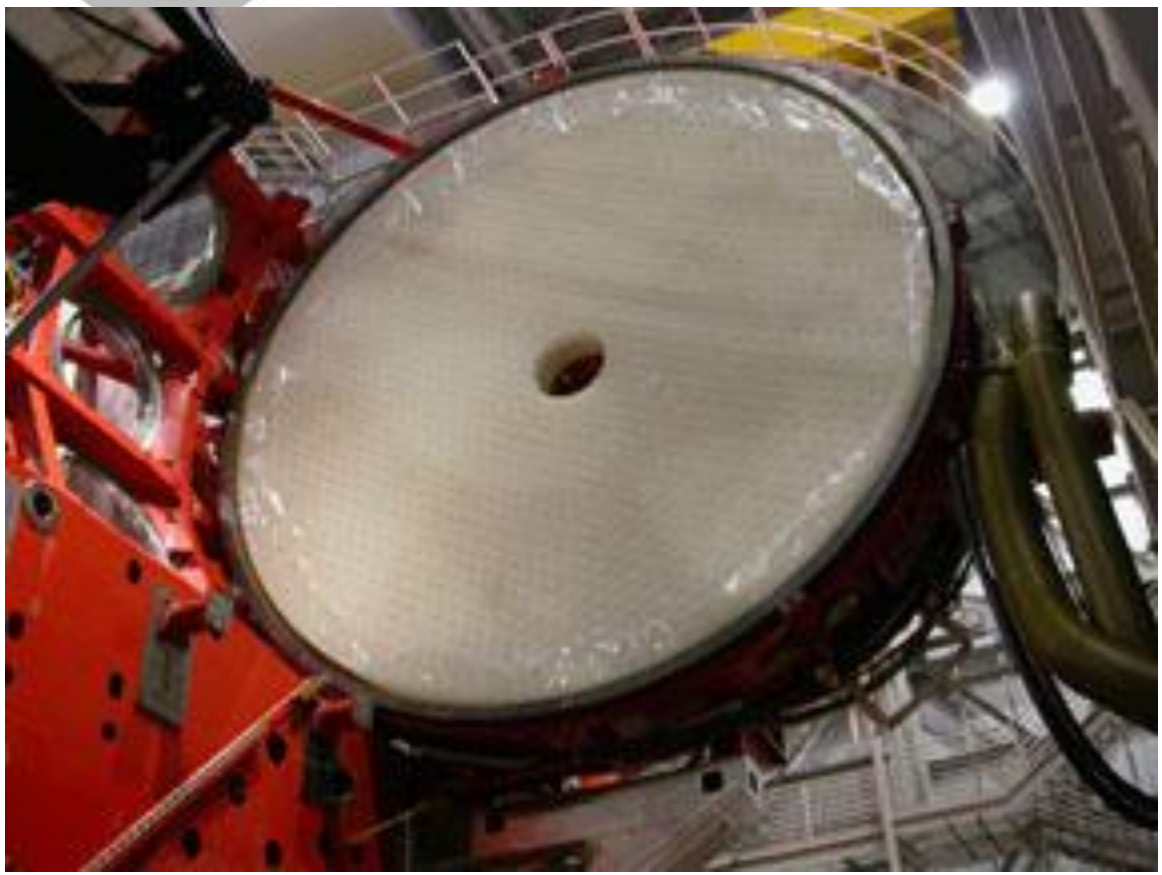
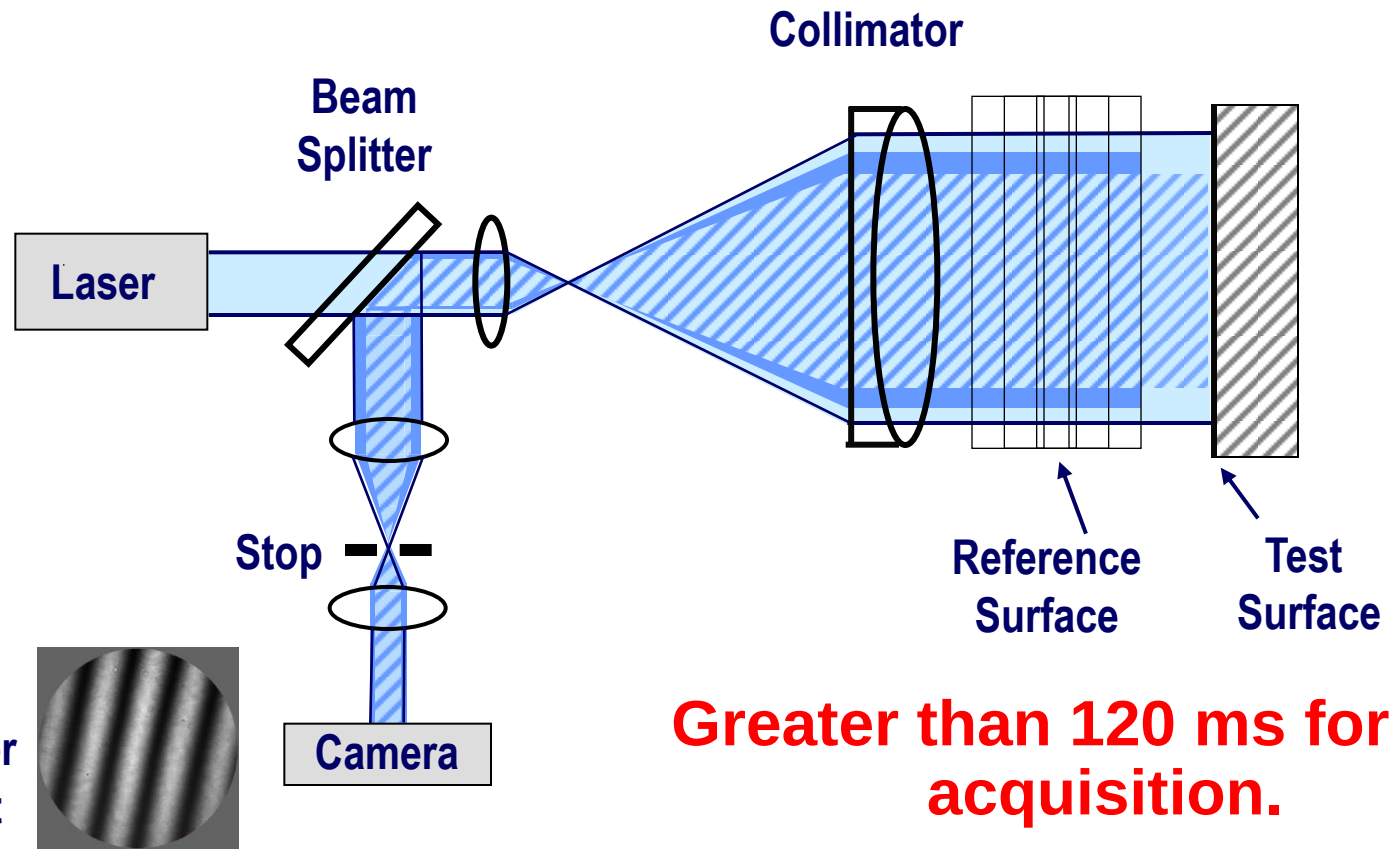


