Piezoelectric Actuators Shaking an Optical Lattice at the high-frequency regime in a Cold Atom Experiment

Motivation

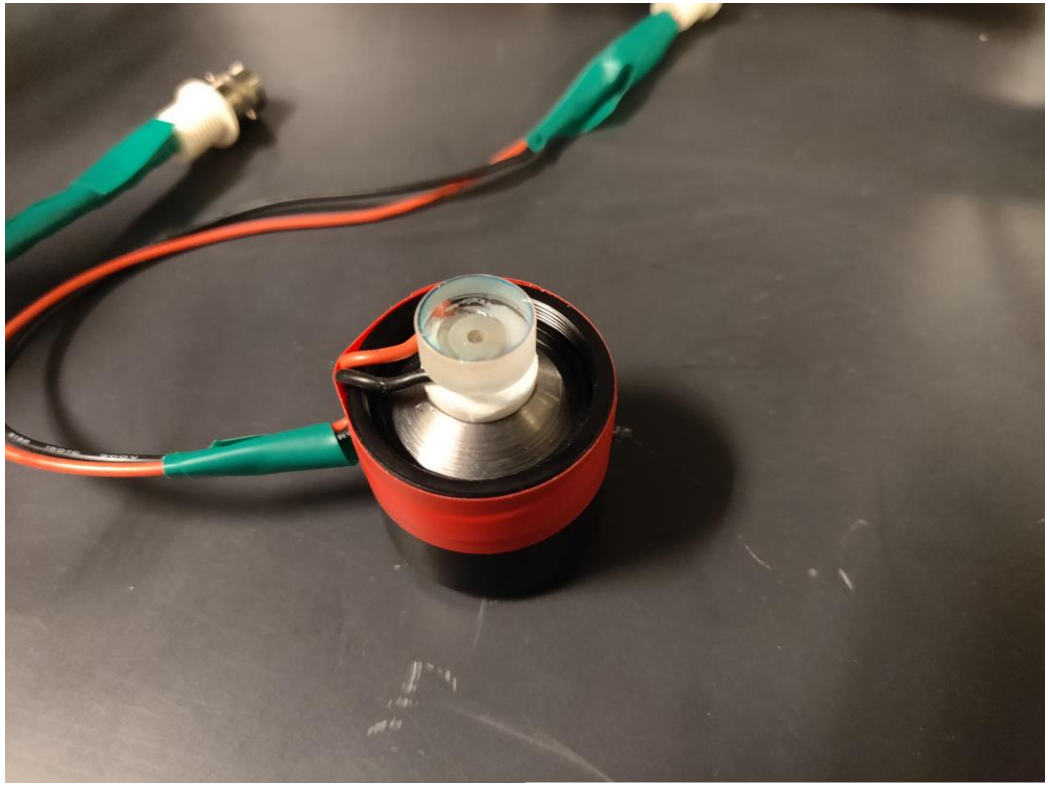
$$\hat{H}(\tau) = \frac{\hat{p}}{2m} + V_{lat}(\hat{x}) - F(\tau)\hat{x}$$

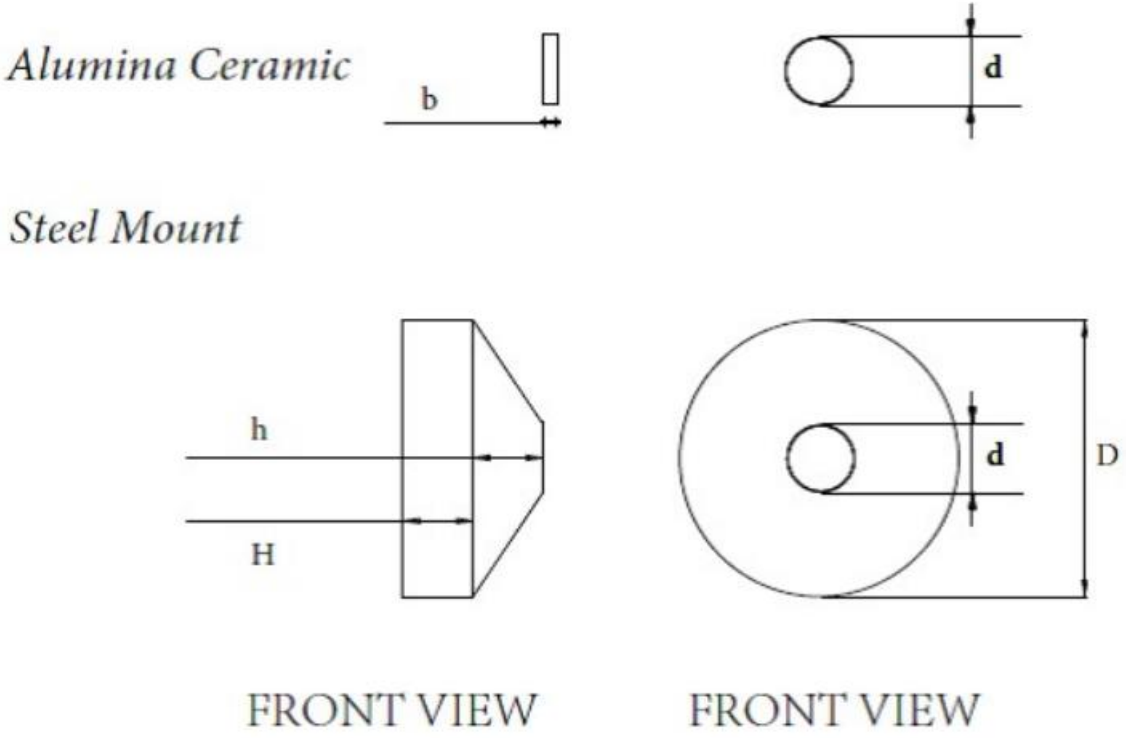
$$\begin{aligned}\hat{H} &= -t \sum_{<\boldsymbol{j},\boldsymbol{l}>\sigma} (c^{\dagger}_{\boldsymbol{j}\sigma} c_{\boldsymbol{l}\sigma} + c^{\dagger}_{\boldsymbol{l}\sigma} c_{\boldsymbol{j}\sigma}) - F(\tau) \sum_{i} ia\hat{n}_i \\ &= -t \sum_{<\boldsymbol{j},\boldsymbol{l}>\sigma} (c^{\dagger}_{\boldsymbol{j}\sigma} c_{\boldsymbol{l}\sigma} + c^{\dagger}_{\boldsymbol{l}\sigma} c_{\boldsymbol{j}\sigma}) - \hbar\omega_{lat} K_0 sin(\omega_{lat}) \sum_{i} ia\hat{n}_i\end{aligned}$$

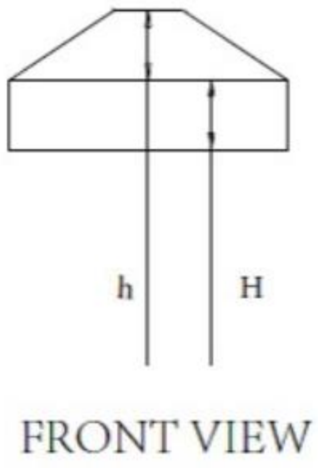
(Sandra Buob, 2018)

Equipment and Design:

- Piezo actuator (-mirror mount)







H = 2 cm, h = 0.5 cm, D = 2.5 cm, d = 1.26 cm.

