Vibe: A New Process For High Speed Polishing Of Optical Elements

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Abstract: The concept for polishing optical elements with a process called **VIBE** is presented. Application to non uniformly sloped optics such as aspheric shapes is detailed. Initial results on spherical surfaces are presented. A few technical challenges to be overcome are outlined.

In the last 20 years the mantra of optics manufacturers has been BETTER, FASTER, CHEAPER. There have been a number of techniques that have been adopted in an effort to satisfy this. BETTER has lead to very effective, though not inexpensive, techniques such as ion milling, MRF, zonal polishing and other deterministic removal methods. These methods usually involve making a sample spot which is then accurately measured to determine the profile of material removal. The lens to be polished is also measured carefully. Using sophisticated software, the machine calculates how long the spot needs to be on every part of the lens to bring the lens surface into compliance. FASTER has been achieved with the development of high speed polishing polyurethane lap type systems. These systems polish the entire surface simultaneously and do so at a very rapid rate. Much to the chagrin of the US manufactures, CHEAPER has been usually achieved by moving off shore to areas where the cost of labor is much reduced. There is no class of machinery that does BETTER, FASTER, and CHEAPER simultaneously.

Mike Mandina, President of Optimax, has often mused at ways to satisfy all three simultaneously. He is always on the lookout for ways to utilize or adapt techniques developed in other industries to optics fabrication. For years he wondered why modifications of techniques used to prepare and polish hardwood floors or blend and polish automotive finishes couldn't be leveraged into the optical industry. He was always impressed by the speed at which these processes happen as compared with the slow speed of polishing optics. Over time and numerous experiments he has now brought to use a process that in fact incorporates multiple techniques developed outside of the optical shop. (United States Patent 6,942,554 B1).

Conventional polishing of optical elements involves moving a polishing lap over the entire surface to be polished in such a manor that eventually almost every portion of the polisher will rub across almost every portion of the part. It is most easily visualized if we look at a simplified motion pattern of planetary polishing. In this case, the part is allowed or forced to rotate as the lap slowly passes beneath the part. The locus of a point on the part is shown in Figure 1. As the part rotates it generates a spiral across a band of the lap. Fig 1A shows after approximately 5 revolutions. Fig 1B shows after significantly more revolutions. Fig1C shows that after a while that one spot on the lens will essentially sweep across the entire band of the polishing lap.

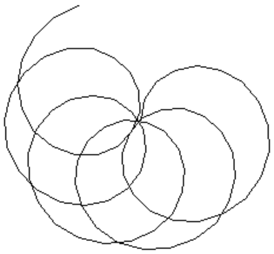


Fig 1A

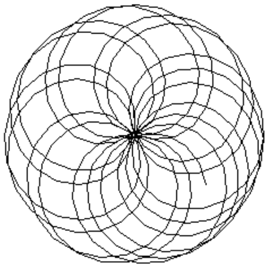


Fig 1 B

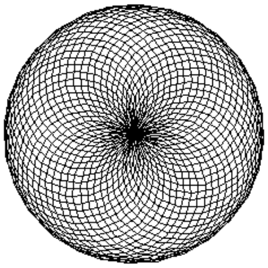


Fig 1C [i]

If the optic to be polished is an asphere and not a sphere, the slope will vary across the part. If the polishing lap were to move over the entire surface, as is the case for spherical polishing, the intentional aspherical shape would be eliminated. Mandina pursued a method that moves the polishing lap only short distances on the part. His reasoning was that abrupt slope changes in optical elements is unusual. If the polishing lap could move randomly but only a short absolute distance from a starting position, the local slope could be maintained, but the surfaced could be polished. To satisfy the FASTER and CHEAPER requirements, the entire surface would need to contacted by the lap simultaneously. Instead of the gentle oscillation of conventional polishing laps, the lap would move vigorously about its central position in a high speed vibration motion. Hence the name VIBE was given to the process.

Consider the shape of a radial symmetric optic that has both concave and convex curvatures. Schmidt correction plates are a common example of this type of surface.

