Measurement of seismic motion at Large-scale Cryogenic Gravitational wave Telescope project site

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Abstract

The LCGT interferometer will be constructed in Kamioka mine because seimic motion is extremely small. However, in previous investigations, only the seismic motion around the center of the mine was measured. Since the size of the LCGT interferometer is comparable with that of the mountain, the mirrors must be far from the center. We measured seismic motion of inside and outside of the mine to investigate the position dependece. Seismic motion of outside of the mine is larger than that at

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center of the mine. The seimic motion in a mine tunnel is enough small at location which is 50 m far from a entrance. Therefore, "underground" is an important keyword for LCGT. Ditches to bring groundwater to outside should be 60 m far from the main mirrors.

1 Introduction

LCGT (Large-scale Cryogenic Gravitational wave Telescope) is one of the second generation projects of interferometeric gravitational wave detectors. One of the key issues of LCGT is a extremely silent site, Kamioka mine. This mine is in Hida city, the north side of Gifu prefecture (220 km west from Tokyo), Japan. Previous measurment showed seismic motion in Kamioka mine is 100 or 1000 times smaller than that in suburb area. It implies not only small seimic noise but also stable operations of the interferometer. However, here is a problem; all locations of the previous measurement were near the center of the mine. Since the size of the LCGT interferometer (the length of baselines is 3 km) is almost the same as the mountain, the mirrors must be far from the mine center. Therefore, the position dependence of seismic motion should be investigated. We measured seimic motion at various points in and near Kamioka mine (May 2005). The results are summarized in this report[1].

2 Outline of Kamioka mine

Kamioka mine is in Ikenoyama. The altitude of the top of this moutain is about 1400 m. The altitude of the mine entrance is about 300 m. The (Atotsu and Mozumi) tunnels (in Fig. 2) from the entrances to the center of the mine (a few km length) are almost in horizontal planes. Since the center of the mine is below the mountain top, the mine center is "1000 m underground".

Before our investigation, seismic motion in Kamioka mine was measured at various points as shown in Fig. 1, the mine office [2], in front of the SuperKamiokande[2] [3], LISM site[3] [4], and CLIO site[4] [5]. Their results were similar; the seimic motion in Kamika mine is 100 times or 1000 times smaller than that at suburb area. Based on their results, the

[1] The author (Yamamoto) reported these results in the meeting of Physical Society of Japan (14 September 2005 at Osaka City University)[1].

[2] SuperKamiokande is the world famous water Cherenkov neutrino detector which proved the neutrino oscillation [6].

[3] LISM(Laser Interferometer gravitational-wave Small observatory in a Mine) is the project for a 20 m baseline interferometric gravitational wave detector in Kamioka mine [4].

[4] CLIO(Cryogenic Laser Interferometer Observatory) is the project for a 100 m baseline cryogenic interferometer [7]. This is the prototype for LCGT.

linear spectral density of the seismic motion in Kamioka mine is often desctibed as

$$\sqrt{G(f)} = 10^{-9}[\mathrm{m}/\sqrt{\mathrm{Hz}}]\left(\frac{1\ \mathrm{Hz}}{f}\right)^2. \tag{1}$$

However, all points of the seimic motion measurement were near the center of the mine nevertheless the mirrors of the LCGT interferometer are far from the center as shown Fig. 1.

