Fiber Bragg Grating

A promising technology for wind turbine blade strain detection

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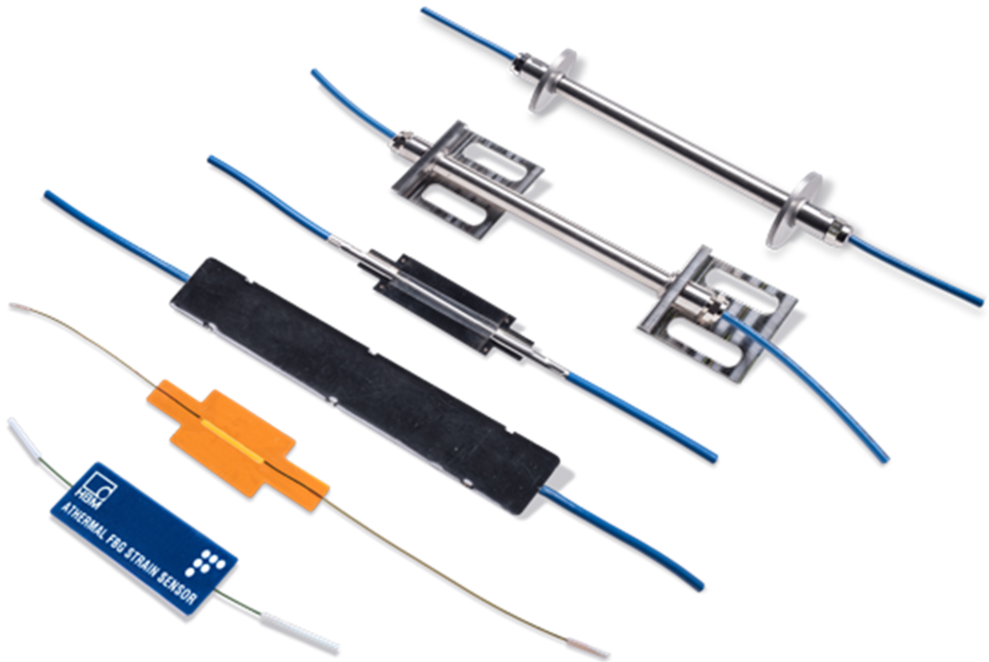
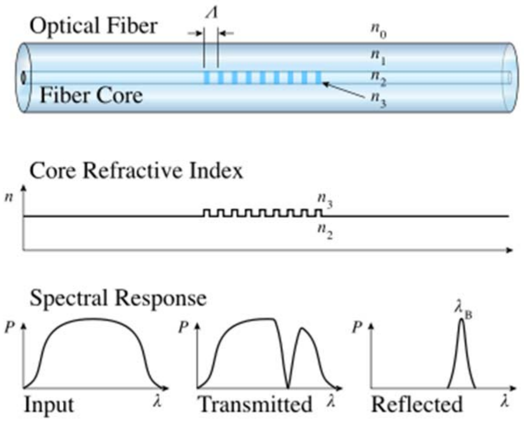
Outline

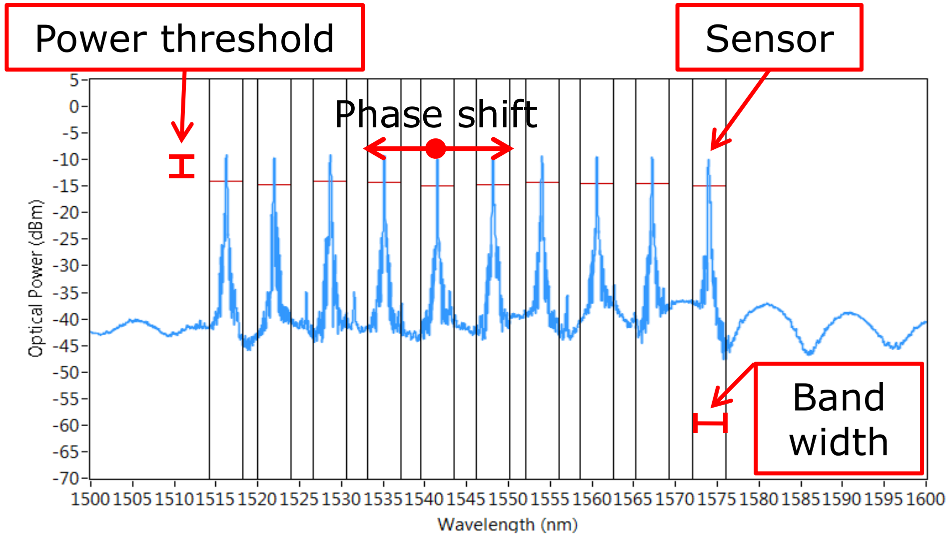


1. Fiber Bragg Grating working principle.
2. FBG installation on a 34m blade quasi-statically tested to failure.
3. Findings about FBG measurement data.
4. FBG pros and cons.
5. Conclusions