Meter Class Mirror Surface Metrology

August 2008

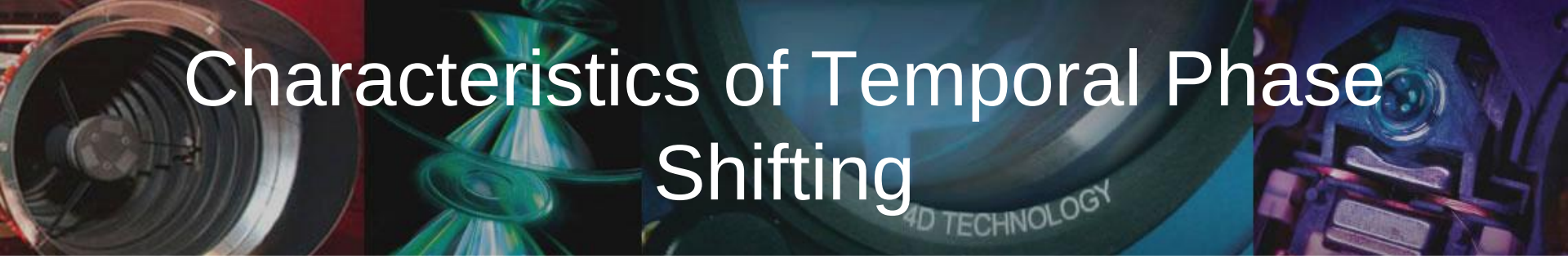
Temporal Phase Shifting Laser Interferometer



Greater than 120 ms for data acquisition.

Temporal Phase-Shifting Fizeau Interferometer

Characteristics of Temporal Phase Shifting



- Provides 3D surface data with high out-of-plane resolution (nm) and repeatability (<nm)
- Isolation from Mechanical Vibration Required.
  - Air Isolation Table
  - Rigid coupling between test part and interferometer
- Isolation from Air Flow Required.
  - Enclosure over entire test area.

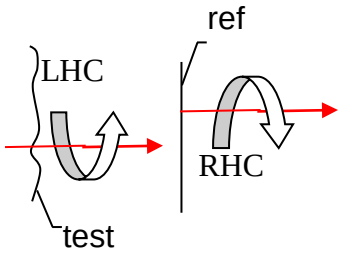
Large Mirror Metrology Challenges

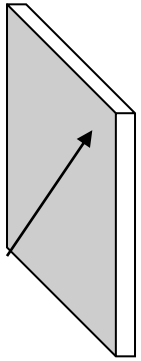
- Large mirrors are difficult to isolate from mechanical vibrations.
- Large distances between metrology and part allows environmental issues with air turbulence.

