New Concepts and Applications for geodetical Monitoring with Fibreoptic Sensing (FOS)

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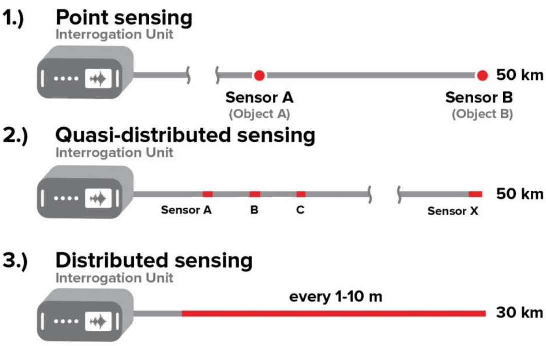
1. Theoretical Background

In telecommunications fibre optics are used since 1969. By improving the technology it became possible to use it for further applications. In the field of sensing technology fibre optic sensors are known since the 1980s and have recently become optimized for engineering geodesy.
Due to the state of art parameters like material temperature, ambient air temperature, acoustics and alternations of length can be determined. A big advantage of fibreoptic sensing is, that there is no need of a power supply or a processor unit on site. Furthermore high precision, high resolution, static and dynamic measurement data is delivered.
Dr.Döller ZT GmbH is doing fibre optic sensing since 2010 focused on railway infrastructure observation. Several FO sensing projects (bridges, tunnels) have been realized since that.

FOS – Systems

Figure 1: FOS-Systems



Ad 1.) Point sensors are single Fibre-Bragg-Grating Sensors. This sensor has an accuracy of a few micrometers which is sensitive for elongation and compression. A few of these sensors can be connected in line and work parallel.
Ad 2.) Several Fibre-Bragg-Grating Sensors are implemented directly in a single mode fibre. The functionality is identical to using single Fibre-Bragg-Grating Sensors.
Ad 3.) The distributed sensing is not based on bragg-grating sensors but the singlemode fibre and its typical characteristics itself, which means the change of the light transmission and back reflection on the fibre.
Advantages:

- Insensitivity to electromagnetic interferences
- Sensors can be integrated in the compound
- No power supply and data connection needed at the site (sensors are supplied by laserlight transmitted from the fibre)
- High resolution and high accuracy
- Long distances between sensor and measuring unit are possible (up to 50 km depending on the sensing system)
- On one single fibre many Fibre-Bragg-Grating sensors can be arranged
- Long-term stability and corrosion resistance

2. History of applications

2.1. Structural Health Monitoring with Fibre Optic Sensing: „ÖBB-Bridge Großhaslau (Lower Austria)“

The bridge in Großhaslau has been built in 2009 and 2010 in the course of the bypass Großhaslau. It is situated between Martinsberg and Schwarzenau. This bridge is one of eight bridges of the bypass project “B36 bypass Großhaslau” of the federal state Lower Austria.

Figure 2: ÖBB-Bridge Großhaslau (Lower Austria)

During the construction progress in 2010 cracks have been observed, which led to surveys from summer to spring 2010. The bridge became monitored in behalf of the ÖBB Infrastructure company (Krems) and the settling could be stopped by structural engineering methods.

Figure 3: Crack in the bridge

After these activities it was decided to use a long-term, permanent monitoring system for the further observation.

So the object was suitable for using fibre optic sensing technique (FOS). It should serve as a permanent test site which can be controlled easily by terrestrial measurements.

Primarily the behaviour of the bridge under variation of load should be observed.

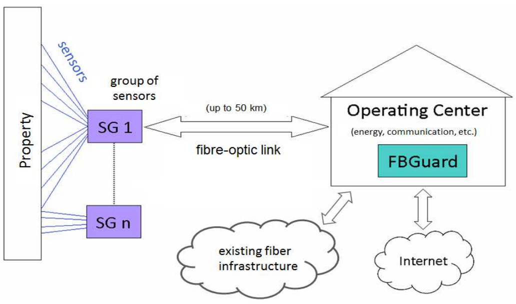


Figure 4: General system configuration

The complete FOS (Fibre Optic Sensing) system includes 16 pcs. sensors, 10 pcs. to measure small movements on bridge vs. basement, 2 pcs. fibre bragg grating-strains sensor to measure vertical movement of the rails vs. the ground and 4 pcs. FOS-temperature sensors for temperature compensation. The interrogator, FBGuard from company Safibra, is placed in the railway station Großglobnitz. An additional FO-cable was installed between the railway station and the bridge to link the interrogator and the FO sensors.

