LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T080233-00-D *Advanced LIGO* 08 Sep 2008

Beam Splitter Optical Surface Deformation due to Gravity

Calum Torrie Dennis Coyne

Distribution of this document:
LIGO Scientific 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/

1 Introduction

The gravitational load (body force) on the Beam Splitter Optic is supported in the Advanced LIGO suspensions by wire loops which go round the barrel of the optic breaking off from prisms on the side of the optic. The stress field created by the gravitational load and the resulting ear bond reaction forces will cause a deformation of the optic. We are concerned with the deformation of the optical surfaces, which are polished in a horizontal orientation.

2 Model

The fused silica Beam Splitter dimensions are 370 mm diameter by 60 mm thick. There are no flats on this optic. The optic nominally weighs ~ 14 kg. A three-dimensional finite element model, Static Structural Analysis, created with the ANSYS Workbench version-11.1 software, depicted in Figure-1, represented this geometry. The bevels and the wedge angle of the optics were not included in this model. The mesh consists of 62,00 solid elements (SOLID187) and 100,000 nodes. In the analysis reported here only a vertical gravity vector is considered and the boundary conditions are as follows: -

1) Cylindrical support applied to two areas on bottom of barrel rep wire loop (radial: fixed, axial: fixed ,tangent: free)

2) Displacement applied to centre location on bottom to remove clocking motion (X: 0 , Y: free , Z:0). The clocking was observed when I only used boundary condition #1.

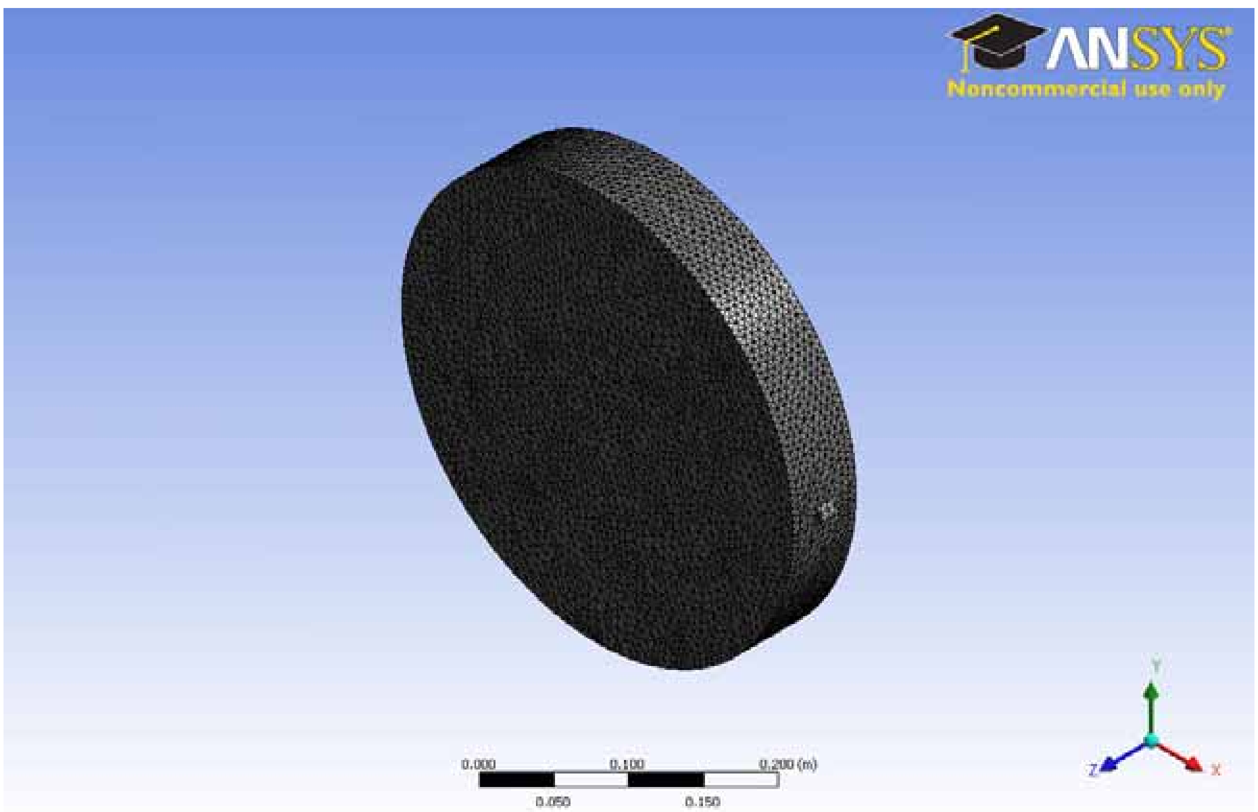

Figure 1: Finite Element Mesh (The mesh consists of 62,000 solid elements and 100,000 nodes.)

