Combining SSI & MRF to Reach λ/75 PV on a Plano

Presented By:
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Introduction

High precision optical flat surfaces are used in a number of applications, including reference surfaces, stage mirrors, and laser cavities. Manufacturing a plano surface to λ/75 peak-to-valley (PV) can be challenging for many reasons.

- Conventional polishing methods usually are not deterministic enough to reach this level of precision for various part sizes and aperture shapes with predictable throughput.
- Magnetorheological Finishing (MRF™) is a computer-controlled subaperture polishing process, that is deterministic. However, computer controlled processes like MRF need sufficiently-accurate, full-aperture metrology to "drive" the process, i.e. to tell the software where the highs & lows of the surface error are.
- Metrology needs to be accurate enough in two (2) key quality areas:
  - **Vertical resolution/accuracy** – the ability for the instrument to resolve and accurately quantify the amplitude of the highs & lows of the surface error
  - **Lateral resolution/accuracy** – the ability of the instrument to accurately represent the position of the highs & lows of the surface error

Demonstration Objectives

In this case study, we present a method for manufacturing optical flats to λ/75 PV by combining the power of Subaperture Stitching Interferometry (SSI™) and MRF technologies. The SSI data provides the high resolution and high accuracy necessary to drive the MRF polishing process to these high levels of precision.

- Part prescription
  - Full Aperture: 108mm
  - Clear Aperture: 107mm
  - Surface Shape: Plano
  - Material: Fused Silica
- Machines/Process Used
  - ASI(Q), utilizing QED's QIS interferometer
    - 6" transmission flat (TF)
  - Horizontal QIS
    - 6" transmission flat leveraging three-flat test
  - Q-flex™ 300 platform
    - 20 mm polishing wheel – for highest resolution
    - D11 MR Fluid – for fastest cycle times

Q-flex 300

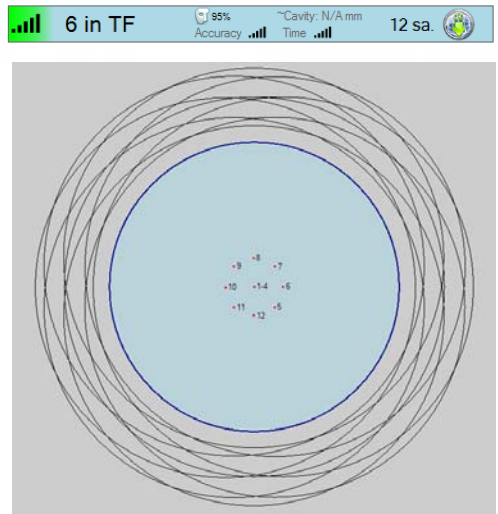
ASI(Q)

You Can't Make What You Can't Measure

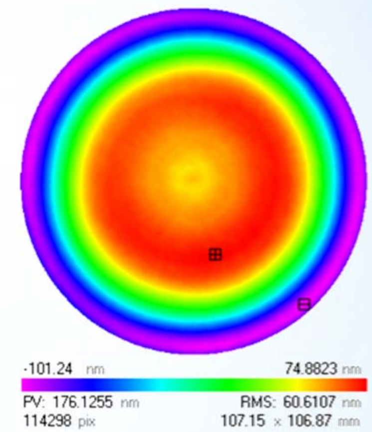
Reference wave calibration enables fabrication of an optic with higher precision than the reference surface used to measure it!

ASI(Q)

