LuphoScan, Form Talysurf® PGI Optics Range

Slope error analysis

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In this note, slope error analysis required by the optical industry are introduced. The specifications of slope error in Aspherics Analysis Utility (AAU) and LuphoSoft of Taylor Hobson (TH) software are explained.

Introduction

In the optical industry, form error is an important parameter for the quality control of optical lenses. With tolerances getting tighter, optical designers are becoming increasingly aware of the importance of specifying the slope error.

Slope error is calculated as a subset of the form error, and measures its rate change, which may seriously degrade optical system performance, especially for systems with aspheric surfaces. The slopes resulting from midspatial (0.5 – 4 mm) frequency errors in subaperture polishing can devastate systems. Applying slope error specification to traditional form error analysis can be helpful for controlling the optical component's quality, and therefore improve system performance.

Specification of slope error (common method of optical industry)

The specification of slope error must contain at least the slope error and an integration length. Sampling length can also be included if needed (see figure 1.1).

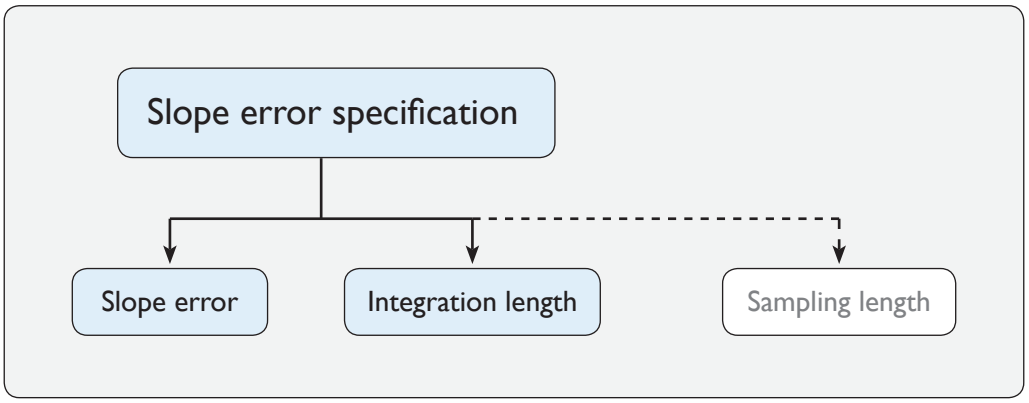

Figure 1.1 - Slope error specification

Slope error measurement is carried out as shown in figure 1.2 (Page 2). For a given horizontal length, the increase or decrease in form error at the end point relative to the start point is measured. The larger the slope angle is, the larger the slope error will be.

Note: Slope error calculation is made after surface form removal.

