4ème JOURNEE NATIONALE CONTROLE SANTE ET MONITORING DES STRUCTURES

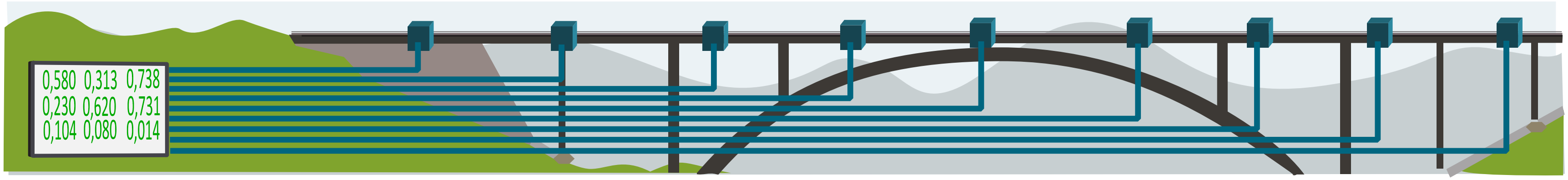
Distributed fiber-optic strain measurements: Brillouin sensing in geotechnical applications

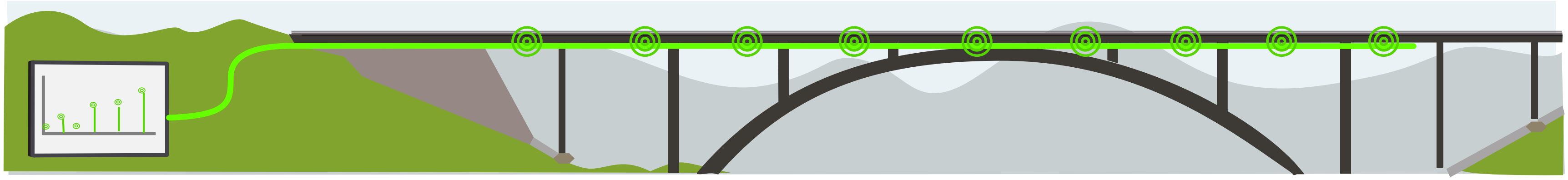
DIMIONE Systems - Olivier MERCEREAU
SHM-France
6 juillet 2021

Distributed Fiber-Optic Sensing

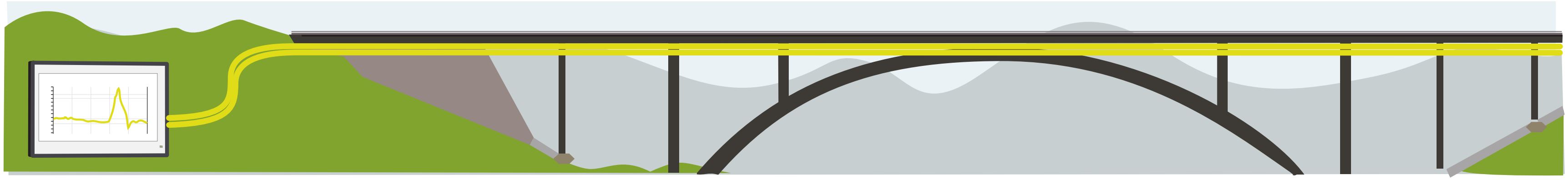
Discrete sensors:



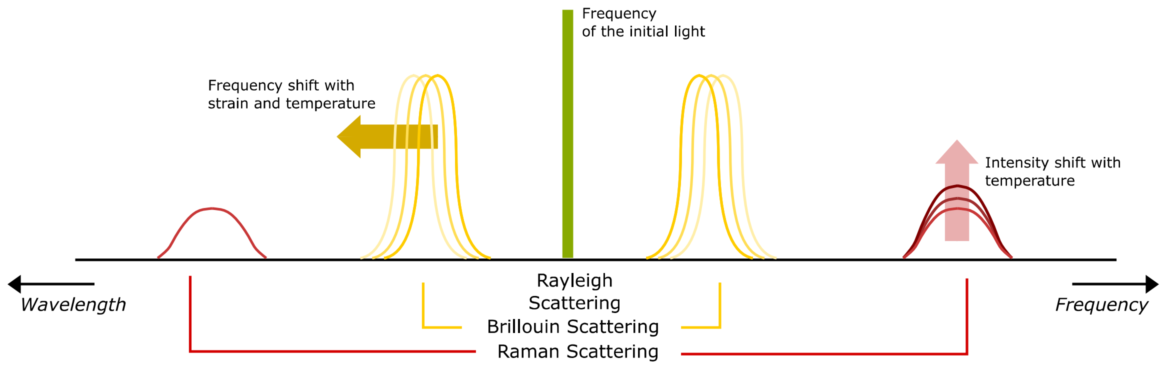
Quasi-distributed sensors:

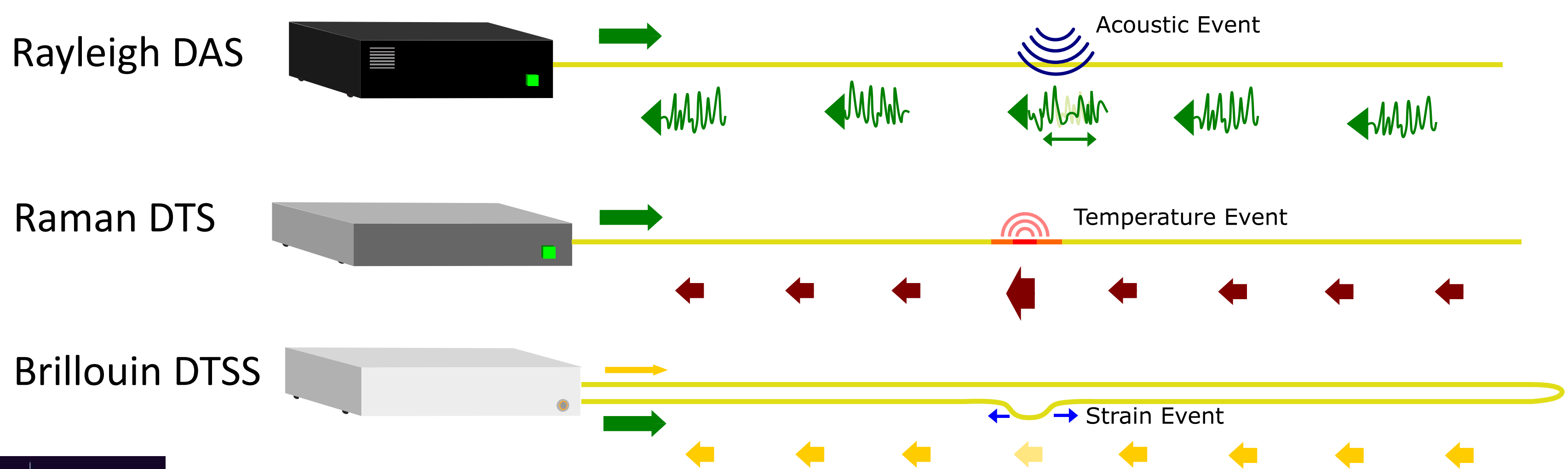


Truly distributed sensors:



Technology Overview: DAS, DTS, DTSS





Technology Overview: DAS, DTS, DTSS

	Rayleigh DAS	Raman DTS	Brillouin DTSS
Technology	Dynamic strain / vibration / acoustic sensing	Temperature sensing	Static strain and temperature sensing
Physical information	Geometrical fluctuations of Rayleigh pattern	Relative change of Raman intensity	Absolute change of Brillouin frequency shift
Applications	Seismic profiling Intrusion detection Leakage detection …	Power cable rating Fire detection Leakage detection …	Structural integrity Geohazard detection Deformation monitoring …
Capabilities	Real-time distributed acoustic data	Absolute temperature readings, insensitive to strain	Long-term stable strain measurements, no re-calibration
Limitations and challenges	Long-term variations	Absolute readings sensitive to attenuation changes	Cross-sensitivity strain/ temperature, not dynamic

The DTSS system for industry assignments

Distributed strain and temperature sensing with the Brillouin optical frequency domain analysis.

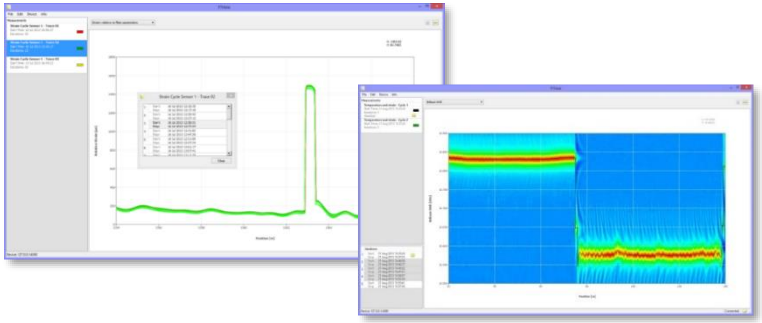
Technical outline:

Loop configuration (BOFDA):