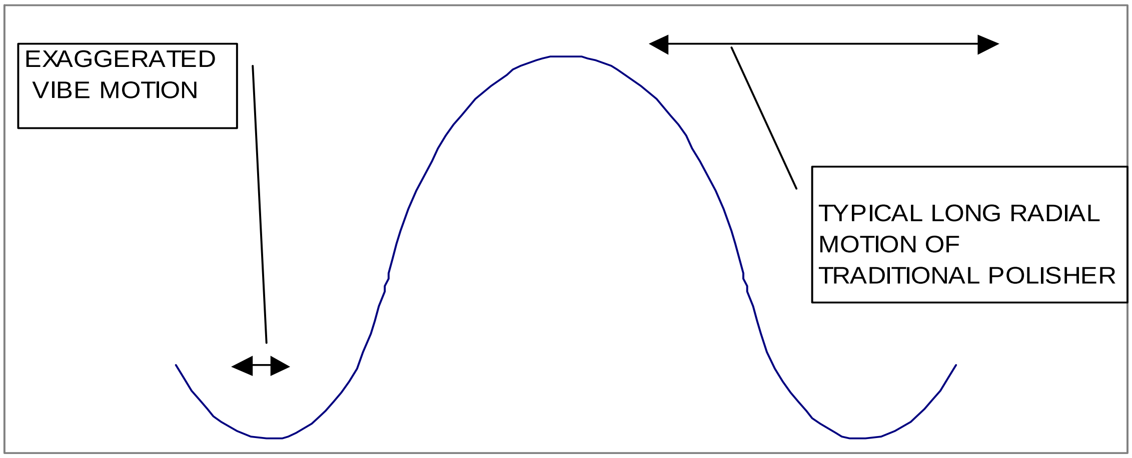


Figure 2. Surface that has both convex and concave curvatures.

As can be seen in the Figure 2 any long radial motion of the polishing lap would tend to flatten the crest relative to the valleys. If however, the motion of the polisher were limited to short lengths, then it may be possible to polish the entire surface. In essence the polisher VIBRATES about a position but the entire surface of the part is contacted simultaneously. Another way of thinking about the process is to visualize an array of independent spot polishers and then let the size of each polisher become small while simultaneously letting the number of polishers grow large. What is created is a full contact polisher with varying slope that match the varying slope of the asphere.

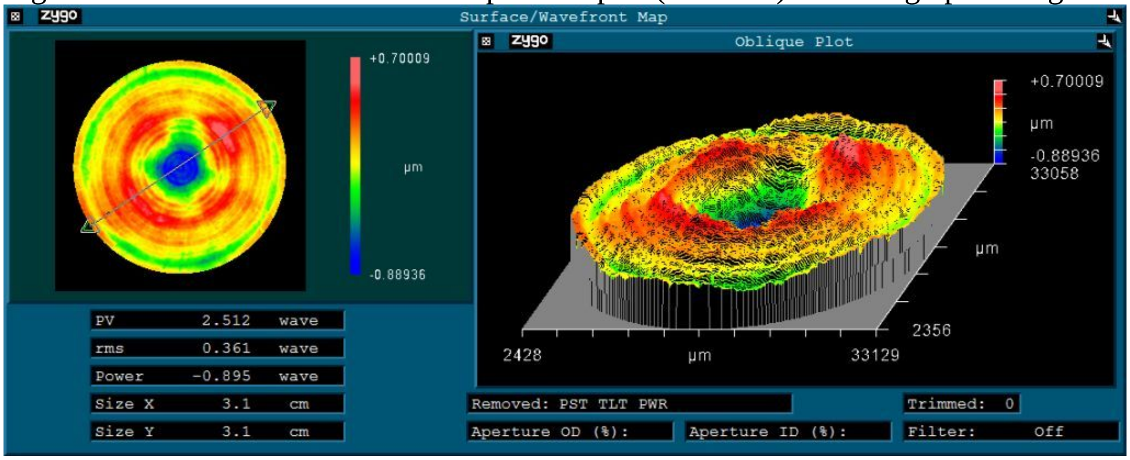
After significant work, such a process, now called “VIBE”, has been developed and is now used in routine production for selected elements. This process works for precision optics of all shapes. The clear advantage of the VIBE is that it allows FAST polishing of surfaces of non uniform slope.

Although the major thrust of the research is to be able to rapidly produce aspheres, developmental work has concentrated on plano and spherical shapes. The driving force for this is the ease of measurement when compared to aspheres. Once the process and hardware has been perfected for spherical parts, aspheres will be next.

Development efforts have been concentrated in 2 major areas. Development of a machine platform capable of sustaining the intense vibrations and stresses and construction of a series of polishers that provide the control, surface quality, and removal rates required for commercial success.

At the present time it appears that two types of polishers will be needed. One to rapidly remove the bulk of the material while maintaining overall shape. A second polisher will be used to provide the final surface quality. Bonding polishing media to compliant backings is not an easy task. Many combinations have been tried. Figure 4 and 5 show typical results after a rough polish and fine polish. We have experienced significant variation in the process as we learn which variables are more important than others. After we have achieved reasonable repeatability, we expect that modeling will help optimize the physical parameters of the compliant lap materials.

