Report of the

Technical Advisory Committee

for the

Large-scale Cryogenic Gravitational wave Telescope (LCGT)

Held at the Institute for Cosmic Ray Research,
University of Tokyo
on August 23, 2005

Date of this Report
October 1, 2005

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Executive Summary

The Technical Advisory Committee (TAC) for the Large-scale Cryogenic Gravitational wave Telescope (LCGT) met at the Institute for Cosmic Ray research (ICRR) of the University of Tokyo on August 23, 2005. The focus of this meeting was to assess the readiness of LCGT as a project for possible near-term funding, and to give advice on the technical aspects of the project. The Technical Report of LCGT (dated 10 August 2005) was provided by the LCGT team to the TAC in advance of the meeting. In addition, three of the committee members visited the Kamioka site and toured the CLIO facility there. At the committee meeting, presentations on the most important technical aspects of the project were made by team members, and the TAC had the opportunity to question and discuss issues with the relevant team members. Based on these presentations, the TAC discussed its findings in executive session and agreed on the conclusions and observations given in this Executive Summary.

The committee found the scientific case for LCGT to be strong, as have similar committees assessing other large gravitational wave projects (Advanced LIGO, Virgo, etc). The most accurately predictable signals come from the in-spiral phase of binary neutron stars—at its design sensitivity, LCGT is likely to detect these at a rate of 5-10 per year. Other sources, such as binary black holes, are more speculative, but the LCGT sensitivity makes them also good candidates for searches. High sensitivity, combined with a favorable geographic location to complement other planned interferometers, make LCGT an important component in a global network.

The TAC discussed the plan to build two detectors sharing a common vacuum system for the long arms, and concluded that the relatively low cost for the second detector is justified. Used with care, the two detectors can make stand-alone detections of in-spiral and burst gravitational waves, and enables a high sensitivity search for a stochastic background.

The TAC's assessment is that the LCGT conceptual design is fundamentally sound, with a substantial body of testing to back it up. There are many options in the design and many decisions to be made, but the research to support these decisions is underway. Care must be taken in every decision, to ensure that all impacts are considered. Some issues in the design of LCGT (e.g., the digital control system, or the possible need to deal with parametric optical instabilities) have not yet been elaborated, but none of these appear to be insurmountable, and many can benefit from collaboration with other projects in the world where similar problems are being addressed.

In particular, the feature of LCGT which most distinguishes it from large gravitational wave interferometers being planned elsewhere in the world (Advanced LIGO, Advanced Virgo, GEO-HF) is the use of cryogenics. This is a technically challenging undertaking, but many of the key aspects of the design have already been demonstrated individually and an integrated test (CLIO) is underway in Kamioka mine. The demonstration of the required heat removal capability with no increase in vibration at the cold-stage is a very promising and important development. The committee believes that research and development for this part of the project is moving forward well.

Other unique aspects of the design include the underground location to reduce ground vibrations ("seismic noise") and the choice of sapphire as the mirror substrate material, taking advantage of its high thermal conductivity and low thermal expansion characteristics at cryogenic temperatures. The committee found both of these choices to be well-justified.

The LCGT team has developed good working relations with other large projects in the world through the TAMA project, including a recently established collaboration with LIGO on sapphire optics. The ultimate value of a large detector such as LCGT can only be realized in the context of a global network. The committee encourages the LCGT to continue its international collaborations, and to expand them whenever possible.

The committee heard about the plans to organize the project by transferring staff from NAOJ to ICRR if LCGT is approved for funding. The current team will need substantial augmentation to succeed with such an ambitious project, but the senior staff in LCGT are capable physicists and experienced in gravitational wave detection. If the project is funded, it will be possible to attract first-rate postdocs, and the senior staff should be able to integrate them into the project rapidly.

Based on these considerations, we recommend a prompt start to the project. The scientific case is recognized internationally, the project team is strong, and the technology, though challenging, is feasible. If it moves forward within the next one to two years with adequate budget and support, LCGT can have a leading position among the world's gravitational wave detectors.

Report of Technical Advisory Committee for LCGT

1. Introduction

The Technical Advisory Committee for the Large-scale Cryogenic Gravitational wave Telescope (LCGT) met at the Institute for Cosmic Ray research (ICRR) of the University of Tokyo on August 23, 2005. The focus of this meeting was to assess the technical readiness of LCGT as a project for possible near-term funding, and to give advice on the technical aspects of the project; cost and management were not included in the charge to the committee. The Technical Report of LCGT (dated 10 August 2005) was provided by the LCGT team to the TAC in advance of the meeting. In addition, three of the committee members (Cerdonio, Drever and Whitcomb) visited the Kamioka site and toured the CLIO facility there. At the committee meeting, presentations on the most important aspects of the project were made by team members, and the TAC had the opportunity to question and discuss issues with the relevant team members. We want to thank the LCGT for their openness and willingness to answer questions.

