PGI and CCI – contact and non-contact techniques

Advanced contact and non-contact metrology for characterisation of optical lenses

Yang Yu, PhD; Richard Smith

Introduction

Traditional spherical optics become heavier and larger as lenses are combined to achieve an increase in functionality and precision, but in recent years modern optical designs have employed aspheric and diffractive optics to reduce the number of lenses needed: one aspheric or diffractive lens can replace several conventional spherical lenses and as a result the weight, cost and space used are all reduced, achieving a more compact and better performing optical system.

Diffractive lenses are normally used by optical designers to correct for 'chromatic aberration' and aspheric optics can be used to reduce or eliminate 'spherical aberration', thereby improving focus quality. Diffractive optics provide new and powerful degrees of freedom for lens design and result in high quality data from optical systems.

More recently, the use of asphero-diffractive lenses has significantly reduced the number of lenses required by an optical system and greatly minimised chromatic and spherical aberration errors by means of compensation techniques: diffractive zones can be adopted to compensate for chromatic aberration arising from the refractive properties of the lens.

Key parameters – lens form and roughness

Lens form is one of the most important optical design parameters used to control the quality of precision aspheric and asphero-diffractive optics, ensuring they perform as required. In addition, surface roughness affects performance. It is therefore essential to use the very best and most efficient measurement techniques.

In this application note we provide some examples of the measurement of aspheric and asphero-diffractive lenses using both contact (PGI) and non-contact (CCI) metrology and we proceed with an introduction to each technique.

Typical applications

- *Mobile phone cameras*
- *DVD read/write heads*
- *Bar-code scanners*
- *High power LED optics*
- *Blu-Ray DVD optics*
- *Cameras*
- *Projectors*
- *Automotive and medical Head-up displays (HUD)*
- *Infra-red thermal imaging for rescue and security*
- *Astronomy*
- *Spectroscopy*
- *Optical communications*
- *Biomedics*

Advanced metrology for optics

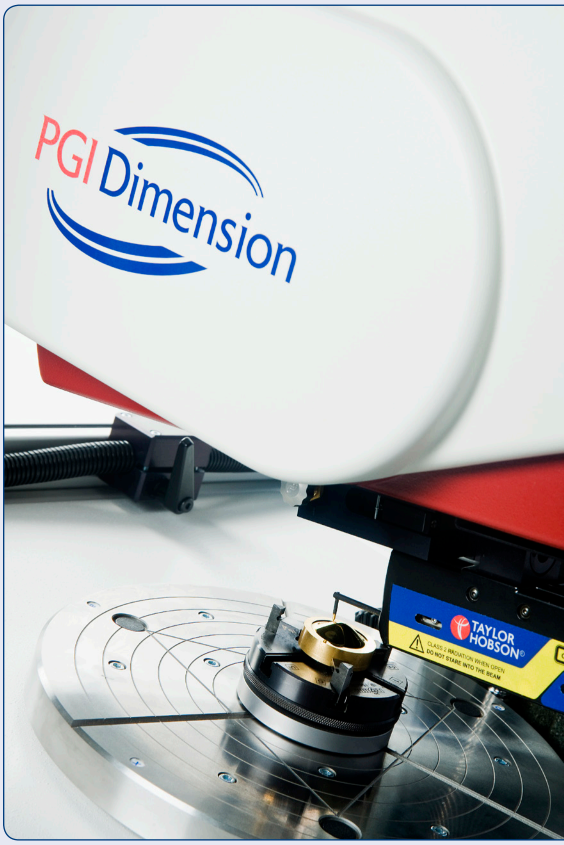
With the rapid evolution of optics, suitable advanced metrology tools are necessary for characterizing lenses with more complex shapes, of various sizes and made of different materials. A number of metrology tools have been employed to measure the aspheric and asphero-diffractive lenses. For instance, contact stylus profilometry and non-contact interferometry techniques.

