Aspheric Surface Shaping

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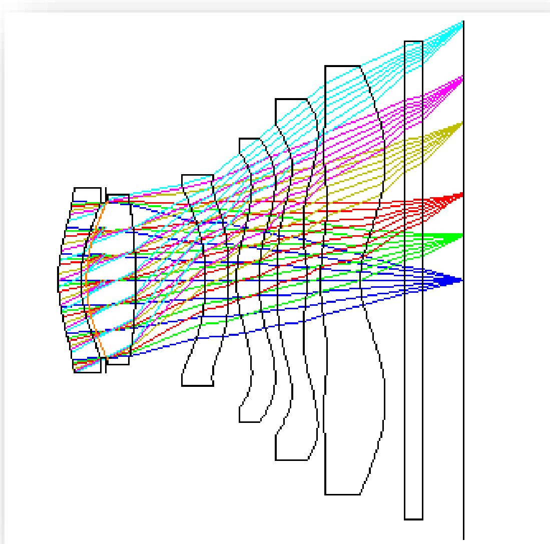
Aspheric surfaces are becoming more common in almost all areas of optical imaging. These can be either plastic or glass or a hybrid of both. There are many considerations to make when dealing with aspheres in a design, but one that is quite common deals with surface turnarounds.

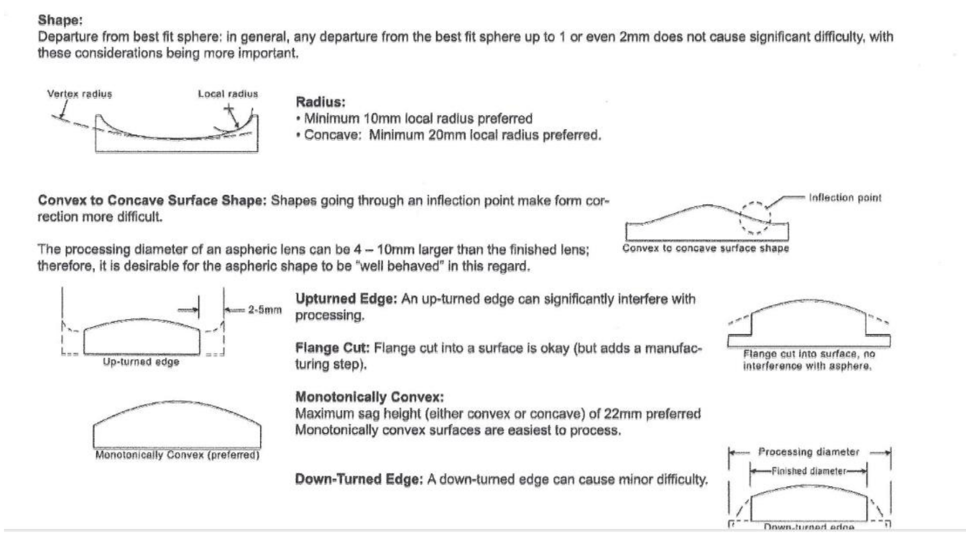
A surface turnaround occurs when the optical surface changes curvature direction along the radial dimension of the surface. A multi-element molded plastic asphere design is shown below with many such turnarounds.



Cell Phone Camera Lens

The last three elements of this design show very pronounced turn arounds. This type of surface change typically occurs when using high order aspheres, where the optimizer is trying to minimize the aberration of a local field point. Turnarounds can happen even on simpler designs though (low order asphere designs) and be quite a challenge, especially when the optical element is to be made out of glass. The glass grinding tools don't have small enough tip radii and won't fit to be able to make sharp turn arounds. Another challenge with optical elements with turnaround is that they are more sensitive to positional errors and make assembly more difficult. The positional sensitivity depends on the rate of change of the turnaround and will vary from design to design

Though the example shown above shows turnarounds at all zones of the lens, the steepest/quickest surface slope changes tend to occur at the edges of optical elements. These important to correct as the designer often forgets that the curvature of an asphere is important not only in the clear aperture but also out of it, as the tool must grind the lens past the known clear aperture before edging operations. Kreischer Optics, a well-known aspheric lens generating company, has an aspherical guideline page on this feature. http://www.kreischer.com/userfiles/aspheric_design_guide14.pdf



Shape:
Departure from best fit sphere: in general, any departure from the best fit sphere up to 1 or even 2mm does not cause significant difficulty, with these considerations being more important.

Radius:
• Minimum 10mm local radius preferred
• Concave: Minimum 20mm local radius preferred.

Convex to Concave Surface Shape: Shapes going through an inflection point make form correction more difficult.

The processing diameter of an aspheric lens can be 4 – 10mm larger than the finished lens; therefore, it is desirable for the aspheric shape to be "well behaved" in this regard.

Upturned Edge: An up-turned edge can significantly interfere with processing.

Flange Cut: Flange cut into a surface is okay (but adds a manufacturing step).

Monotonically Convex:
Maximum sag height (either convex or concave) of 22mm preferred
Monotonically convex surfaces are easiest to process.

Down-Turned Edge: A down-turned edge can cause minor difficulty.

In order to keep the optical surface prescription smoothly varying even outside the clear aperture, I have found that utilizing zonal slope terms can help to ensure that the lens surface does not exceed what can be made. Zonal slope terms must be generated manually in the merit function. This is easily done by taking the difference in the surface sag at various points along the radius and out past the desired clear aperture, then setting these to have the desired/allowable change per zonal location in the aperture (the sign of the slope and the magnitude must be controlled to keep the surface smoothly varying). The maximum allowable change depends on the fabrication tooling and the manufacturer and the positional tolerance that can be held in your design. I have had to typically use three to four zones around the area that wants to turn around in order to correct for the turnaround effects in the surface. If only one or two zones are used, then the optimizer tends to just shift the location of the curvature to a lower or higher zone while maintaining the same fabrication problem.

If these zonal slope terms are used early in the merit function, the aspherical surface prescriptions tends to stay well behaved and the aspheric surface will not have quick turnarounds that make the element more positionally sensitive and more difficult to make.