Towards the Measurement of Vacuum Magnetic Birefringence: A Laser Heterodyne Polarimeter

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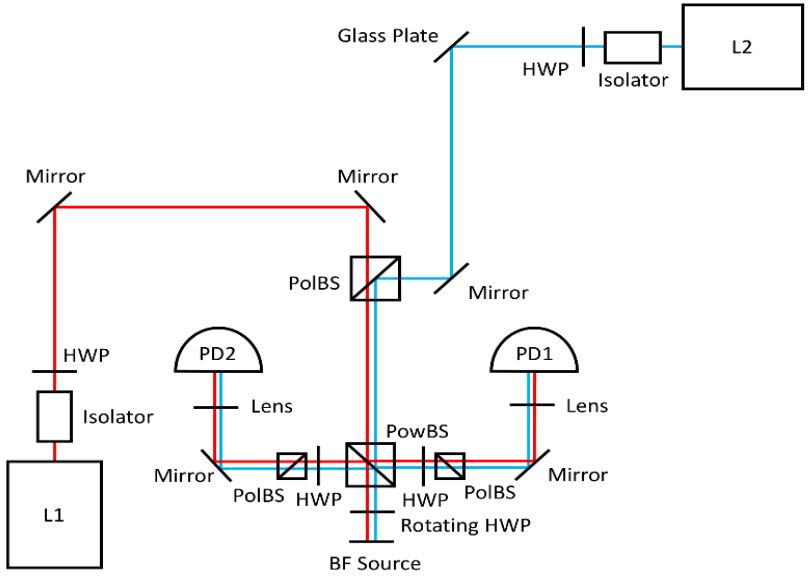
Vacuum Magnetic Birefringence

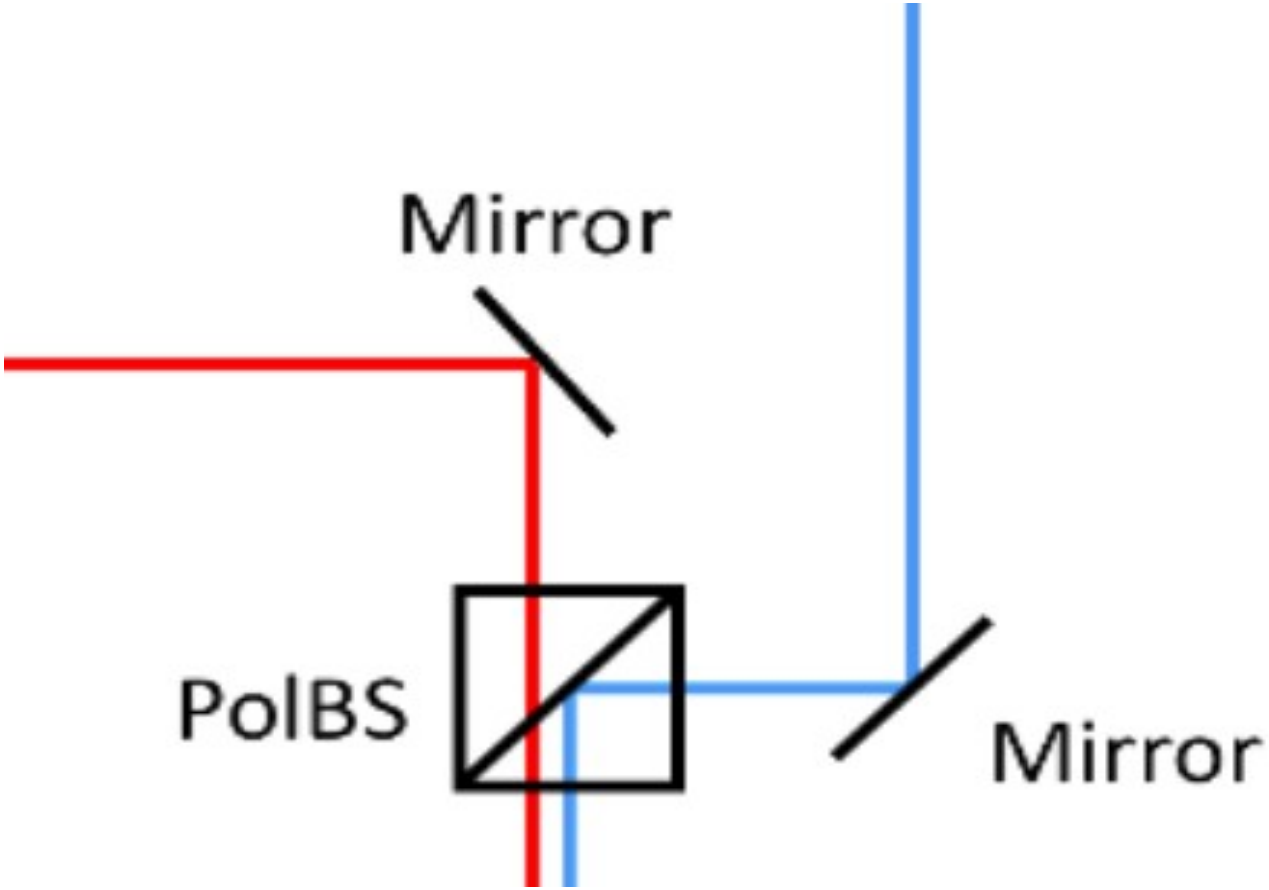
- Prediction of QED that is not yet confirmed
- Magnetic field in vacuum gives polarization dependent index of refraction
- Effect is very small
- LHC magnet yields $\Delta n = n_{\parallel} - n_{\perp} = 2.81 \text{ X } 10^{-22}$
- Optical cavity in magnetic field increases effective length of magnetic field region
- Can Use ALPS II Cavities and Magnets for VMB measurement

Laser Heterodyne Polarimeter

- Initial step towards VMB measurement
- Apparatus to Characterize Mirror Birefringence

