BAM Federal Institute for Materials Research and Testing, Berlin

Fiber optic system for monitoring large earth structures

Aleksander Wosniok (BAM)

3 November 2011

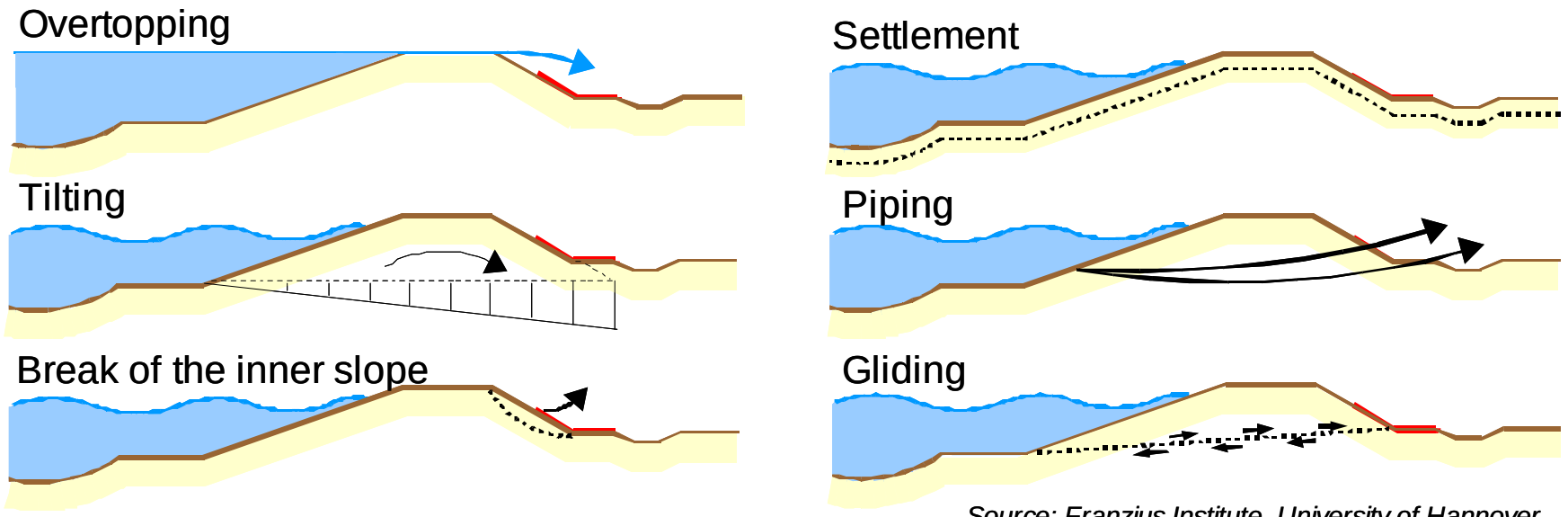
- Motivation
- Components of dams and dikes structural health monitoring systems
- Distributed optical fiber sensors
  - Brillouin system
  - POF-OTDR
- Experimental validation of sensor systems
- Conclusion

Technical safety of geotechnical and civil infrastructure

Nachterstedt, Germany, 18 July 2009

Cologne, Germany, 3 March 2009

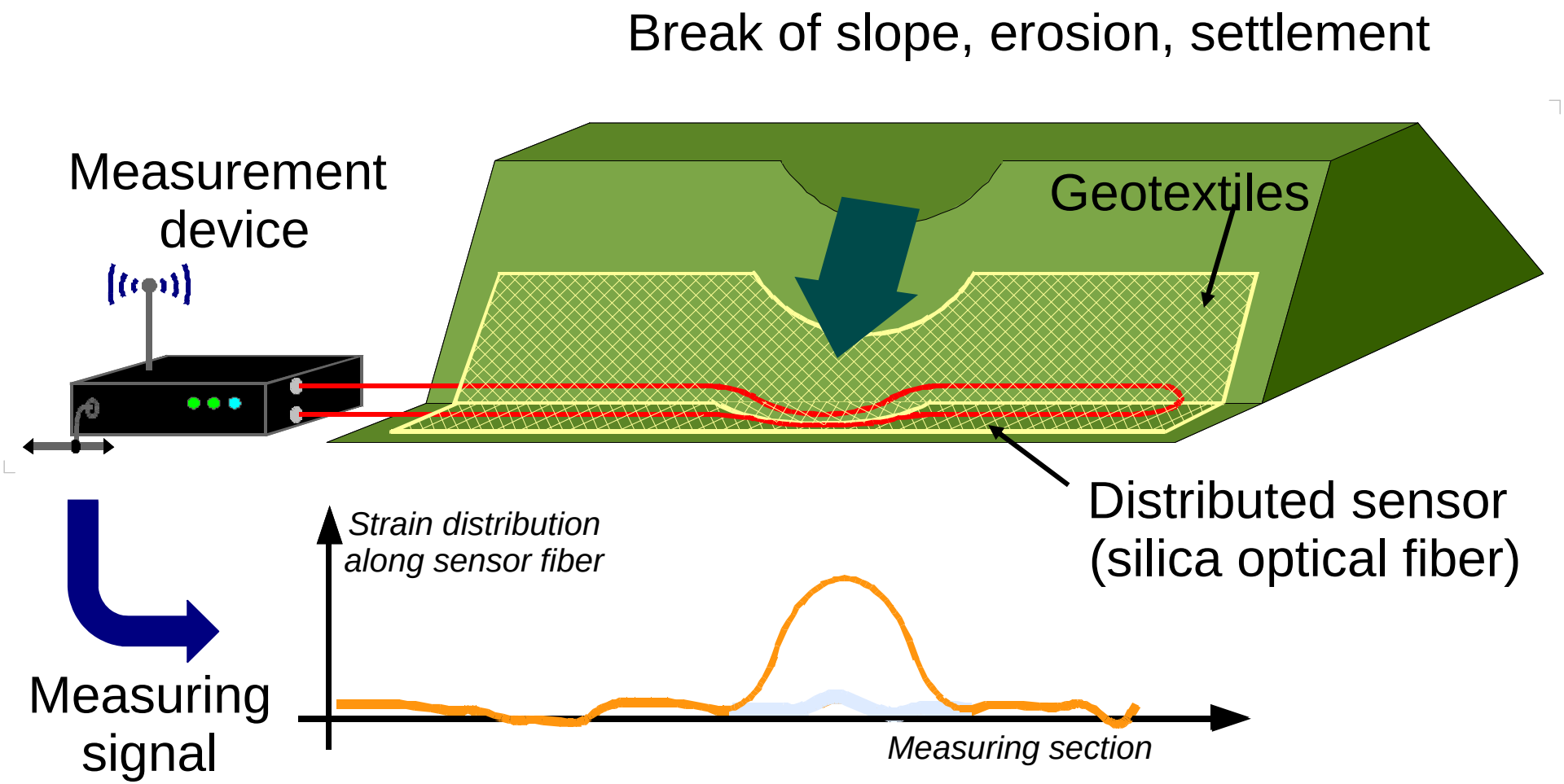
Some important causes of dam and dike failures:



Source: Franzius Institute, University of Hannover

Critical zone: *Landside of the dike*

Monitoring task: *Spatially resolved strain and temperature detection*

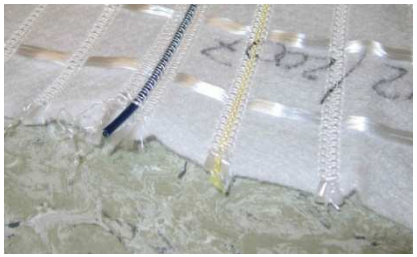

Break of slope, erosion, settlement
Measurement device
Geotextiles
Distributed sensor (silica optical fiber)
Strain distribution along sensor fiber
Measuring signal
Measuring section

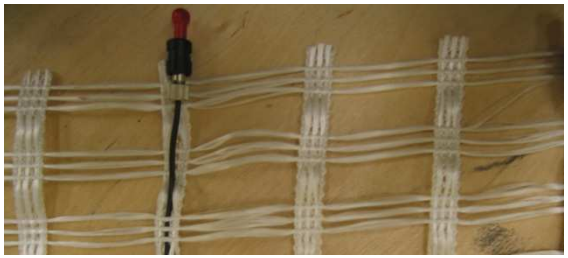
Components of dams and dikes structural health monitoring systems

Geosynthetics are used to strengthen riverbanks and for reinforcement of road and railway embankments.

<u>New trend:</u> Adaptation of geotextiles and geogrids to the monitoring of ground construction!

Intelligent geosynthetics:

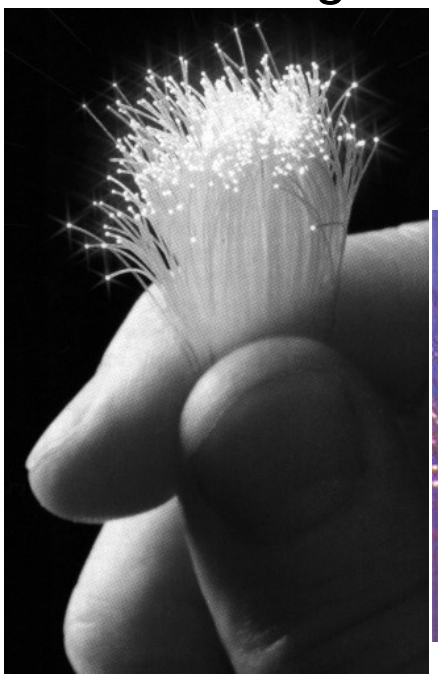


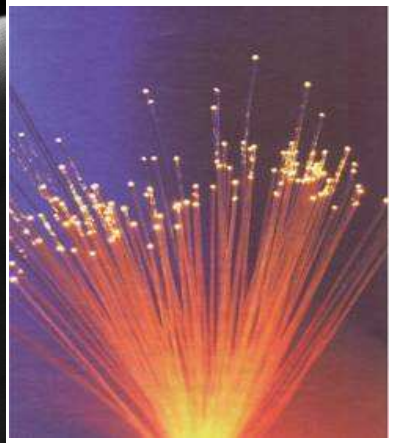


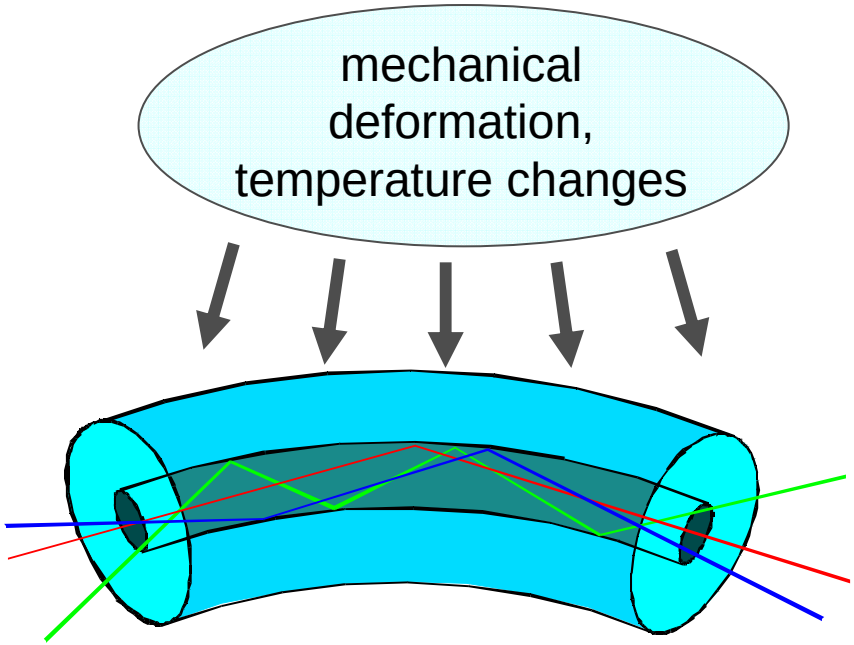
The geomaterials do not lose their original functionality by integrating sensors.

Silica and plastic optical fibers:

Propagation of light followed by the phenomenon of total internal reflection at the border of the fiber's core and cladding.







Fiber optic sensors can be used to measure:

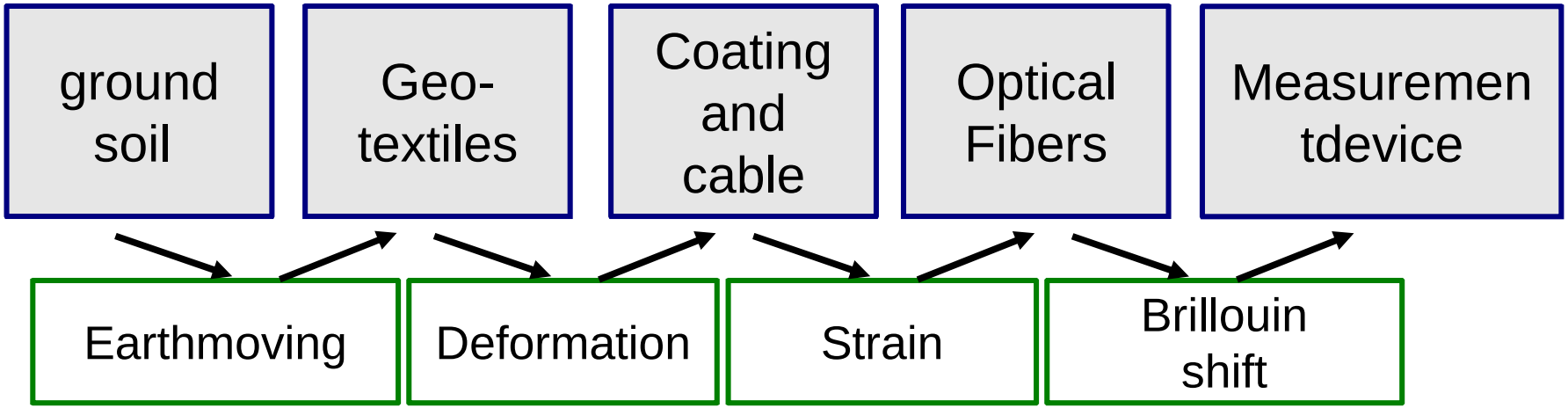
- in inaccessible areas
- in harsh environments
- distributed along several kilometers long sections.

Integration of fiber optic sensors

Heavy machinery used for dike construction might damage the optical fibers.

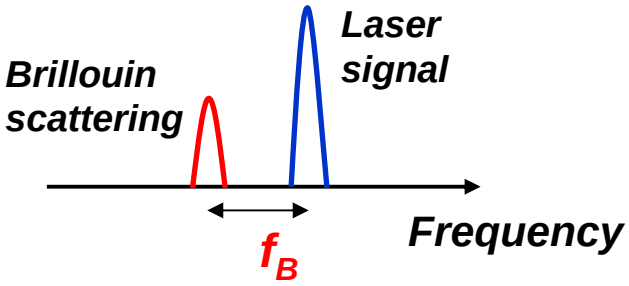
Manual embedding provides good results for the condition of the embedded sensors.

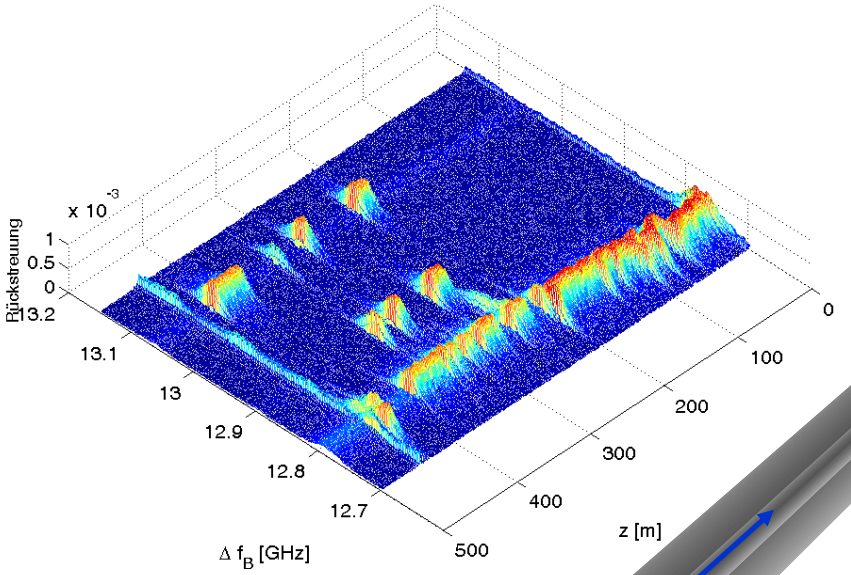
A long chain of transmission of physical quantities is to take into account:

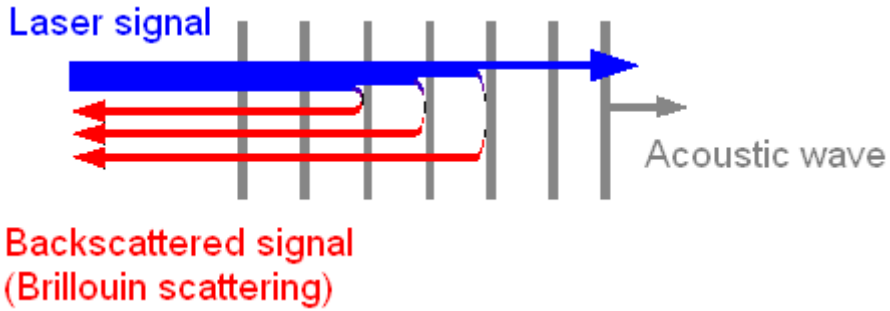


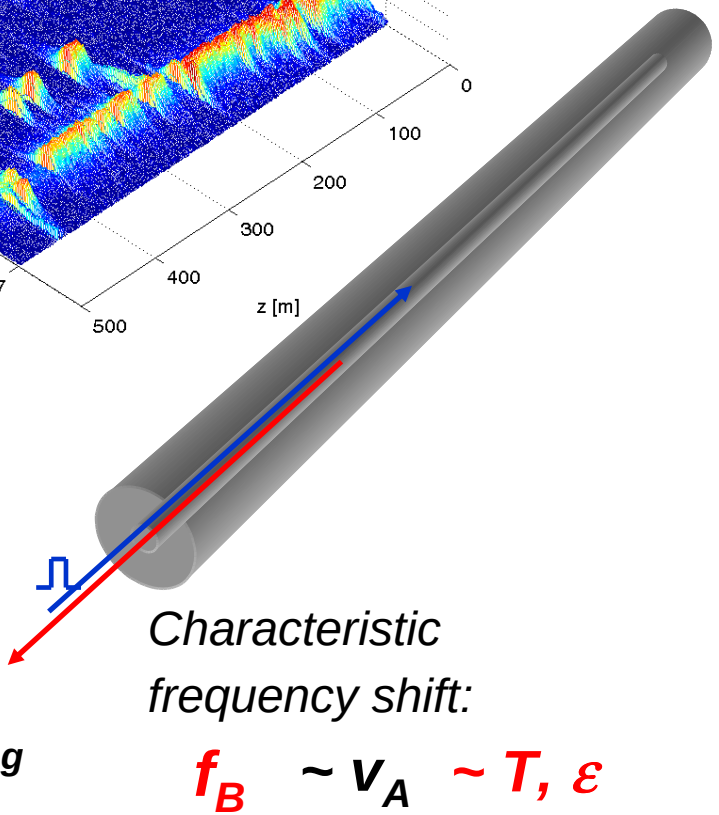
Each of the four parameters (distance range, spatial resolution, measuring accuracy, testing time) can be optimized at the expense of the other three!

Stimulated Brillouin Scattering (SBS)





