4D PhaseCam Capabilities

Modal Analysis
and
Multiple-Wavelength Mirror Phasing

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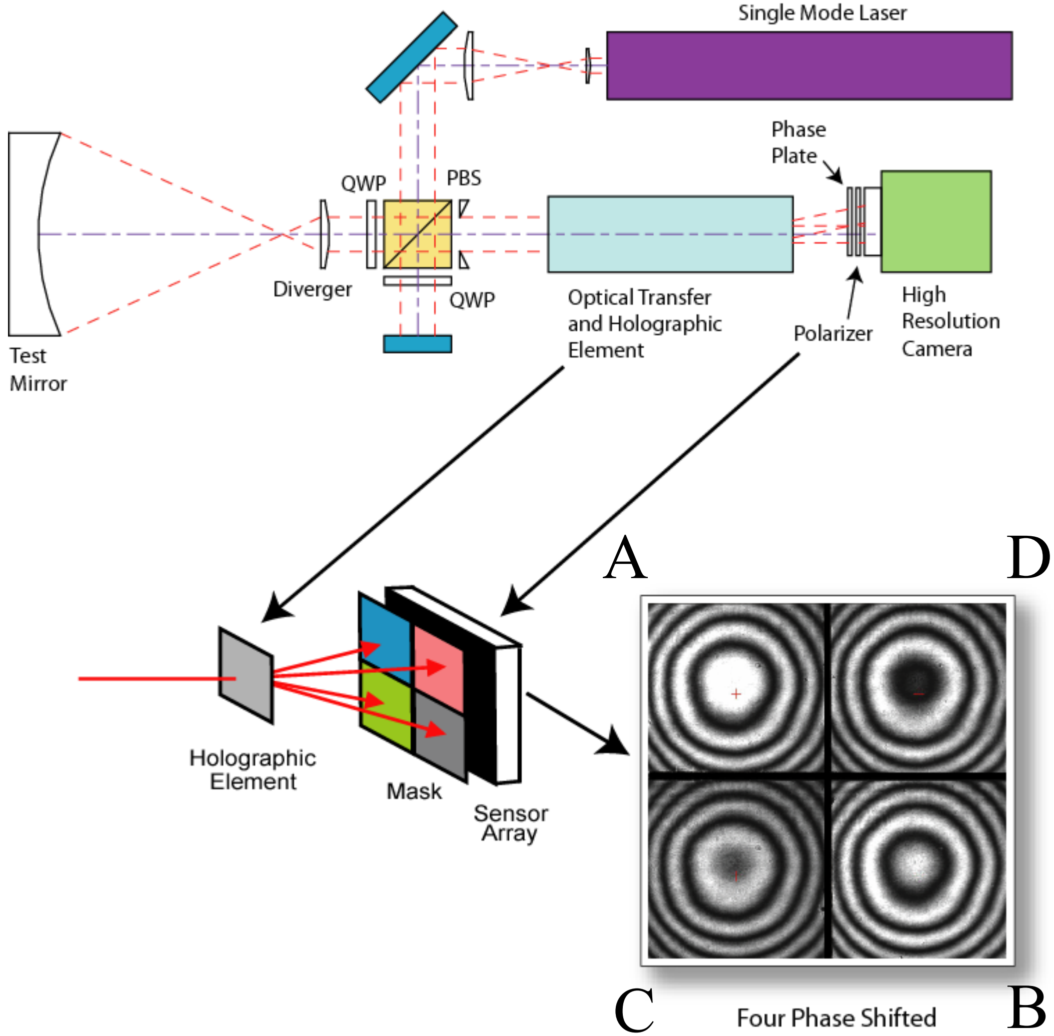
4D PhaseCam Technology



Four Phase Shifted Interferograms on Detector

<u>Single Frame PSI</u>

Benefits:

- High resolution interferometric measurement
- Insensitive to vibration & turbulence
- Easy to set up and use

$$\tan \varphi = \left(\frac{B - D}{A - C} \right)$$

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MODAL ANALYSIS

Modal Analysis

- Synchronous detection of periodic motion
  - Vibration induced modes
    - Resonance analysis
    - Mechanical rigidity analysis
- Asynchronous detection of impulse response
- Requirements
  - High speed data capture
  - Drive signal
  - Synchronization capability
  - PhaseCam provides everything needed!

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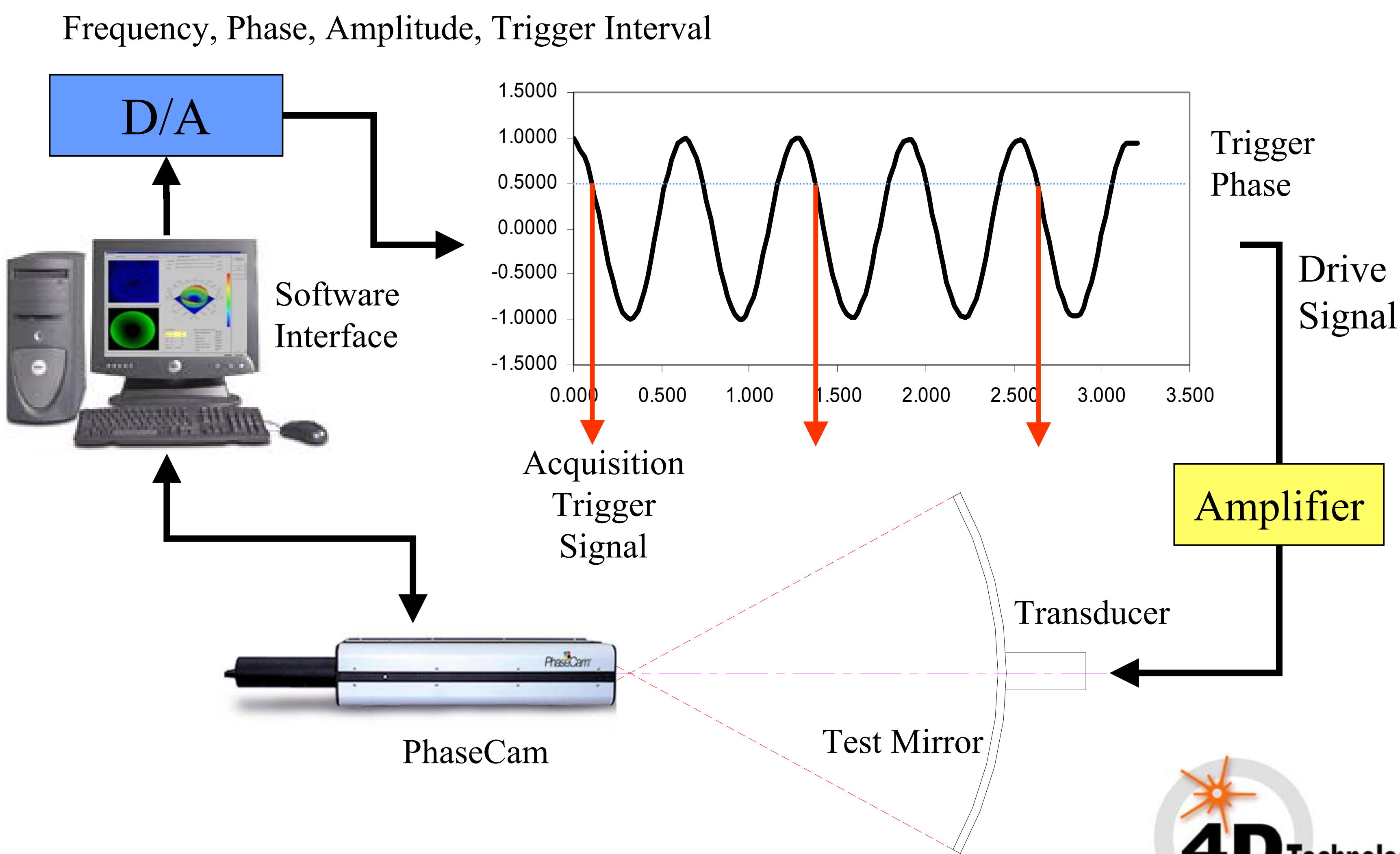
Modal Analysis - Schematic