As well as the boundary conditions described above gravity is applied in the vertical direction, Y direction in the model.

3 Deformation Field

The finite element analysis indicates a peak transverse (normal to the optic face) deformation of ~ 3 nm total as shown in figure 2 below.

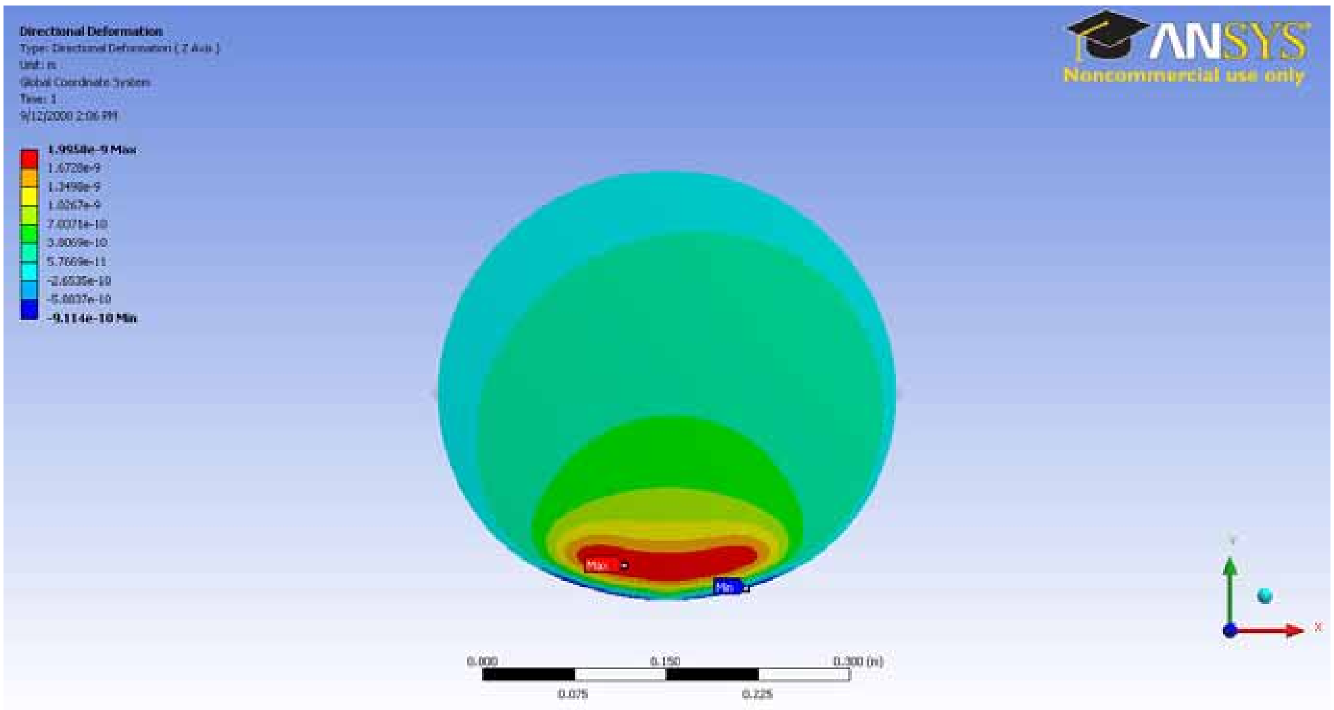

Figure 2: Front Surface Normal Displacement

4 Comparison to ETM work in LIGO-T050184

The finite element analysis indicates a peak transverse (normal to the optic face) deformation of ~ +/- 4 nm, or 8 nm total, which compares with the work done in LIGO-T050184.