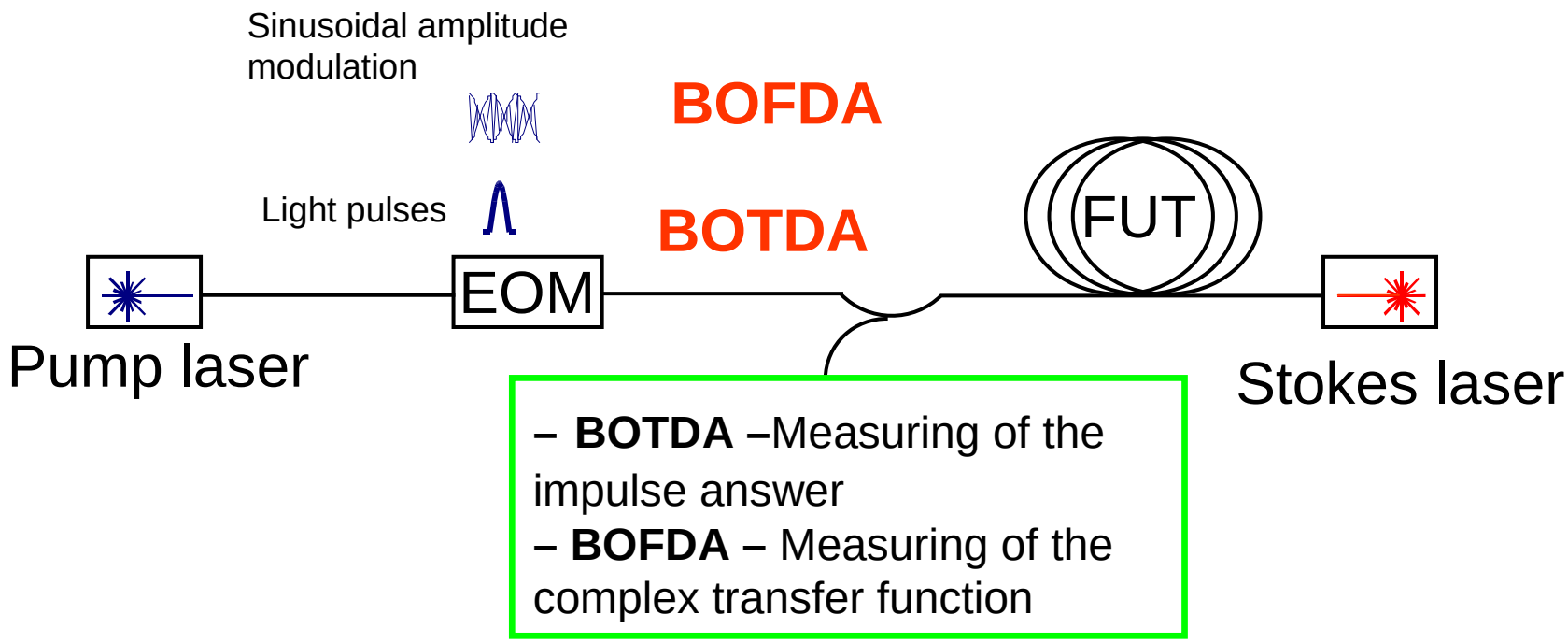




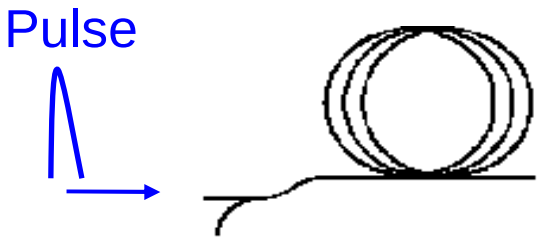
Characteristic frequency shift:

$f_B \sim v_A \sim T, \varepsilon$

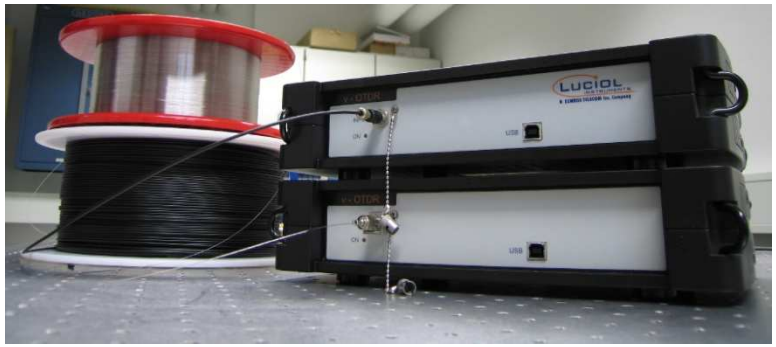
Brillouin system



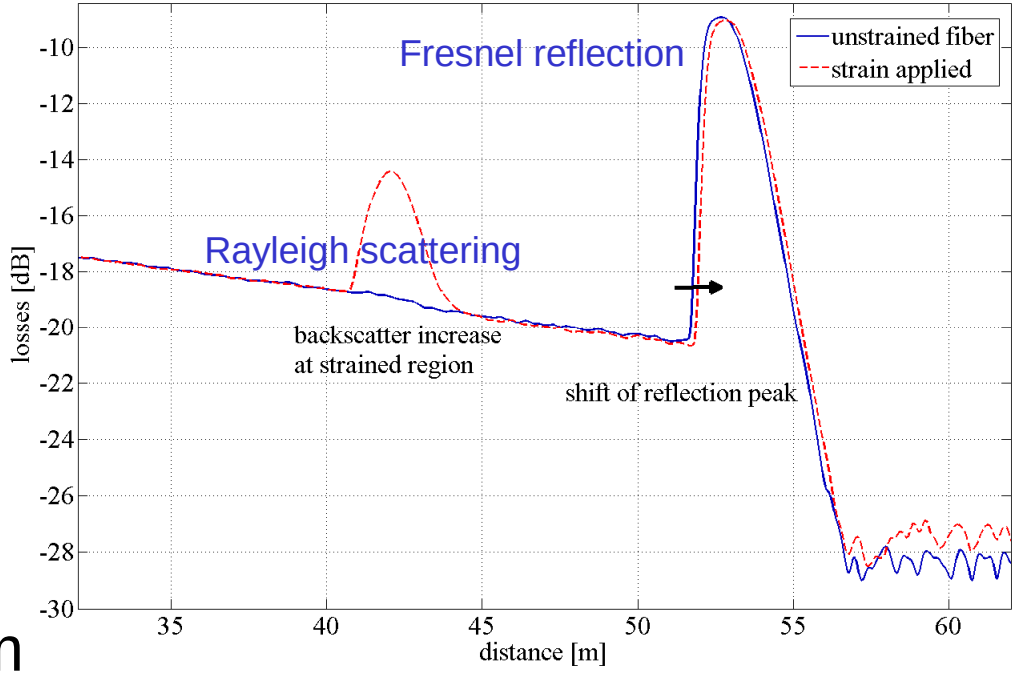
Distance range: **20 km** **Spatial resolution:** **0.5 m**



