7th International Conference
on Smart Monitoring,
Assessment and Rehabilitation
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UNIVERSITÀ DEGLI STUDI
DI SALERNO

SMAR 2024

Empa
Materials Science and Technology

Distributed Fibre Optic Sensors (DFOS) in Measurements of Rail Strain and Displacements

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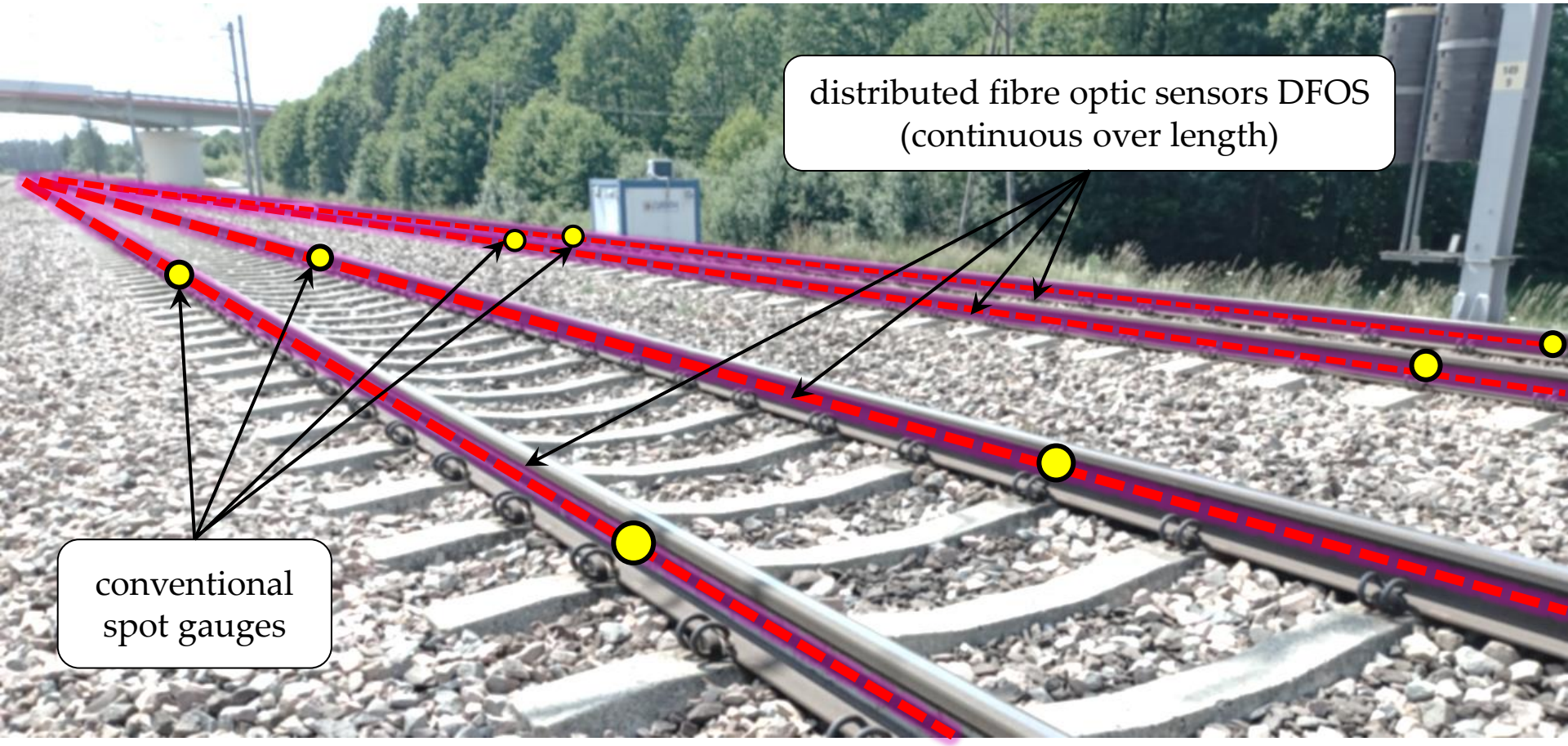
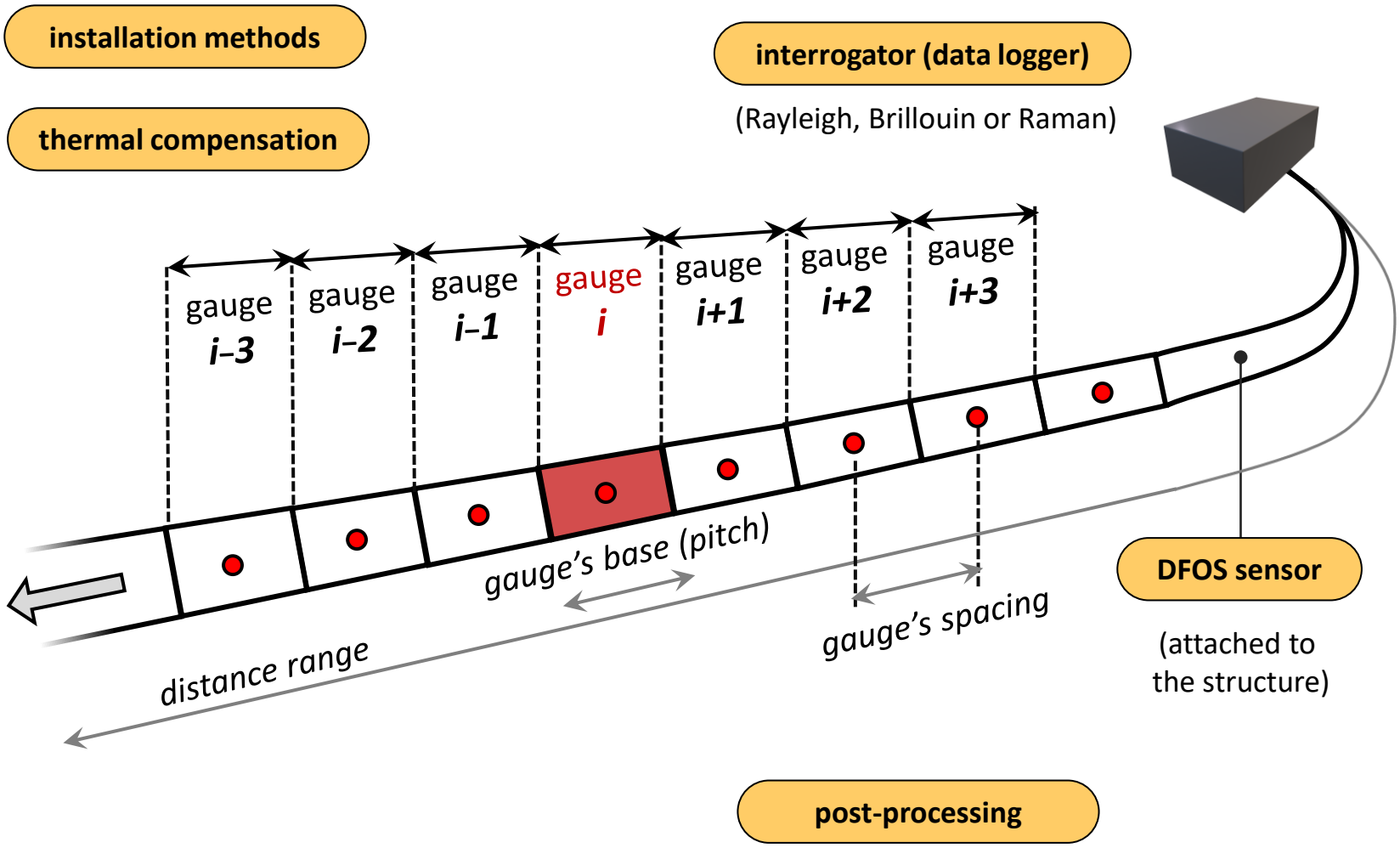
nerve-sensors.com

