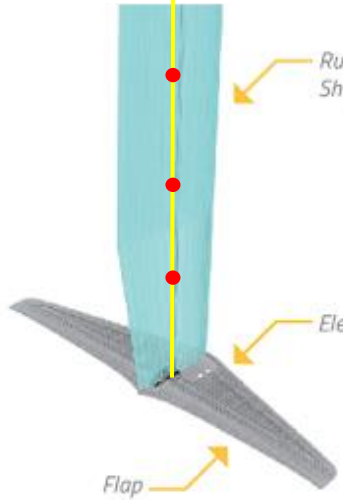


Optical fiber cables junction 2

Conventional

Rugged cable multi-channels

Structure



Fiber optic sensing basic requirements

1 Interrogator

TCP / IP

Optical fiber cable

2 Optical fiber cables junction

SD

Data logging

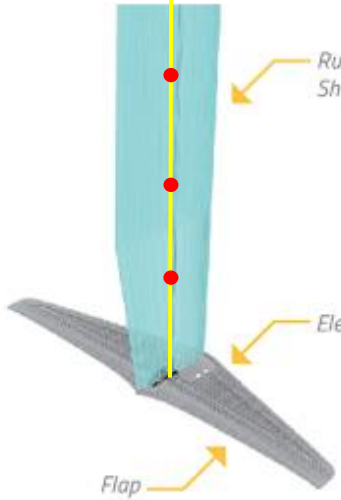
Alarms notifications

Fiber optic connectors 3

Conventional FC-APC

Watertight connectors

Structure



Fiber optic sensing basic requirements

1 Interrogator

TCP / IP

2 Optical fiber cables junction

Optical fiber cable

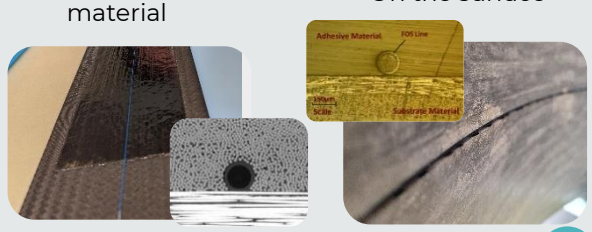
SD

Data logging

Alarms notifications

Inside the material

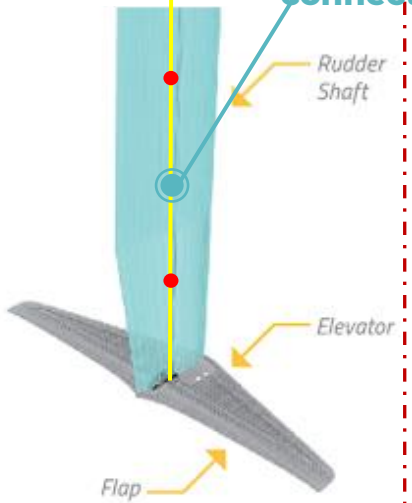
On the surface



Fiber optic transducers (FBG) 4

Structure

3 Fiber optic connections



Fiber optic sensing basic requirements

1 Interrogator

TCP / IP

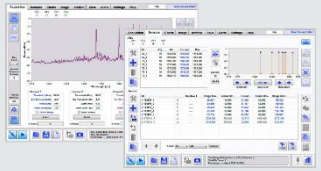
Optical fiber cable

2 Optical fiber cables junction

Data logging

Alarms notifications

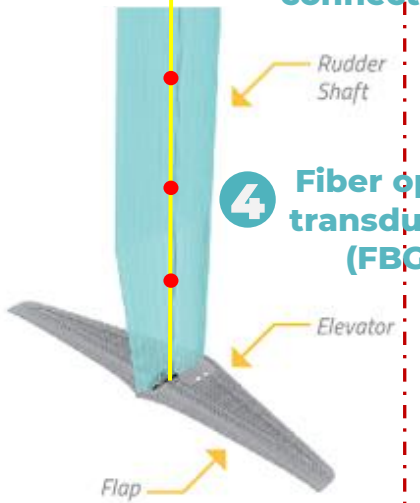
5 Software for recording and supervision



