LIGO-M990163-00-M

Louisiana State University Experimental Gravitation Group
Six Month Progress Report
February 15, 1999

Submitted by Warren Johnson

LIVINGSTON ENVIRONMENTAL MONITORING

Rai Weiss assigned several of his students, Sara Veatch and Shourov Chatterji, to make measurements of AC magnetic fields and seismic motion at both Hanford and Livingston, with particular attention to the correlations between the sites. They enlisted and trained Michelle Kingham of our group to be the local party responsible for the instruments and the data handling. She has performed every task assigned to her, and is in a position to take greater responsibility. The measurements of AC magnetic field were reported in Veatch's thesis. One conclusion is that lightning strikes could be a source of coincident events at both sites that could masquerade as a real gravitational wave. The seismic motion studies wait for further direction from MIT.

CRYOGENIC SUSPENSION

Warren Johnson and Philip Adams have again proposed to NSF to begin a program of research on cryogenic suspension of the test masses of LIGO. We maintain that a cryogenic suspension is the most promising method for reduction of pendulum thermal noise, a fundamental source at low frequencies. Major reduction of low-frequency noise will be necessary to reach the most prominent goal of the LIGO project: detection of the final inspiral of a binary neutron star system.

There is no longer any question that major reductions in pendulum thermal noise will be crucial for the success of an advanced LIGO. We have attempted to convince the suspension experts that there is a reasonable chance that a cryogenic suspension is the best bet to make truly major reductions in this noise. We suggest that the engineering issues raised by a cryogenic suspension can be largely deferred until after we have demonstrated the scientific feasibility of reducing pendulum noise.

We have shown that the ultimate pendulum noise source at room temperature, "thermoeleastic" dissipation, will be reduced to insignificance in a cryogenic suspension made with metal wire.

The first objective of the proposed research is to demonstrate that there are no new damping mechanisms at cryogenic temperatures that affect only thin wires. The second objective is to demonstrate that the "dissipation dilution" effect has the desired value when the thin wires are put under large tension. The third objective is to demonstrate a metal-oxide bonding process that is strong enough and does not add excessive damping. The fourth objective is to demonstrate that oxide suspension fibers can be made to satisfy the conflicting requirements: 1) cold suspension elements, and 2) warm optic surfaces, and 3) high Q.

A small experimental effort, what we can manage with no financial support, has begun with undergraduate student labor.

HANFORD VISIT

Warren Johnson visited the Hanford Observatory during the last 2 weeks of July and the first week of August. The occasion was the first article test of the HAM seismic isolation system, led by Mark Barton of Caltech, wit h major assistance from Joe Giaime of JILA, Matt Smith and Alex Marin of MIT, and Gabriela Gonzalez of Penn State. Since vibration isolation is a common problem for both types of gravitational wave detectors, he came to contribute whatever labor was needed, to learn about the special needs of an interferometer system, and the learn the details of the hardware and testing procedures.

Mark Barton has written up these tests as Transfer Function and Drift Measurements on the First Article HAM, LIGO-T980084. They were quite successful in reaching their planned objectives, which were: measuring creep in the optics table suspension, measuring the transfer functions from the support table to the optics table at low frequencies, and determining that that there were no surprises in the this response.

From the perspective of an old suspension designer, these tests were both impressive and frustrating. They were impressive because the goals of the tests were met in an expeditious manner. They were frustrating because they tests were nowhere near ambitious enough to determine whether two critical requirements have been met: 1) sufficient vibration isolation at frequencies well above the seismic wall ($f > 50$ Hz) and, 2) a demonstration that non-Gaussian noise generated inside the suspension is small enough to meet the requirements for a true observatory.

NEW FACULTY WORKING ON LIGO RESEARCH

There has been an extraordinary growth in the actual and potential manpower working on LIGO research.

Joe Giaime will be coming to LSU in the fall as an Assistant Professor of Physics. In August, our department voted to commit major resources to increasing the impact of LSU on the LIGO project. One result was a faculty search for an experienced experimentalist who wanted to work on LIGO I. Candidates for the position visited during the fall, and gave talks at the department Colloquium on their LIGO related research. An offer was extended to Joe Giaime, and he accepted in January. His academic appointment will begin in the fall. New lab space for LIGO research in the Physics department will be available.

