A spectral filter analyzer for Bragg grating based strain and temperature measurements

N. Samfirescu*, K. Wagenbach*, T. Tschudi*, M. A. Bader*, N. Lauinger*,**, T. Schanze*,**

*Photonik Zentrum Hessen in Wetzlar AG, Charlotte-Bamberg-Str. 6, D-35578 Wetzlar
**CORRSYS 3D Sensors AG, Charlotte-Bamberg-Str. 6, D-35578 Wetzlar

Mail to: narcis.samfirescu@pzh-wetzlar.de

To measure several Bragg grating sensors simultaneously, a novel combination of optical and electronical components has been developed for light intensity independent conversions of wavelength into electrical signal amplitudes. The spectral analyzer allows fast, stable, and precise measurements of strain and temperature with Bragg grating based sensors.

1 Introduction

To poll optical Bragg gratings designed for strain and temperature measurement sensors different types of interrogators are currently in use: interferometers, tunable lasers and devices employing spectral filters for wavelength-amplitude conversions. Most of the commercially available interrogators are very expensive. However, for many applications including civil structure monitoring (Fig. 1) economic optical C-band interrogators are desired.

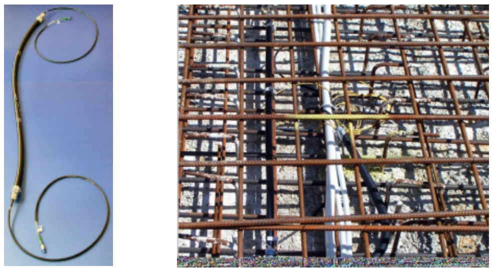

Fig. 1 *Fiber Bragg-sensor designed for civil structure monitoring (AOS GmbH, Dresden and CORRSYS 3D Sensors AG, Wetzlar: Hausertorbrücke, Wetzlar).*

2 Method

To measure a fibre Bragg grating a small spectral sampling bandwidth is very often sufficient, e.g. 20 nm (Fig. 2). In order to obtain light intensity independent conversions of Bragg wavelengths into electrical signal amplitudes adequate for subsequent signal processing a new combination of optical and electronical components has been developed (Fig. 3). A working point stabilized SLED is connected by optical fibres to a coupler which also directs the reflected light from the Bragg sensor to a detector. The detection principle consists of a beam splitter, two collimator lenses and two filters for complementary or independent wavelength-intensity conversion. The filtered light beams are converted independently by photodiodes on a single chip. For subsequent fast electronical signal acquisition and processing, especially the computation of the contrast of the signals of two diodes to assure a light intensity independent spectral analysis. Figure 4 shows how to use appropriate spectral filters to obtain the contrast signal proportional to strain or temperature as measured by a Bragg grating. Due to our chip integrated photodiode approach the obtained signal is highly compensated against fluctuations of the light source, aging or temperature drift of the detector. The signal quality depends more on the filter quality and not on the detector properties which makes the system cheap.

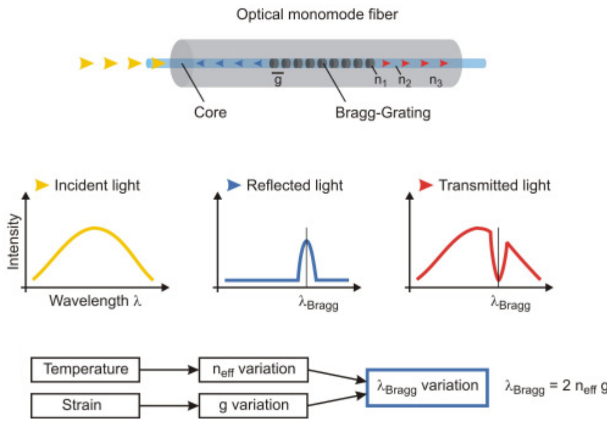

Fig. 2 *The fibre Bragg grating – principle.*

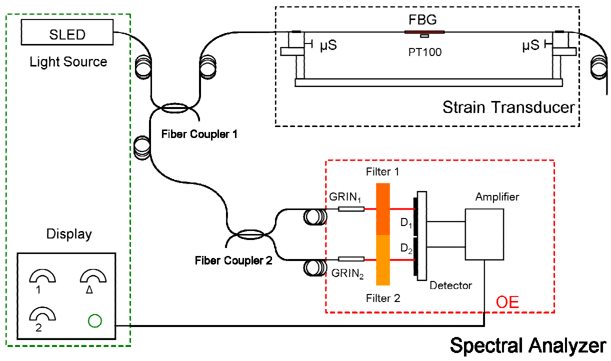

Fig. 3 *Scheme of our approach.*

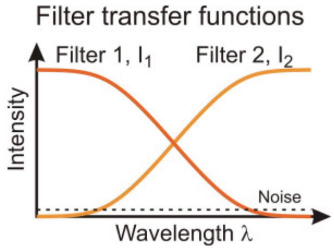

Fig. 4 *Signal contrast $S=(I_2-I_1)/(I_2+I_1)$ is a monotonic function of λ and invariant to light intensity changes.*