Equipment and Design:

- Piezo controller

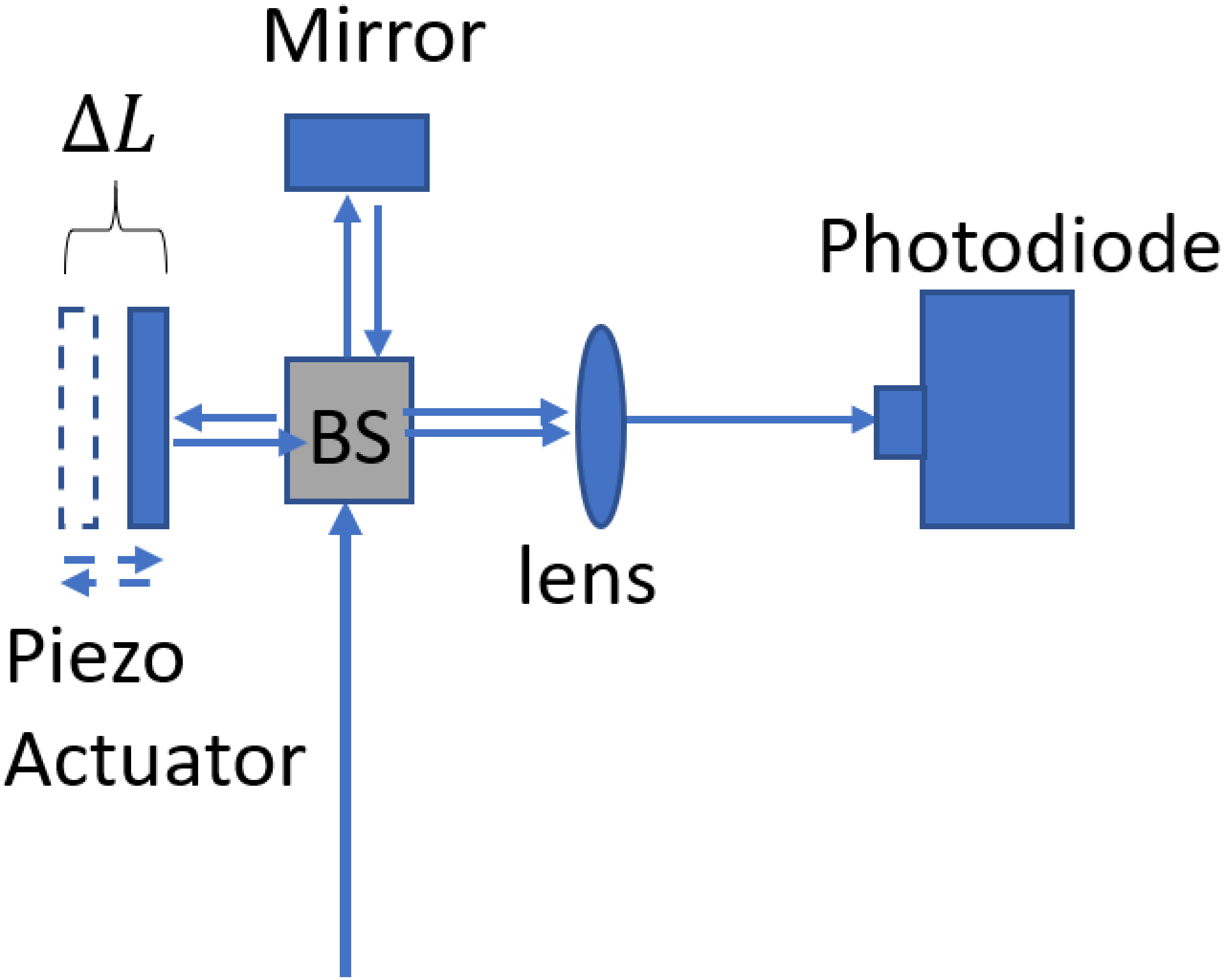
	Noliac	**Tripod**	**Ring**
Model	NAC2013	NAC2012(×3)	NAC2121
Shape	square	3×square	ring
Dimensions(mm)	5×5×2	3×3×2	6-2×2
Capacitance (nF)	190	65(each)	105
Voltage range (V)	0∼150	0∼150	0∼200
Max Stroke (μm)	3.3	3.3	3.3
Stiffness (N/μm)	318	115	321

$$I_{rms} = \frac{VppC\pi f}{\sqrt{2}}$$

Equipment and Design:

- Michelson Interferometer

$$I_{out} \propto E_{tot}E_{tot}^* = 2E_{out}^2(1 + cos2k(d_1 - d_2))$$
$$= 2E_{out}^2(1 + cos\frac{4\pi(d_1 - d_2)}{\lambda})$$



Performance:

- frequency response
- the maximum expansion
- the static steering-error
- micromotion

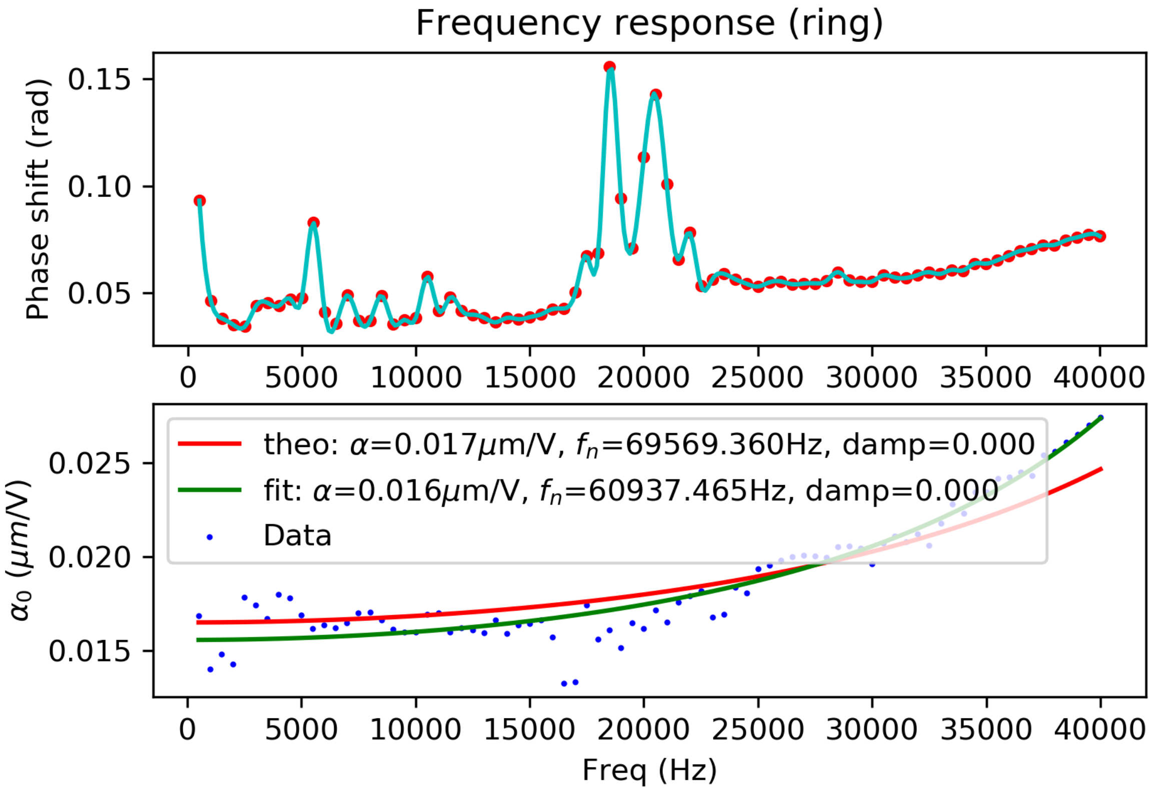
(a) Noliac with $\Phi = 25mm$, $m = 6.80g$