Basic Specifications

- Output: +/- 5V Analog sinusoid, TTL trigger, impedance: > 100 kΩ
- Camera Gating Mode
  - Min shutter time = 30 micro-second
  - Frequency: 0-3 kHz
  - Max Velocity: 2600 microns/second
- Laser Strobe Mode
  - Min shutter time = 1 micro-second
  - Frequency: 0-100 kHz
  - Max Velocity: 80,000 microns/second
- Asynchronous Capture Mode
  - 30 fps
- Controls
  - Amplitude
  - Frequency
  - Phase

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Modal Analysis – Features & Benefits

- Features
  - Simple, easy to use interface
  - Temporal averaging of each data point possible
  - Standard PhaseCam can be upgraded for modal measurement
- Benefits
  - Simple measurement of frequency response
  - Simple acquisition of temporal data
  - Accurate determination of modal deflection
  - Synchronous detection allows random vibration noise to be averaged out

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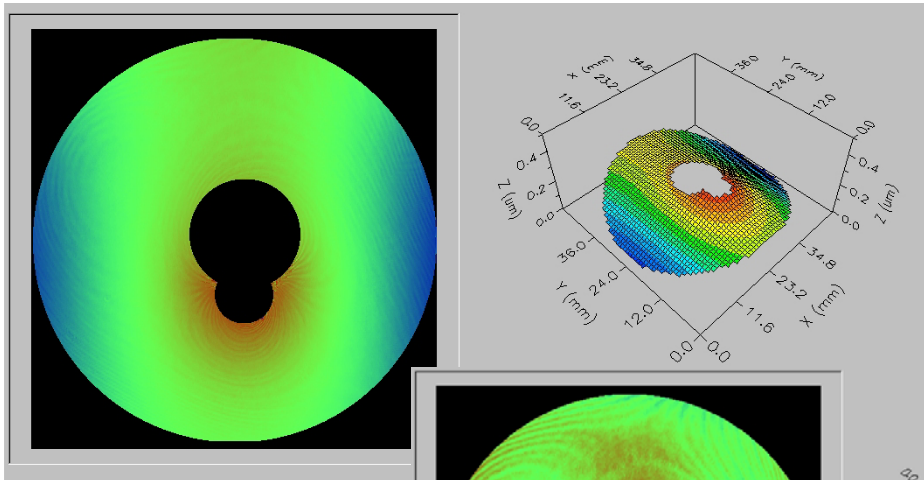
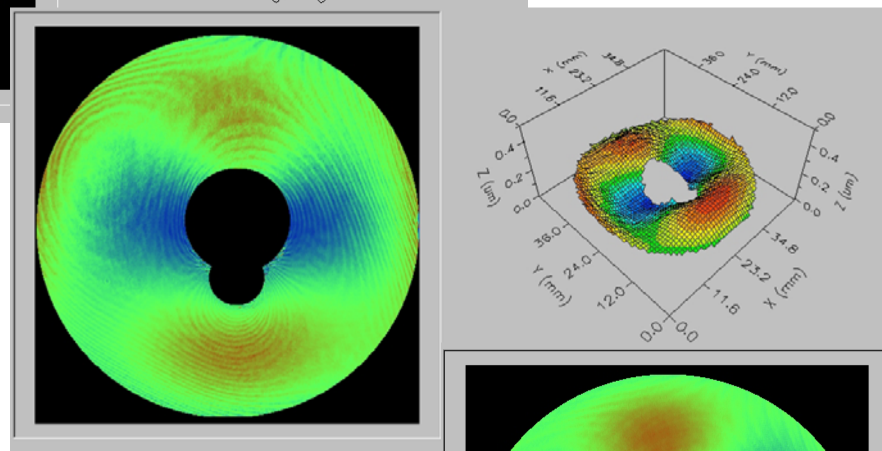
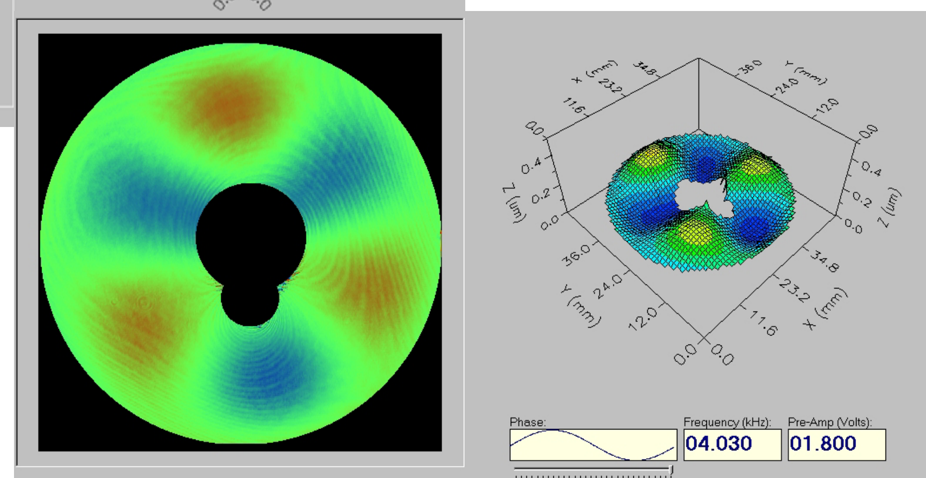
Disk Platter Modes



