Low coherence wavefront probe for nanometer level free-form metrology

NASA SBIR Phase II: NNX17CG04C
April 2017 Start
December 2018 Finish

Outline

- The Problem: Metrology of Freeforms
- Free Form Metrology Technical Limitations
- Probe Technology
- Progress to Date
- Commercial Impact
- Äpre Instruments background

Industry Limitation

Free form optics have known advantages. Lack of metrology limits manufacture

- Basic Metrology Requirements
  - – Low Measurement Uncertainty (<50 nm rms 2σ)
  - – Measure “Any” Shape (includes aspheres & spheres)
  - – High speed (<5 minutes)
  - – Surface slopes ≤60°
  - – Form & Mid-Spatial Frequencies (0.1 to 4 mega points)
  - Nominally <150 mm X 150 mm parts
    - Up to 500 mm X 500 mm parts

NASA Project Goals

- Free form 2D profile map
- 2 nm 2σ RMS measurement uncertainty
  - 10^3 < CMM, and 10^2 < State of the Art
- Non-contact
- Large acceptance angle: >30°
- 50 mm X 50 mm measurement area

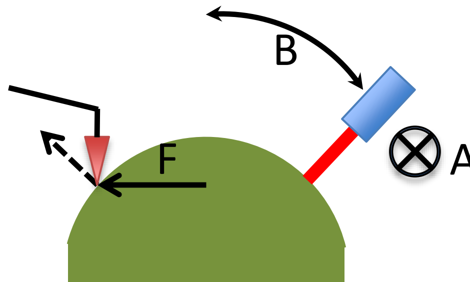
Today’s Free form Metrology Technical Limitations

Touch Probes

- Pros
  - Any roughness
  - ≤60° slopes
  - Low cost (probe)
  - X,Y,Z metrology frame
- Cons
  - Surface Damage
  - Slow (10’s of minutes)
  - Low image resolution
  - Limited accuracy
    - Ball sphericity
    - Side loads
    - Z-sensitivity cosine error

Interferometer Probe

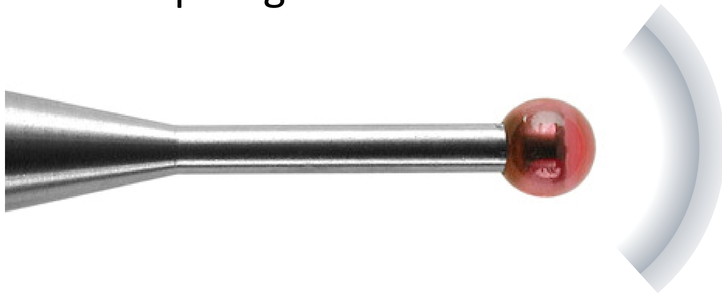
- Pros
  - Non-contact
  - nm Z-sensitivity
  - Normal to surface
  - Promise high image resolution
- Cons
  - Polished only
  - Moderately Slow (1 kHz)
  - 2° slope limitation
  - $ > contact probe $
  - Limited accuracy
    - X,Y,Z,A,B metrology frame required
    - Retrace errors – off normal