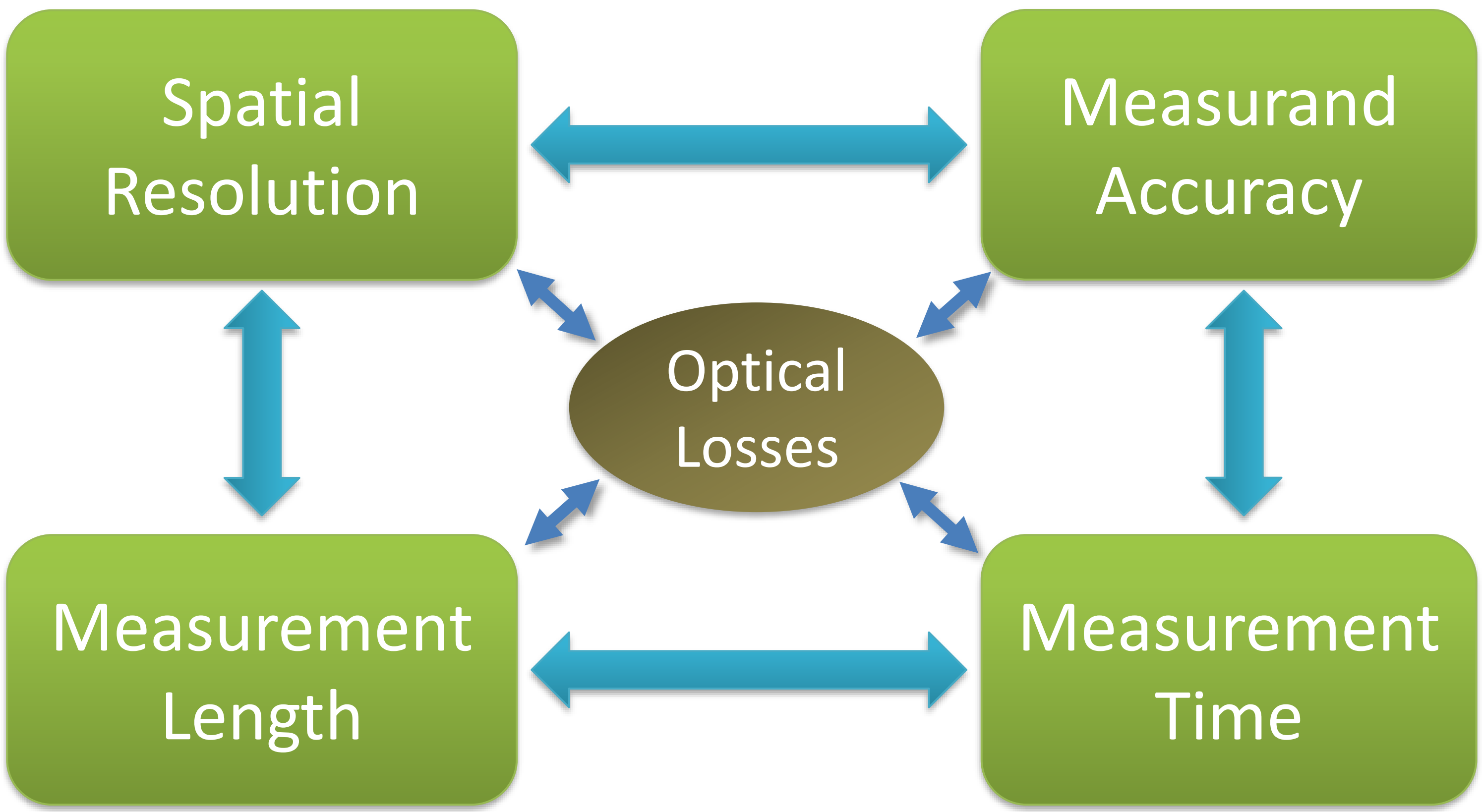
- Spatial resolution: < 0.2 m
- Measurement length > 50 km
- Repeatability: < 0.1°C, 2 µm/m

Single-ended configuration (BOFDR):

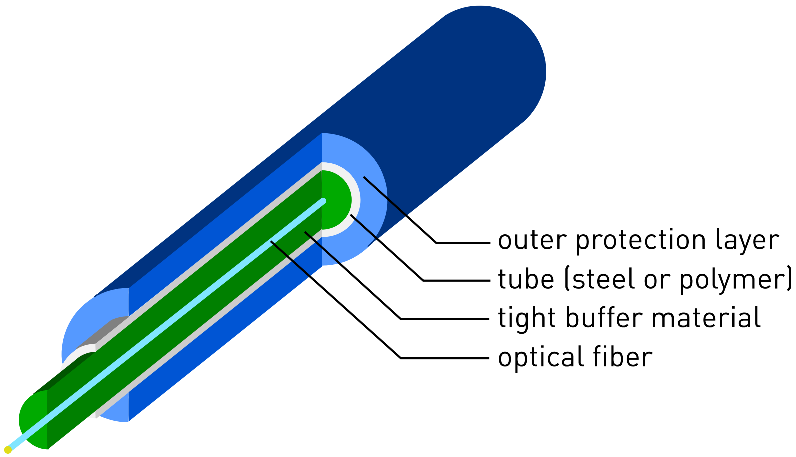
- Spatial resolution: 1.5 m
- Measurement length: > 25 km
- Repeatability: < 1°C, 20 µm/m