Phase Grating Interferometry (PGI) is a contact stylus profilometry, which can offer larger gauge range to resolution when compared with other tradional profilometers, such as inductive gauges and laser interferometers. Coherence Correlation Interferometry (CCI) instruments provide advanced 3-dimensional non-contact surface characterization. The technique is fast and accurate and provides a high resolution 3D image together with analysis that includes 3D roughness, 3D form analysis and 2D profile measurements.

Phase Grating Interferometry (PGI)

"PGI Dimension's enhanced capabilities support IR Optics, projector lenses, digital camera lenses, high power LEDs, Blu-ray and standard DVD optics and cellphone camera lenses."

Dr Daniel Mansfield, Research Manager and Company Physicist, Taylor Hobson



PGI Dimension

PGI Dimension is based on two technologies – Aspheric profilometry and high accuracy roundness.

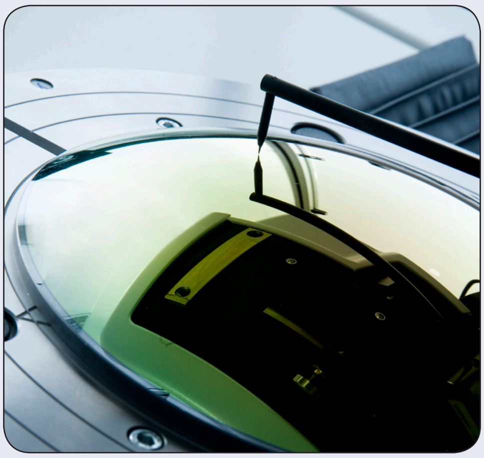
- Slope angles up to 85 deg
- Up to 300 mm diameter
- Sags of up to 50 mm
- High accurate alignment of the rotate part axis
- Patented proven fusion method
- Patented calibrations
- Gauge noise <1nm RMS

Phase Grating Interferometry

The 'Phase Grating Interferometry' (PGI) gauge is Taylor Hobson's state of the art gauge. This particular gauge employs a special grating. Laser photodiodes are used to detect interference signals resulting from the stylus movement.

Compared with traditional inductive gauge and laser interferometer gauge, this type of transducer offers an exceptionally large gauge range to resolution whilst giving a reduction in physical size. Typically, this metrological gauge with a respective range and resolution of 12.5 mm and resolution up to 0.2 nm, represents a distinct change in gauging technology.

- Extremely high accuracy and linearity
- Large range and high resolution
- Resolution independent of gauge range
- Ratiometric processing of signals returned from the sensors
- Changes in signal level or laser wavelength have no effect on results



Coherence Correlation Interferometry (CCI)