Ultimate Probe Combines Best of Both

Ultimate Probe

Simple X,Y,Z Metrology Frame
Steep Angles



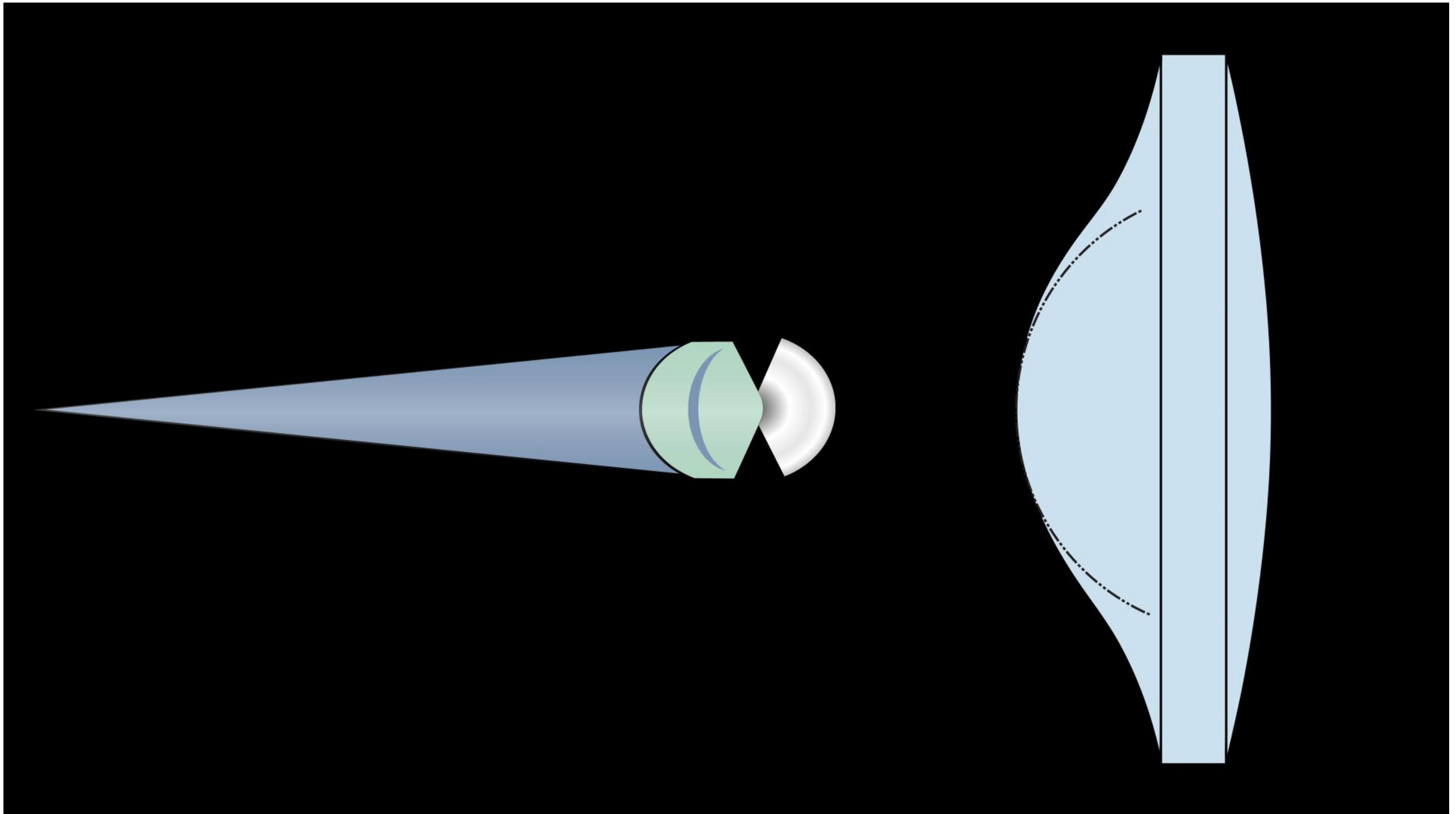
Non-Contact
4 KHz data acquisition
Normal to surface measurement
Nanometer level sensitivity