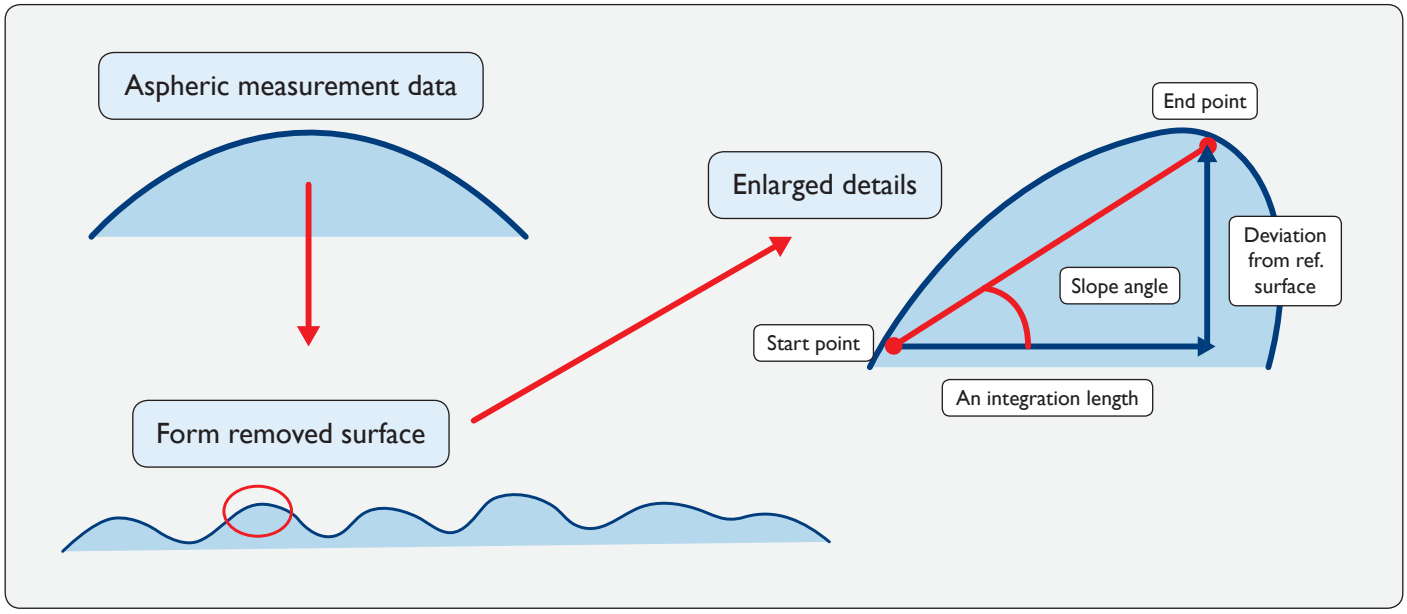

Figure 1.2 - Slope error measurement

Calculation of slope error parameters

1. 2D slope error analysis in Aspheric Analysis Utility (AAU)

The slope error is analysed based on common methods for optical industry (see Fig 1). By applying a 2D slope error band filter, a user-defined "window" moves along the profile and calculates the line slope of the collection of points within it. All the absolute values are recorded into an array ("slope array") when the "window" is moving along the profile.