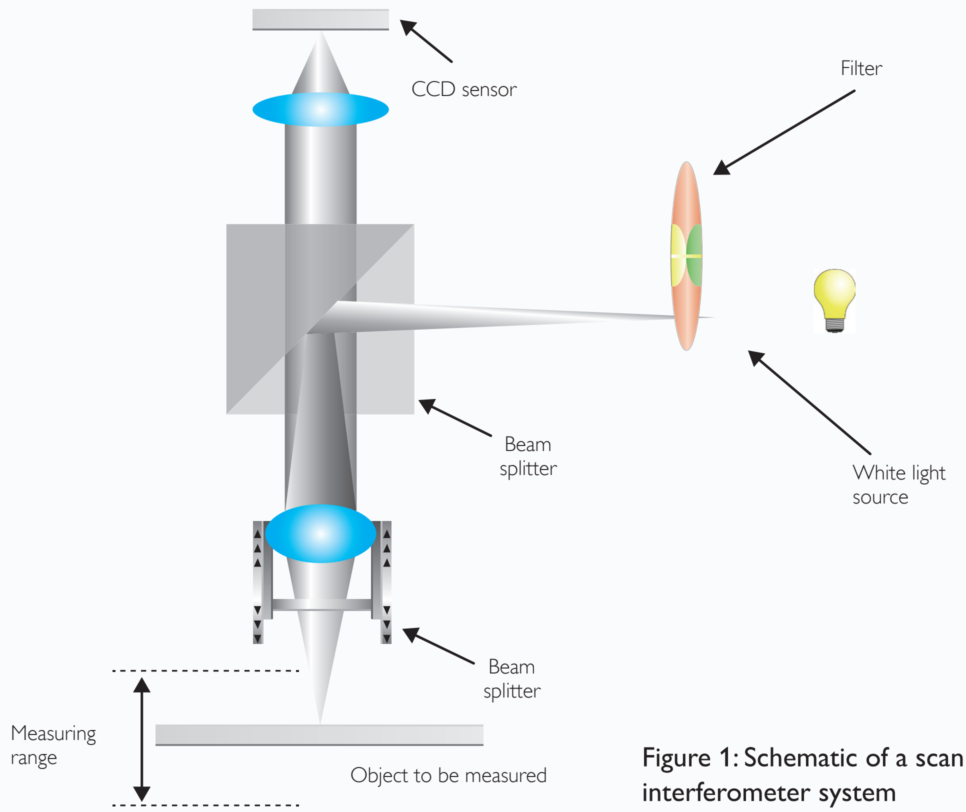


Figure 1: Schematic of a scanning interferometer system

"The wide variety of industrial applications mean that Coherence Correlation Interferometry is increasingly important"

Dr Mike Conroy, Business Development Manager, Taylor Hobson Ltd.

A schematic of a scanning interferometer system is shown in Figure 1. Light from the light source is directed towards the objective lens by the upper beam splitter and the light is then split into two separate beams by the lower beam splitter.

One beam is directed towards the sample and the other is directed towards an internal reference mirror. The two beams recombine and are sent to the detector. As the interferometric objective is scanned in the z direction, interference occurs when the path lengths of the two beams are the same. The detector measures the intensity, taking a series of snapshots as the sample is measured.

This creates an intensity map of the light being reflected from the surface, which is then used to create a 3D image of the surface being measured. Different techniques are used to control the movement of the interferometer and also to calculate the surface parameters. The accuracy and repeatability of the scanning white-light measurement are dependent on the control of the scanning mechanism and the calculation of the surface properties from the interference data.

Coherence Correlation Interferometry[1] is becoming increasingly important for measurements in many applications, providing:

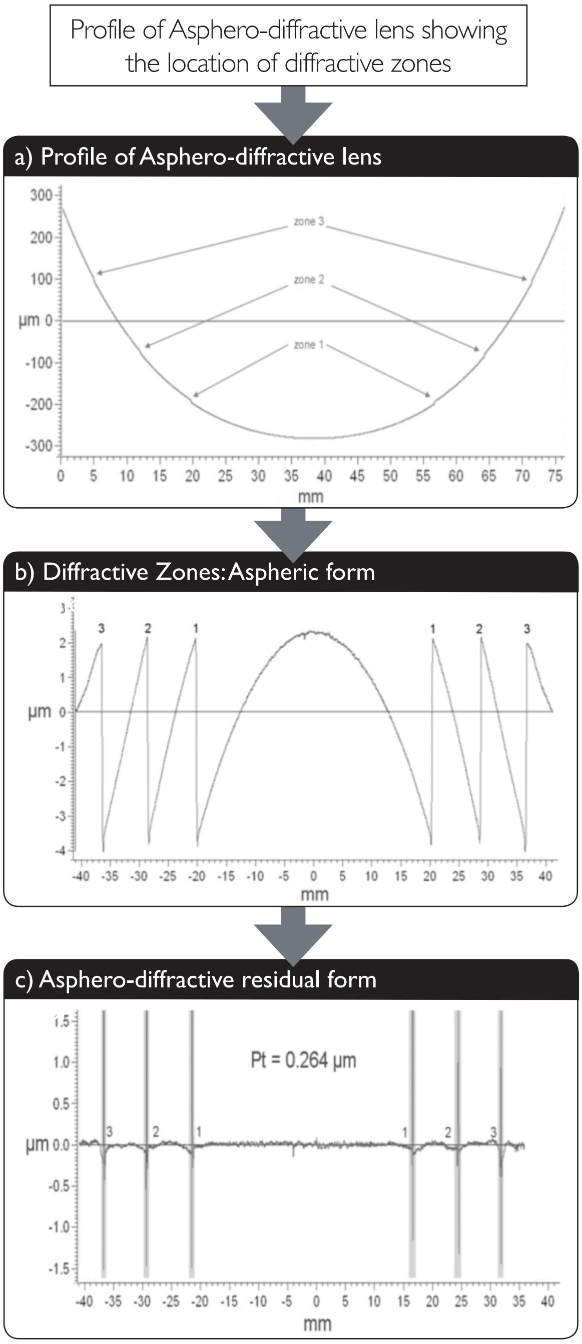
- Fully automatic non-destructive measurements
- Accurate and quantitative characterization of surfaces
- Sub-angstrom resolution regardless of the scanning range used
- Fast and convenient sample loading and set-up
- Capability of measuring a wide range of materials
- Highly repeatable measurements
- Roughness and step-height analysis in one measurement
- Film thickness and interfacial surface measurement capability