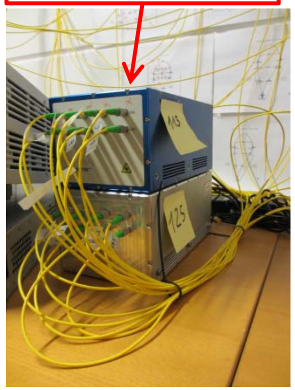
FBG working principle



$$\Delta\varepsilon[\mu m/\mu] = 1000\ \Delta\lambda[nm] / 1.2$$



Bragg Meter

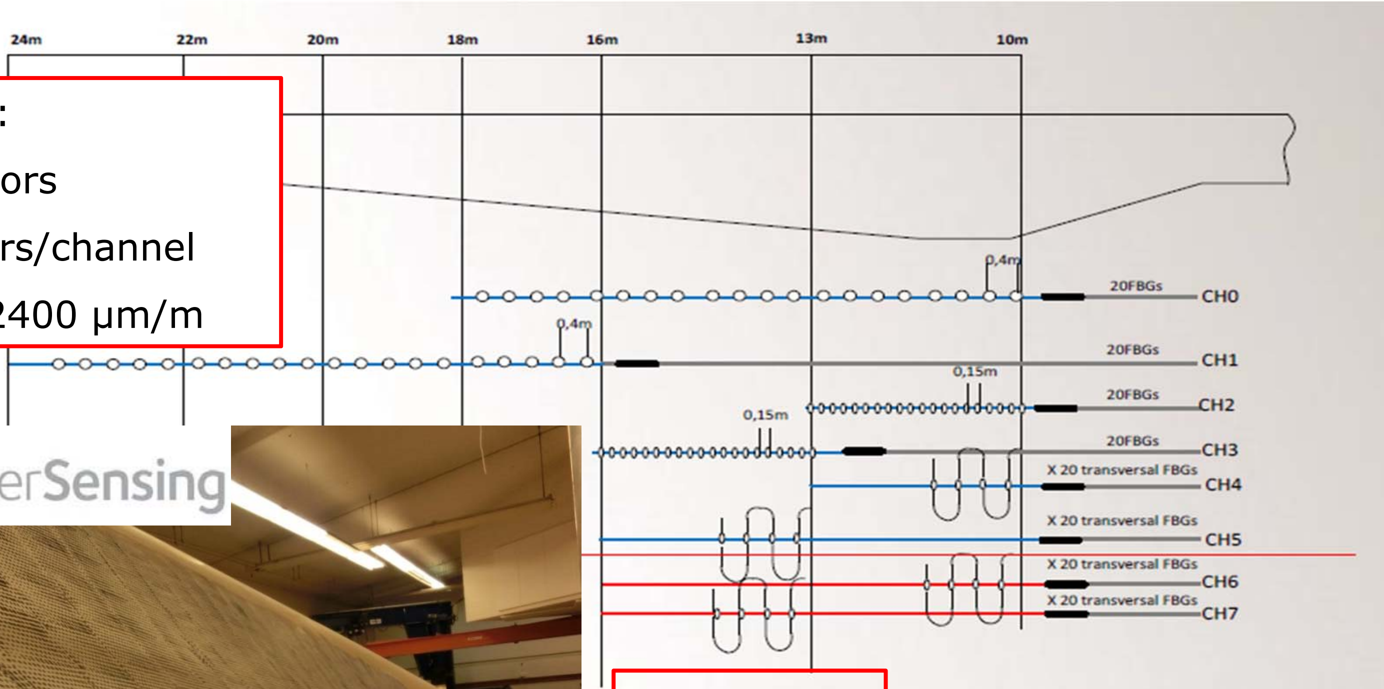


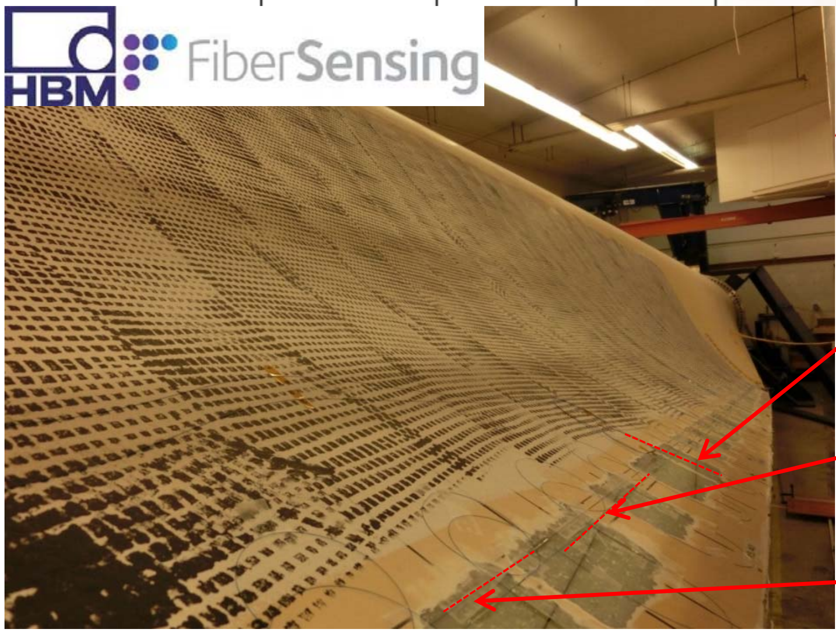
Wavelength measurement	1 S/s	100 S/s	500 S/s
Range	100 nm (1500 to 1600 nm)		
Resolution	1.0 pm	5.0 pm	5.0 pm
Absolute accuracy	± 2.0 pm	± 10.0 pm	± 10.0 pm
Sensors per channel	25 (maximum recommended)		
Optical channels	1,4 or 8		
Optical detection	Logarithmic	Linear (selectable gain steps)	
Dynamic range	> 50 dB	> 25 dB	> 25 dB

FBG application on a SSP34m blade

FBG system:

- 160 sensors
- 10 sensors/channel
- $\Delta\varepsilon = \pm\ 2400\ \mu m/m$

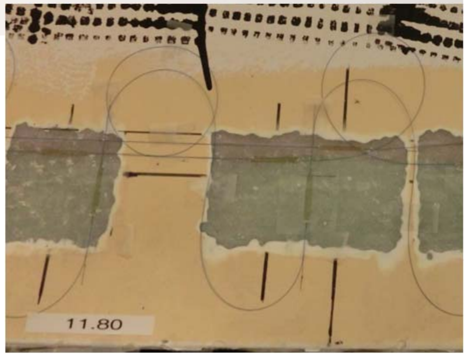




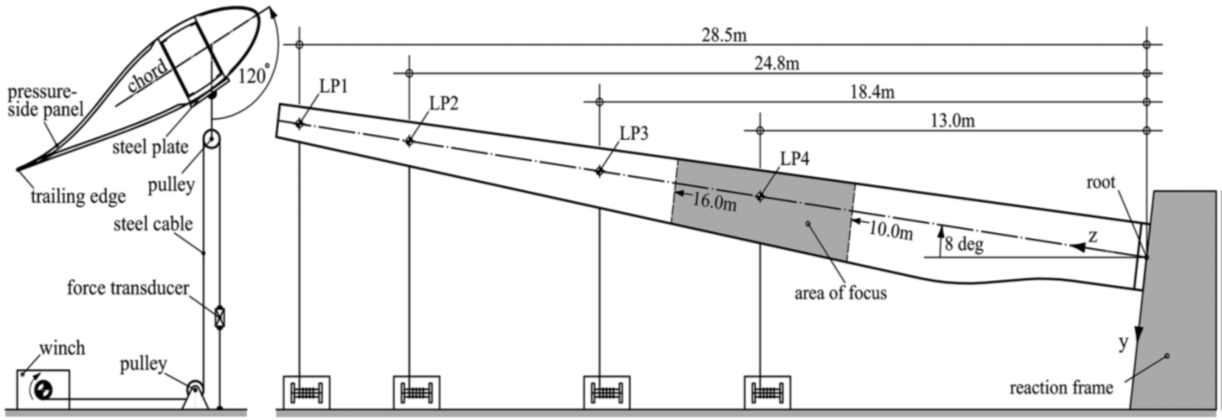
Transversal fiber line #3

Longitudinal fiber line #2

Longitudinal fiber line #1

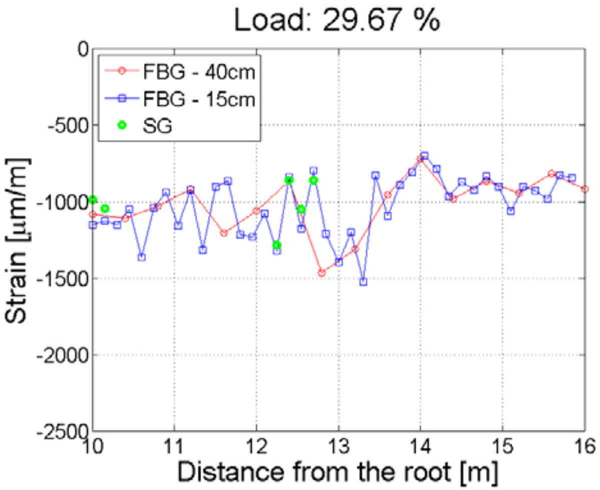


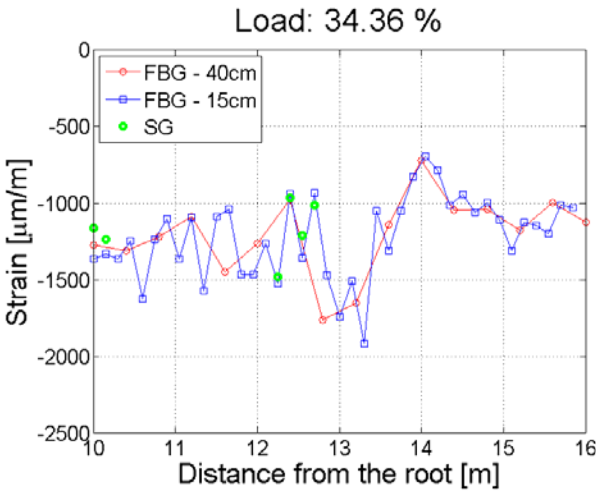
FBG applied to full scale blade test