0.304 kHz



3.130 kHz



4.030 kHz

Frequency

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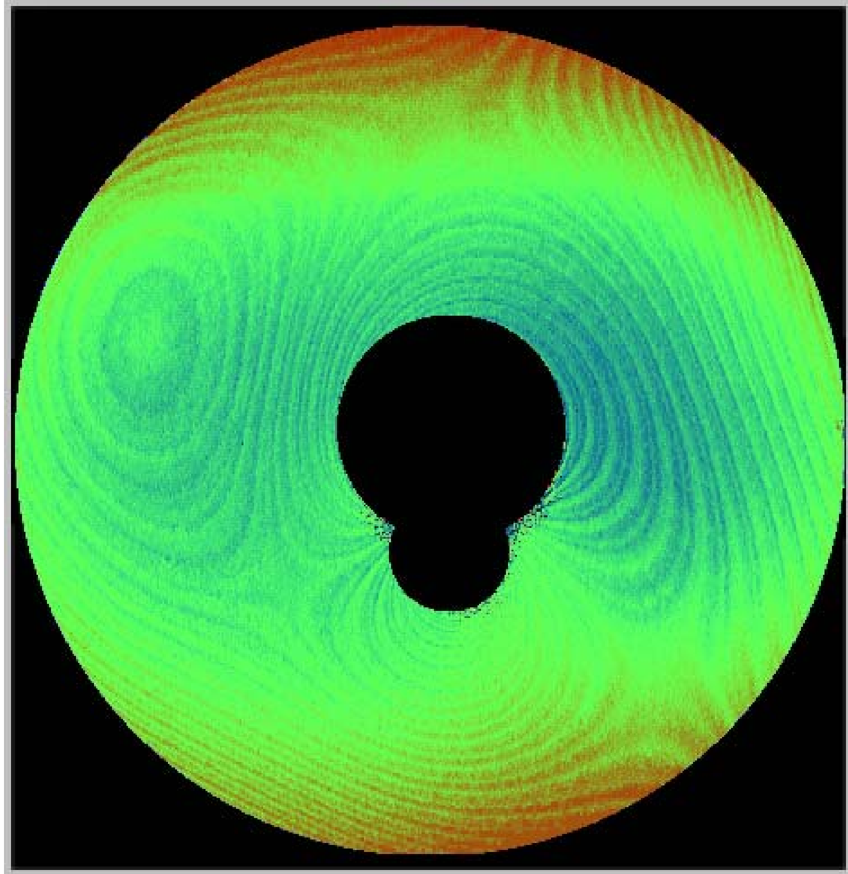
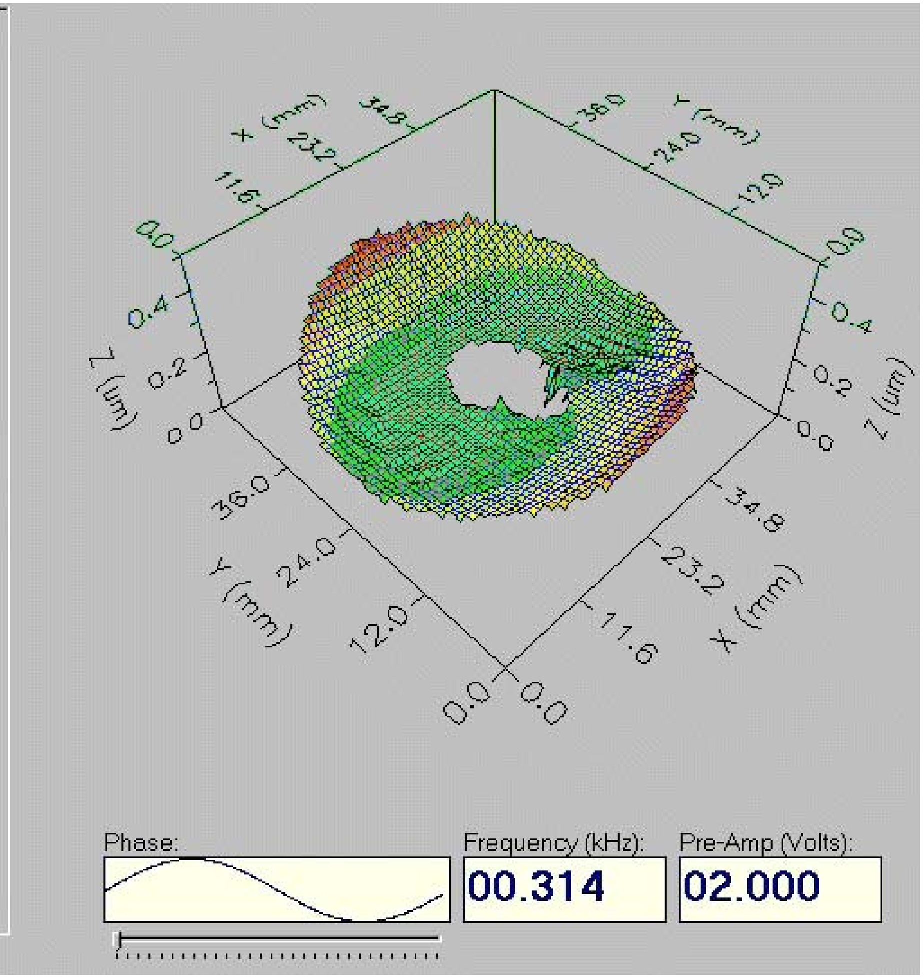
Modal Movie - Disk Platter Vibration