Case 1 – Optical lens measurement using Phase Grating Interferometry

A large and shallow asphero-diffractive concave lens with a 75 mm diameter and sag of 0.5 mm was tested using PGI Dimension. The ratio of the sag against the diameter is less than 0.01, making the centring and levelling of the measurement very challenging for most of the instruments.

Measurement of a large and shallow asphero-diffractive concave lens using PGI Dimension

Figure 2: Analysis process of an Asphero-diffractive lens



The PGI Dimension employs a patented sample alignment feature, which utilises the principal of symmetry to align the sample to the instrument's rotational axis, thereby ensuring that profiles are traced over the sample's true aspheric axis. This is essential when measuring small or steep-sided optics where off-axis measurements can introduce significant form errors. This feature also makes the precise measurement of a large and shallow lens possible.

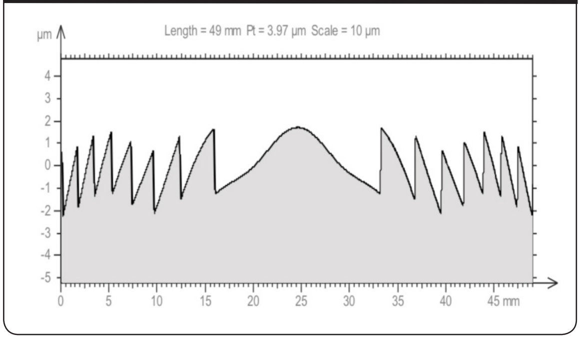
Case 2 – Optical lens measurement using Phase Grating Interferometry

An asphero-diffractive convex lens with a 60 mm diameter and a 3 µm step height was measured before and after the compensation of the lens form during the manufacturing process using PGI Dimension. The test results are shown as in Figure 3.

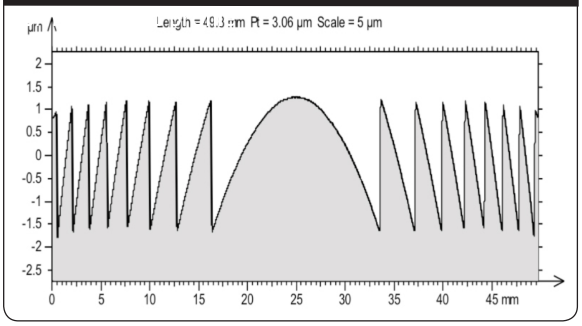
Test of process improvement on an asphero-diffractive convex lens using PGI Dimension