(b) Ring with $\Phi = 12.5mm$, $m = 1.68g$

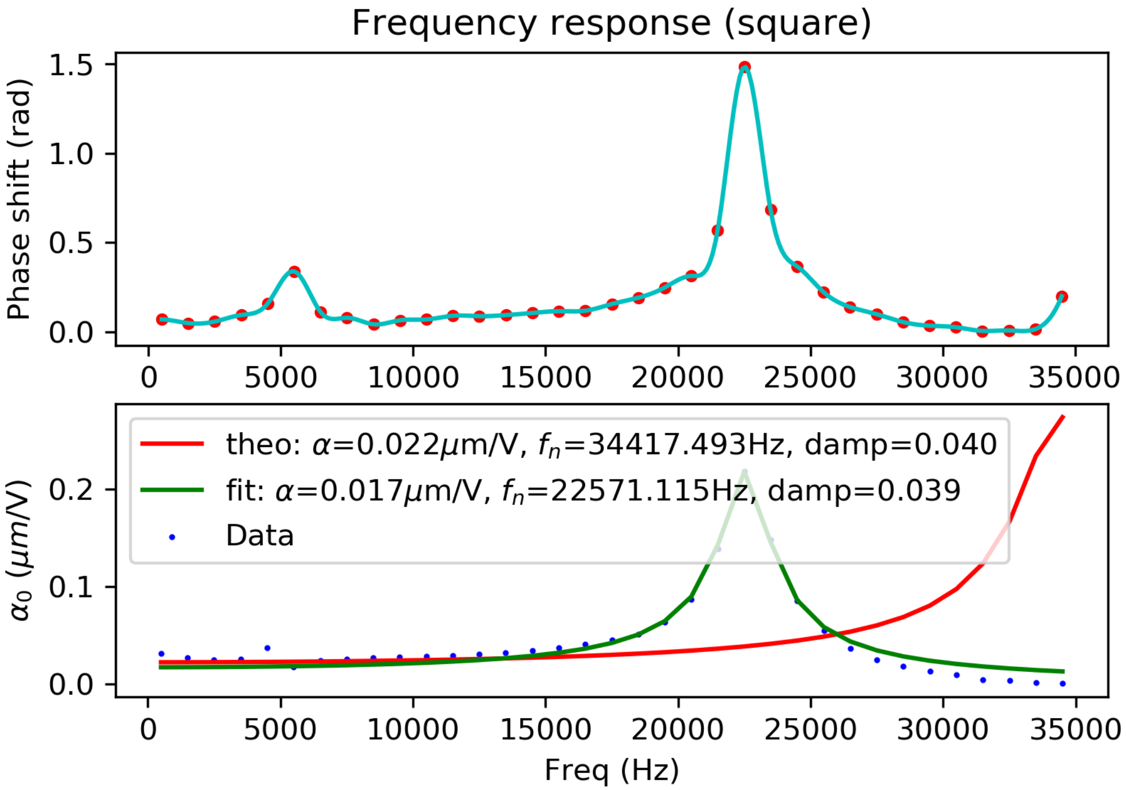
(c) Square with $\Phi = 7.0mm$, $m = 0.18g$

