

Extending magnetorheological finishing to address short radius concave surfaces and mid-spatial frequency errors

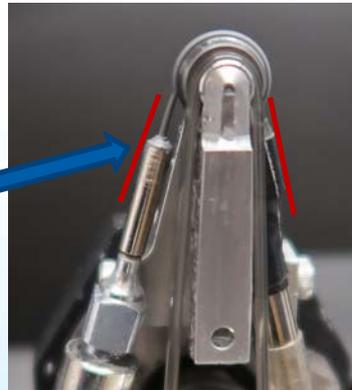
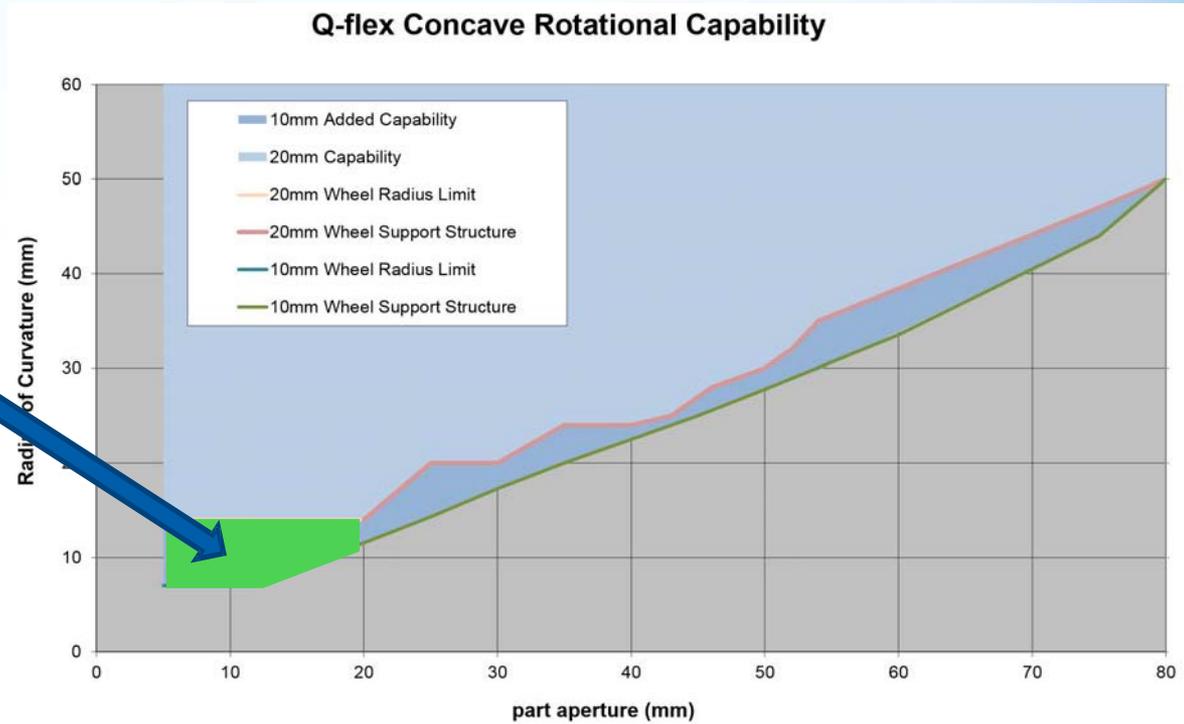
Presented By:

Chris Maloney, William Messner

QED Technologies, Inc., 1040 University Avenue,
Rochester, NY, USA 14607

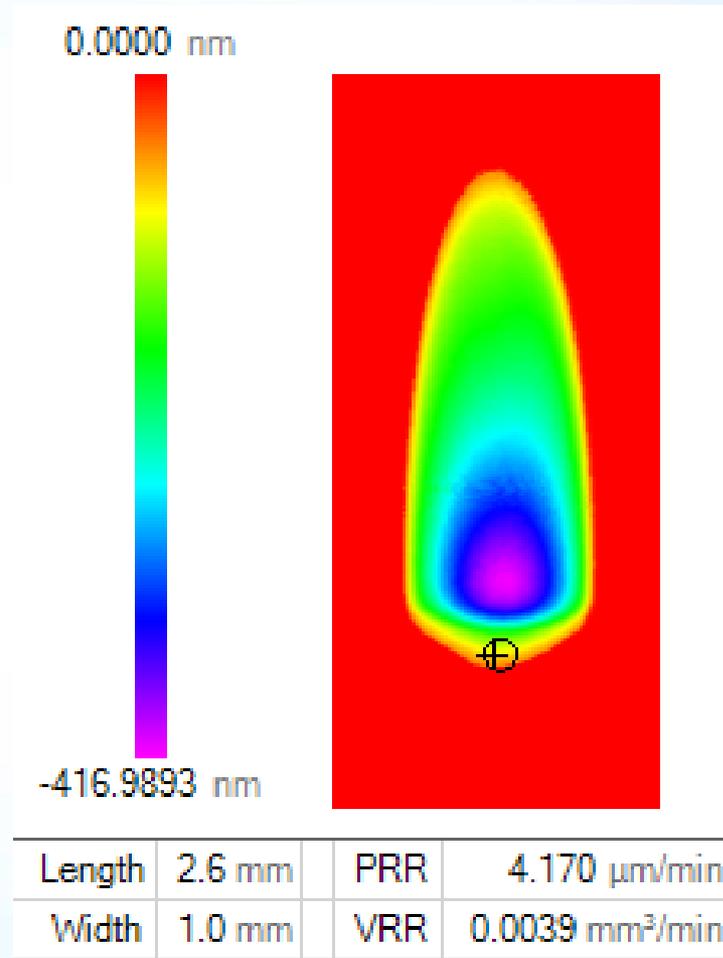
Polishing short radius concaves

- ❖ 10 mm MRF wheel capability as compared to the 20 mm MRF wheel capability
- ❖ Has a more usable range for small, high NA workpieces
- ❖ **The 10 mm MRF wheel is capable of polishing a 7 mm radius**
- ❖ The 20 mm wheel is only capable of polishing down to a 14 mm radius
- ❖ Geometrically designed for optic clearance



Polishing short radius concaves - spot

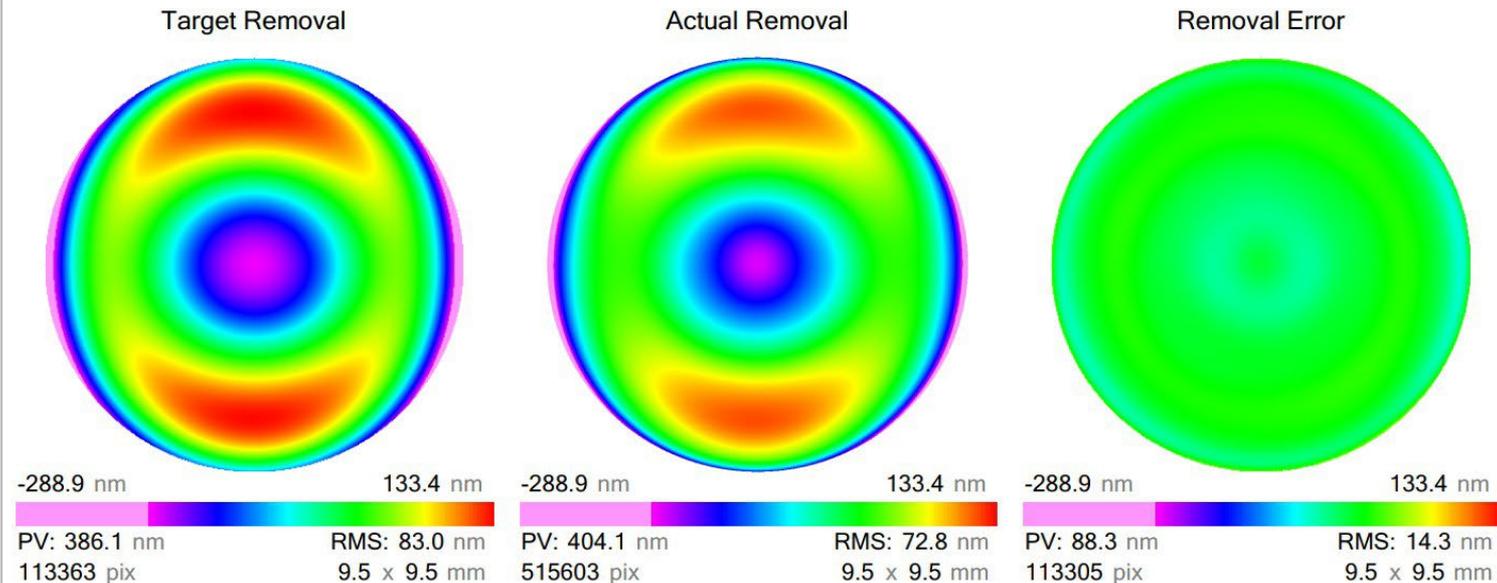
- ❖ Figure test was conducted on a 10mm diameter 7.8 mm radius of curvature concave optic.
- ❖ Equipment = 10 mm MRF wheel using C12 fluid on a Q-flex 100 platform
- ❖ Example spot from 7.8 mm ROC concave



