Piezoelectric effect measurement update (Noise and initial design considerations)

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Overview

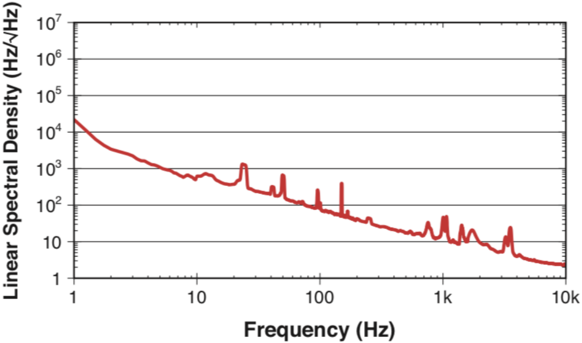
1. How big is the Piezoelectric effect?
2. Competing with laser frequency noise
3. Electrode / Sample mount

Some preliminary figures

- According to Marty Fejer $\frac{\partial \phi}{\partial \mathrm{E}} \approx 4.5 * 10^{-10} \frac{\mathrm{m}}{\mathrm{V}}$
- Conservatively we can attempt to create a setup that would generate Electric fields on the order of 10 V / 2.5 cm = 400 V/m
- This would lead to an effect of $1.8 * 10^{-7}$ $[\mathrm{rad}]$ or $3.05 * 10^{-14}[\mathrm{m}]$
- This is for a single layer so we could multiply by the number of AlGaAs layers? (Maybe increases the effect by an order of magnitude?)

Light source: Mephisto 2000 NE

Frequency Noise[1]



Frequency noise to phase noise

- Assuming that the largest laser frequency fluctuations ($\Delta f_{\mathrm{laser}}$) 11,500 Hz away from the carrier frequency. Can calculate this as phase noise $\left(\frac{\Delta f_{\mathrm{laser}}}{f_{\mathrm{laser}}}\right)$ on the order of $4.08 * 10^{-11}$ [rad]
- If we are to use a simple Fabry-Perot cavity to measure this effect, we would need:
$$\frac{\Delta f_{\mathrm{laser}}}{f_{\mathrm{laser}}} < \frac{\Delta L_{\mathrm{cav}}}{L_{\mathrm{cav}}}$$
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 $\frac{3.05*10^{-14}}{.01} = 3.05 * 10^{-12}$ [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?)