12 tips from Optimax to improve lens design for manufacturing
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OPTIMAX Systems, Inc.

Manufacturer of custom optics for research and industry for 26 years
Dedicated to Small volume, High Quality, Quick Delivery
America’s largest precision optics manufacturer
Specialize in all surface shapes on optical elements 3-400 mm in diameter
4,000 ft² state of the art coating department within
All parts are manufactured to customer-supplied specifications and include final inspection data

Opticians: 200
Employees: 300
www.optimaxsi.com
sales@optimaxsi.com
Ontario, NY
Why the Tips?

• Speed up the turnaround and lower the cost of your optical components

• Foster communication between lens designers and manufacturing shops
  • 80% are standard jobs, 20% are subject to confusion
  • Manufacturers can communicate preferences for drawings and specifications
  • Listen to the needs of the designers
1. Use the Optimax Manufacturing Tolerances Chart

### Optimax Manufacturing Tolerances Chart

Optimax provides rapid delivery services for a wide variety of optics ranging in size from 10-100mm. Below are tolerance guidelines for prototype optics with optical surfaces of f/1 or slower. Tighter tolerances may be possible depending on part size, shape and/or material. Optimax stocks large inventories of ECO-FRIENDLY preferred glasses.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Commercial</th>
<th>Precision</th>
<th>High Precision</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glass Material (n&lt;sub&gt;a&lt;/sub&gt;, n&lt;sub&gt;d&lt;/sub&gt;)</td>
<td>±0.001, ±0.8%</td>
<td>±0.0005, ±0.5%</td>
<td>Melt Data</td>
</tr>
<tr>
<td>Diameter (mm)</td>
<td>±0.00/-0.10</td>
<td>+0.000/-0.025</td>
<td>+0.000/-0.015</td>
</tr>
<tr>
<td>Center Thickness (mm)</td>
<td>±0.150</td>
<td>±0.050</td>
<td>±0.025</td>
</tr>
<tr>
<td>SAG (mm)</td>
<td>±0.050</td>
<td>±0.025</td>
<td>±0.015</td>
</tr>
<tr>
<td>Clear Aperture</td>
<td>80%</td>
<td>90%</td>
<td>90%</td>
</tr>
<tr>
<td>Radius (larger of two)</td>
<td>±0.2% or 5 fr</td>
<td>±0.1% or 3 fr</td>
<td>±0.05% or 1 fr</td>
</tr>
<tr>
<td>Irregularity - Interferometer (fringes)</td>
<td>2</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Irregularity - Profilometer (microns)</td>
<td>±10</td>
<td>±1</td>
<td>±0.5</td>
</tr>
<tr>
<td>Wedge Lens (ETD, mm)</td>
<td>0.050</td>
<td>0.010</td>
<td>0.005</td>
</tr>
<tr>
<td>Wedge Prism (TIA, arc min)</td>
<td>±5</td>
<td>±1</td>
<td>±0.5</td>
</tr>
<tr>
<td>Bevels (face width @ 45°, mm)</td>
<td>&lt;1.0</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Scratch - D1G (MIL-PRF-138308)</td>
<td>80 - 50</td>
<td>60 - 40</td>
<td>20 - 10</td>
</tr>
<tr>
<td>Surface Roughness (Å rms)</td>
<td>50</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>AR Coating (R&lt;sub&gt;ave&lt;/sub&gt;)</td>
<td>MgF&lt;sub&gt;2&lt;/sub&gt; R &lt; 1.5%</td>
<td>BBAR R &lt; 0.5%</td>
<td>V-coat R&lt;0.2%</td>
</tr>
</tbody>
</table>

Zemax

https://www.optimaxsi.com/technical-expertise/tools-and-charts/
2. Consider using ISO 10110

- Every company's drawings look different
- OEOSC/ANSI, APOMA, Savvy Optics, and Optimax recommending ISO 10110 to help "facilitate commerce"
- Optimax is investing in training
- OpticStudio is improving the ISO Element Drawing
- Change is not easy, but optics are not easy
3. Units – Leave No Assumptions

• Until we are all using the same standard...

• Tell us if you mean waves or fringes
• Tell us the wavelength at which you want your part measured
• Tell us your dimensions (use mm when possible)
• Use 3 decimal places for mm, 4 for inches
• Tell us if you mean surface or wavefront, single pass, double pass
• Roughness: Angstroms or nanometers?
• Wedge: mm, arcminutes, other?
4. Specifying Radius for Spheres

- You may specify a radius tolerance (i.e., TRAD ±0.5 mm)
- Or a power (i.e., TFRN ±1.5)
- If you specify both, we ADD them together

- If radius < 3 m, radii are ultimately measured interferometrically
- If radius > 3 m
  - Try to push flat in your design
  - If you can’t, try our Test Plate list
  - other
5. Some Old Favorites

• Use an asymmetric distribution when analyzing CT tolerance

• Avoid similar radii in meniscus lenses

• Avoid similar radii in BCX or BCC lenses
  • The direction cannot be marked until the edging is complete
  • Even after marking, it’s a 50/50 chance at all stages