Philip Adams, a condensed matter and low temperature experimentalist, has long experience with cryogenic measurements that are relevant to LIGO. In particular, he is an expert in the production and properties of thin metal films, and has built a number of high mechanical Q oscillators for work in condensed matter physics. If the cryogenic proposal is successful, he will be able to commit a major portion of his research time to the condensed matter problems important to LIGO.

Robert "Bob" Svoboda, a neutrino physicist who has been heavily involved in the IMB and the SuperK experiments, and incidentally is married to Julien Svoboda (a new staff member at LLO), is spending a month at Hanford and Caltech to learn how to transfer his expertise in large computer models of neutrino detectors to large computer models of gravitational wave detectors. He hopes to spend much of his time as a LIGO researcher.

Roger McNeil, a particle physicist who has worked for years at CERN on the L3 experiment, is looking for a role in either fast-look data analysis at Livingston or advanced control systems.

Joel Tohline, an astrophysicist with extensive experience in hydrodynamic models of binary star formation and merger, will spend a sabbatical year at Caltech with Thorne's group, learning how to contribute to source behavior calculations of highly condensed systems.

Anthony Rizzi has recently been appointed Adjunct Professor of Physics at LSU, joining Mark Coles, director of LLO. Anthony has come to LLO as a staff member, after some years in the aerospace industry and then a theoretical thesis in GR for Christodoulou at Princeton. He is spending one day a week at LSU, partly to interact with Tohline and with Juhan Frank, an astrophysicist who is an expert on accretion disks, X-ray sources, and condensed objects that are potential gravity wave sources.

A joint (LSU and LLO) physics seminar on gravitational waves has begun meeting on a nearly weekly schedule.

MAGNETIC NOISE

Rai Weiss visited LLO just before Christmas to measure environmental noise at the Livingston site, now that essentially all of the civil construction is done. The LSU group helped out, and provided some large induction coils that could be used to make sensitive measures of the AC magnetic noise. This visit stimulated the LSU group to a more systematic program of measuring AC magnetic noise at LLO.

We have reached several conclusions: 1) It is more important to measure the AC magnetic field gradient, because the force on the test mass magnets depends on gradient, not field. 2) It is straightforward to measure the gradient directly, by the use of two connected coils with windings of opposite direction. 3) it is possible to measure gradients that nearly as small as what is required for LIGO I. This situation is apparently unique, because the tools are just about good enough to experimentally prove whether or not this noise source is small enough to meet requirements. For every other noise source (such as seismic vibration) it is not now possible to experimentally prove that the isolation systems are good enough.

We have made enough measurements to become confidant that they have become reliable, and to conclude that there are two major problems that will require immediate attention. They are:

1) A broad band of magnetic field and gradient noise, extending from less than 30 Hz to more than 100 Hz. It is strong enough to exceed design requirements, unless the shielding and balancing of magnetic noise is very good. This noise appears only in the LVEA (corner building) and not in the Yarm endstation, therefore it is not generated in the measuring instruments nor is it intrinsic to the wider area. The source is probably electrical or electronic machinery somewhere nearby. Unfortunately, several tests suggest it is not machinery that can be turned off during data runs.

2) Large spatial variation of the AC magnetic field at the "power line" frequencies (i.e., 60 Hz and its harmonics). The B-field at the power line frequencies does not vary greatly with position, but the gradient of B does; the causes for this are not yet obvious. Since gradient is more important than field, this implies large forces on the mirrors at the power line frequencies. This means that the shielding and balancing of the magnetic forces on the mirrors must be very good, or we have to hope we can find a way to live with large power lines in the data.

At this point, it is not clear how much shielding and balancing will actually be provided by the chambers and the apparatus. The obvious features of the chambers suggest both field reduction, which will reduce the gradient, and bending of field lines, which will increase the gradient.