Supply by the interrogator manufacturer

Structure

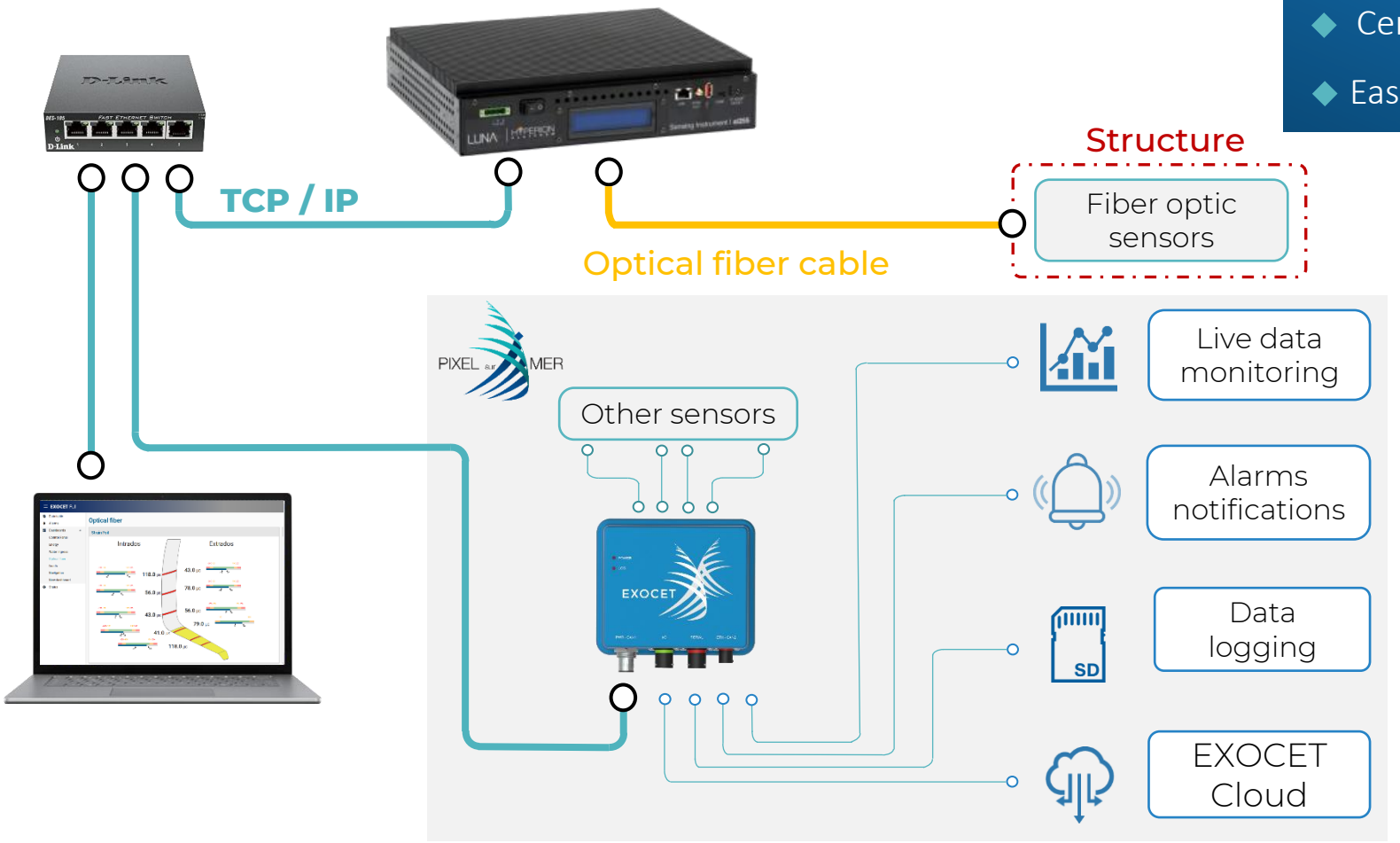
3 Fiber optic connections

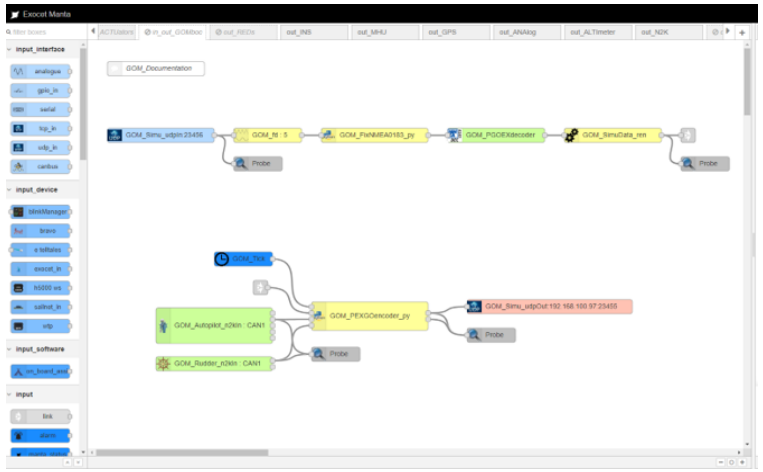


4 Fiber optic transducers (FBG)

Fiber optic sensing completed requirements

- Easy to configure