Three Core Technologies

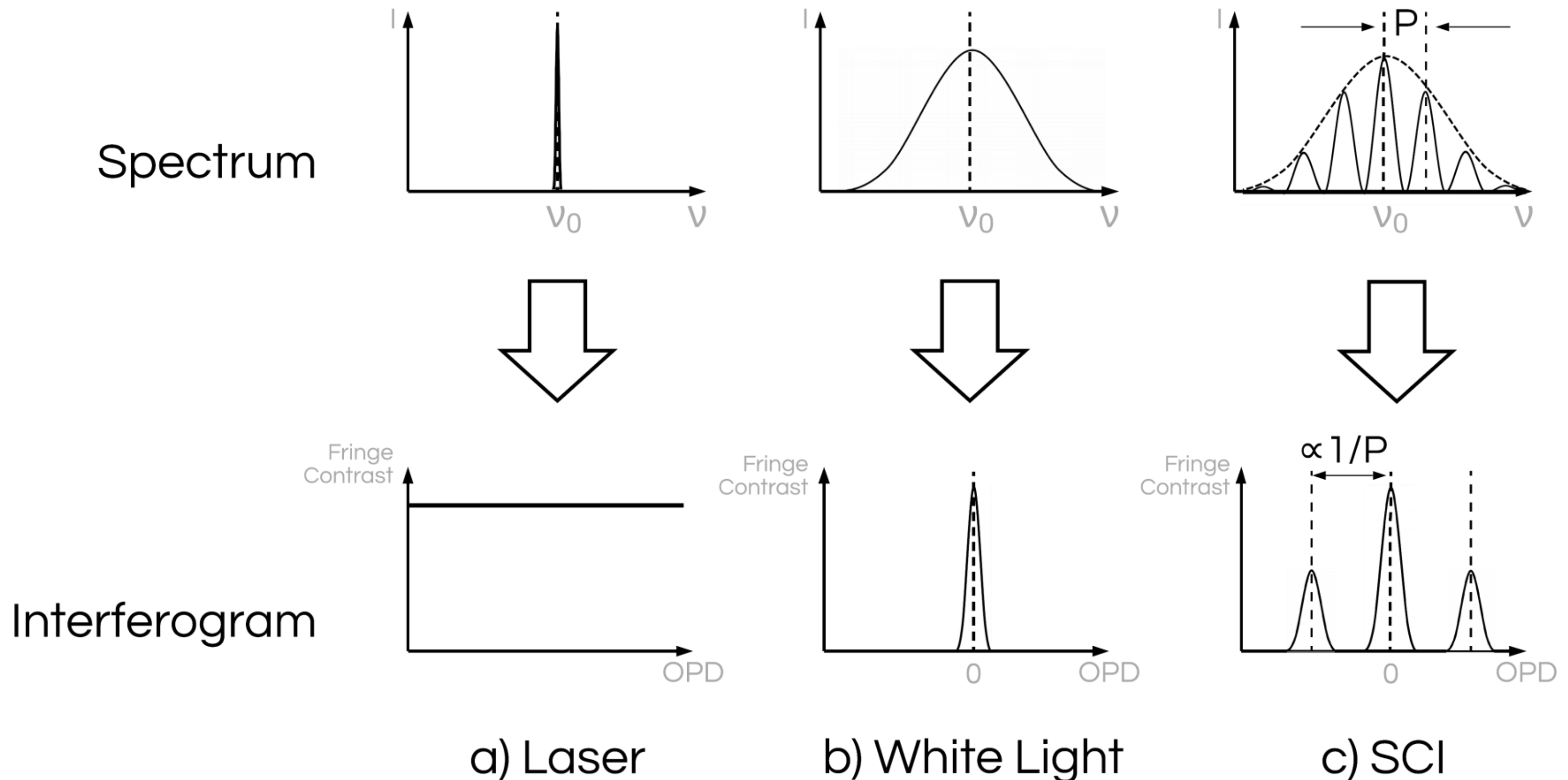
- Spectrally Controlled Interferometry (SCI)[1]
- Divergent Spherical Wavefront Fizeau with localized interference[1]
- Signal Detection/Analysis