SHM SYSTEM

PK

AGH

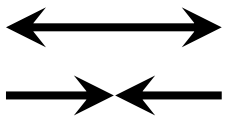

distributed fibre optic sensors DFOS
(continuous over length)
conventional
spot gauges

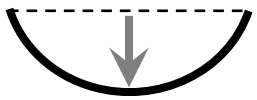

installation methods
thermal compensation
interrogator (data logger)
(Rayleigh, Brillouin or Raman)
gauge i–3
gauge i–2
gauge i–1
gauge i
gauge i+1
gauge i+2
gauge i+3
gauge's base (pitch)
gauge's spacing
distance range
DFOS sensor
(attached to the structure)
post-processing

DEVICE + SENSORS + INSTALLATION

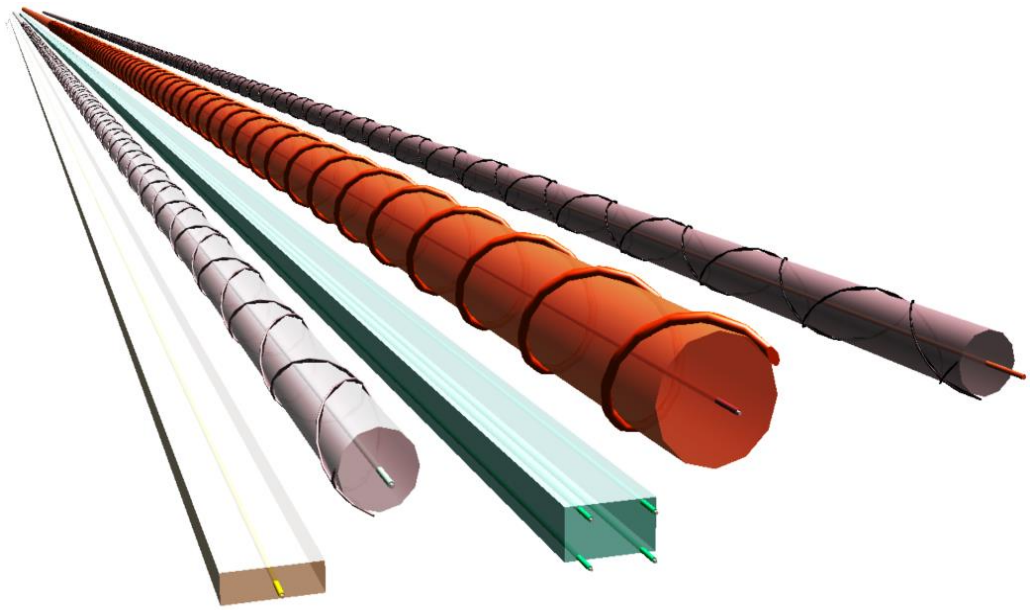
Distributed fibre optic sensing DFOS

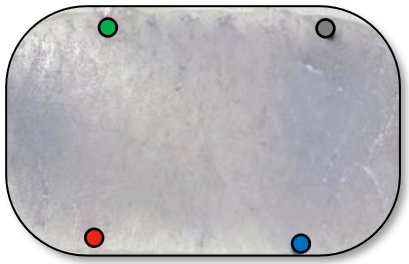
με	°C	mm	nε/s
DSS (strain, crack)	**DTS** (temperature)	**DDS** (displacement)	**DAS** (acoustic)

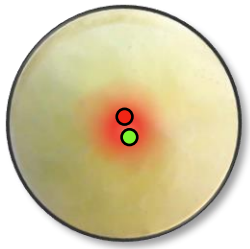




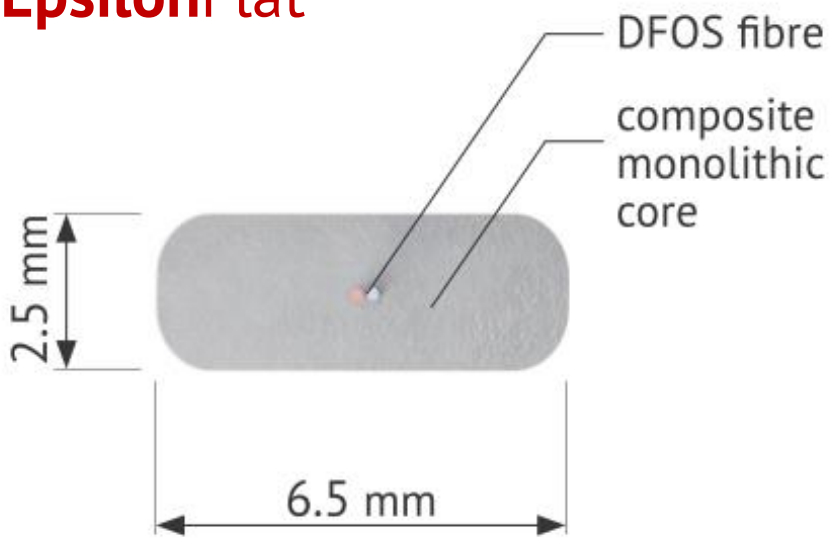

1) diameter
2) shape
3) elasticity (E)
4) maximum strain
5) braid
5) fibres arangement and number
6) bending radius
7) strength / robustness
8) mechanical and thermal resistance





