LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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Mode mixing and beam size in a FP cavity with imperfect surface

Hiroaki Yamamoto

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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

Numerical analysis of the suggestion by Stefan Ballmer about the mode contamination in a FP cavity when the beam size becomes large.

The beam size is not a major factor about the FP cavity design for the current quality of mirror surfaces.

2 Setup

FP cavity : Length = 4km, large aperture (60cm) to avoid the effect of the clipping loss. The test mass ROC, same value for ITM and ETM, is changed to calculate mode mixing with beam sizes between 5cm to 18cm. Finesses is the same for aLIGO, T(ITM) = 0.014, T(ETM) = 5ppm.

Mirror surface : aLIGO like PSD, $A / (1 + (f / f_0)^2)$, f_0 = 1/5cm, power, tilt and astigmatism subtracted. A is adjusted to make the final rms to be a given value. Results shown is for rms = 0.1nm. Real aLIGO optics rms is 0.2~0.3nm. 100 pairs of random maps are generated.

3 Numerical Result

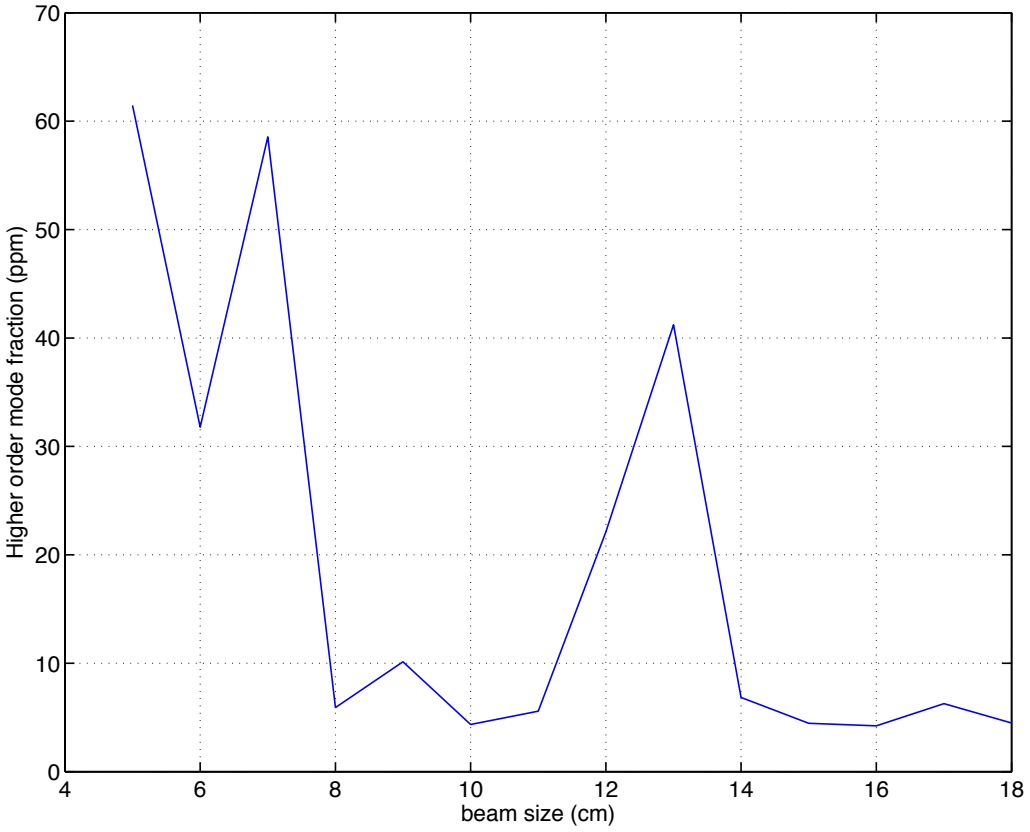

Figure 1 Contrast defect vs beam size

The higher order mode fraction (HOM) in a cavity was calculated using the setup mentioned above. The diffractive loss is 2ppm even for the largest beam size case. The contrast defect is around twice of this HOM, assuming roughness of two arms are independent.

This result is based on the surface map with rms of 0.1nm, and it scales as rms^2 for other values of rms. With the current aLIGO surface quality, this needs to be scaled by factor of 4~9.

The three peaks at 5cm, 7cm and 13cm are due to higher order mode resonances, n+m=19, 17 and 11 for each, due to the gouy phase for each choice of ROC. The following plot shows the rountrip phase (modulo π), and three square boxes show the accidental resonances.

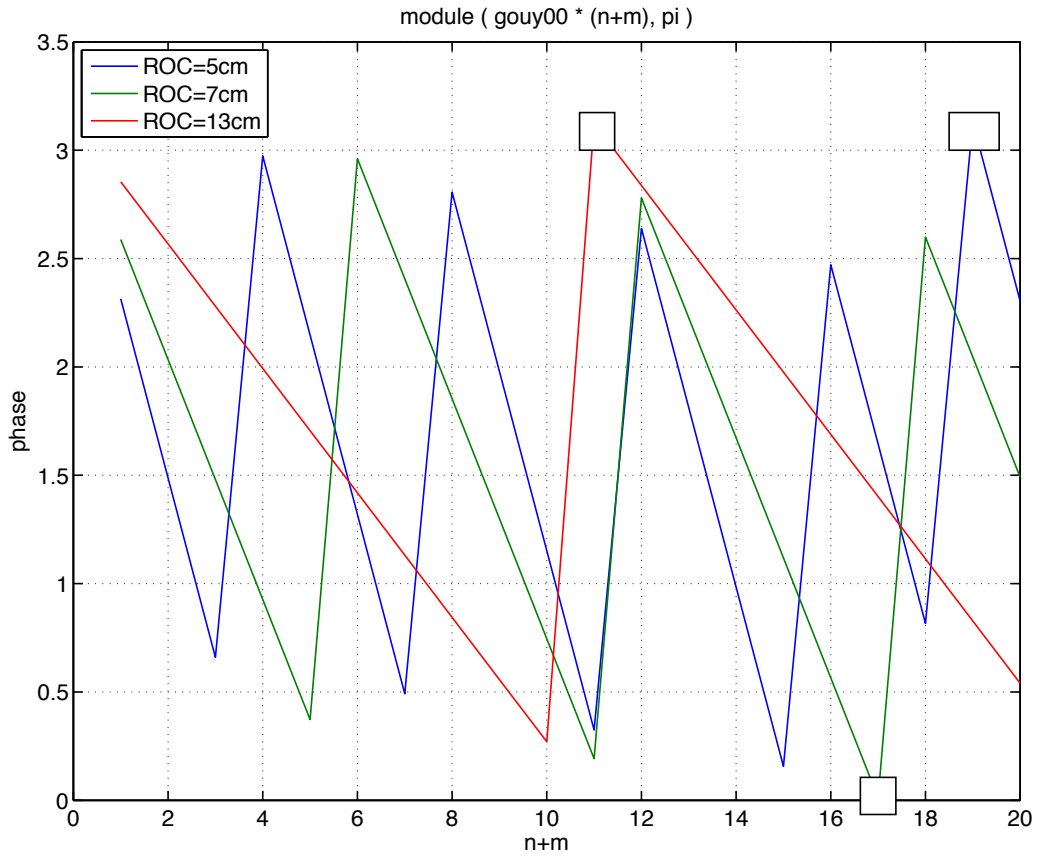

Figure 2 Roundtrip phases for various modes

4 Conclusion

So long as the ROCs of ITM and ETM are chosen to avoid higher order mode resonances, the mode mixing due to the surface roughness for a Gaussian beam does not compromise the performance even for a large beam size.