- Frequency response

Square actuator with $\Phi = 25.0mm$



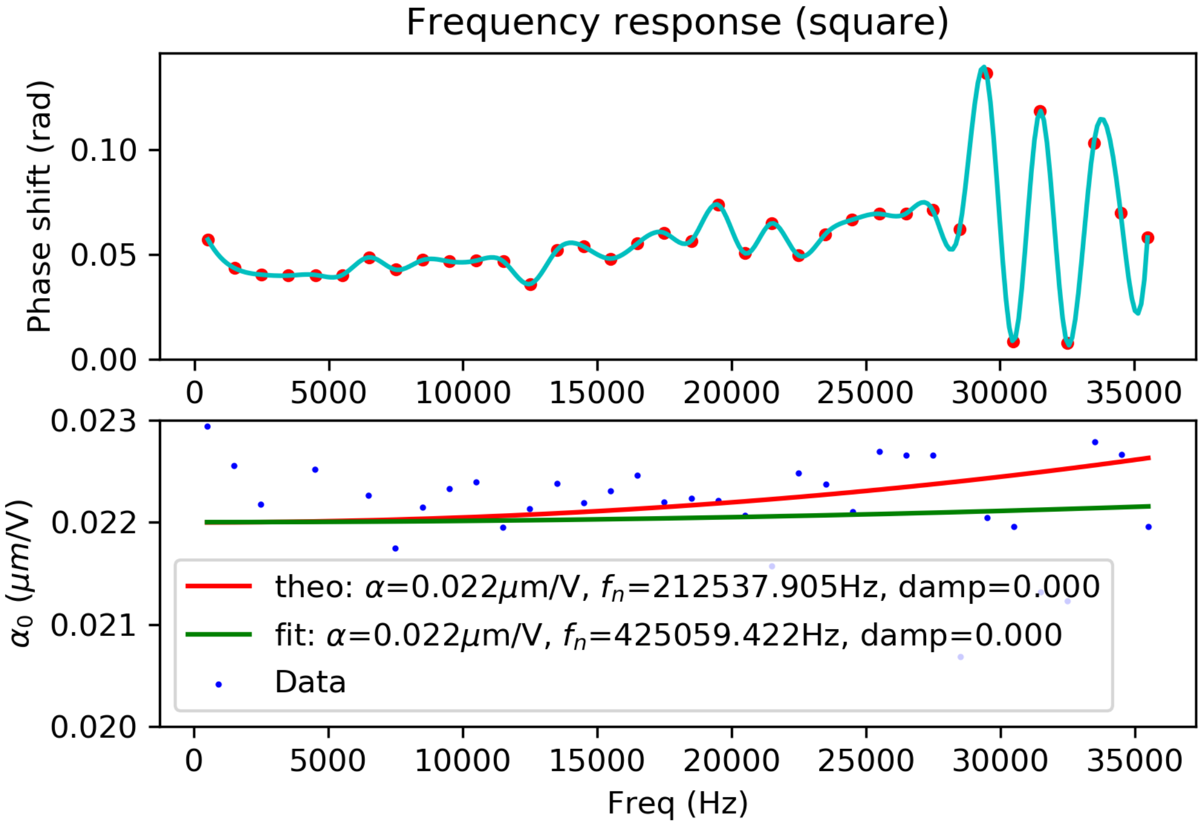
Ring actuator with $\Phi = 12.5mm$



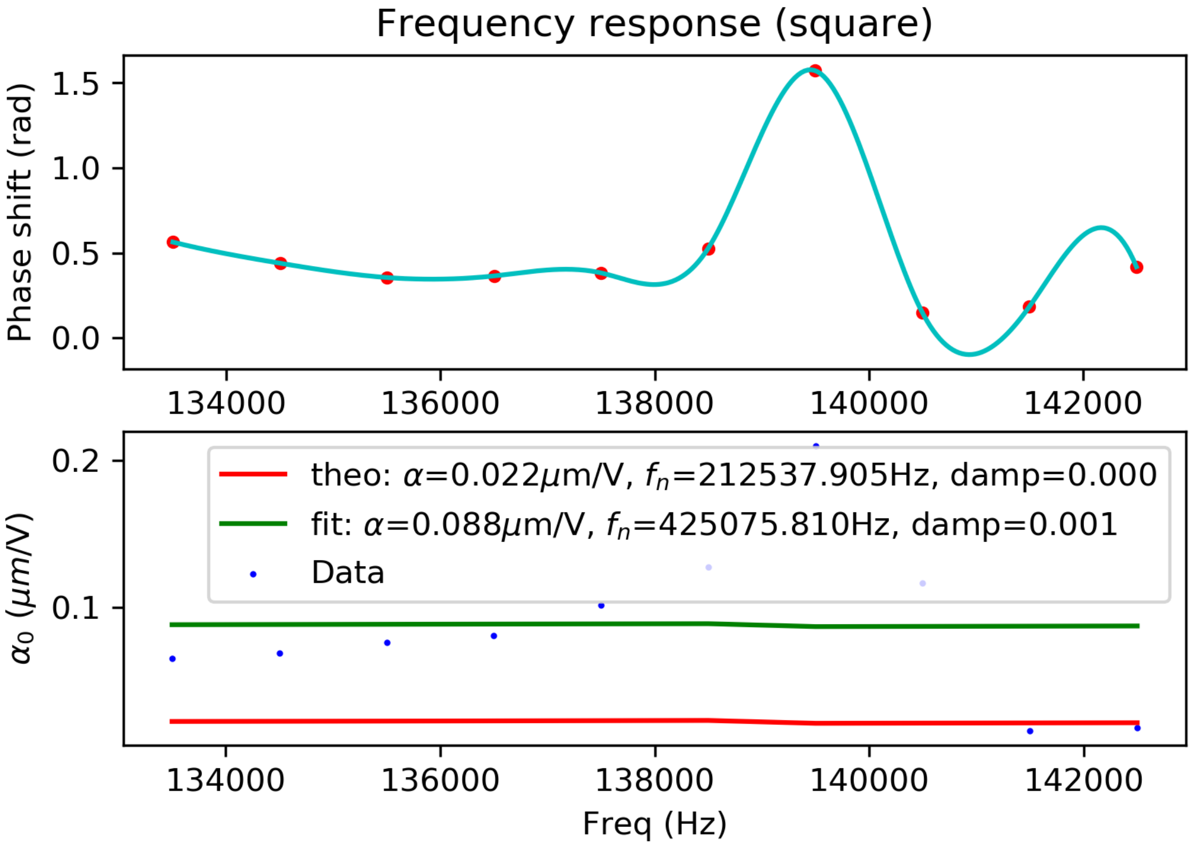
- Frequency response