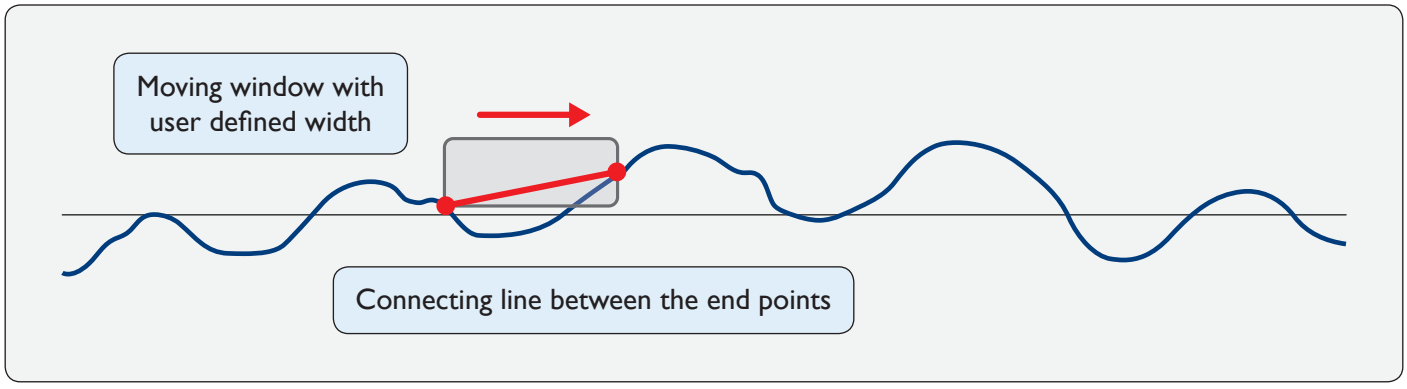

Figure 2 - Calculation of Slope error parameters in AAU

2D Slope error parameters in AAU

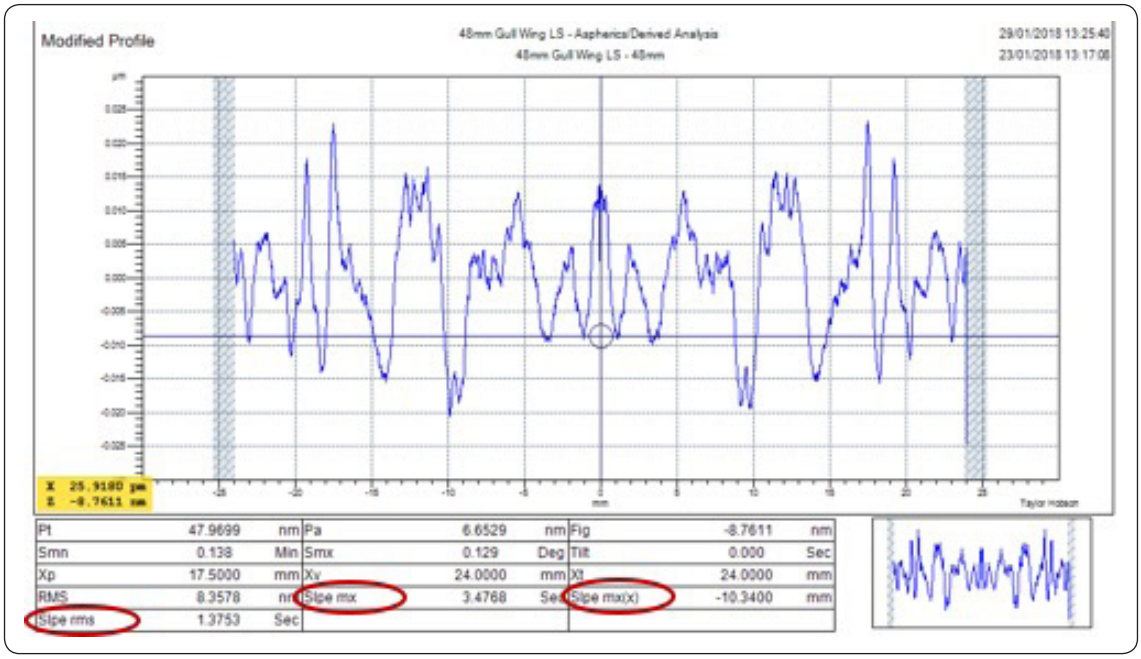

Figure 3 - An example of Aspheric analysis in AAU

Table 1 - 2D Slope error parameters in AAU

Slope parameters	Unit	
Slpe mx	angle deg/min/sec	Maximum slope
Slpe mx (x)	mm	The position of the max slope
Slpe rms	angle deg/min/sec	rms of the slope
Slpe ave	angle deg/min/sec	The average slope value isn't displayed in the current AAU, but available in the text file of "Export Analysis Results"

2. 3D slope error analysis in LuphoScan software (Luphosoft)

With a user defined 3D slope error band filter, a LS fitting plane (dx X dy) is used to fit all the areal data within this defined area, and the slopes are then calculated in X & Y directions. See the below table which shows the slope parameters in LuphoScan.

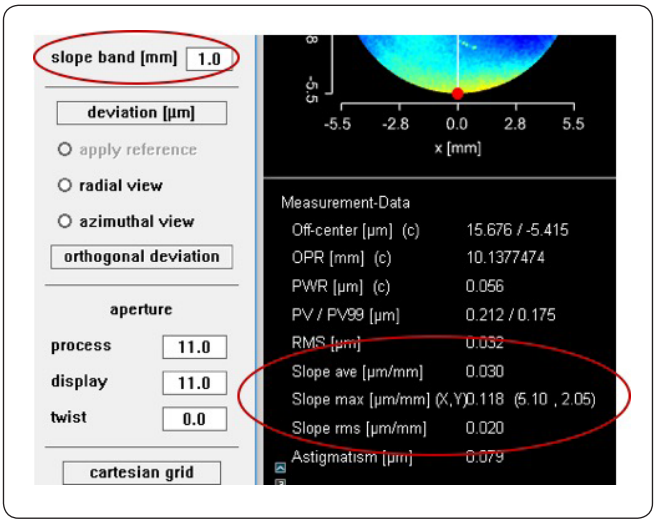

Figure 4 - An example

Table 1 - 3D Slope error parameters in LuphoSoft

3D Slope parameters	Unit	
Slope ave	μm/mm	Average slope
Slope max (x, y)	μm/mm	maximum slope and its position of the max slope
Slpe rms	μm/mm	rms of the slope

Note: The average slope value in the software is the absolute value of sqrt (slope X^2 + slope Y^2).

Comparison of LuphoScan measurement and PGI measurement results

Comparison of slope error results between AAU and LuphoSoft cannot be made directly because of their differences explained in this document. However, the comparison of LuphoScan measurement and PGI measurement can be achieved by exporting LuphoScan data the corresponding 'prf' data , then analyse both LuphoScan data and PGI data in AAU.

Summary

The slope error analysis (resulting from midspatial frequencies) introduced in this note, obtained for example from aspheric form error analysis, are mainly used for quality control of optical components in the optical industry. It is different from the general slope parameters '7 points slope error analysis' (refer to ISO 4287), used for high spatial frequency analysis of any surface. It can be analysed using 'SAG analysis' in AAU.

References

1. Light B,' Specifying and Measuring Slope Error of Optical Surface', Optimax Systems, 2009.
2. J.J. Kumler et al,"Measuring surface slope error on precision aspheres", Proc. SPIE 6671, Pg 66710U (2007).

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