Based on these presentations, the TAC discussed its findings in executive session and agreed on the conclusions and observations given in the Executive Summary. Details of the assessment of the LCGT program are given in the full text of this report. The charge to the TAC for this meeting is provided in Appendix A of this report. Members of the Technical Advisory Committee are listed in Appendix B. The agenda for the meeting at ICRR is given in Appendix C.

2. Scientific Case, Astrophysics

Gravitational waves are one of the most fundamental predictions of Einstein's theory of general relativity. The existence of gravitational waves was verified in 1993, indirectly, from observations of orbital change of the binary neutron star. But, direct observation has not done yet. The significance of direct detection of gravitational waves is not only that the Einstein's general relativity is verified, but also the parameter range of the Brans-Dicke theory which is another gravity theory probably can be decided quite accurately.

The importance of the direct detection is not restricted to just this fundamental physics verification. That is the start of new astronomy. Like neutrino astronomy, it means to obtain the new tool which observes outer space. If several detectors on the Earth can detect the gravitational wave which is emitted from the same object, big development will be expected to astronomy and physics. In that sense, it is quite important to detect the gravitational wave directly.

LCGT, like other projects of other gravitational wave detection, has chosen the gravitational waves which are emitted from in-spiral phase of the binary neutron stars most as its benchmark target because of its high detection probability. The binary neutron star loses energy and angular momentum due to the emission of the gravitational wave, spiraling in until finally it merges into a single object. Immediately before that merging,

the strong emission of the gravitational wave starts, because the gravitational field in binary system is strong, at the same time, the system is far from the axisymmetry. The reasons which motivate this process as a benchmark target are:
1. Emission of the gravitational wave has been predicted accurately by theoretical calculations. For various types of compact binaries (e.g., binary neutron star, or binary with a neutron star and a block hole), the template of the gravitational waveform is obtained already.
2. Especially, since the gravitational waveform has characteristic feature in the early phase of in-spiral of the binary neutron star, verification of detection can be easier.
3. The sensitivity of LCGT is sufficiently high from frequency dependent viewpoint to the gravitational wave from this process.

A key point is the estimate rate of detection. When the strength of the gravitational wave which is estimated theoretically is supposed, a single LCGT interferometer would detect the in-spiral of a binary neutron star within 185Mpc. In case of the two LCGT interferometers proposed, this range extends to 257Mpc. As for the number of binary neutron stars which exist in one galaxy, because it depends on the galaxy model, detection frequency changes in the model dependency. From the standard model of galaxy, a single LCGT interferometer would detect 2.8 events per one, and in the case of two LCGT, they are 7.9 events. Even pessimistic estimates give rates of one event per one year or more, so the detection target is thought to be set appropriately.

When the gravitational wave from the binary neutron star is detected, the effect which it causes to the physics is large. If it is possible to receive the signal with high S/N, the mass and the radius of the neutron star will be determined by comparing with the waveform which the theory estimates. Those data will be very important for the physics of neutron star as well as the study of the high density matter, nuclear physics, etc.

After the merging of the binary neutron star, if the combined mass of the neutron stars exceeds the mass limit of a neutron star, a black hole will be formed. If the ringing down mode of the gravitational wave due to quasi-normal mode of that black hole is verified, it becomes the first direct detection of black hole. Again, the significance is very large.

Cooperating with the gravitational wave detection project of Advanced LIGO and VIRGO etc. are quite important. The location of LCGT is especially important to complement any whole-sky coverage and for determining the source direction. The existence of a world-wide network is very important not only to give confidence concerning detection and to increase the reliability of waveform, but also to enable gravitational wave astronomy. That network can simultaneously determine the distance and the direction to the object. Being able to determine distance brings the new possibility of exceeding existing astronomy. For example, we can determine Hubble constant at the precision which may be higher than past.

LCGT carries out big contribution to other aspects of astrophysics. An example is the detection of burst gravitational wave which comes from supernova explosion or stellar-core collapse processes. The sensitivity of LCGT is sufficient to observe waves in the frequency of 100-1000 Hz from the Milky Way center. New knowledge will be obtained concerning the physics of last stage of evolution of the star.

