LIGO-T000088-00-R

AIGO: A Southern Hemisphere Second Generation Gravitational Wave Observatory

D.E. McClelland, D.G. Blair[1] and R.J. Sandeman
Department of Physics, The Australian National University
Canberra 0200, Australia.

Abstract

AIGO is a second generation long baseline laser interferometer gravitational wave detector planned to be constructed in Australia by an international consortium. We have embarked on a research program to conduct laboratory scale tests and construct numerical models of second generation detector concepts. Our aim is to develop and test the major components of an instrument, planned for construction toward the end of the decade, which has a sensitivity 10 - 100 times better than those presently under construction.

1. Introduction

The Australian Consortium for Laser Interferometer Detection (ACLID) is a consortium of Australian Universities and industry charged with tasks of
(i) designing a long baseline laser interferometer gravitational wave detector - the Australian International Gravitational wave Observatory (AIGO) - with a sensitivity 10 to 100 times better than those currently under construction;
(ii) carrying out R&D toward the construction of such an instrument and
(iii) investigate national and international participation in the project. To date, India, China and Argentina have joined the AIGO project. India will be investigating vacuum system design and fabrication as well as data processing; China has expertise in optical componentry whilst Argentina will be contributing to the optimisation and fabrication of the vibration isolators.

Fig.1 shows a predicted sensitivity vs. frequency for the first generation of long baseline interferometers[1]. Below 20 Hz, the noise floor is dominated by seismic noise; between 20 Hz and about 1 kHz, thermal noise in the mirror masses and suspension system are dominant whilst above 1 kHz shot noise is the limiting factor. In addition interferometers are very sensitive to wavefront distortions. To achieve the 10 to 100 fold improvement, the Australian university participants - the Australian National University (ANU), the University of Western Australia (UWA) and the University of Adelaide (UA) will focus on the following main areas: vibration isolation and thermal noise suppression; advanced optical topologies with signal extraction and control; and the development of high power, stabilised lasers and novel optical elements.

---

[1] Department of Physics, University of Western Australia

MG7

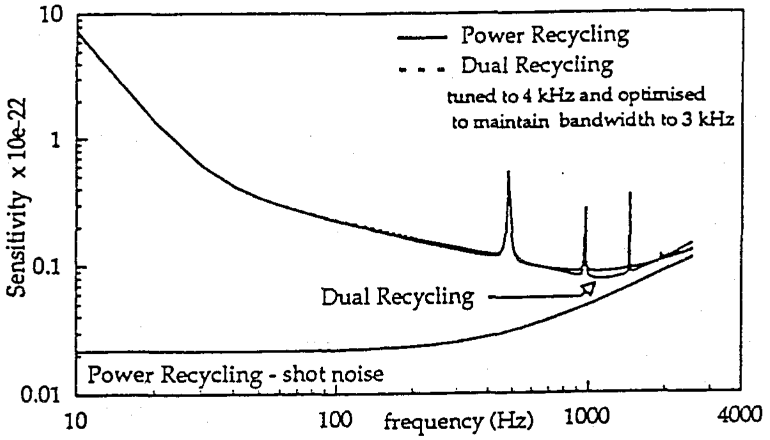

Fig.1 Predicted sensitivity vs. frequency for a 3 km baseline, Fabry-Perot arm cavity Michelson interferometer with power recycling, and tuned dual recycling. The bottom trace depicts the shot noise floor in the case of power recycling.

2. Vibration Isolation and thermal noise suppression

We have already designed and built all-metal vibration isolators with a cut-off frequency below 10 Hz[2]. Recently, at UWA, we have perfected a passive pre-isolator based on an inverted pendulum design, which has 30 mHz frequency (see Fig.2a). Perhaps the most significant breakthrough however, is a test mass design based on a physical pendulum which allows complete elimination of violin string modes (Fig.2b, traces (a) and (b)).