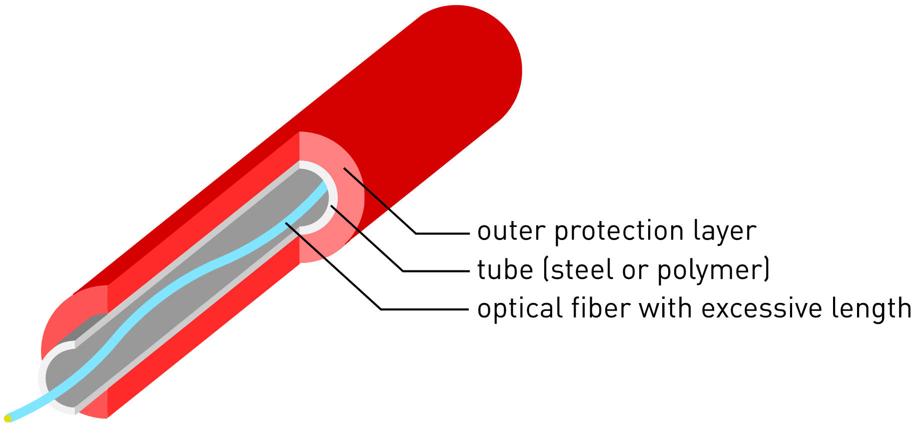


Performance parameters



Fiber-optic sensing cables for DTSS





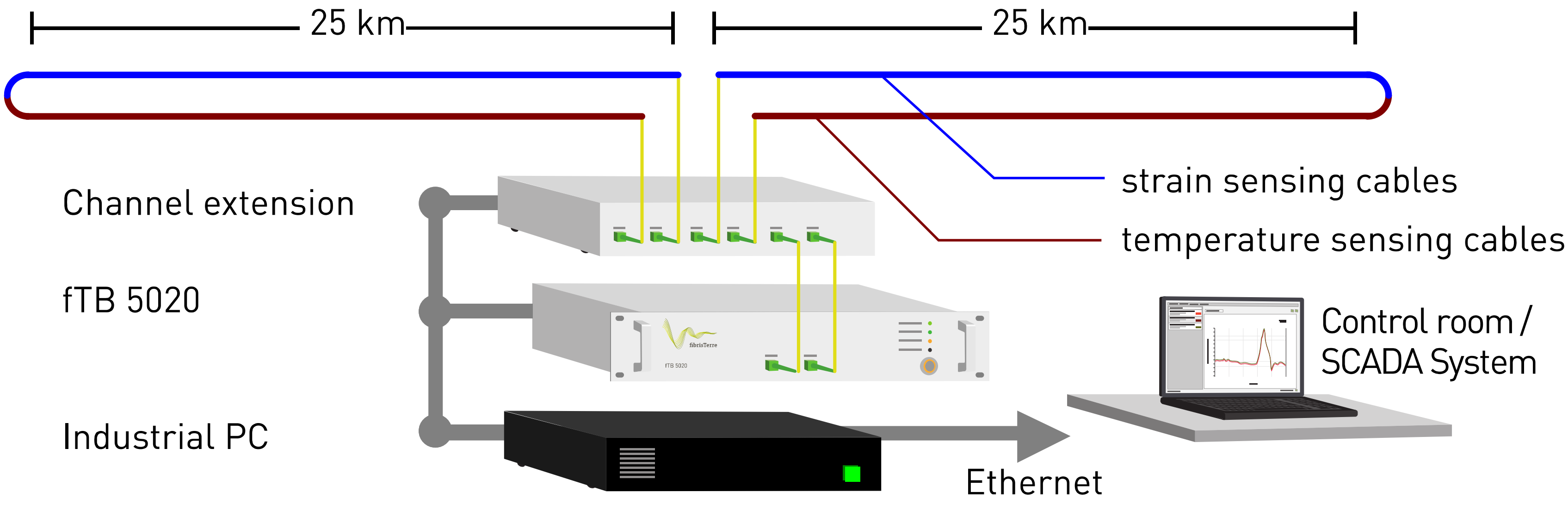
Strain sensing cable:

- Tight-buffered design for strain transfer into the fiber
- Metallic or non-metallic designs
- Round or rectangular cross sections

Temperature sensing cable:

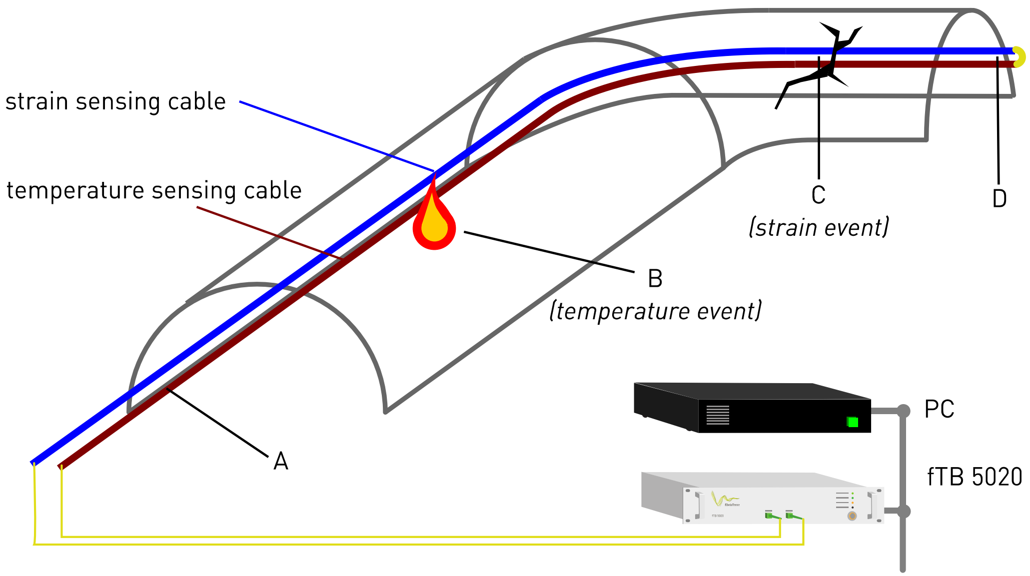
- Loose-tube design for strain decoupling
- Excessive fiber length inside tube
- Metallic or non-metallic designs