• Watch your diameter to thickness ratio
  • < 10:1 usually provides a stable surface
  • When > 10:1, the part may be unstable in processing
  • When > 10:1, the part may be distorted in testing
  • If > 10:1, be prepared to participate in plans for mounting
6. Specifying Element Wedge

- Wedge, centering, TIR, runout, decenter, wobble, prism, ETD
- For symmetric parts with spheres
  - There are up to 8 possible tolerances
  - Try to specify one value for each lens
  - If you specify x and y directions, we RSS
  - If you specify TSDX and TIRX, we convert and RSS
  - Specify as ETD (mm) when possible

**Tolerance Data Editor**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>TSDX</td>
<td>4</td>
<td>0.000000</td>
<td>-0.200000</td>
<td>0.200000</td>
</tr>
<tr>
<td>36</td>
<td>TSDY</td>
<td>4</td>
<td>0.000000</td>
<td>-0.200000</td>
<td>0.200000</td>
</tr>
<tr>
<td>37</td>
<td>TIRX</td>
<td>4</td>
<td>0.000000</td>
<td>-0.200000</td>
<td>0.200000</td>
</tr>
<tr>
<td>38</td>
<td>TIRY</td>
<td>4</td>
<td>0.000000</td>
<td>-0.200000</td>
<td>0.200000</td>
</tr>
<tr>
<td>39</td>
<td>TSDX</td>
<td>5</td>
<td>0.000000</td>
<td>-0.200000</td>
<td>0.200000</td>
</tr>
<tr>
<td>40</td>
<td>TSDY</td>
<td>5</td>
<td>0.000000</td>
<td>-0.200000</td>
<td>0.200000</td>
</tr>
<tr>
<td>41</td>
<td>TIRX</td>
<td>5</td>
<td>0.000000</td>
<td>-0.200000</td>
<td>0.200000</td>
</tr>
<tr>
<td>42</td>
<td>TIRY</td>
<td>5</td>
<td>0.000000</td>
<td>-0.200000</td>
<td>0.200000</td>
</tr>
</tbody>
</table>
7. Different manufacturing and measurement tolerances

- Occasionally, customers use measured data (R or CT) to assemble/align their optical system.
- Do not make an assumption about the uncertainty in the measured value. You must specify. Simply use a NOTE.

NOTES

1. The final CT shall be measured and reported with an uncertainty of ±0.010 mm
8. Balance element tolerances for low cost and turnaround

- **Do not** use the same magnitude tolerance on all surfaces
- For fabrication efficiency:
  - Use the TOL analysis to loosen low sensitivity tolerances
  - Loosen tolerances on lenses with soft materials and high slopes
  - Put the tight tolerances on hard, slow surfaces
- Use Optimax Manufacturing Tolerances Chart to guide choices
9. Use Robust Peak-to-Valley (PVr)

- When you know you want to specify PV
- PVr is not affected by noise, spikey data, fiducials, and different camera resolutions
- PV has been getting worse as sensors get better
- Robust, no tricks, no questions about filtering

\[ PV_r = PV_{36Gen} + 3 \times \text{rms}_{Zres} \]

REFERENCE: Chris J. Evans, Zygo Corporation, PVr—a robust amplitude parameter for optical surface specification, Optical Engineering 48(4), 043605 (April 2009)
10. Defining Aberrations Well

• When specifying limits on specific aberrations, or targeting aberrations, be explicit
• There are too many standards- Seidels, Zernikes, Standard, Annular, Fringe, OpticStudio®, CodeV®, ISO, ANSI, Zygo MetroPro®, MX®

Please specify:
1. The type of aberration
2. The Zernike scheme
3. The coefficient numbering/equation
4. The coefficient units
5. The dimension definition (surface or wavefront)
6. The normalization aperture

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**EXAMPLE**

Surface 2 shall be plano with the following Standard Zernike terms over the surface CA:

- \( Z4: (p^2) \cos(2A) = 1.23 \pm 0.10 \) waves, HeNe
- \( Z5: (2p^2 - 1) = -1.87 \pm 0.10 \) waves, HeNe
11. Tips for Aspheres

• It will likely save money to design 2 mild aspheres rather than 1 challenging aspheric surface

• Include a sag table on the drawing

• Design outside the final intended CA by 7-8 mm on the diameter (set semi-diam > CA)

• Specify the \( R_v \) tolerance and irregularity
  • Do not tolerance conic and aspheric terms
  • Specify aberrations if needed

• Concave aspheric surfaces are limited due to tool radius restrictions
  • Work with manufacturer
12. Final Tip: Metrology

- Making it vs. Measuring it
- Understand how your manufacturer plans to test each lens parameter
- How will you know your specifications are met?
Tools

• See the many tools, charts, papers, videos, webinars on www.optimaxsi.com

• Stay tuned for upgrades to the Cost Estimator in OpticStudio
12 tips from Optimax: Summary

• Following these tips will help reduce cost and time for optics manufacturing
  • Specifications will be easier to understand
  • Parts will be easier to manufacture and test
  • Fewer mistakes will occur

• Increased communication between lens designers and lens fabricators will increase efficiency over time

• If these tips present challenges, help us to understand

• Think about drawing standards: more is not necessarily better
• More questions? E-mail Jennifer at jmichels@optimaxsi.com
Thank you!

• Please submit your questions using the GoToWebinar controls