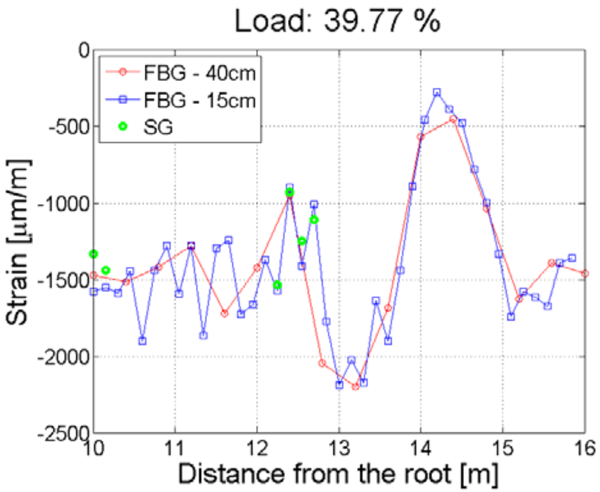


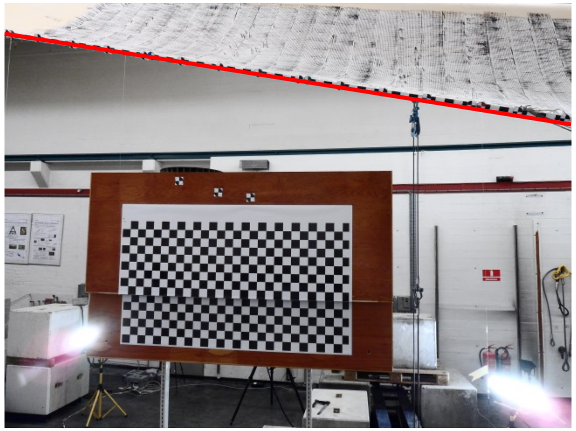
- Full scale blade test up to failure of a SSP 34m blade
- Loading configuration where the blade TE was under compression
- Local buckling along the TE measured by means of the FBGs
- FBG measurements were used to validate a 3D numerical blade model

