Experiment to measure the Pockels effect from an HR AlGaAs coating (update)

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Pockels Effect (quick summary)

- Same physics used in electro-optic modulators (dn/dE)
- For AlGaAs HR coating (grown along [001] crystallographic direction):

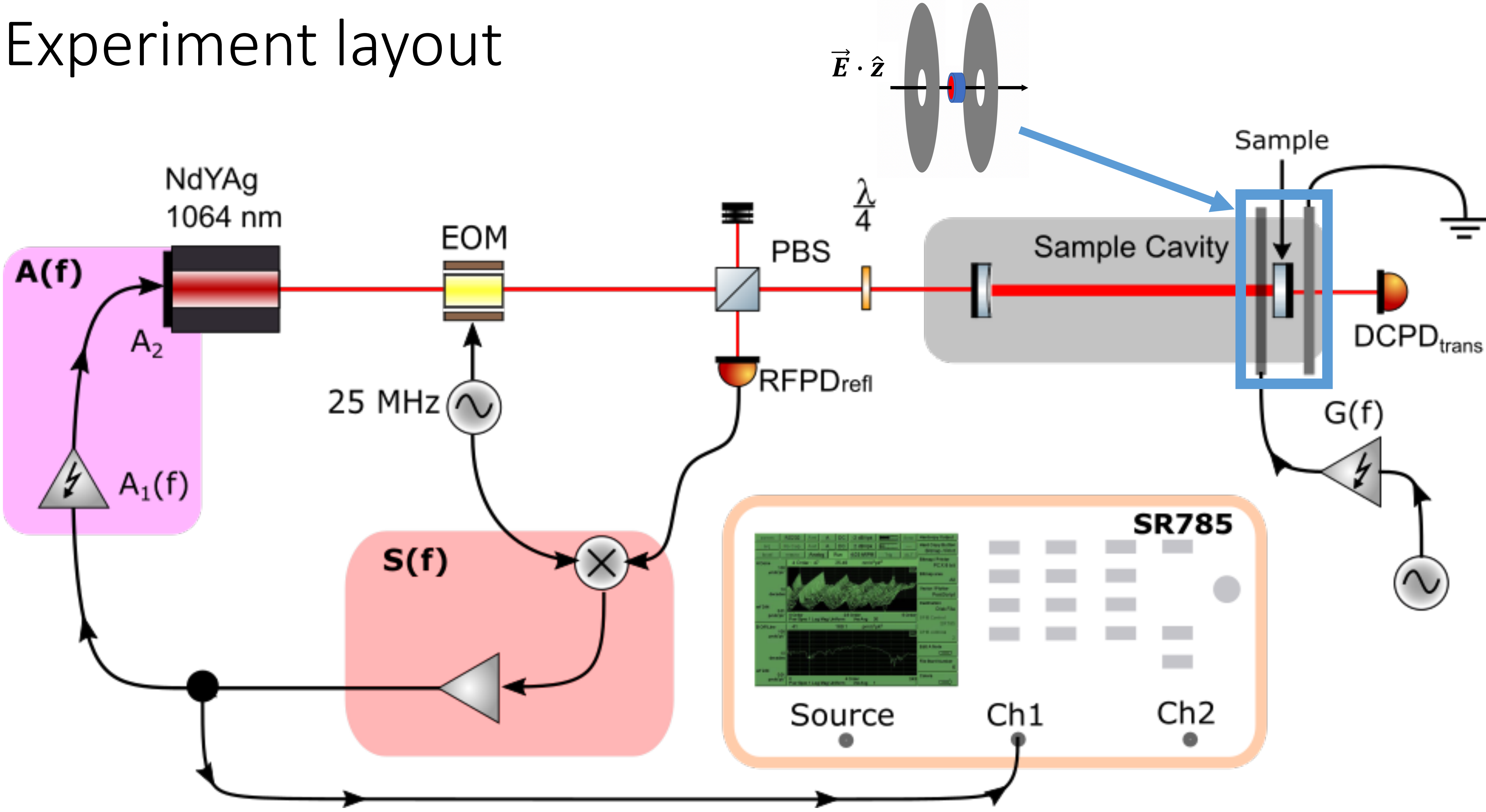
$$\left|\frac{\partial \phi}{\partial E_z}\right| = \pi \frac{r_{41}}{2}\left(n_2 {n_3}^2 + n_3 {n_2}^2\right) + \frac{n_2/n_3}{1-\left(\frac{n_2}{n_3}\right)^2}$$

Where r_{41} (-1.2e-12 [m/V]) is the electro-optic coefficient and n_2 (3.0087) and $n_3(3.4426)$ are low and high index layers of the HR coating respectively

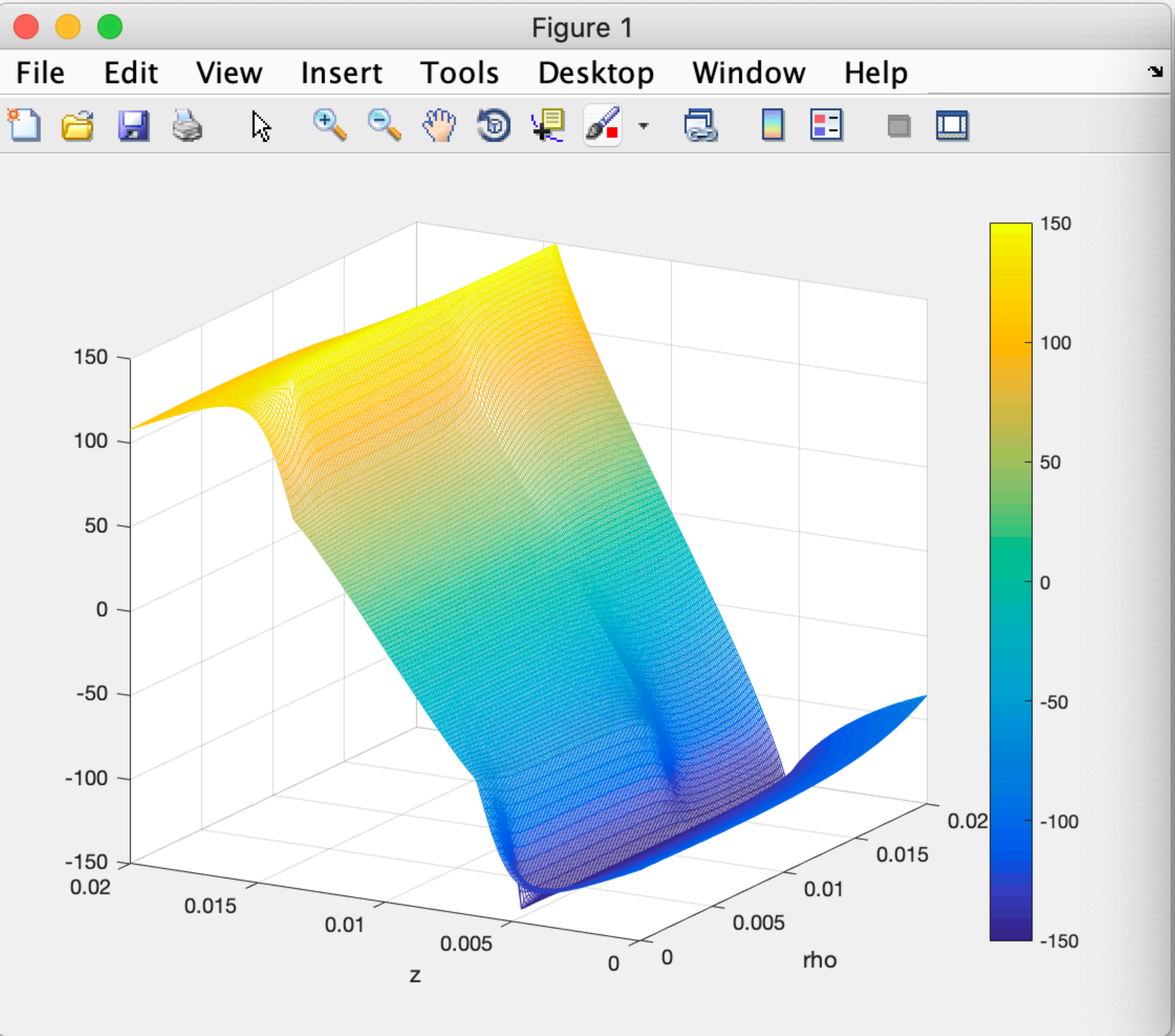
- And for $\lambda = 1064nm$ in reflection:

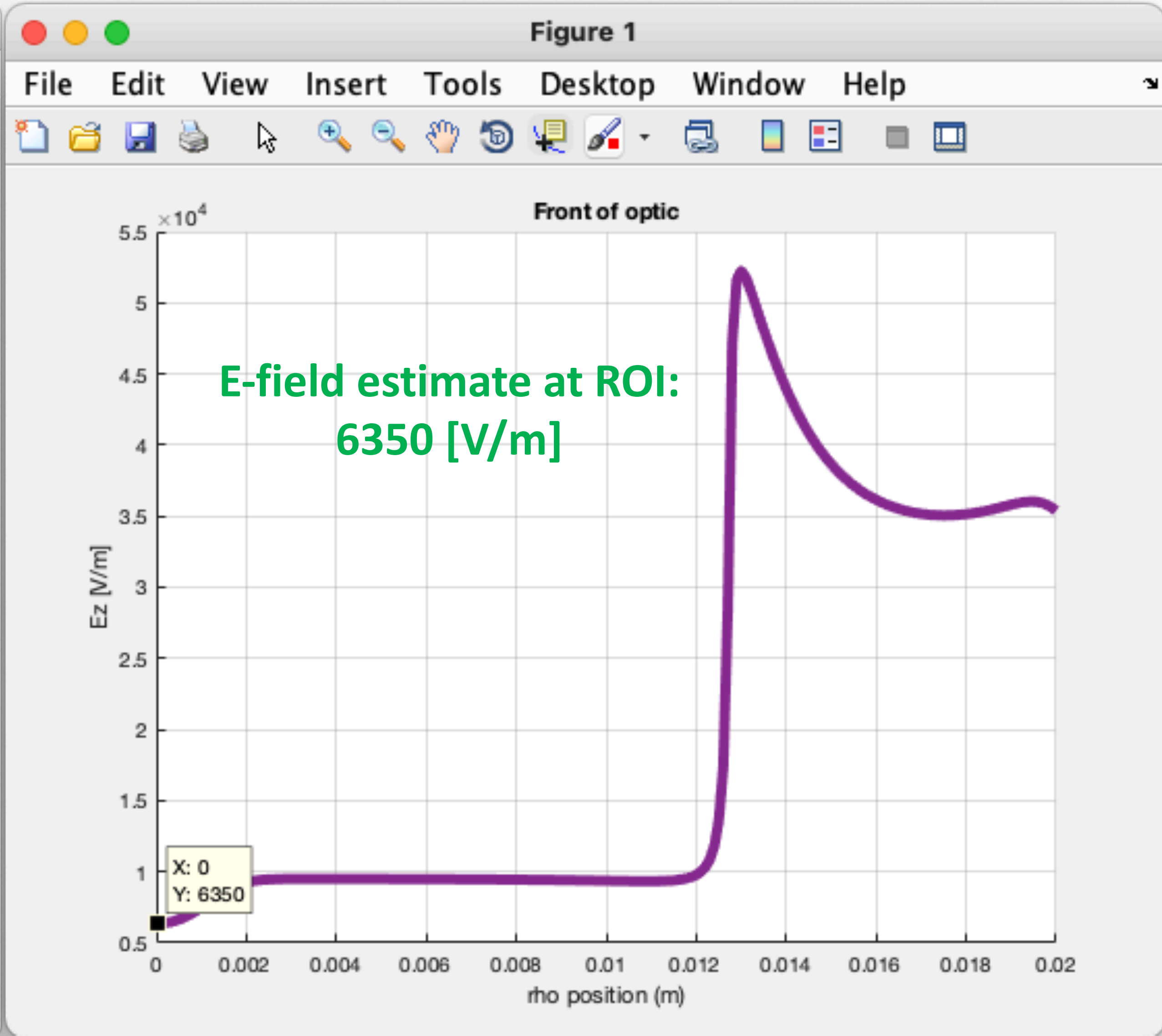
$$\left|\frac{\partial x}{\partial E_z}\right| = 3.8*10^{-17}\ [\mathrm{m/V/m}]$$

