Status of LCGT and CLIO

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Abstract. The Japanese gravitational wave proposal, LCGT (Large-scale Cryogenic Gravitational wave Telescope), is to construct a 3km underground interferometer with cryogenic mirrors in the Kamioka Mine. CLIO (Cryogenic Laser Interferometer Observatory) is a 100m-baseline underground cryogenic interferometer built at the same site to serve as a bridge connecting CLIK (7m-baseline prototype cryogenic interferometer) and the planned LCGT. The site of CLIO is near the Super-Kamiokande neutrino detector. The tunnel for CLIO was dug in 2002, and a strain meter for geophysics was installed in the same tunnel in 2003. CLIO was installed in 2005 and the operation started in 2006.

1. Introduction
In 1990’s, large laser interferometers were built to detect gravitational waves. There are four kilometer-scale interferometers in the world, three LIGO interferometers in U.S. [1] and one Virgo interferometer in Italy [2], and two sub-kilometer-scale interferometers, GEO600 in Germany [3] and TAMA in Japan [4]. LIGO has just finished the long-term observation named S5 since the end of 2005. The sensitivity of LIGO is good enough to detect coalescing binary neutron star events at 16 Mpc away [5]. But we want to expand the range of observation to 180 Mpc during the next decade. The sensitivity of LIGO will be improved by one order when the next major upgrade is completed (Advanced LIGO [6]). The Japanese plan, LCGT [7], is to construct a 3km underground interferometer with cryogenic mirrors in the Kamioka Mine. The merit of constructing underground is that the seismic motion is much quieter. The seismic noise is expected to be smaller by two orders of magnitude than that in the city area. The mirror cooling is adopted to reduce the thermal noise of mirrors, which is the major noise source in the signal band when the seismic and quantum noises are suppressed enough. We expect that LCGT will detect one event per month.

2. Source of gravitational waves
The target source of LCGT is the coalescence of binary neutron stars at 180Mpc. The theory of general relativity predicts that orbital energy and angular momentum are carried away from the binary star system by gravitational waves radiated from the system. The binary star is one of the most common sources of gravitational wave, and is the simplest case understood. In 1974, Joseph Taylor and Russell Hulse found a binary neutron star in our own galaxy. The period of the orbital motion is 7.75 hours, and is decreasing by about 76 millionths of a second per year. The effect was just as Einstein’s theory predicted. The point is that the binary neutron star will merge for the last time and make a black hole with strong gravitational wave radiation. Another source is the continuous gravitational wave radiated from nearby pulsars with rapid rotation. LCGT is expected to have a good sensitivity below 100Hz and suitable for detecting continuous waves.
3. CLIO
CLIO [8,9] was constructed to demonstrate two unique technologies of LCGT, one to utilize quiet and stable environment in the Kamioka mine and another to adopt sapphire mirrors at cryogenic temperature for thermal noise reduction. CLIO has the locked Fabry-Perot interferometer configuration equipped with a ring mode cleaner for the laser frequency stabilization and the cooling system using refrigerators to cool the sapphire mirrors at 20 K. Whole of the interferometer is housed in tunnels as shown in Fig. 1. The Kamioka mine is located on very hard bedrock and its elastic wave velocity reaches up to 5000 m/sec.

Cryogenic cooling system is shown in Fig.2 [10]. We use pulse-tube-type cryocoolers with low mechanical vibrations. The sapphire mirrors with 10cm in diameter are suspended by pure aluminium wires and cooled down to 20K within a week.

Figure 1. Overview of CLIO with the Mode Cleaner and the Cryostats

Figure 2. Cryogenic cooling system of CLIO is described. It is connected to several meter vacuum pipes with radiation shield inside.
4. Geophysical strain meter
At the same site, a geophysical strain meter with 100 m baseline [11, 12] was constructed to detect directly the earth core resonance mode in the milli-herz frequency range. It consists of a Michelson interferometer whose mirrors are fixed on the bedrock. The second harmonics wave length (532 nm) of YAG is used for the light source and its frequency is stabilized within an absorption line width of iodine gas [13].

5. Summary
CLIO was constructed in the Kamioka Mine to demonstrate the cryogenic techniques for LCGT. We started the operation of CLIO in 2006. The 57-hours observation data were taken in February 2007 and analyzed for continuous gravitational wave from the pulsar J0835-4510 (Vela pulsar) at the frequency twice of its rotational frequency (~ 22.38 Hz). We use an analysis method based on a matched filtering with a correction of pulsar spin down, a Doppler effect caused by the relative motion between the pulsar and the Earth, and so on [14]. The result of analysis will be submitted soon [15].

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