Gravity potential measurement using optical lattice clocks and its applications to geodesy, seismology and volcanology in the future

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Gravity potential measurements using optical lattice clocks based on the general relativity are going to achieve a relative precision of an order of 10^{-18} in a few hours, corresponding to an order of centimeters in terms of height. Relativistic geodesy using optical lattice clocks allows us to directly determine the gravity potential at the Earth's surface, which is expected to improve a static geoid model serving as the reference of height, combined with other geodetic data. However, in plate subduction zones like Japan where crustal deformation is active compared with the stable continents, time variations in the gravity potential caused by tectonic phenomena should also be considered. In this presentation, geophysical impacts of monitoring temporal potential changes with a precision of 1 cm are discussed. Measured potential variations are much more sensitive to height changes of observation sites than to the underground mass redistributions. This means that optical lattice clocks can be used as an altimeter, which enables us to evaluate height changes observed with space geodetic techniques. The height changes determined from the potential measurement are free from the errors due to atmospheric phase delays in the GNSS. A more reliable and faster determination of height may improve a precision of monitoring water vapor in the atmosphere in the context of the GNSS meteorology. Gravity measurement is also sensible to height changes. However, it suffers from groundwater disturbances near the surface, which is almost negligible when measuring the gravity potential variation. Therefore, optical lattice clocks, when combined with gravity measurement, will help real-time monitoring of movements of crustal fluids such as magma, by correcting for apparent gravity changes due to rapid height changes.

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