LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

LIGO-T070085-00-W *Enhanced LIGO* 04/26/2007

Revised PSL Table Modematching for eLigo

Anamaria Effler, Rick Savage, Justin Garofoli, Doug Cook

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/

1 Introduction

The purpose of this document is to present the methods by which the proposal for the eLigo PSL table layout was reached. Also, it will be useful as a reference for the modematching parameters.

2 Changes from Current PSL Table Setup

The major changes which have affected the table layout are:

- New 35W laser; box required to be in the closest corner of the table, 75cm X 75cm, with the output beam emerging 18-25cm from left side, with a waist of 0.21 mm located 7.0cm outside the box;
- A diagnostic breadboard for the laser, 60cm X 49 cm;
- The EOM outside the laser is no longer necessary, the EOM will be mounted inside the laser between the oscillator and the amplifier heads;
- The three EOMs after the PMC on the main beam path have been combined into one EOM in which the modulating field will be parallel to the surface of the table, eliminating the need to rotate the polarization of the laser beam before this EOM;
- The transmissive optics in the main beam path will receive a special AR coating from REO to reduce the power levels in the ghost beams;

3 Modematching

There are three major “cells” on the main beam path which require a new modematching setup. The first is from the laser to the PMC, the second is from the PMC to the EOM and the third is from the EOM to the MC (see figure below). This figure can be found on the mLigo wiki.

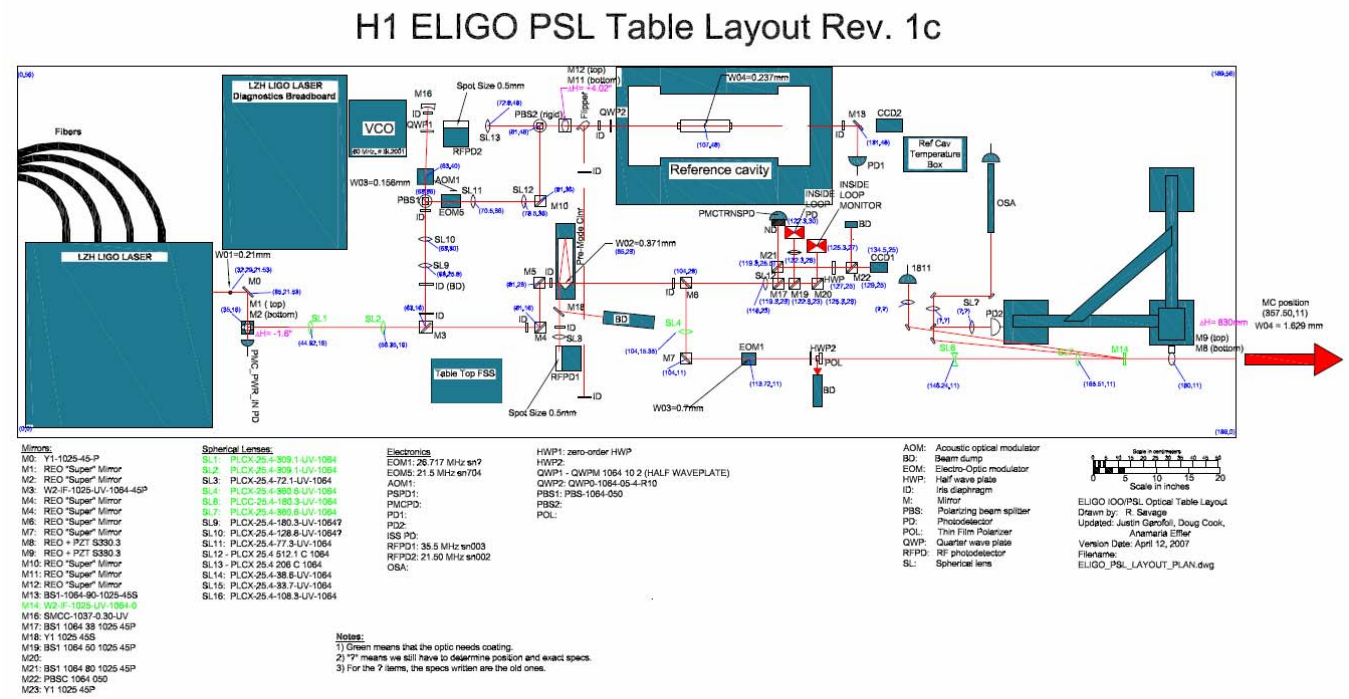

Fig. 1 Proposed PSL Table Layout

3.1 Requirements

The two modematching lenses for the first "cell" are constrained to be between the turning periscope and the M3 steering mirror. The modematching from the PMC to the EOM can be done with only one lens, so it can sit anywhere between the two optical elements. The third cell, into the MC, requires the lenses to be placed before the periscope.