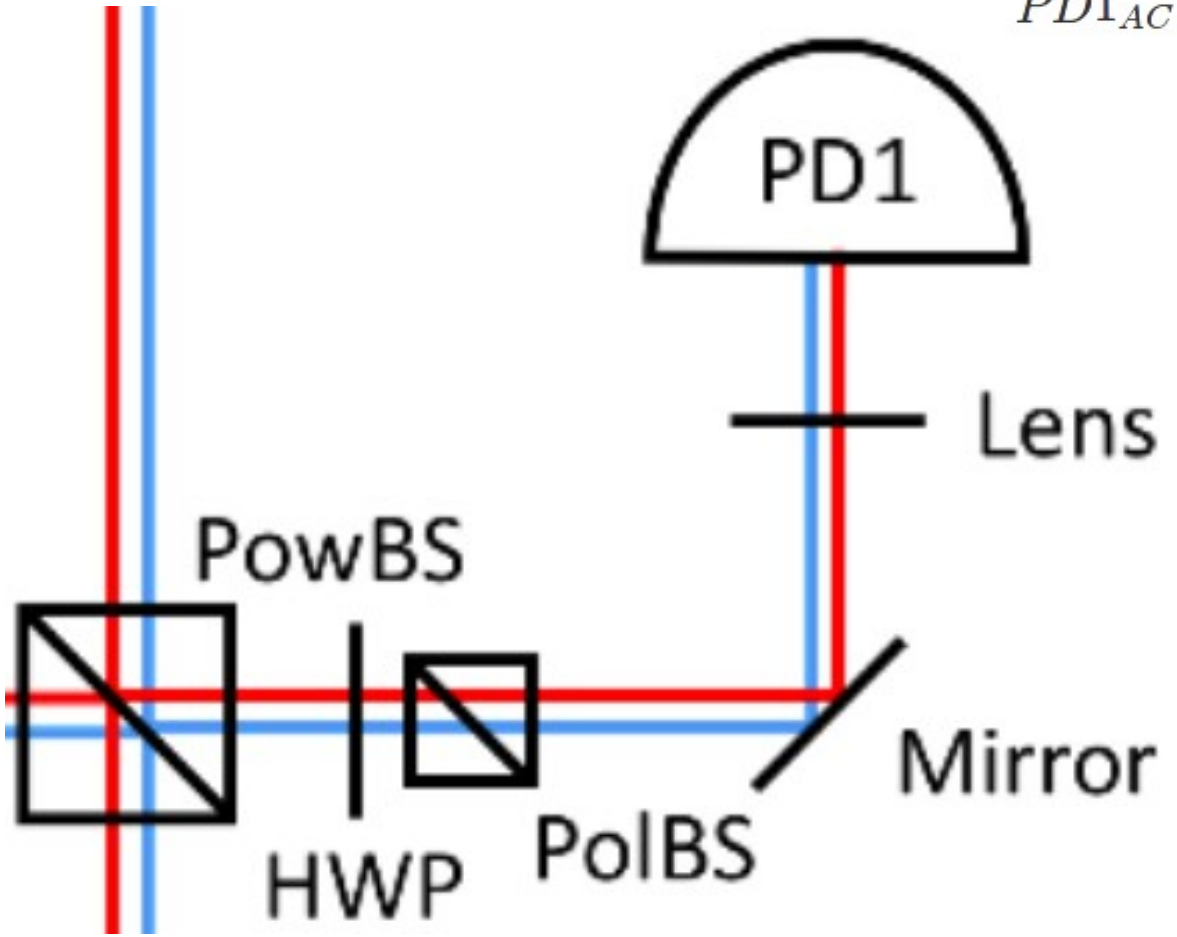


Combine two orthogonally polarized phase-locked Laser Fields



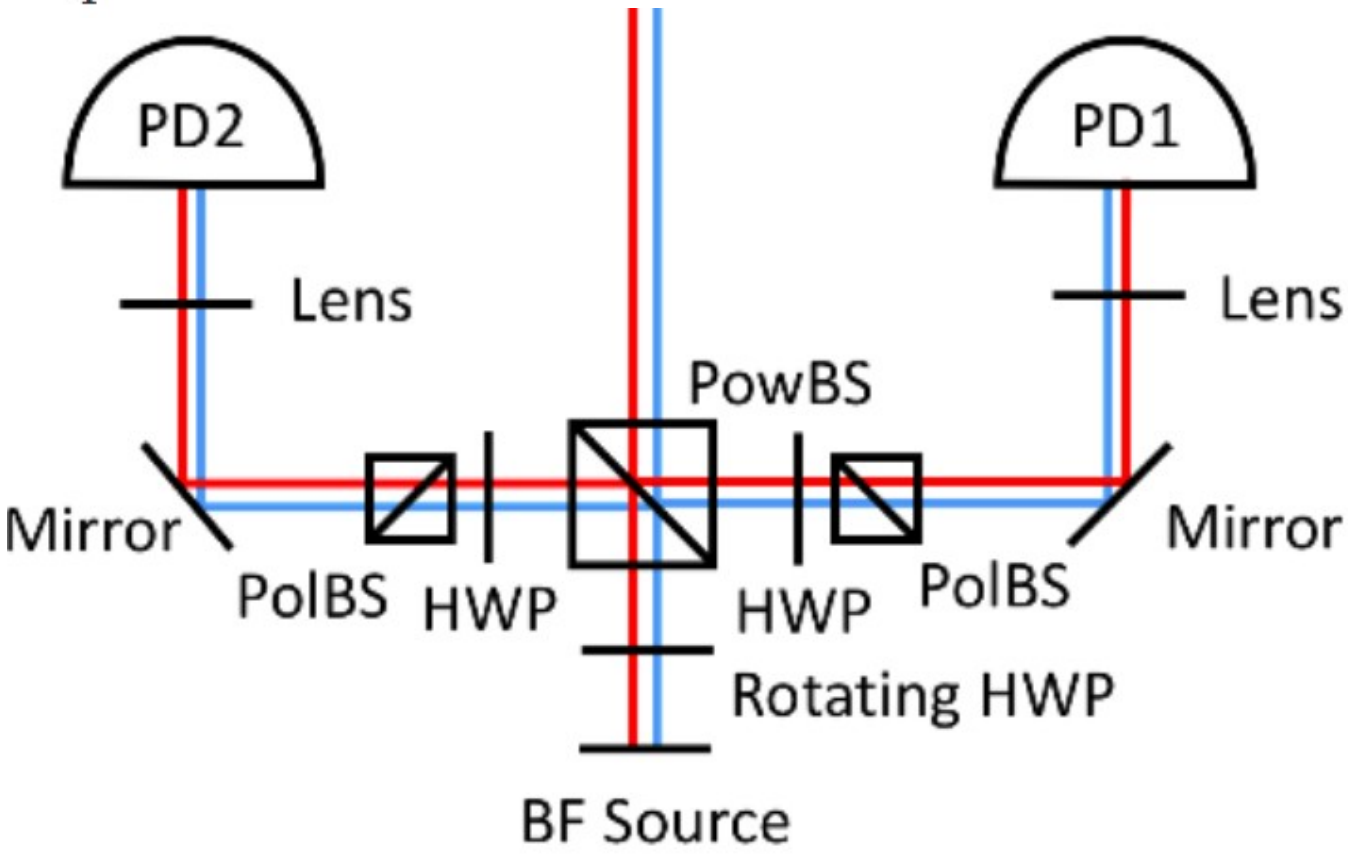
Reference signal Path

$$PD1_{AC} = \frac{AB}{2}\cos(\Omega t)$$



Add Birefringence Path

$$PD2_{AC} \approx \frac{AB}{4}\cos(\Omega t + \phi) \quad \phi = \delta\cos(4\omega_0 t) - 2\epsilon\cos(2\omega_0 t)$$