POF-OTDR



POF-OTDR „*Luciol*"

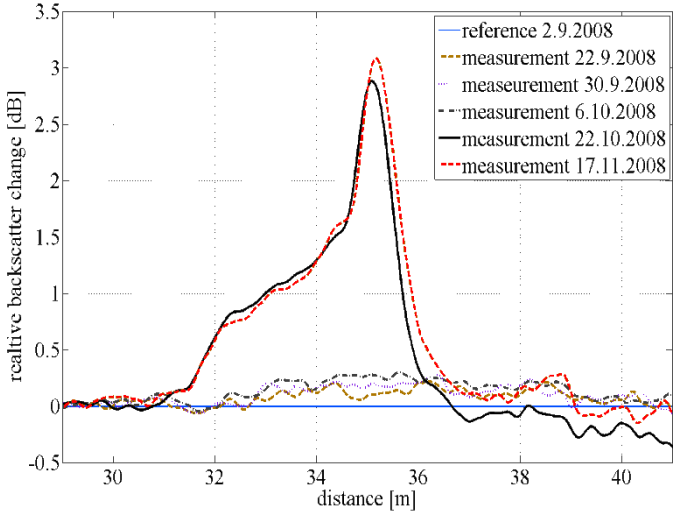


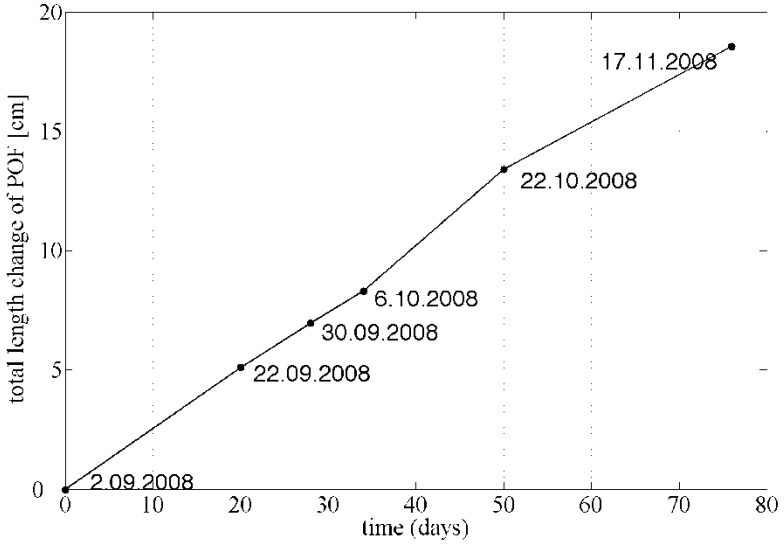
- Distance range : 100 m
- Spatial resolution : 10 cm
- Measuring range of strain : > 40 %