Finally, for LCGT there is a possibility of detection concerning continuous gravitational wave emission sources. The candidate sources are pulsars or other rapidly rotating neutron stars. The high sensitivity of LCGT at low frequencies makes it particularly suitable for detecting these sources. It has been theoretically estimated that several detectable neutron stars exist, and these are quite important research objects.

From above we can conclude that LCGT can detect the gravitational wave several times per one year and those scientific meaning from there is quite important. The contributions to the development of physics and astronomy are unique.

3. Technical Feasibility and Issues

Infrastructure (Incl. Vacuum System)

One of the key features of LCGT is its underground location. The TAC feels that the location in Kamioka mine offers significant advantages for LCGT. The lower seismic noise and the potential for greater thermal stability are both significant. ICRR has substantial experience in operating in an underground environment, with the successes of Kamiokande and Super Kamiokande, and this should facilitate the construction and operation of LCGT. The TAC hopes that the tunnel excavation will be configured to offer sufficient flexibility to accommodate any unforeseen developments during design and commissioning, as well as the future evolution of a long-lived facility.

The vacuum system is one of the major cost items for LCGT, but the technology is well within modern capabilities. Careful attention should be made to maintaining the cleanliness of the vacuum system (including particulates) and the control of scattered light. Comparing LCGT requirements with the experience of other projects should give confidence in the design, or identify any areas where minor modifications might be warranted.

One of the major concerns about cryogenic interferometers has been the possibility of contamination of the optics. The design of LCGT has a cryogenic shield which extends in front of the optics to limit radiation and contaminants. In addition the mirrors are designed to be at ~20K, compared with the 8K surrounding shield. As a result, the contamination level of the LCGT mirror should be controllable.

Interferometer Design and Control

The LCGT interferometer is planned as a resonant-sideband extracted Fabry-Perot Michelson interferometer with modest power recycling. This configuration is similar to that planned for other interferometers being planned for the next generation. The LCGT team, through their experience with TAMA300 are experienced and knowledgeable about noise sources, design processes, and the complex interactions that govern these instruments.

The TAC does not see any insurmountable technical problem to the LCGT interferometer design and control systems. We see no reason to delay LCGT, even though the TAMA300 interferometer has not reached its design sensitivity. The limiting factors for TAMA300 are understood and are expected to be solved in LCGT. The success of other large gravitational wave interferometers around the world (LIGO, Virgo, GEO) lend confidence to the feasibility of interferometry at such sensitivity.

The cryogenic conditions of LCGT place some different requirements on the interferometer and its components, so the fact that some of the design decisions made by the LCGT team should not be surprising. Furthermore, some of the design decisions shown in the Technical Report may still be under discussion. However, it would be wise for the LCGT team to review the following issues and be sure that their decisions are justified:

- The beam locations proposed in the Technical report are much closer to the beamtube walls than other projects have chosen. This could make LCGT more sensitivity to the motion of the beamtube walls due to scattering and diffraction.
- The LCGT design described in the report uses rf modulation sensing for all degrees of freedom while some other projects have changed to a DC readout scheme.
- A full simulation of the interferometer to model the lock acquisition process and to verify that all features needed to smoothly and quickly acquire locked status should be undertaken before the design of the control systems is finalized.
- The same simulation that is developed for lock acquisition can be used to verify the design of interferometer control loops. These loops involve difficult trades between increasing gain to suppress disturbances, and not exciting resonances or injecting out of band noise into the servo loop.
- The other two multi-kilometer interferometers have made a commitment to a mostly digital control system to hold the interferometer in lock and aligned. Such systems have proven to have great flexibility and adequate speed and noise performance. It would be wise for LCGT to learn more about the capabilities of such systems before making final design decisions about the controls.
- Parametric instabilities, which couple optical energy stored in the arm cavities into resonant modes of the test masses via optical pressure (Brillouin scattering), has recently been identified as an issue for other large interferometers. The importance of this effect should be evaluated for LCGT.

We want to emphasize that these issues are not viewed as flaws in the LCGT design or issues which are insolvable—all are in the capability of current technology. The reason for mentioning them is to encourage comparisons with other projects and understanding why different decisions are appropriate.

Laser, Input and Output Optics

LCGT requires a unique optical system to perform the ultra-high sensitivity arm length comparison. A high performance and reliable laser and associated optics are proposed for LCGT system. The scientific and engineering balance between the light source and optics is critical to achieve the best LCGT performance.