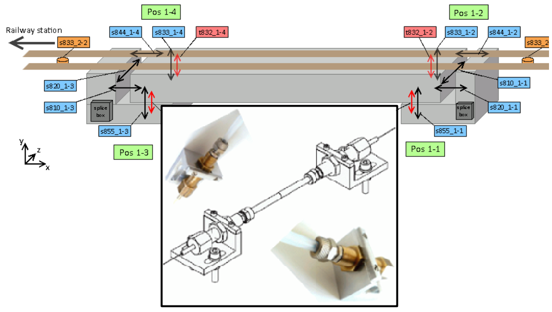
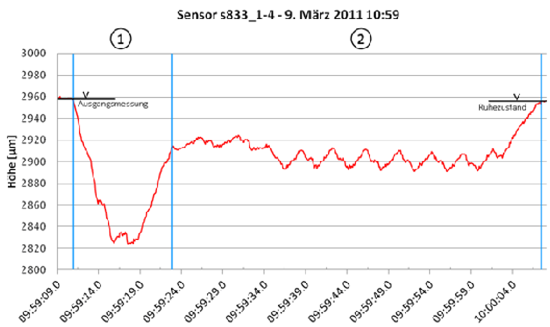


Figure 5: Overview of bridge sensors and L-bracket strain sensors

Figure 6:Interogation unit FBGuard

Figure 7 and Figure 8: Strain sensors and Rail-movement sensors installed at the bridge and rail



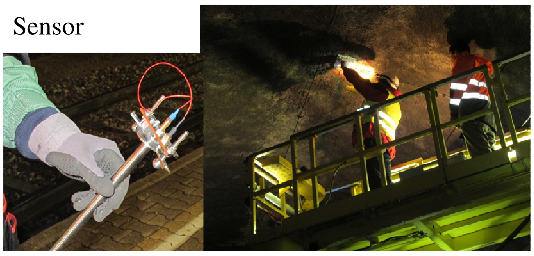
① traction engine
② load relieving = empty wagon

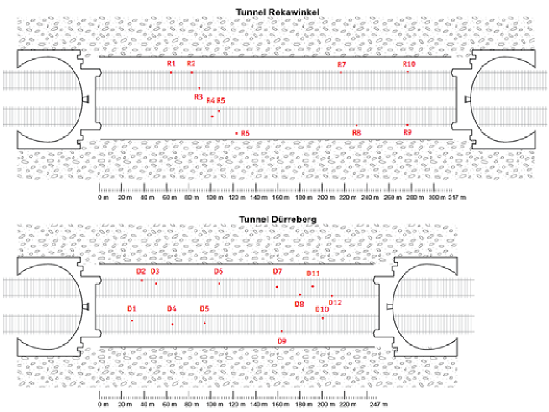
2.2. Permanent surveying „Tunnel Rekawinkel and Dürreberg“

In these two tunnels FBG-Sensors were installed on the inner layer to observe movements relative to the basement.

kleiner Dürrebergtunnel (green)
Rekawinkeltunnel (blue)