The program used for the two-lens modematching is an old FORTRAN code called mode10. Unfortunately, some of the source code has been lost, so due to lack of time to recreate a newer version, perhaps in MatLab, a compiled version of the code has been used. The advantage is that it uses the CVI list of lenses to look for possibilities and lists all of them. The program asks for minimum distances from the input waist to the first lens (s1) and from the output waist to the second lens (s2), as well as the sizes of the input and output waists. These are important parameters to keep track of, since varying them will yield completely different results.

3.2 Main Path Optics and Locations

The following table shows the main path optics, including the table edge. The distances are shown both in cm and inches; the FORTRAN program requires distances in cm, while the table has mounting holes every inch, so it is easier to mark the elements in inches. This will probably also be useful during installation.

Optic	Size	Position on drawing(in)	Distance from laser w01(cm/in)	Distance from prev. optic(cm/in)
Laser w01	0.21mm	32.29, 21.53	0	0
SL1	68.8cm	44.92, 16	46.13 / 18.16	46.13 / 18.16
SL2	68.8cm	56.35, 16	75.16 / 29.59	29.03 / 11.43
PMC w02	0.371mm	85, 23	165.71 / 65.24	90.55 / 35.65
SL4	80.2cm	104, 15.35	233.4 / 91.89	67.69 / 26.65
EOM w03	0.7mm	113.72, 11	269.14 / 105.96	35.74 / 14.07
SL6	-40.1cm	146.24, 11	351.74 / 138.48	82.60 / 32.52
SL7	80.2cm	165.51, 11	400.69 / 157.75	48.95 / 19.27
Table edge	-	189, 11	460.35 / 181.24	59.66 / 23.49
MC w04	1.629mm	-	888.34 / 349.74	427.99 / 168.5

Table 1. Main Path Components (w means waist, SL means lens)

The next table shows the modematching parameters used in the program and the results obtained for each of the three cells. *D* total is the distance between the two waists, *d restricted* is the length within which the lenses can be placed for modematching, and *d12* is the distance between the two lenses. Since the second cell has only one lens, some of the parameters are missing. The restricted distance was calculated by taking the nearest optic (see 3.1) and claiming that the lens should be at least 4 inches away from it.

Distances	Cell 1:Laser to PMC	Cell 2: PMC to EOM	Cell 3: EOM to MC
Input waist	0.21mm	0.371mm	0.7mm
Output waist	0.371mm	0.7mm	1.629mm
s1 min	31.09cm / 12.24in	10.16cm / 4in	10.16cm / 4in
s1	46.13cm / 18.16in	67.69cm /26.65in	82.60cm /32.52in
s2 min	83.82cm / 33in	10.16cm / 4in	461.01cm / 181.5in
s2	90.55cm / 35.65in	-	487.65cm / 191.99in
d total	165.71cm / 65.24in	103.43cm / 40.72in	619.2cm / 243.78in
d restricted	50.8cm / 20in	83.11cm / 32.72in	147.92cm / 58.24in
d12	29.03cm / 11.43in	-	48.95cm / 19.27in

Table 2. Modematching cells with their parameters

The next figure shows the beam size as it propagates from the laser to the mode cleaner, as well as the locations of the waists in the scenario described above.