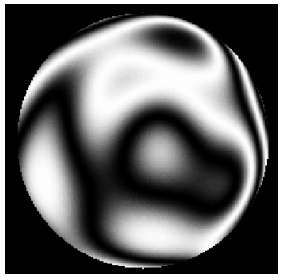
Vibration and Air Flow

Dynamic Phase Shift Method

Use polarizer as phase shifter





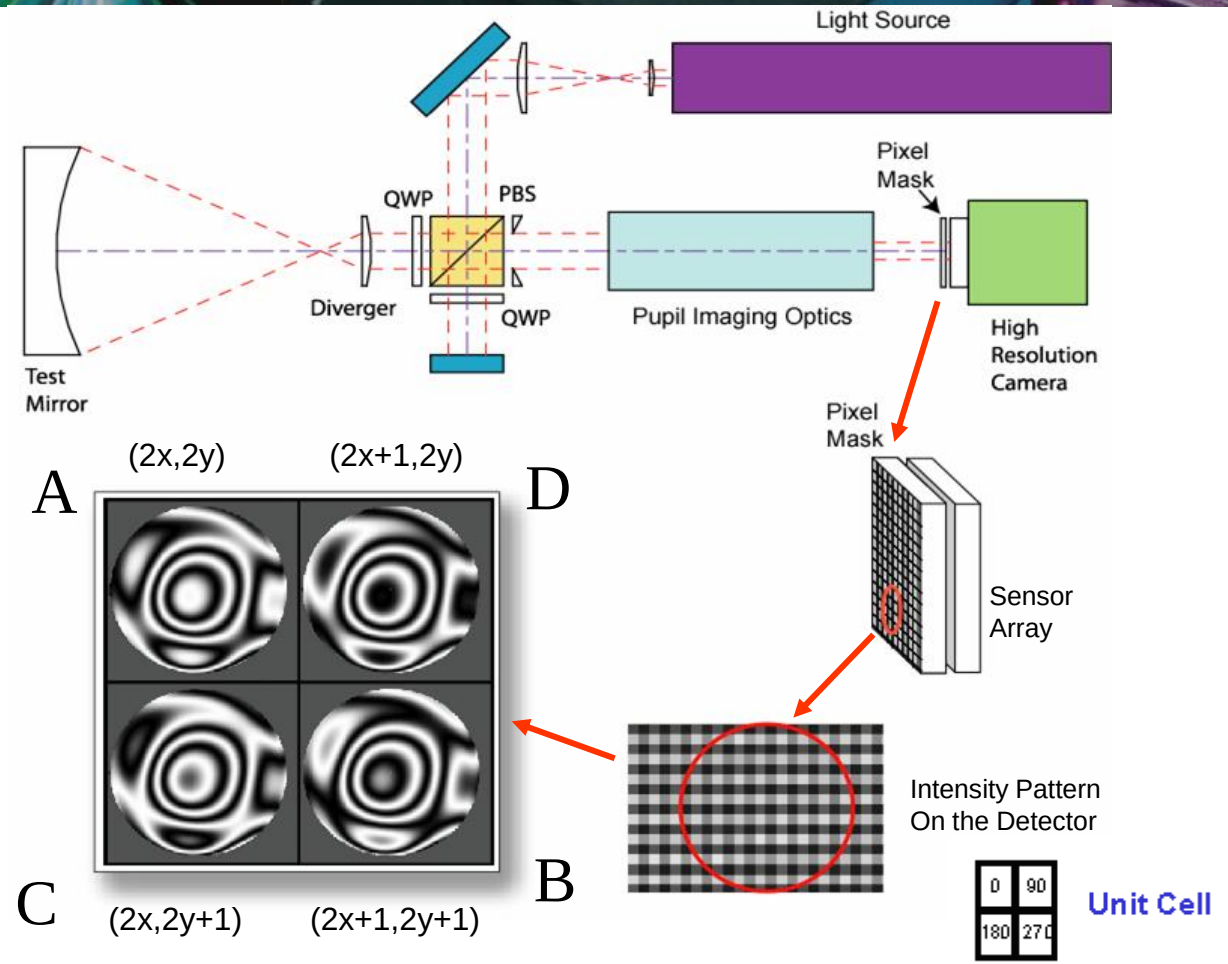


Circ. Pol. Beams (θ) + linear polarizer (α) ⟶ $I = I_T(1+\gamma Cos(\theta + 2\alpha))$

Phase-shift depends on polarizer angle

Kothiyal and Delsile, Appl. Opt. V24 n24 p4439 (1985)
Kemo, et. al, Appl Opt. V41 n 13 p2448 (2002)

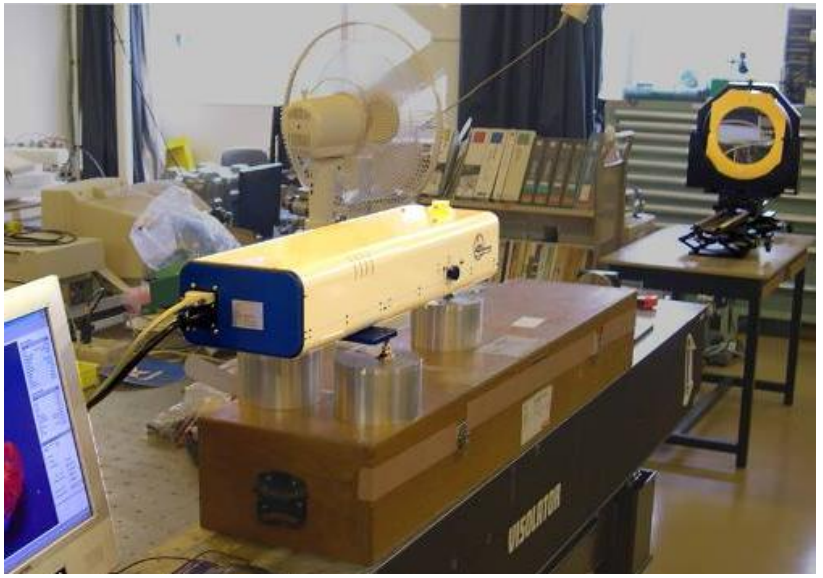
Pixelated Phase Mask



- All frames acquired in one camera integration time!

Dynamic Interferometry Advantages

- Overcomes poor environments
  - Insensitive to vibration, air turbulence, other noise
- Excels in challenging test configurations
  - Large optics, long paths, test chambers
- Coated/Uncoated mirrors can be measured without attenuation filters.



