A first for a unique instrument

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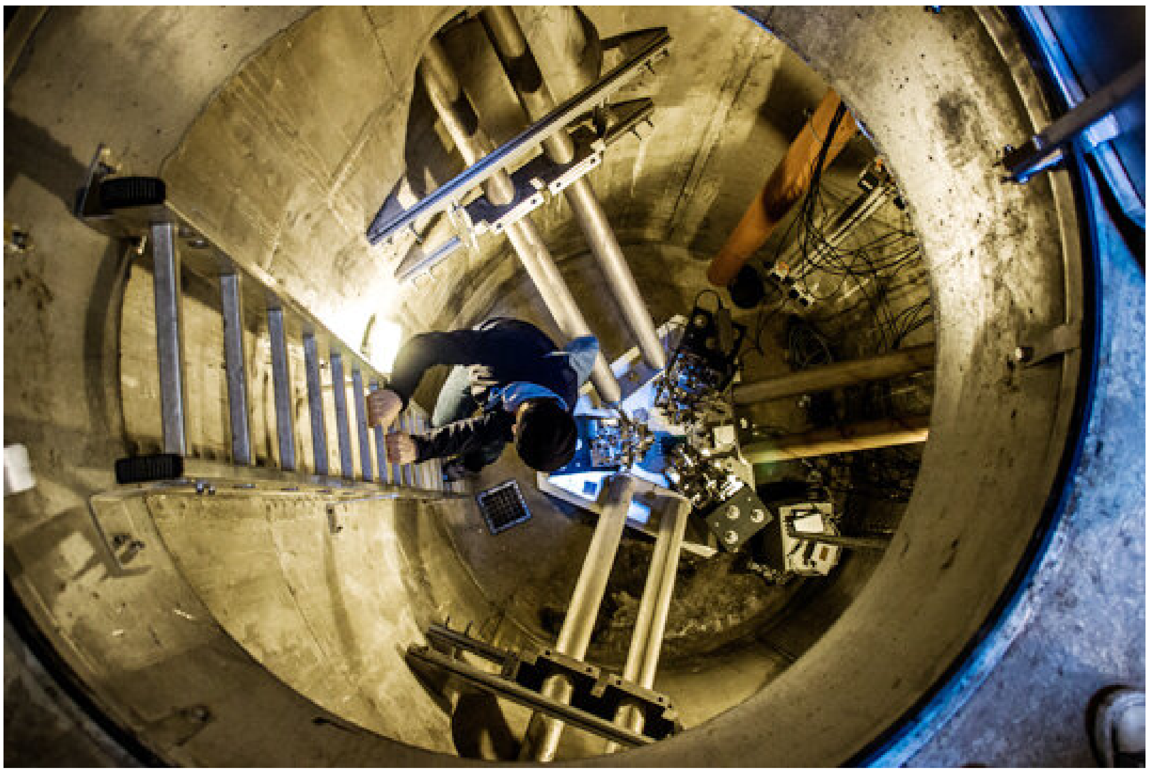

View of the ring laser in Fürstenfeldbruck west of Munich, which can monitor Earth's rate of rotation with high accuracy. It has now determined these parameters with unprecedented precision for a standalone ground-based instrument. Credit: LMU Geophysical Observatory

Geophysicists at Ludwig-Maximilians Universitaet (LMU) in Munich have measured Earth's spin and axis orientation with a novel ring laser, and provided the most precise determination of these parameters yet achieved by a ground-based instrument without the need for stellar range finding.

Buried amid the pastures and cropland near the town of Fürstenfeldbruck to the west of Munich is a scientific instrument that is 'one of a kind.' It's a ring laser named ROMY, which is essentially a rotation sensor. On its completion three years ago, the prestigious research journal *Science* hailed ROMY as "the most sophisticated instrument of its type in the world." The acronym refers to one of its uses—detecting rotational motions in seismology. But in addition to quantifying ground rotation caused by earthquakes, ROMY can sense minute alterations in the Earth's rotational velocity as well as changes in its axis of orientation. These fluctuations are caused not only by seismic events but by factors such as ocean currents and shifts in the distribution of ice masses, among other factors.

Now a group of geophysicists led by Professors Heiner Igel (LMU) and Ulrich Schreiber (Technical University of Munich) report the results of the first continuous high-precision measurements of the Earth's rotational parameters in the journal *Physical Review Letters*. The authors refer to the data as a 'proof of concept'—and the results demonstrate that ROMY has passed its first real test with flying colors. "It's the most precise instrument for the measurement of ground rotations in the world," says Igel, Professor of Seismology at LMU. Accurate quantification of rotational motions is also important for determining the contribution of seismic noise to the data acquired by the two gravitational wave detectors currently in operation (LIGO and LIGO Virgo). So ROMY's applications extend well beyond observational seismology on our planet.

With the aid of a grant from the European Research Council (ERC), Igel and Schreiber developed the concept for the ROMY ring laser. The construction of the observatory, which was largely financed by LMU Munich, was an extremely challenging undertaking. Even the concrete structure in which ROMY is housed had to be erected with millimeter precision. ROMY is made up of a set of four ring lasers that form the faces of an inverted tetrahedron (and each side is 12 m long). Two laser beams circulate in opposite directions around each face of the instrument. The beam traveling in the direction of rotation takes longer than its counterpart to complete each lap. This in turn causes its wavelength to be stretched, while other is compressed. The difference in wavelength depends on the precise orientation of each face with respect to the direction and orientation of Earth's rotation. Data from three of the four rings suffice to determine all the parameters of planetary rotation.

The fact that the ring laser has more than met its design criteria is naturally a relief—and a source of great satisfaction—for Igel. "We are able to measure not only the orientation of the Earth's axis of rotation, but also its rate of spin," he explains. The method so far employed to measure these parameters with high accuracy relies on very long baseline interferometry (VLBI). This requires the use of a worldwide network of radio telescopes, which use changes in the relative timing of pulsed emissions from distant quasars to determine their own positions. Owing to the involvement of multiple observatories, the VLBI data can only be analyzed after several hours. ROMY has some considerable advantages over this approach. It outputs data virtually in real time, which allows it to monitor short-term changes in rotation parameters. Thus, the new study is based on continuous observations over a period of more than 6 weeks. During this time, ROMY detected changes in the mean orientation of the Earth's axis of less than 1 arc second.

In future and with further improvements, ROMY's high-precision measurements will complement the data obtained by the VLBI strategy, and will serve as standard values for geodesy and seismology. The measurements are also of potential scientific interest in fields such as the physics of earthquakes and seismic tomography, says Igel. "In the context of seismology, we have already obtained very valuable data on from earthquakes and seismic waves caused by ocean currents," he adds.

More information: André Gebauer et al, Reconstruction of the Instantaneous Earth Rotation Vector with Sub-Arcsecond Resolution Using a Large Scale Ring Laser Array, *Physical Review Letters* (2020). DOI: 10.1103/PhysRevLett.125.033605

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