5th IWGoRS workshop, Sun Moon Lake, Taiwan, September 22-26, 2019

Experimental perspectives for rotational seismology – construction of optical fiber sensors set

Leszek R. JAROSZEWICZ[1], Anna T. KURZYCH[1], Zbigniew KRAJEWSKI[1], Krzysztof TEISSEYRE[2], Michał DUDEK[1], Jerzy K. KOWALSKI[3]

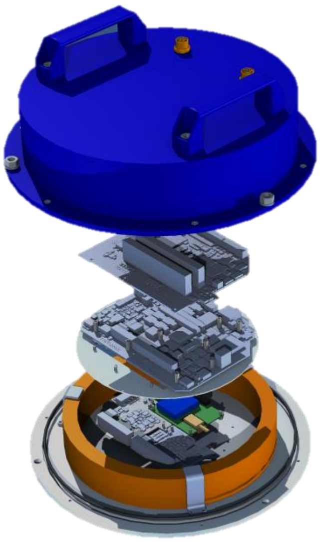
[1]*Institute of Applied Physics, Military University of Technology, Warsaw, POLAND*
[2]*Institute of Geophysics, Polish Academy of Sciences, Warsaw, POLAND*
[3]*Elproma-Elektronika Ltd, Warsaw, POLAND*

Characterizing, quantifying as well as modeling of ground motion require data about translational ground displacements and strain measurements. Until recently, there have been only three linear components of soil movement measured in the seismology and seismic engineering (along two horizontal x, y, and z-axis). From above reason only these three degrees of freedom associated with the translational motion or acceleration along Cartesian reference frame have been recorded, applying different sensors: seismometers or accelerometers, indirectly neglecting the rotation motion components. The three rotation components have been underestimated because of lack of appropriate and accurate devices. This situation was also resulted from the negative attitude of many scientists towards rotational movements because according to the classical description, they should quickly disappear with distance from the hypocenter. Recently, it turned out that three rotational components can provide additional valuable information for seismology. Rapidly developing interest of rotational seismology, which affected new advanced devices, points out that there are significant needs for research both theoretical but most of all, experimental in this field.

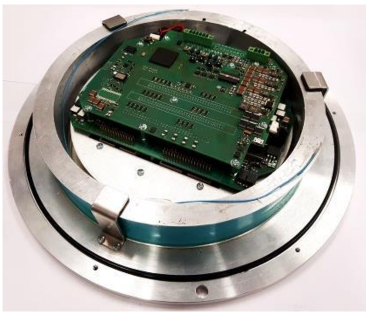
In order to fulfill all technical requirements of the sensor for the rotational seismology, we have designed device based on the Sagnac effect which first of all gives insensitivity to linear motions and detects only rotational component in axis chosen by the sensor. Our system named FOSREM - Fibre-Optic System for Rotational Events&Phenomena Monitoring (see Figure 1) apply the principle of FOG in a closed-loop configuration, which is based on the compensatory phase measurement method. It has wide measuring range both in the domain of the signal amplitude ($3 \cdot 10^{-8}$ – 10 rad/s) as well as frequency [from DC to 328.12/n Hz (n=1, …, 128)]. It is a portable device equipped with an independent power supply. The remote control is also protected via Telemetric Server. We present laboratory investigation of two such systems which confirm their parameters, among others Allan variance analysis with Angle Random Walk and Bias Instability determination. The obtained parameters confirmed that our systems are appropriate for valuable data delivery connected with rotational seismology.

Moreover, the application of at least two sensors which register data in a correlated way is necessary to ensure the reliability of the gathered data. In this point one can refer to three scientists awarded the Nobel Prize for physics in 2017: Rainer Weiss, Kip Thorne and Barry Barish. They were creators of gravitational waves detectors LIGO (Laser Interferometer

Gravitational-Wave Observatory). LIGO consists of two widely-separated interferometers operated in unison to detect gravitational waves. On September 14, 2015, at 09:50:45 UTC the two detectors of the Laser Interferometer Gravitational-Wave Observatory simultaneously observed a transient gravitational-wave signal. It shows that the searching of the correlation between two instruments common measuring the same quantity is a key element in the verification of a complex measurement.



a)



b) c)

Fig. 1 FOSREM - Fibre-Optic System for Rotational Events&Phenomena Monitoring: a) 3D visualization, b) technical realization of the optical and electronic part, c) the upper part of the housing.

In order to determine the correlation between the obtained data from two FOSREMs, we applied a specially designed Matlab script which allows to read the data from both FOSREMs simultaneously and to calculate the Pearson’s correlation coefficient.

Field research carried out by FOSREMs presented in this article was conducted to evaluate the nature of tilt and torsion phenomena generated by the mining activity. We present data resulted from long-term monitoring of rotational events recorded by two interferometric optical fiber sensors and mechanical rotational one. Comparison of results provided by two kinds of instruments shows a good correlation between signals. Thus it emphasized the gathered data reliability.