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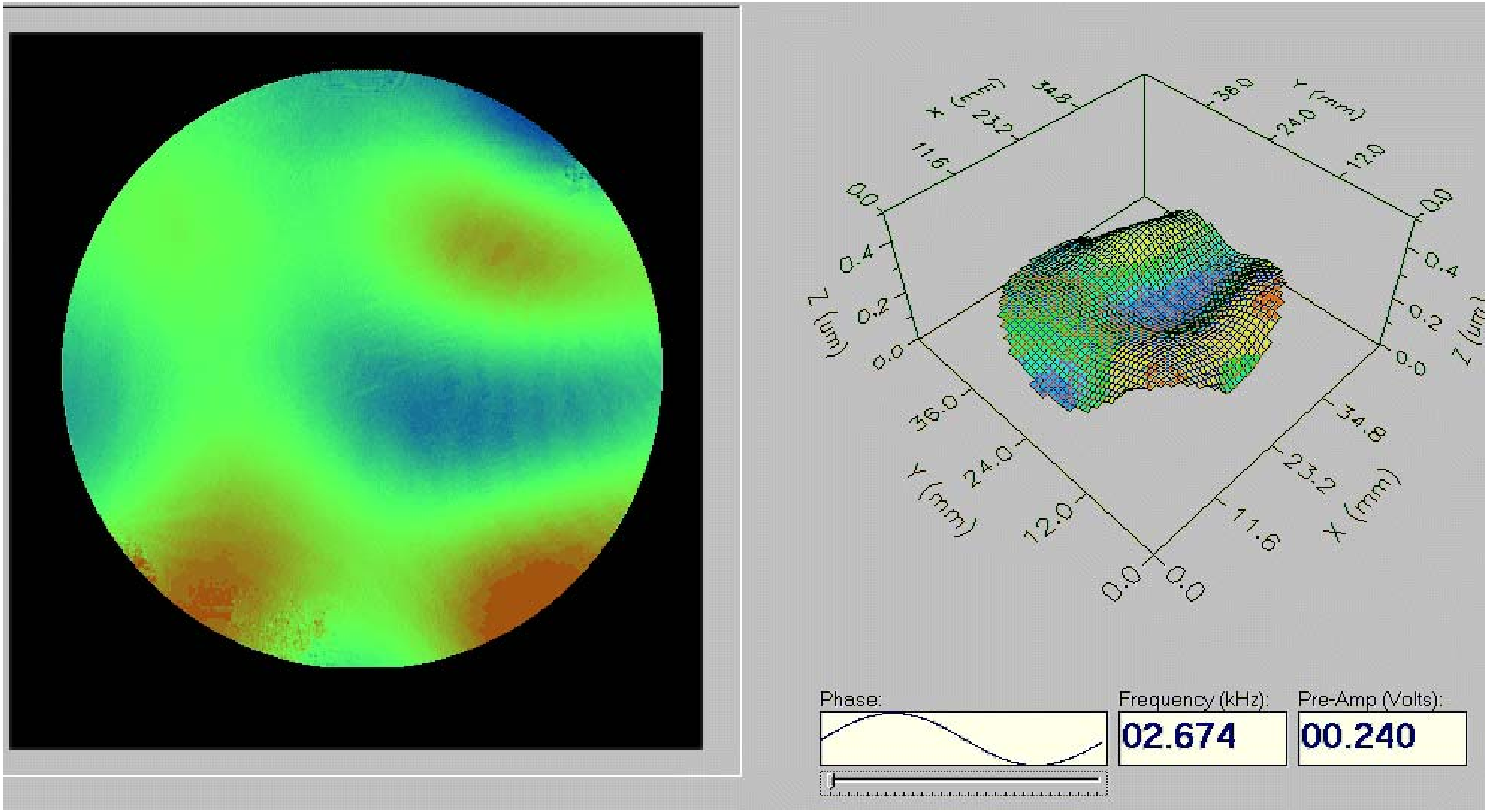
Modal Movie – Membrane Mirror



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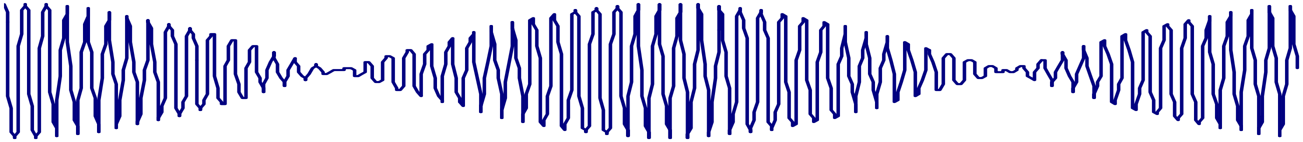
TWO WAVELENGTH MEASUREMENTS

Multiple Wavelength PhaseCam

- 2 Wavelengths can be used to extend range



2 Frequencies beat together to form a long equivalent wavelength

- A measurement is made at each wavelength

$$\Delta opd = 2\Delta z = \frac{\Delta\phi_e}{2\pi}\lambda_e$$

$$\Delta\phi_e = \Delta\phi_1 - \Delta\phi_2 \qquad\qquad \lambda_e = \frac{\lambda_1\lambda_2}{|\lambda_1 - \lambda_2|}$$

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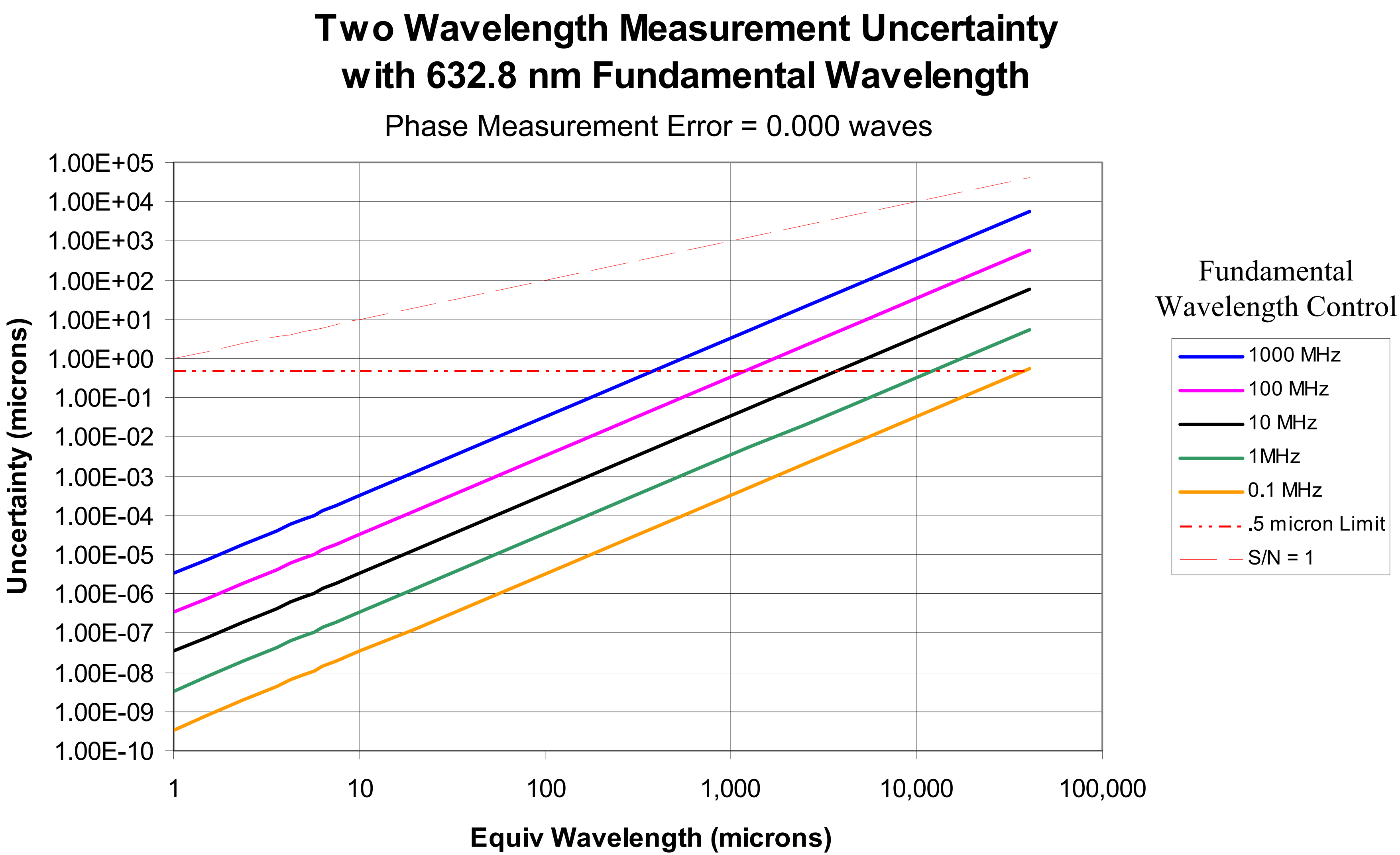
2 Wavelength Measurement Uncertainty