Polishing short radius concaves (cont.)

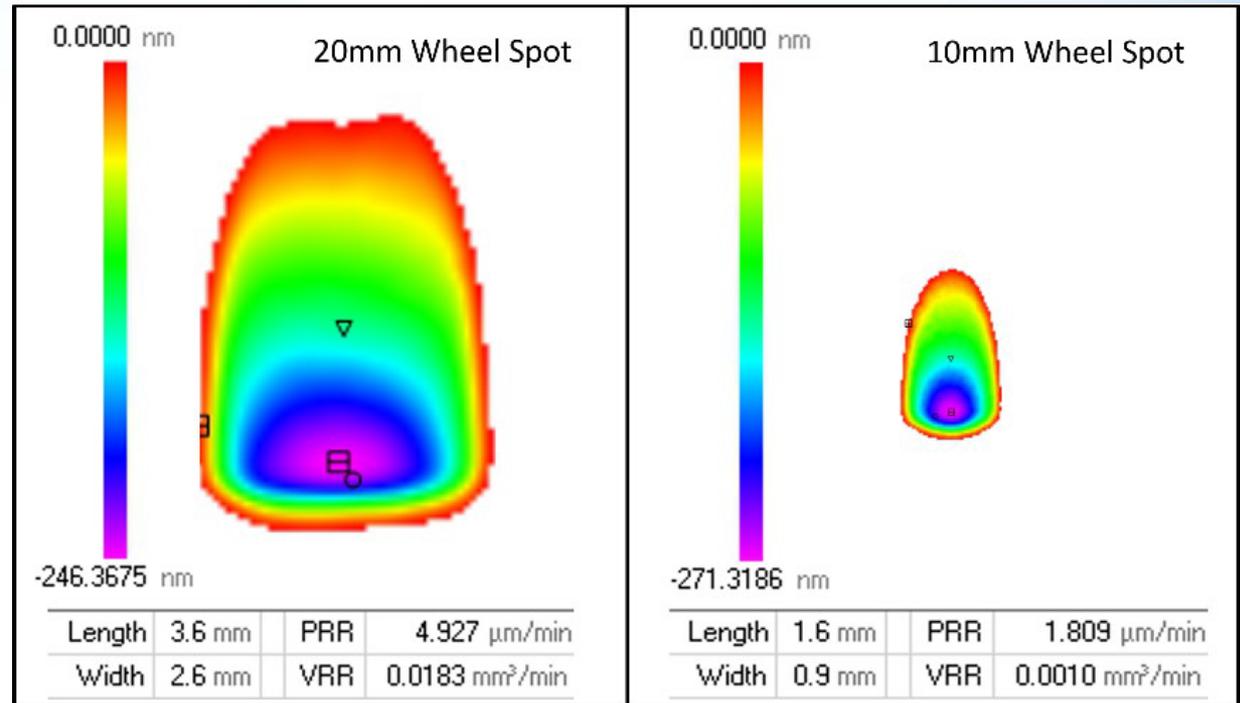
- ◆ Results show an introduction of 73 nm RMS of irregularity of the 83 nm RMS of irregularity target
- ◆ Subtracting our actual removal from the target removal we show an RMS of 14.5 nm of removal error
- ◆ **Achieved 83% convergence**