- Synchronised data from multiple sensors
- Alarm settings suitable for the context
- Centralized data monitoring displaying
- Easier data processing and accessible remotely





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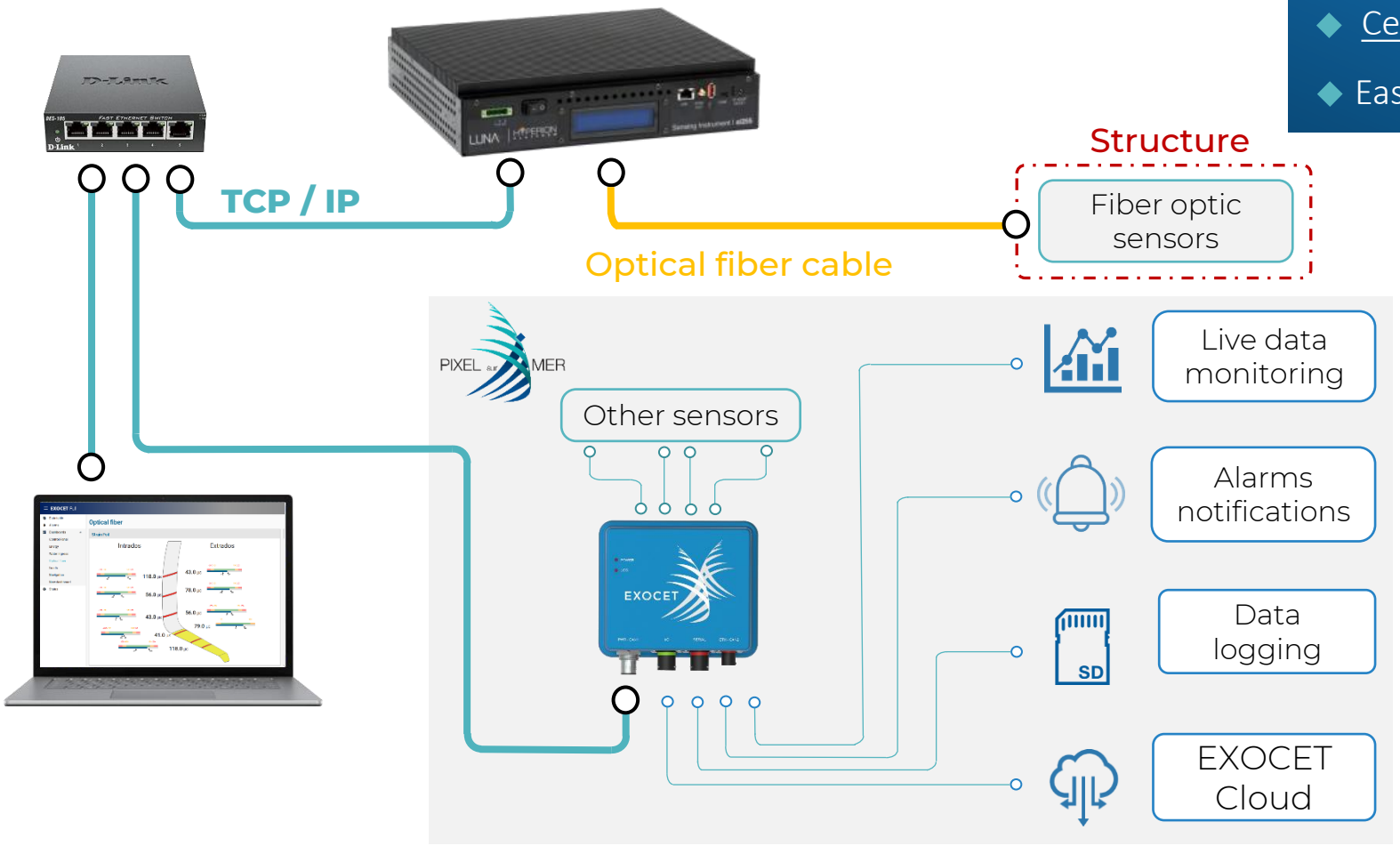