$$\partial\Delta\phi_e = \partial(\Delta\phi_1 - \Delta\phi_2)$$

Ranges from 0-1

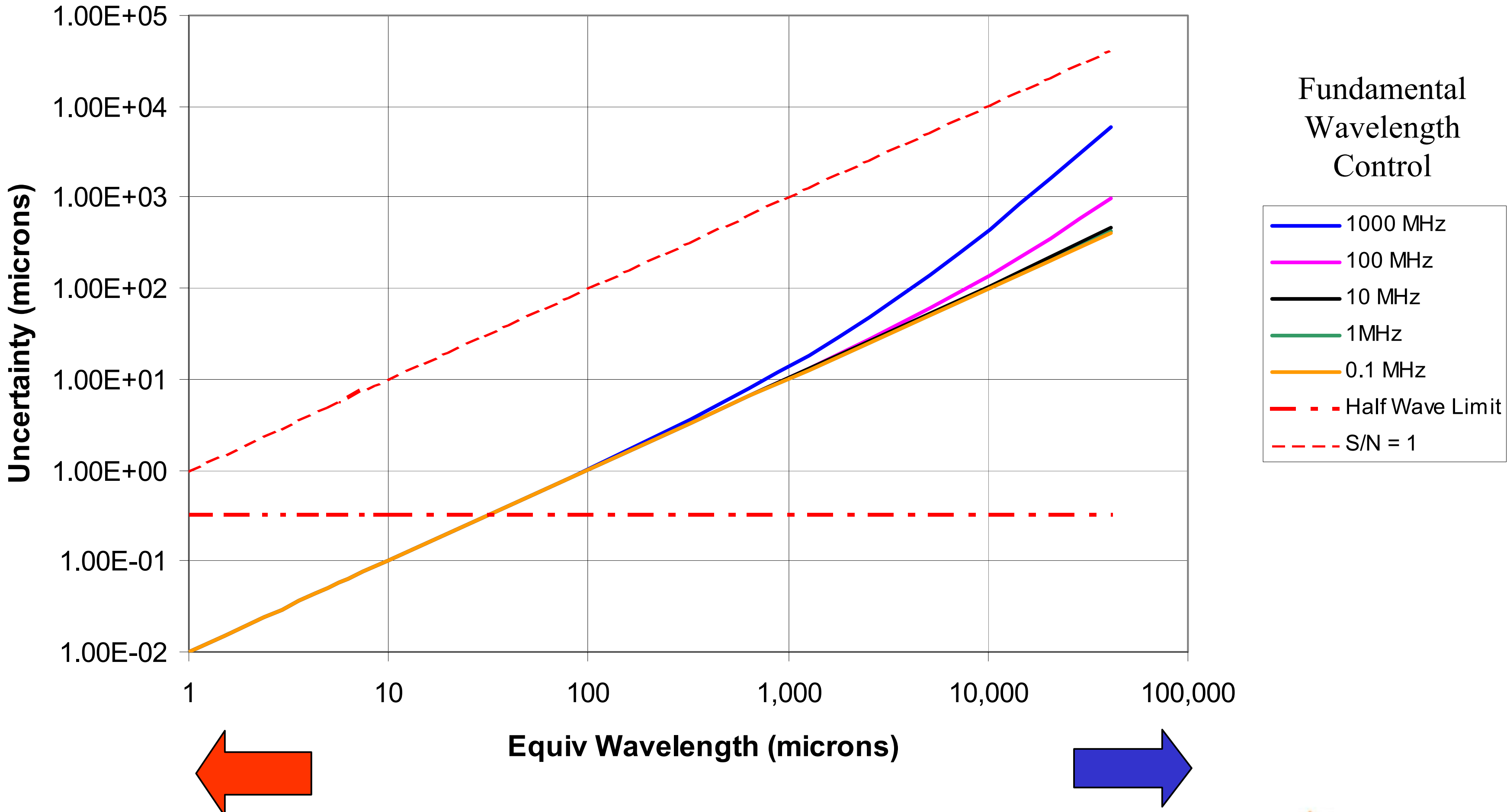
$$\partial\Delta opd = \underbrace{\frac{\partial\Delta\phi_e}{2\pi}\lambda_e}_{\text{Error due to Phase Measurement Uncertainty}} + \underbrace{\frac{\Delta\phi_e}{2\pi}\left(\frac{\lambda_e}{\lambda_1}\right)^2 \partial\lambda_1}_{\text{Error due to Synthetic Wavelength Uncertainty}}$$



Uncertainty (OPD) due to Laser Frequency Jitter Only

Two Wavelength Measurement Uncertainty with 632.8 nm Fundamental Wavelength

Phase measurement uncertainty = 0.01 waves



Large Δλ
Dispersion an issue

Small Δλ
Wavelength control more important

2 Wavelength Conclusions

- Frequency difference must be very carefully controlled
  - Commercial tunable lasers have the required capability
  - Calibration is required to remove effects of dispersion
  - Maximum range of 40-80 microns (OPD) will give resolution below ½ the fundamental wavelength
  - Achromatic slope must be controlled to measure across gaps
- Fundamental phase measurement accuracy drives the measurement accuracy.
  - Sources of error must be minimized
  - This is a two-measurement process so maximum speed is required
  - Sensitivity to vibration is increased
- Multiple ranges at different wavelengths may be used to "zoom in". This will require precise calibration.