Experiment layout

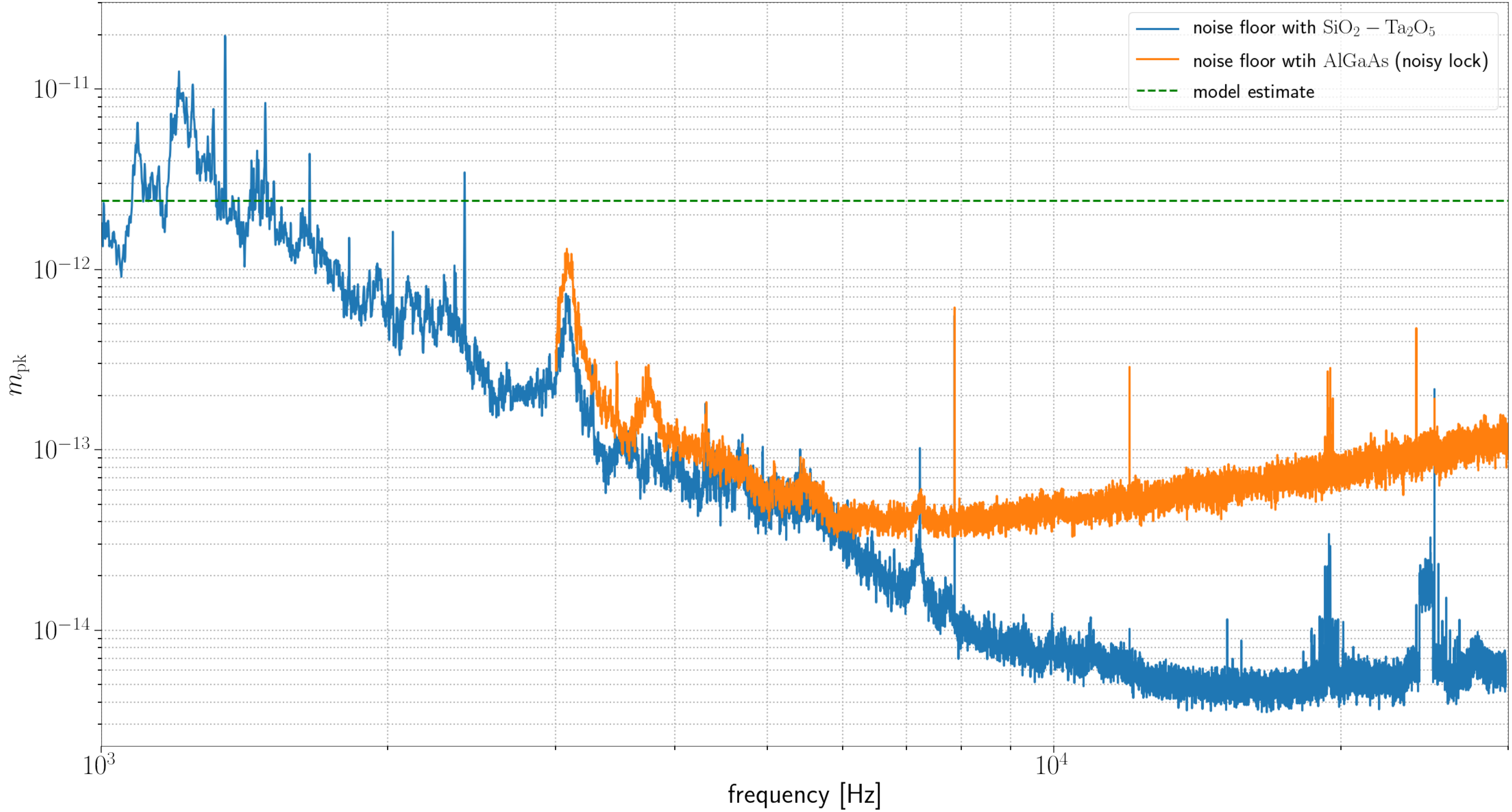


Electric field estimate within coating

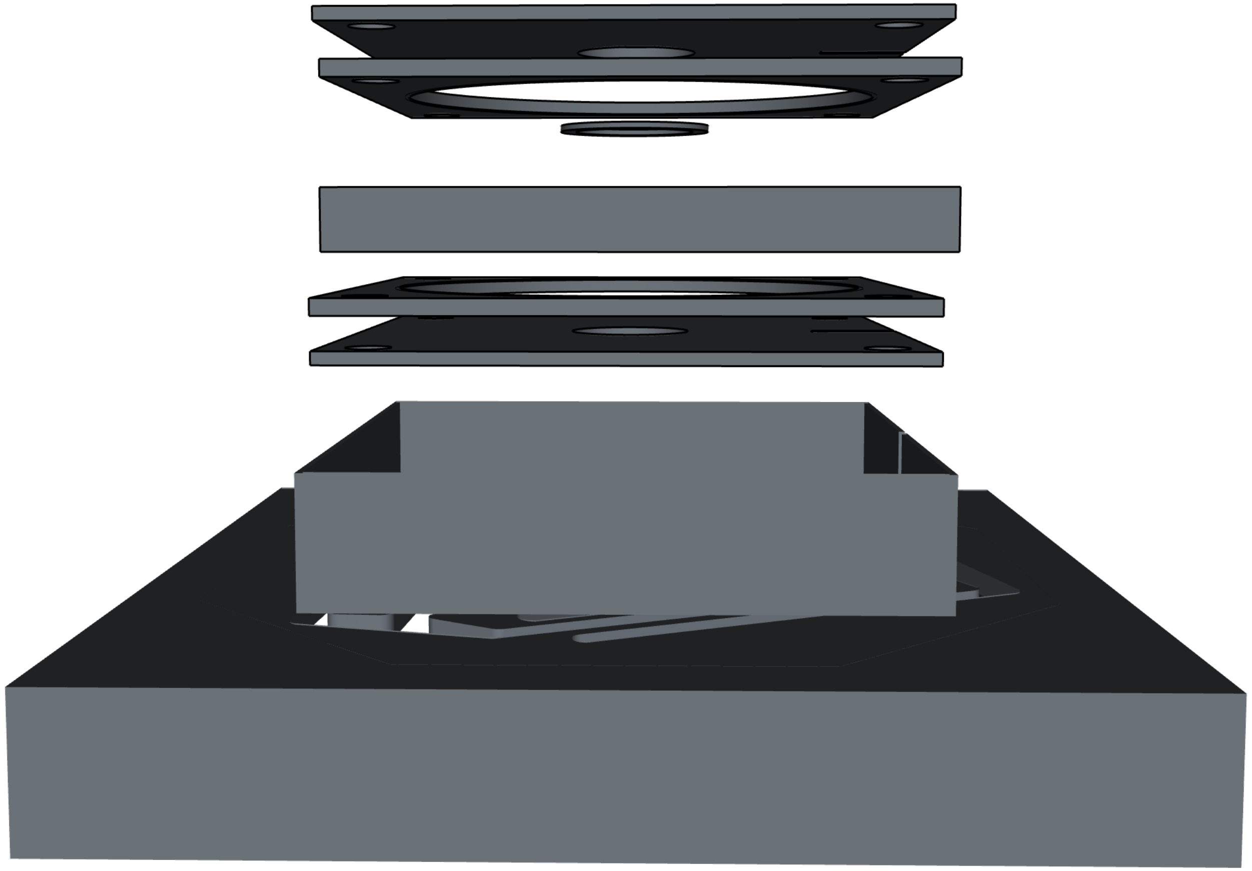


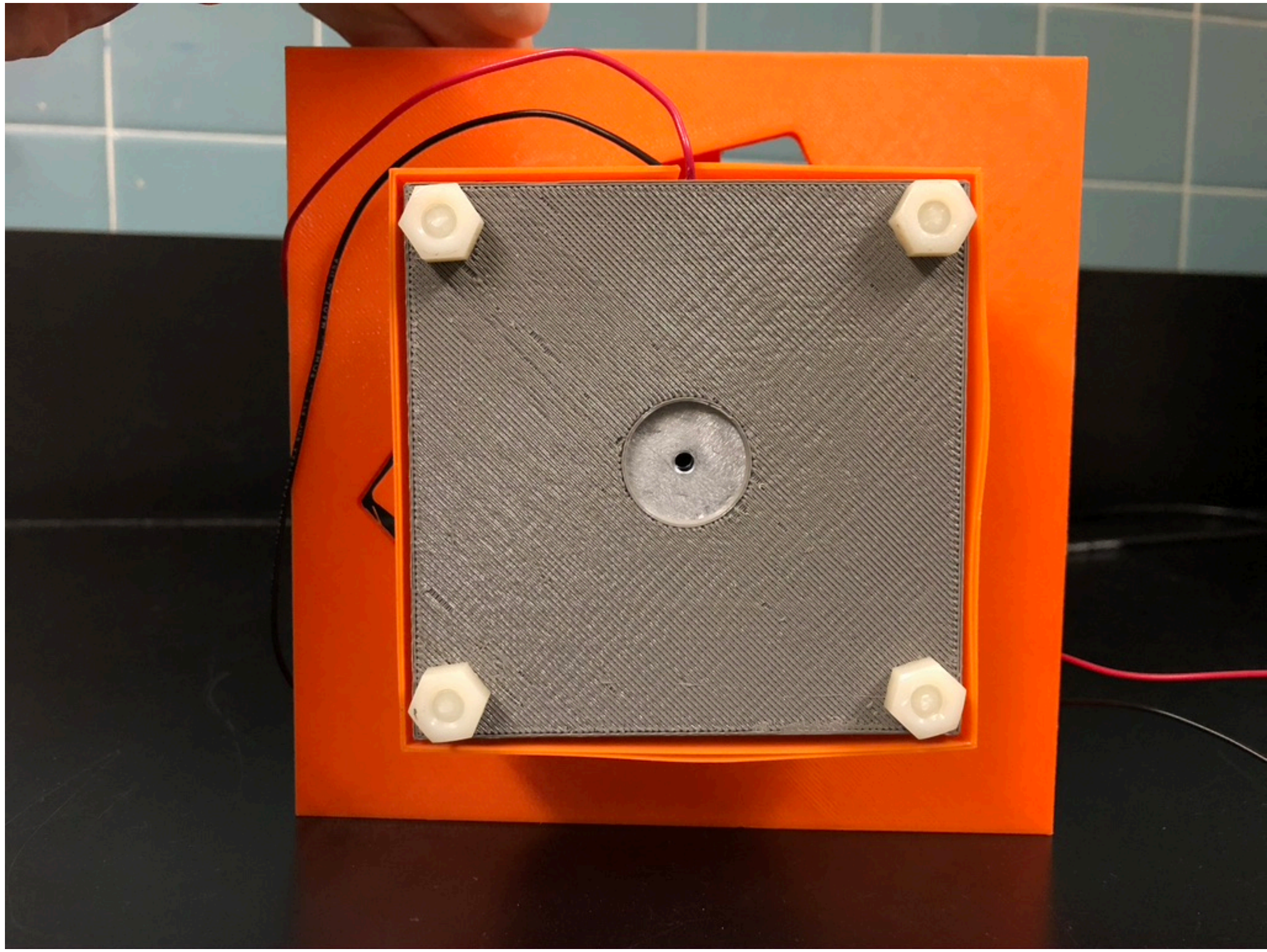


Measurable using in-air cavity



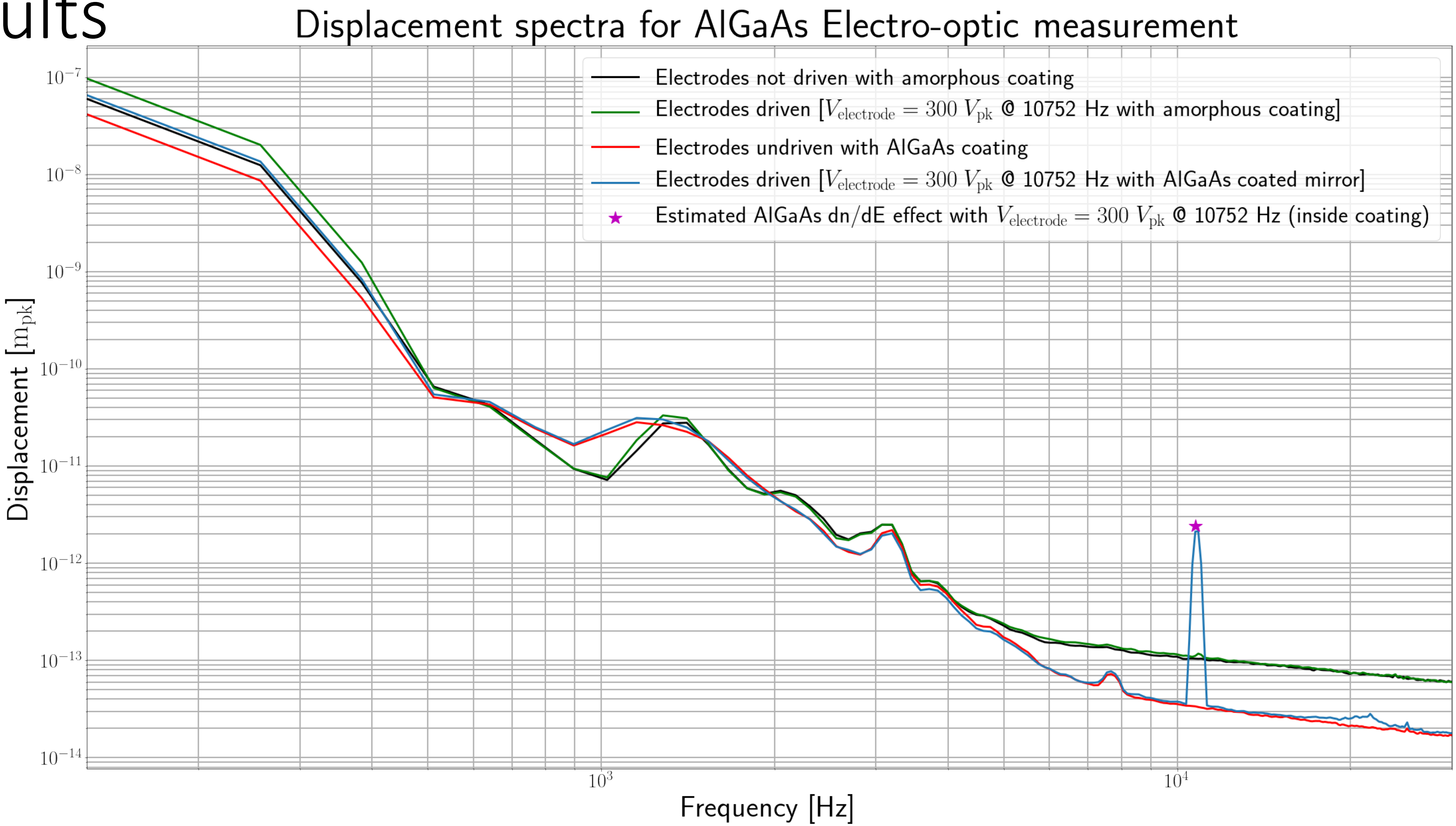
3D printed optical mount



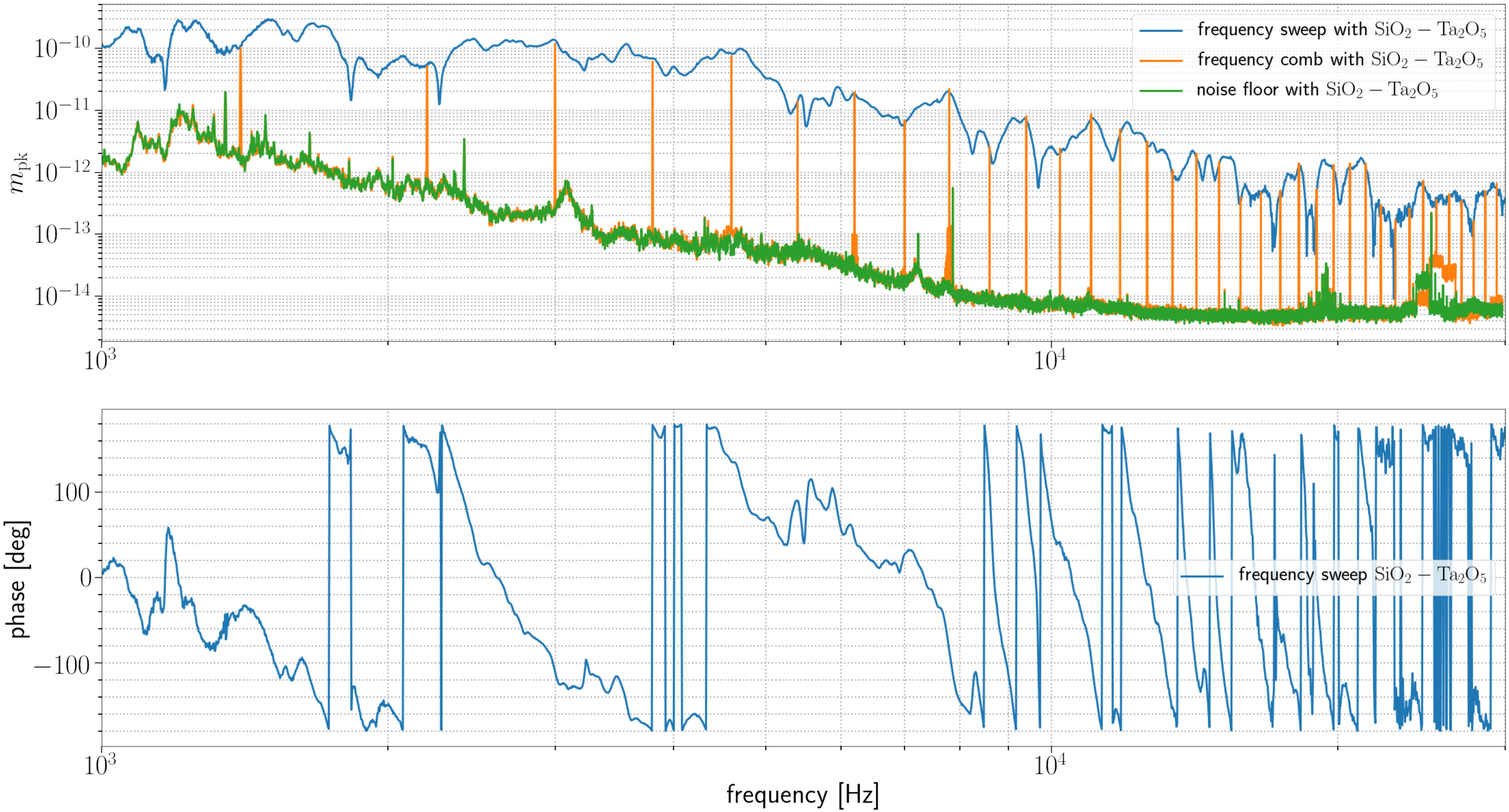


Ortho-planar spring design for pitch and yaw control