[1] US & International Patents and Patents Pending

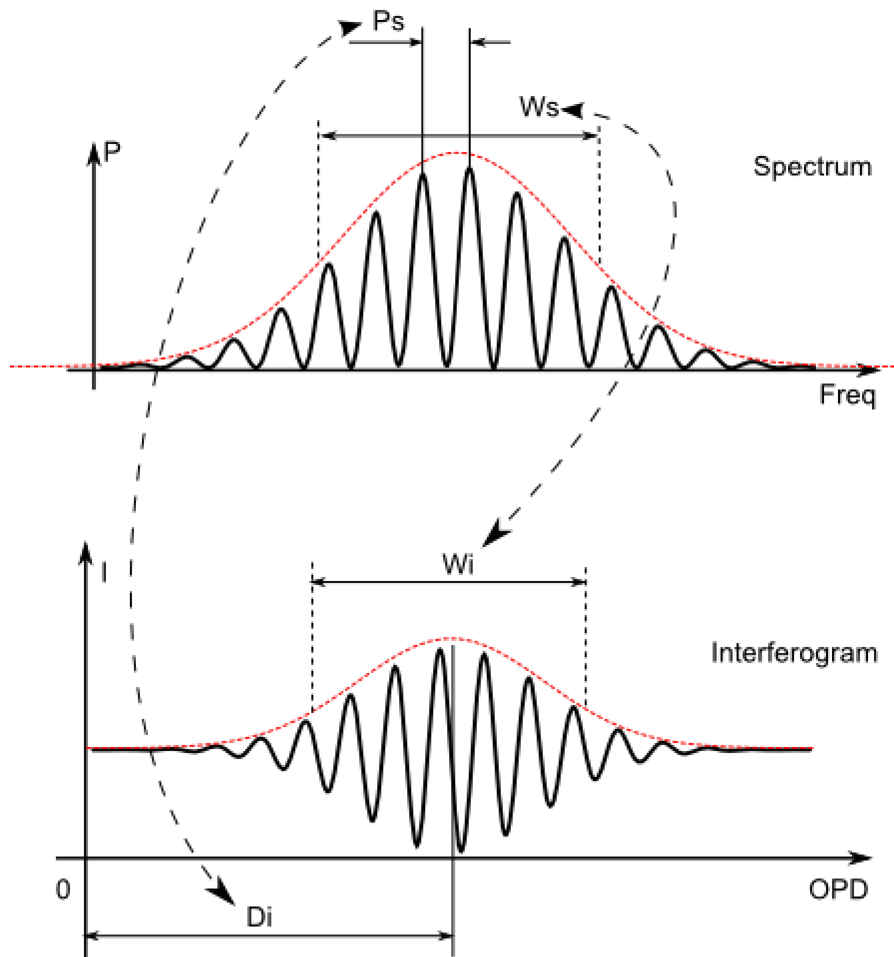
The V-Probe



Source Spectrum Drives Interference Fringe Formation



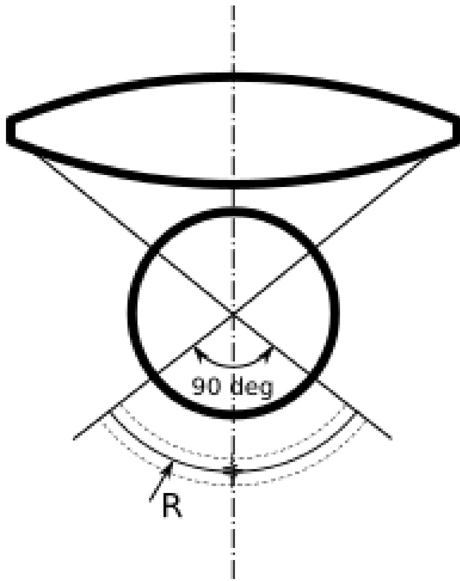
Three SCI Control Parameters



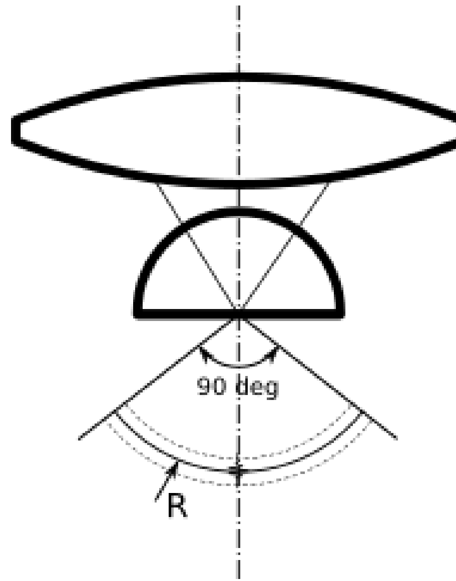
- $W_s \propto 1/W_i$
- $P_s \propto 1/D_i$
- $\phi_s = \phi_i$

KEY POINT: Fixing the source period (P_s) under abroad band source (W_i) creates a fixed narrow region of interference in front of a simple Fizeau interferometer