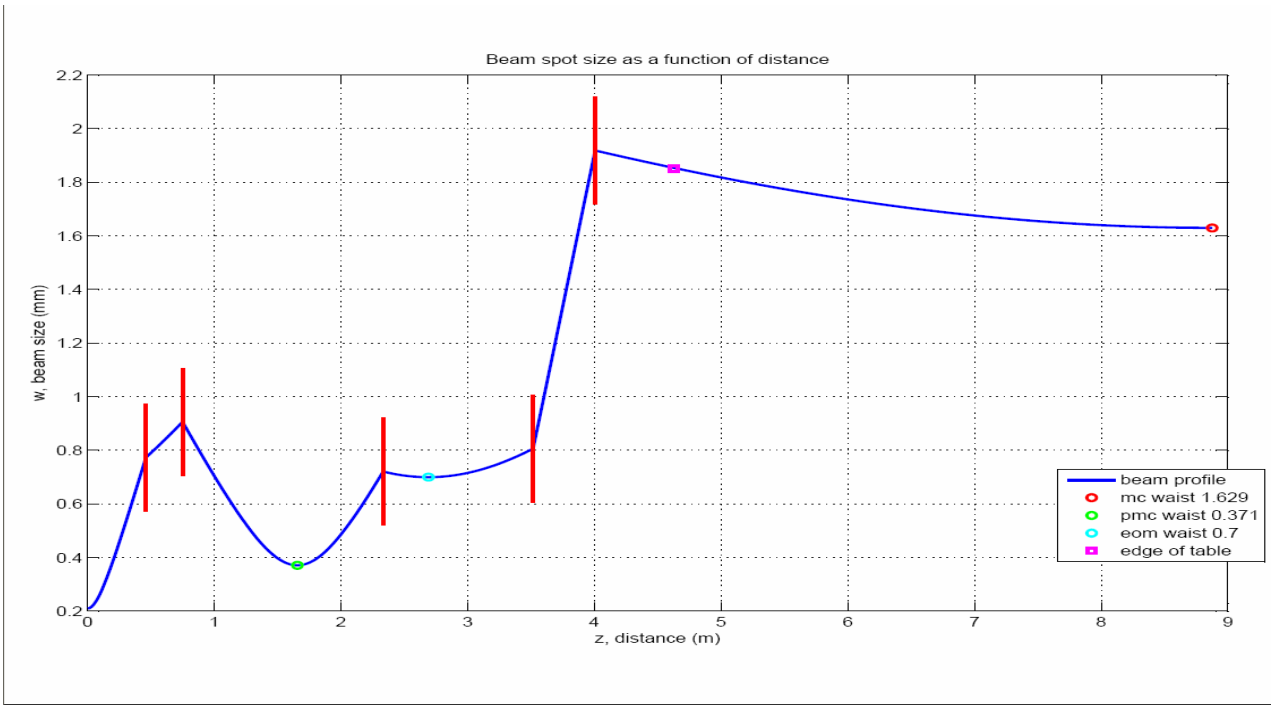

Fig.2 Beam size as it propagates from laser to MC

Notice in the picture above that there are no intermediate undesired waists. This is important since any waist presents the danger of introducing large noise into the interferometer; a randomly floating dust particle would occlude a significant fraction of the beam at such a waist, while if it traversed a wider beam, this noise would be greatly reduced.

3.3 Flexibility of the cells

Since some of the parameters of the laser or of the components may vary from design to implementation, it is important for the modematching to adjust just by moving the current lenses, and not by having to replace them. That would cost time and money, especially because the main path optics require a special coating and cannot simply be bought off the shelf.

By varying some of the distances and waists involved, the lenses chosen were the ones which remained within the space required while also providing the desired modematching.

3.3.1 Dithering Cell 1

The following figure shows where the two lenses have to move in order to maintain the proper modematching into the PMC. The designed laser waist is 0.21mm, so two of the graphs show where the lenses would be if the laser waist was slightly wider or thinner. The other two modify the distance from the laser to the PMC by 20cm. The black limits shown are 4 inches away from the optic that constitutes that limit, so even if the lens is close to the limit, it would still be a viable configuration since it would be at least 4 inches from the nearest optic.

