OP1.006 Asphere Metrology Memo

Rich Youngworth, June 4, 2014

OEOSC TC172/SC1/WG4/TF5 Aspherics

The purpose of this communication is to finalize the re-examined scope of OP1.006.

Background

The motivation for having a standard specific to asphere metrology goes back a long way. First, drawings are being standardized in this area, but corresponding metrology standards are lacking. Many industrial partners cite an immediate need to standardize key relevant measurement factors. The question then becomes one of the scope for such a standard.

The scope for OP1.006 in the PINS filed with ANSI states, in its entirety:
"**Proposed Title**: PINS/OEOSC OP1.006, Proposed American National Standard for Optics and Electro-Optical Instruments — Optical Elements and Assemblies — Asphere Metrology
Proposed Scope: A document that provides standardized and accurate terminology that ties to the description of the surface and test methods for testing of the surface. This ANSI standard will include:
- a generalized description of test methods, including freeforms;
- a connection back to IS010110 (and ANSI equivalent) of how aspheric surfaces are defined;
- cross-referencing to conformance testing (acceptance testing) along with appropriate decision rules to facilitate ease of quality assurance;
- appropriate definitions given for different commonly used terms for disambiguation such as asphere, anamorph, freeform, gull wings, and so forth.

Reason for creating the standard: Aspheres are an emerging technology and the metrology for them is crucial. Although attention has been given to them for drawing standards, metrology standards are insufficient for enabling the industry to standardize key germane measurement facets."

The rationale has not changed. In terms of scope we are currently deferring freeforms to a later date so that we get the standard completed as Freeforms mature. Nothing should prevent expansion of this standard to freeforms (or use or extension of it to general surfaces or freeforms). Otherwise the original scope concept generally remains intact with standard topics that define relevant asphere metrology terminology, limit the work to surface form and radius types of measurements, describe asphere metrology methods generally, define measurement result expressions, and tie specifications to metrology methods to facilitate the ease of quality assurance.

Rationale for Re-Examining the Scope

An initial effort to draft OP1.006 was started in earnest in 2013. After some progress, concerns about the utility of the draft and what it is “standardizing” were raised by multiple people. The primary concern is that the standard scope may be too broad and informative as currently being implemented. Where is the “standard” in the standard, per se. In response to such concerns, Dave Aikens said these metrology standards tend to come in two flavors:
- Metrology standards that give top level descriptions of how to make measurements
- Method standards that first define a parameter and then give ways to do it (or often multiple methods)

Due to the fact that the former tend to be technical report format, the rescope of OP1.006 attempts the latter. Informative material can be included appendices if warranted, and of course people can write up other materials for publication if so desired.

At this juncture Rich Youngworth has delivered the rescope document that will be vetted by the reconstructed. The rescope will then be allocated to a reconstituted team of volunteers to distribute the workload.

Re-Examining the Scope (former attempt)

The former document had the following topics and sections, clearly oriented on the tests themselves along with “pitfalls” that leads to an informative document:

1. Scope
2. Normative References
3. Terms and Definitions
4. Instruments to Measure Irregularity of Aspheric Surfaces
   Interferometer
   Stitching Interferometer
   Interferometer with a Null Corrector (spherical, CGH, conic null, sub-nyquist interferometer)
   Relative displacement measurements (normal to nominal, z-dirction, other non-normal)
5. Absolute shape of an aspheric surface measurements
   CMM
   Profilometer
6. Instruments to Measure the Surface Slope of an Aspheric Surface Using Deflectometry (is SCOTS in here?)
7. Instruments to Measure Components with Aspheric Surfaces
   - Transmitted wavefront test
   - Shack-Hartmann
   - Other functional testing)
8. Other concerns regarding instruments
   - Distortion/mapping
   - Lateral calibration
   - Sampling grid / dimensionality

  - Instrument transfer function
  - Focusing
  - Knowledge of the reference wavefront for interferometric tests

9. Expression of Measurement Results
   - Surface form errors including removal of alignment errors, surface form error in terms of toleranced coefficients, radius of an asphere
   - Residual or mid-spatial frequency errors
   - Edge artifacts and masking
   - Slope with PSD, Zernike Residual, Amplitude Spectral Density, Structure Functions, other functions such as wavelet transforms; and
   - had a question on what irregularity these terms are analyzed

Appendices – nothing had been finalized yet, likely informative additional information.

Refining the Scope

The proposed scope and outline will now identify key parameters to verify on drawings for aspheric components. The standard will then define methods to verify the given construction parameters. It is key that the document is written from the metrologist's perspective for proper verification with traceability (where applicable).