Square actuator with $\Phi = 7.0mm$

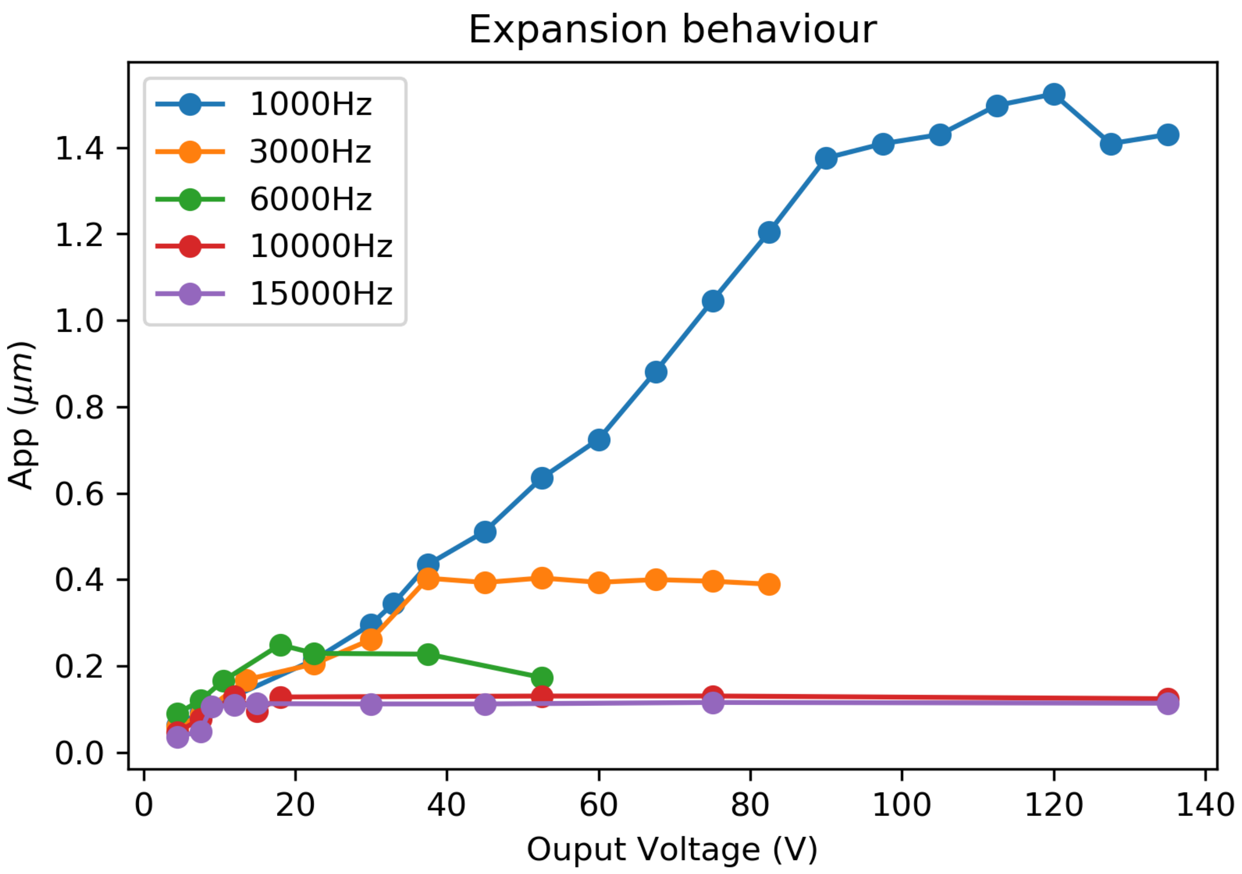
$f < 40kHz$



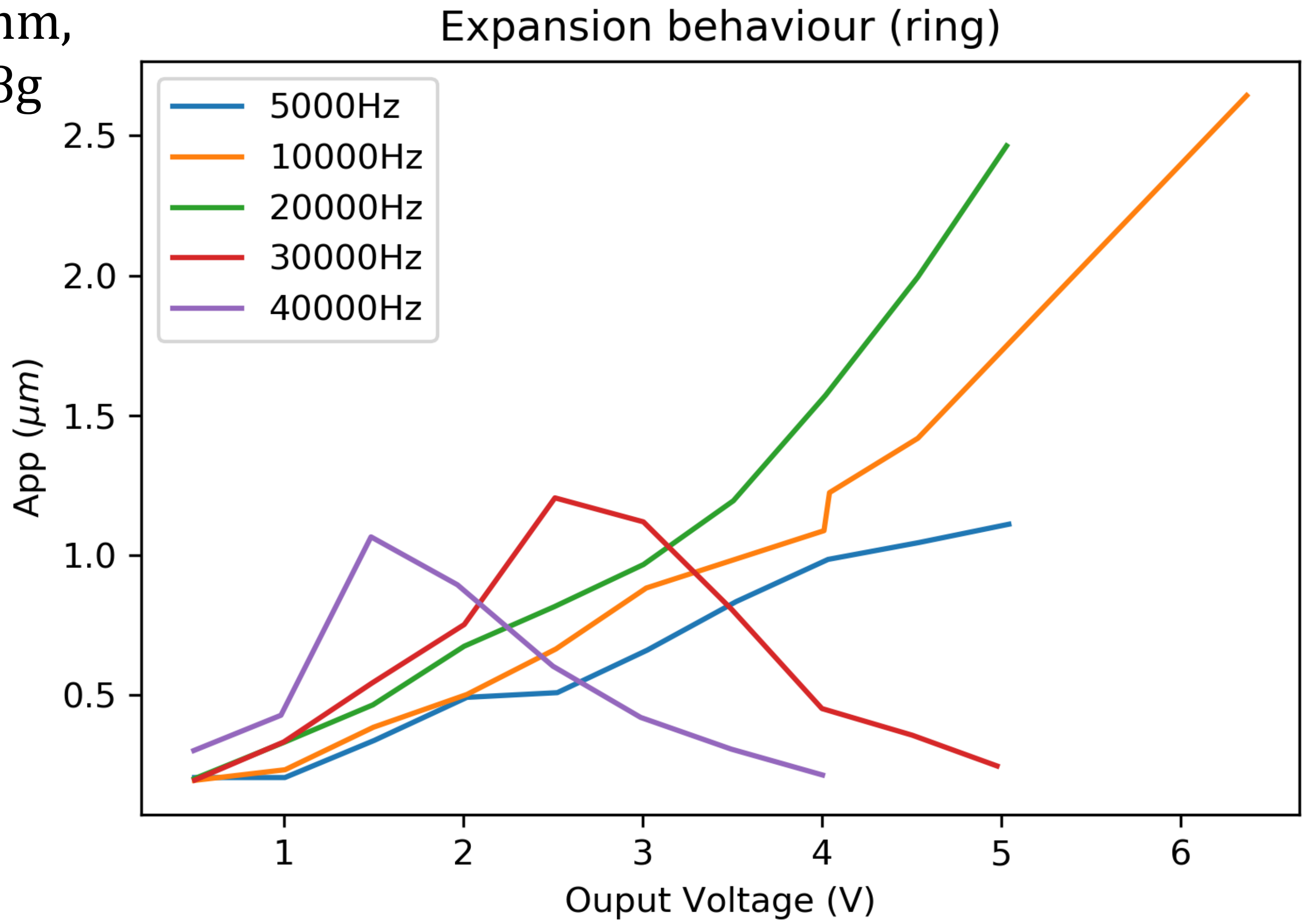
$f > 130kHz$



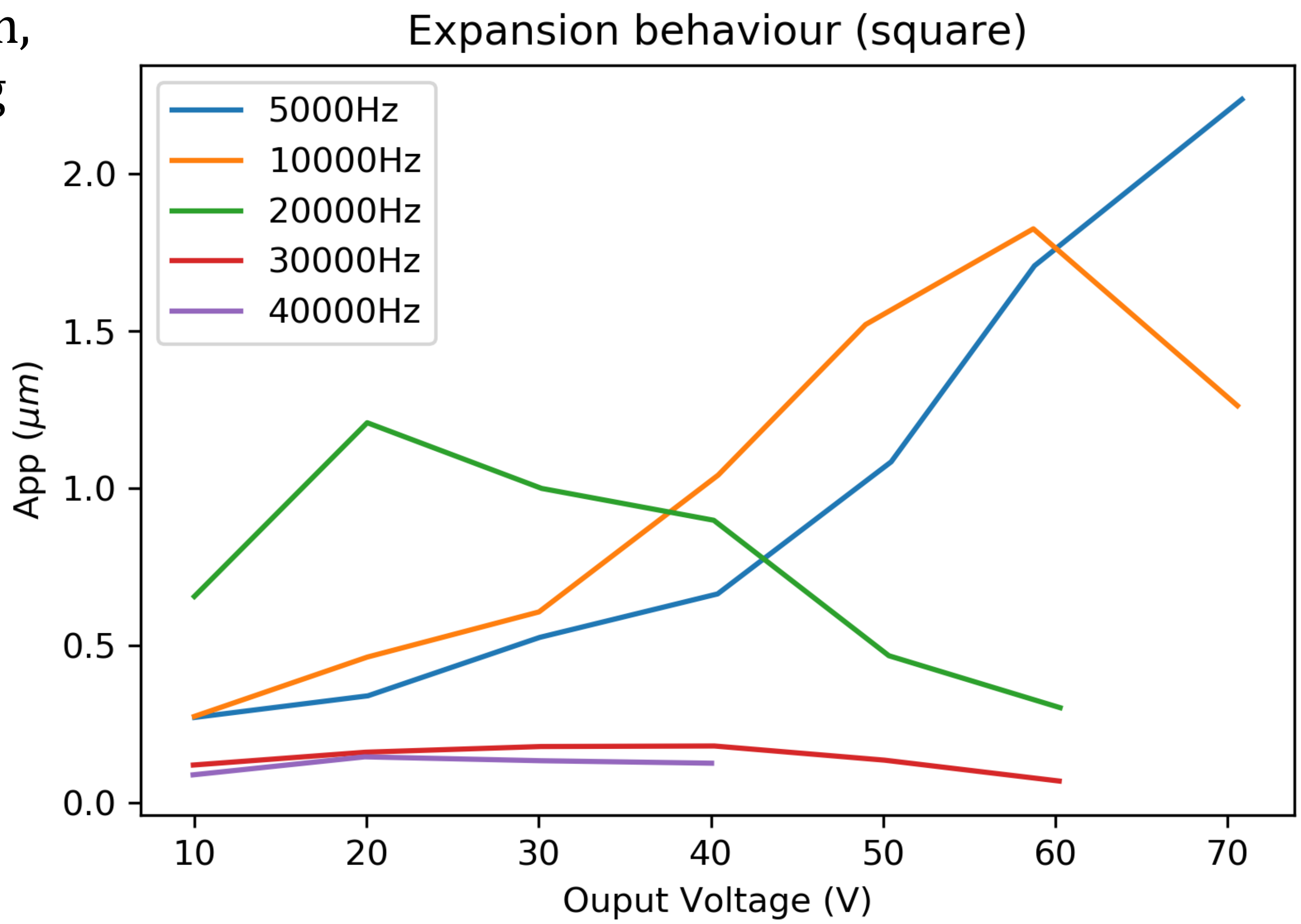