Figure Introduction Results



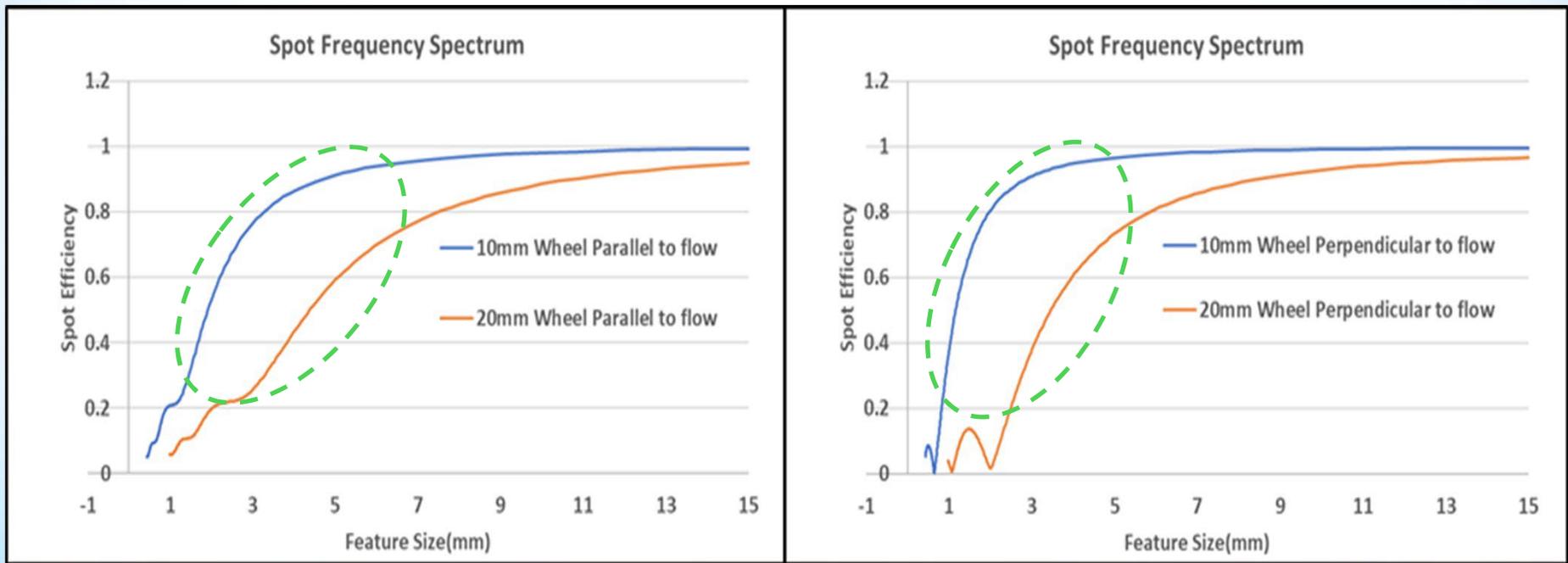
Correction of mid-spatial frequency errors

- ◆ A comparison between the 20 mm wheel spot and the 10 mm wheel spot is shown
- ◆ **Smaller wheel – smaller spots – smaller feature correction**
- ◆ Remember we are trading off cycle time for spot fidelity. Care must be taken to use the tool wisely