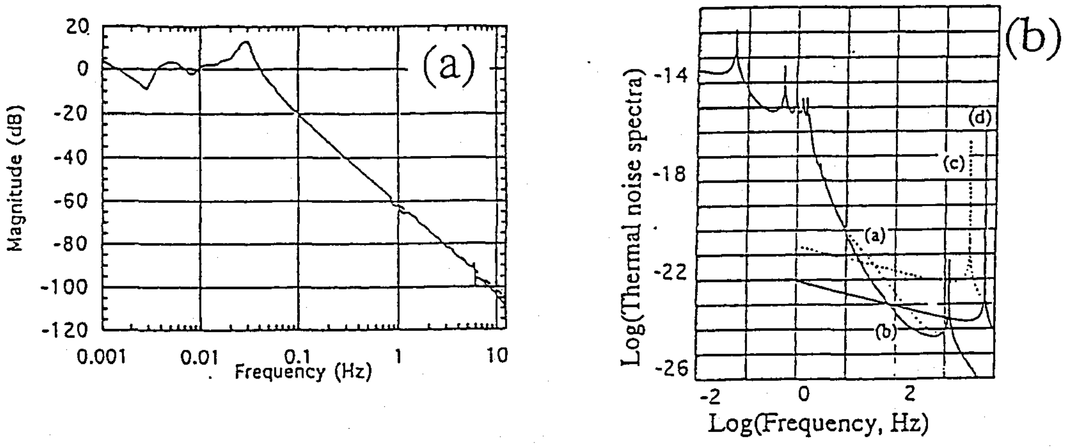

Fig.2 (a) Transfer function of the folded pendulum with resonant frequency of 29.4 mHz. The dashed curve is a model prediction. (b) Comparison of thermal noise of compound pendulum with thin membrane susp. Membrane stretching f = 700 Hz; Q= 10^5; Pend. Q factors:(a) 10^7 (b) 10^9 (c) Al pendulum Q=10^6 , f=3 kHz (d) Sapphire, Q=10^8, f=6kHz

With these concepts we expect to be able to design a mirror mass suspension with a thermal noise cut-off frequency below about 200 Hz. This should lead to a sensitivity gain of at least 4 around 500 Hz.

3. Advanced Optical Topologies

We are currently investigating both numerically and in bench-top instruments advanced optical configurations, in particular, dual recycling[3]. The dashed curve in Fig.1, is the predicted sensitivity if dual recycling was implemented on a first generation instrument whilst keeping reasonable sensitivity upto 3 kHz. It shows a modest sensitivity gain (1.3) at the tuned frequency (1 kHz), but such a device would be much more tolerant to distortions[4].

Lowering the thermal noise cut-off to 200 Hz, makes it possible to employ a high degree of signal recycling in a frequency range where there are predicted to be interesting sources to give performance upto 10 times the standard instrument in a narrow bandwidth. Experiments are underway at ANU to demonstrate the control and locking topology for a dual recycling device and demonstrate sensitivity enhancement

4. Laser Development

In the region of Fig.1 above 1 kHz (after lowering the thermal noise cut-off, above 200 Hz) the noise budget is dominated by quantum (shot) noise of the laser light. We are establishing a program at UA to build 100 watt, diode laser pumped, solid state lasers. This scale up in laser power accompanied by the necessary improvement in optical components, will improve the sensitivity by upto a factor of 10 in the shot noise region of the frequency response.

To achieve the necessary frequency and intensity stability, we will injection lock the high power laser using a monolithic low power master laser. In a collaborative project with the Laser Zentrum Hannover, Ralph at al[5] at the ANU, have developed a full quantum mechanical model of an injection locked system which reproduces, quantitatively, the behaviour observed in injection locking experiments at LZH. The quantitative understanding of injection locking is a major step toward our goal.

5. References

1. Parameters used for power recycling correspond to projections for the Virgo interferometer.
2. J. Li, D. Blair and F. van Kann, Proc. International Workshop on Exp. Grav., Pakistan (1993).
3. B.J. Meers, Phys.Rev.D38 (1988) 2317.
4. D.E. McClelland, C.M. Savage, A.J.Tridgell and R. Mavaddat, Phys.Rev.D48 (1993) 5475.
5. T.C. Ralph, C.C. Harb, H.-A. Bachor, I. Freitag, H. Welling*(in preparation).*