LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T040223-01-D *LIGO* December 2, 2004

Ribbons / Dumbbell Fibers
(Moving from parallel to serial effort)

Helena Armandula

Distribution of this document:
LIGO Science Collaboration

This is an internal working note
of the LIGO Project.

California Institute of Technology
LIGO Project – MS 18-34
1200 E. California Blvd.
Pasadena, CA 91125
Phone (626) 395-2129
Fax (626) 304-9834
E-mail: info@ligo.caltech.edu

Massachusetts Institute of Technology
LIGO Project – NW17-161
175 Albany St
Cambridge, MA 02139
Phone (617) 253-4824
Fax (617) 253-7014
E-mail: info@ligo.mit.edu

LIGO Hanford Observatory
P.O. Box 1970
Mail Stop S9-02
Richland WA 99352
Phone 509-372-8106
Fax 509-372-8137

LIGO Livingston Observatory
P.O. Box 940
Livingston, LA 70754
Phone 225-686-3100
Fax 225-686-7189

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

Introduction

The baseline design for Advanced LIGO has been developed based on the use of fused silica ribbons instead of circular fibers for the ETM's and ITM's suspensions in an effort to minimize thermal noise.
Ribbons have the advantage of an increased dilution factor and of pushing up the thermoelastic peak in frequency, which has the effect of reducing the loss at the critical 10 Hz region.

Initially, it was thought that ribbons had to be twisted to prevent buckling during alignment when the mirrors were suspended. The twists presented a challenging manufacturing issue. On this premise, another alternative to ribbons was considered: dumbbell fibers, probably easier to manufacture than twisted ribbons, and with similar enhanced noise performance over circular fibers, (ref. Phil Willems LIGO T020003).

It was then decided to have a parallel effort at Caltech to develop and test dumbbell fibers and to have, at an specific date, an evaluation of both, ribbons and dumbbell fibers, leading to a down select decision.

However, given the shortage in manpower, just the very basic research was completed at Caltech on dumbbell fibers.

Later on, it was decided that twists on ribbons will not be necessary, (Jim Hough, Caroline Cantley, E-mail communication 07/2003, Jim Hough's note 09/2003), thus, removing the biggest ribbon manufacturing hurdle.

Current research up- date

The development of silica ribbons that meet Advanced LIGO noise performance requirements, as well as a CO2 laser machine to manufacture and weld them and methods of characterization, are underway at the University of Glasgow under the direction of Dr. Caroline Cantley.

All work up-to-date suggests that ribbon manufacturing is feasible.

A preliminary design review is targeted by September 2005.

Glasgow is expected to test the ribbon manufacturing procedures for Advanced LIGO at LASTI (2006)

Parallel vs. serial effort

At present, the parallel effort to develop dumbbell fibers has stopped at Caltech.

The ribbon manufacturing development is moving ahead without major problems at Glasgow.

At the time when a parallel development effort was ongoing, a selection criteria was established to aid the selection between ribbon and dumbbell fibers based on their performance.

Ribbons/dumbbell fibers were expected to comply with the present AdvLIGO design requirement that limits thermal noise.

These are the aspects considered for the selection criteria:

1) Noise performance tests and analysis: intrinsic material loss, pendulum loss

2) Manufacturing tests

a) strength of ribbon / fiber, immediate and long term

b) shape reproducibility

3) Assembly tests

a) ease and reliability of welding

b) ease of repair

c) strength of weld, immediate and long term

Plan

If ribbon manufacturing problems or failures are encountered during the LASTI effort, (planned for late 2006) the ribbons at LASTI can be replaced by circular fibers, which will be well developed at this stage. LASTI will lack the sensitivity required to test Advanced LIGO noise performance. In this case we propose to initiate a serial effort to resume the development of dumbbell fibers. LIGO installation will not start till about 1st quarter of CY2010[1]. Fiber/ribbon production would likely not need to start until near the end of CY2008 (allowing time for training and fiber/ribbon fabrication facility shake-down). This allows about 2 years to develop the alternative of dumbbell fibers. There is no anticipated impact to the balance of the suspension design.

Because the manufacturing methods and welding techniques with the CO2 machine will be well developed at that time, it should be straight forward to pull dumbbell fibers. Most of the work could be directed to manufacturing the dumbbell aspect of the fiber, characterizing the fiber and assuring sufficient uniformity and repeatability.

The LIGO Lab will likely request Glasgow University to undertake the dumbbell fiber project (if it is deemed necessary), since they are in an advantageous position by having the equipment and the knowledge acquired thorough previous developments. In addition, the scope for delivering a ribbon or fiber that meets advanced LIGO requirements, is within the UK's current work scope. However, the decision on which group would pursue dumbbell fiber development will not be made until the decision point is reached in late 2006.

Conclusion

The original plan for Advanced LIGO was to pursue the development of ribbons and dumbbell fibers in parallel. The reality is that we do not have the manpower to develop dumbbell fibers at Caltech.

---

[1] The Advanced LIGO project dates are based on NSF MREFC funding starting with FY07 funding and is based on a schedule synopsis provided by Carol Wilkinson, email 11/8/2004 in preparation for the Nov 2004 NSF annual review of the LIGO Lab.

There appear to be no show-stoppers on the current ribbon development. The SUS team (U of Glasgow, LIGO Lab) will test the manufacturability of ribbons in the LASTI prototype testing. If failures occur at LASTI, there is sufficient time before Advanced LIGO fiber/ribbon production starts (late 2008) to initiate a serial effort to develop, characterize/qualify and manufacture dumbbell fibers. Because most of the manufacturing techniques common to any fiber or ribbon (e.g. fiber pulling and welding) will be mature at this time, most of the effort would be concentrated on the unique aspects of dumbbell fiber production, characterization and assuring uniformity and quality of the fiber.