Fig. 5 *The prototype.*

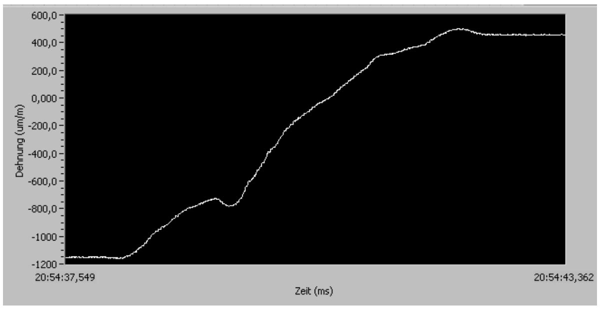

Fig. 6 *Strain measurement using FBG – sensor and the new spectral analyzer.*

3 Results

To show the feasibility of our approach a prototype of a C-band spectral filter based interrogator has been developed. (Fig. 5). The working range of the system is about 10 nm, thus adapted to C-band fibre Bragg gratings. The spectral resolution of the system is less than 25 pm within a spectral working range of 5 nm. Potential interference patterns due to the spectral filters were prevented by a special treatment of the filter surfaces. The achieved linearity and stability of the system depends very strongly on the characteristics of the spectral filters and not on the photodiodes. An example of a strain measurement with a Bragg sensor and this new spectral analyzer is shown in Fig. 6. Using high quality filters the results of our approach are – to our knowledge – in good correspondence with other principles for Bragg grating strain and temperature measurements (Tab. 1).

4 Conclusion

We have developed a novel spectral measurement principle. The manufactured spectral analyzer prototype allows fast, stable and precise measurements of strain and temperature with Bragg grating based sensors.

Due to its design our spectral analyzer is insensitive to aging or temperature drift of the detector and is well suited for cost effective applications.

	Speed (Hz)	Res./Acc. (pm)	Number of Sensors	Notes	Price (T€)
Wavelength/ Amplitude Conversion	500-2000	5/15	1/Channel	no moving parts	<5/Channel
Spectrometer (CCD)	2-200	1/5	32	no moving parts	c. 25
Time Domain Reflectometer	2-2000	5/15	32	no moving parts	c. 15
Tunable Filters/Lasers	0.2-200	1/5	32	moving parts	> 35
Arrayed Waveguide Grating	<2000	<0.5/not known	>100	no moving parts	not known
New Spectral Evaluation Unit	>500	1.2/12	4/Channel	no moving parts	<8

Tab. 1 *Evaluation units for fiber Bragg sensors.*

References

[1] J. and C. Dakin, *Optical Fiber Sensors – Volume Four; Applications, Analysis, and Future Trends*, (Artech House, Boston, London, 1997)

[2] A. Othonos, „Fiber Bragg Gratings", in *Rev. Sci. Instrum.* **68**(12), (1997)

[3] J. M. López-Higuera, *Handbook of Optical Fibre Technology*, (John Wiley & Sons, LTD 2002)

[4] F. T. S. Yu, S. Yin, *Fiber Optic Sensors*, (Marcel Dekker, Inc., New York, Basel 2002)

[5] CORSYS 3D Sensors AG, „Untersuchungsbericht – Leistungsrechnung für optische Auswerteeinheit", *internal report (2005)*

[6] T. Tschudi, R. Blin, M. Schmidt, „Optical Spectrometer", *Patent WO002007082678A1* (2007)

[7] N. Samfirescu, *The Development of a Spectral Evaluation Unit for Strain Measurements*, (diploma thesis, Physics Faculty, University of Siegen, Siegen 2007)

[8] N. Samfirescu, M. A. Bader, T. Schanze: "A novel spectral filter analyzer for Bragg grating based strain and temperature measurements", Workshop: Optical Spectrometer: Design, Technology, Application and Trend, *IPHT Jena (11^{th}-12^{th} March 2008)*