Flat top Beam interferometer Intermediate report to COC

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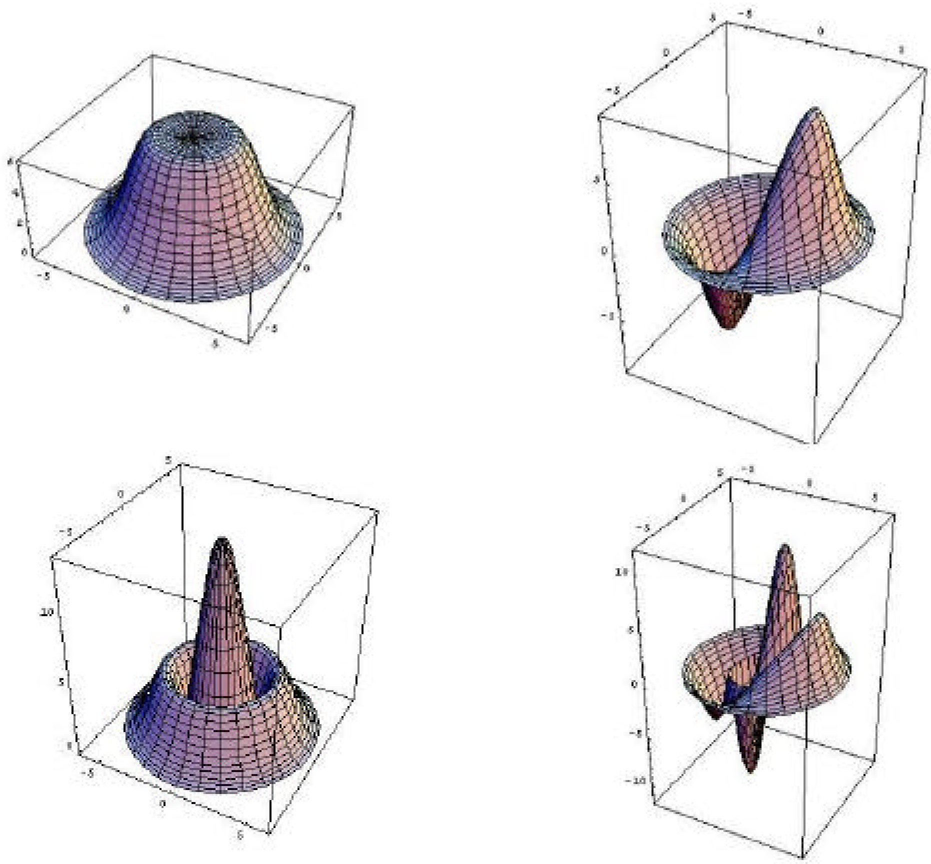
Theoretical analysis:

We investigated the equivalence between concentric cavities and parallel-plane resonators and use this equivalence to construct the non spherical mirrors that supports a flat top beam in an almost concentric cavity, whose fundamental mode has the same transverse distribution as the flat top beam proposed as an alternative for Advanced LIGO, in order to reduce thermoelastic noise. We have compared the two configurations in terms of sensitivity to symmetric misalignment of the mirrors and shown that in the quasi-concentric configuration the cavity is less prone to become unstable and therefore it is easier to control.

We used Fresnel-Kirchoff integral and paraxial approximation to find the integral equation that affords us to find (numerically) the eigenmodes and eigenvalues of the cavity.

Even if we don't know analytically the modes of the two configurations we found a simple relation between the eigenvalues and the distributions of the field over the mirrors in the two cases in such a way that once we have the results for one cavity, we can immediately say what are the results for the other one.

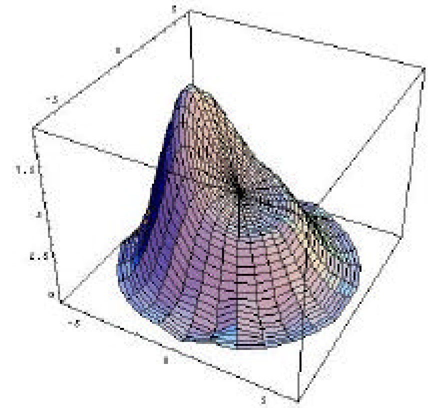
In the following figure there are the first modes of the Mexican Hat Nearly Flat cavity corresponding to the TEM00,TEM10,TEM01,TEM11 where the first number refers to the angular part and the second to the radial one.