Spherical Diverging SCI Fizeau

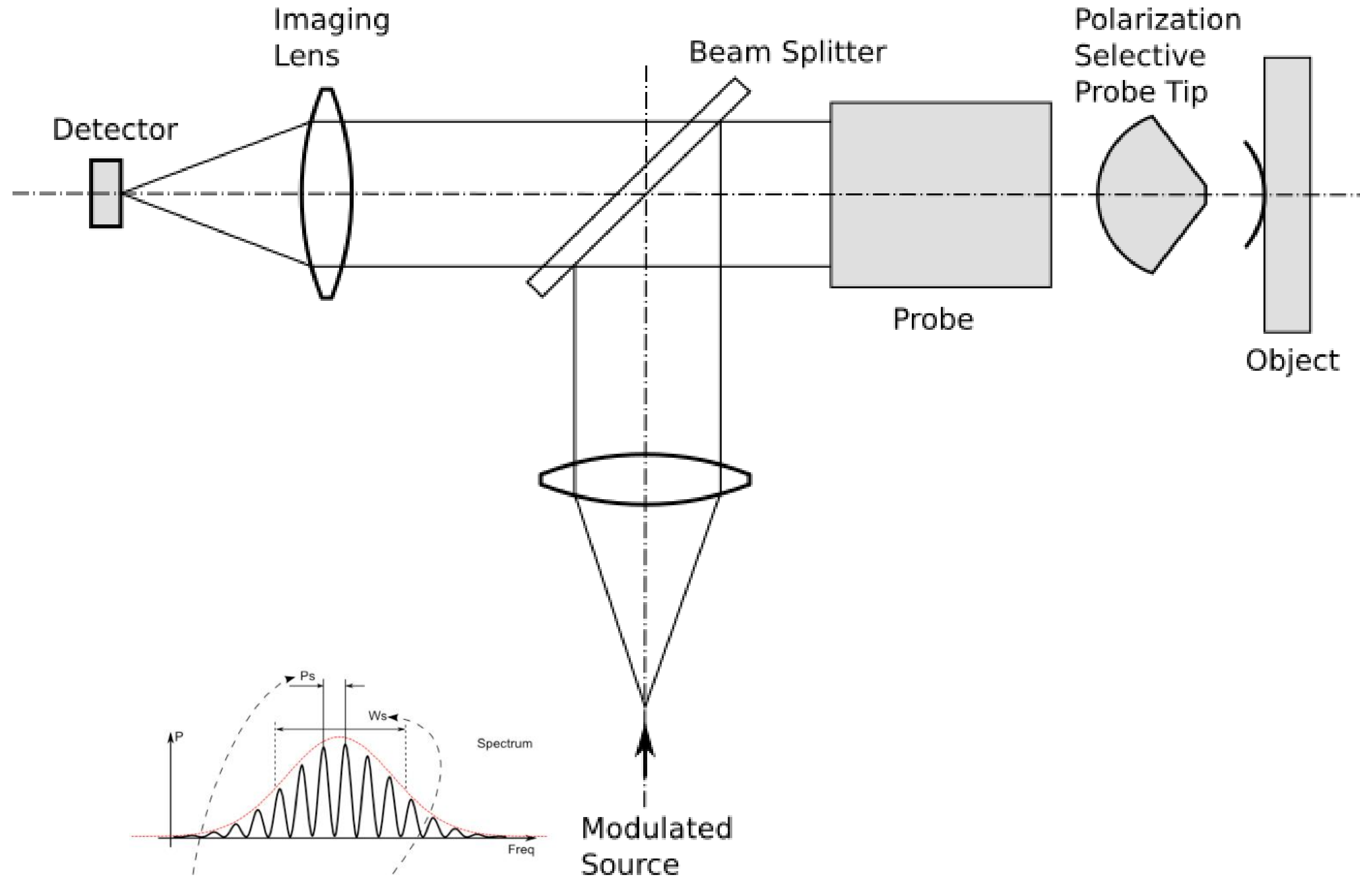


Fizeau Reference:
Ball Lens Surface

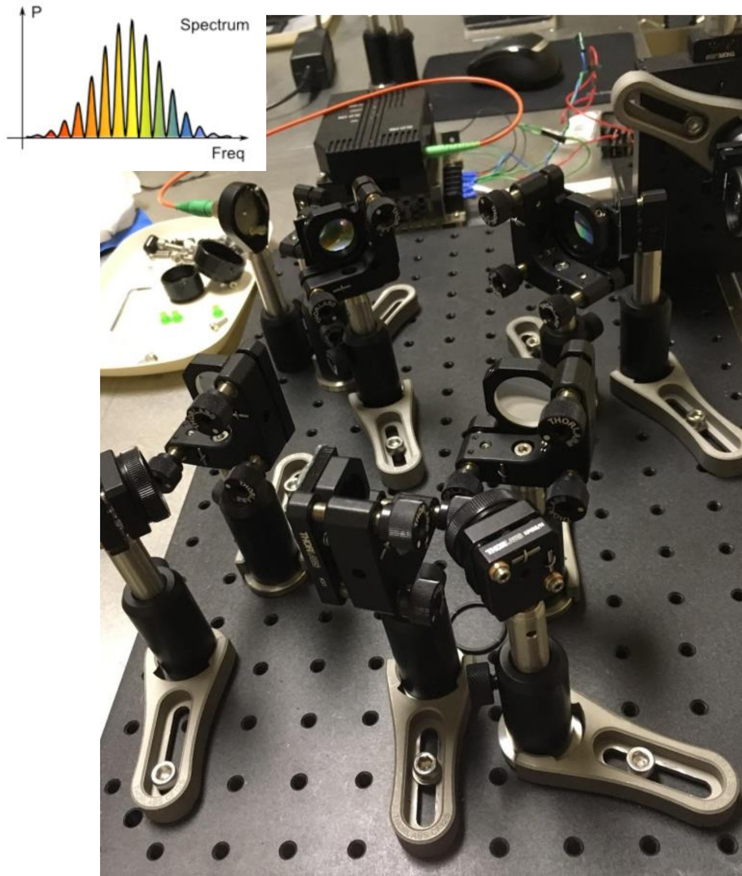


Fizeau Reference:
Diffraction Limited Point