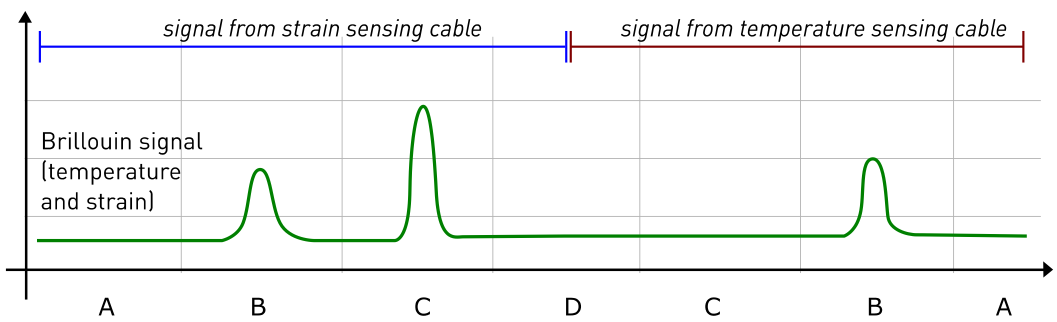
Typical installation set-up

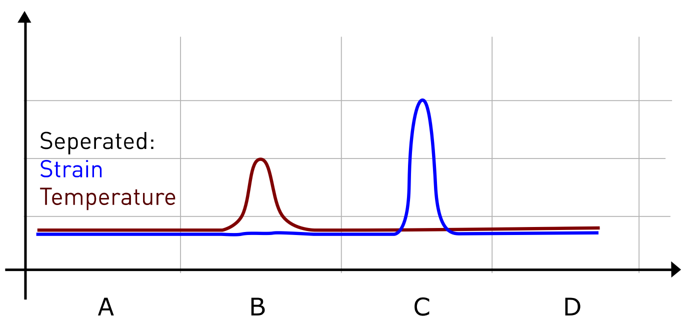


- Loop configuration can be used for temperature compensation
- Fiber-optic switches for channel multiplexing
- Data transfer to control room by Ethernet connection

Separating strain and temperature in DTSS

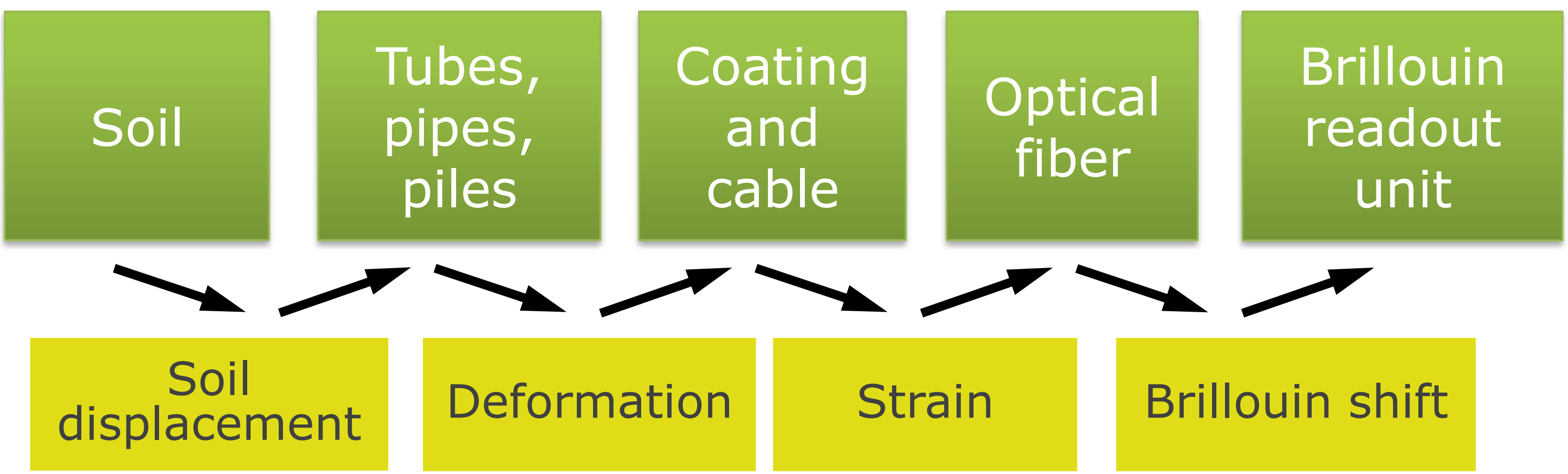






Sensing cables in geotechnical applications

The transfer chain from the soil to the signal:



1) Well integrity monitoring with DTSS

Enhanced integrity monitoring via distributed strain sensing along the cemented production casing of salt cavern wells