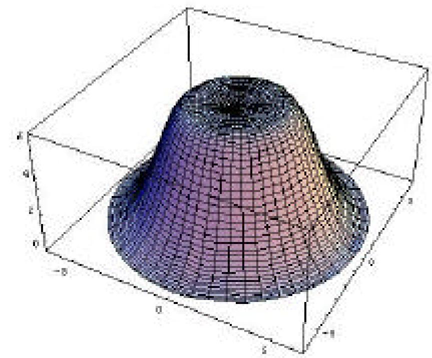


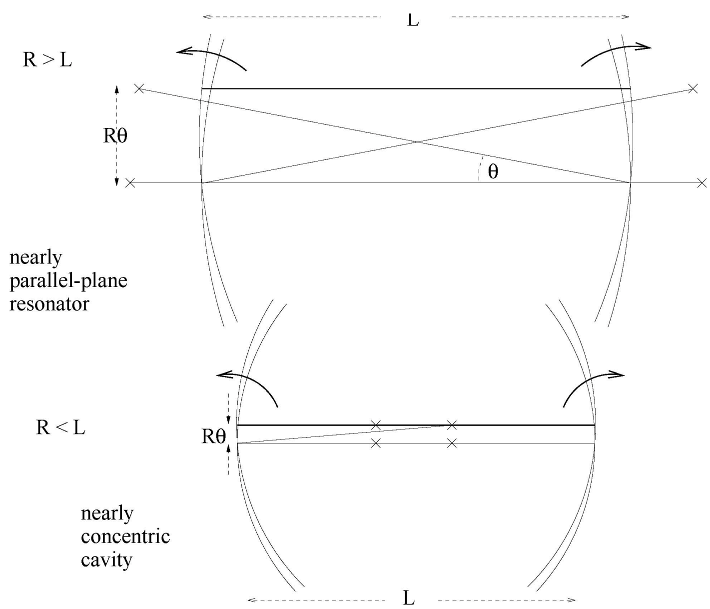
We used a general first and second order solution to the perturbation problem for a complex symmetric (non Hermitian) kernel using the known property of bi-orthogonality between its eigenfunctions and the eigenfunctions of the transposed (or adjoint) operator.

We used this formalism to calculate the coupling between the fundamental and the first higher order mode, induced by a symmetric misalignment of the cavity's mirrors for a Mexican Hat nearly flat and nearly concentric configurations. Using this perturbation theory and our numerical calculation for the modes of the cavity we found that the MH-concentric configuration is about 247 times less sensitive to symmetrical tilting than the MH-flat configuration (using the parameters for the baseline Advanced-LIGO). In order to check these results using the perturbation theory we wrote a Mathematica notebook to compute the electromagnetic field across the mirrors of the cavity where an initially launched wave is reflected back and forth between the misaligned mirrors until a steady-state field distribution is obtained (this technique was adopted by Fox and Li to study the resonant modes in a Maser Interferometer). This is a simulation of what really happens in an optical cavity and it will be useful also to make a comparison with the experimental results from our Mexican-Hat cavity we are building.

In the following figures there are the field distributions over the mirror's surfaces for a symmetrical tilt of 10^-7 rad in the case of MH-flat (left) and MH-concentric (right). You can see that the coupling between the fundamental and the first higher mode is very small for the nearly concentric cavity (quantitative analysis of these numerical simulation are in progress).







Experimental work:

In this month we are still mounting the mechanics of the interferometer. After the delivery of the invar, we are tested the thermal expansion coefficient of the three rods and after we have assembled the internal structure except the optics. For what concern the suspention system we have found the working point of each blade and that means without any driver we have a resonant frequency around 0.7 Hz . During the work for the calibration of the blade we received the wood stuff to support the vacuum pipe.
So now we have received everything and in the next 2 weeks we are trying to finish the assembling of the mechanics part of the interferometer.