Previously reported single frequency drive results



Frequency sweep test (SiO_2-Ta_2O_5 sample mirror)



Next Steps

- Further investigation as to why we see the drive coupling into the PDH error signal for SiO_2/Ta_2O_5 sample
  - Potential mechanical instability of 3D printed mount
  - Electronics crosstalk
- Once aforementioned coupling is addressed, attempt to measure Pockels effect with AlGaAs sample
- Investment in calibration sample
- Measure effect with separate individual polarizations

Refrences

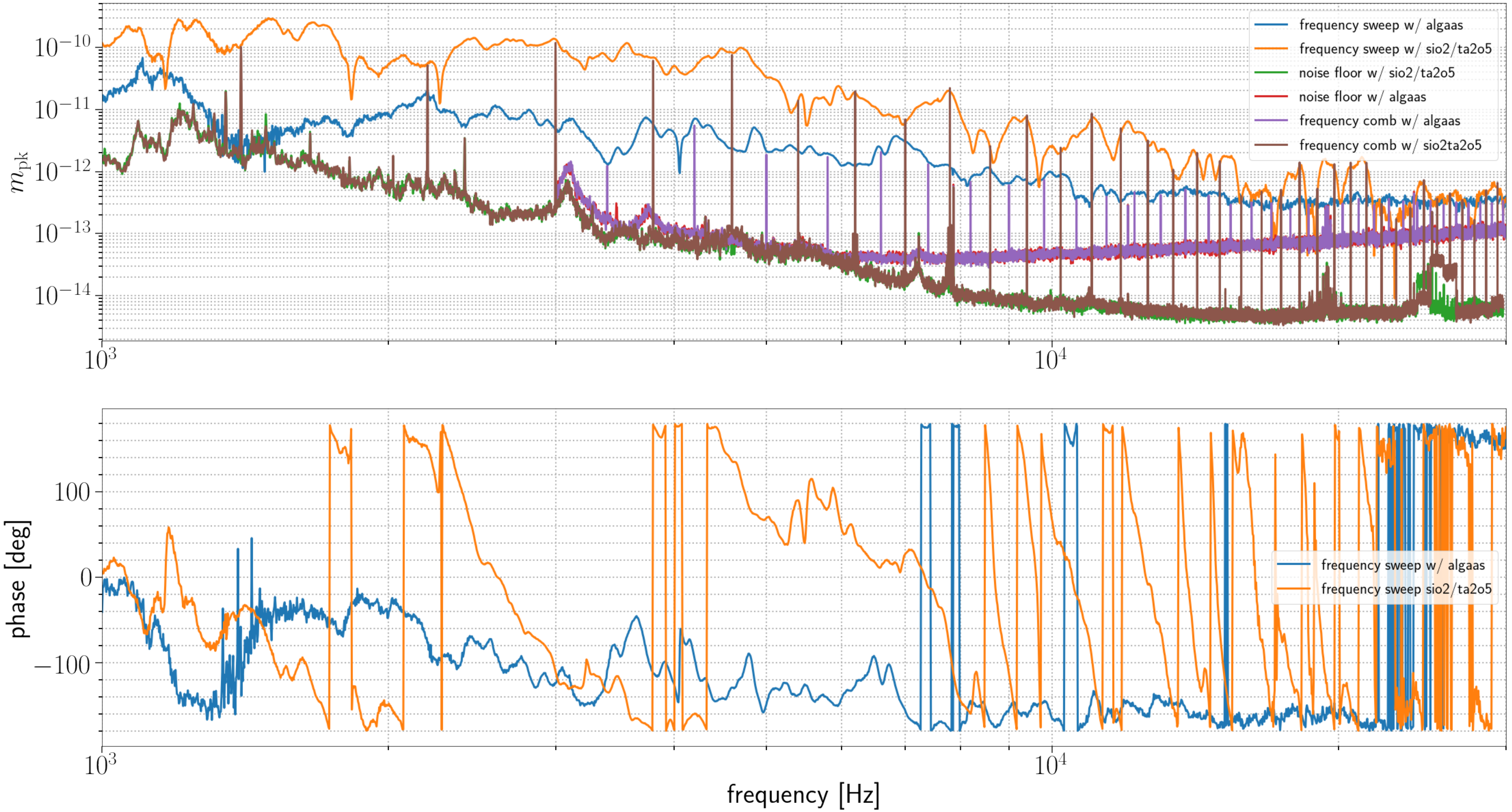
- Fejer, M.M. , *Electro-optic Effects in AlGaAs mirrors* , (2018)
- Yariv, A., 1988, *Quantum electronics*, 3rd edn, (John Wiley & Sons)
- BYU CMR, *Ortho-planar spring design* : https://www.thingiverse.com/thing:3007261

Thank you!

Questions? Suggestions?