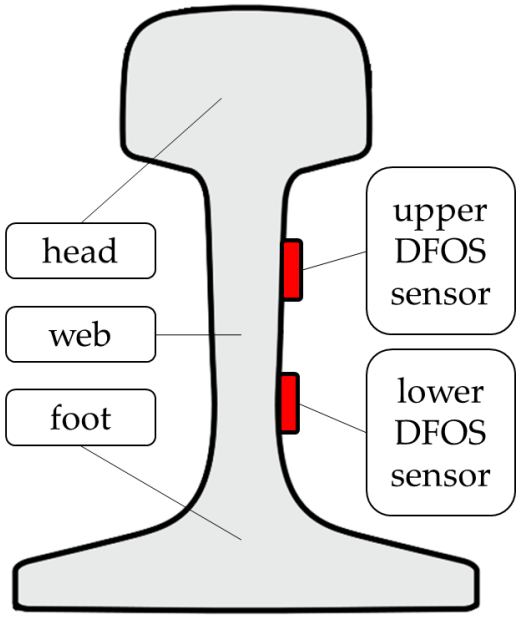


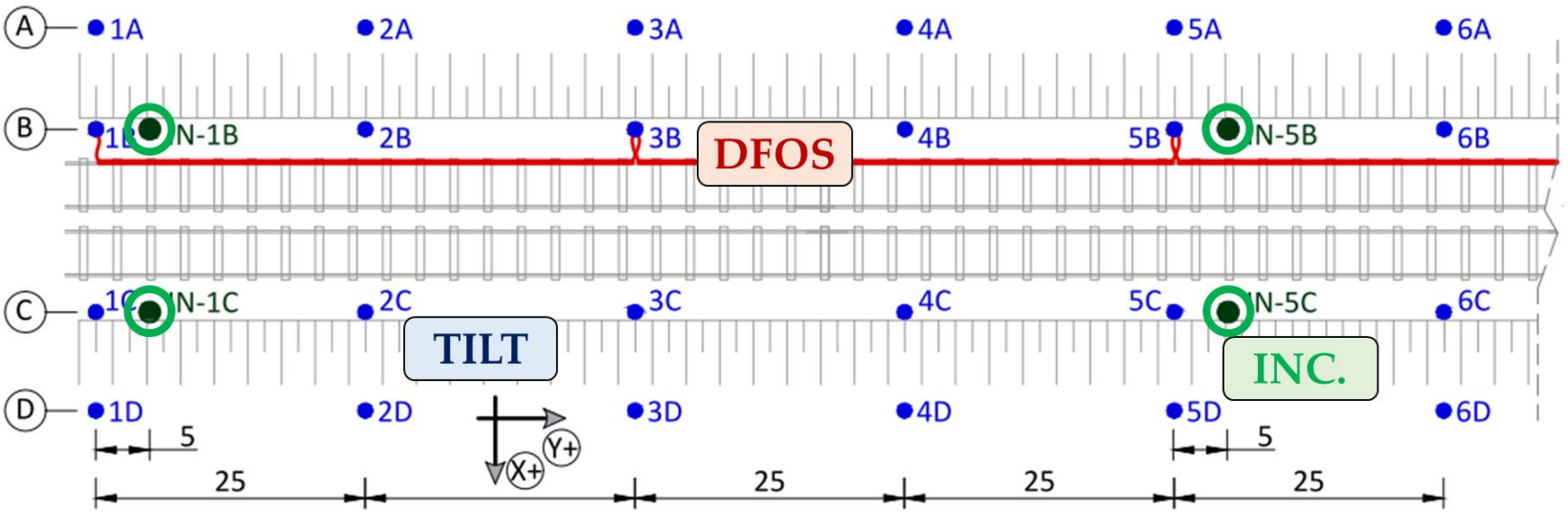
EpsilonFlat

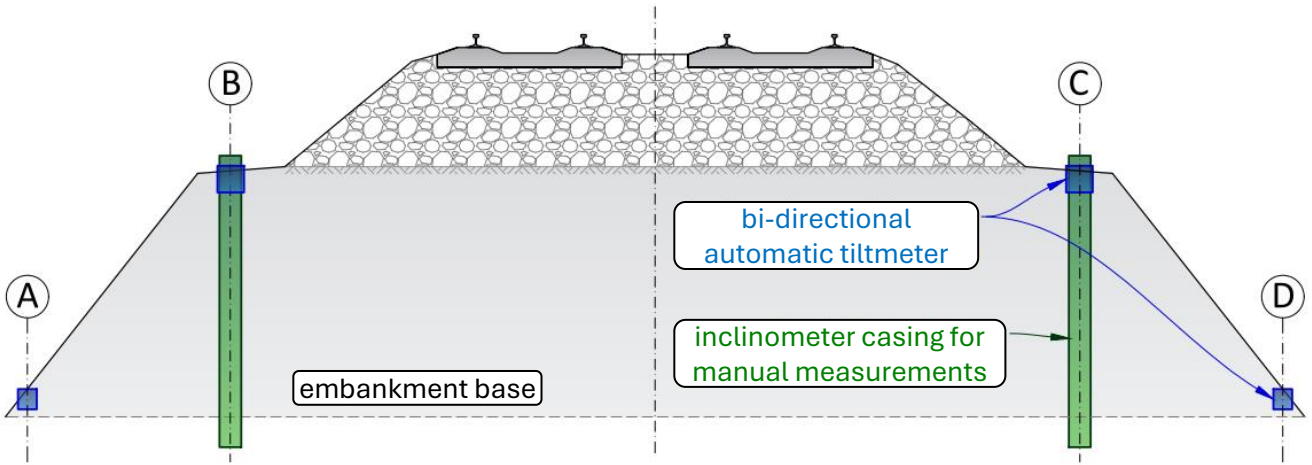


Railway project
in Poland

- strains, stress, temperatures, curvatures, and shape
- more than **2,200 m** of sensing path
- three scatterings: Rayleigh, Brillouin, and Raman
- five independent optical devices
- short-term load tests and long-term monitoring
- static and dynamic readings
- DFOS supported by automatic inclinometer system





