

Draft Minutes  
 ASC OP1 Optics and Electro-Optical Instruments – Optical Elements and Assemblies – Wavefront Standard  
 Monday May 14, 2007, 1:30 p.m. – 5:00 p.m.  
 Rochester Riverside Convention Center  
 Aqueduct B  
 123 East Main Street, Rochester, NY 14604

| <b>Attending</b>                    | <b>Committee Members (6 of 16 w/1 alt.)</b> | <b>Representing</b>               |
|-------------------------------------|---|-----------------------------------|
| <input checked="" type="checkbox"/> | David Aikens                                | Zygo Corporation.                 |
| <input checked="" type="checkbox"/> | Gordon Boulton                              | JDSU                              |
| <input type="checkbox"/>            | Andre Brunfeld                              | Xyratex                           |
| <input type="checkbox"/>            | Benjamin Catching (Alternate)               | JDSU                              |
| <input type="checkbox"/>            | Walter Czajkowski                           | APOMA (Edmund Optics)             |
| <input checked="" type="checkbox"/> | Marla Dowell (by phone)                     | IEEE/LEOS (NIST)                  |
| <input type="checkbox"/>            | Andrei Brunfeld                             | Xyratex                           |
| <input type="checkbox"/>            | Lincoln Endelman                            | SPIE                              |
| <input type="checkbox"/>            | John M. Hamilton                            | Northrop Grumman Corporation      |
| <input checked="" type="checkbox"/> | James E. Harvey                             | CREOL                             |
| <input type="checkbox"/>            | Hal Johnson                                 | Harold Johnson Optical Lab        |
| <input type="checkbox"/>            | Michael Morrill                             | Lockheed Martin Space Systems Co. |
| <input type="checkbox"/>            | William Royall                              | Eastman Kodak Company (Retired)   |
| <input type="checkbox"/>            | Peter Z. Takacs                             | Brookhaven National Lab           |
| <input type="checkbox"/>            | Trey Turner                                 | Research Electro-Optics, Inc.     |
| <input checked="" type="checkbox"/> | Steven VanKerkhove                          | Corning Tropel                    |
| <input checked="" type="checkbox"/> | Ray Williamson                              | Ray Williamson Consulting         |
| <b>Observers (3)</b>                |   |                                   |
| <input checked="" type="checkbox"/> | Gene Kohlenberg                             | OEOSC                             |
| <input checked="" type="checkbox"/> | Stephen Martinek                            | 4D Technology                     |
| <input checked="" type="checkbox"/> | Dr. Valeriy V. Yashchuk                     | Berkeley National Laboratory      |

**Auditor’s Summary of Meeting**

The Task Force reviewed the items that should be included in each of the two draft standards that are under development. The document that will be known as OP1.004 will cover drawing indications for statistical measurement of optical wavefronts. The second one, OP1.005, will cover drawing indications for deterministic measurement of optical wavefronts. After a brief review of a draft scope for OP1.004, a representative from the Berkeley National Laboratory discussed “Two dimensional power spectral density measurements of X-ray optics with the MicroMap interferometric microscope.” This presentation contained information pertinent to OP1.004.

Then the Task Force began reviewing The first cut of a draft of OP1.005. The Task Force Leader volunteered to continue working on the draft using the suggestions offered during the meeting.

The group agreed to meet again in San Diego, CA in August.

**1. Welcome and Introductions**

S. VanKerkhove opened the meeting at 1:45 p.m. with a round of introductions.

**2. Adoption of Agenda**

G. Boulton moved that the draft agenda as modified at this meeting be adopted. D. Aikens seconded the motion. The motion carried unanimously.

### 3. Approval of draft minutes of the January 20, 2007 meeting

D. Aikens moved that the minutes of the previous meeting be approved as presented on the OEOSC web site. G. Boulbee seconded the motion. The motion carried unanimously.