Experimental Setup

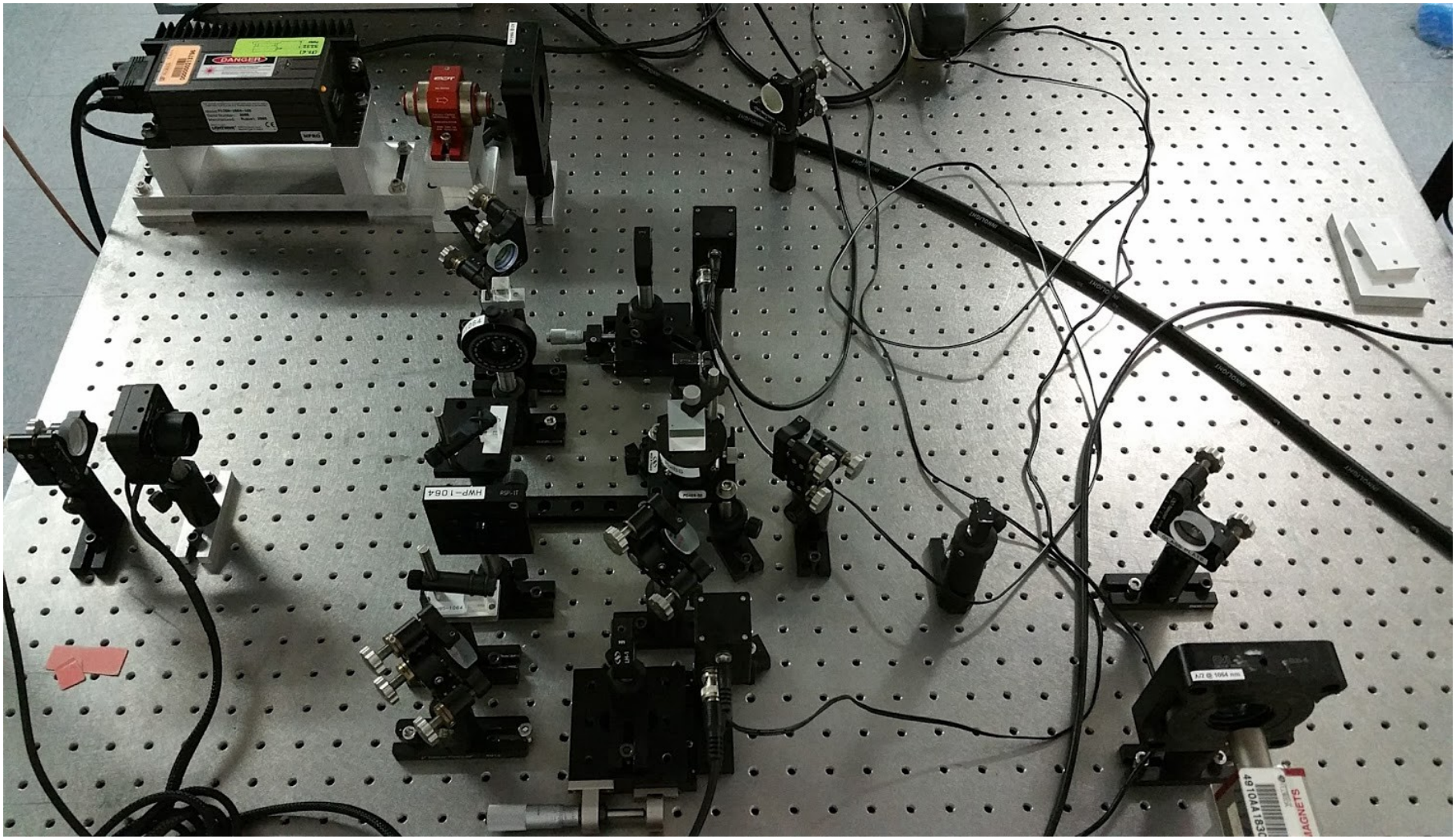
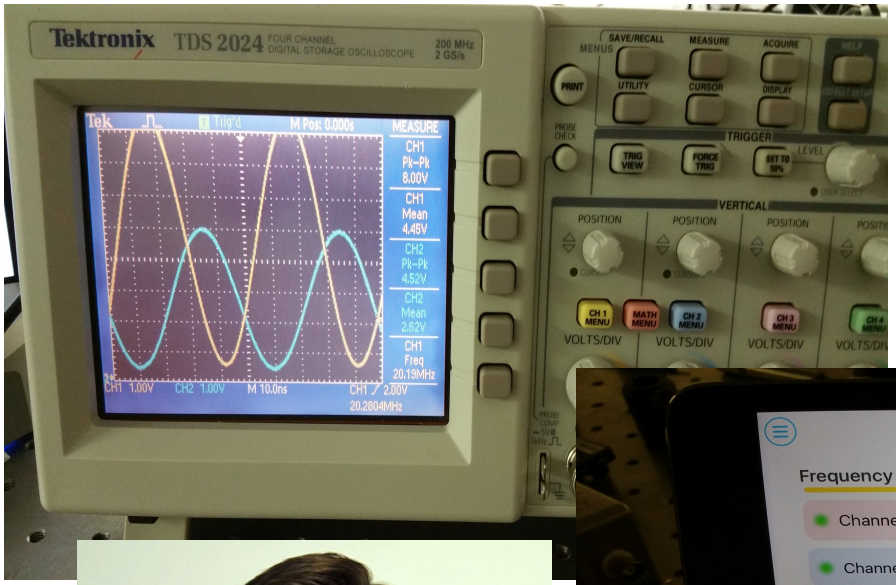
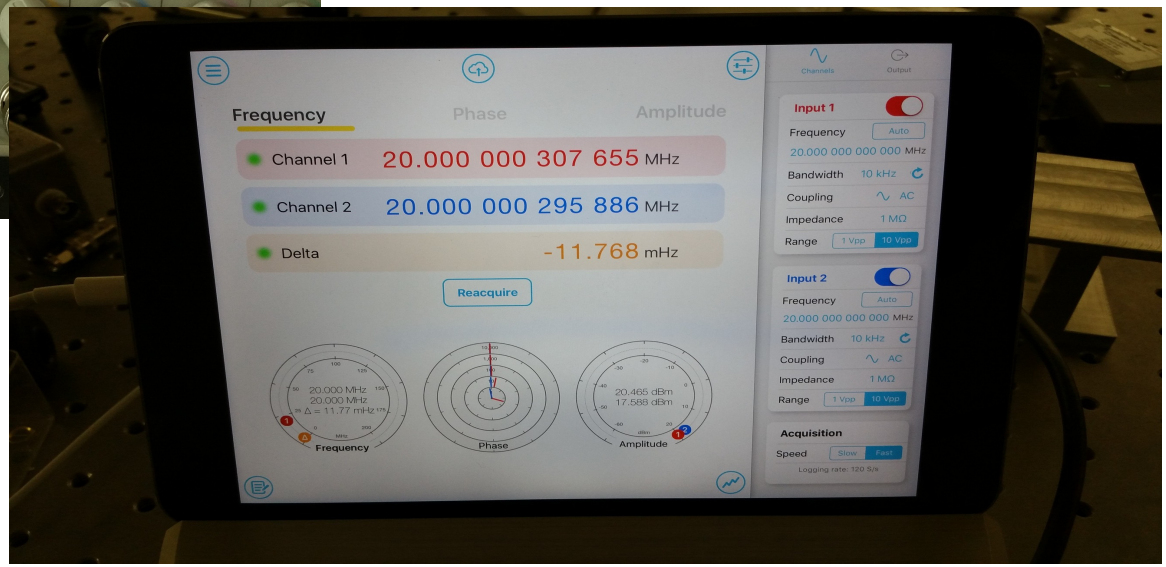
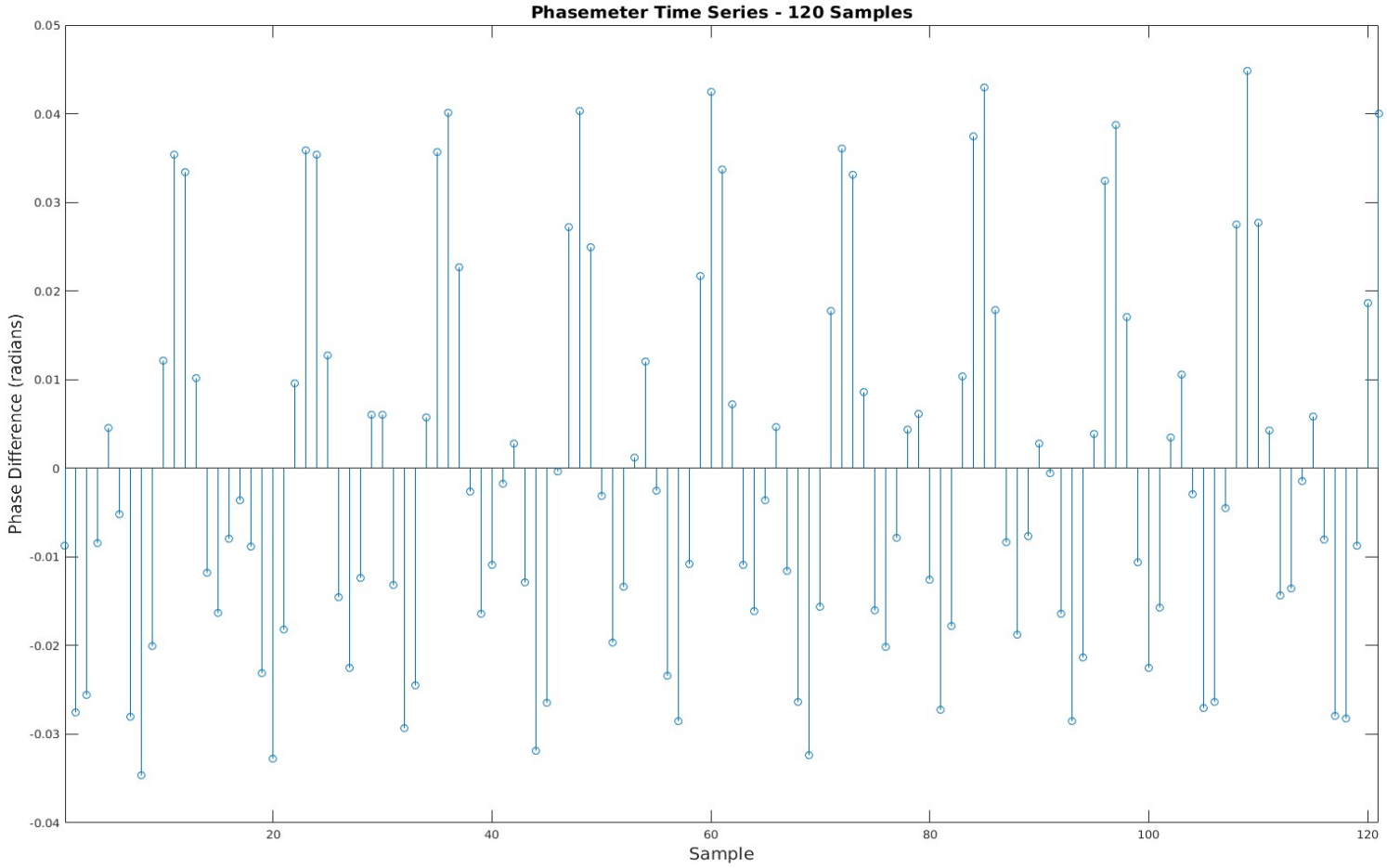


