Piezoelectric effect measurement update (Electrode plate design)

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Overview

Geometries

- Thin Circular Plate
- Thin Square Plate
- Write the strength of the E-field at particular ROI
- Plate would be machined out of Aluminum and would be held at a constant potential with lab power supply
- With this information we calculate an approximate surface charge density of (?) and we estimate that the distance between the electrode plates are at an optimal distance at (?)

Circular electrodes with central hole

- To the first order we might be able to say that the electric field at the region of interest (beam spot) is simply:

$$E_{\mathrm{total}} = \frac{V}{d}$$

This assumes two infinitely sized parallel plate capacitor electrodes a distance d apart.

- Estimated electric field from disk with hole (not considering fringe effects):

$$E_A = \frac{\sigma d}{2\epsilon_{\mathrm{o}}}\left[\frac{1}{\sqrt{d^2 + r'^2}} + \frac{1}{\sqrt{d^2 + R^2}}\right]$$

Considering both plates we can say that E_{total} at location A is:

$$E_{\mathrm{total}} = 2 * E_A$$

This expression considers the hole at the center of the electrodes, and the finite size of the electrode plates

Optical considerations

- Cavity Size / Beam spot size on sample
- $$\frac{\Delta f_{\mathrm{laser}}}{f_{\mathrm{laser}}} < \frac{\Delta L_{\mathrm{cav}}}{L_{\mathrm{cav}}}$$
  Where I am considering ΔL_{cav} to be the induced length change due to the piezoelectric effect.
- Assuming we have a 10 cm length cavity we can estimate $\frac{3.05*10^{-14}}{.01} = 3.05 * 10^{-12}$ $[\mathrm{rad}]$ which lies an order of magnitude below the effect we wish to measure. :(
- Can modulate the electric field at some higher frequency where the frequency noise is less of an issue (how fast can we modulate the field and still notice the effect? $\rightarrow$ Impulse / Step response analysis)

PDH locking

- First attempt to suppress laser frequency noise while keeping simple cavity design in mind.
- Black states (ref) that a closed loop PDH system can suppress frequency noise (n) below the reference cavity pole frequency by a factor of

$$\frac{1}{1 + H(s) * D(s) * K(s)}$$

  Where H(s) [Hz/V] is the laser transfer function, D(s) [V/Hz] is the PDH transfer function, and K(s) is the servo gain.
- Dont have exact values to propose but this could be a place to start.
- Propose we use the LIGO PMC we have on the AMM table as refrence cavity. (Might want to double check how destructive this could be to phase camera peeps)
- If this does not provide enough suppression, we might have to move on to an interferometer design.

Electrode design

- Am thinking of machining a thin square aluminum plate significantly larger than the size of the optic so to avoid field fringe effects. (Might need to do some quick calculations to establish the minimum size of this plate)
- Will also want to drill a hole in the center of the plate so to allow the beam to pass through to the AlGaAs sample without introducing any spatial defects to the intra-cavity beam. (Can do some calculations for optimal aperture size)

Sample / electrode mount(s)

Traditional metallic optic mounts could introduce unwanted charge distributions. Need to think of ways around this. Here are some inital thoughts:

In-air

- 3D printed flexure optic mount
- Could potentially be a simple one piece print

In-vacuum

- Monolithic fused silica holder (Work on 3d printed concept? request to have made at Corning?)
- Dont know how we would embed a fused silica holder in vacuum (suspended?) (clamped on table?)