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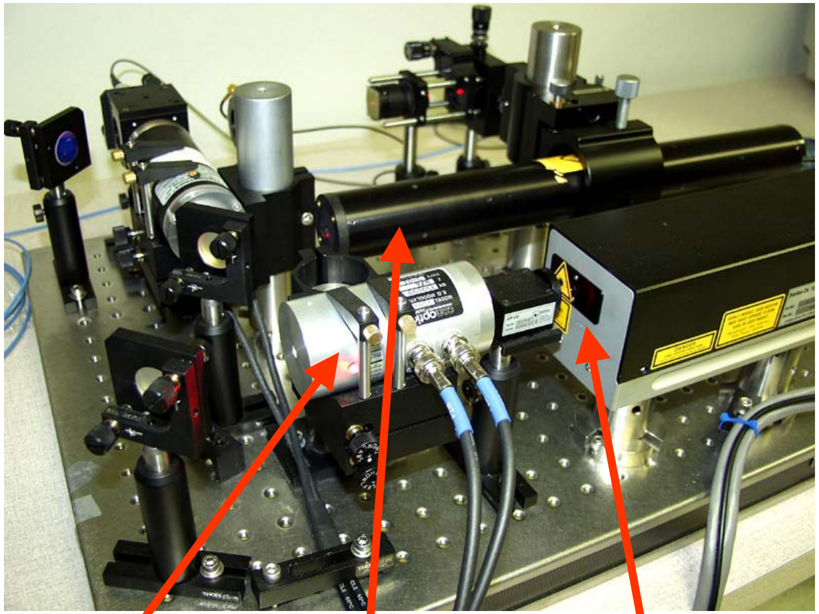
Two Wavelength Breadboard Demo