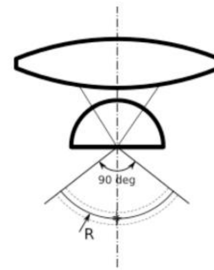
Probe Schematic: Fizeau Interferometer

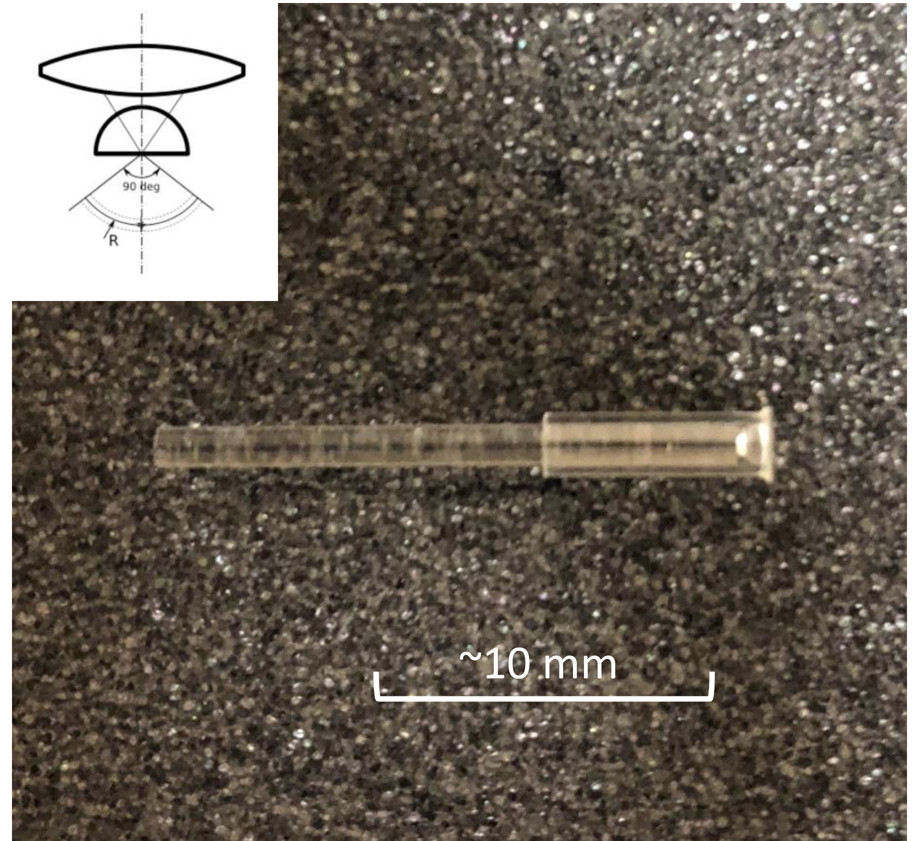


Project Status: November 2018 (90% through Phase II)