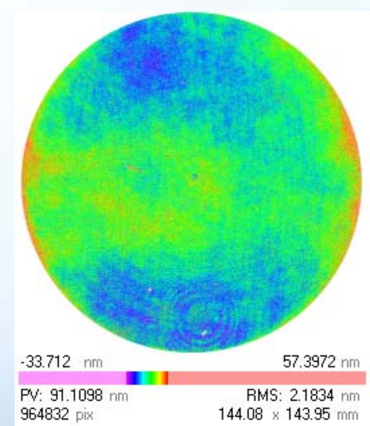
Stitched Lattice Design



Surface Measurement



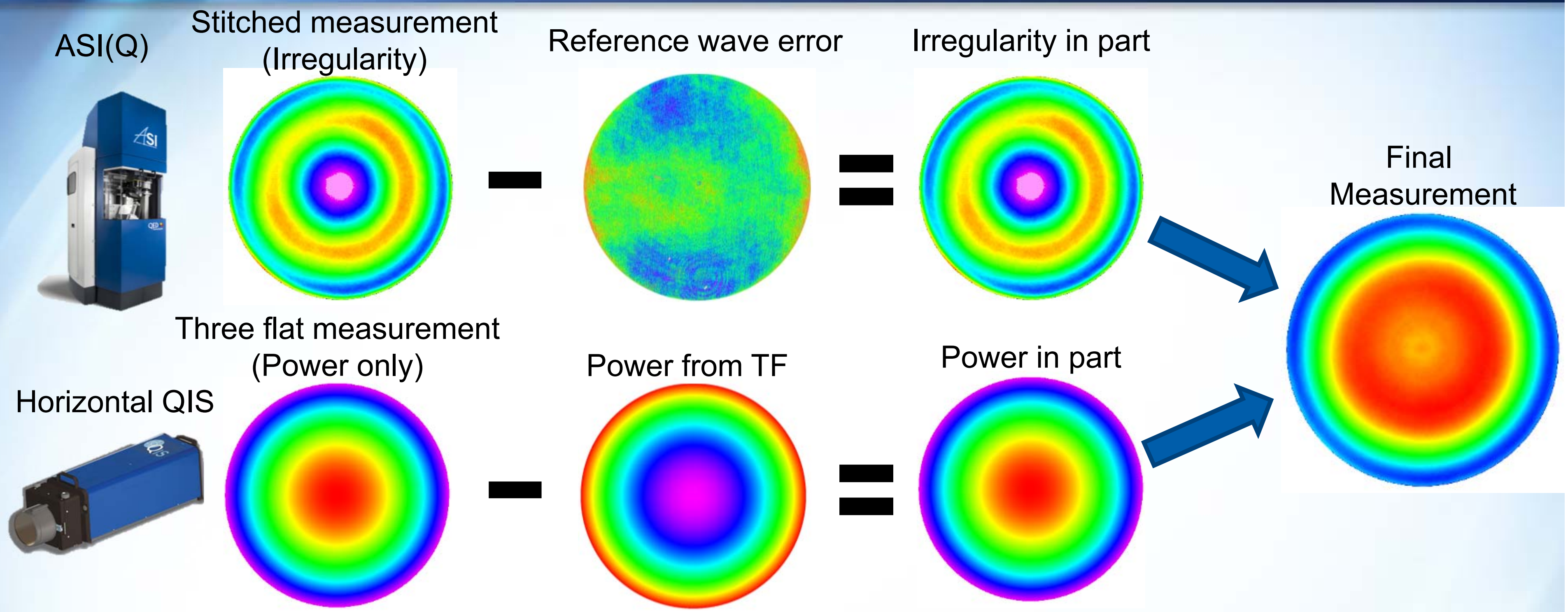
Reference Wave Error
(Includes TF and interferometer errors)



- ASI(Q) is used to make a stitched measurement of the flats
- 12 measurements are made and are stitched together
- Through stitching we are able to calculate and remove reference wave error from the TF and interferometer
  - In this case an additional random average calibration was made to remove high frequency errors
  - This method provides an accurate measurement of irregularity