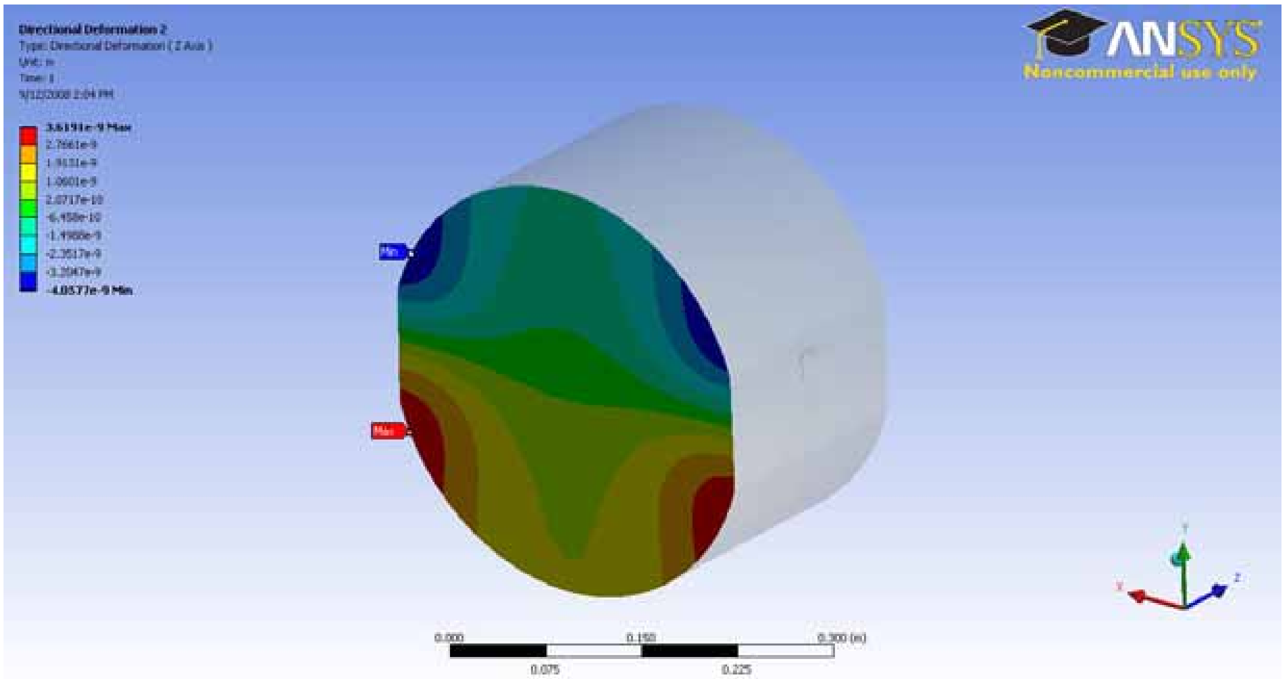

Figure 3: - Front Surface Normal Deformation of the ETM Optic (Isometric)

5 Actions and Further Work

I have now given a file with HR surface node deformation results to Hiro and written up the associated draft memo.

I would like to look at use of Cartesian co-ordinates to apply force as an alternative method to that described above (I have been talking to Riccardo DeSalvo about this)) and eventually (not urgent) decompose results into zernikes and include in a revision to this memo.

