Meter Class Mirror Surface Metrology

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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

\[
\text{Circ. Pol. Beams } (\theta) + \text{ linear polarizer } (\alpha) \rightarrow I = I_T (1 + \gamma \cos (\theta + 2\alpha))
\]

Phase-shift depends on polarizer angle

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

Figure testing of 300 mm Zerodur mirrors at cryogenic temperatures, Baer & Lotz, SPIE 4822-4 July 2002
4D Technology Corporation

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 $\frac{1}{4} \lambda$.
- Mirror segments may have step discontinuities of microns to millimeters.
Two-Wavelength Measurement for Segmented Mirrors

- 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

Integral Source  Interferometer
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

- Reference
- Collimator
- Beam Splitter
- Stop
- QWP
- Camera
- Pixelated Mask
- Short coherence source
- HWP
- PBS
- ΔL
- ΔL
- ΔL
- R
- T
- Coherent
- Pathmatch controls which surface is measured
- Pixelated Mask
- Background
- Polarizations
- S1
- S2

Coherent

Pathmatch controls which surface is measured
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