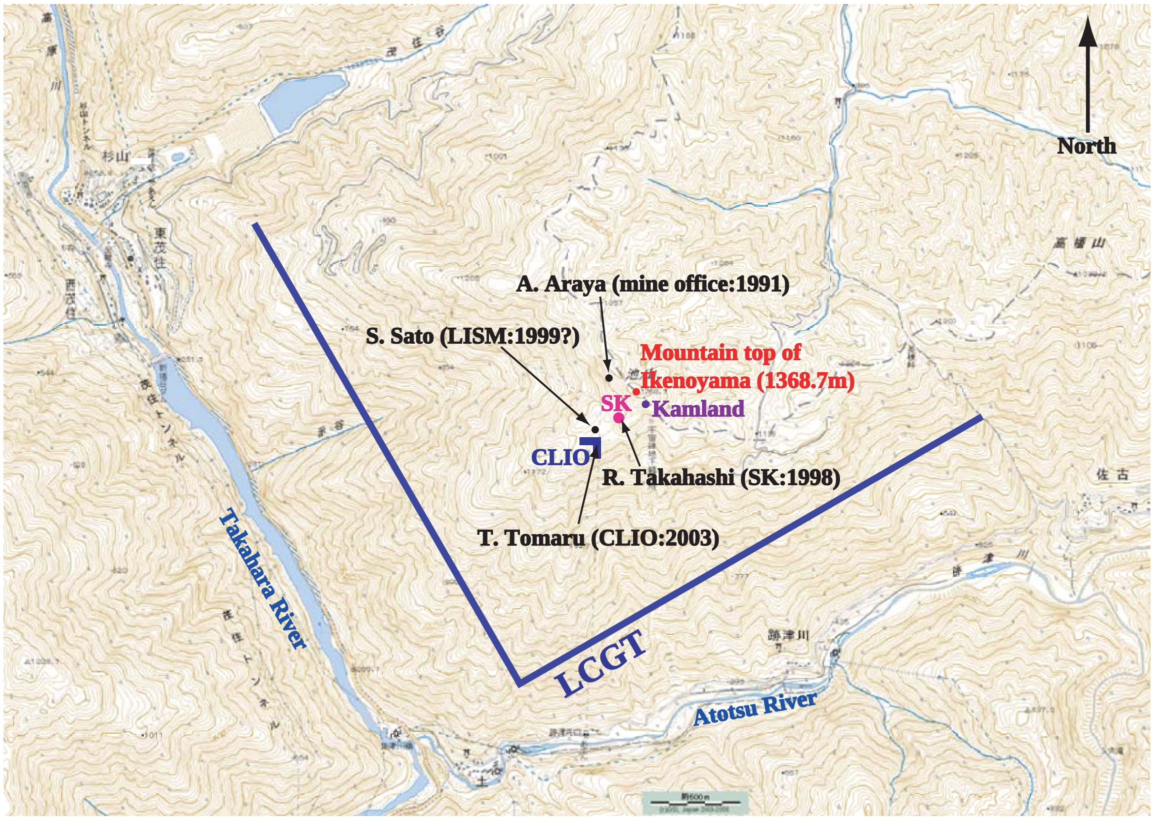

Figure 1: Map of Kamioka mine. This mine is in Ikenoyama. The top of this mountain is around the center of this map (red point). The center of mine is below this top. There are Atotsu and Takahara rivers on the south and west sides of Ikenoyama. Previous seismic motion mearement points are shown (A. Araya [2], R. Takahashi [3], S. Sato [4], T. Tomaru [5]). The blue thick lines are baselines of the LCGT interferometer. The length of baselines is 3 km.

3 Locations of measurement

We measured seismic motion at various points in and near the mine (red points in Fig. 2). The points of outside of the mine were as follows. There is the Atotsu river on the south side of Ikenoyama. We measured seimic motion at 3 positions along this rever (Do, Atotsu (mine entrance) office, 500 m west from Atosu office). On the northwest side of the mine, there is the domitory of Institute for Cosmic Ray Research. We measured motion on the entrance of the domitory. Near this domitory, there is the Mozumi office and the entrance of the Mozumi tunnel. We measured seismic motion at outside of the Mozumi office.

The Mozumi tunnel is straight from the entrace to the mine center. We measured seismic motion in this tunnel to investigate the position dependece of seismic motion (0 m, 50 m, 100 m 200 m, 500 m and 800 m from entrance). Moreover, as a reference, we measured seismic motion at the CLIO cite (center of mine).