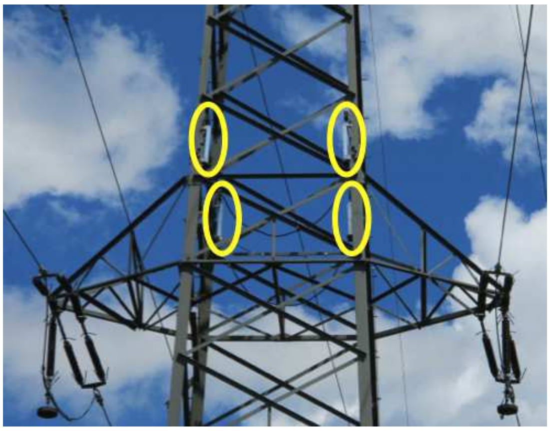
Sensor

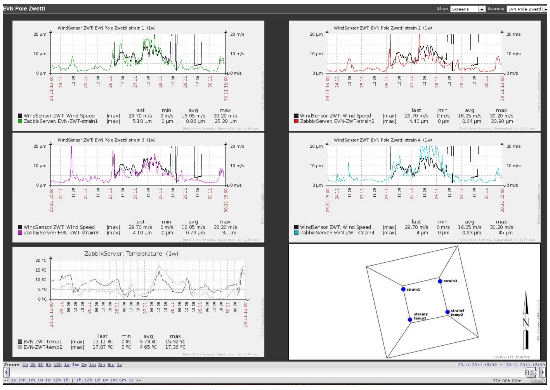




2.3. Permanent surveying „Pylon“

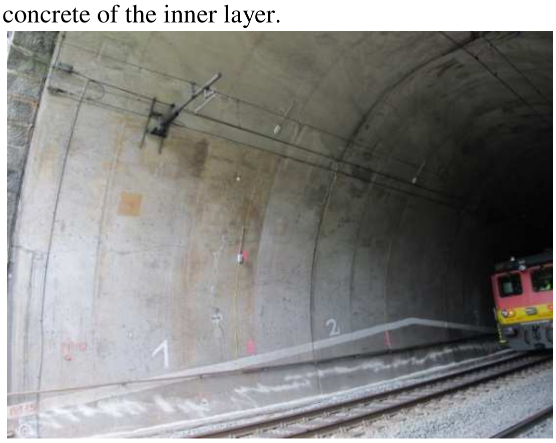
This observed pylon had an asymmetric load of cables. Especially iceloads in the wintertime produce extra forces which have to be seduced. Therefore four FBG-strainsensors had been installed at the corner irons to measure strain under different conditions.





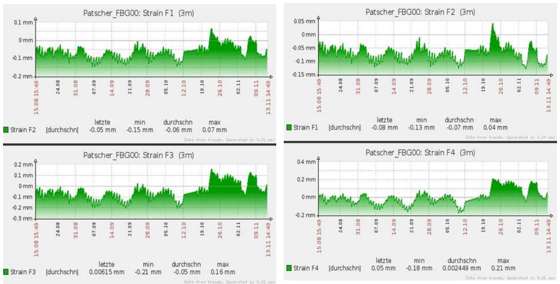
2.4. Tunnels

Crack monitoring in railwaytunnel “Patschertunnel” In this tunnel 10 pcs. FBG-sensors were installed to measure changes of the width of small cracks in the concrete of the inner layer.

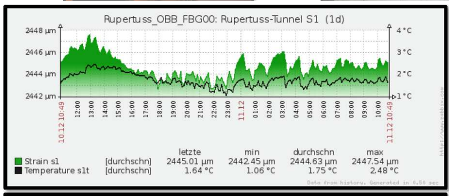


wiring

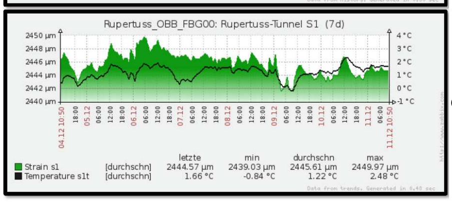
Europe bridge



“Rupertustunnel”



one day

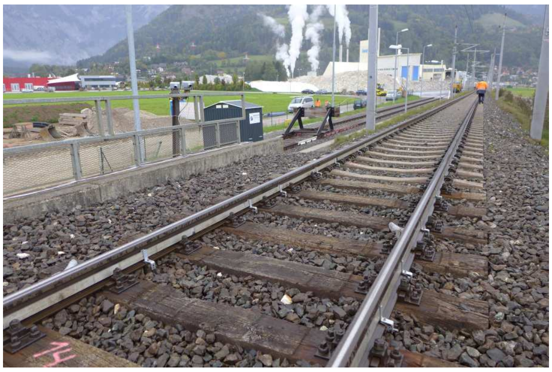


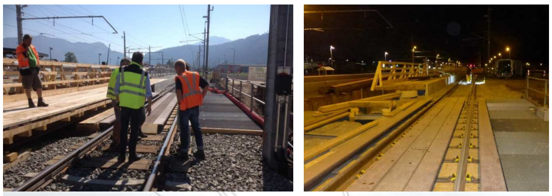
one week

2.5. Railway bridge Liezen

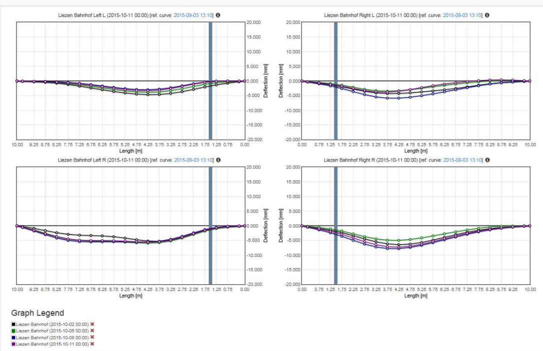
Two different systems, bendline and ObjectSense, were used to measure rail deformation during construction activities on a concrete railway bridge.