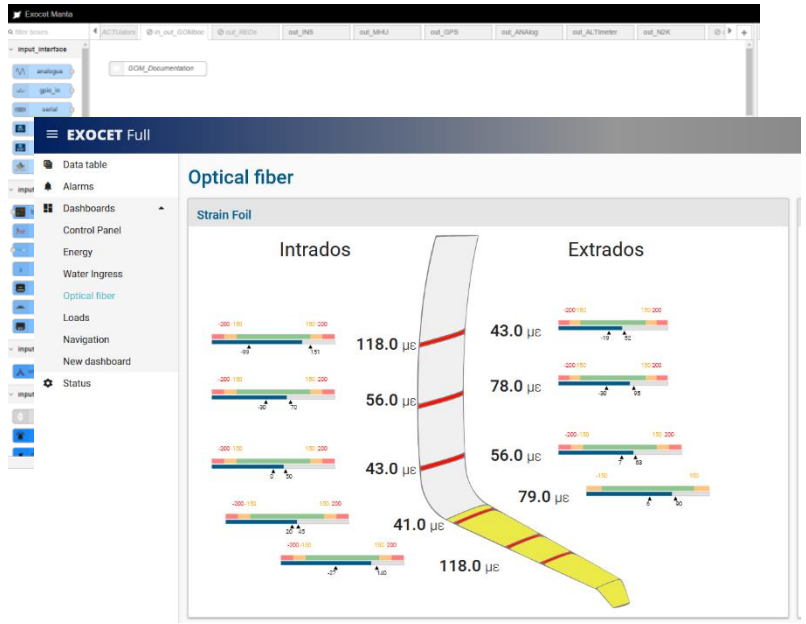

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