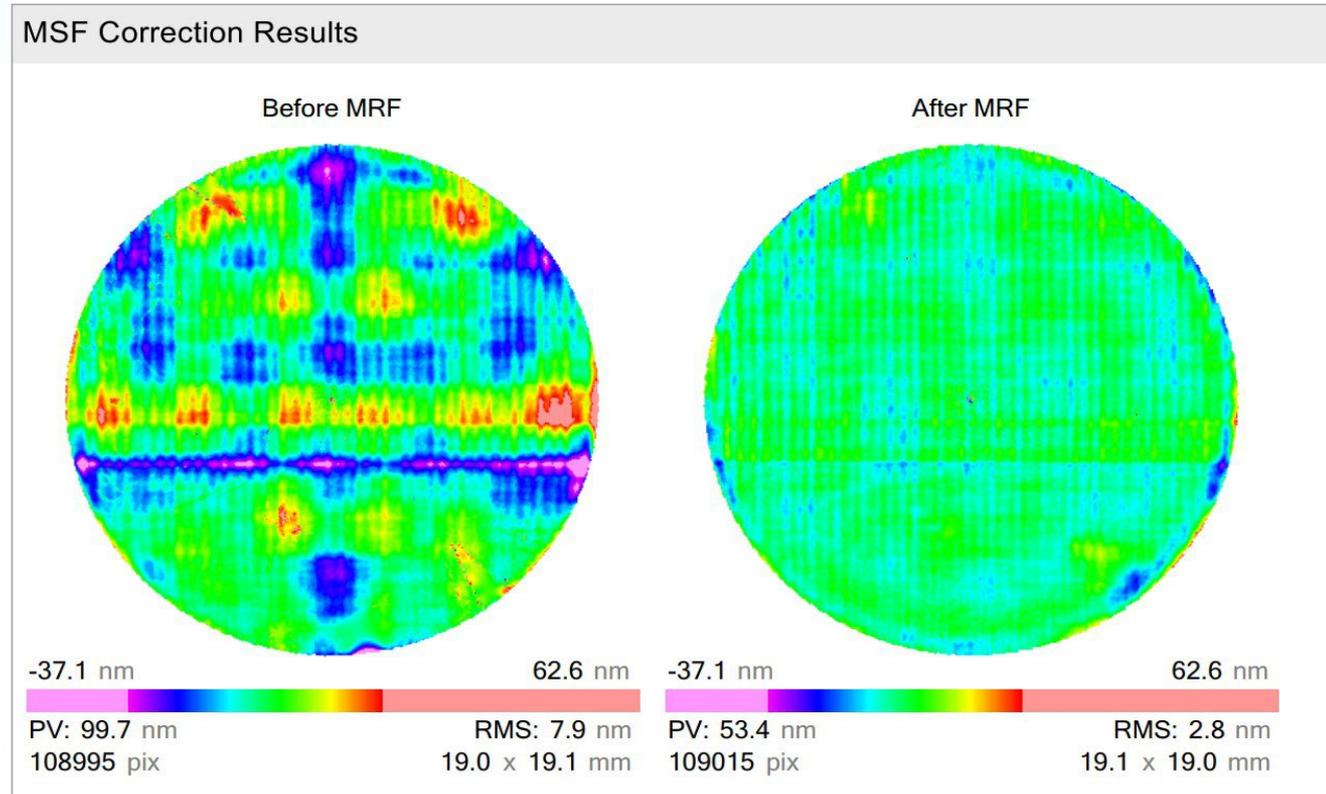
Spot Spatial Frequency

- ◆ It has been previously reported that MRF can correct features as small as ~2 mm
- ◆ The 10 mm wheel has a higher efficiency for correcting smaller feature sizes