- Maximum displacement



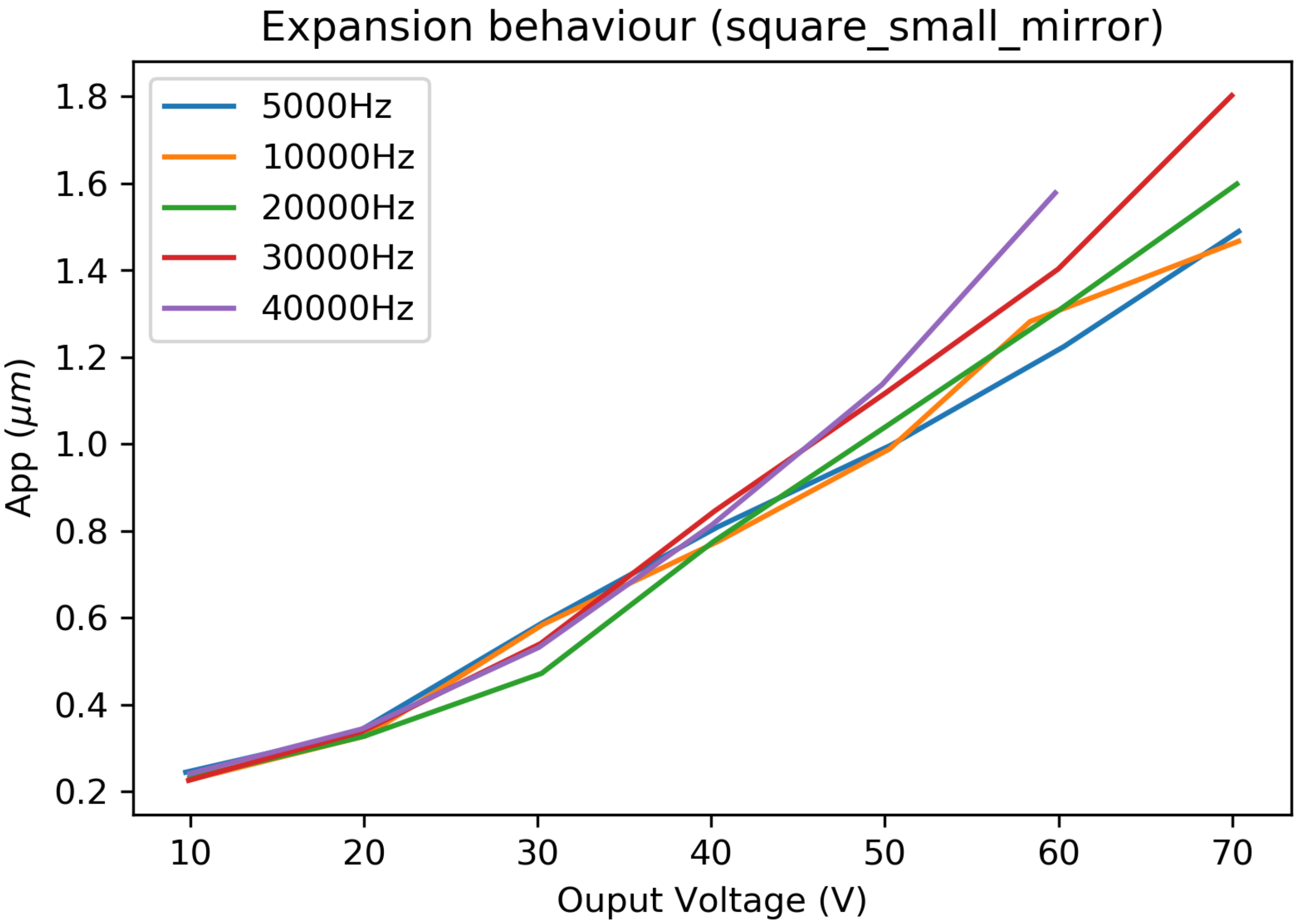
$\Phi = 12.5mm$,
$m = 1.68g$



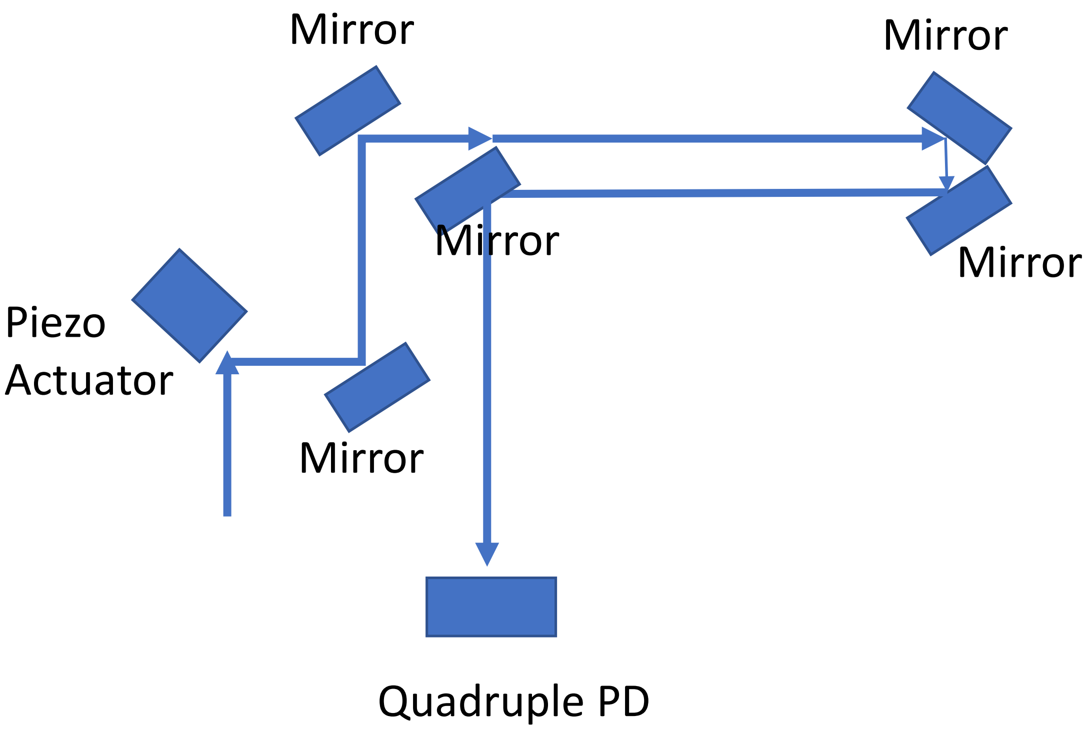
$\Phi = 25\text{mm},$
$\text{m} = 6.8\text{g}$

