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A highly sensitive instrument for direct and long-term observations of seismic and natural-mode rotational movements

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Over the last decade, the interest of rotational ground movements has become significant in the field of seismological research, especially in seismic engineering. Being able to reliably detect and record rotational motions is a key point in rotational seismology to better understand the origin of earthquakes and in particular to relate them to the geological context. The area of rotational seismology includes seismology, earthquake engineering, seismotectonic, geodesy as well as gravitation waves. Generally, in classical approach, seismic events are monitored by underground and surface seismic stations based on translational vibration sensors (seismometers, geophones, accelerometers). However, a full description of wave motion requires information about both displacements along the three perpendicular axes X, Y, and Z as well the rotation around these axes. The lack of a possibility of complete wave motion measurements results mainly due to technical difficulties in providing the appropriate sensors meeting all technical requirements of rotational seismology.

In this paper we present the laboratory analysis and field records of the fibre-optic seismograph (FOS) that utilizes the Sagnac effect based on a minimum optical configuration designed for a huge fibre-optic gyroscope with special attention to angular motion detection. Presented FOS utilizes a closed-loop configuration, which is based on the compensatory phase measurement method as well as specific electronic system. The experimental results showed that described FOS is characterized by a wide measuring range, it detects signals with amplitudes ranging from several dozen nrad/s up to even few rad/s and frequencies from 0.01 Hz to 100 Hz. The determined angle random walk was equal to $3\square10^{-8}$ rad/s and bias instability was equal to $2\square10^{-8}$ rad/s. Moreover, besides the laboratory verification of FOS's proper operation, the field observation results are also presented. Aforementioned device is constantly registering rotational motions in the seismological observatory located in the basement of the Książ Castle near Wałbrzych, Poland. We present the rotational events induced by the exploitation of the copper ore deposit in this area as well as long-term measurements, showing results confirming positive detection of small differences in Earth's rotation rate – mainly diurnal and semi-diurnal. The presented data give broad view of the potential FOS's application in the area of rotational seismology, including seismic monitoring in observatories, buildings, mines, chimneys and even on glaciers and in their vicinity.