Research environment: 0.0008λ rms 1σ repeatability

PhaseCam Twyman-Green Interferometers

PhaseCam 4020

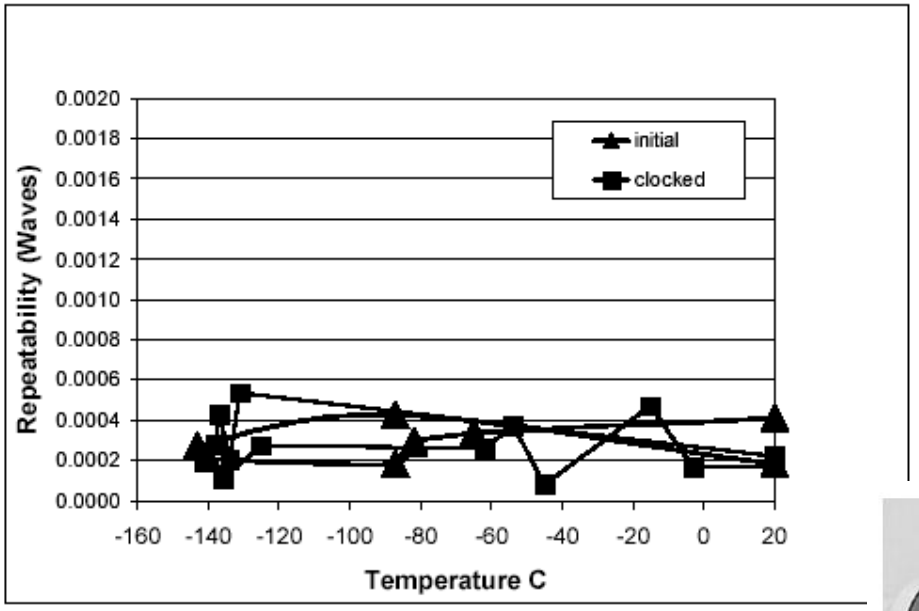
- Concave mirrors with reflectivity from 1- 100%
- Flats < 7 mm diameter
- Modal analysis of concave mirrors or flats
- IR wavelengths available

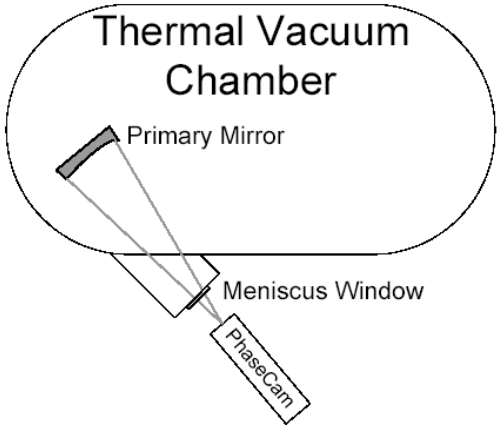
PhaseCam 5030

- Adds motorized zoom, focus, beam ratio and beam block
  - For use in remote installations, pressure vessels, environment chambers
  - 4M-pixel option for high spatial sampling

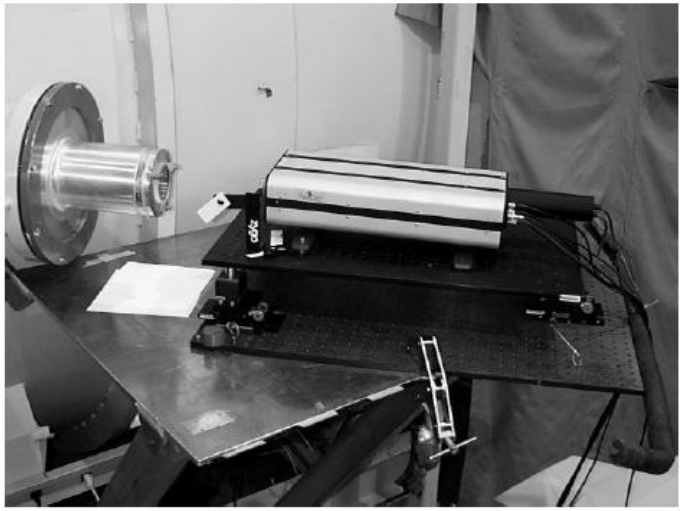
30 Meter Test Tunnel

Cryogenic Figure Tests





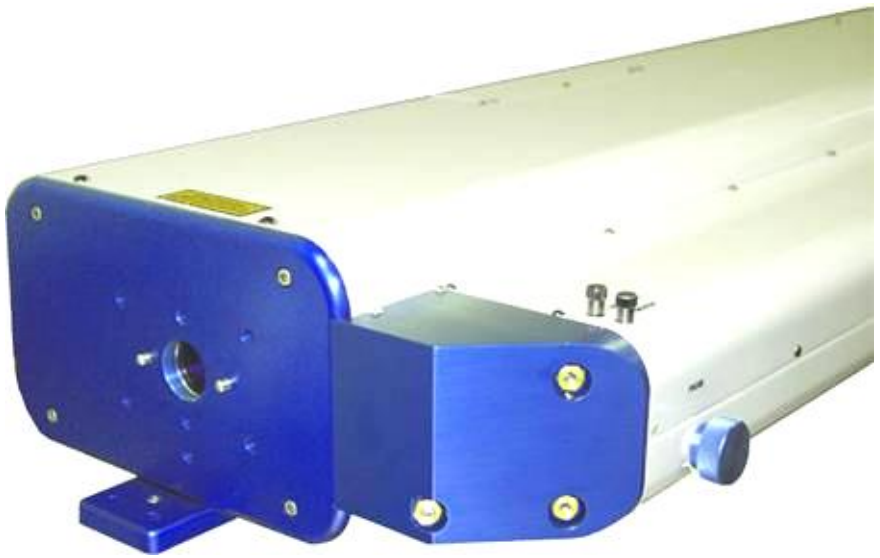
<u>Figure testing of 300 mm Zerodur mirrors at cryogenic temperatures</u>, Baer & Lotz, SPIE 4822-4 July 2002