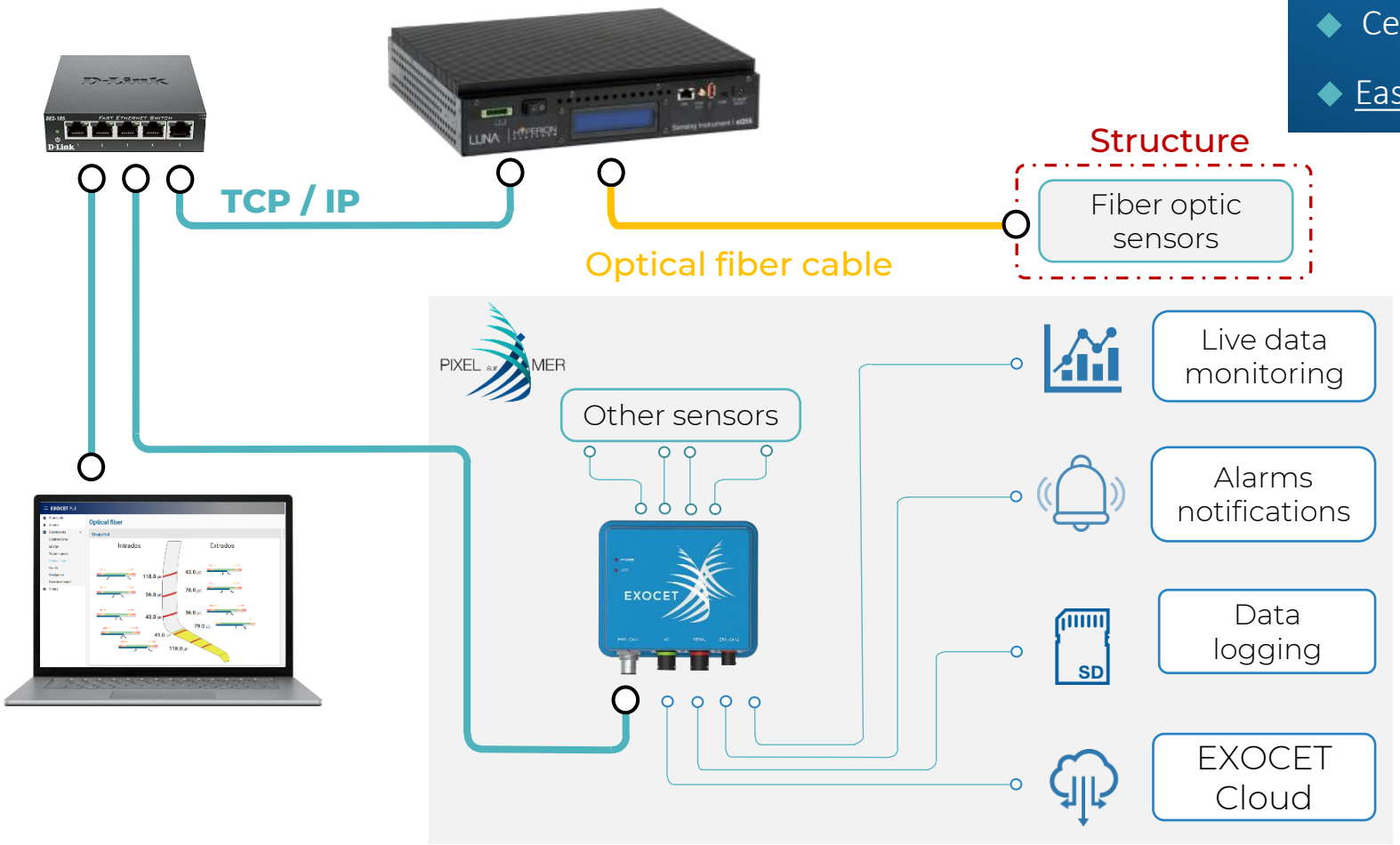
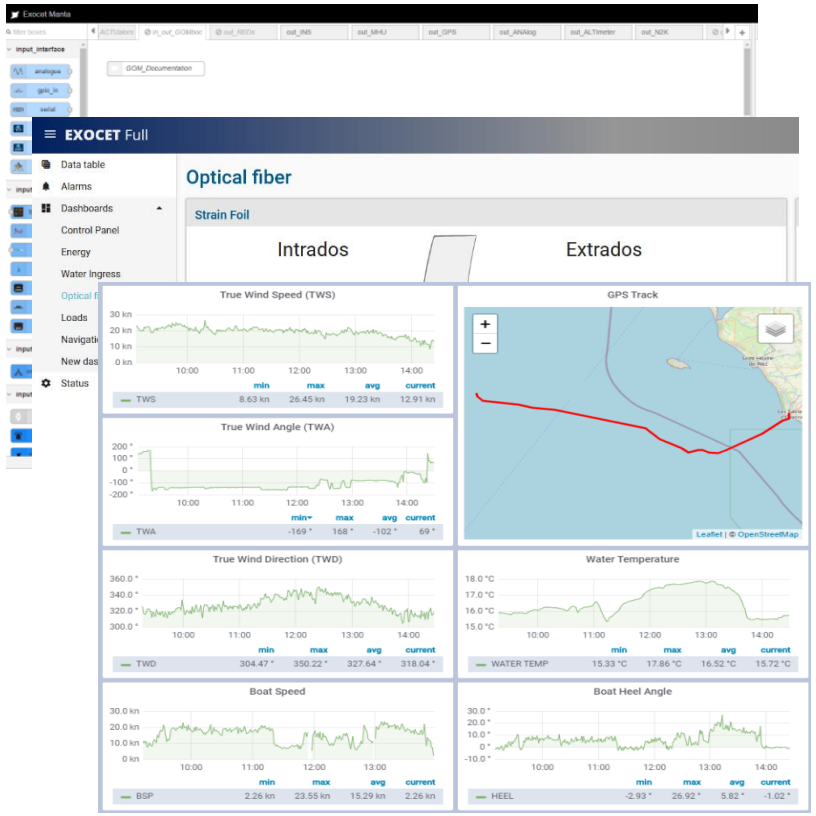
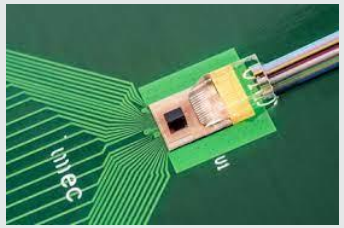




