„Rotations: a new observable for Earth Sciences“

Abstract

Seismology is a science primarily based on the observation of three components of ground motions (N-S, E-W, up-down) around a reference point. Standard seismometers and the global and regional seismic networks are well developed and record the motions from which the current understanding of the earth’s interior (seismic tomography) and the earthquake rupture process are derived. Nevertheless, theoretical Earth scientists have pointed our for decades that – in addition to translations – rotations around three vertical axes should also be recorded. Such rotational motions (1) are relevant for earthquake induced damage; (2) may improve the imaging of internal structures and earthquake source processes; and (3) are necessary to allow the recovery of the complete motion of a measurement point. Until recently such observations were not possible due to the lack of instrumental sensitivity. In the past years a high-resolution instrument based on ring laser technology was developed that allowed for the first time the observation of *one* such rotational component consistent with theoretical predictions. The goal of this project is to set up the first high-resolution three-component rotation sensor based on ring laser technology, verify and demonstrate its accuracy and show the relevance of rotational motions for the diverse fields such as seismic tomography, geodesy, earthquake engineering, volcanology and earthquake physics. The long-term goal is the development of appropriate mobile rotation sensors and their incorporation into the world-wide seismic networks.

Some Key points:

- This is the first time rotational motions with high enough resolution for BB seismology is possible
- Consistency with translations has been demonstrated for one component only
- Tilt motions (rotations around horizontal axes) are not well understood, as tiltmeters don’t measure tilts, tremendous progress could be made with this new technology
- The tilt problem is highly relevant for projects measuring gravitational waves (eg LIGO), seismic instrumentation (particular strong motion instruments as tilts are contaminating translational recordings, also for OBSs)
- The new observables allow new data processing and imaging approaches (see papers)
- It is an emerging field, 50 papers submitted to a BSSA special issue to appear in 2009
- Development of high- and low-resolution sensors one of the key issues to resolve over the next years
- Wide range of applications in earthquake engineering, seismic instrumentation, earthquake physics, seismic tomography, geodesy, physics, etc.

Fig. 1. ***Left:*** Three components of rotational motions that can be measured with rotation sensors as well as three components of translations measured with standard seismometers. ***Right***: Rotation of a symmetric structure thats is difficult to explain with pure translational motions. Rotational accelerations are thought to cause such effects.

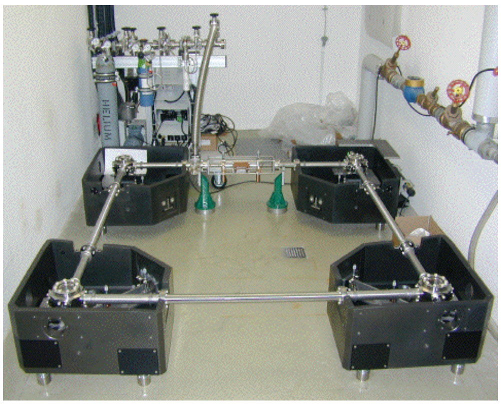

Fig. 2. Prototype of one-component rotation sensor based on ring laser technology.

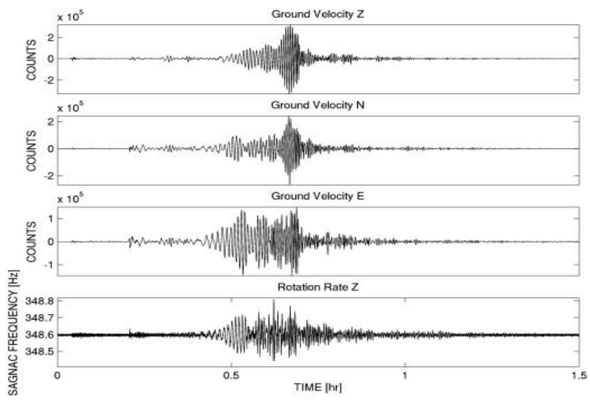

Fig. 3. Raw data, top three traces are the translational components and bottom trace ist he vertical component of rotation of the M8.1 Hokkaido earthquake, September 25, 2003.

Workplan

1. Installation of a three-component ring laser sensor at the PFO Observatory
2. Setup of data acquisition, data archiving and data dissemination infrastructure (international network)

3. Setup of broadband sensor array around the ring laser location
4. Data analysis and modelling
    a. Joint processing of rotations and translations (phase velocities, cross-correlations, frequency and azimuth-depedent effects, etc)
    b. Comparison with array-derived rotations (all components)
    c. Modelling observations with 3-D synthetics (eg SpecFem)

Cost Estimates

3C Ringlaser

Item	Costs (k$)
3-Component Ringlaser	120
12 Mirrors	30
Pumpstand	38
Lasergas	11
2 Data-loggers (1000Hz)	50
6 Demodulators	8
3 Emitters	24
PMT + PIN-Diode	19
Misc.	100
Total	**400**

Other Costs

Item	Costs (k$)
Installation	100
3yr Postdoc	300
Travel/Conferences	60
Total	**460**

Relevant Publications

1. Igel, H., Cochard, A., Wassermann, J., Schreiber, U., Velikoseltsev, A., Dinh, N.P., 2007. Broadband observations of rotational ground motions, Geophiyscal Journal International, 168(1), 182-197, doi:10.1111/j.1365-246X.2006.03146.x.
2. Igel, H., Schreiber, K.U., Flaws, A., Schuberth, B., Velikoseltsev, A., Cochard, A., 2005. Rotational motions induced by the M8.1 Tokachi-oki earthquake, September

25, 2003, Geophys. Res. Lett., Vol 32, L08309, doi:10.1029/2004GL022336. (Journal Highlight of the American Geophysical Union).

3. Suryanto, W., Wassermann, J., Igel, H., Cochard, A., Vollmer, D., Scherbaum, F., A. Velikoseltsev, U. Schreiber. First comparison of seismic array derived rotations with direct ring laser measurements of rotational ground motion, Bull. Seism. Soc. Am., 96(6), 2059-2071, doi:10.1785/0120060004 (2006).
4. Schreiber, U., Stedman, G., Igel, H., Flaws, A., 2006. Ring Laser Gyroscopes as Rotation Sensors for Seismic Wave Studies, in “Earthquake source asymmetry, structural media and rotation effects” eds. Teisseyre et al., Springer Verlag, 377-391.
5. Cochard, A., Igel, H., Flaws, A., Schuberth, B., Wassermann, J., Suryanto, W., 2006. Rotational motions in seismology, in “Earthquake source asymmetry, structural media and rotation effects” eds. Teisseyre et al., Springer Verlag, 391-413.

plus the preprints