AiF Ideen eine Zukunft geben

POLYTEC

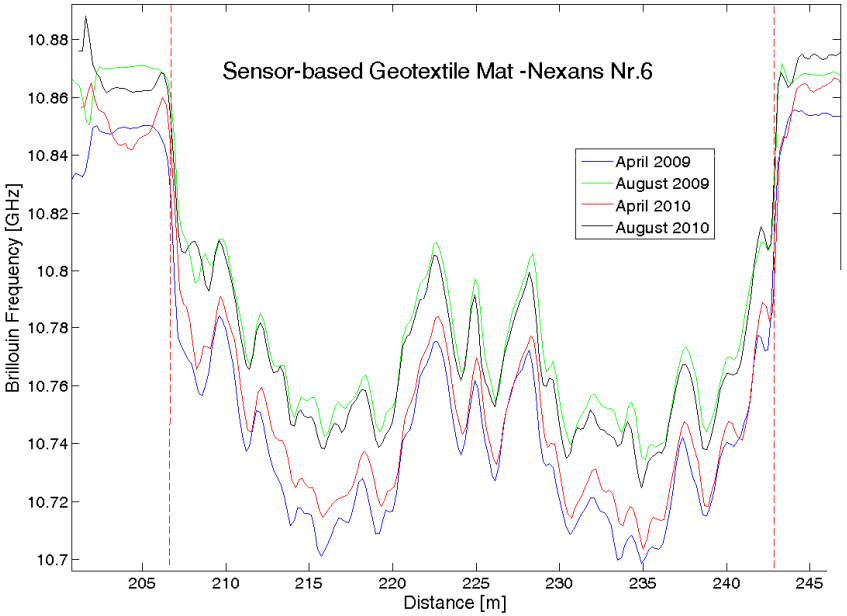
POF-OTDR – Field test





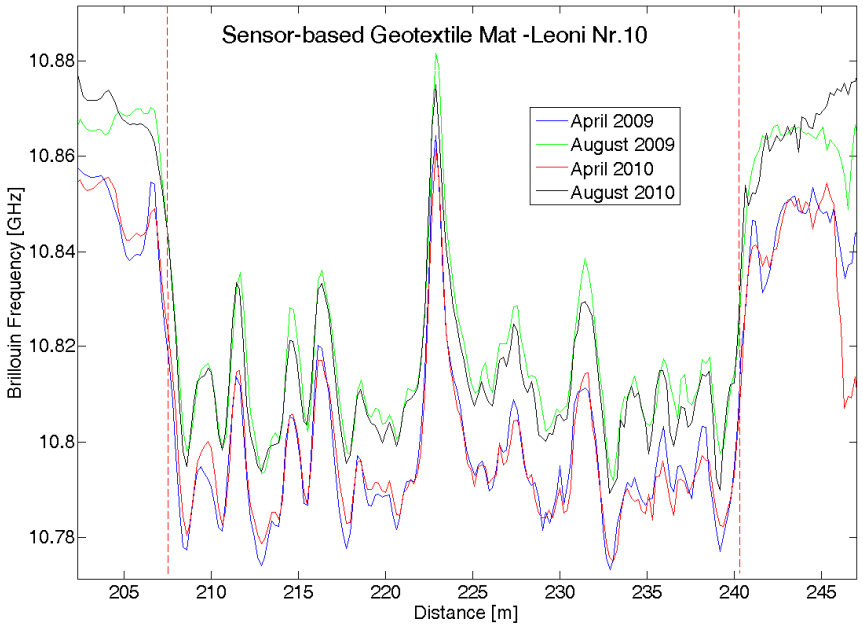
Experimental validation of sensor systems

Bundesministerium
für Wirtschaft
und Technologie



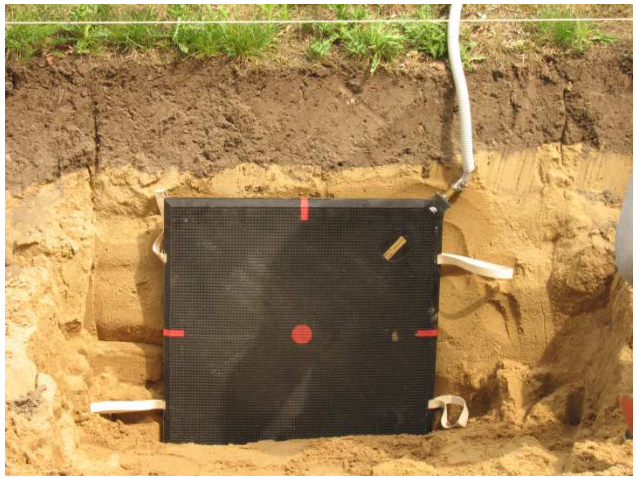
$$\frac{d f_B}{d \varepsilon} = 500 \text{ MHz/\% at } \lambda = 1.55 \text{ µm}$$