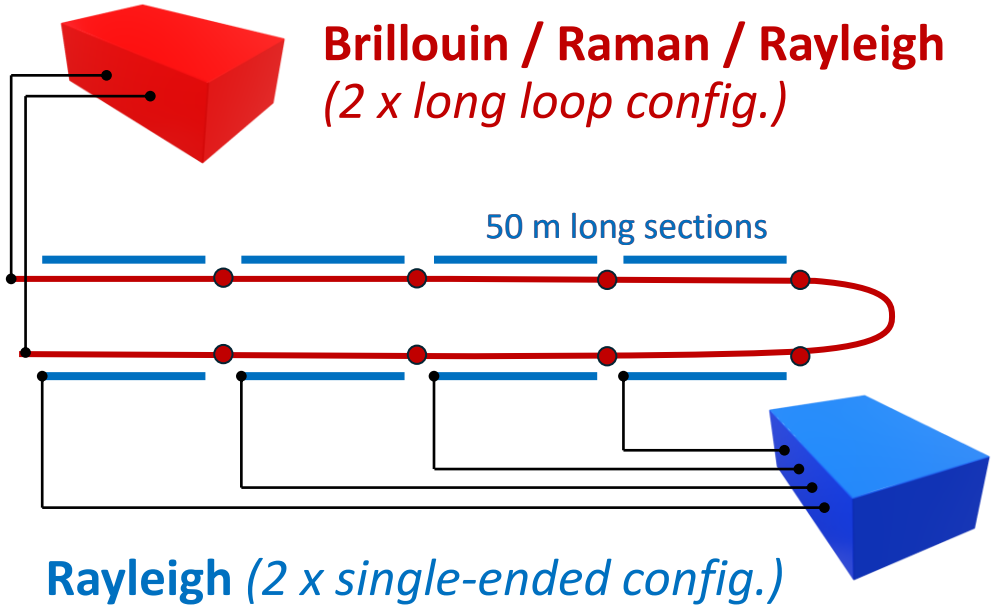


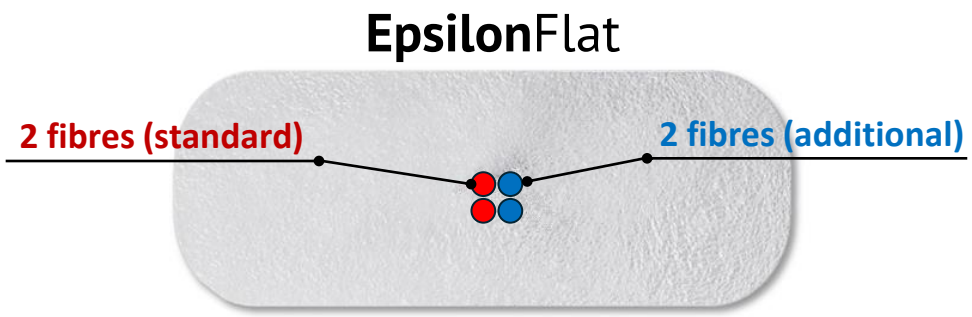
periodical DFOS & inclinometer sessions

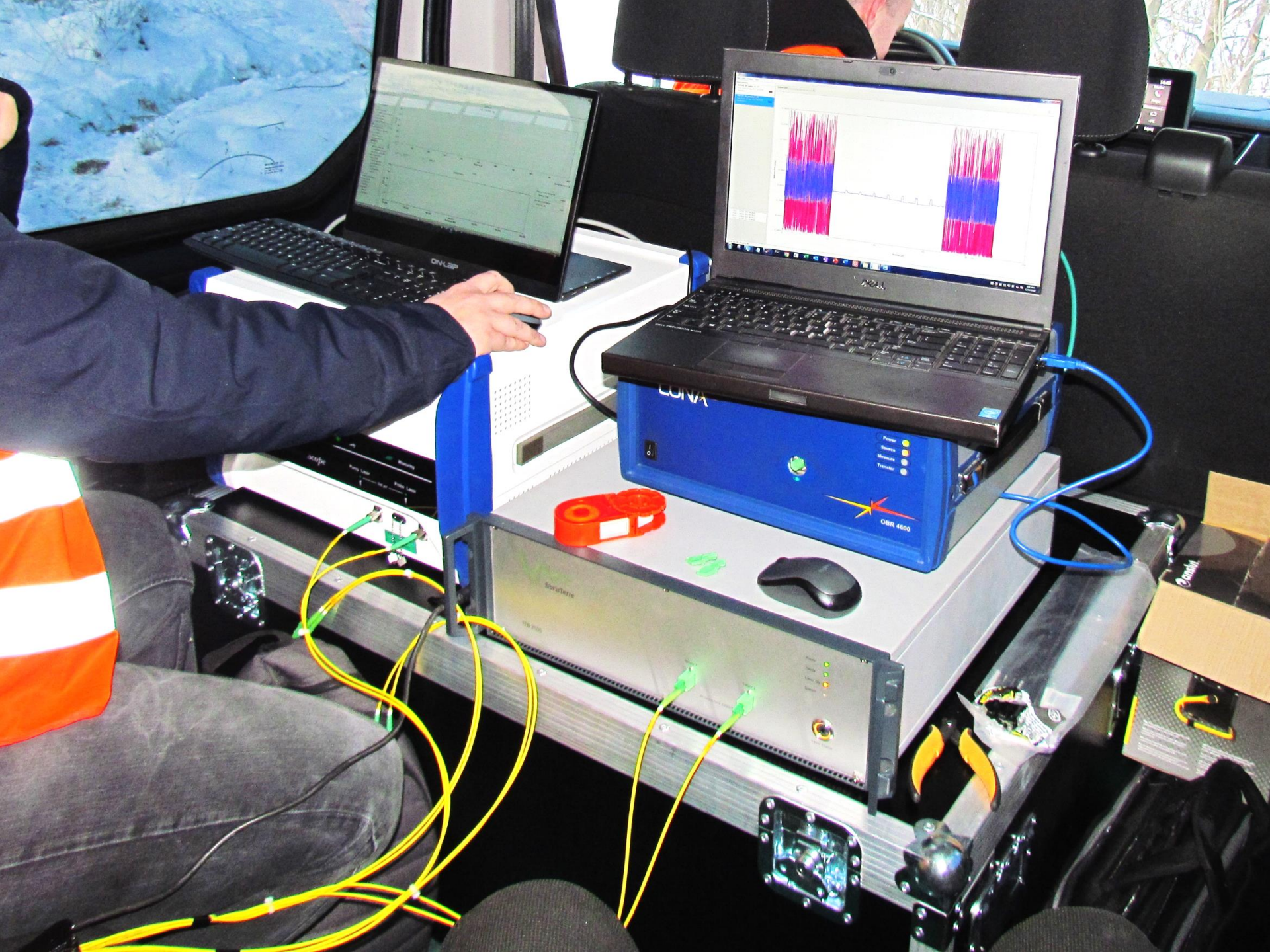
+

automatic tiltmeter system

Installation

