Sagnac Interferometry for the Determination of Rotations in Seismology

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ABSTRACT

Characteristic parameters such as sensitivity, scaling factor stability and instrumental drift are usually used to qualify rotational sensors in navigation. In this group of sensors, ring lasers may be considered as one of the most important representatives. The sensitivity to rotation improves significantly as the size of such instruments is scaled up. However this also results in much higher demands on mechanical stability of large ring laser gyroscopes. In our laboratories in Germany, New Zealand and USA we have constructed and operated more than 6 ring lasers with effective areas between 1 and 800 m^2 realized in various different ways and for a diversity of goals. With respect to stability and sensitivity some of these sensors exceed the performance of typical navigational ring laser gyros by several orders of magnitude both in sensitivity and with respect to residual drift i.e. their long-term sensor stability.

Signals from solid Earth tides, microseismics, teleseismic events as well as high frequency components of the nutation of the rotational axis of the Earth (known as diurnal polar motion) can now readily be observed with these instruments. A comparison with the theory behind some of these observed geophysical signals demonstrates a high reliability of the ring laser measurements over a broad range. Ring Lasers offer various advantages for their application in seismology. They are entirely insensitive to translations and they measure rotation absolute with respect to the local universe. Since ring lasers are active laser interferometers the experienced magnitude of a rotational input signal becomes visible as a variation of the beat frequency between two optical beams. This is another distinct difference between a typical seismometer and a rotational sensor based on the Sagnac effect. Fiber Optic Gyros (FOG) also exploit the Sagnac effect. Their advantage is that the scaling factor of this device can be made very large by winding a glas fiber to a coil, thus increasing the effective sensor area by the number of turns of the fiber. However, since they are passive interferometers with the light source external to the interferometer, they measure the phase difference between two counter-rotating optical beams rather than a frequency difference as it is the case with ring lasers. Nonreciprocal effects inside the fiber also cause measurement errors. We have build a very large FOG from a fiber of approximately 2.2 km length with 161 turns on a zerodur disc of 4.2 m in diameter in a highly temperature stable laboratory. This passive Sagnac interferometer is operated in parallel to the large G ring laser at the Geodetic Observatory in Wettzell (Germany) in order to study their properties by comparing the two instruments. Small fiber optic gyros appear to be very suitable for the study of the behavior of civil engineering structures under the influence of wind load or earthquakes. Shaketable measurements on several model structures have demonstrated good agreement with FOG derived building excitations and accelerometer measurements.

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