2 Wavelength Fiber Feed Source

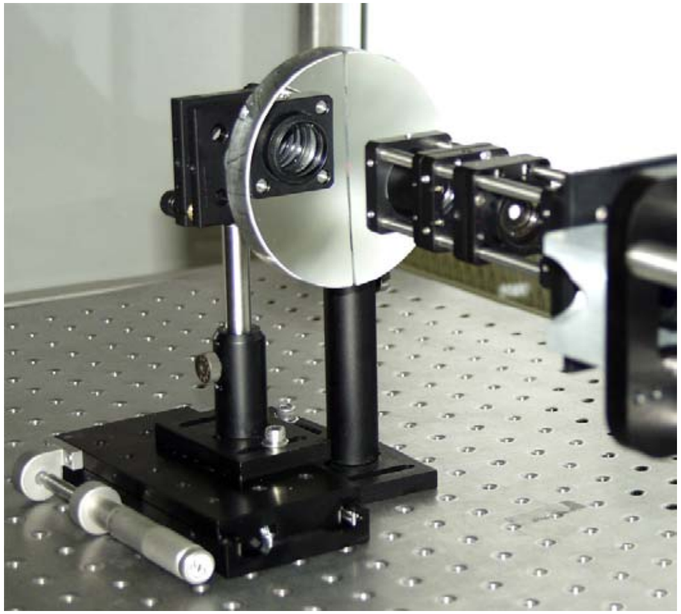


EOM (2x) Switches

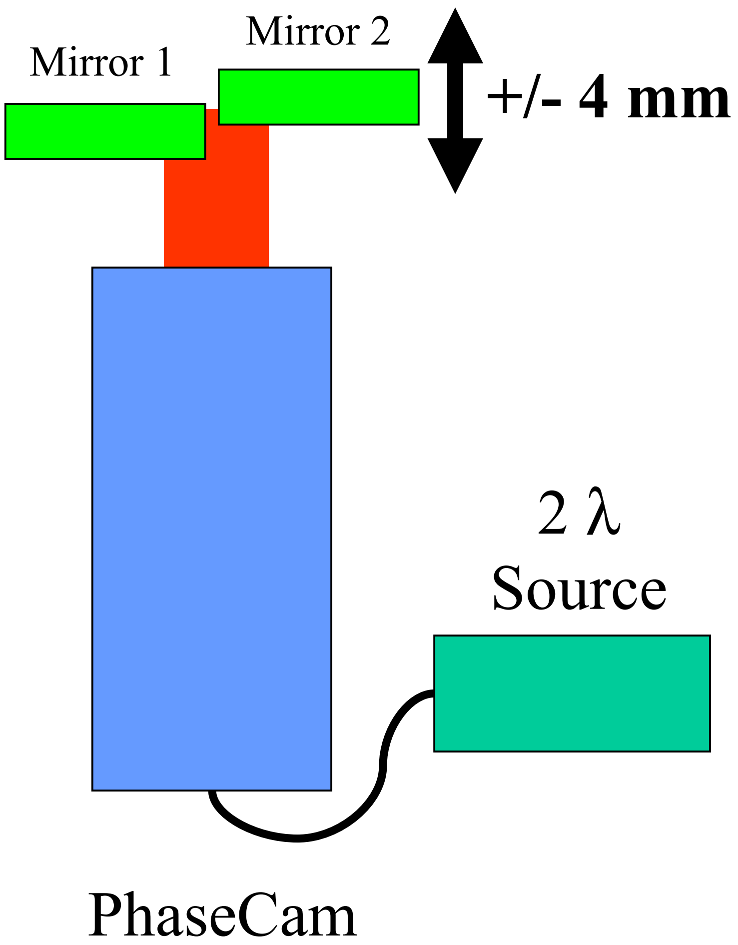
Unstabilized HeNe

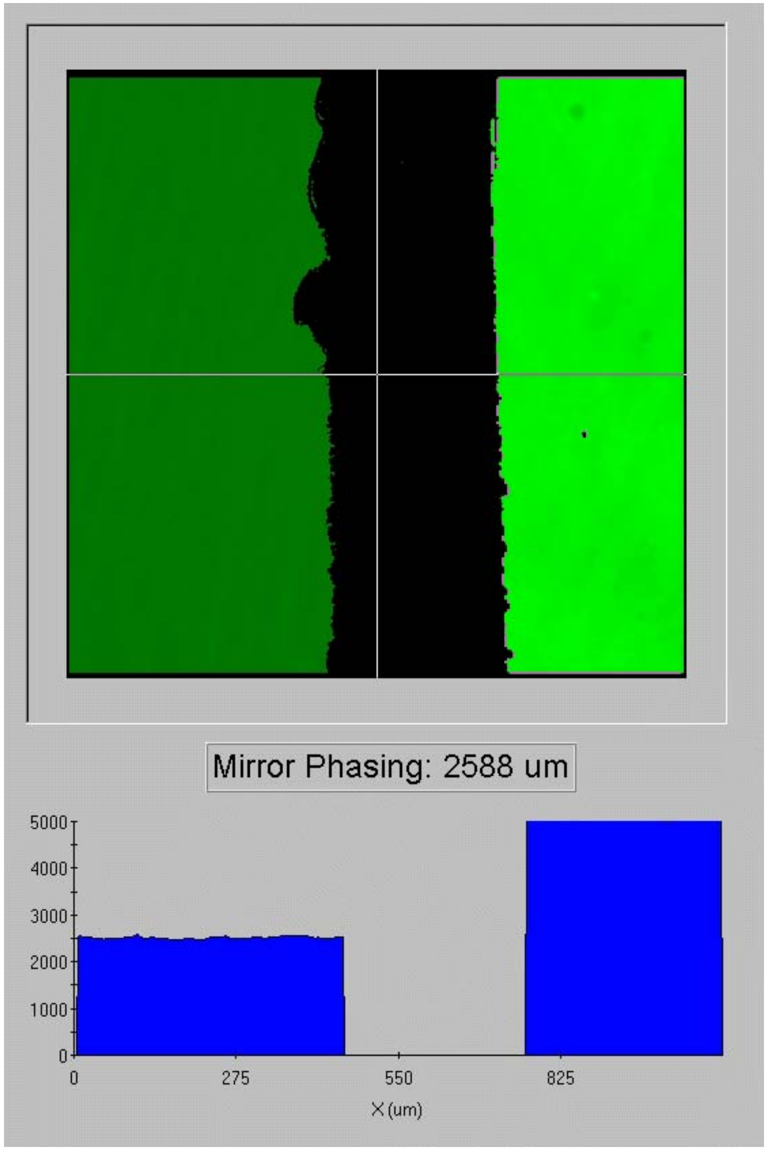
Tunable Laser

Split Mirror on Stage

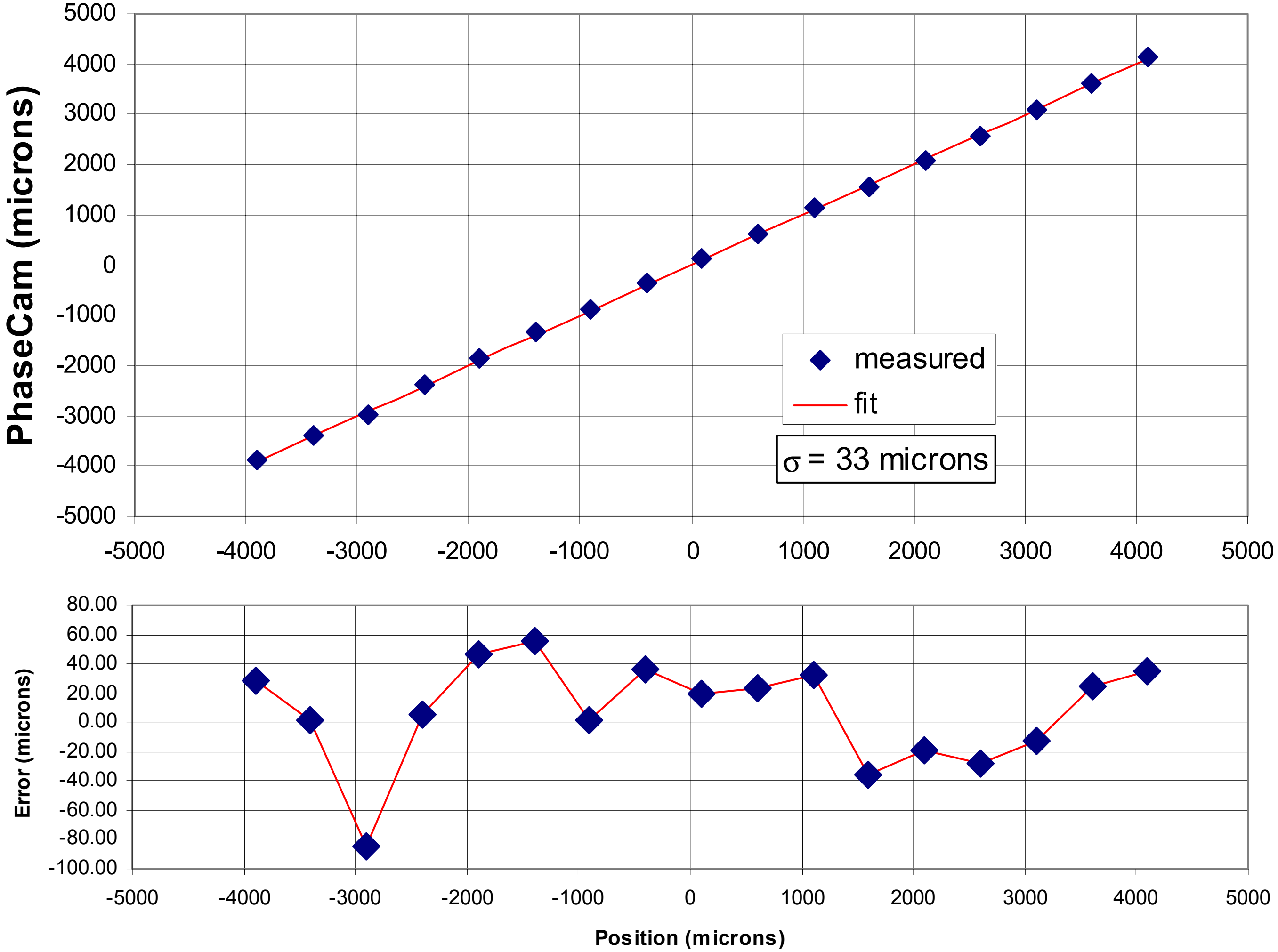


Phasing Movie



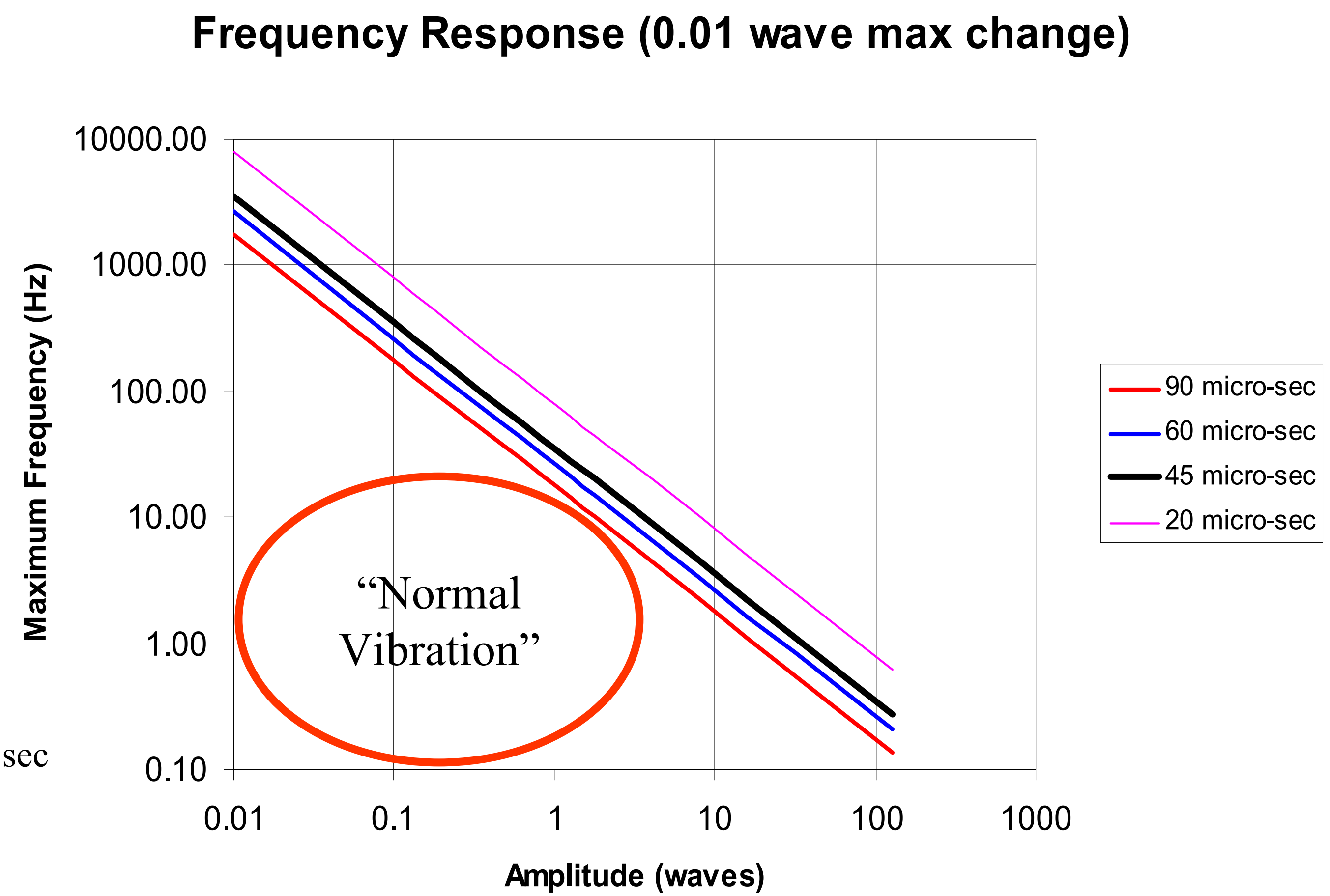


Accuracy at 11.4 mm Synthetic Wavelength

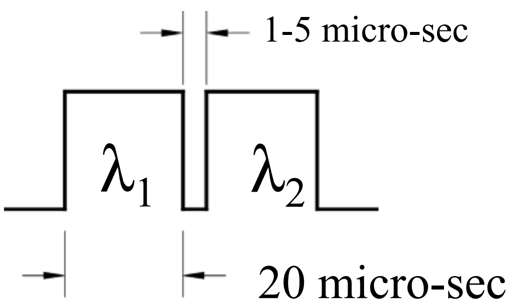


This agrees reasonably well with our estimated accuracy!