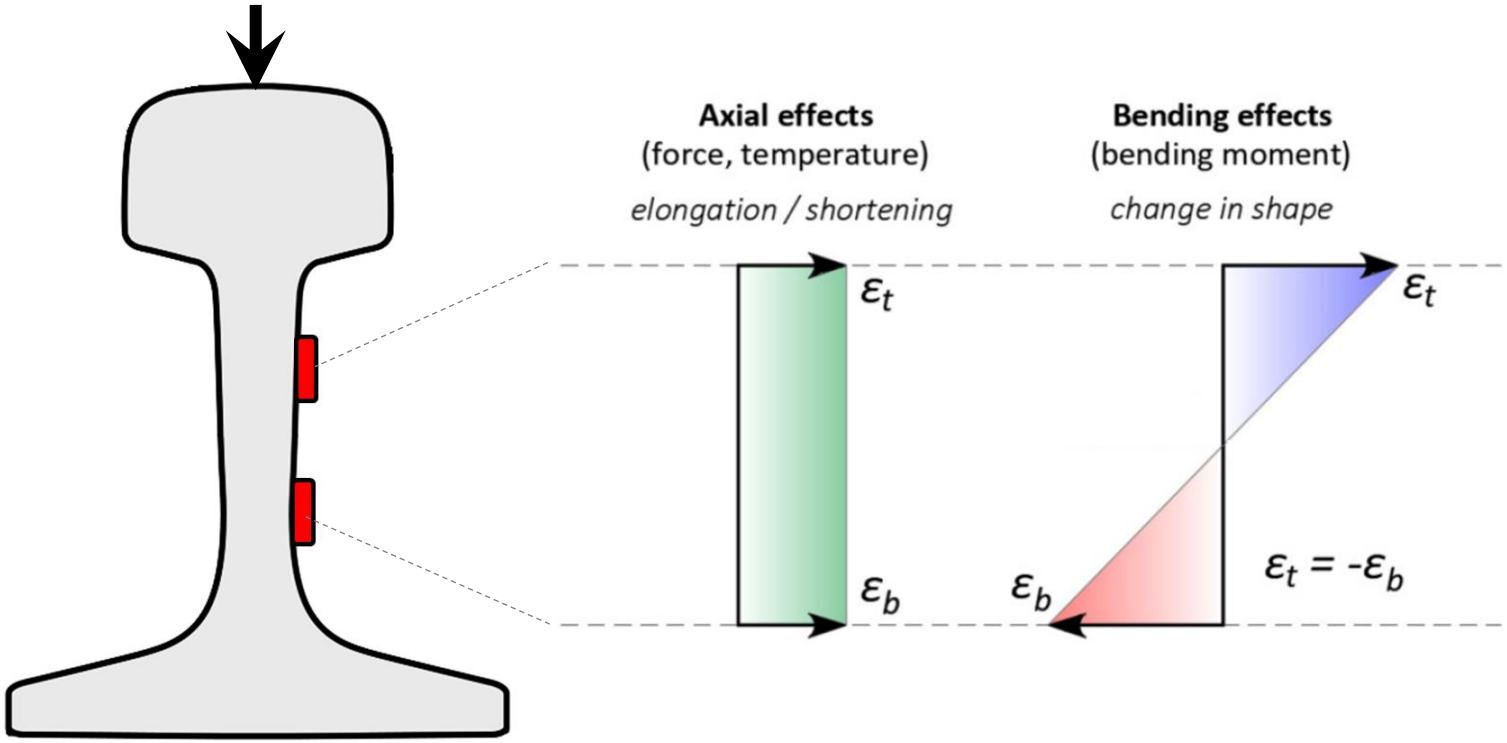

Brillouin / Raman / Rayleigh
(2 x long loop config.)
50 m long sections
Rayleigh (2 x single-ended config.)


EpsilonFlat
2 fibres (standard)
2 fibres (additional)