Technologies™

Measurement Process



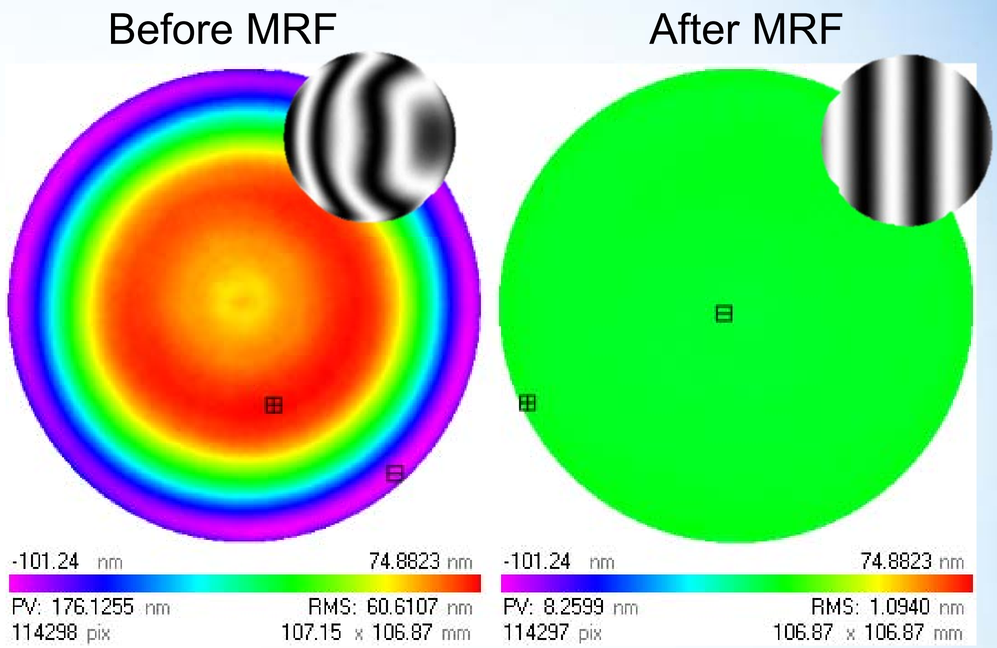
- Plano is measured on ASI(Q) using subaperture stitching to get high resolution ***irregularity measurement***
  - This method provides an accurate measurement of irregularity with very high lateral resolution
  - Reference wave error is calculated and subtracted from stitching process
- Plano is measured on horizontal interferometer to get most accurate measurement of ***power***
  - Three flat test is a known method for acquiring an absolute measurement of power
  - Known power from TF is subtracted
- Power and irregularity measurements are combined using QED.NET analysis tools to provide ideal hitmap for MRF

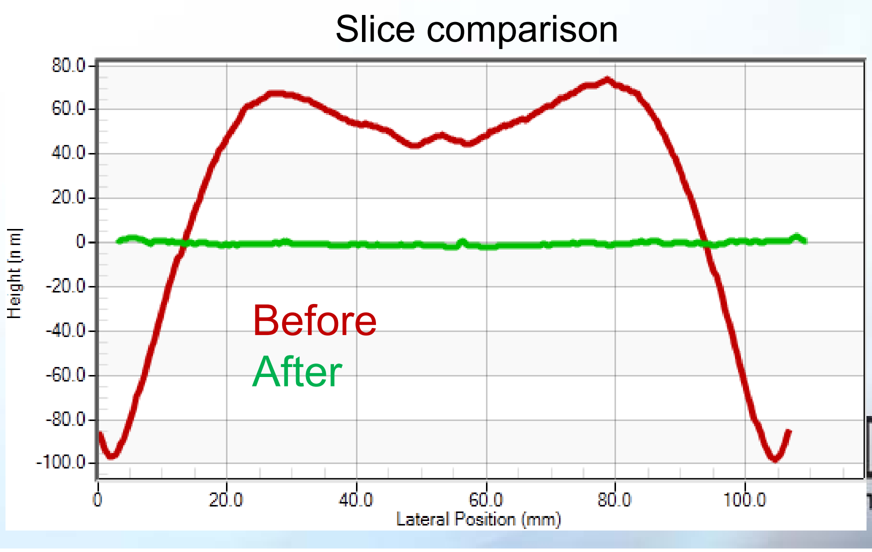
MRF Figure Correction Results

- PV improved from λ/4 to λ/75!
- 100x RMS improvement!
  - Final RMS of 1.1nm was achieved
  - Rotational polishing was chosen to efficiently correct mostly rotationally symmetric errors
  - All corrections were made with QED's smallest (20mm) polishing wheel to achieve the best performance near the edge of the part and for correcting MSF errors
  - D11 fluid, our highest removal rate fluid, minimizes run time

Plano part has a PV of λ/75 after 2 runs and only 3 hours of polishing

Notes:
- Piston and tilt removed
- 3x3 median filter applied
- Plots on same scale