(Around 150 microns)

2 Measurement Vibration Sensitivity



Acquisition Timing (goal)



Assume 0.010 wave limit to look at effect of acquisition timing

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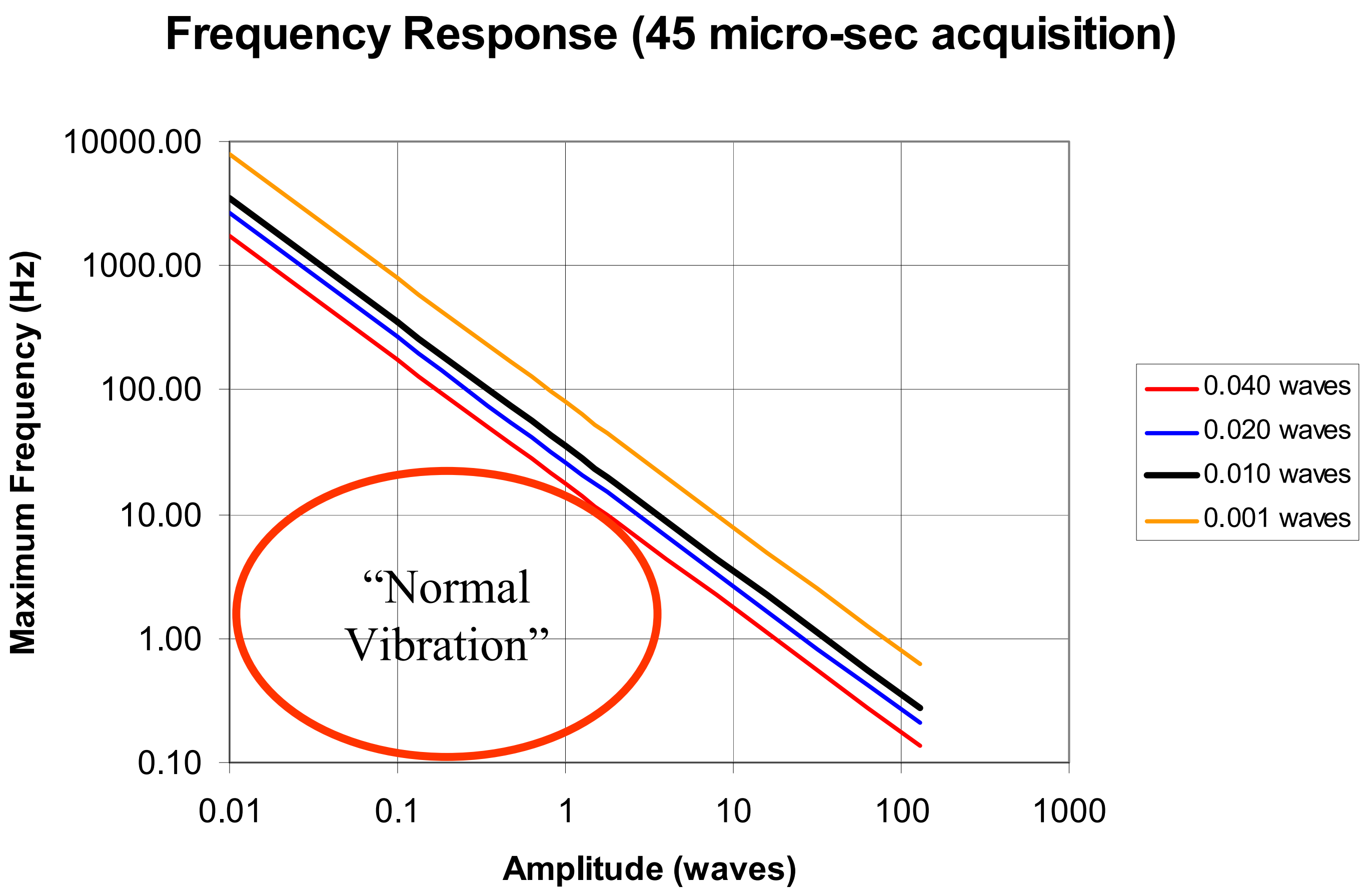
2 Measurement Vibration Sensitivity



Lets assume we can acquire two frames in 45 micro-seconds and look at effect of change in wavefront amplitude.

CONTACT INFORMATION

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