Breadboard SCI Source

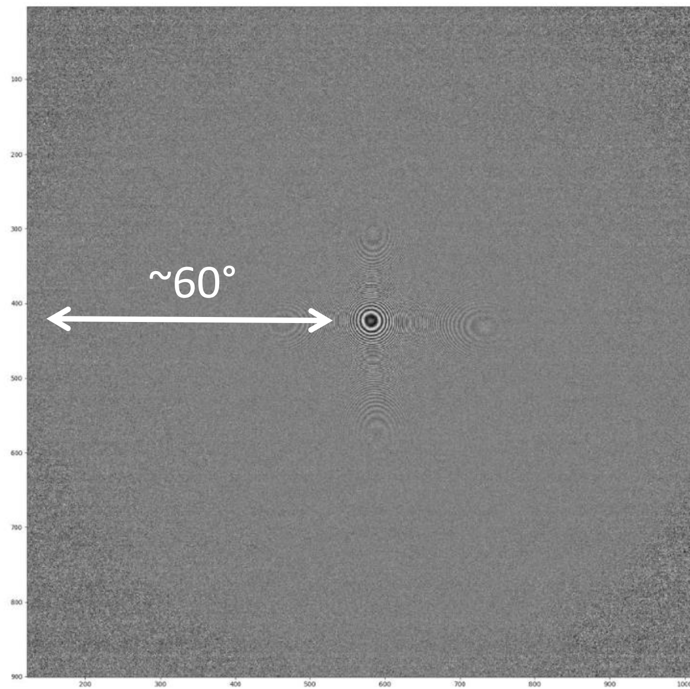




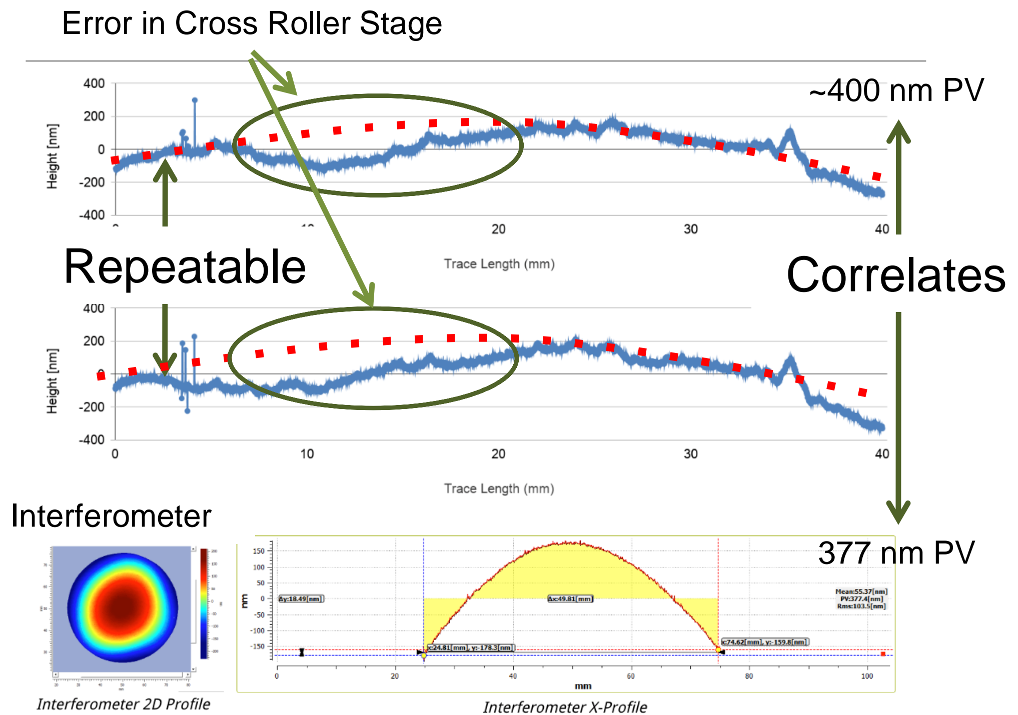
Alpha Interferometer Probe Tip

Probe: Repeatable and Correlates to Interferometer

Probe Detecting
Flat Surface



Measured Flat Surface 1D Profile
Compares with Interferometer
(Tilt/Power Removed)



Interferometer 2D Profile

Interferometer X-Profile

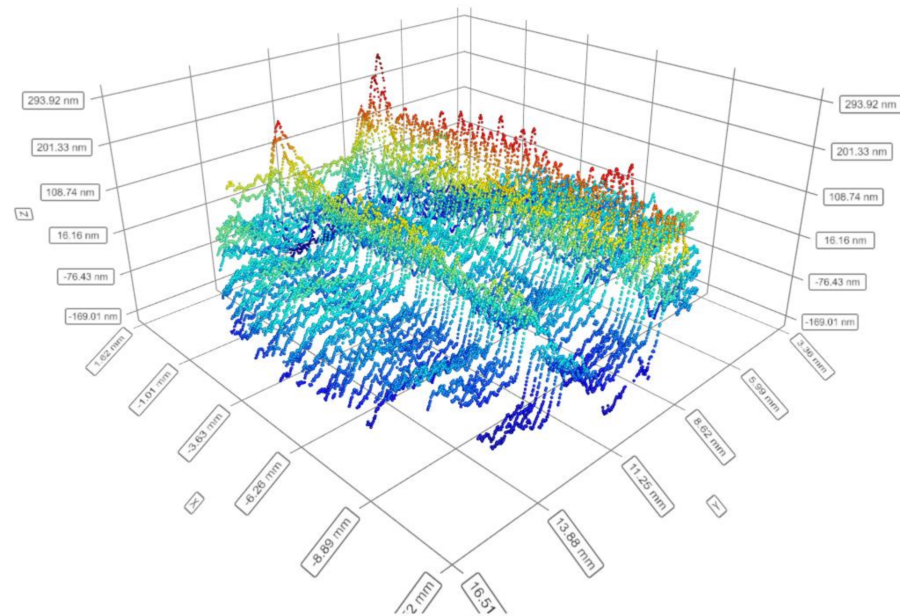
400 Hz Data Rate Possible with Present Detectors