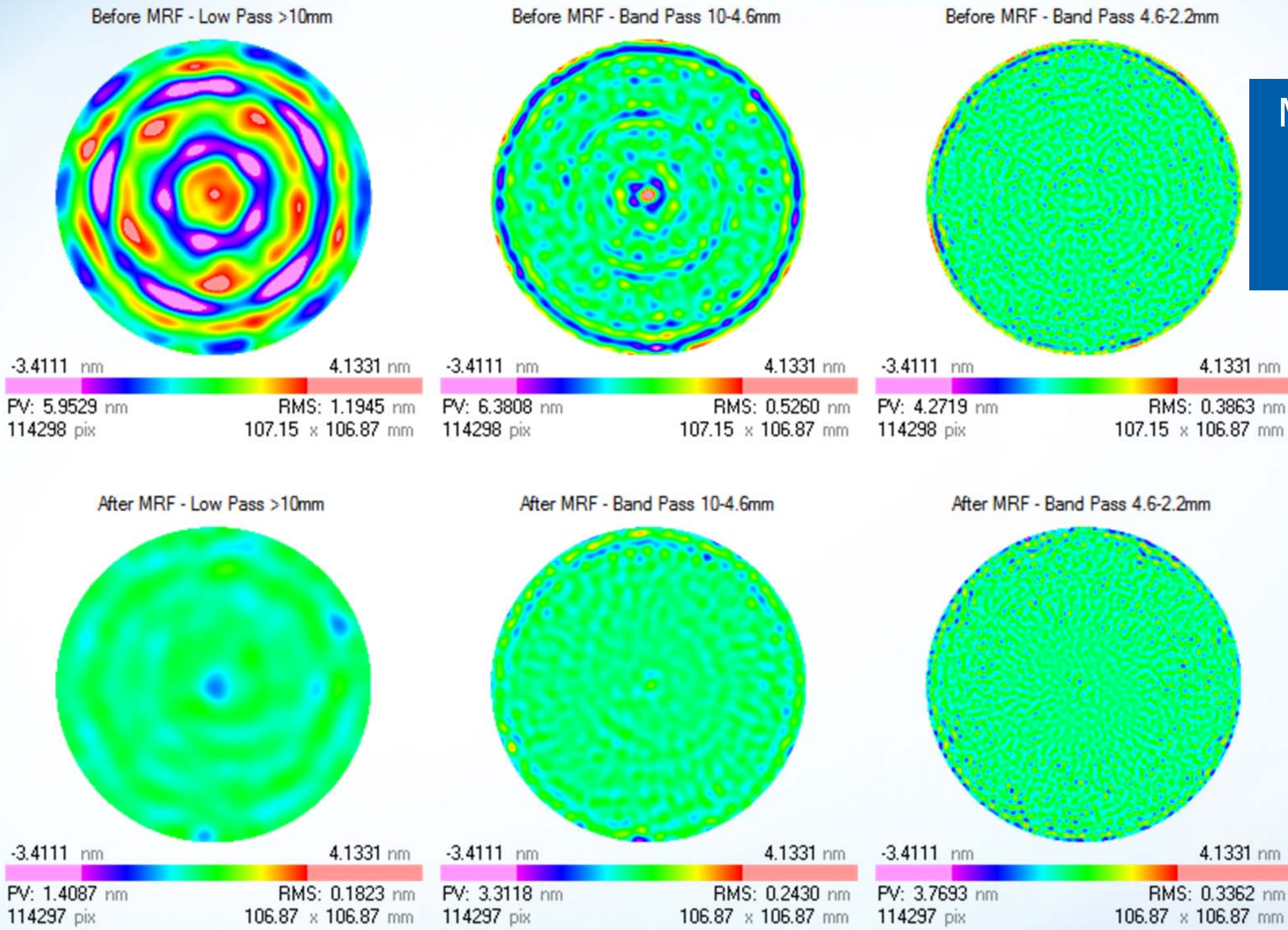


Mid-Spatial Frequency Correction

36 Zernikes Removed	Low Pass Filter >10mm	Band Pass Filter 10-4.6mm	Band Pass Filter 4.6-2.2mm

Before MRF

After MRF



MRF provides efficient correction of MSF errors

6.6x RMS Improvement | **2.2x RMS Improvement** | **Slight Improvement**

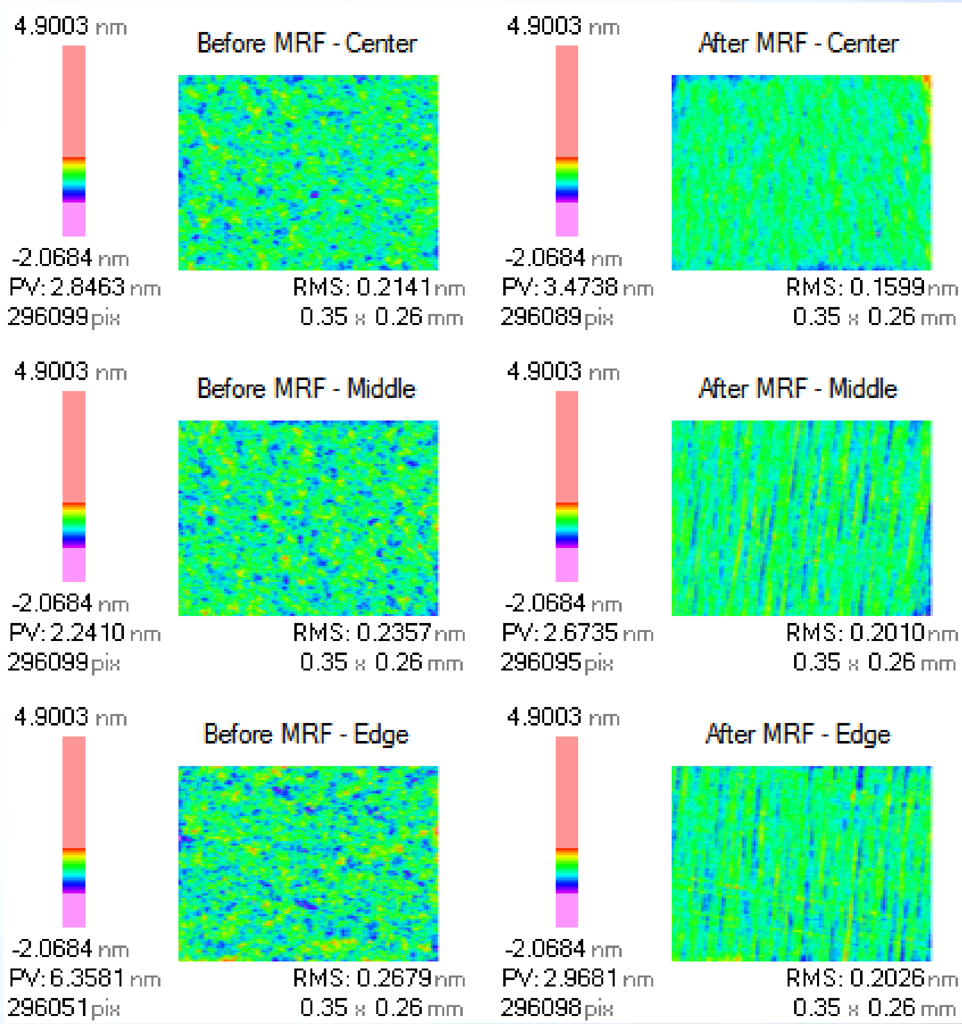
QED Technologies™

Surface Roughness Improvement

X Edge
X Middle
X Center

Average RMS of three measurements improved from 2.4Å to 1.9Å after MRF with D11

Before MRF | After MRF



Notes:
- Zygo NewView WLI used to measure roughness
- 20x Magnification
- Plane aberrations removed
- 80µm – 2.5µm Band pass filter applied as per ISO10110-8 roughness spec
- Spikes removed

Conclusions

- λ/75 PV was reached after just 2 runs and 3 hours of polishing!
- D11 fluid improved the surface roughness to 1.9Å RMS
- Using only D11 fluid provided a fast cycle time
  - Only 3 hours of polishing needed
- Careful metrology is required to reach a target of λ/75 PV
  - Stitching with ASI(Q) removes reference wave error and provides the most accurate measurement of irregularity
  - Three flat test on horizontal interferometer provides an absolute measurement of power
  - QED.NET analysis tools can be used to merge data quickly and easily. *(For more information about QED.NET analysis tools visit https://qedmrf.com/en/mrfpolishing/mrf-applications/using-qed-analysis-notebooks)*