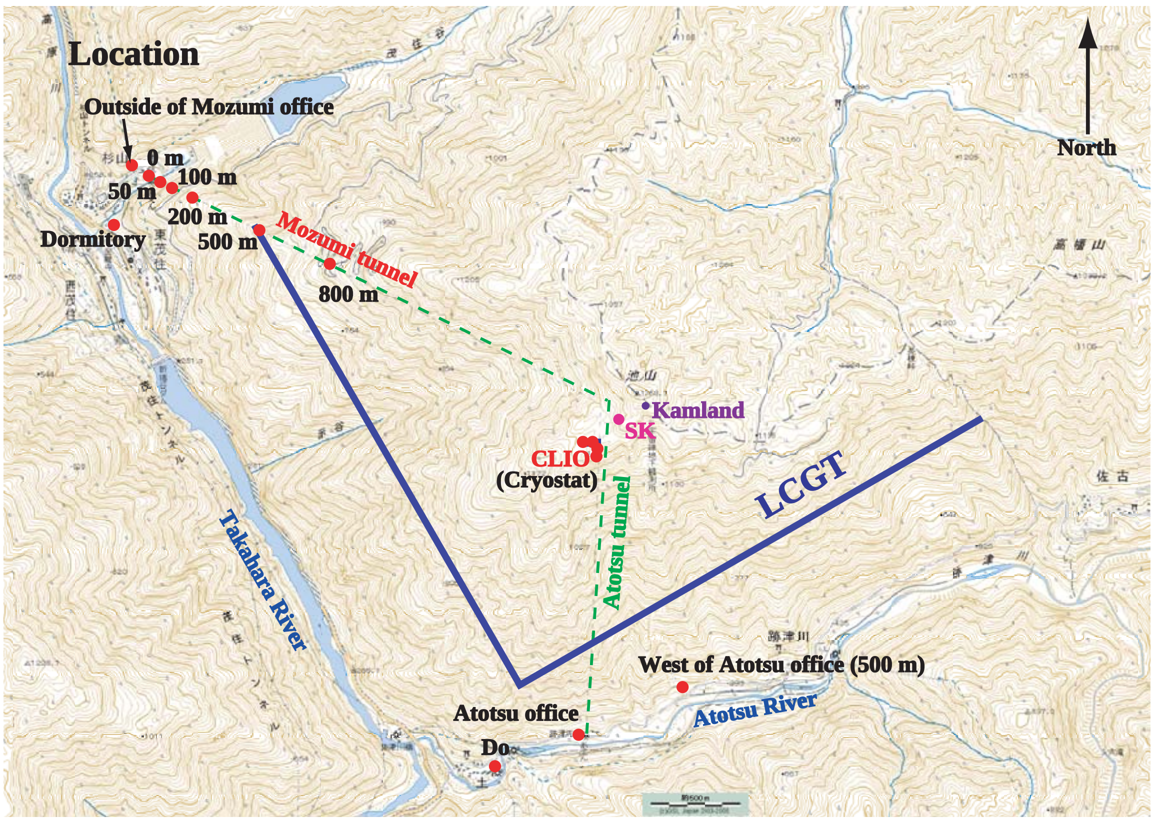

Figure 2: Map of Kamioka mine. Our seismic motion mearement points are shown (red points). Measurement points of outside of the mine were Do, Atotsu (mine entrance) office, 500 m west from Atosu office, domitory, outside of Mizumi office. We also measured seismic motion along the Mozumi tunnel (0 m, 50 m, 100 m 200 m, 500 m and 800 m from the entrance). As a reference, we measured seismic motion at the CLIO cite (center of mine). The blue thick lines are baselines of the LCGT interferometer. The length of baselines is 3 km.

4 Measurement method

We used commercial inteferometric accelerometers, RION LA-50 [8]. This is about 15 cm in length and less than 10 cm in diameter. It is able to measure horizontal and vertical direction acceleration. The observation band is between 0.1 Hz and 100 Hz.

In almost cases of our investigation, it was not possible to use AC power supplies as like usual experiments in a laboratories. We prepared two large batteries and a DC-AC covertor. After measurement in a day, these batteries must be charged in that night (if we use them on the next day).

Except for the Mozumi tunnel, we put accelerometers on a flat surface when seimic motion was measured. In the Mozumi tunnel, it was difficult to find appropriate a flat surface. We brought aluminum plates and fixed them on the wall of the tunnel using cement. The accelerometer was put on this plate and fixed as shown in Fig.3.