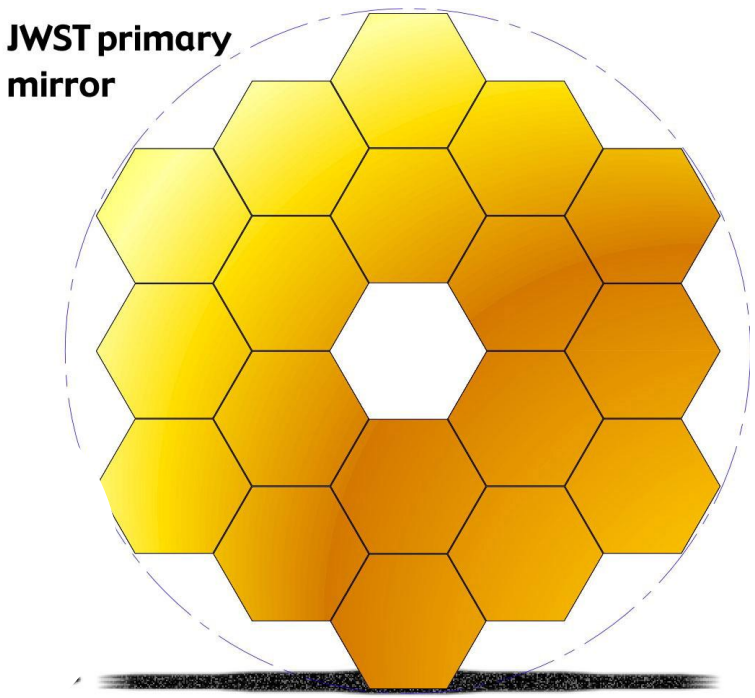
Low Return Tests

4020HP

- Excellent for low reflectivity (low return) test setups requiring dynamic performance



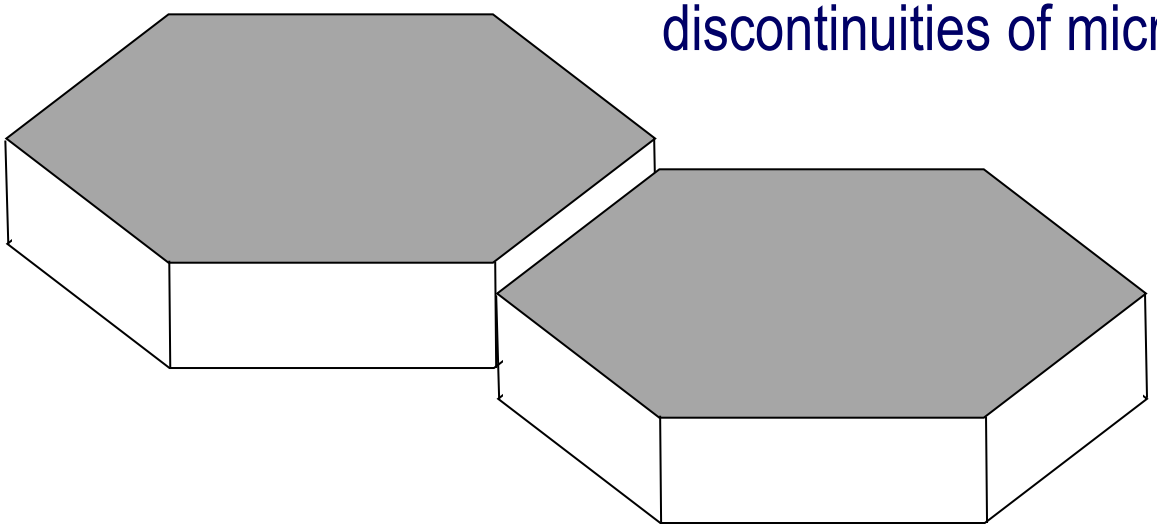
Applications of Multi-Wavelength Dynamic Interferometry



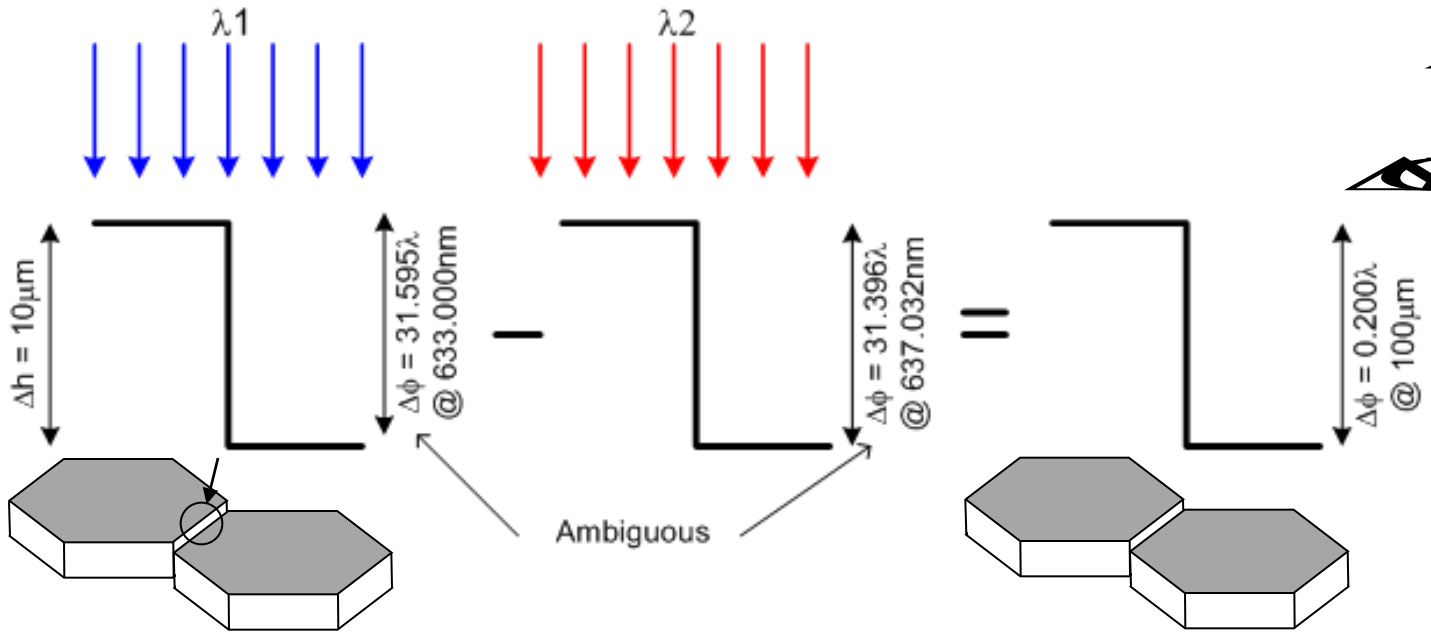
- Phasing of multi-segment mirror arrays
- Surface shape of individual mirror segments.

