Synthetic Aperture Interferometry: An Alternative Approach to In-Process Measurement of Polished Aspherics
The optical problem
Commercial solutions
Synthetic Aperture Interferometry (SAI)
  The concept
  Anamorphic probe design
  Scanning strategy
  Signal processing
  Some subtleties
  Results
Discussion
<table>
<thead>
<tr>
<th><strong>Stylus</strong></th>
<th><strong>Optical</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Contacting</td>
<td>• Non-contacting</td>
</tr>
<tr>
<td>• May damage</td>
<td>• The accepted method for</td>
</tr>
<tr>
<td>• Surface form</td>
<td>spherical optics</td>
</tr>
<tr>
<td>• Surface finish</td>
<td>• Modifications required for</td>
</tr>
<tr>
<td>• Proven</td>
<td>steep aspherics</td>
</tr>
<tr>
<td>• Slow</td>
<td>• Potentially faster</td>
</tr>
<tr>
<td>• Expensive</td>
<td>• Potentially cheaper</td>
</tr>
</tbody>
</table>
The Optical Problem:

... Too many fringes
Sub-Nyquist Sampling

*Intellium™ Asphere*

Fizeau Interferometer
Zygo Verifire Axial Scanning Fizeau Interferometer
Synthetic Aperture Interferometry (SAI)

Test Lens

Probe
SAI: A Straightforward Concept

- A common path design
- Inexpensive
- Easy to use
Some Early Interferograms

A Note on NA
Anamorphic Probe

Receive Fiber

Source Fiber

Cylindrical Lens (Anamorphic Lens)

Achromatic Doublet

Fold Mirror

Beam Splitter

Test Optic

Aspheric Lens

(a)

(b)
Anamorphic Probe

- Fibre Holder
- Collimating Lens
- Cylindrical Lens
- Pellicle Beam Splitter
- Tubes
- Fold Mirror
- Aspheric Lens
Sampling Strategy

1600 samples @ 16 samples per revolution

1600 samples @ 160 samples per revolution
Two methods were used to calculate phase:

- **Method 1.**
  - Phase Locked Loop (PLL)
  - 1D phase unwrapping

- **Method 2.**
  - Demodulation to an intermediate frequency using knowledge of the ideal form
  - 1D phase unwrapping

Typical raw data; a scan (less than 0.1mm) through the centre of a lens
Some Subtleties

Backward Configuration
- Only rear return depends on test surface
- More accurate

Forward Configuration
- Both returns depend on test surface
- More useful on machine
- “Blind” to certain form error
The “Blind Vector”

Reference surface

Test surface

Probe

y

x

y

x

Reference surface

Test surface

Probe

d

x_1

x_2

S_1, S_3

S_{m-1}

S_{m+1}

O_{m-1}

O_{m+1}

O_{m-1}

O_{m+1}

S_{m-3}

S_{m+3}

S_m
Results: $\phi=40\text{mm}$, $F=125\text{mm}$, Plano-convex Test Lens

Future plans

- External “reference cap”
  - “Backward configuration from the front”
  - Closer to a common path
  - A spherical surface will do
  - Requires a way to identify returns from other surfaces

- Wavelength scanning
  - Possible to identify returns from each surface
  - Remove directional ambiguity (increase/decrease in path length)
  - Like OCT
  - Use VCSEL?
Conclusions

- Synthetic Aperture Interferometry (SAI) can be used for on-machine testing

Practicality:
- A small source/receive fibre probe is necessary
- An anamorphic design is best for nominally symmetric optics
- The technique is common path and tolerant to vibration

Analysis:
- Signal analysis requires care
- A-priori knowledge of surface form helps

To do:
- Implement wavelength scanning/”reference cap” method