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First observation of rotational motions from Earth's free oscillations

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At most seismological observatories, earthquake induced ground motions are measured using broadband seismometers. These seismometers record three components of translational motions, usually in the vertical, North-South and East-West direction. However, for a comprehensive understanding of seismic waves, it would be of advantage to measure in addition six components of strain and three components of rotation. While at several places strainmeters have been operating for decades, the techniques for measuring rotations are still under development.

One of the areas of research where measurements of rotations could be helpful is the study of the Earth's free oscillations. Since the Earth's free oscillations allow putting constraints on the large scale structure of the Earth and provide the only data that can give direct information about 3D density variations, any improvement or complement to existing normal mode observations is desirable. However, the measurement of low-frequency free oscillations requires sensors with a high sensitivity, and until recently, it was not possible to make direct observations of free oscillations with the rotation sensors available.

At present, the most sensitive instrument for the measurement of seismic rotations in a broad frequency range is the G ring laser system at the geodetic observatory at Wettzell in Southeast Germany. This instrument acts as a single component rotation sensor and measures the rotation rate around a vertical axis. Due to this special orientation, it is only sensitive to horizontally polarized shear waves or, in terms of free oscillations of the Earth, toroidal modes. Thus, the Wettzell ring laser can serve as a sensor for toroidal free oscillations of the Earth.

Here we present the first observations of free oscillations with this instrument, made after the $M_W = 8.1$ earthquake near the Samoa Islands on September 29, 2009. We show that several toroidal modes can be detected in the ring laser data and that our observations are in reasonable agreement with synthetic seismograms computed by normal mode summation.

The detection of normal modes in a ring laser recording shows that this is a promising technology for low-frequency seismology in the future. Given this new observation, it seems even possible to use vertically mounted ring lasers for the first measurement of true tilt without any contaminations from translational motions.