Figure 3: Photograph of an accelerometer fixed in the Mozumi tunnel.

5 Results

5.1 Outside of mine

The Fig. 4 shows that typical (horizontal) seismic motion[5]. Vertical motion is similar to horizontal one. Below 1 Hz, the seimic motion is comparable with that at the center of the mine (CLIO perpendicular end). However, above 1 Hz, the seismic motion is larger. Moreover, above 10 Hz, the seismic motion of outside of the mine is comparable with that at Kashiwa near Tokyo although Kamioka mine is far from large cities. The key word "underground" is essential for the LCGT project.

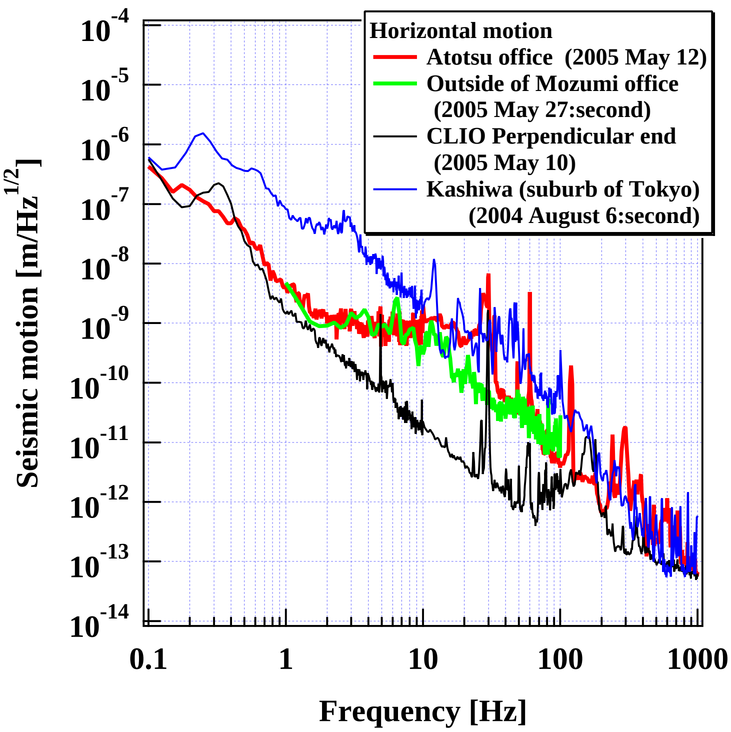

Figure 4: Typical measured seismic motion of outside of Kamioka mine (Atotsu office (red) and outside of the Mozumi office (green)). As references, the seismic motion at the CLIO site (center of mine, black) and Kashiwa (suburb of Tokyo, blue) are also shown.

[5]The results of the other locations were similar.

5.2 Inside of mine

Figure 5 shows the horizontal[6] seismic motion in the Mozumi tunnel. The seismic motion is enough small[7] even if the distance from the entrance is only 50 m. The mirrors must be at least 50 m far from the ground.