$$\frac{d f_B}{d T} = 1.1 \text{ MHz/K at } \lambda = 1.55 \text{ µm}$$

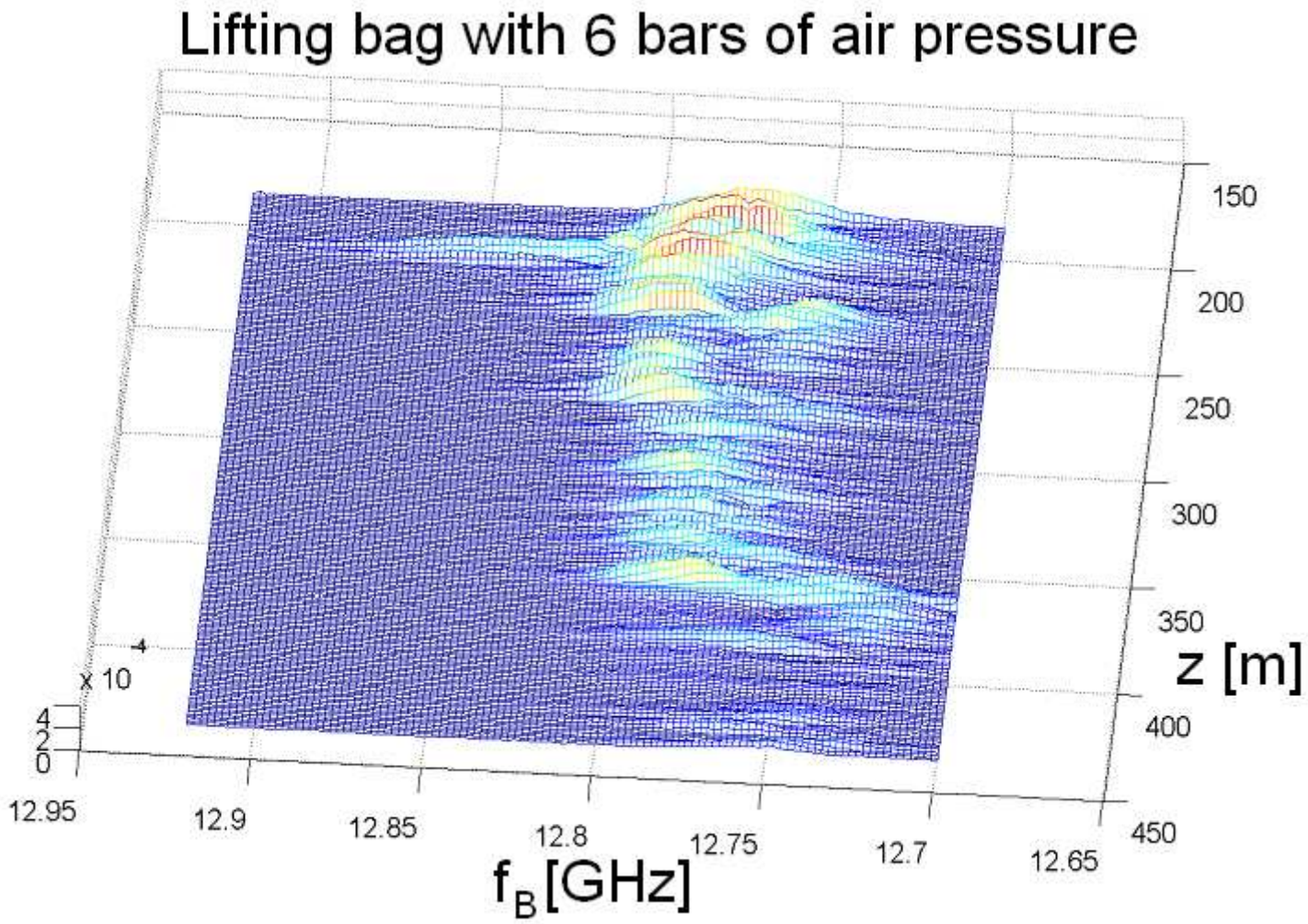


Field test of distributed strain measurement

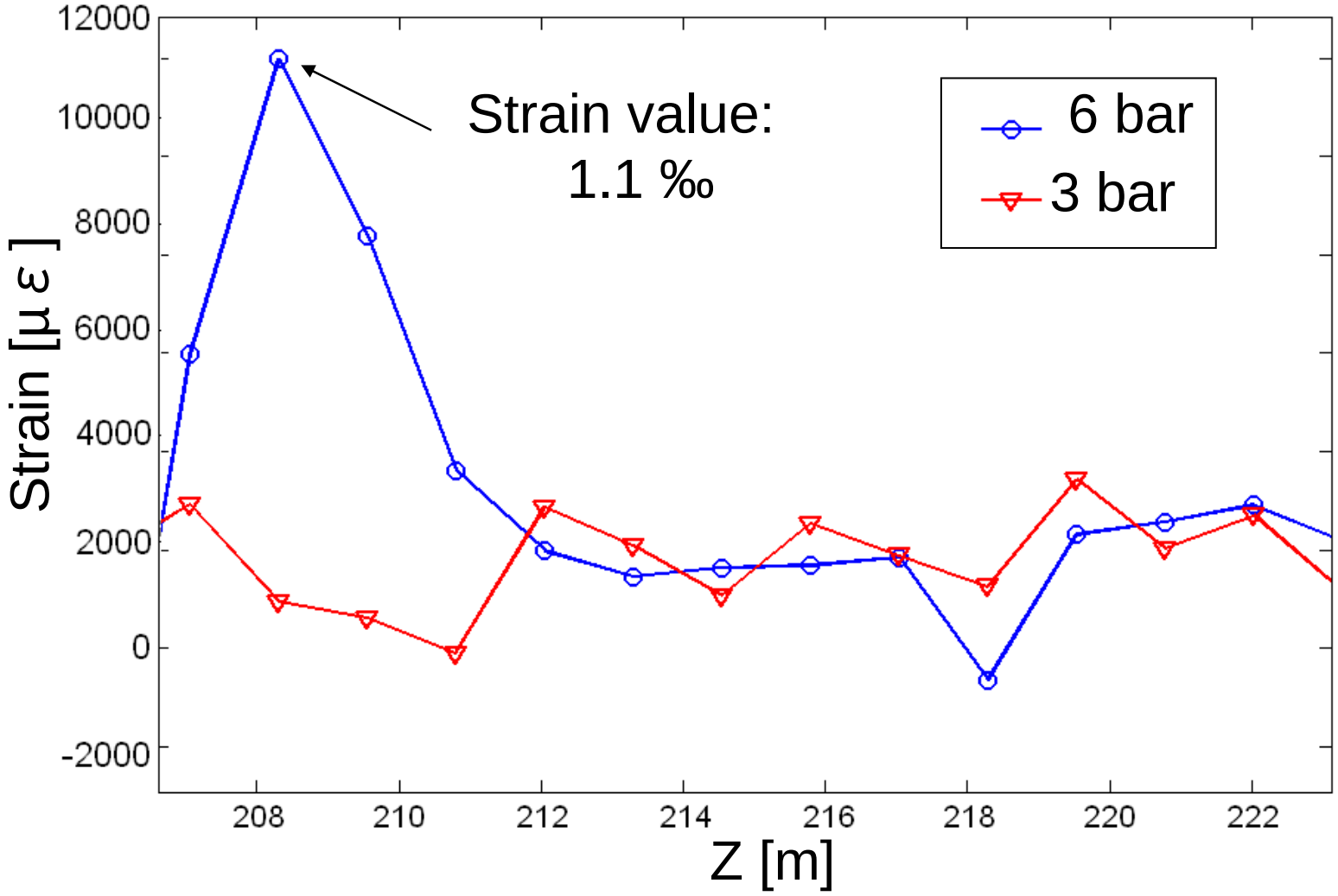
Several samples of sensor-based geosynthetics have been embedded into a 15 m long laboratory dike at the University of Hannover.



Brillouin gain spectra



Strain distribution alongside the dike



- Methods for the distributed strain measurement in optical silica and polymer fibers have been implemented for the application in the field
- All components of the dike monitoring system were analyzed
- A precise specification of the system parameters will be possible after further field tests

Thank you !

GLÖTZL Gesellschaft für Baumeßtechnik mbH

UNIVERSITÄT HANNOVER
FRANZIUS-INSTITUT
FÜR WASSERBAU UND KÜSTENINGENIEURWESEN
Univ.-Prof. Dr.-Ing. C. Zimmermann

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