Figure 3: Test results of process improvement on an Asphero-diffractive convex lens

a) Pre-compensation with aspheric



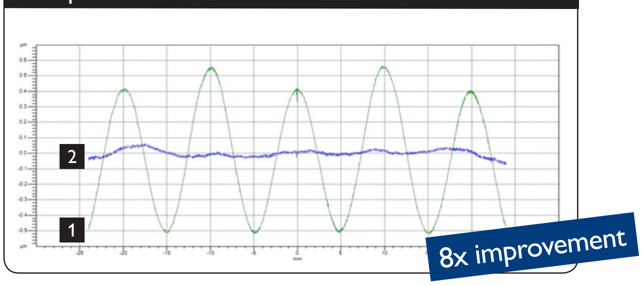
b) Post-compensation with aspheric



Design data of the axisymmetric diffractive lens

- 60 mm convex radius
- K= -1

c) Residual error comparison with Asphero-diffractive form removed error



1 Pre-compensation
2 Post-compensation

The results show how the PGI Dimension gives manufacturers precision control of key parameters during and after the manufacturing process, cutting production costs and ensuring lens quality and correct performance.

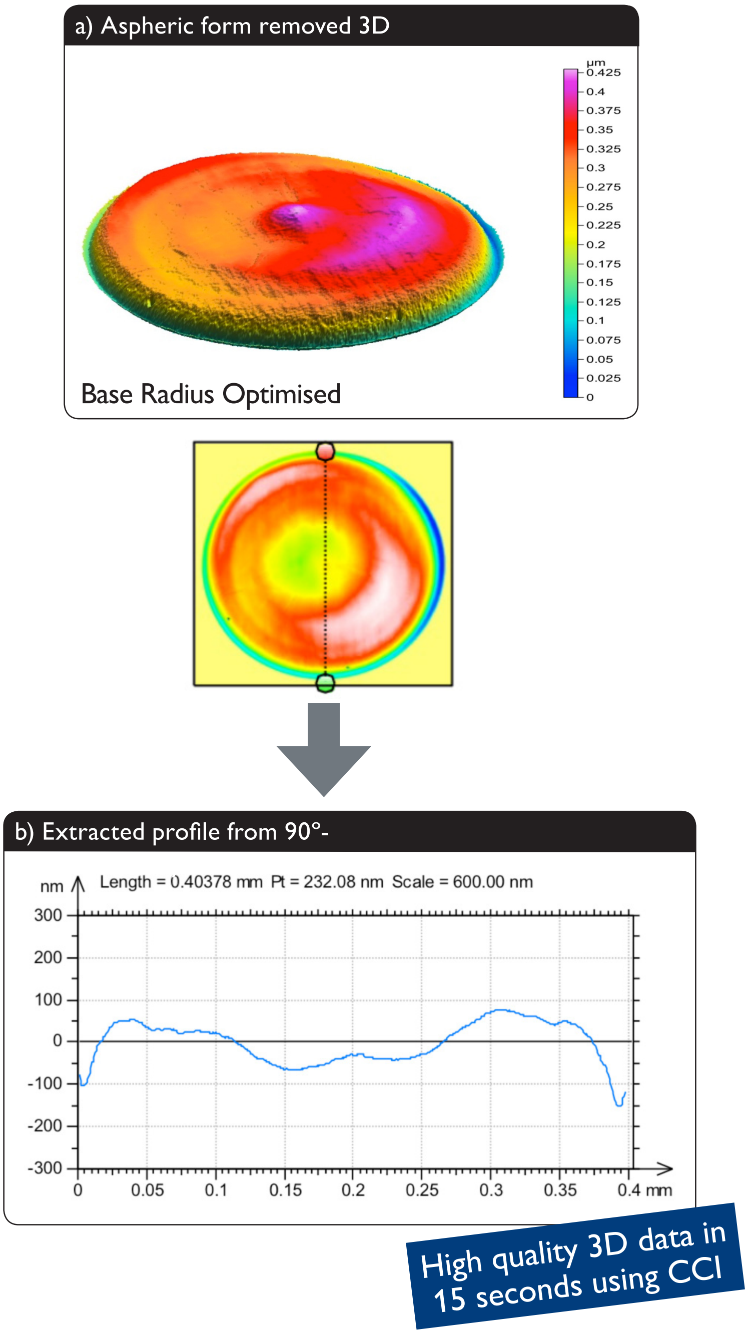
Case 3 – Optical lens measurement using Coherence Correlation

Lens form is one of the most important optical design parameters to control the quality of the precision aspheric and asphero-diffractive optics.