Single Wavelength Measurements for Segmented Mirrors

- Single wavelength techniques cannot accurately measure steps between mirror segments greater than ¼ λ.
- Mirror segments may have step discontinuities of microns to millimeters.



Two-Wavelength Measurement for Segmented Mirrors

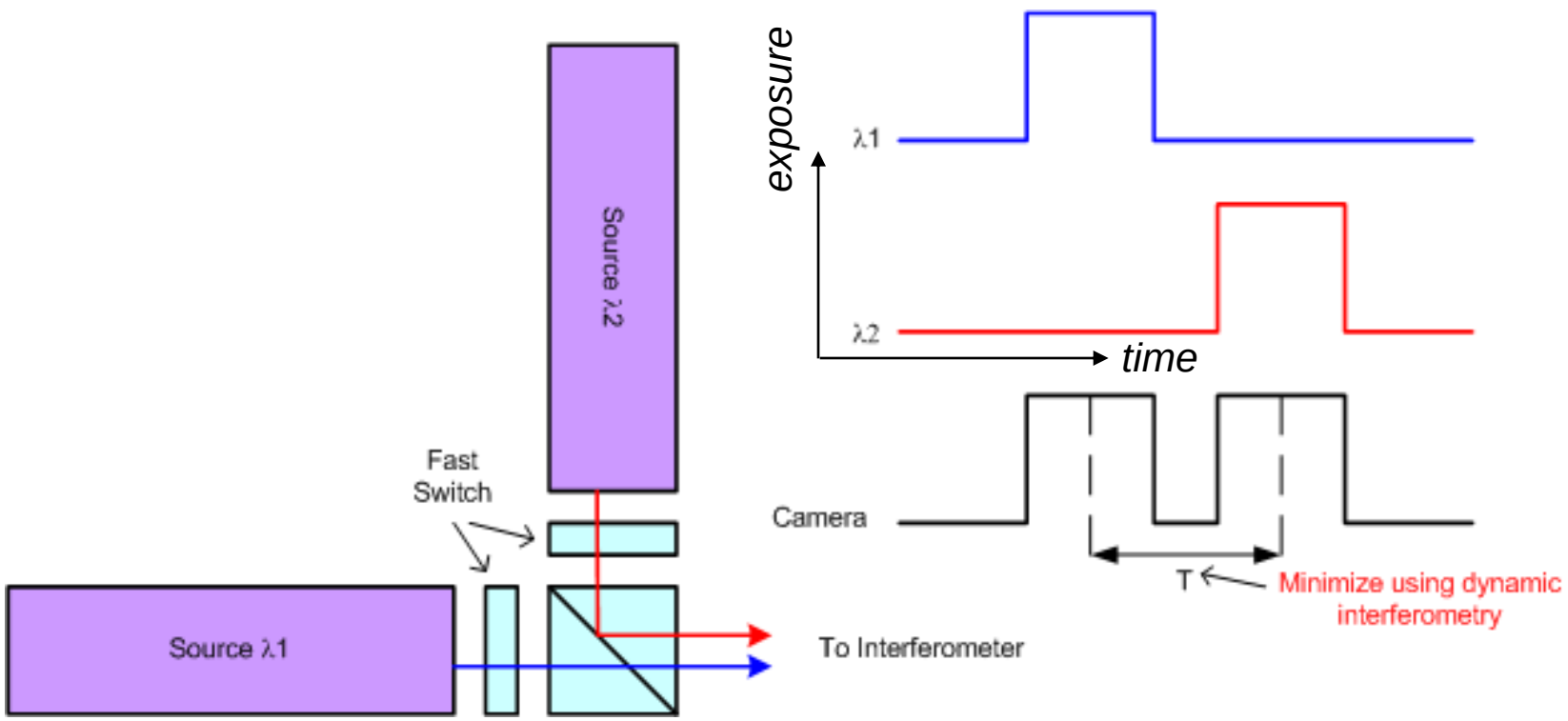


$$\Delta\phi = \frac{2\pi}{\lambda}\Delta h$$

$$\lambda_s = \frac{\lambda_1 \cdot \lambda_2}{|\lambda_2 - \lambda_1|}$$

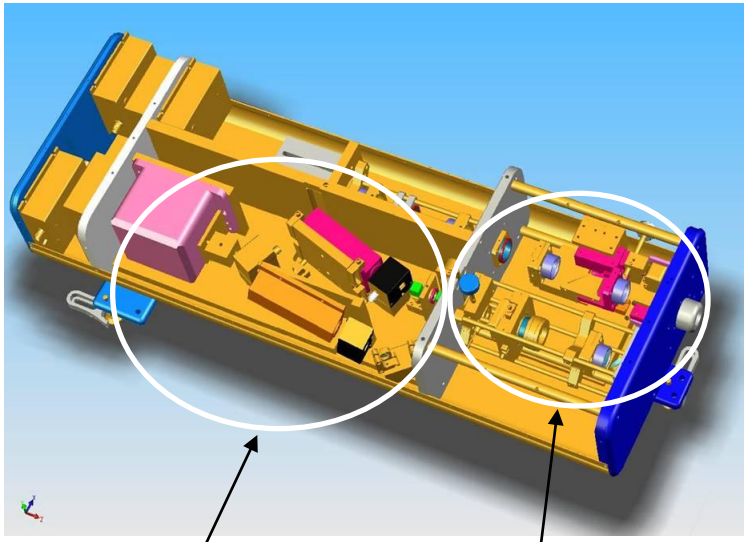
- Dynamic range of interferometric measurements can be increased by measuring step discontinuity using two different wavelengths sequentially.

