LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY
- LIGO -
CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Technical Note	**LIGO-T080074-00-R**	2008/06/29

Current Work on the LIGO 40m Noise Budget

W.M. Jones

Distribution of this document:

ISC Group

California Institute of Technology
LIGO Project, MS 18-34
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project, Room NW22-295
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
Route 10, Mile Marker 2
Richland, WA 99352
Phone (509) 372-8106
Fax (509) 372-8137
E-mail: info@ligo.caltech.edu

LIGO Livingston Observatory
19100 LIGO Lane
Livingston, LA 70754
Phone (225) 686-3100
Fax (225) 686-7189
E-mail: info@ligo.caltech.edu

http://www.ligo.caltech.edu/

1 Overview of Project

The Laser Interferometer Gravitational Wave Observatory (LIGO) is one of the most ambitious projects in modern physics. A joint effort between researchers at Caltech and MIT, LIGO hopes to simultaneously realize two goals

1. Verify by direct observation the existence of gravitational waves as predicted by general relativity.
2. Use the world's first gravitational observatory to make unique observations of the universe's most dense and least understood phenomena.

To achieve these goals LIGO employs three heavily modified Michelson Interferometers as gravitational wave observatories. The first observatory has an arm-length of 4 km and is located in Hanford, Washington along with the second observatory with a 2 km arm-length. The third observatory is located in Livingston, Louisiana and has an arm-length of 4 km. Multiple observatories located far from each other allows LIGO analysts to mitigate local effects by demanding coincident detection of a gravitational wave. Furthermore, with separated observatories, analysts may triangulate the source of an incoming signal. General relativity predicts that sources such as inspiraling neutron stars and certain types of stellar collapse will emit strong, polorized gravitational waves that will radiate outward through space at the speed of light. When such a gravitational wave passes through the dectector, one arm of the interferometer will lengthen while the other will contract. The 4 km interferometers can detect a change in arm-length on the order of 10^{-18}. Because the volume of space probed is proportional to the cube of the strain sensitivity [7], minimization of environmental and instrumental noise sources becomes paramount.

The level of precision required for the observatories, roughly a thousandth the diameter of a proton, demands careful catalogue and control of noise sources. Thee sources include environmental and instrumental noise sources:

1. Environmental
   - Seismic - This is noise associated with minor and major seismic disturbances near the observatory. These can include minor earthquakes, nearby constructions, or even a well used highway located near by. LIGO attempts to seismically isolate the mirrored test masses by placing the entire system on a series of stacks.
2. Instrumental
   - Shot noise This is noise associated with statistical fluctuations in the number of photons in the beam.
   - Thermal noise This is noise associated with heating of various elements of the interferometer. As an example, the laser light incident on the mirrored test masses raises the temperature of the test masses. The thermally excited test masses then begin to vibrate at detectable amplitudes [7].

- Shot noise This is noise associated with statistical fluctuations in the number of photons in the beam. To reduce thermal noise LIGO employs a lower power beam. With a beam of this type, the statistical nature of photon collision becomes noticeable.
- Sensor noise This is a general term for noise associated with particular sensors that control the interferometer (For example, the noise associated with the optical shadow sensor and electro-magnetic actuator (OSEM).).

The above is a small sample noise sources which must be accounted for by LIGO researchers. An accurate catalogue of noise sources and their effect on the interferometer is necessary to determine what is limiting the accuracy of the observatory [1]. This catalogue is a noise budget. To

2 Previous Work on 40m Noise Budget

Previous work to construct a noise budget for the 40m facility has centered around modifying existing methods for creating an automated noise budget. The sites at Livingston, Louisiana and at Hanford, Washington both use a set of MATLAB scripts to regularly create noise budgets. The goal is to modify that code to work at the 40 m site. These modifications

3 Current State of Noise Budget

The current noise budget is shown below

4 Future Goals

4.1 Noise Associated with OSEM System

As mentioned in the overview,

4.1.1 Calibration of the Bartington Magnetometer

References

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[7] LIGO Science Collaboration: *LIGO: The Laser-Interferometer Gravitational-Wave Observatory*, http://www.arXiv.org, 2007.