Realistic optical drawing specifications from a metrology point of view

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Engineers who design optical systems for a living specify optical components on a regular basis. A well-specified optic controls only the necessary parameters. Unfortunately, the specifications on drawings often do not consider the nuances of the measurement process, resulting in discrepancies between what the designer thought they were specifying and what the optical shop is measuring. This often results in components that are over specified and more expensive than necessary, or worse, components which are underspecified and do not work for the intended application. This talk will look at some widely used optical surface specifications and provide guidance on how to use them properly to minimize the ambiguity between the customer and the supplier. © 2019 Zygo Corporation.

OCIS codes: 120.0120, 080.2208

1. Introduction

Those of us who fabricate and test optical components for a living often encounter optical drawings where we wish we could ask the originator “What did you mean by that?” and those of us who purchase optical components often look at the received component and say, “That’s not what I wanted!”. Most of us have tested parts to a spec of λ/n only to have a single pixel cause by dust or edge diffraction result in a peak to valley measurement >>λ/n reported by the interferometer. We know the part is good enough for the application, but we cannot pass it because the data does not meet the required specification, because a small number of pixels being out of specification. We have to call the customer and request a waiver. These problems can be avoided, and the customer can get what they need at a lower cost if the optical surface is specified properly.

2. An Example - PV, PVr and RMS

How should optical surfaces be specified? For most applications the effect of an optical surface on the performance of an optical system is weighted according to surface area. In other words, if 95% of a surface is within specification and 5% is out of specification, then 95% of the light will end up in the right place and 5% will be directed elsewhere. For many imaging applications this is more than adequate, yet we specify the surface using a single number–Peak-to-Valley or PV over the entire surface. The traditional PV value is not the best way to specify the surface as it is affected by dust and diffraction, resulting in a failing part even when much less than 1% of the surface area is out of specification.

There has to be a better way to specify the surface!

2.1 Option 1 - PV without all of the points

The option to filter outlying data points is often seen on drawings by large government facilities. The specification will be stated something like “PV < 0.05 waves with no more than 2% of data points removed”. This allows the user to either mask out small areas where there are obvious problems or to set a specification and use a result such as “Points within PV specification”.

2.2 Option 2 – PVr

The Robust PV known as PVr was proposed by Chris Evans a number of years ago[1] and it is now written into the ISO 10110 Part 5 standard.[2] PVr is designed to compute the PV of a surface without being biased by spurious points or small, out-of-specification areas. PVr is derived from the RMS residual after removing the first 36 Fringe Zernike polynomials and then adding 3 times the RMS to the PV of the 36 term Zernike fit. The PVr result essentially eliminates all points which vary from the overall surface form by more than three standard deviations. PVr is a preferable replacement for PV, but it can be tripped up by some pathological cases so the results should be evaluated for reasonableness.

2.3 Option 3 – RMS

RMS is actually an area weighted result by definition. Using RMS is a very good option because it is minimally affected by single or a small number of bad points, it can be applied to all aperture shapes and it is quick to compute. You may ask with all of this going for it, why isn't it used more often? The primary reason is that this is not how lens design programs do tolerancing and people do not think in RMS, It is not trivial to convert lens design tolerance values into an RMS specification and a person cannot look at a surface map which fails an RMS spec and know how improve it to meet the specification.

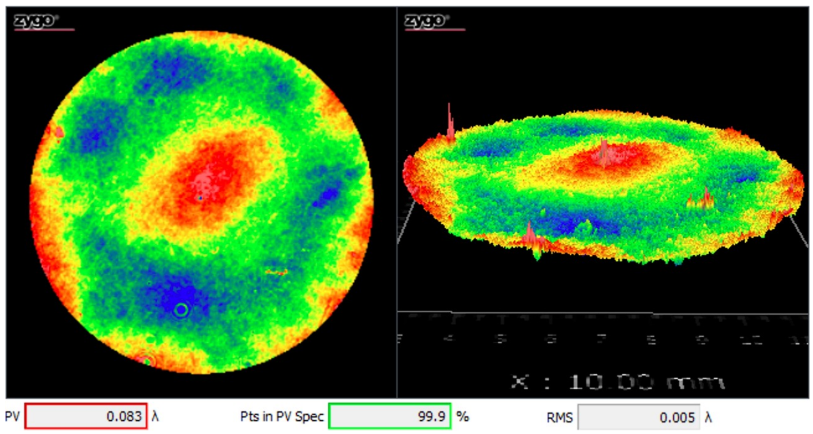

Figure 1. Test part with 0.05 λ specification. Small spikes in data cause it to fail but only 0.1% of the surface is out of spec so a Points in PV Specification tolerance of 99% would allow this part to pass.

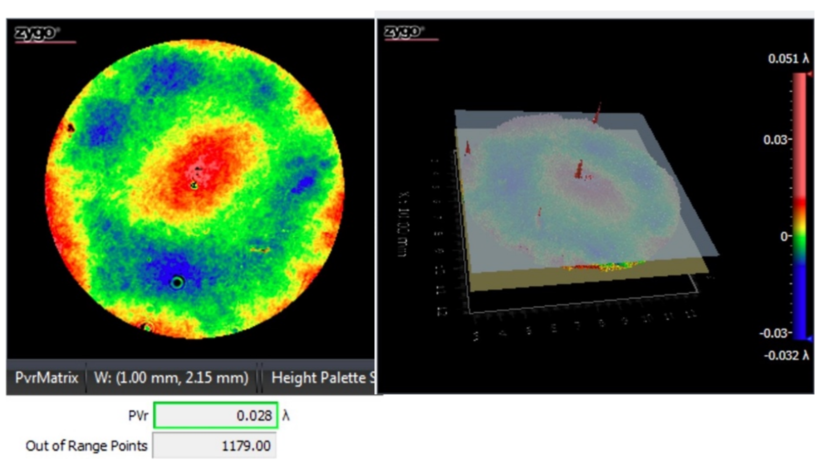

Figure 2. PVr of the same part. Note that it easily meets the specification and only 1179 of 380,000 points (0.3%) were removed.

3. Discussion

The previous was just one example of alternative specifications. The presentation will cover this example as well as PSD and surface slope and discuss how to implement these specifications using the ISO 10110standard drawing format[3,4].

4. References

[1] C. Evans, *PVr—a robust amplitude parameter for optical surface specification*, Optical Engineering, Vol 48(4), 2009, pp. 043605-1 - 043605-8

[2] ISO "*Optics and photonics—Preparation of drawings for optical elements and systems—Part 5: Surface form tolerances,*" ISO 10110 Part 5, 3rd ed. 2015

[3] Eric Herman, Richard N. Youngworth, David M. Aikens, *Translating from American MIL drawings to ISO 10110*, Proc. SPIE 10742, 1074254(2018).

[4] Eric Herman, Richard N. Youngworth, David M. Aikens, *Modern Optical Drawings: The Journey from MIL to ANSI to ISO drawing formats*, Proc. SPIE 10742, 1077420P(2018)