SURF Progress Report One: Non-Gaussian Beams for Interferometric Gravitational Wave Detectors

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Abstract

Thermal noise forms a significant part of the noise budget of interferometric gravitational wave (GW) detectors. This investigation is concerned with a novel method of suppressing thermal noise by reshaping laser beams and mirrors. The current state of research in the field is detailed and current work is discussed.

1 Background

Future GW detectors will be limited in sensitivity by thermal noise in their suspended mirrors. The principal sources of thermal noise are thermoelastic noise, coating thermal noise and Brownian thermal noise[1]. Current theory [1, 2] dictates that increasing the size of laser beam incident on the mirrors will combat all of the aforementioned noise sources.

However, it is not possible to simply increase the size of the Gaussian beam due to prohibitive diffraction losses. In response to this problem several members of the LIGO Scientific Collaboration proposed an exciting method of increasing beam size via non-Gaussian beams. This solution was the so-called mesa beam, Fig.1 shows the profile of a mesa beam and the Mexican hat mirror which supports this beam.

Theoretical calculations [3, 4, 5] predict that mesa beams shall offer significant advantages over Gaussian beams without being substantially more difficult to control. Before MH beams may be considered a viable option for Adv LIGO we must show that the experimental generation and management of mesa beams agrees with these works.

[1] coating thermal noise is most important for the currently favoured fused silica substrates; thermoelastic noise is the main concern for sapphire.

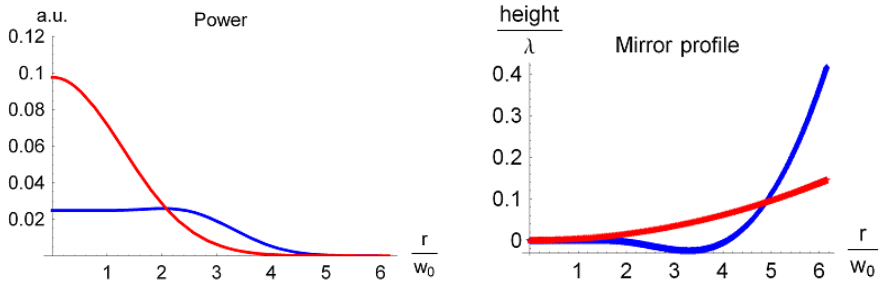

Figure 1: Beam intensity and mirror profiles [2]

2 Current work

A prototype cavity, capable of supporting both traditional Gaussian beams and the new mesa beams has been constructed at Caltech [6]. Recently the switch to MH mirrors was made.

Current work involves adjusting the configuration of input/output optics and other ancillary systems to lock the cavity to the 00 mesa mode (it is this mode which provides discernable gains over Gaussian beams). At present the cavity favours higher order modes. At lower orders the cavity is extremely unstable and superpositions of many modes are seen. At present the most promising data shows what is thought to be a superposition of the 00 and 01 mesa modes with approximately 60% of the observed intensity residing in the 00 mode.

3 Work to date

3.1 Mode-matching telescope

The first task undertaken was the design of an improved mode-matching telescope to better couple the Gaussian input to the cavity. This involved research on resonator theory and extensive computer modelling.

It is anticipated that using the new input optics will improve the ability of the cavity to sustain the fundamental mesa mode and assist us in achieving our goals.

The purchase of 2" optic elements (both lenses and mirrors) is required to support the larger beam produced by this new telescope. These items are readily available and discussions are ongoing with a member of staff (Phil Willems) as to which items will best serve our purpose.

3.2 Beam analysis

Computer code has been written to fit experimental data from our cavity to simulations - from FFT code for example. This shall permit us to gauge the accuracy of current understanding. It may also be feasible to use this work to analyse known tilts and translations of the cavity mirrors once stable operation has been achieved.

4 Further work

Research goals for the coming month include:

- producing a stable 00 mesa mode within the experimental cavity
- obtaining quantitative data on the sensitivity of mesa beams beam to known tilts, translations and figure errors of the mirror
- extending the investigation to other MH mirrors to define the principal design criteria for full-scale implementation of mesa beam technology to long baseline GW detectors

References

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