Installation



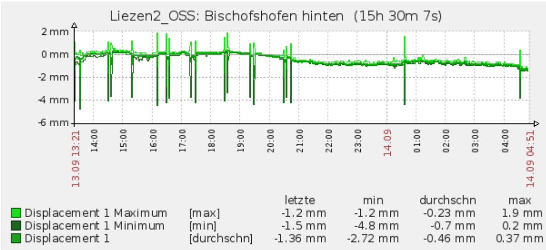


Data visualisation bendline

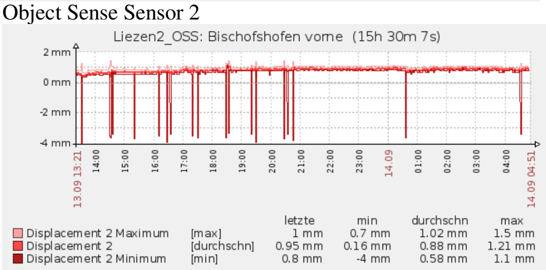


Data visualisation Object Sense

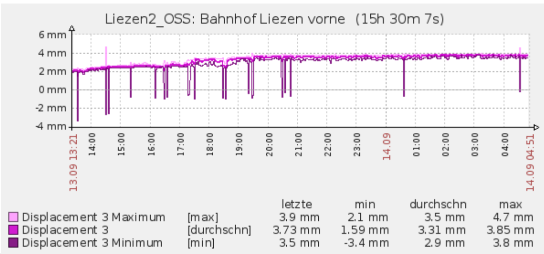
Object Sense Sensor 1



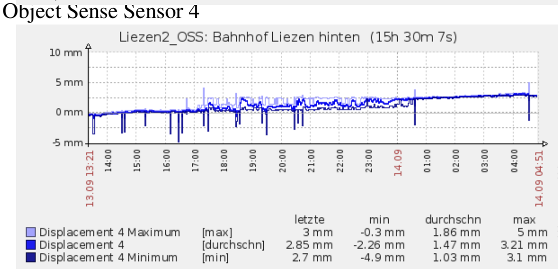
Object Sense Sensor 2



Object Sense Sensor 3



Object Sense Sensor 4



3. R&D activities

Nowadays fibreoptical sensors are used in many tasks like

- Deformation analyses
- Conservation of evidence
- Detection of loads
- Monitoring of times of strain (e.g. train transit)
- Type of load (traction engine, empty or full wagon)
- Change in cracks and clearances
- Temperature measurement

3.1. General conception for Sensor applications at railway infrastructure

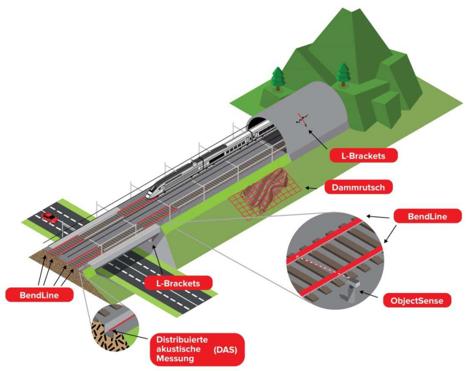


Figure 9: Fibre optic sensor applications at railway infra-structure

3.2. Distributed acoustic sensing on fibre optic cables

In 2012 Dr.Döller ZT and NBG FOSA started to approve the on Rayleigh scattering based distributed acoustic sensing system its ability to monitor special events on railway infrastructures.

Rockfall

Flatspots

Short circuit

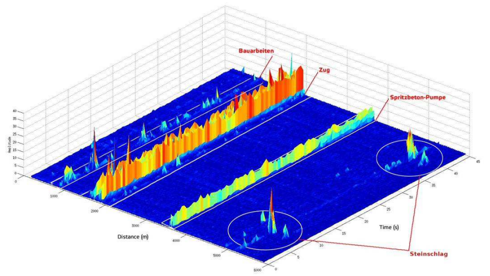
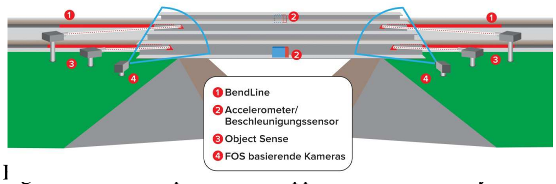


Figure 10: Fibre monitoring data

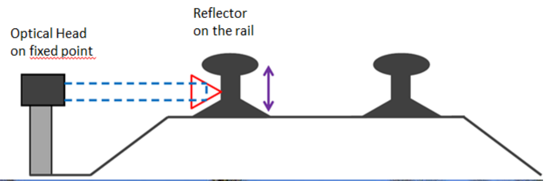
3.3. Project high performance auxiliary bridge (HHB 265)

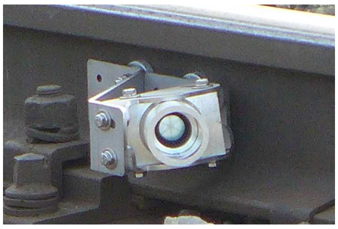


structure

3.4. Object Sense

Principle: Light from the light source is reflected from different points





3.5. Fibre optical Camera

classical Camera:

Model fibre optical camera:
Development of optical cameras powered by two single mode fibres.

4. References

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