Research carried out by

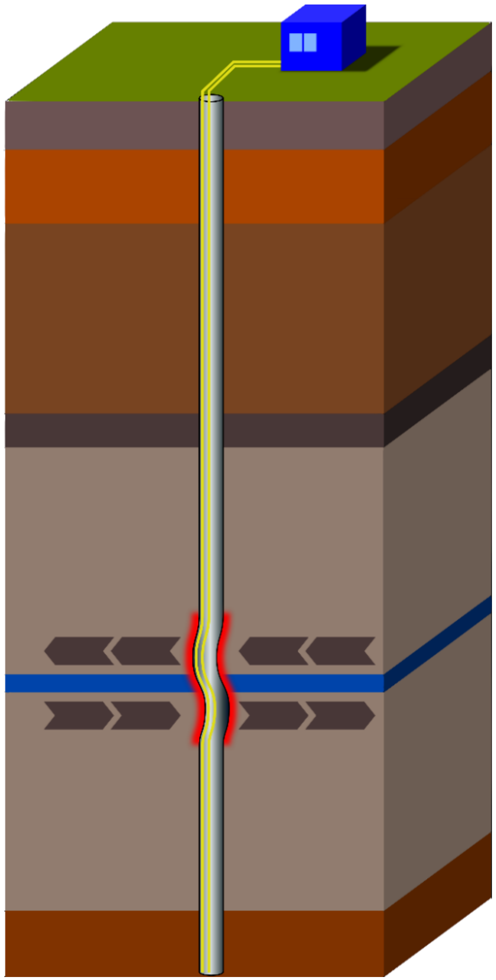
- ESK GmbH –

  Maurice Schlichtenmayer,

  Carsten Pretzschner
- fibrisTerre Systems GmbH –

  Nils Nöther, Massimo Facchini

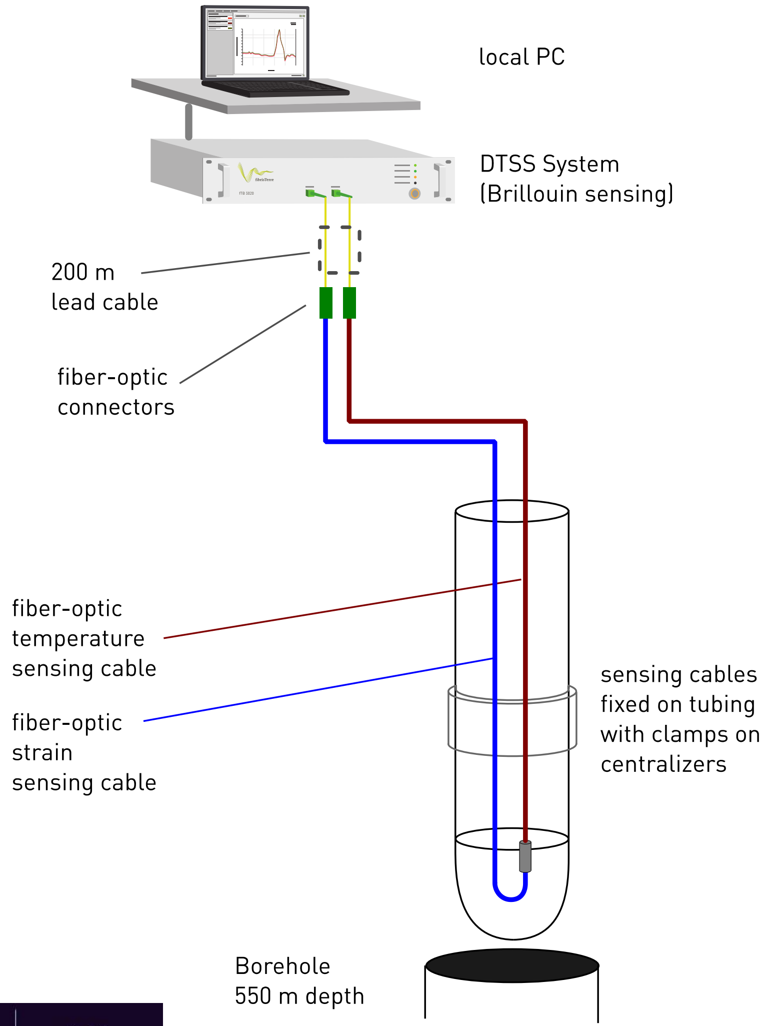
Vertical tubings: How to measure strain?



Challenges:

- Reliable strain coupling to the structure required
- Temperature compensation necessary
- Limited accessibility for installation