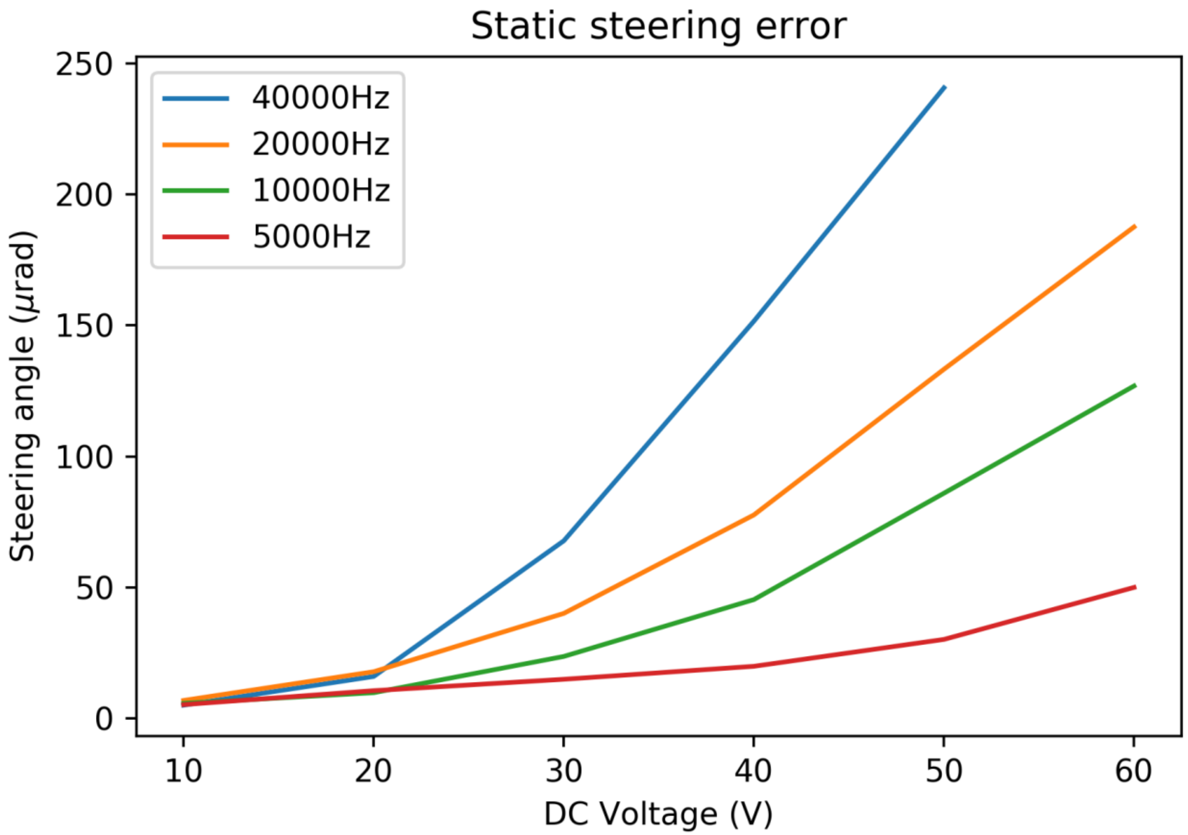


$\Phi = 7mm$,
$m = 0.18g$

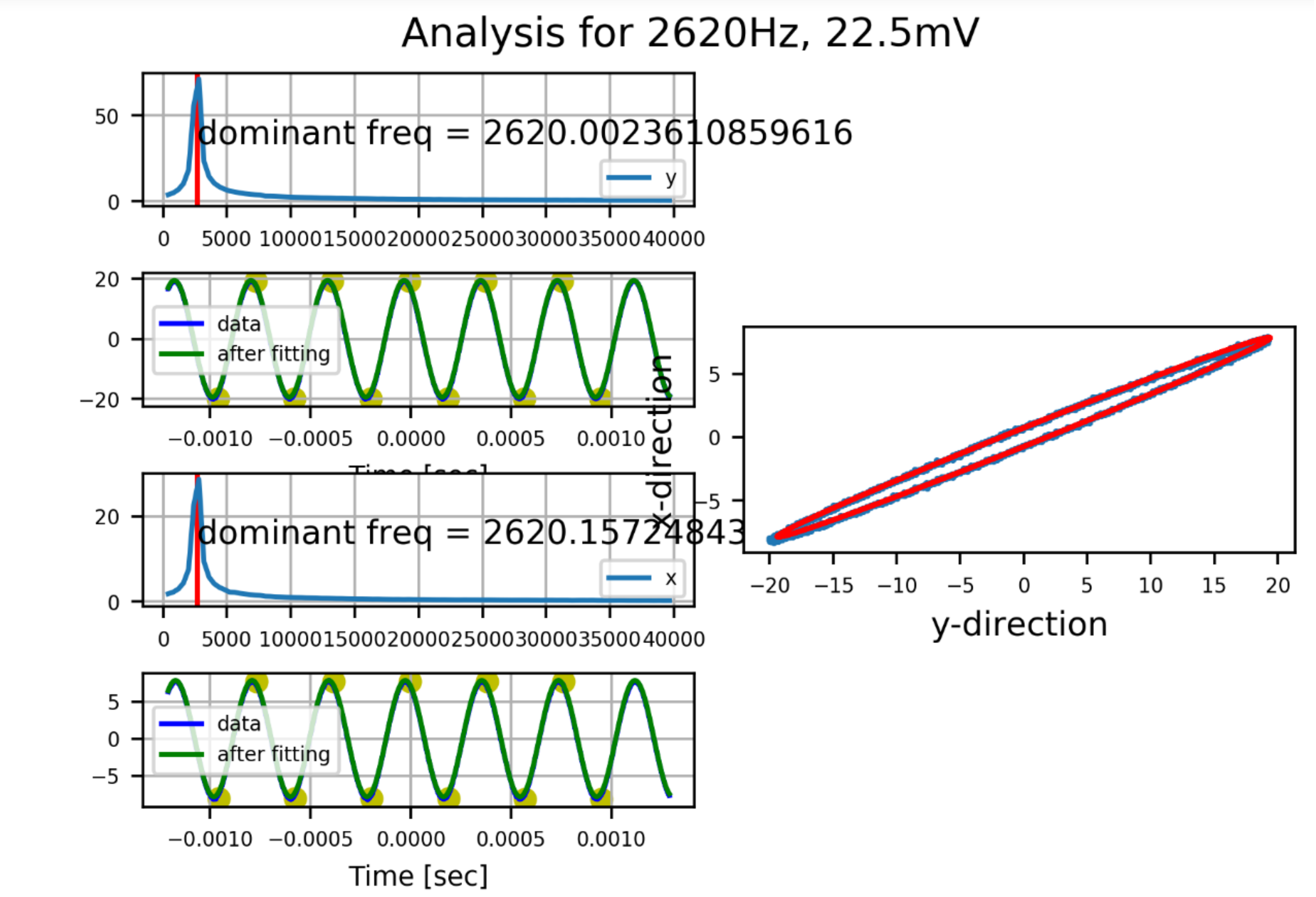


- Static steering error

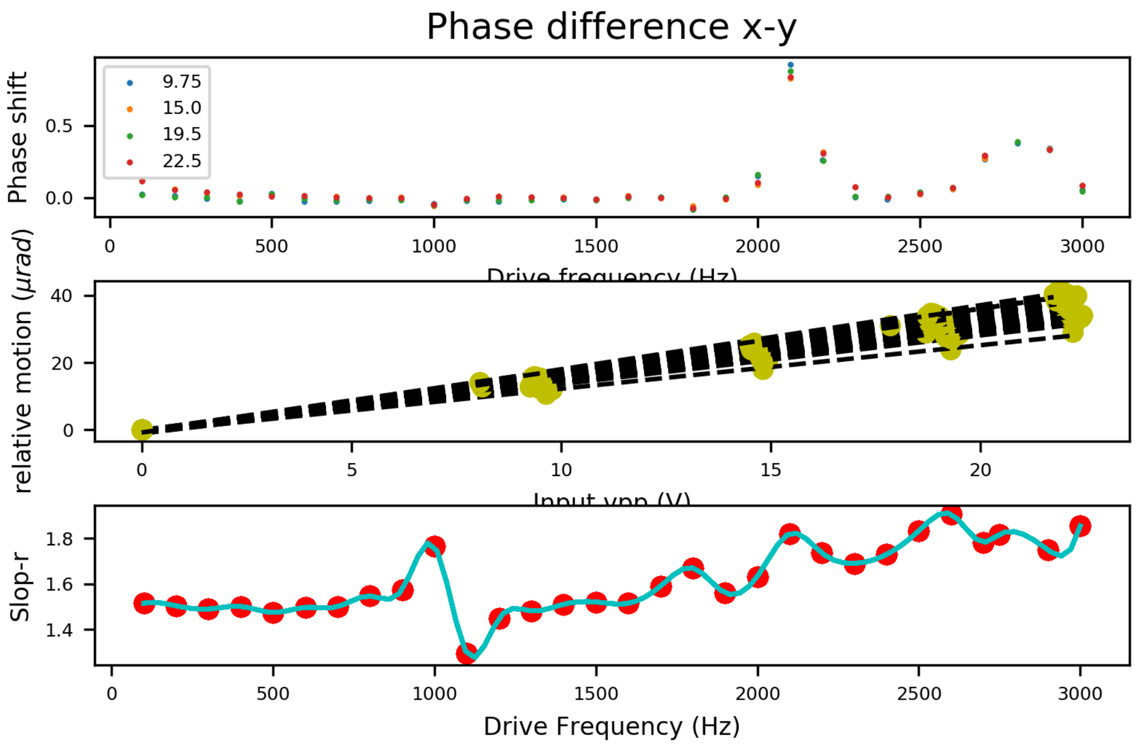


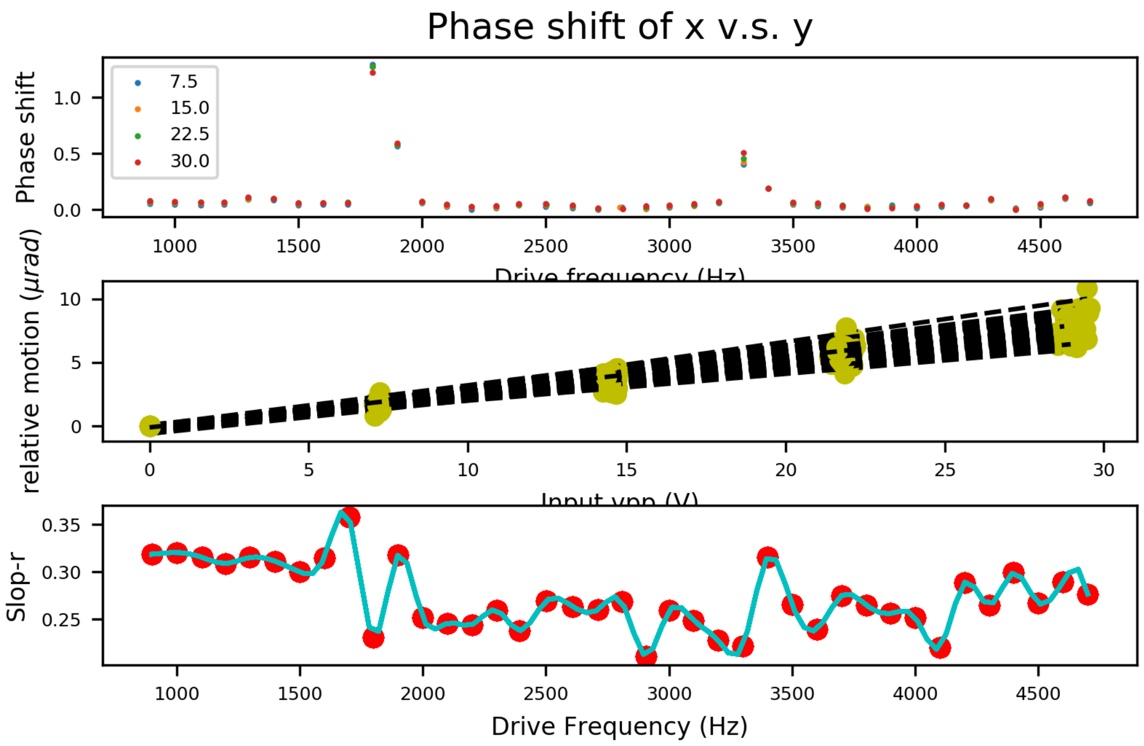


- Micro-motion



- Micro-motion





- Fix the model
- Consider a offset independent method
- Figure out the source of other harmonics
- Expand the measurement of micromotion to higher frequencies, and figure out why two axes have different resonances
- Measure the static steering error, compare it with the micromotion and find a method to solve it (maybe by the composition of lenses)
- Build the tripod piezo

Reference:

- T. C. Briles, D. C. Yost, A. Cing¨oz, J. Ye, and T. R. Schibli, “Simple piezoelectric-actuated mirror with 180 kHz servo bandwidth,” Opt. Express 18(10), 9739–9746 (2010).
- Sandra Buob, Characterization of Piezoelectric Actuators to Shake an Optical Lattice in a Cold Atom Experiment (2018)