# Observations of Rotational Ground Motions using Ring Laser Gyros

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## ABSTRACT

It has been noted by theoretical seismologists for decades that - in addition to translations and strains - the rotational part of ground motions should also be recorded. It is expected that collocated measurements of translations and rotations may (1) allow transformation of translational seismograms to the complete ground motion of an observation point; (2) help to further constrain rupture processes; (3) provide additional hazard- relevant information to earthquake engineers. The lack of instrumental resolution used to be the main obstacle to observing rotational motions. Recently, ring laser technology has provided the means to develop instruments that allow in principle the observation of rotational motions in a wide frequency band and epicentral distance range. We investigate whether this technology - originally designed for geodesy - is capable of providing accurate and useful observations for seismology. We report observations of rotations around a vertical axis of several earthquakes obtained by a 4x4m ring laser installed in SE-Germany and compare them to collocated broadband translations. Assuming plane transverse wave propagation, acceleration and rotation rate should be in phase and their amplitude ratio proportional to horizontal phase velocity. We show that most of the observations can be explained under these assumptions and that the collocated observations allow the estimation of wavefield properties (e.g., phase velocities, propagation directions), otherwise only accessible through seismic array measurements, polarization analysis, or additional strain measurements.

These first investigations focused on the verification of the new observable "rotation" by comparison with standard seismometer recordings and through a comparison with rotational motions derived from a small seismic array around the ring laser. This verification phase can be considered a great success: the ring laser does seem to capture the rotational motions with high accuracy in a very wide frequency band (with a unit transfer function). The question now is whether this type of information is useful in seismology, i.e., whether it provides further information on subsurface structure, seismic sources and/or hazard relevant parameters. First steps in this direction are the estimation of Love wave dispersion curves from collocated measurements of translations and rotations. We can show using both synthetic data and observations that we can derive accurate dispersion curves from point measurements. In principle this opens up the possibility to invert for shear wave structure. Sensitivities for such inverse problems are currently being developed using adjoint methodologies. Another interesting observation is rotational energy in the P-coda. This energy is explained as coming from P-SH conversions close to the receivers. These observations may allow us to put tighter constraints on the subsurface scattering properties. An important future direction is the analysis of rotations around horizontal axes (tilt) as tiltmeters are highly sensitive to transverse motions in the seismic frequency band.