Importance of Fast Acquisition



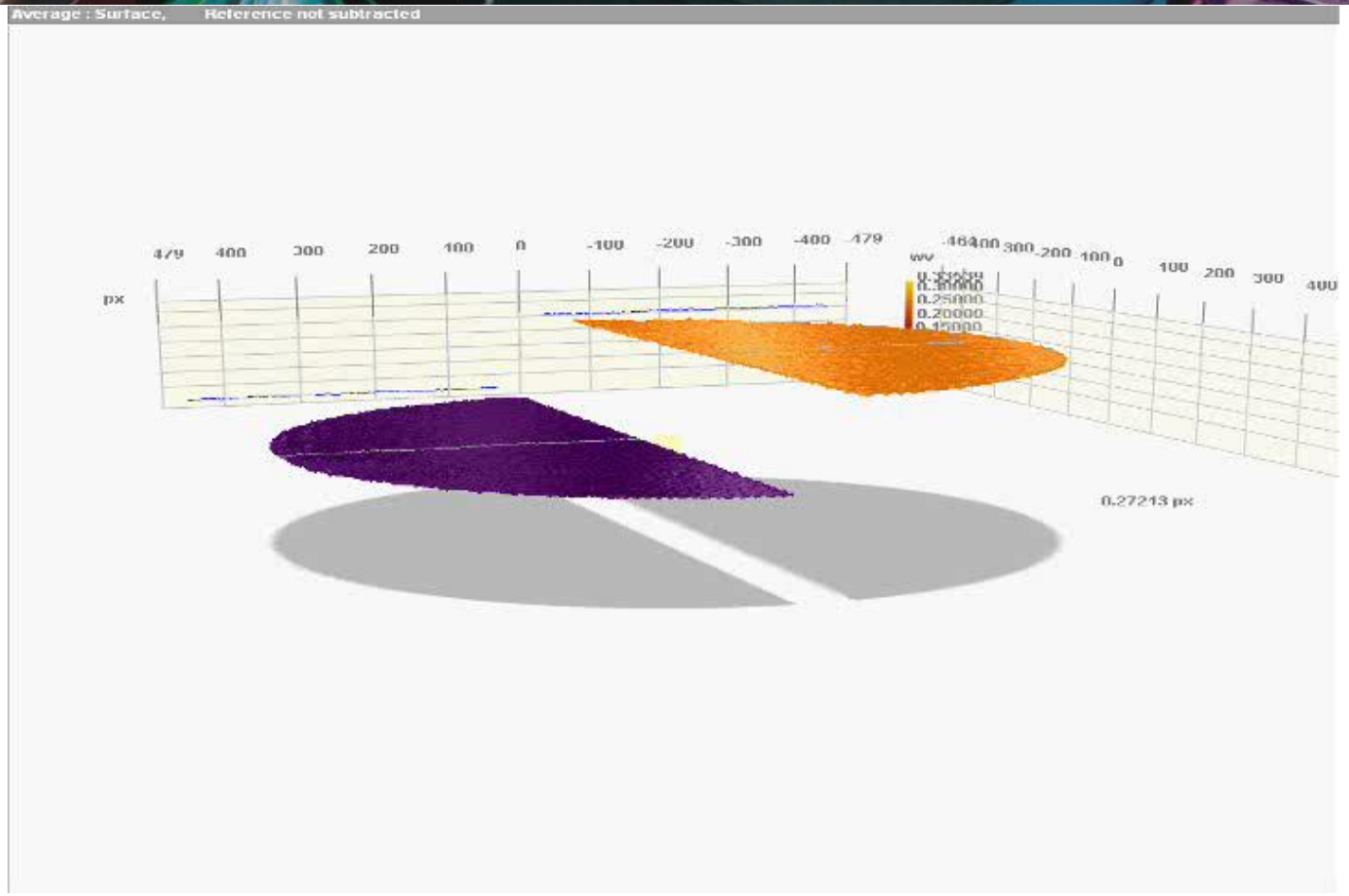
- Rapid acquisition required to minimize changes in step height between frames in the presence of non-common mode vibrations.

PhaseCam MW



- Extends range from nm to mm
- 3 Laser Sources, two fixed, one tunable
- Synthetic wavelengths from 18um to 10 mm
- Fundamental at 637 nm

MultiWave Dynamic Measurement



Parabola cut in half with section translated +/- 2 mm

FizCam 2000

- Dynamic Fizeau Interferometer
- 4, 6 and 12 inch apertures available
- Short Coherence Source
- Measure transparent samples with multiple surfaces
  - Sample Thickness from <200 µm to 400 mm
  - Prisms
  - Remote cavity testing
  - Index of homogeneity
  - Beam expanders

FizCam and James Webb Space Telescope (JWST)