1. Laser System

An injection locked system for frequency stabilization and a MOPA system for intensity stabilization have been developed for LCGT program. The injection locked system with a ring cavity slave laser is well designed. The laser-diode-pumped module with polarization rotating plate to compensate the thermally induced birefringent effect is quite reliable and high power single transverse mode operation has been demonstrated. The 100W-level MOPA system is compact. The stabilization experiments have been carried out successfully.

2. Input Optics

The plans for the input optics are fundamentally sound. Qualifying transmitting components for use at full laser power needs attention, but is expected to be technically achievable. The LCGT team should carefully consider the configurations of modecleaner and the optical isolation elements. The proposed 180 m modecleaner can be a significant source of backscatter into the interferometer and may be a source of excess noise. If further calculations prove this to be the case, simple modifications to the layout can remedy the problem.

3. Output Optics

An output modecleaner plays an important role in the design of LCGT, as it does with other interferometer planned for the next generation. However, the world-wide interferometer community has relatively little experimental experience with the performance of output modecleaners, and some tests (LIGO in particular) have not shown the noise improvements expected. Although the TAC expects that the LCGT output modecleaner will function as desired, we encourage the LCGT team to get experience with output modecleaners in high sensitivity interferometry as soon as practical.

4. Summary

The proposal of laser and associated optics for LCGT program is quite reasonable, and the development and construction of LCGT in Kamioka mine is feasible. To maximize success, the LCGT laser system should be very stable and reliable for construction and measurement. From this point, a conservative design policy is appropriate. The TAC is satisfied in the basic design and performance of this proposal.

5. Advanced research

Cryogenic techniques are applicable not only for test mass optics, but also for laser technique. High thermal conductivity and almost zero expansion in sapphire substrate are quite useful to develop higher performance and highly stable laser system at cryogenic operation. Such facts are well-known, but it is not easy to develop such a laser system for industrial application. LCGT brings together the technologies to develop such high performance laser system for science and industry. Such type of R&D program could be organized in parallel to the LCGT program in cooperation with the laser science community.

Cryogenic Mirrors

As an innovative instrument based on interferometry at cryogenic temperatures, cryogenic mirrors are at the core of LCGT, and thus their configuration is critical to reach the sensitivity goal. One of the unique features of the LCGT design is that operation at cryogenic temperatures makes thermal lensing negligible.

In particular the mirrors must allow one to reach the Standard Quantum Limit in the vicinities of 100 Hz, a choice common to other advanced interferometric detector projects. Thus the critical requirements are that i) they must contribute low thermal noise and ii) they must allow operation at cryogenic temperatures when the appropriately high light power is present in the cavities.

Thermal noise in the mirrors comes from 1) volume "brownian" fluctuations in the substrate 2) volume "brownian" fluctuations in the coating 3) temperature fluctuations in the substrate, via the thermal expansion 4) temperature fluctuations in the coating, via the thermal expansion.

The LCGT team investigated the basic idea and measured the fundamental performance of sapphire substrate at cryogenic temperature. They measured the mechanical Q value of higher than 10^8 at less than 10K. The thermal expansion coefficient of sapphire at 20K was measured to be 10000 times smaller than in room temperature. It is one or two order of magnitude smaller than CaF2. These experimental data reported in LCGT report gave a strong support for the LCGT concept as expected.

The choice of sapphire as substrate makes contribution 1) low enough, as the mechanical dissipation is very low, as demonstrated by Q measurements down to 4 K. As for 2), the loss angle of $SiO_2Ta_2O_5$ coating on sapphire has been measured down to 4 K, showing that its value and constancy with temperature is ultimately the limiting factor. The 3) and 4) noise sources are known as thermoelastic noise and have one contribution, which comes from the relation between fluctuation and dissipation and another contribution, which comes from fluctuations in the absorbed light power. According to recent theory, at low temperatures the coating would not intervene in either of the contributions, so the thermoelastic noise is evaluated from the thermoelastic properties of sapphire and found low enough. In the end the optimal mirror temperature for operation is identified as 20 K.

As for the heating of substrate and coating by light power in the cavities, it appears that at the temperature of choice 20 K the heat can be removed with a factor 3 safety margin.

One of the possible problems of the sapphire mirror is the absorption. The absorption coefficient of sapphire substrate is larger than that of silica substrate. LCGT program solves this problem by combining the cryogenic temperature and Resonant Sideband Extraction (RSE). The thermal lensing effect in sapphire is negligible at cryogenic temperature because of its high thermal conduction and lower temperature dependence refractive index. In addition, the RSE technique decreases the power flow in the interferometer optics. This is a unique feature of LCGT in comparison with other advanced interferometric detectors.