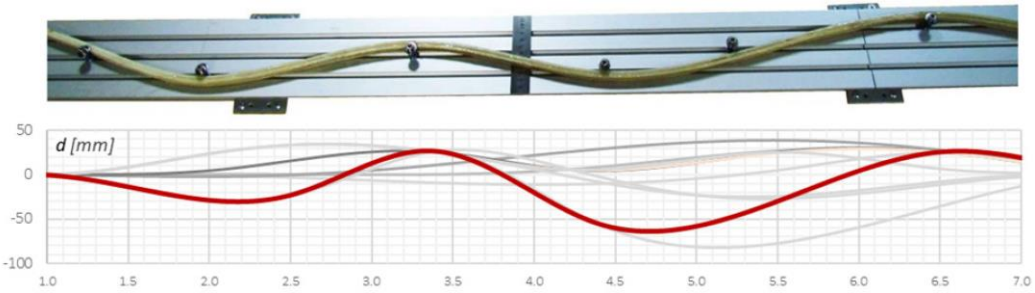

LUNA
OBR 4600

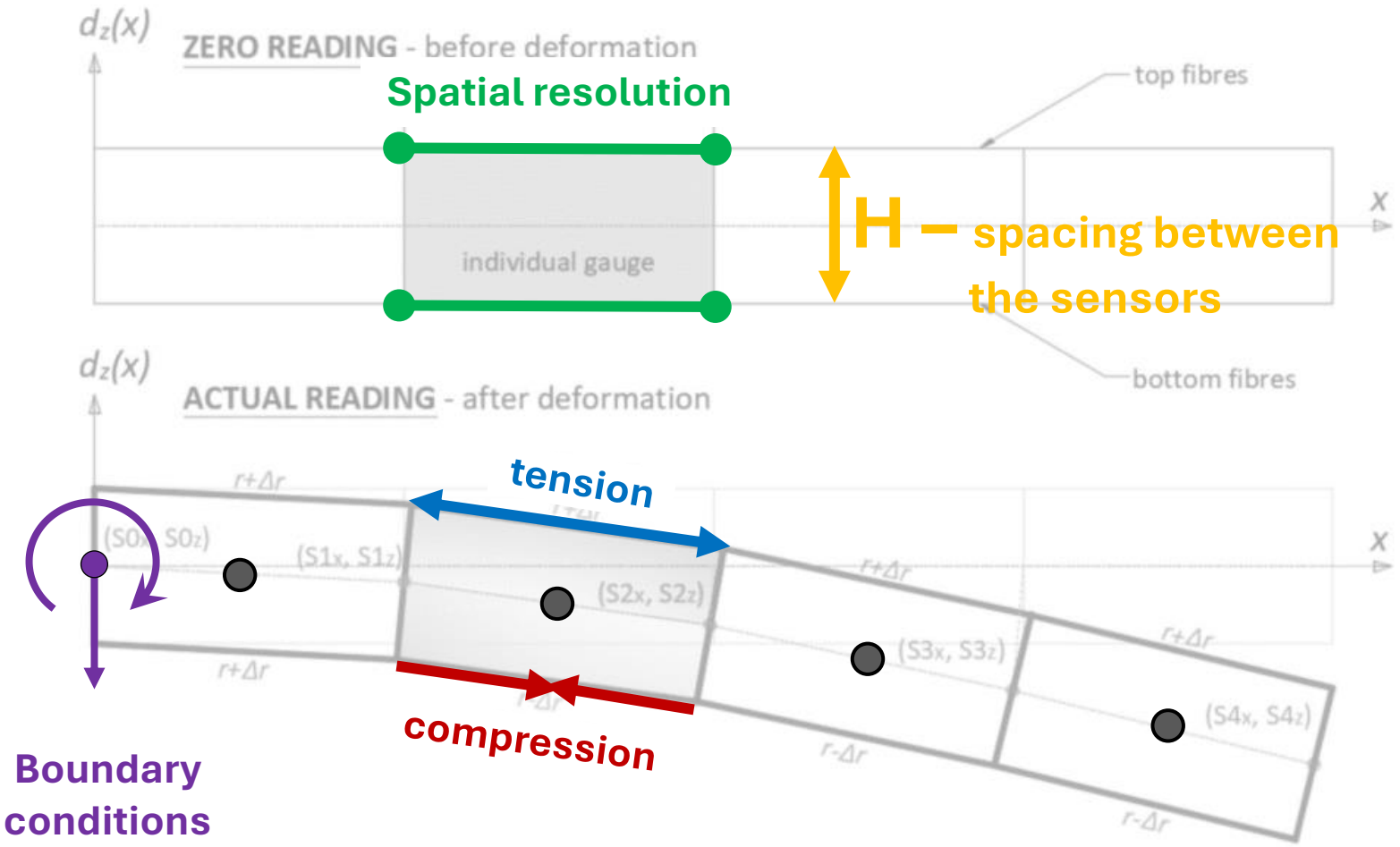
Goals & challanges

160 km/h → 250 km/h

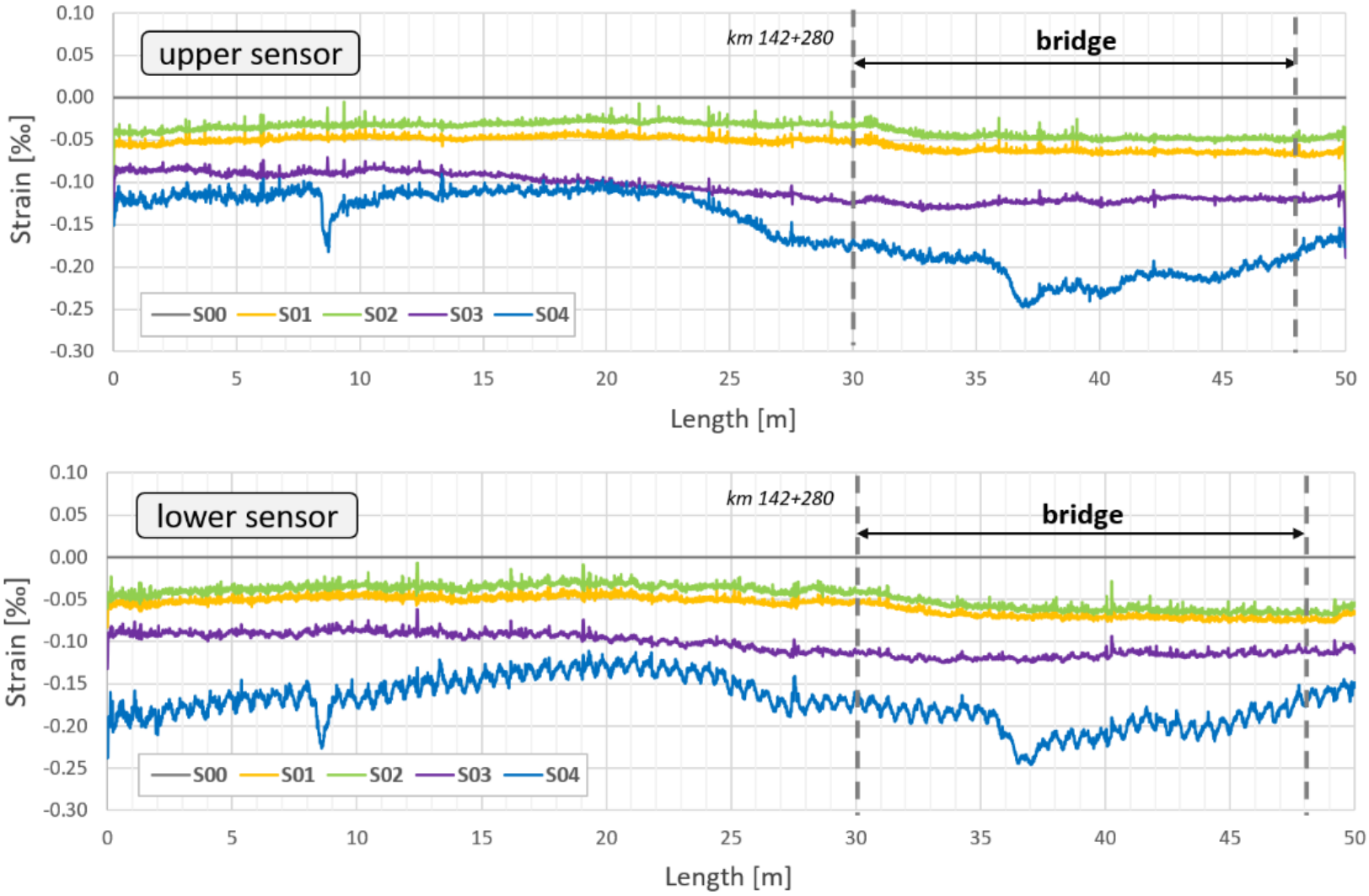


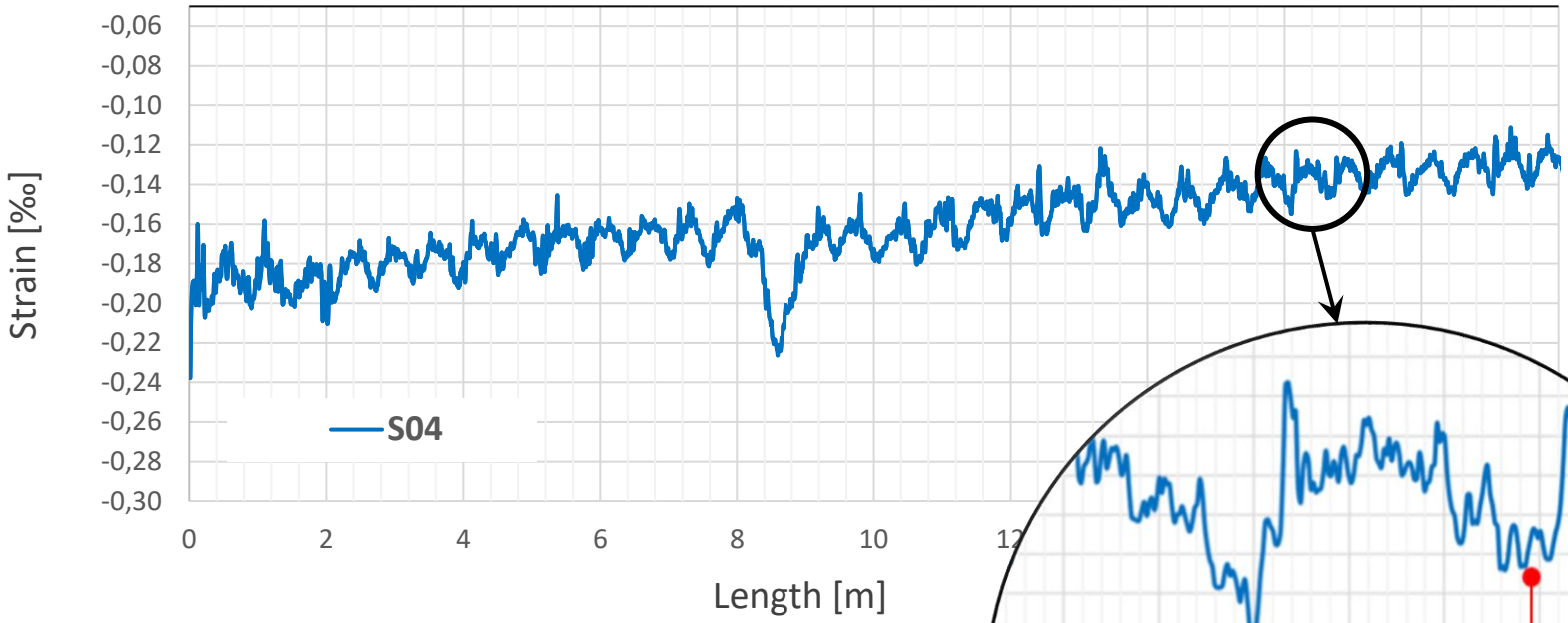
3DSensor
shape sensing

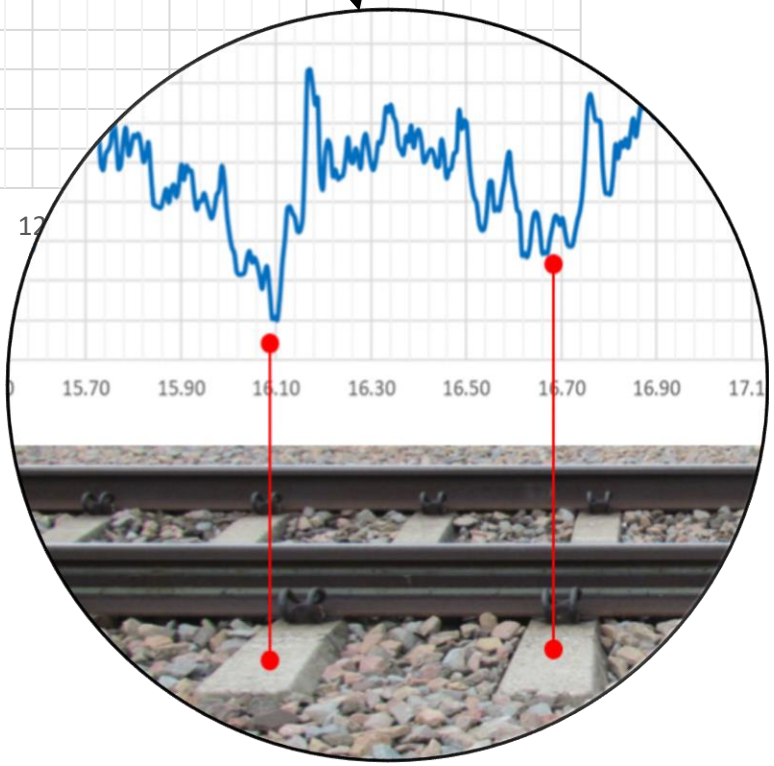


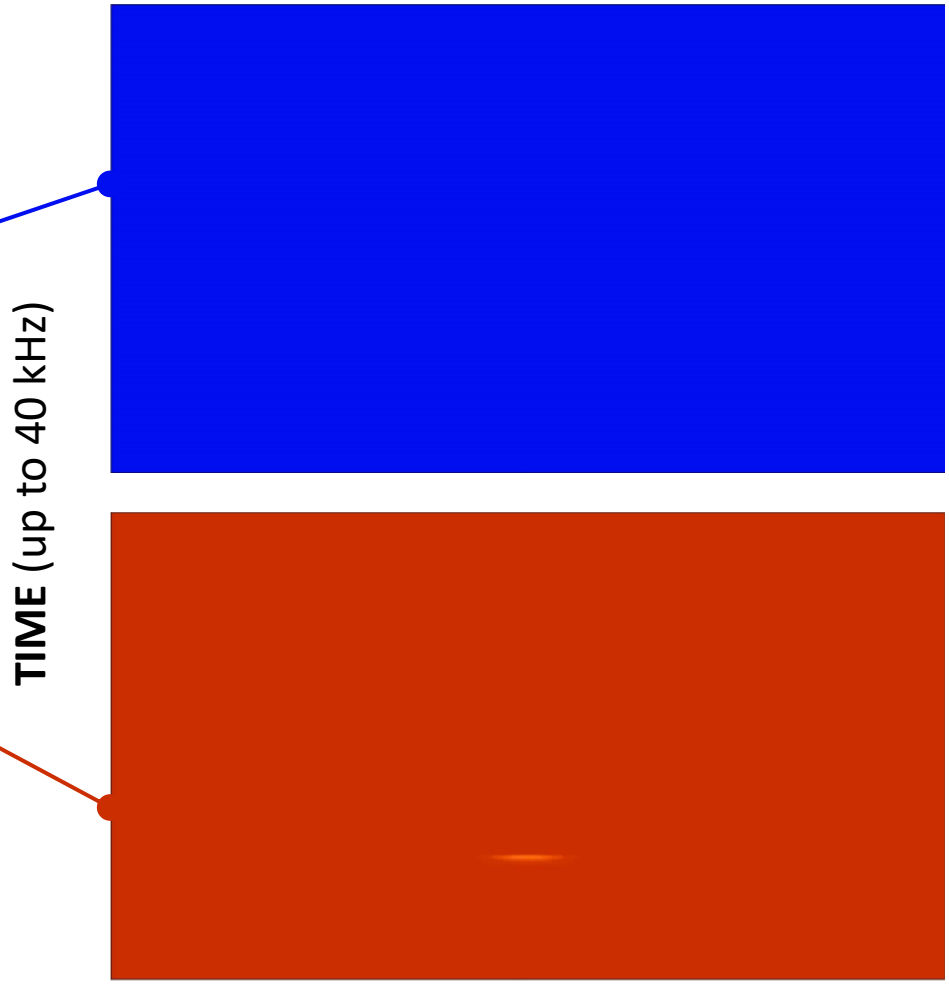

$d_z(x)$
ZERO READING - before deformation
Spatial resolution
top fibres
individual gauge
H – spacing between the sensors