JWST Secondary Mirror Test Configuration
80cm diameter hyperboloid surface

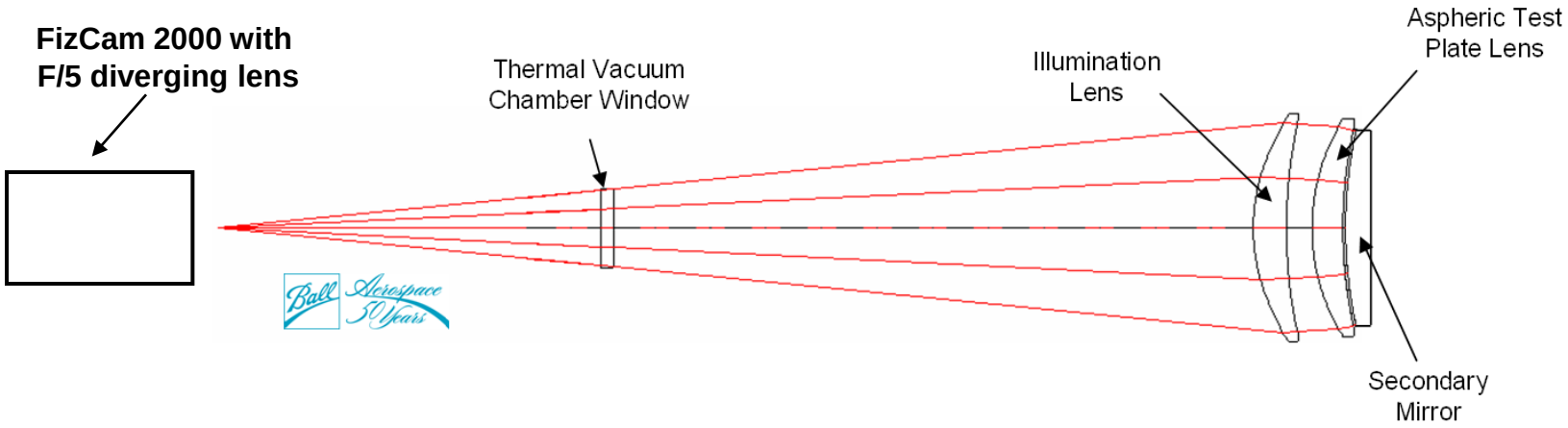
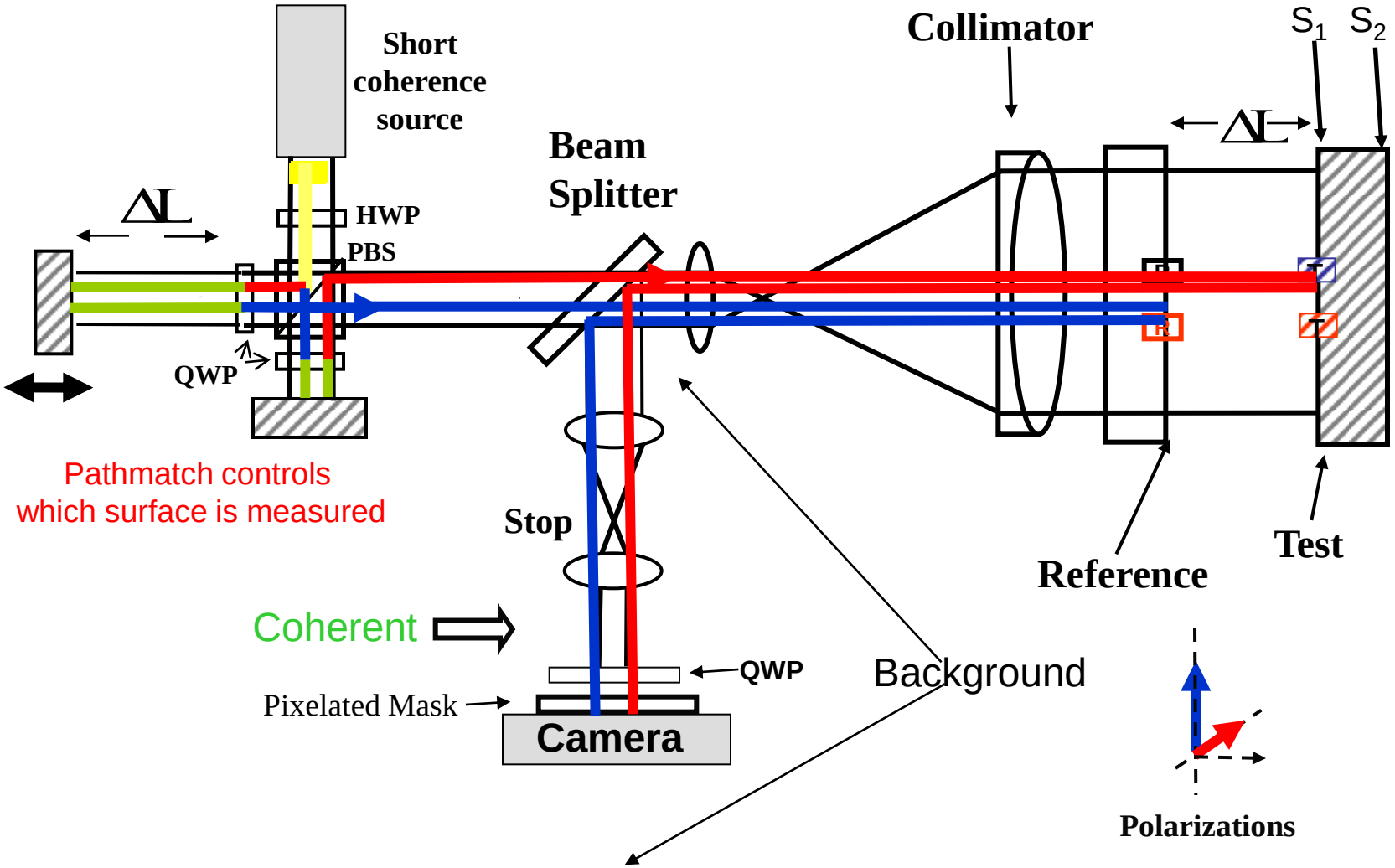


Figure courtesy of K. Smith, Ball Aerospace

FizCam 2000 Interferometer



Conclusion

- Dynamic interferometry is award winning technology, proven daily in demanding roles worldwide
- Accurately measures surface shape in challenging environments
- Enables difficult measurements in tough testing configurations