EXTRA SLIDES

Frequency sweep test (both sample mirrors)



Calibration

This frequency response measurement records the following ratio in dB of the following:

$$\alpha(f) = \frac{CH2(f)}{Source} \quad (1)$$

We also know that the error signal spectra of the loop is probed by $\mathrm{CH2}(f)$:

$$\mathrm{C}H2(f) = \frac{S(f) * (signal\ [V])}{(1 - OLG(f))} \quad (2)$$

Where $(signal\ [V])$ is the uncalibrated voltage output from the mixer, $S(f)$ is the FSS transfer function, and $OLG(f)$ is the open loop gain of the PDH system.

Calibration (cont.)

And we know $OLG(f) = S(f) * A_1(f) * A_2$ so :

$$(signal\ [m]) = CH2(f) * A_1\,(f) * A_2 * \frac{1 - OLG(f)}{OLG(f)} * \frac{L_{cav}}{f_{laser}} \qquad (4)$$

Where $\boldsymbol{A_1(f), A_2}$ are a high voltage amplifier response and measured response of the laser piezo respectively. $\boldsymbol{L_{cav}}$ is the sample cavity length, $\boldsymbol{f_{laser}}$ is the laser frequency. $(\boldsymbol{signal}\ [\boldsymbol{m}])$ is the effective cavity length change from the Pockels effect.

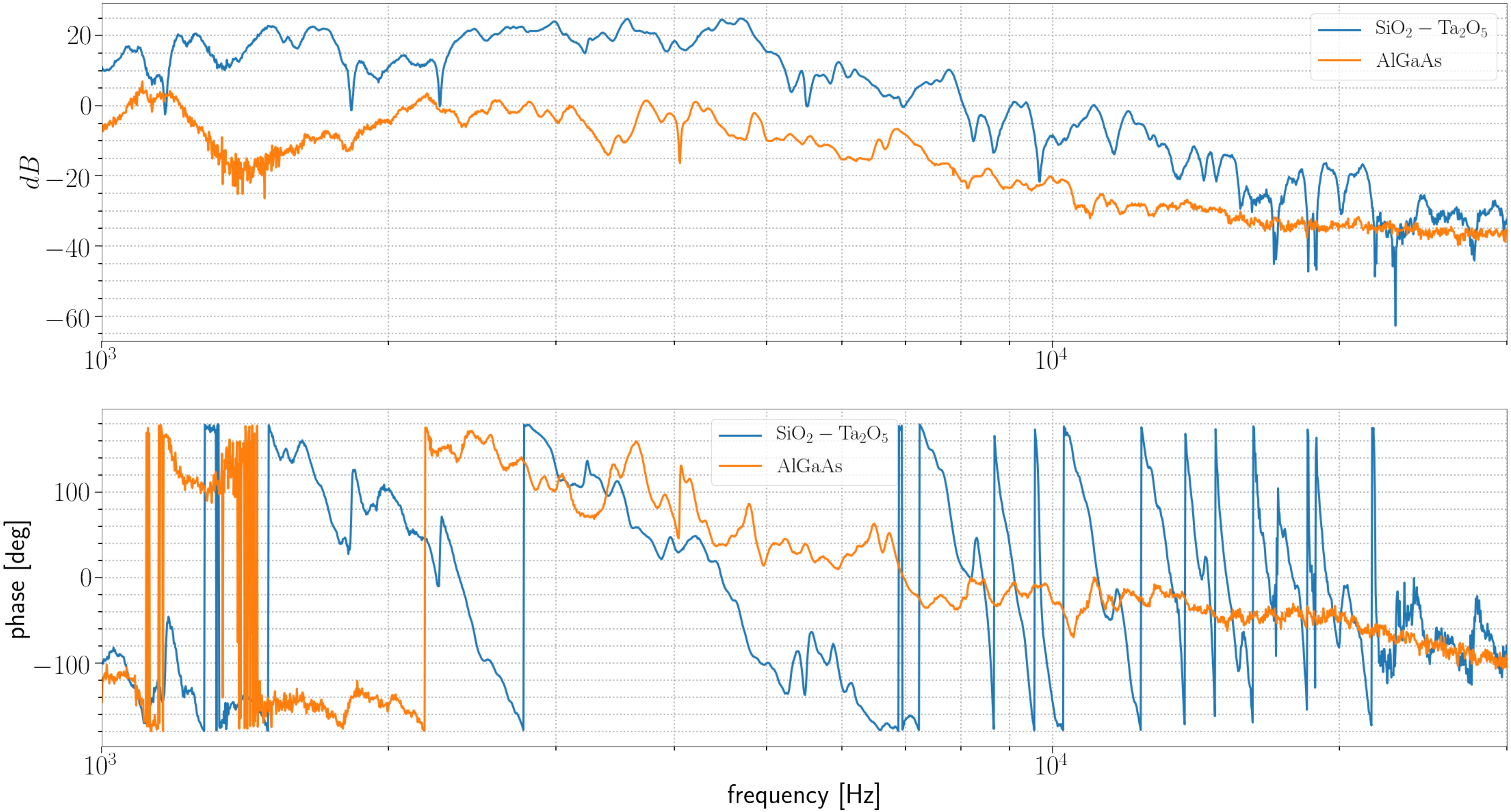
Substitute (1) into (4):

$$(signal\ [m]) = Source * \alpha(f) * A_1\,(f) * A_2 * \frac{1 - OLG(f)}{OLG(f)} * \frac{L_{cav}}{f_{laser}} \qquad (5)$$

Measured : $Source, \alpha(f), OLG(f), A_1(f),\ \ A_2, and\ L_{cav}$

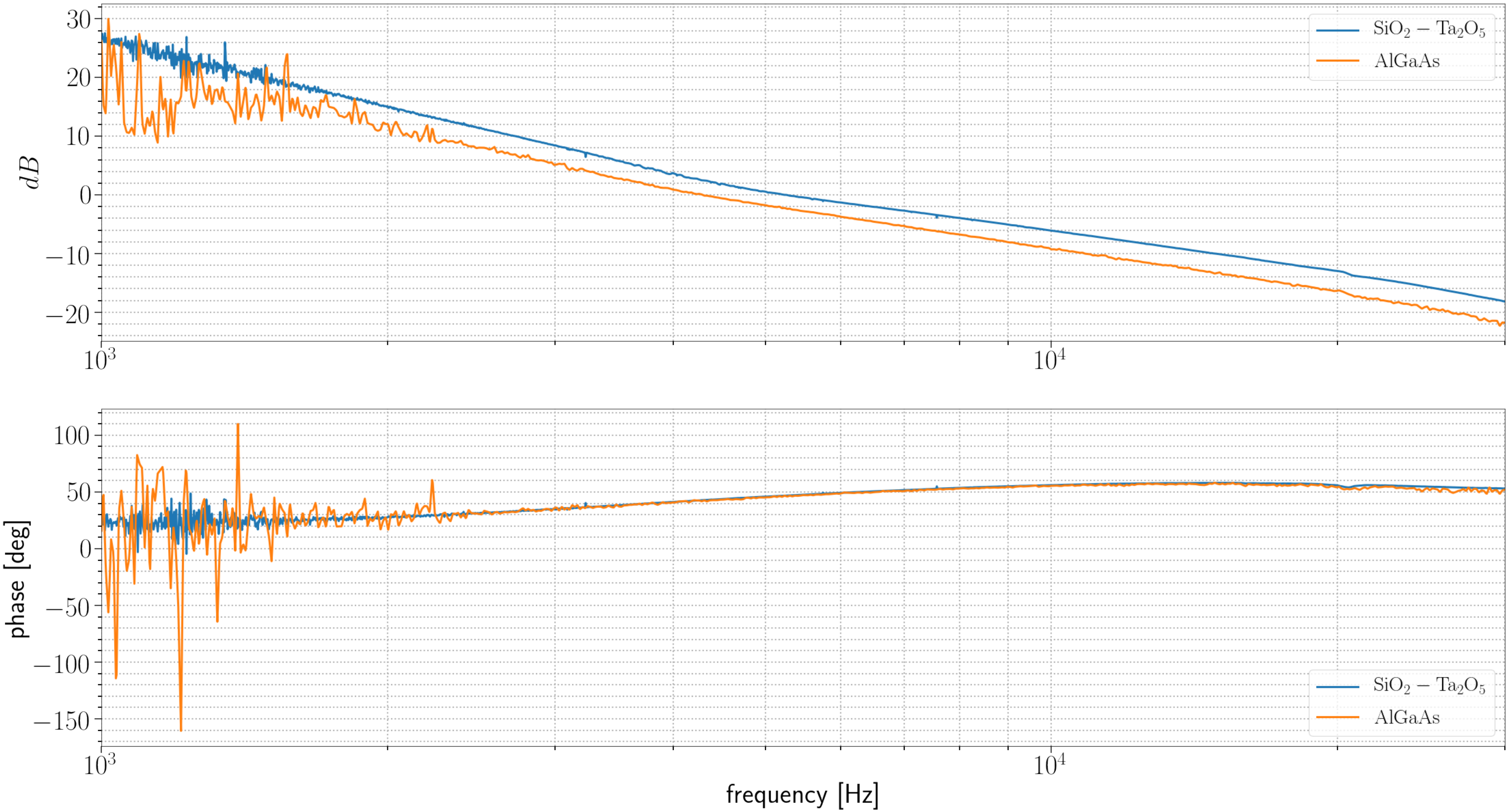
$Source = 5\,V_{pk}$ and L_{cav}= .165 m, $f_{laser} = 2.8\text{e}14$ Hz