bottom fibres
X
$d_z(x)$
ACTUAL READING - after deformation
tension
compression
Boundary conditions
r+Δr
r-Δr
(S0x, S0z)
(S1x, S1z)
(S2x, S2z)
(S3x, S3z)
(S4x, S4z)

Example results

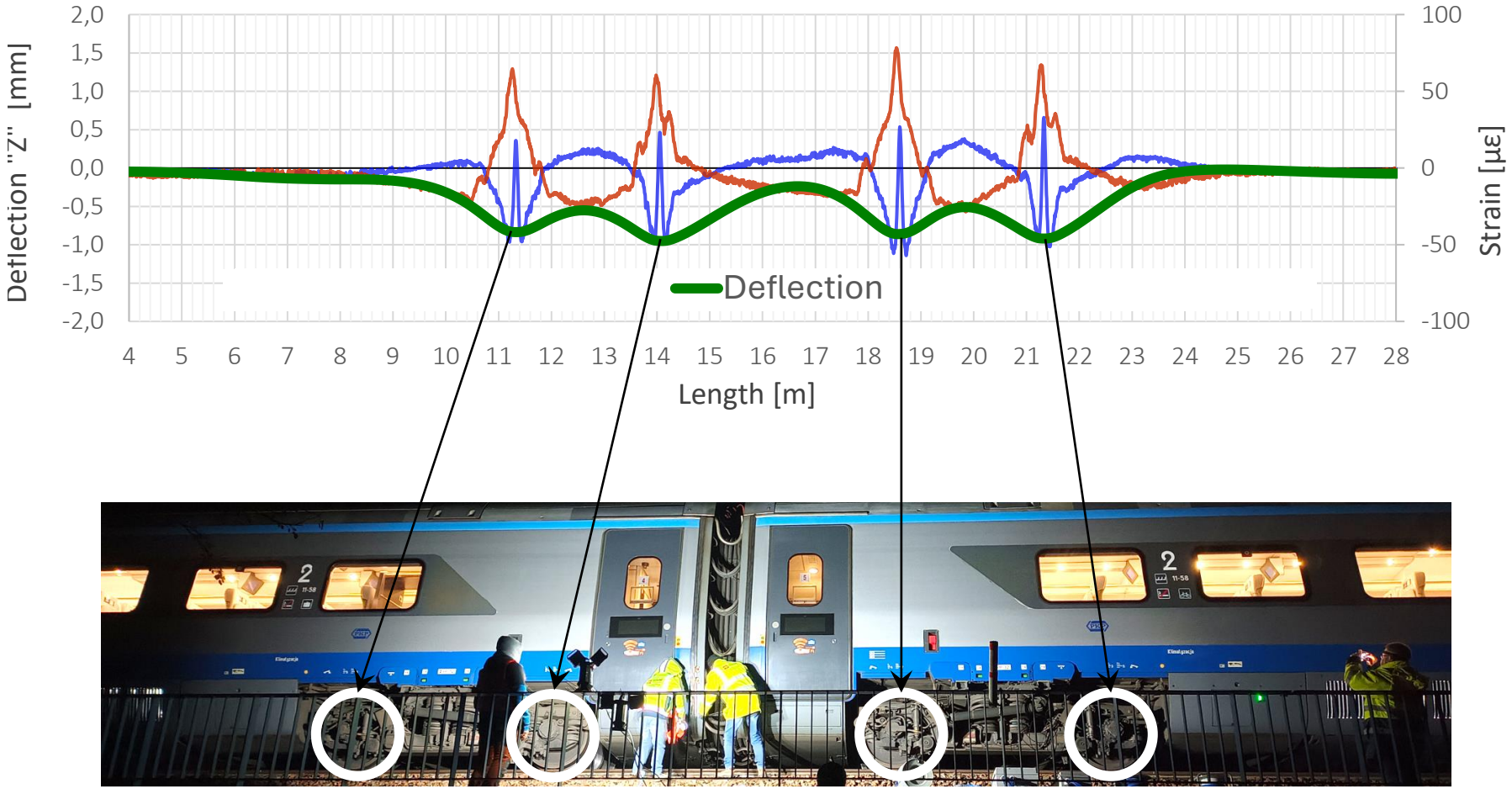

upper sensor
km 142+280
bridge
Strain [‰]
0.10
0.05
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
S00
S01
S02
S03
S04
0
5
10
15
20
25
30
35
40
45
50
Length [m]
lower sensor
km 142+280
bridge
Strain [‰]
Length [m]


Strain [‰]
-0,06
-0,08
-0,10
-0,12
-0,14
-0,16
-0,18
-0,20
-0,22
-0,24
-0,26
-0,28
-0,30
0
2
4
6
8
10
S04
Length [m]


15.70
15.90
16.10
16.30
16.50
16.70
16.90

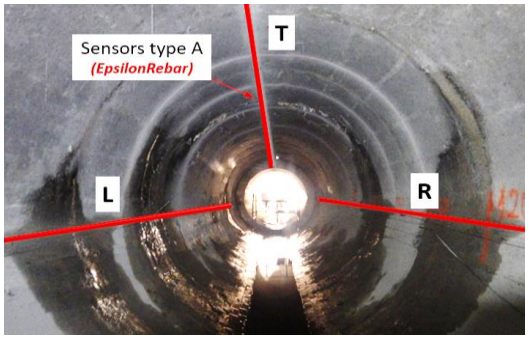

TIME (up to 40 kHz)
DISTANCE (up to 150 km)


2


Deflection "Z" [mm]
2,0
1,5
1,0
0,5
0,0
-0,5
-1,0
-1,5
-2,0
100
50
0
-50
-100
Strain [με]
Deflection
4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28
Length [m]

Summary

Summary



Thank you!