Optical lens measurement using Coherence Correlation Interferometry

Figure 4: Measurement of a miniature aspheric lens using CCI

A 0.4 mm diameter aspheric concave glass lens was tested using CCI instrument



Notes: 15 seconds was only taken for the CCI measurements

CCI provides rapid and accurate 3D morphological measurements. It can provide both 3D roughness results and form error in one measurement to completely suit the requirements from the optical manufacturers.

Conclusions

The modern metrologist now has both contact and non-contact measurement solutions available and a combination of these techniques now provides a more detailed understanding of optical components. Phase Grating Interferometry (PGI) with sub-nanometre vertical resolution and sub-micron lateral resolution can provide detailed characterization of a wide range of components including shallow and steep-sided optics. PGI dimension is becoming ideal metrology tool for precision form measurement of a comprehensive range of lenses, moulds and other spherical or aspheric products.

PGI Dimension is also designed for the measurement of diffractive lenses. It allows manufacturers to precisely control key parameters such as underlying form error, step height and zone position during and after the manufacturing process. This allows the instrument to measure optics used in a wide range of applications

Non-contact Coherence Correlation Interferometry with sub-angstrom vertical resolution provides rapid and accurate 3D morphological measurements which can fill up the gap of PGI measurements, including fragile surfaces, structured surfaces and the miniature optical lens.

Acknowledgments

The authors would like to express thanks to Erik Stover and Mike Conroy at Taylor Hobson for their support with measurements and valuable discussions.

References

1. Ian K. Buehring and Daniel Mansfield, U.S. Patent 5517307 (14 May, 1996)
2. Y. Yu et al., Characterization of optical lens using contact and non-contact interferometry techniques, **AOMATT 2012: 6th International Symposium on Advanced Optical Manufacturing and Testing Technologies.**

Application notes are available for download at www.taylor-hobson.com/learning-zone

Learning Zone

Metrology Books | User Guides | Application notes | White papers | Metrology A to Z | Ask a question | Software Updates | Teleconference archives | Stylus definitions | Training materials

First time visitor? **sign up here** to access all downloads

Please login below

Email Address:

Password:

Sign in Forgotten your Password?

Some other relevant application notes

A130 Accurate measurement of optical coating thickness

A131 Advanced metrology for anti-reflection coatings used in photovoltaics devices

A139 High precision measurement of steep-sided miniature aspheres

A142 Unique measurement capability for steep-sded small hemispheres

A143 New software to reduce set-up time for grinding and diamond turning

A144 Definitive assessment of radius accuracy and form error

Taylor Hobson UK
(Global Headquarters)
PO Box 36, 2 New Star Road
Leicester, LE4 9JD, England

Tel: +44 116 276 3771
taylor-hobson.sales@ametek.com

Taylor Hobson France
Tel: +33 130 68 89 30
taylor-hobson.france@ametek.com

Taylor Hobson Germany
Tel: +49 611 973040
taylor-hobson.germany@ametek.com

Taylor Hobson India
Tel: +91 80 67823200
taylor-hobson.india@ametek.com

Taylor Hobson Italy
Tel: +39 02 946 93401
taylor-hobson.italy@ametek.com

Taylor Hobson Japan
Tel: +81 36809 2406
taylor-hobson.japan@ametek.com

Taylor Hobson Korea
Tel: +82 31 888 5255
taylor-hobson.korea@ametek.com

Taylor Hobson China Beijing Office
Tel: +86 10 8526 2111
taylor-hobson.beijing@ametek.com

Taylor Hobson China Shanghai Office
Tel: +86 21 58685111-110
taylor-hobson.shanghai@ametek.com

Taylor Hobson Singapore
Tel: +65 6484 2388 Ext 120
taylor-hobson.singapore@ametek.com

Taylor Hobson USA
Tel: +1 630 621 3099
taylor-hobson.usa@ametek.com