Japanese Underground Gravitational Wave Detector

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A laser interferometer gravitational wave antenna with a baseline length of 20 m (LISM) was developed at a site 1000 m underground, near Kamioka,
Japan. This project was a unique demonstration of a prototype laser interferometer for gravitational wave observation located underground. The extremely stable environment is the prime motivation for going underground. In their paper (S Sato et al. 2004 arXiv.org/abs/gr-qc/0403080), S. Sato et al. demonstrated ultra-stable operation of the interferometer and reported a well-maintained antenna sensitivity.

In order to detect the rare astrophysical events that generate gravitational wave (GW) radiation, sufficient stability is required for GW antennas to allow long-term observation. In practice, seismic excitation is one of the most common disturbances effecting stable operation of suspended-mirror laser interferometers. A straightforward means to allow more stable operation is therefore to locate the antenna, the “observatory”, at a “quiet” site.

First-generation ground-based gravitational wave antennas (LIGO-I, VIRGO, GEO600,
TAMA300) are expected to come on-line early in this decade as a global network searching for astrophysical gravitational wave radiation. At present, some of the detectors are already operating intermittently, hoping to observe the spacetime strain of the universe.

The aim of these international projects is to directly detect gravitational radiation, faint ripples in the spacetime fabric. There are several kinds of expected astrophysical sources, including chirping gravitational waves from inspiraling compact star binaries, burst signals from supernovae explosions, and the stochastic background radiation. The expected event rate of these sources is, however, quite low even if the uncertainty of the population estimate is taken into account, so, to avoid missing these rare and faint signals, stable operation of the detector, keeping the duty cycle and the detector sensitivity high and also keeping the data quality high, are indispensable requirements for a gravitational wave observatory. In general, the technologies used in a laser interferometer are based on an ultra-high precision measurement pursuing extremely high sensitivity, so the instruments are very sensitive to almost all kinds of noise, disturbances and drifts. The noise source that most commonly disturbs stable operation of suspended-mirror laser interferometers is seismic excitation. The most promising solution for this problem is to avoid the source of these disturbances by selecting a quiet environment for a detector site.

The goal of this project (LISM, Laser Interferometer gravitational-wave Small observatory in a Mine) is to demonstrate stable operation of the laser interferometer and to obtain high quality data for searching for gravitational waves at a well-suited observatory site.

The 20-m baseline laser interferometer was originally developed for various prototyping experiments at the campus of The National Astronomical Observatory of Japan, in Mitaka, a suburb of Tokyo from 1991 to 1998. In 1999, it was moved to the Kamioka mine in order to perform long-term, stable observations as LISM. In this paper, the merit of going underground and the demonstrated stable operation of the antenna are reported.

Kamioka is in a mountainous area, about 220 km west of Tokyo. The observatory site is inside a mountain. The laboratory facility was built 1000 m underground beneath the top of the mountain, utilizing some of the tunnel network that was originally developed for commercial mining activity. This site is also well-known as the site for the Super-Kamiokande nucleon decay experiment and other cosmic ray experiments, which all need a low-background environment deep underground. This site is the most probable candidate for the future Japanese fullscale gravitational wave antenna project, LCGT.