Fiber optic sensing leads

Essential features :

Spectral width : > 80 nm
Cons. : < 10 W
Weight : < 1 kg
Channels nb. : min. 4
Vibration resistance
Dimensions : similar to a smartphone
Cost : < 7000 € *(make it more accessible)*



Silicon photonics

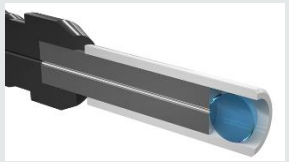
1 Interrogator

Heat-resistant optical connectors (T > 120°C)

Temperature : > 120°C
Coating : Flexible, polymer-based and rugged

Rugged optical connectors

Insensitivity to dirt and debris
Easy to maintain
Compact *(⌀ < 10 mm)*

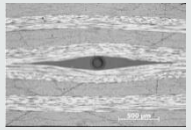


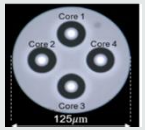
TCP / IP

2 Optical fiber cables junction

5 Software for recording and supervision

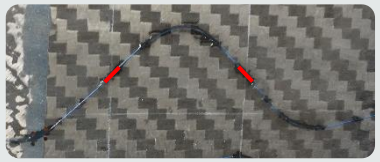
Measuring temperature separately from strain





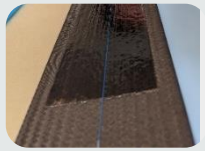
Research project CAFCA

Multidirectional strain measurement (shear strain)



Need to be more compact
(grating writing within a see-through patch?)

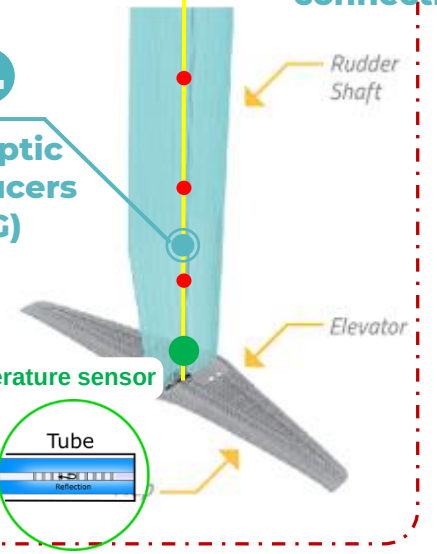
Improving optical fiber features for embedded installations



3 Fiber optic connections

Structure

4 Fiber optic transducers (FBG)



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