Photo Detector Signals

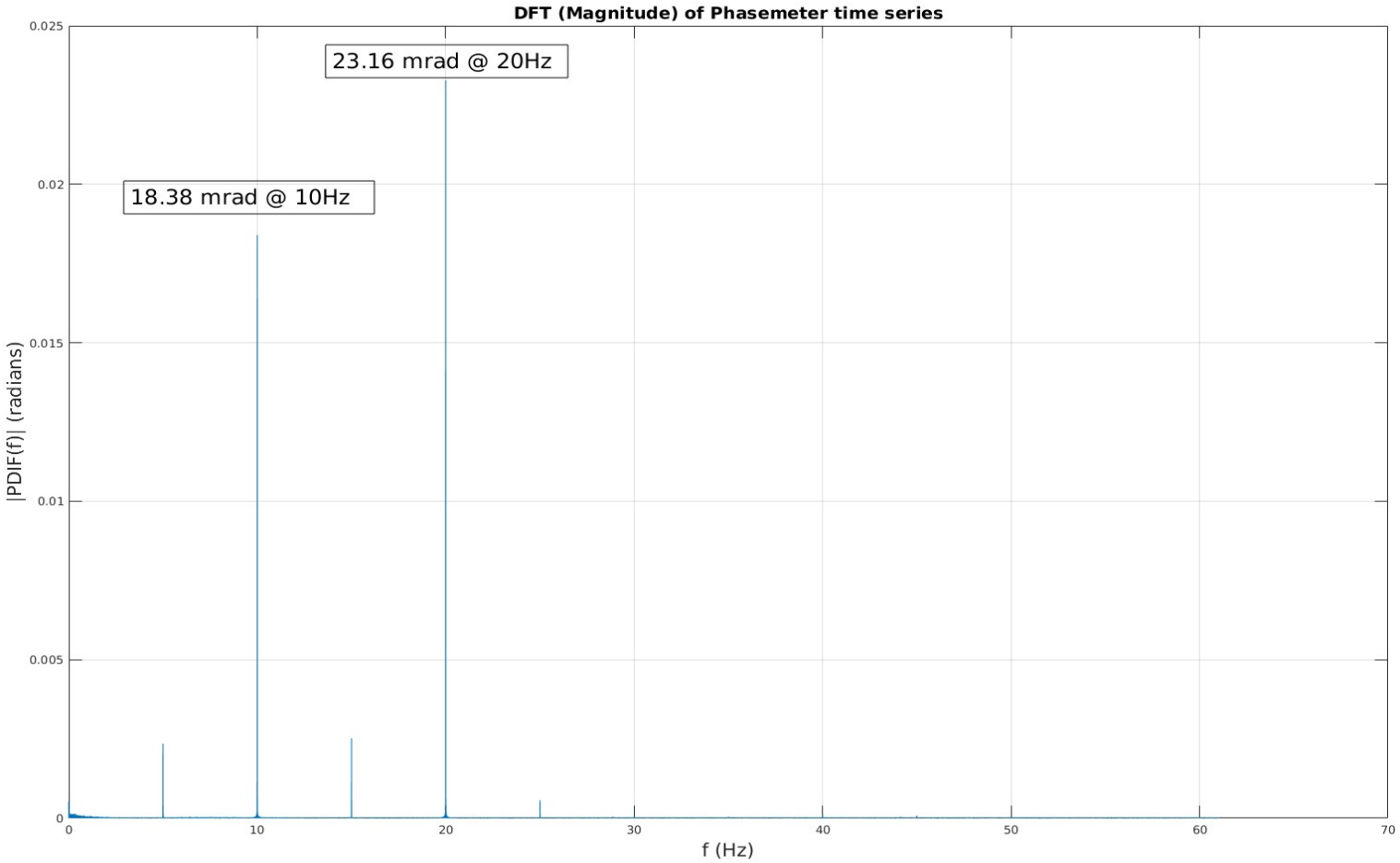




Moku Phasemeter Time Series - 122 Hz Sampling Rate



DFT (Magnitude) of Phasemeter Time Series

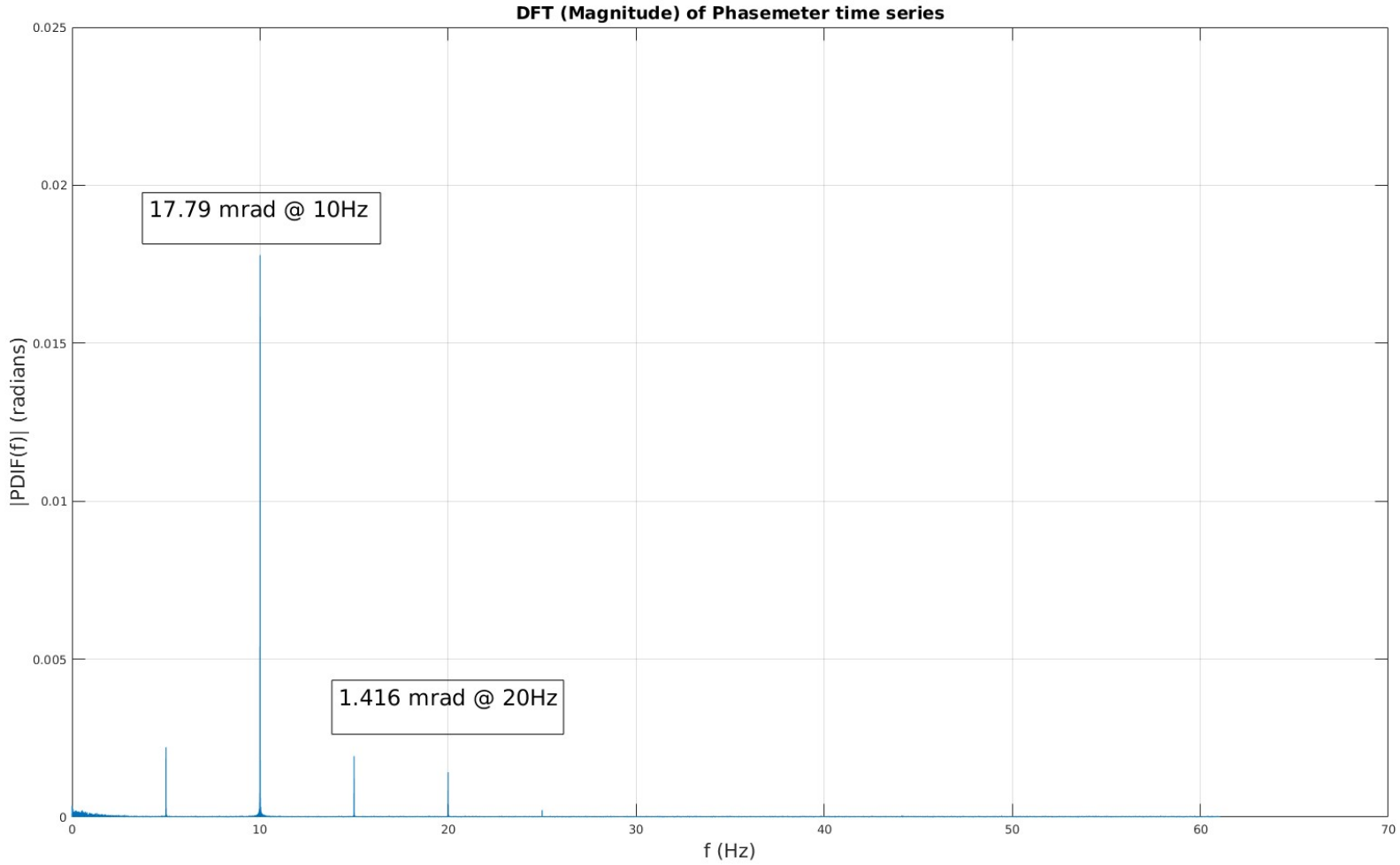


30 Minute Run with Newport 'bad' Mirror

- See signals at the expected 2 and 4 times rotation rate
- Also see signals at odd multiples