$\alpha(f)$



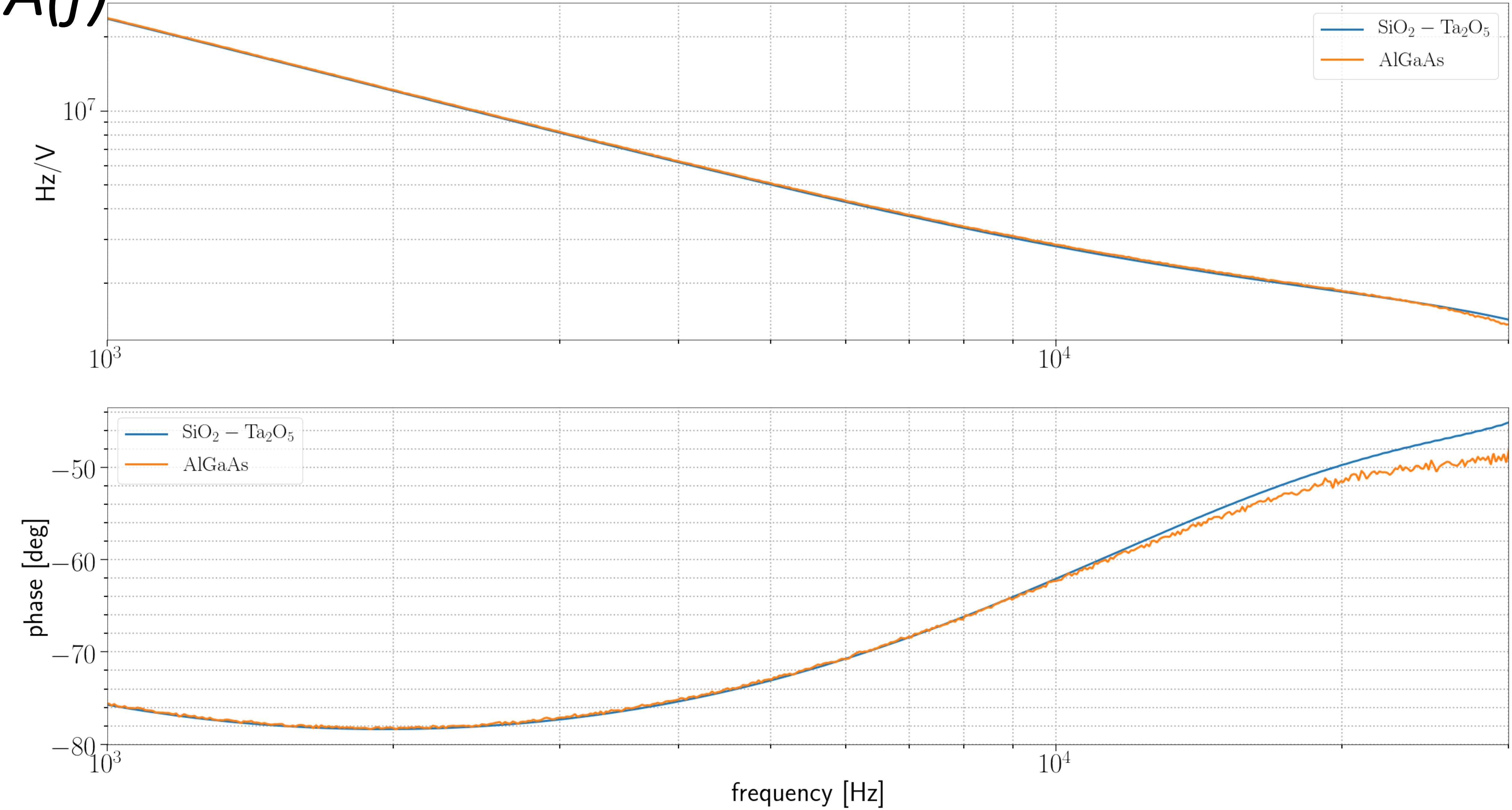
20
0
−20
−40
−60
dB
10^3
10^4
$SiO_2 - Ta_2O_5$
AlGaAs
100
0
−100
phase [deg]
10^3
10^4
$SiO_2 - Ta_2O_5$
AlGaAs
frequency [Hz]