The proposed configuration meets comfortably the requirements and is substantiated by a wealth of dedicated measurements. The theory concerning the temperature behavior of substrate and coating thermoelastic noise has received recently confirmation by a few groups, including TAMA-LCGT, with experiments at room temperature and the results from available experiments with cavities at low temperature do not contradict its inferred validity at low temperatures.

In conclusion, the proposed concept for the cryogenic mirrors appears feasible with available frontier technologies.

Cryogenics

The requirement is to have in steady state the mirrors at 20 K, while properly insulated from mechanical vibrations and protected from condensation of contaminants coming from parts at higher temperatures.

A detailed design of heat flow and of heat shielding has been produced, in which cryocoolers remove heat at the required rate from shields at 100 K and 8 K respectively. This last shield is a large area colder than the mirrors which should guarantee that contaminants would rather condense there before reaching the mirrors. Heat links with vibration isolators connect the mirrors system to the 8 K shield to remove the heat the mirrors absorb from the light beam. Each sub-part requires somewhat different thermomechanical properties, which have been analyzed in detail to allow the choice of the proper material and of the proper geometry.

Cryocoolers of the kind to be used have been preliminarily tested and showed, as delivered, an excessive low frequency mechanical vibration noise. After a series of attempts, suitable modifications were proposed to the producer, which were then implemented in prototypes and, when tested, performed according to requirements.

A full test of the heat flow design together with measurements of the vibration insulation levels is underway with the construction and operation of the CLIO interferometer. Once it is fully operational, the result will be a strong demonstration that requirements can be met with the available technology.

In conclusion the cryogenics appear quite feasible and should not present any particular risky feature, as the overall design and all the details appear well under control.

Seismic Isolation/Suspensions

The suspensions for the optics in LCGT must meet two sets of requirements: low mechanical loss to ensure low thermal noise, and adequate thermal conductivity to allow extraction of heat from the optics. The LCGT team has performed substantial research toward the design of these suspensions and has drawn widely from other research efforts around the world. Although much of the design is still to be worked out in detail, the TAC believes that all technical issues can be solved with current state-of-the-art technology.

One of the major advantages of the Kamioka site is its lower seismic noise compared with the locations of other gravitational wave interferometers around the world. The seismic isolation system is based on a design developed jointly with LIGO scientists for TAMA300. This system is well proven from laboratory tests and will be tested in an integrated way after its installation in TAMA300 during the next year. For these reasons, the seismic isolation system is expected to meet requirements with a minimum of risk.

Suspension Point Interferometer

One of the major challenges in development of an effective cryogenic laser interferometer is the removal of heat produced in the test masses without introduction of vibration from the cryocooling equipment above the very low levels allowable. Preliminary experiments and estimates for the LCGT have led to a proposed design with a separately isolated cooling system connected by soft heat-link wires via a suspension platform at a temperature of 14 K to an "upper mass". The test mass and the recoil mass are suspended from this isolation mass by sapphire fibers.

To reduce coupling of vibrations through the upper mass it is proposed that the upper masses at the ends of each interferometer arm are linked by a suspension point interferometer, with force feedback to minimize changes in their separation. This technique, although an old idea, does seem in principle to provide a good solution to the special vibration isolation problem here. Laboratory experiments have shown that motions in unwanted degrees of freedom may degrade isolation at some frequencies, but this may be controlled by careful design. Results as a whole are encouraging. Further, experimental work is recommended, and numerical simulation of the mechanical system may be helpful here.

The suspension point interferometer technique described does introduce the complexity of an additional interferometer, but this may be a simplified version of the main interferometer, and it can provide benefits including a potentially useful reserve in isolation. There may even be the later possibility mentioned of operation of the suspension interferometer as a separate gravity-wave detector at another frequency.

Data Analysis

The experience of researchers with TAMA data analysis gives them a good basis for projecting the requirements for the LCGT data analysis systems. A detailed analysis of the computing requirements for each type of search is recommended. Other projects in the world may be projecting higher computational needs, and this should be understood by the LCGT team. However, the technical requirements are achievable, and the only issue is to design an adequate system and to estimate the costs accurately.

The eventual need to operate LCGT as a key member in the international network (below) should also be taken into account in sizing the data analysis systems. This may impact the required data storage requirements (due to the need to store data from other projects), and computational power (because of computationally intensive network search techniques).