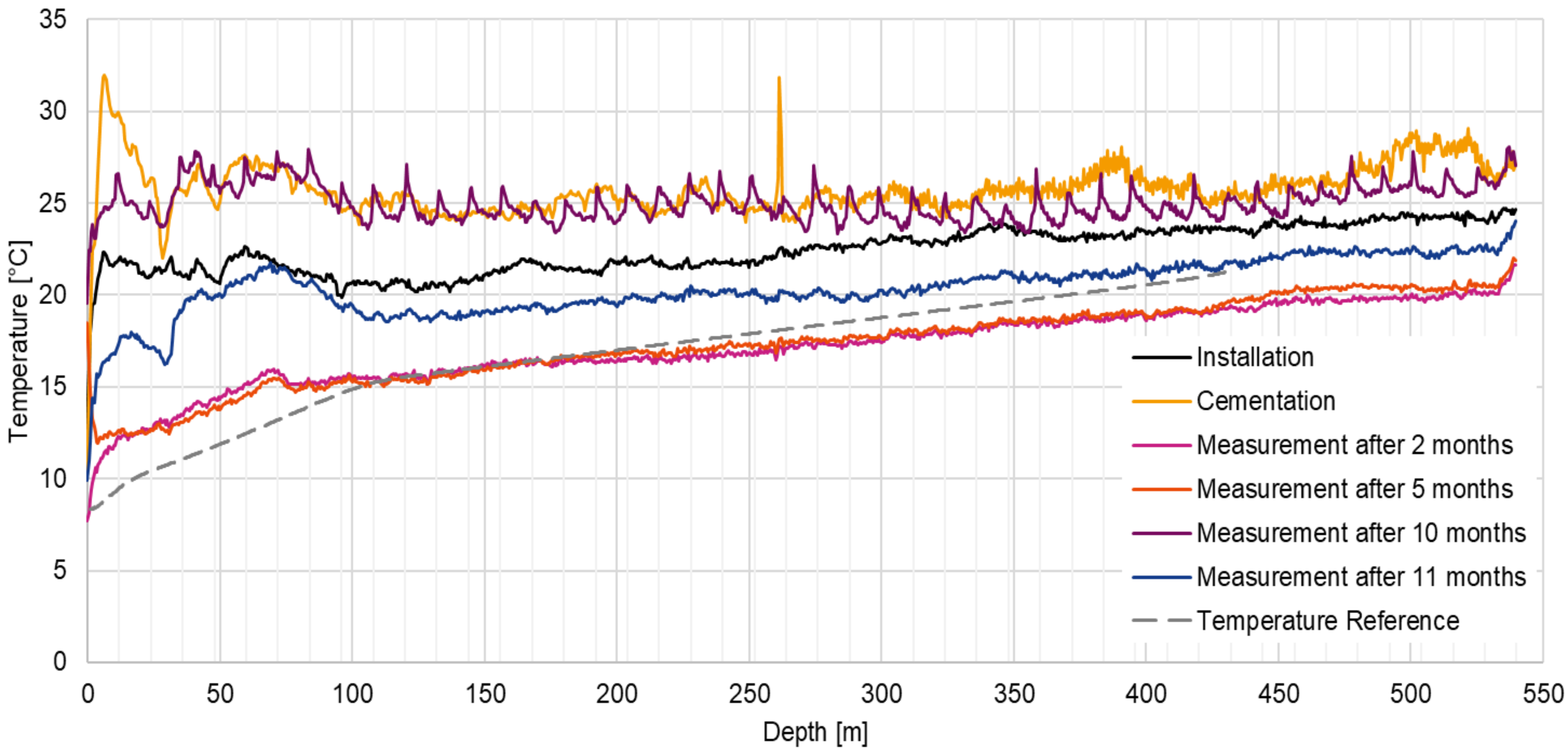
Installation of the sensing cables



- Strain and temperature sensing cables were attached to the borehole casing
- Positioning was fixed by clamping the cables on the centralizers
- A pre-manufactured sealed loop element interconnects the cables at the low end

Results from the measurement campaign

Absolute temperature readings:



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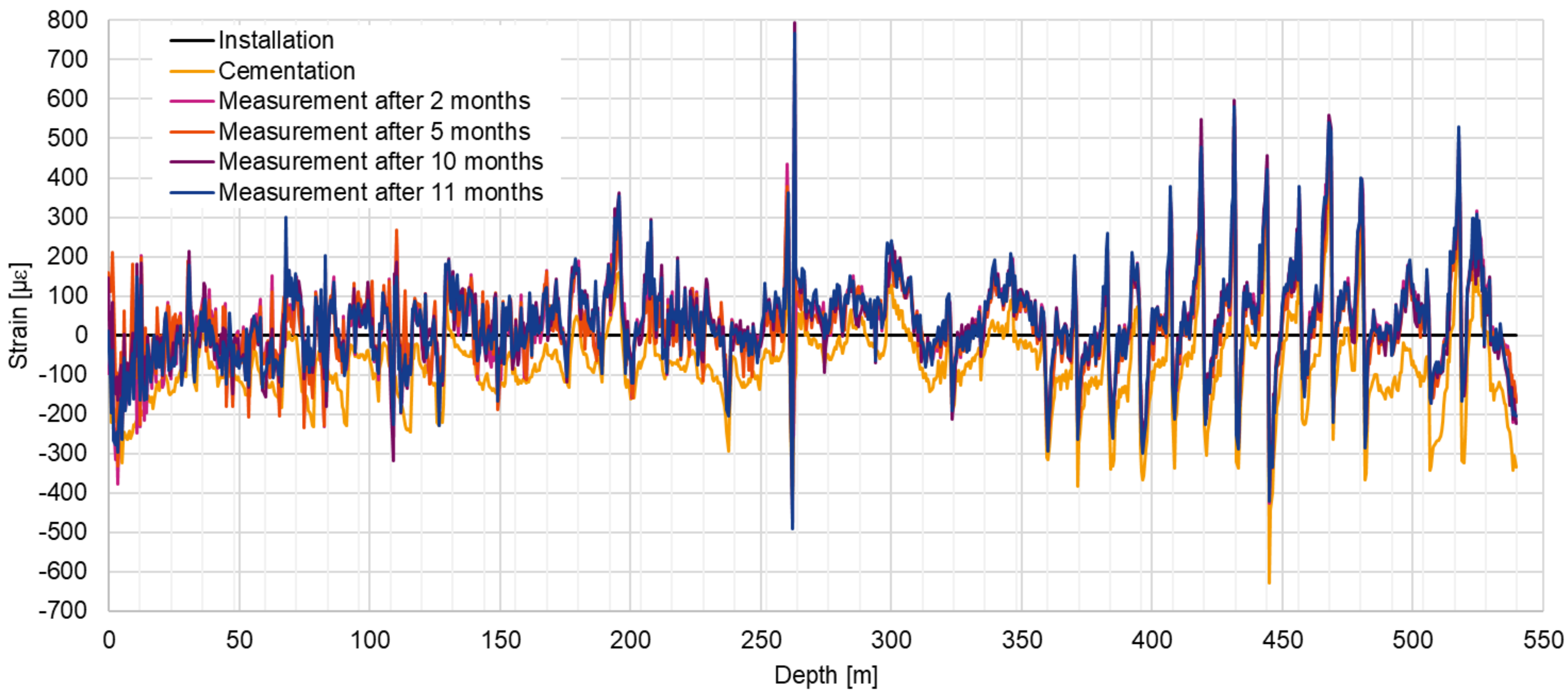
Results from the measurement campaign

Strain readings, baseline and temperature compensated:



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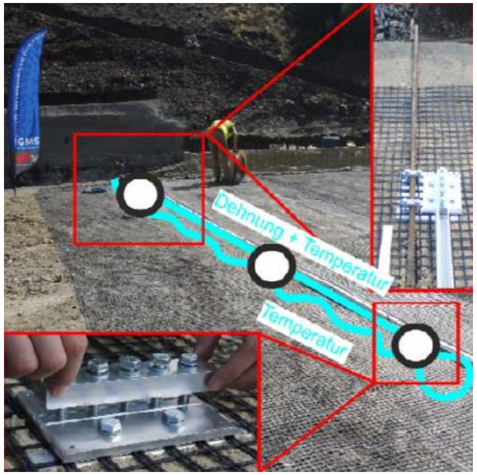
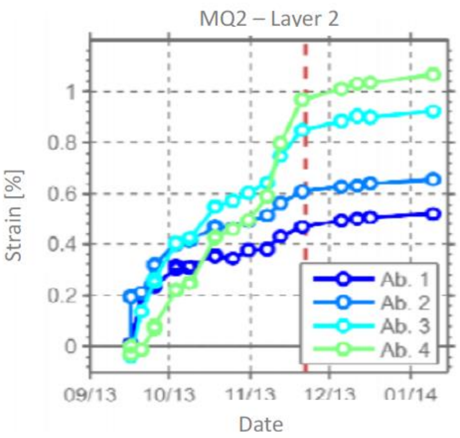
2) In the field: Tunnel construction, Austria