Parameter	Estimate
δ	23.2 mrad
ε	9.19 mrad

DFT Magnitude ThorLabs BB1-E03 Mirror

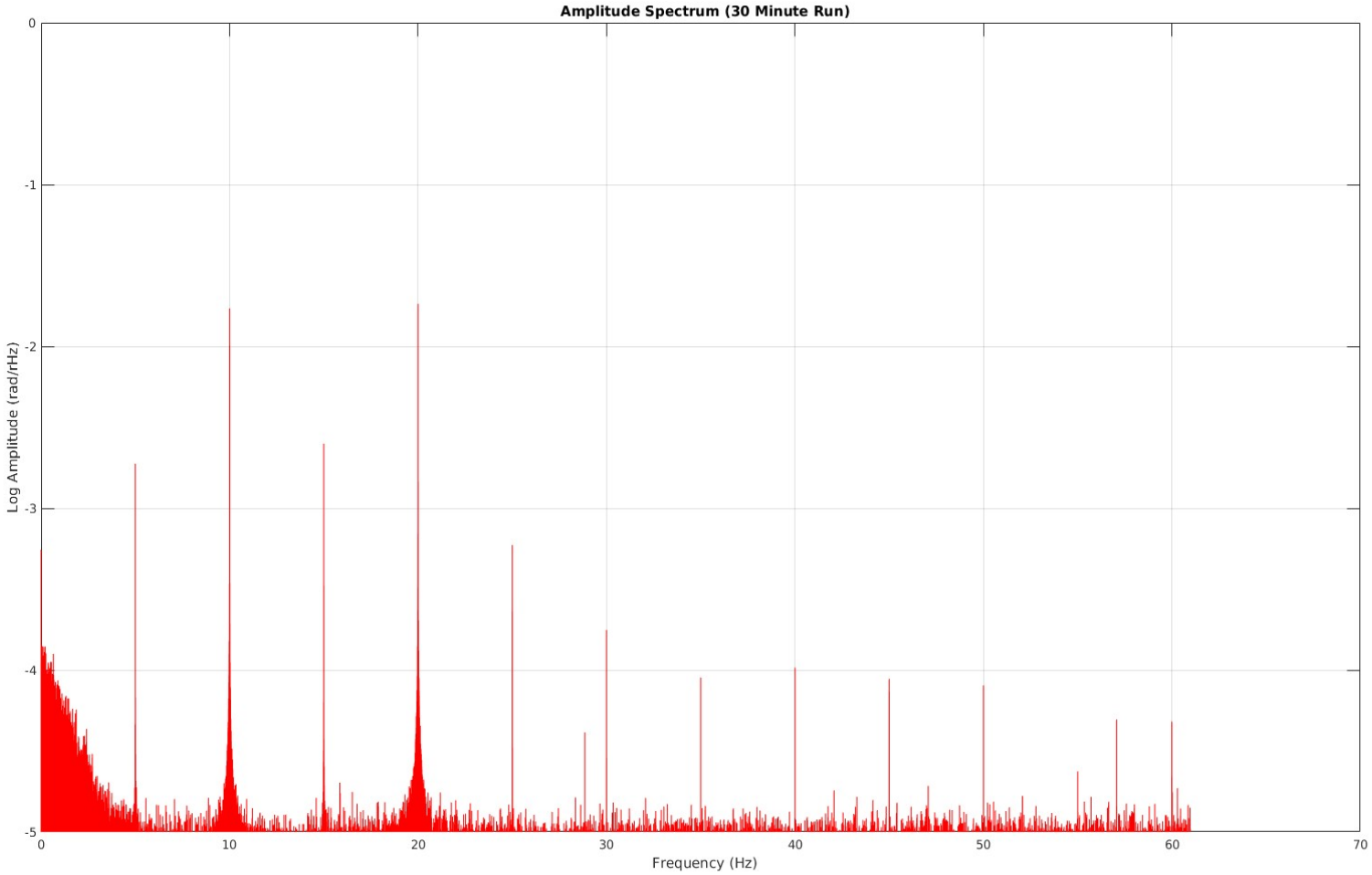


10 Minute Run with BB1-E03 Mirror

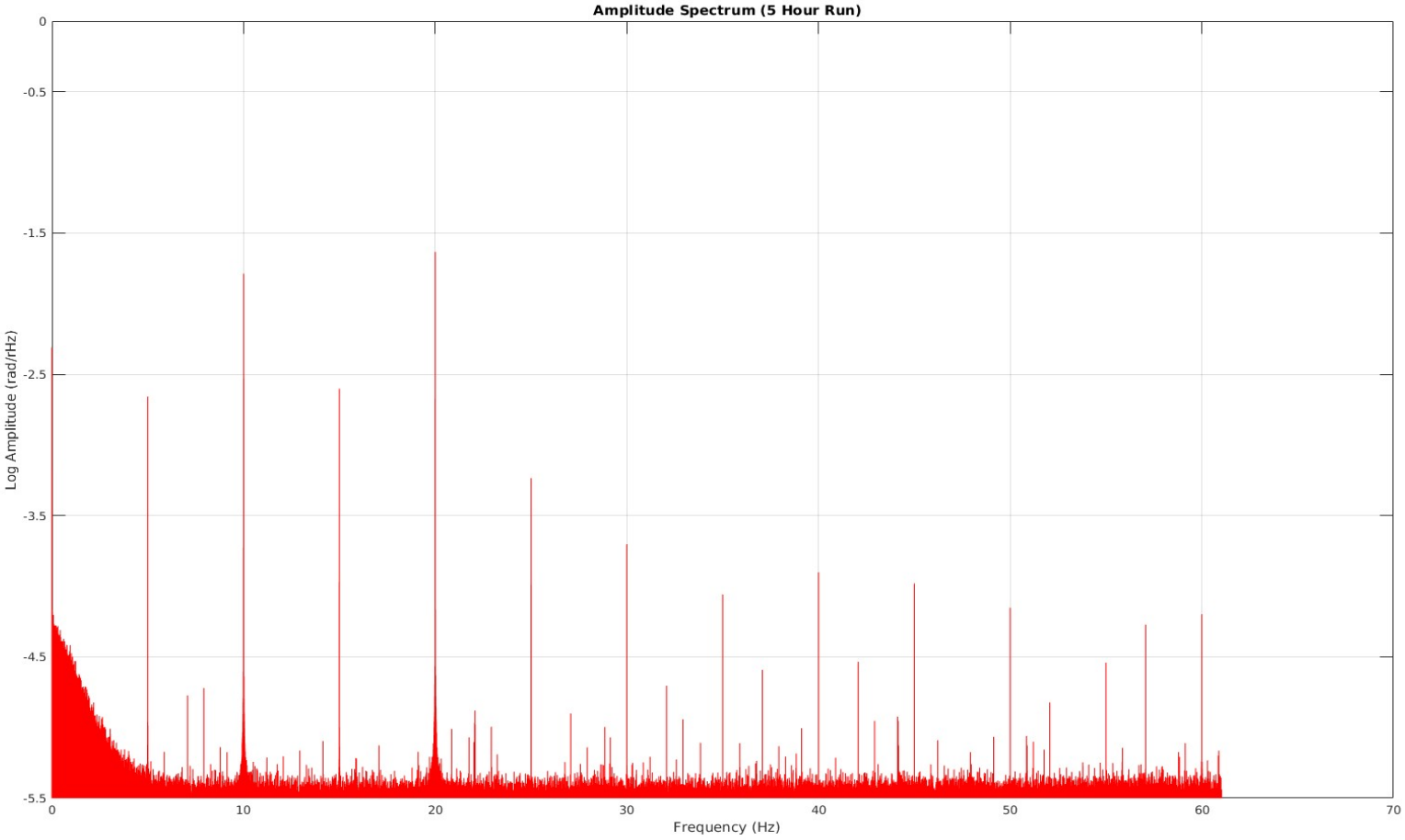
- See much smaller birefringence signal
- See about the same HWP signal