Programming a 2D surface scan now

Next Steps: NASA SBIR

- Construct & measure with α-Probe

Low accuracy XYZ Metrology Frame



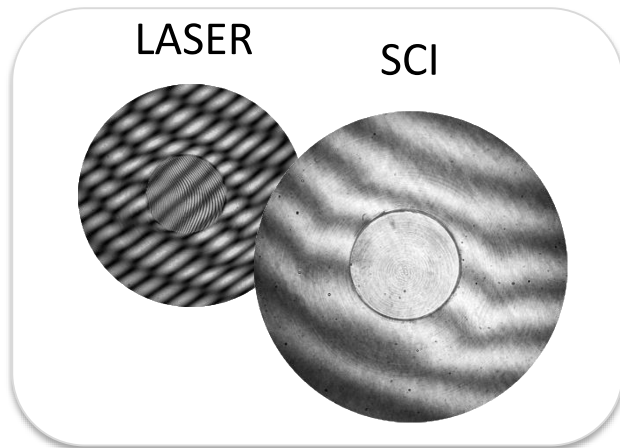
2D Profile Probe Data

Commercial Impact

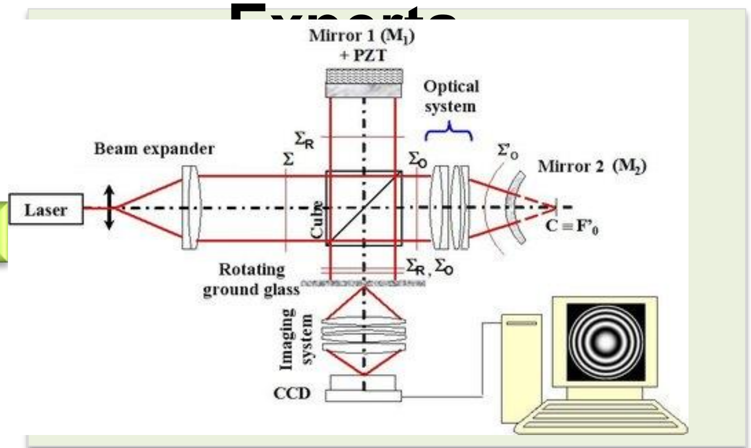
- Standard Fizeau interferometers + SCI
  - 500 mm Range
  - Eliminates back surface reflections
  - Isolates surfaces 50 um
  - Electronically controlled
    - Position
    - Coherence
    - Phase
  - Applications:
    - Etalons, Windows, Prisms down to50 μm thin
- Interest in the Probe system is growing

Interferometers to Advance Your Optical Manufacturing

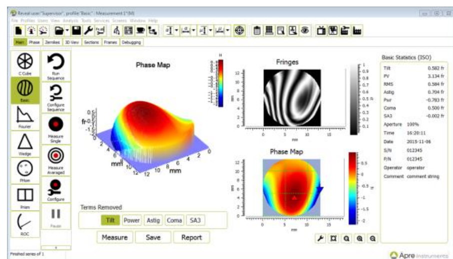
Technology Creation

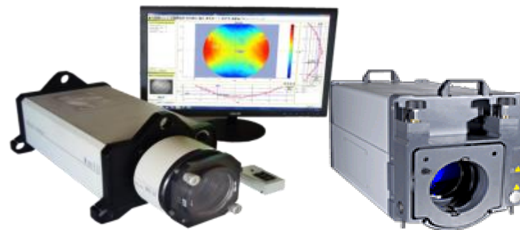


Interferometry Experts



Software **Upgrade/Restore** **Performance** **Custom**





Thank you

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