4. Role in International Network/International Collaborations

Beyond the initial detection of gravitational waves, the full information contained in the waves (the direction to the source, the waveform of each polarization component) can only be extracted by a network of detectors, widely spaced on the earth and with different orientations. Comparable sensitivities and frequency coverage is also important. The location of LCGT, at a large distance from the other large interferometric detectors (LIGO, and Virgo), makes it an important component of such a network. It is important for LCGT to continue to pursue collaborations with these other projects,

On technical and design matters for large gravitational wave interferometers, there is growing expertise and experience in the world that the LCGT team can take advantage of. In particular, there is now a substantial community of scientists who have experience with the design and commissioning of kilometer scale interferometers, and the LCGT team should take advantage of this expertise. In particular, it is important to understand if LCGT is making different design decisions from those being made by other projects around the world and to compare the basis for the differences.

The recent establishment of a collaboration with LIGO on the properties of sapphire is an important step in this direction. Other possible methods for strengthen collaboration with other international gravitational wave projects include participation in and sponsorship of small workshops focused on specific issues (such as parametric instabilities), and exchanges of scientists and postdocs with other projects for periods of weeks to months (for example, to learn about digital control systems).

5. Project Organization and Planning

ICRR, which is the host institute for the LCGT proposal, has been managed under the University of Tokyo as the national facility. ICRR has achieved the major advances in the field of non-accelerator physics and celestial physics, including the opening of neutrino astronomy.

During the development of the LCGT proposal, the ICRR researchers who are central to the proposal have maintained close relationships with the NAOJ researchers who maintain and manage TAMA and the KEK researchers who bring low temperature and vacuum technology. At the stage of research and development which is needed for LCGT planning, this organization is functioning effectively.

However, the TAC believes that during the period of LCGT construction, a restructuring of its organization is necessary. The committee heard about the plans to organize the project by transferring staff from NAOJ to ICRR during the construction phase of LCGT temporarily. This means that the organization, which is formed at present by 4 staff members, will be strengthened substantially. Due to the leadership of this core team, researchers from many other domestic institutions probably can be integrated smoothly. This committee expects that ICRR will pursue this reorganization seriously. Simultaneously, this committee advises ICRR to increase the number of staff, postdocs and engineers for LCGT to the maximum extent possible. Also, this effort offers the opportunity to invite the participation of researchers from around the world.

Appendix A

Charge to the LCGT Technical Advisory Committee

Expectation about LCGT-TAC

1) Evaluate the significance of LCGT in the world-wide GW detection network, the soundness of the objective, the reliability of the design, and point out the meaning of the construction in Japan as soon as possible.

2) Depict what is missing in the report for the technical realization of LCGT. Give advice on the design. For example, we didn't mention the digital control system in the report at all. Mentioning incompleteness of LCGT, if exists, is useful to promote the project.

3) Evaluate our technical skillfulness, our ability of conducting the research and the construction, comparing with other projects in the world.

Appendix B

Members of the LCGT Technical Advisory Committee

Cerdonio, Massimo
Professor of Padova University

Drever, Ronald W.P.
Professor of California Institute of Technology

Kawashima, Nobuki
Professor of Kinki University

Miyama, Shoken
Associate Director of National Astronomical Observatory of Japan

Ueda, Ken-ichi
Director of Institute for Laser Science,
University of Electro-Communications

Whitcomb, Stan (chair)
Deputy Director of LIGO

Secretary:
Ohashi, Masatake
Institute for Cosmic Ray Research

Appendix C

Agenda for the LCGT Technical Advisory Committee Meeting

23 August 2005

Executive session			(9:45-10:00)
1. Introduction			(10:00 – 10:40)
overview of LCGT	Kazuaki Kuroda	40min.	
2. Required technologies			(10:40 - 12:10)
Interferometer	Masaki Ando	30min.	
laser	Norikatsu Mio	30min.	
sapphire mirrors	Takashi Uchiyama	30min.	
- lunch -			
			(13:10 - 14:40)
vibration isolation	Ryu-taro Takahashi	30min	
SPI	Shinji Miyoki	30min	
cryogenic system	Toshikazu Suzuki	30min.	
- break -			
3. Strategy to detect GW			(15:10-16:00)
Sources, twin interferometers	Nobuyuki Kanda	40min.	
misc.		10min.	
Executive session			(16:00-17:00)
material and recommendations			