# Geodetic leveling and gravity measurements for reducing uncertainty of NICT optical frequency standards owing to gravitational redshift and its quantitative evaluation - Part 1

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The International System of Units (SI) defines one second as the time it takes a cesium-133 atom at the ground state to oscillate exactly 9,192,631,770 times. International Atomic Time (TAI) is determined using the output of more than 400 commercial atomic clocks and atomic fountains over 50 national laboratories worldwide. The advancements of optical frequency standards in the last three decades have been dramatic, and the accuracy records of optical frequency standards surpassed those of microwave clocks in late 2000. Consequently, the redefinition of the second has been discussed in the community of time and frequency specialists since mid-2010.

The National Institute of Information and Communications Technology (NICT) has developed the Sr optical lattice clock and optical ion clocks employing In+ and Ca+, then provided Sr data to the BIPM to be referred to for calibrating the tick rate of TAI. The centimeter-level uncertainty of site elevation has caused $10^{-18}$-level frequency uncertainties of optical frequency standards. Therefore, continuous monitoring of vertical movements will be necessary.

Since early 2021, NICT and the Geospatial Information Authority of Japan (GSI) have been jointly conducting leveling surveys and relative gravimeter observations in Koganei NICT headquarters. The contribution of uncertainty due to gravitational redshift in the total uncertainty of the NICT-Sr optical lattice clock has been reduced to the $10^{-19}$ level. We have started to investigate the temporal variation of the ground water level at Koganei and introduced the Micro-g LaCoste's gPhoneX gravimeter last year. We will start continuous gravity measurements in early FY2022 after the gPhoneX calibrations using the FG5 absolute gravimeter by supporting GSI and the National Institute of Polar Research (NIPR). In addition, we will investigate the effects of vertical movements on optical frequency standards measurements using GNSS measurements. We would like to thank Professor Tanaka of the University of Tokyo and Dr. Nawa of The National Institute of Advanced Industrial Science and Technology (AIST) for supporting our research.

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