Slope monitoring for landfill construction:

- Sensor installation fixed to geosynthetics
- Load optimization of trucks

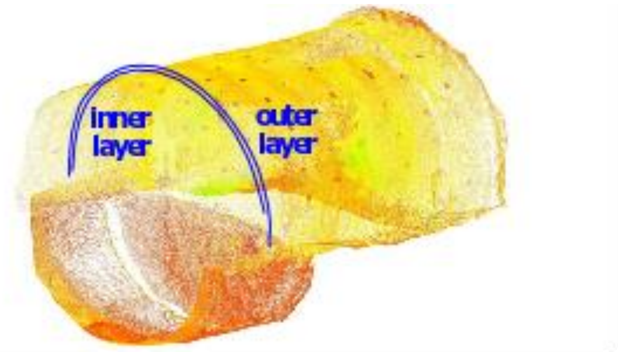
Lienhart et al. "Reinforced Earth Structures at Semmering Base Tunnel–Construction and Monitoring using Fiber Optic Strain Measurements." 10th International Conference on Geosynthetics (10ICG). 2014.

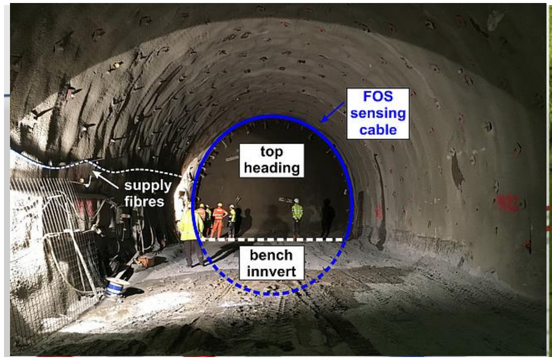


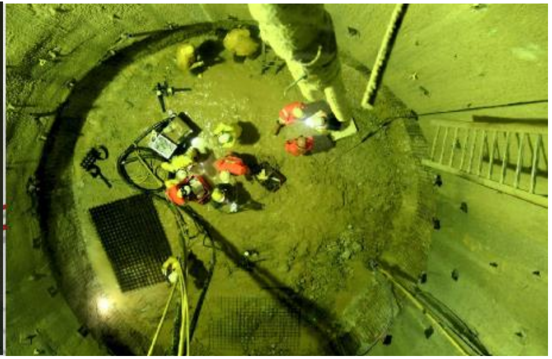
3) In the field: Tunnel monitoring, Austria

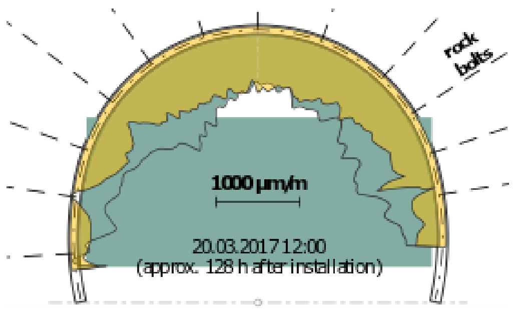
Shape sensing in shotcrete tunnel linings:

- Fiber-optic strain sensing cables installed in cross sections of tunnels and shafts
- Sensor position referenced by laser scans
- Displacement measurements down to cm by DFOS combined with geodetic readings







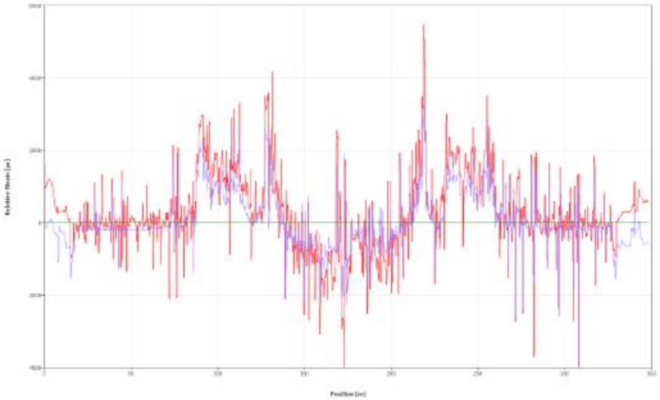


Monsberger, Lienhart: "Distributed fiber optic shape sensing along shotcrete tunnel linings: Methodology, field applications, and monitoring results." Journal of Civil Structural Health Monitoring, 2021.

4) In the field: Sinkhole at railway embankment

Installation of sensing cables

- Subsidence monitoring in sinkhole region
- Long-term measurement over 3 years



Großwig, W. et.al. "Application of distributed Brillouin optical fiber sensor systems in geo-technical monitoring", 6th Asia Pacific Optical Sensors Conference, Shanghai, 10.-14.10.2016

Thank you for you attention!

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