Figure 3A and 3B shows a Ø34 mm spherical part (R 23mm) after rough polishing



PV 2.512 wave
rms 0.361 wave
Power -0.895 wave
Size X 3.1 cm
Size Y 3.1 cm

Removed: PST TLT PWR
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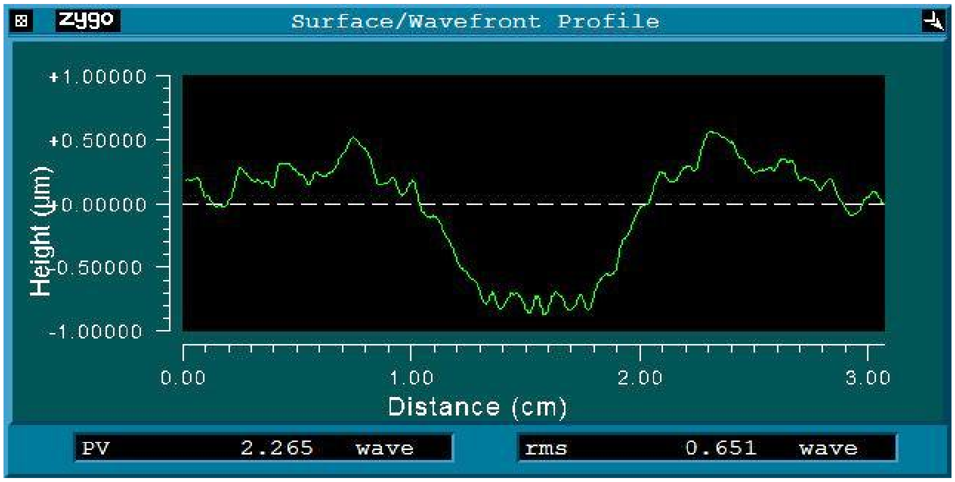
Fig 3A Spherical Part after rough polishing on VIBE



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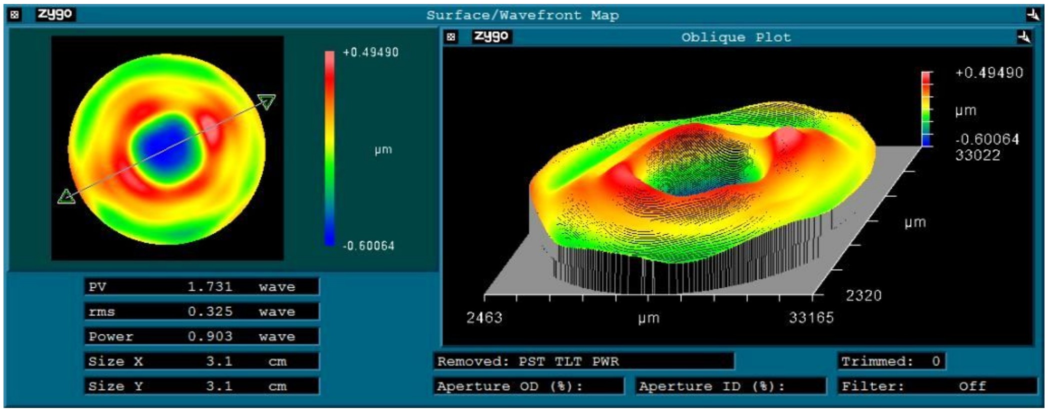
rms 0.651 wave

Fig 3B. Spherical Part after rough polishing on VIBE



PV 1.731 wave

rms 0.325 wave

Power 0.903 wave

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Size Y 3.1 cm

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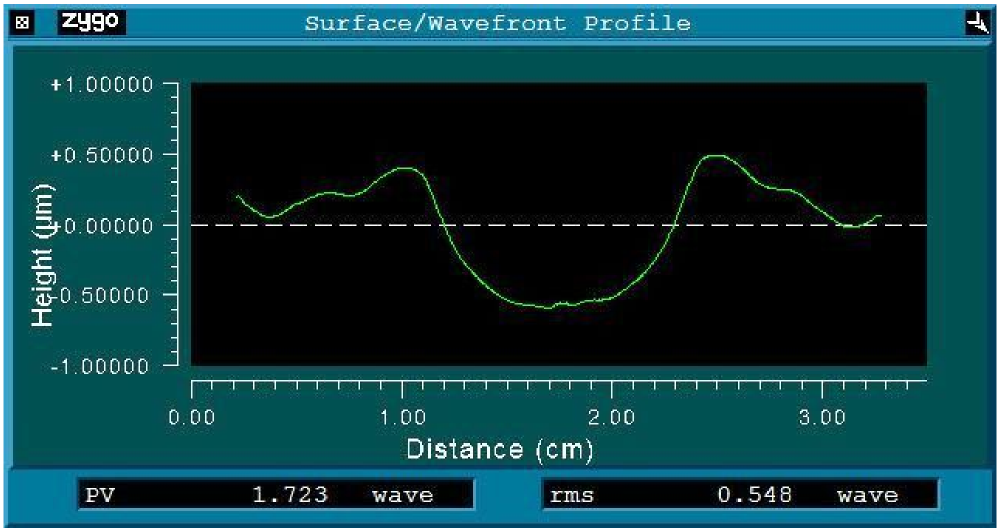
Fig 4A Spherical Part after fine polishing on VIBE



PV 1.723 wave

rms 0.548 wave

Fig 4B Spherical Part after fine polishing on VIBE

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[i] Images generated by using http://www.wordsmith.org/~anu/java/spirograph.html