Parameter	Estimate
δ	1.42 mrad
ε	8.90 mrad

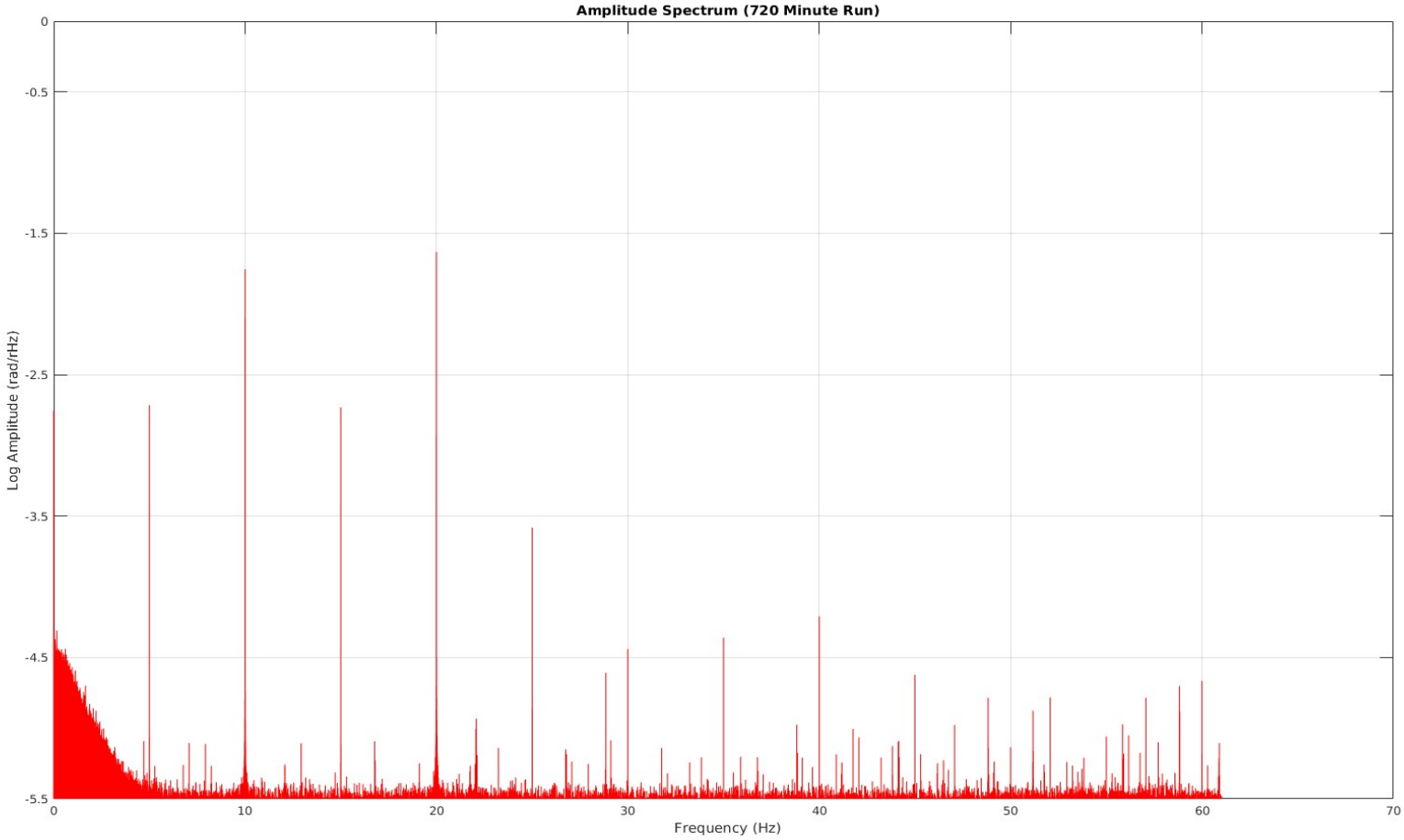
30 Minute Run Noise Floor



300 Minute Run Noise Floor



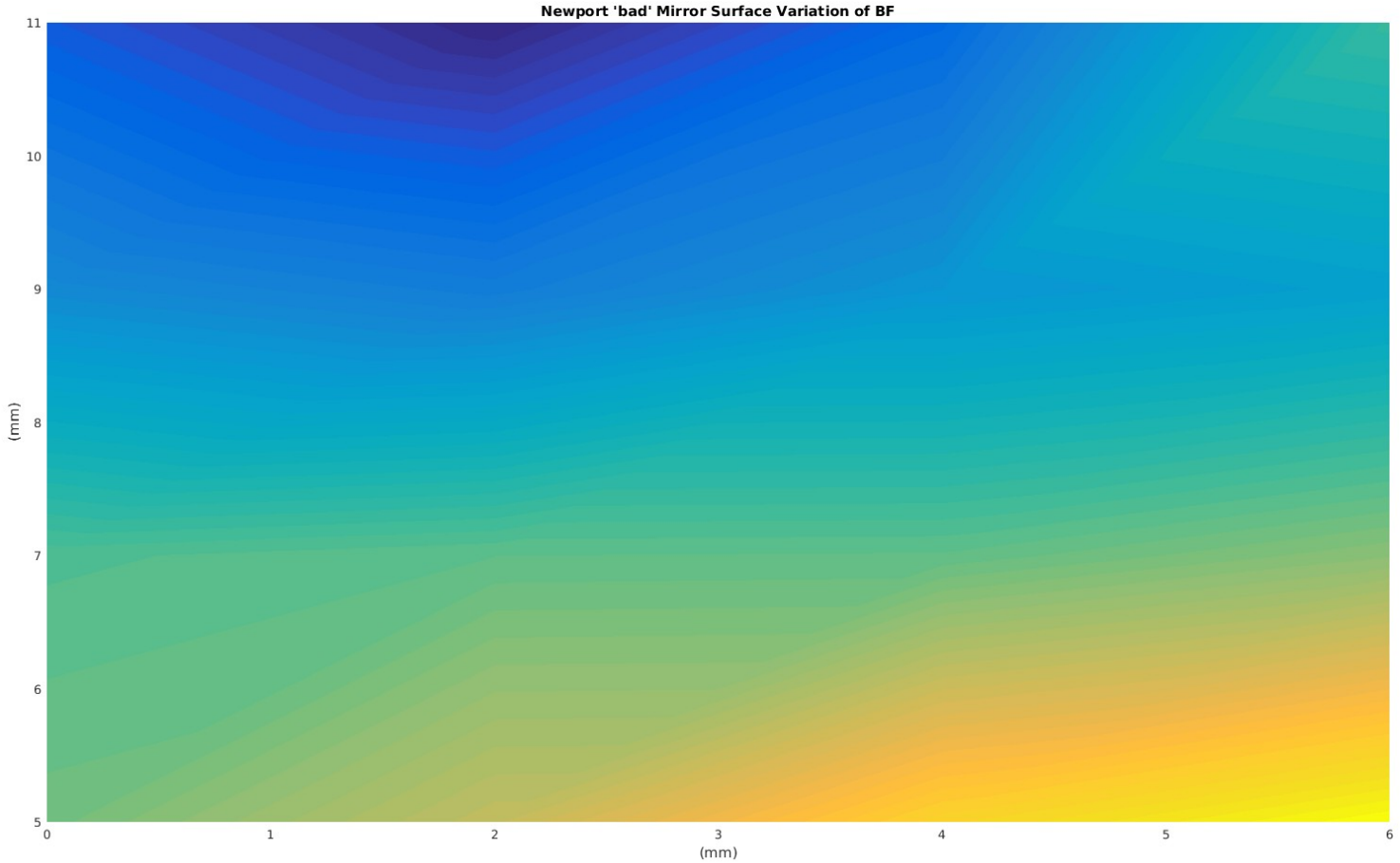
720 Minute Run Noise Floor



Where are We?

- Fleisher, et. al., (2016) used optical cavity ringdown beating to measure BF of 20 μrad per mirror