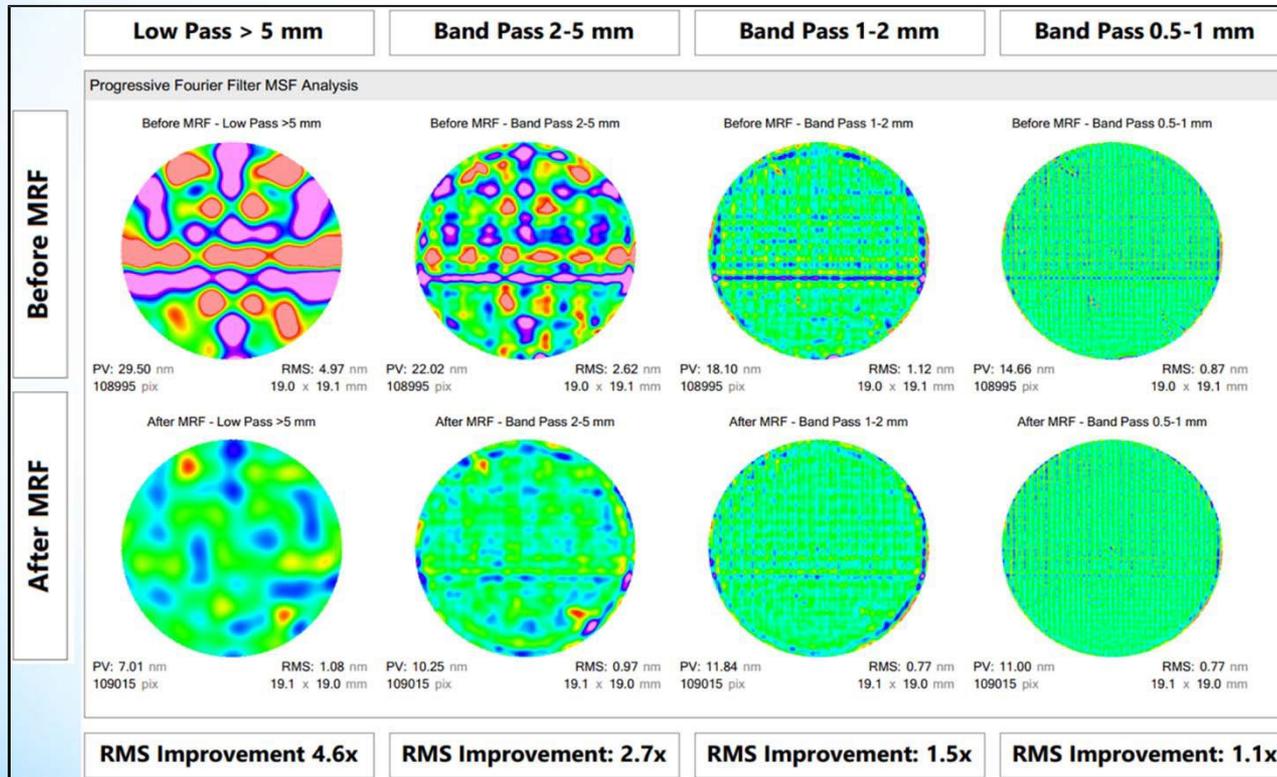
Correction of mid-spatial frequency errors (cont.)

- ◆ Scope - to target and correct real errors on an optical surface demonstrating extended correction efficiency for MSF errors
- ◆ We used the 10 mm wheel with a cerium-based fluid
- ◆ Improved the incoming RMS from 7.9 nm to 2.8 nm after a single MRF iteration



Correction of mid-spatial frequency errors (cont.)

- ◆ Analyzed the metrology using progressively smaller low-pass Fourier filters
- ◆ Data broken into 4 bands after removing 36 Zernike terms
 - used a combination of Fourier filters to look at features >5 mm, 2-5 mm, 1-2 mm and <1 mm



- ◆ Demonstrated that the 10 mm wheel can make improvements to features smaller than 1 mm
- ◆ The trend indicated in the efficiency plot generally agrees with the improvement of each band.

Advantages of small MRF tooling (wheels)

- ◆ Ability to correct small concave high NA parts
 - **Demonstrated low-order convergence >80%**
- ◆ The range of laterally spaced features that are correctable using MRF has been extended
 - **Demonstrated that the 10 mm wheel can make improvements to features smaller than 1 mm**
- ◆ This solution will enable production of high precision reference surfaces, molds and a variety of unique applications