Appendix 1

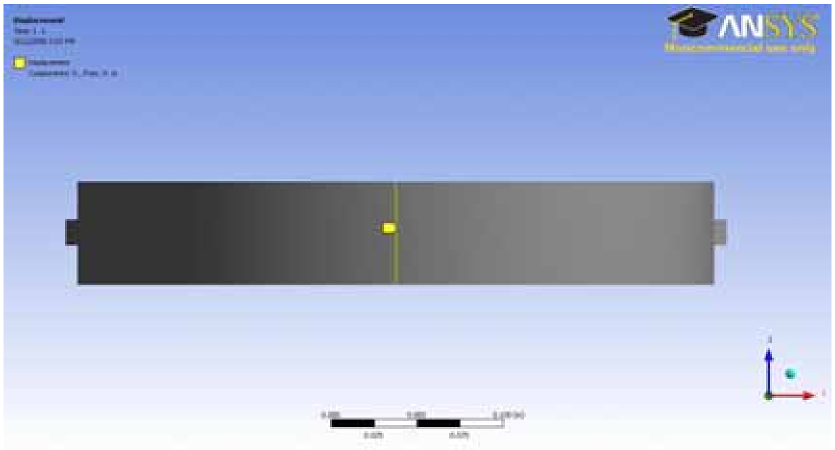

Figure 4: - Displacement support

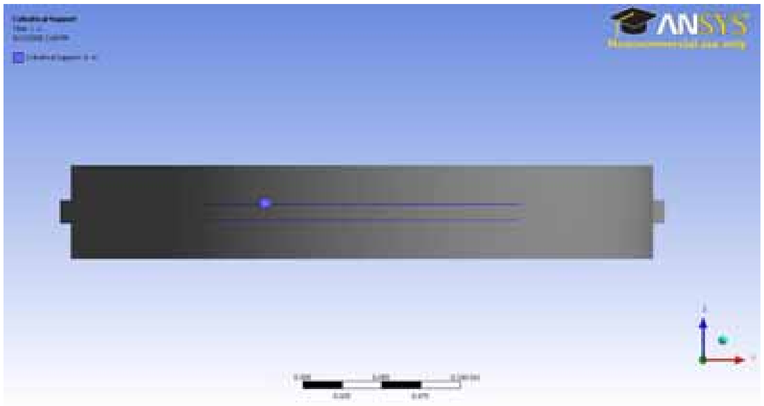

Figure 5: Cylindrical Support

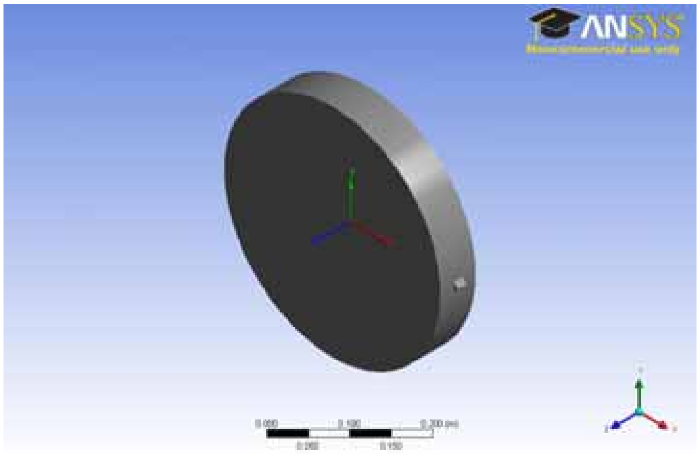

Figure 6: - Co-ordinate System

Appendix 2

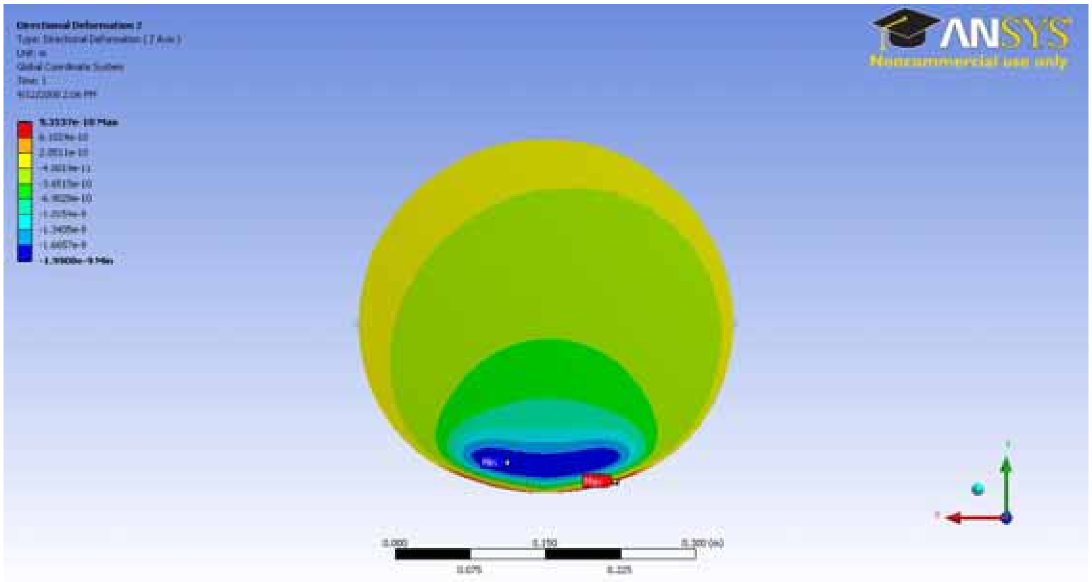

Figure 7: Back Surface Normal Displacement

ANSYS Node Number	X Location (m)	Y Location (m)	Z Location (m)	Directional Deformation (m)
1	5.00E-04	-0.185	3.00E-02	0
419	-5.00E-04	-0.185	3.00E-02	0
420	5.88E-03	-0.18491	3.00E-02	-3.25E-10
421	1.12E-02	-0.18466	3.00E-02	-5.25E-10
422	1.66E-02	-0.18425	3.00E-02	-6.37E-10
423	2.20E-02	-0.18369	3.00E-02	-7.15E-10
424	2.73E-02	-0.18298	3.00E-02	-7.83E-10
425	3.26E-02	-0.18211	3.00E-02	-8.12E-10
426	3.79E-02	-0.18108	3.00E-02	-8.47E-10

Table 1 : Extract of available output available from ANSYS in ASCII or EXCEL files

Appendix 3

The following images are the total deformation of the optic (front, rear and the from below) in the Z direction