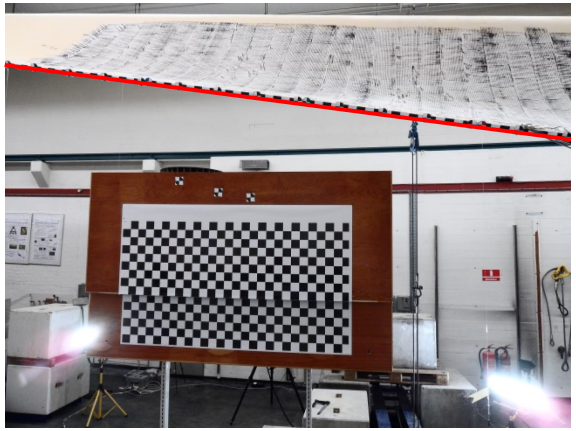
FBG measurement data analysis

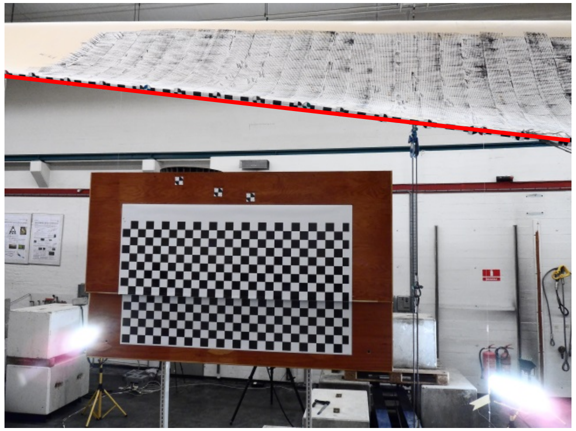








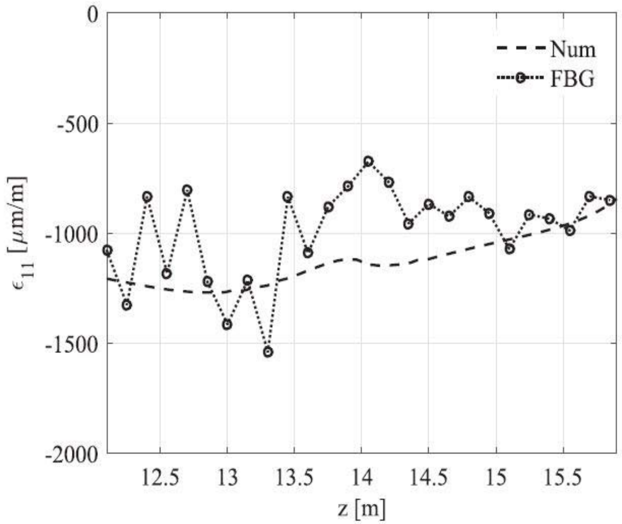




FBG measurement data analysis

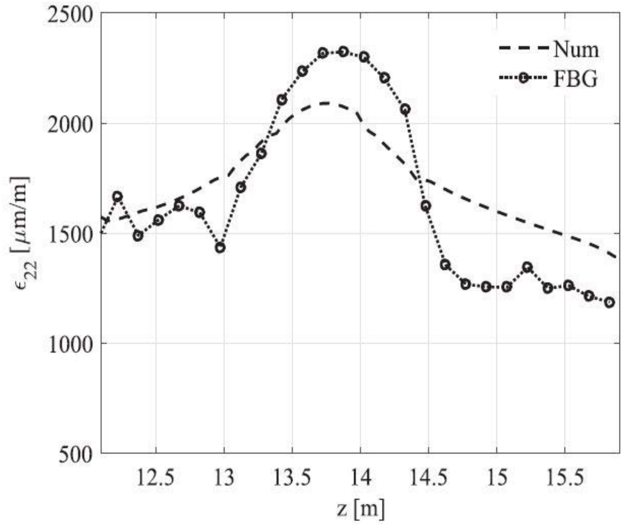
Longitudinal strain along the blade TE in the designated failure area

Load 29.67%



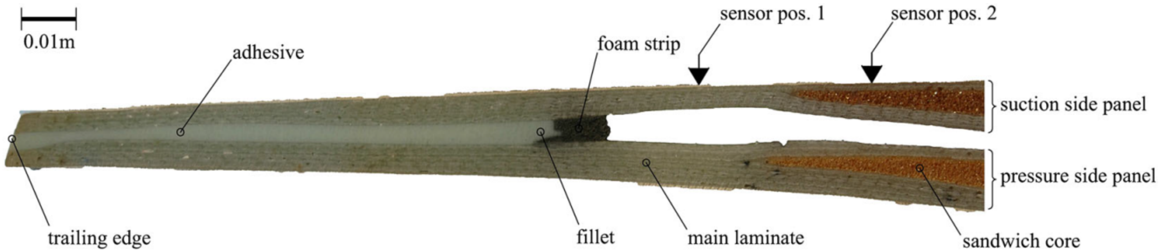
Transversal strain along the blade TE in the designated failure area