OLG



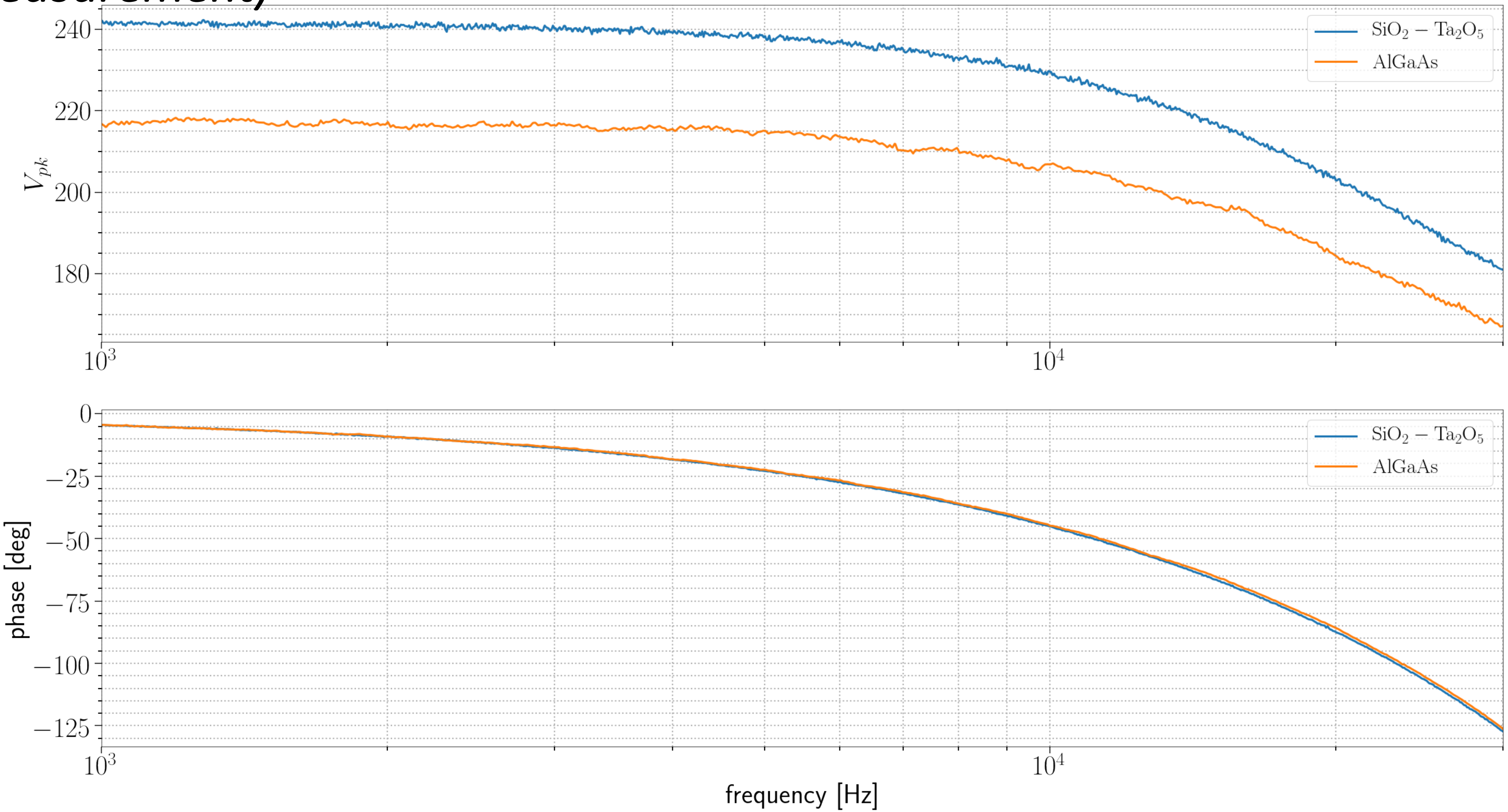
30
20
10
0
−10
−20
dB
10^3
10^4
$SiO_2 - Ta_2O_5$
AlGaAs
100
50
0
−50
−100
−150
phase [deg]
10^3
10^4
frequency [Hz]
$SiO_2 - Ta_2O_5$
AlGaAs

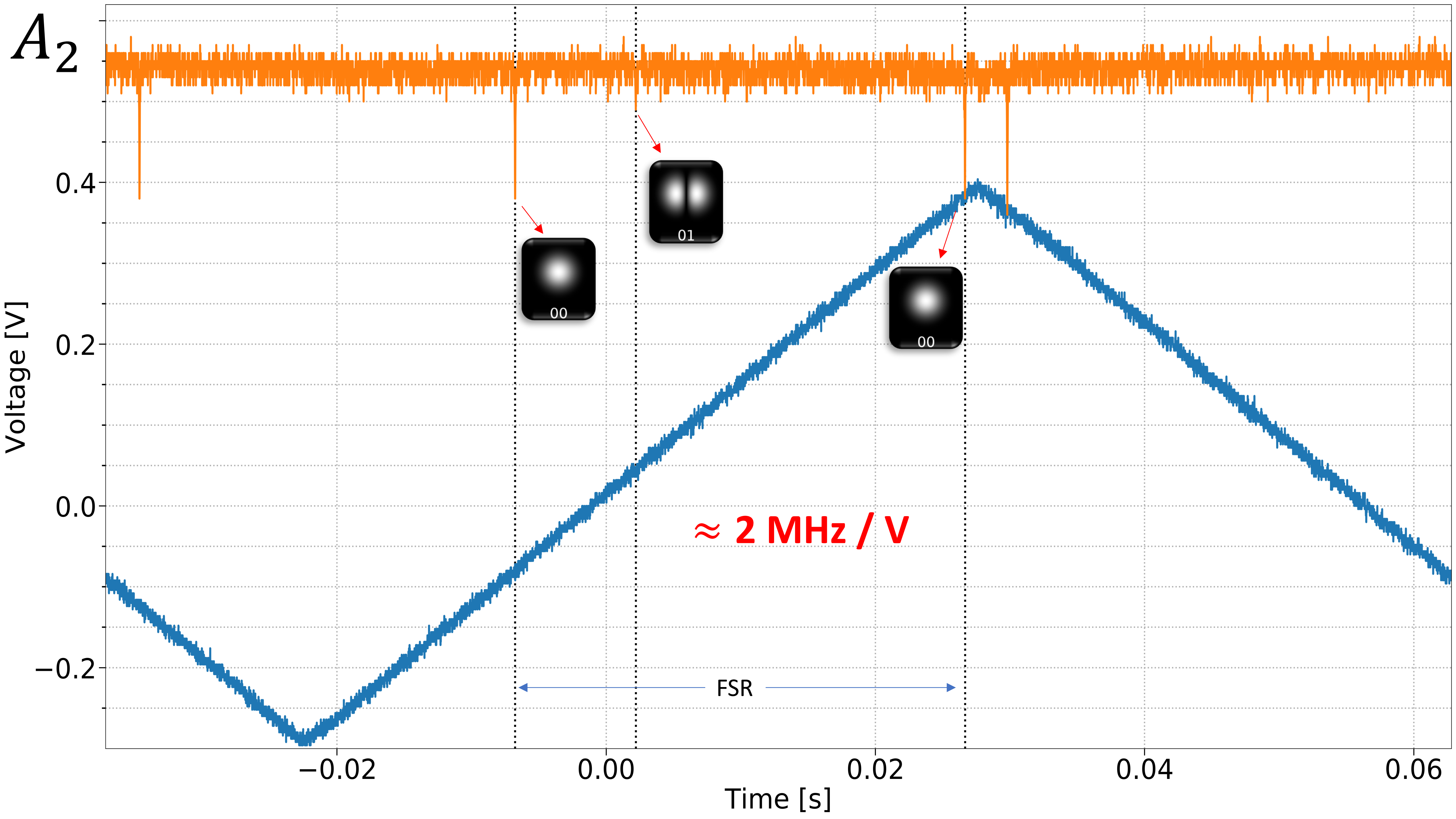
A(f)



$SiO_2 - Ta_2O_5$
AlGaAs
10^7
Hz/V
10^3
10^4
$SiO_2 - Ta_2O_5$
AlGaAs
−50
−60
−70
−80
phase [deg]
10^3
10^4
frequency [Hz]

Voltage on front electrode plate (swept frequency measurement)





A_2
0.4
0.2
0.0
−0.2
Voltage [V]
−0.02
0.00
0.02
0.04
0.06
Time [s]
00
01
00
≈ 2 MHz / V
FSR