- This in the range of the noise floor of our yet to be optimized experiment
- Photodetector (PDA-10CF) differential phase noise is about 600 nrad/rHz (Eichholz)
- Could Moku Phasemeter be folding higher frequency noise into the 60 Hz bandwidth?

Birefringence Variation over Surface of Mirror



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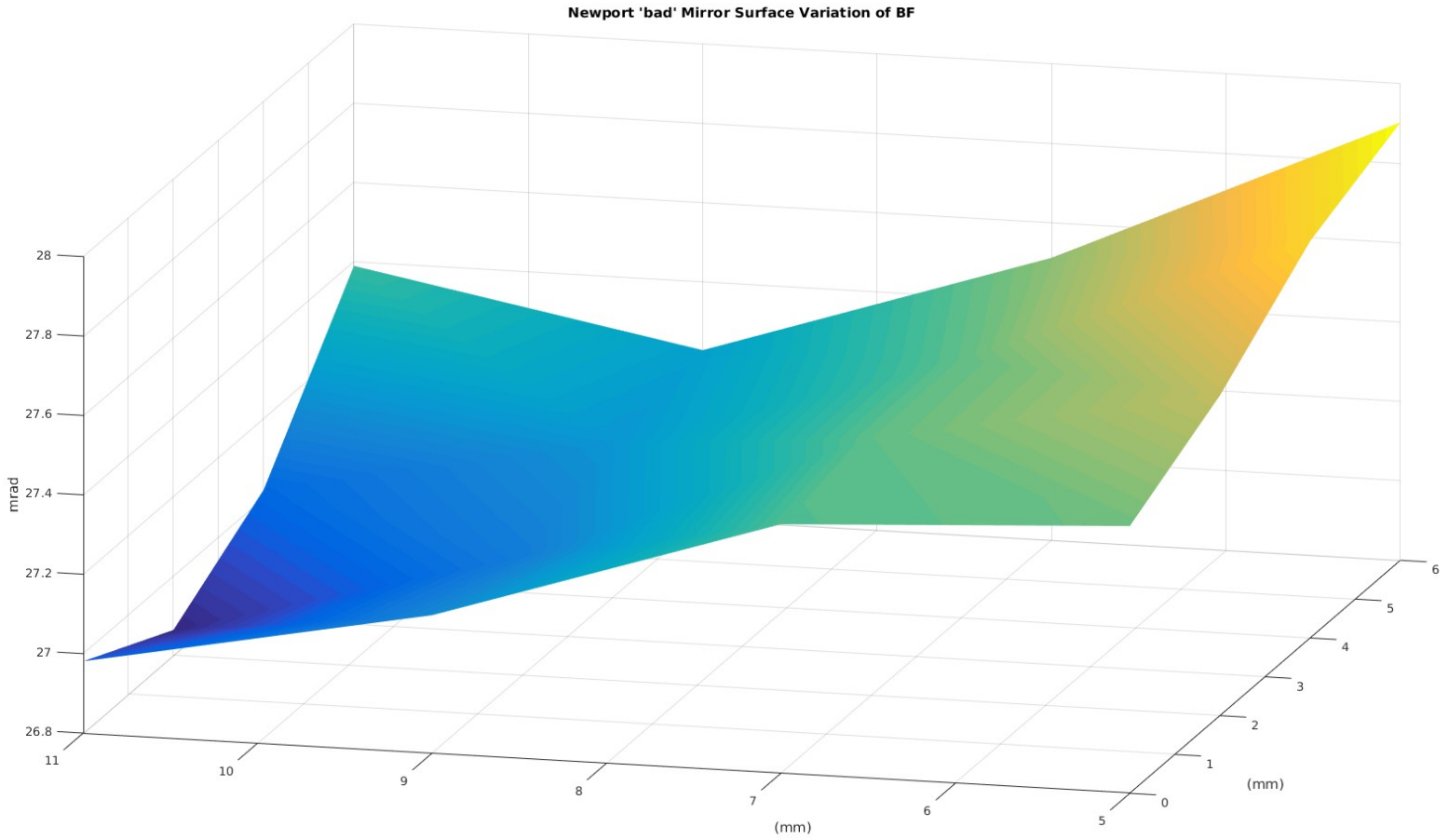