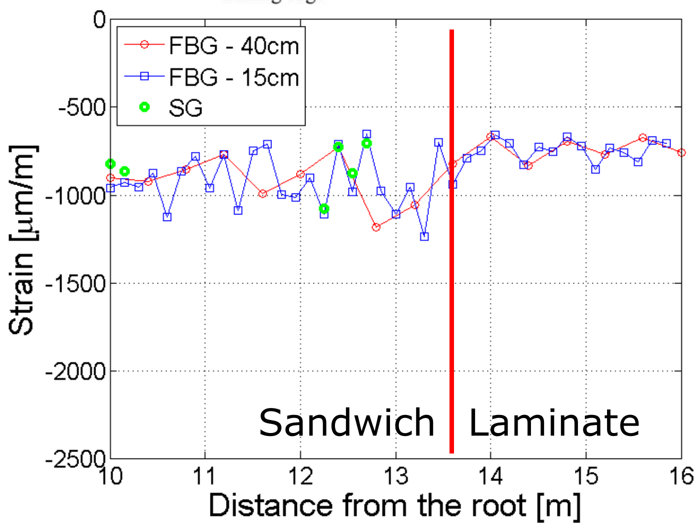
Load 29.67%

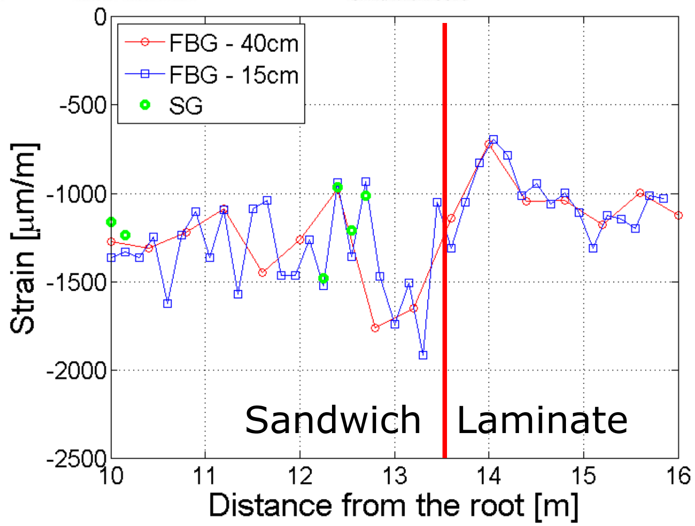


FBG measurement data analysis

- Electrical resistance SGs are consistent with FBGs.
- Pearson's correlation shows good correlation between fine and coarse line for increasing load levels.
- 'Noisy' strain data possibly due to local stress concentrations due to voids and micro cracks.







Fiber Bragg Grating

Pros Much cleaner measurement system
Simple installation and fiber alignment
No electrical problems and less corrosion problems
Surface installation or embedded installation
Better behaviour under fatigue loading ($\Delta\varepsilon = \pm 5000$ µm/m guaranteed for 1E+07 cycles)

Cons The $\Delta\varepsilon$ is a function of the amount of sensor in a line
Lost of data if the sensor goes out of range
Mono-directional strain measurement
Very small sensor measurement area (0.5x4mm)

Conclusions

- FBG is a very promising technology for wind turbine blade health monitoring and surface or intra-panel (embedded FBG) strain detection.
- FBG strain measurements were validated against electrical resistance SG and good agreement was found.
- A compromise solution between the measurable Δε and the number of sensor in a line has to be designed according to the test goals.
- ‘Noise’ in strain measurements is very likely related to structural flaws.
- FBGs are expected to have a better behaviour under fatigue loading.

[1] Kersey AD, “A review of recent developments in fiber optic sensor technology,” Optical Fiber Technology, vol. 2, p. 291–317, 1996.
[2] Hill K, Meltz G, “Fiber Bragg grating technology fundamentals and overview,” Journal of Lightwave Technology, vol. 15, p. 1263–1276, 1997.
[3] Haselbach PH, Eder MA and Belloni F, “A comprehensive investigation of trailing edge damage in a wind turbine rotor blade,” Wind Energy, vol. 17, pp. 657-669, 2015.

Thank you