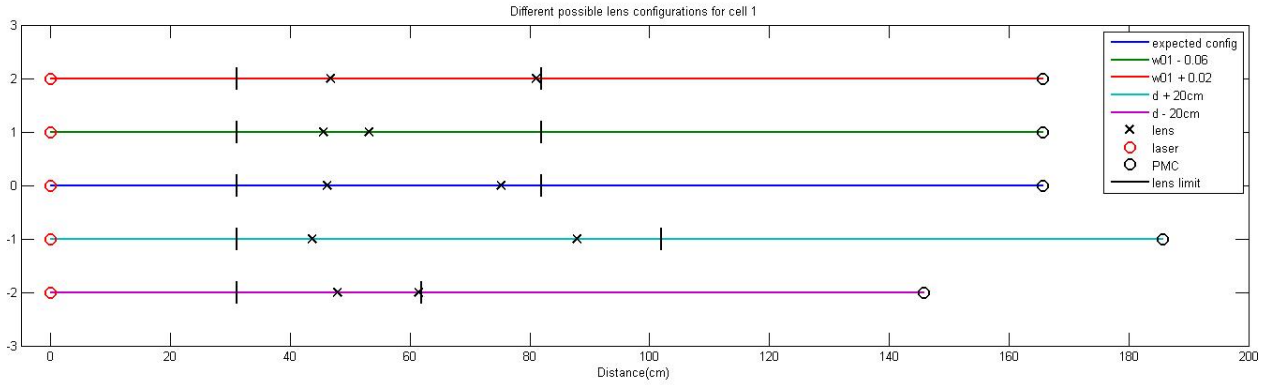

Fig.3 Positions of lenses for cell 1 for different configurations

3.3.2 Dithering Cell 2

Cell 2 is different since it has only one lens. The desired waist in the EOM is between 0.68mm and 0.7mm, so here are the possible results with same lens. The varying parameter is the position of the lens (1 cm increments). Notice that the EOM has to move in order to "catch" the waist. However, since there is only one lens, practically the modematching should be easier than in the case of a two-lens system. The first configuration in the table is the nominal.

Waist(mm)	Distance from PMC to lens(cm)	Distance from PMC to EOM (cm)
0.700	67.7	103.43
0.695	66.7	99.55
0.690	65.7	95.81
0.684	64.7	92.20
0.678	63.7	88.74

Table 3. Varying the position of SL4 and results on modematching

3.3.3 Dithering Cell 3

Just like cell 1, cell 3 has two lenses. A few calculations for their flexibility are shown below, including varying the mode cleaner waist (w04), the EOM waist (w03) and the total distance. The lenses stay well between the limits. The first limit is set by the EOM and the second is set by the periscope which takes the beam off the table.

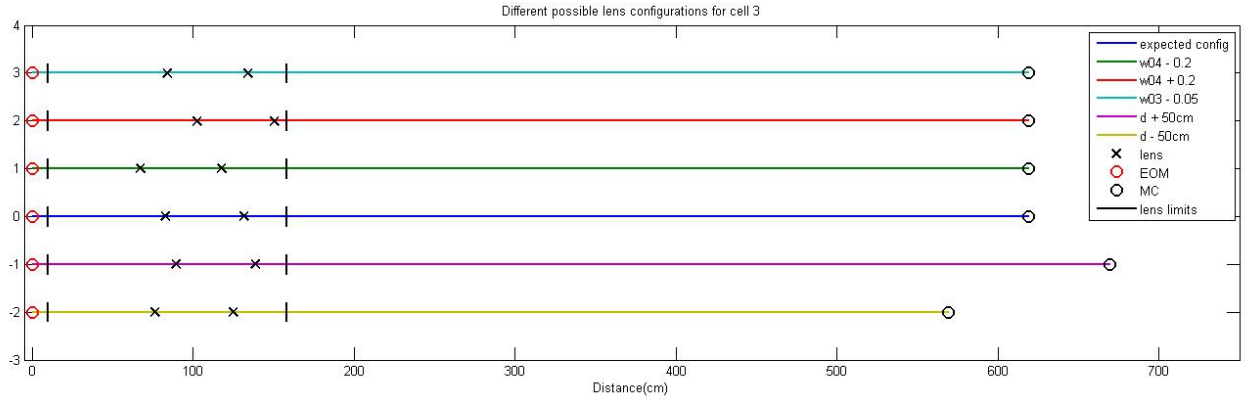

Fig. 4 Position of lenses for different cell 3 configurations

4. Pricing

The lenses necessary for this modematching proposal can be procured (and are in stock) from CVI. The prices and number of items needed are shown in the table below.

Part number	# reqd.	# spares	Surface figure	Scratch/dig	Price ea.
IF-1025-UV	2	2	λ/10	10/5	$92.00
PLCX-25.4-309.1-UV	4	2	λ/10	10/5	$104.40
PLCX-25.4-360.6-UV	4	2	λ/10	10/5	$104.40
PLCC-25.4-180.3-UV	2	2	λ/10	10/5	$110.40

Total: $2062.00

These optics are to receive special REO AR coatings with reflectivity < 0.1% for 1064 nm light at normal incidence. One coating batch (both sides – two runs) costs somewhere between $5k and $6k and can coat around 20 optics. It looks like all of the optics required will fit in one coating batch (we will request a detailed quote via Helena A. who is coordinating the work with REO).

Grand total: ~$8000.00