Determining what parameters require verification with aspheres is paramount. The first step is to determine what standards apply for defining aspheres in drawings. A start to such a relevant list of standards, based on the international drawing standard ISO10110 and OP1.00x as much as possible, is:
ISO10110-5 (surface form),
ISO10110-6 (wedge /decenter),
ISO10110-8 (waviness/ripple) – midfrequency errors and roughness,
ISO10110-12 (aspheric definition) – includes parameters on slope and integration length (+other?),
ISO10110-14 (transmitted wavefront) – if specified in such a way,
ISO10110-19 (general surfaces) – more of a do not violate consideration here for the future.

Additionally, we have substrate and lens material considerations (ISO10110-2 to ISO10110-4), coating specification (ISO10110-9), laser damage threshold (ISO10110-17), ISO14999 (particularly -4) series, and ISO9211 series (environmental factors) that can be referenced, but do not drive what is on a drawing. There are also three OEOSC ANSI documents that are related to the proposed standard:

- OP1.002 (or ISO10110-7 currently in WD) that covers cosmetic specifications which are nominally out of scope for this standard
- OP1.004 on optical wavefront measurement (largely about wavefront data interpretation)
- OP1.005 on statistical evaluation of surfaces (really is post-processing of surface data for statistical metrics like PSD)

OP1.006 should be designed to complement these standards and reference them as needed. Again these documents do not drive what is on a drawing or are not defined as in scope per the design of what constitutes OP1.006 as an asphere metrology standard. Other relevant standards should be added for completeness not only in defining what is measured, but considerations on normative factors for the measurements. This listing is but a start to the exercise.

Proposed Outline Revision for OP1.006 on Asphere Metrology

This proposed outline is organized by drawing parameters one encounters in fabricating aspheric components. The metrology that is used to verify the parameters are then given, with the possibility of multiple measurement methods often being covered. The advantage is that the document then provides some standardized means to verify given drawing parameters, with the negative that specific methods for measurement that can be used for multiple parameters are discussed in multiple sections. It is certainly plausible to include informative annexes as part of the work. Part of the challenge in developing such a document is in the execution and organization to appropriately represent the metrologist's viewpoint.

1. Scope
2. Normative References
3. Terms and Definitions
   Note in these first three sections where appropriate the types of surfaces can be defined whether mirror or lens type. Also definition of key metrology factors for aspheric surface verification can be defined such as the ITF, metrology calibration, datum assement and reference, identification of reference axes relative to datums, and so forth.
4. Surface Radius Measurement (can include multiple local radii or vertex)
   - Parameters to verify
   - Method1, Method2, etc.
5. Surface Form Measurement (note can be merged with Radius verification if appropriate)
   - Parameters to verify
   - Method1, Method2, etc.
6. Surface Irregularity Measurement (note can be merged with Radius/Form verification if appropriate)
   - Parameters to verify
   - Method1, Method2, etc.
7. Surface Midfrequency Error Verification
   - Parameters to verify
   - Method1, Method2, etc.
8. Surface Slope Verification
   - Parameters to verify
   - Method1, Method2, etc.
9. Aspheric Component Wavefront Verification
   - Parameters to verify
   - Method1, Method2, etc.
10. Aspheric Component Decenter/Wedge Verification – asphere axis verification
    - Parameters to verify, include clocking factors and other aspheric cylinder types of parts (although not generalized to freeforms completely)
    - Method1, Method2, etc.

- Requires Datum verification

11. Data Reporting Methods
    - To help ensure compliance with the needs of other standards such as OP1.002, OP1.004, and OP1.005 as well as the any pertinent ISO standards.
    - Raw data should be required for all processing efforts as a normative deliverable.

Appendices as required

Finally, there are the following methods and factors to consider (from the old outline), included here for closer reference.

Interferometer
Stitching Interferometer
Interferometer with a Null Corrector (spherical, CGH, conic null, sub-nyquist interferometer)
Relative displacement measurements (normal to nominal, z-dirction, other non-normal)

CMM
Profilometer
Instruments to Measure the Surface Slope of an Aspheric Surface Using Deflectometry (is SCOTS in here?)

Instruments to Measure Components with Aspheric Surfaces

- Transmitted wavefront test
- Shack-Hartmann
- Other functional testing)

Other concerns regarding instruments

- Distortion/mapping
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- Focusing
- Knowledge of the reference wavefront for interferometric tests

Expression of Measurement Results

- Surface form errors including removal of alignment errors, surface form error in terms of toleranced coefficients, radius of an asphere
- Residual or mid-spatial frequency errors
- Edge artifacts and masking
- Slope with PSD, Zernike Residual, Amplitude Spectral Density, Structure Functions, other functions such as wavelet transforms; and
- had a question on what irregularity these terms are analyzed