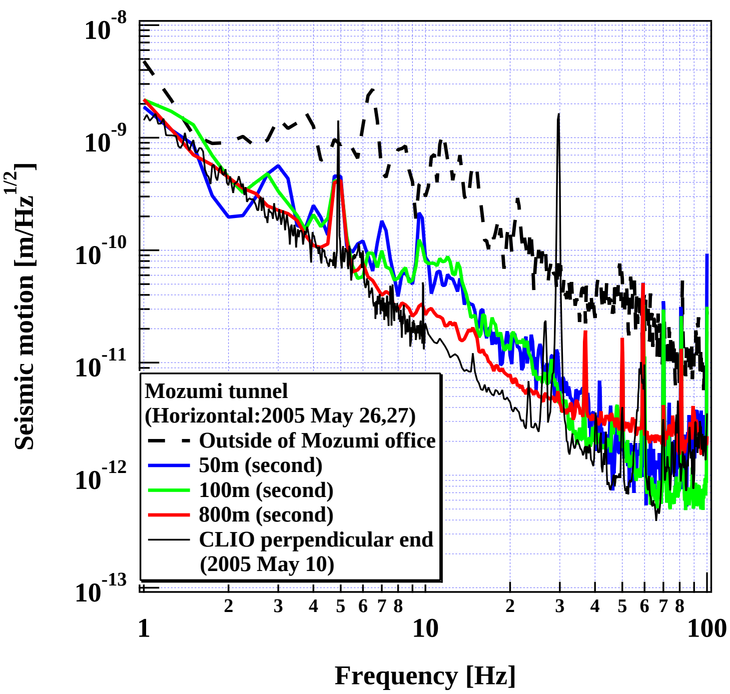

Figure 5: Typical measured seismic motion in the Mozumi tunnel (the distances from the entrance are shown). As references, the seismic motion at the CLIO site (the center of the mine, black solid) and outside of the Mozumi office (black dashed) are also shown.

[6]Unfortunately, after measurement in the Mozumi mine, it was revealed that the RION accelerometer for vertical measurement had problems: worse sensitivity (this sensivity level was about 10 times larger than expected seismic motion). However, at least, we are able to conclude that vertical seismic motion at 50 m (and deeper points) is about 10 times smaller than that of outside of mine.

[7]The results at 200 m and 500 m were a few and 10 times larger than that at the center of the mine, respectively. At 800 m, the seismic motion was measured at twice. Figure 5 shows the second result. The first result was comparable with that at 500 m. The measured seismic motion in time domain showed that the root mean square of seismic motion sometimes becomes larger (maybe, owing to the water current in the ditch). We guess that this is the reason why the 200 m, 500 m, and first 800 m results were larger.

5.3 Problem of water

There are many groundwater sources in Kamioka mine. In order to bring this water to outside, there are ditches along Atotsu and Mozumi tunnels. Ditches along the LCGT interferometer baselines should be necessary. We found that the sound of water current in the Mozumi tunnel is large. Although the effect of this sound on the interferometer output is not known[8], it is better that these ditches are at least 60 m far from mirrors. The reason of the 60 m distance is as follows. The seismic motion around the perpendicular end mirror of the CLIO interferoemeter is enough small. The distance between this perpendicular end mirror and the Atotsu tunnel is 60 m. There is a large ditch along the Atotsu tunnel and a lot of water always flows.

6 Summary

We measured seismic motion of inside and outside of Kamioka mine to search suitable location of mirrors of LCGT interferometer. Seismic motion of outside of the mine above 1 Hz is larger than that of the center of the mine. Moreover, above 10 Hz, seismic motion of outside is comparable with that in suburb area even though Kamioka mine is far from large cities. Measurement along the Mozumi tunnel showed seismic motion at the position which is 50 m far from the entrance is enough small. Therefore, mirrors of LCGT should be at "more than 50 m" underground. In order to bring groundwater to outside, ditches along baselines of LCGT are necessary. Water current might be a source of noise. According to the experience of the CLIO interferometer, ditches must be 60 m far from main mirrors of LCGT.

Acknowledgment

We thank staffs of Kamioka mine because this investigation was impossible without their support. Especially, we appreciate kindness and patience of Mr. Nishitani. He drove a truck along the Mozumi tunnel for our measurement and waited in the cold tunnel until our measurement was finished.

References

[1] K. Yamamoto *et al.*, *Measurement of seismic motion at Large-scale Cryogenic Gravitational wave Telescope project site*, 14th September 2005, The meeting of Physical

[8] The root mean square of seismic motion in the Mozumi tunnel is larger than that at the CLIO site. There is no ditch in the CLIO site

Society of Japan, Osaka City University, Osaka, Japan (JGW-G0500217. All important information in these slides can be found in this report. The size of these slides are huge. The word ”shaft” in these slides means ”tunnel”).

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[8] http://www.kobayasi-riken.or.jp/news/No21/21_5.htm (in Japanese). Web site of RION is http://www.rion.co.jp/english/.