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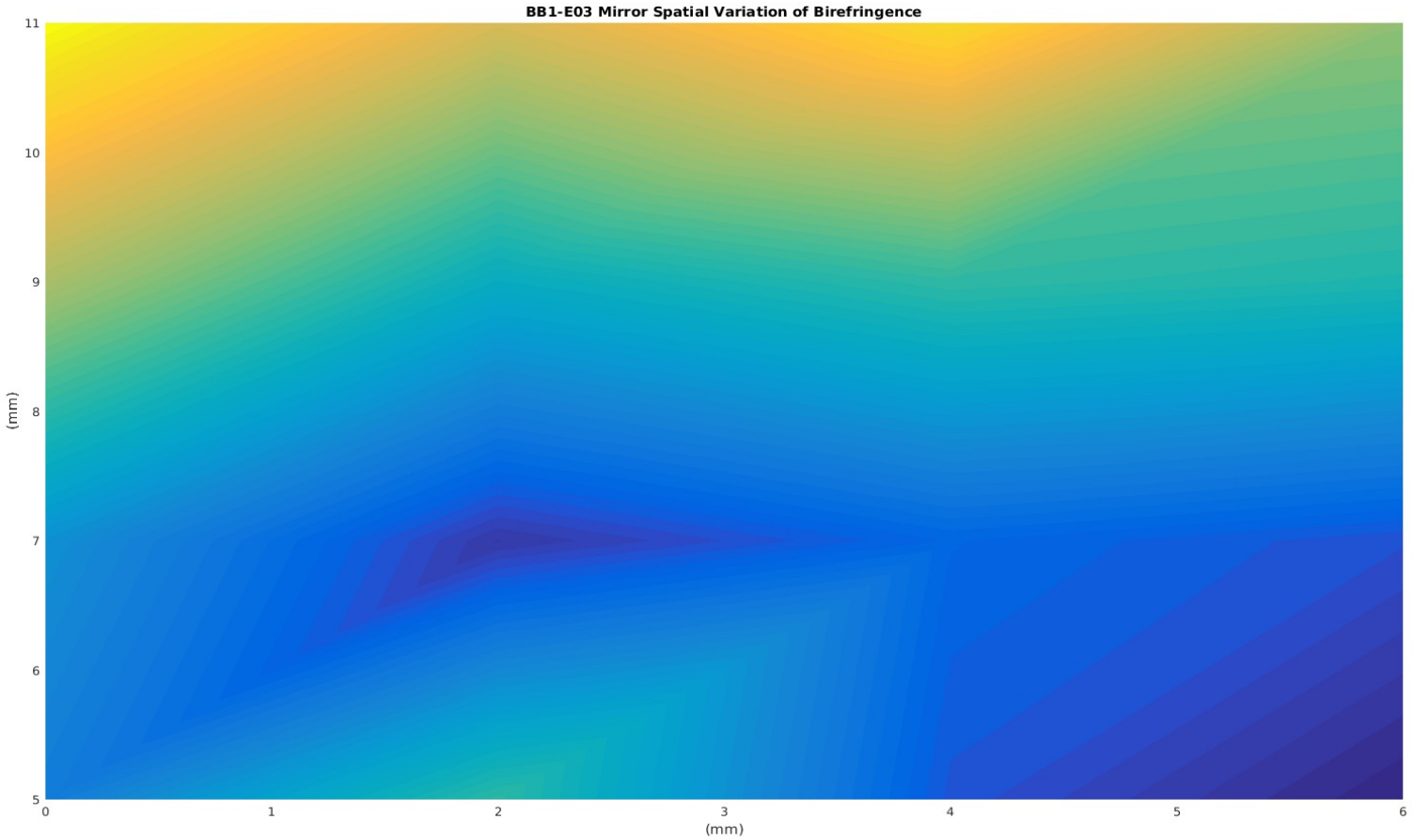

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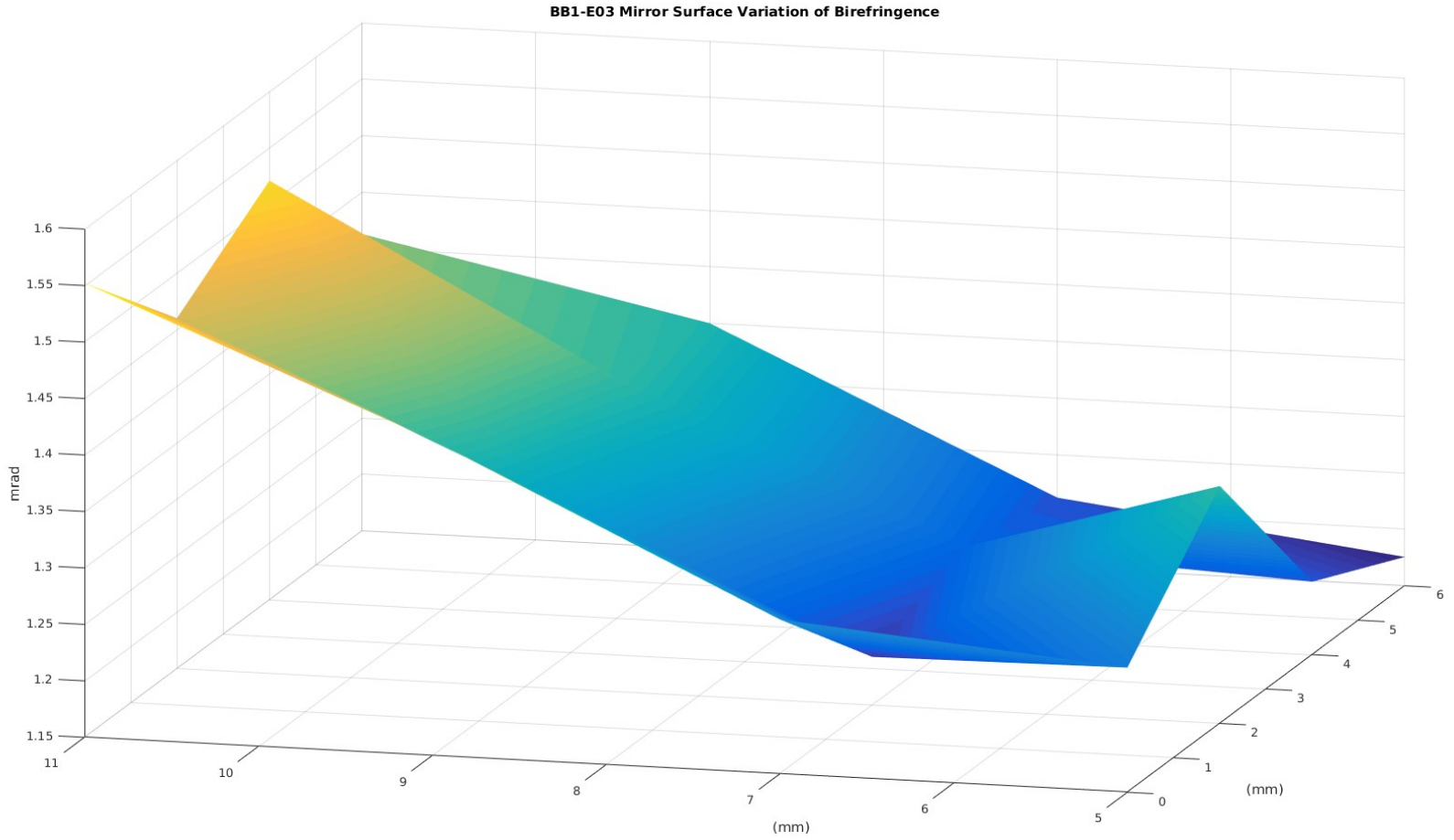
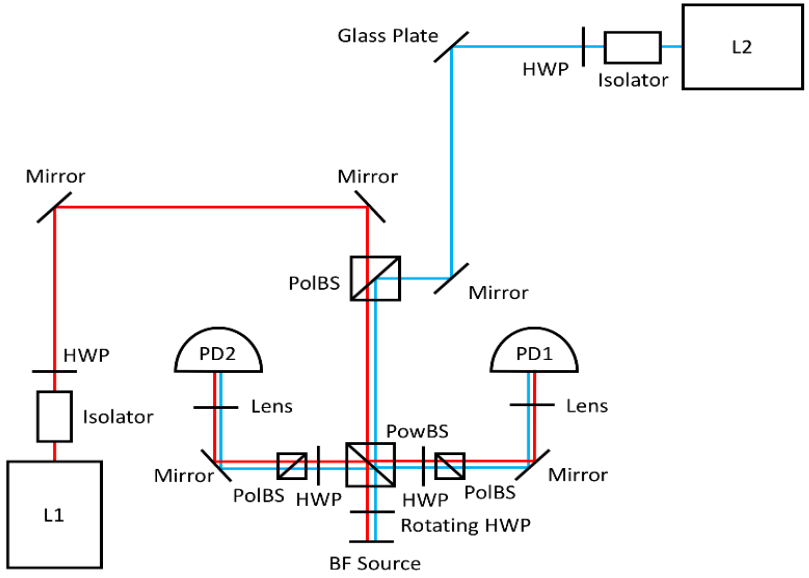


Laser Heterodyne Polarimeter



Thank you for your attention