### 4. Wavefront Standards

#### OP1.004

D. Aikens reviewed P. Takacs draft scope document. The draft scope is available on the OEOSC web site under the ASC OP tab. OP1.004 would be a statistical quantities evaluation regardless of spacial scale length, in contrast to OP1.005, which would have a deterministic quantities scope. P. Takacs will use ISO 10110-8 as the starting point for the OP1.004 draft, and wherever possible keep the definitions from the ISO document. There are specific areas where he proposes to improve the content:

1. Define the statistical quantities with more clarity (expand 1D profile to a 2D profile),
2. the concept of ensemble averaging will be defined with the connection between finite number samples and statistical stability,
3. a method for estimating fluctuations in measured mean in measured values,
4. define detrending techniques, and address distortions resulting from detrending,
5. issues involving the discrete sampling of data, addressing the finite pixel size,
6. define Nyquist frequency for a 2D case,
7. specification of a method for normalizing the frequency spectrum,
8. a method for determining error bars on data sets,
9. address the connection between surface statistics and image quality.

D. Aikens said that the OP document will retain the ISO 10110-8 notation, which will be augmented by treatment of the mathematics behind filtering and handling of spatial data in a 2D environment.

S. VanKerkhove said that the Takacs document looks like a wish list than a scope statement. D. Aikens replied that it is more of a scope of the effort to properly define statistical methods for evaluations. The scope of the standard will probably be a subset of this list.

S. Martinek asked if the list could be included in the standard as a reminder of areas that must be addressed to properly measure optical wavefronts. D. Aikens said that if OP would take ISO 10110-8, address the 2D case, and then caution the user to be concerned about the above list, then the resulting document would be a good beginning for the standard.

S. VanKerkhove asked if some of the material could be included in an informative annex. D. Aikens replied that he didn't know how much of this P. Takacs was expecting to accomplish.

V. Yashchuk said that in order for the measurements to be valid they must first be corrected for the MTF of the system so that data from different measuring systems can be compared. This is a serious issue.

S. Martinek said that in the end this document has to have a simple list of basic parameters for an optics manufacturer who is not worried about scatter, but who is cranking out parts. It cannot be too complicated; it must be utilitarian. The manufacturer must understand the impact that the MTF of the measurement system has on the result; however, most optics manufacturers only worry about low spatial frequencies. ISO 10110 is written with third order optics as a basis; the task force is saying that is ISO 10110's shortcomings; however, simplicity should be maintained. D. Aikens agreed that the ISO documents define notations adequately so that the optics industry can specify the parameters; the documents do not delve into some of the finer points of measurement. They do not define how the manufacturer can do great metrology on optical surfaces. D. Aikens agreed that the task force should not be writing another treatise on metrology, but rather create a tool for the optics industry to use to evaluate optical surfaces. J. Harvey agreed with S. VanKerkhove that a detailed annex could be included to cover the technical issues that the manufacturer should consider.

Then V. Yashchuk discussed issues in developing such a standard, and made a presentation on "Two dimensional power spectral density measurements of X-ray optics with the MicroMap interferometric microscope." This presentation is available on the OEOSC web site under the May 14, 2007 meeting documents section.

S. VanKerkhove recessed the meeting at 3:00 p.m. for 15 minutes.

D. Aikens said that the first draft of OP1.004 would be a success if ISO 10110-8 were modified to include power spectrum calibration.

#### OP1.005

S. VanKerkhove said that it took a while for the task force to decide to separate the statistical evaluation from the deterministic evaluation. The deterministic topic is covered in ISO 10110 parts 5 (surface form) and 14 (transmitted wavefront). Most of what appears in those two parts is good. However, this task force decided that it wanted to write some aspects differently, including further definitions where appropriate.

V. Yashchuk said that he thought that Chebyshev polynomials are probably preferred to Zernike polynomials for this application. D. Aikens agreed that to properly mathematically treat the statistical function, one would like to detrend with some long scale-length function that is orthogonal over the data that one is trying to detrend. The Zernike polynomials are

not clean; they bleed into the power spectrum. Polynomials, such as Chebyshev, are cleaner for this application. However, the customer base is expecting Zernike polynomials. The task force is stuck with Zernike polynomials for the deterministic part. The task force has to decide how it will handle the detrending for the statistical part. S. Martinek said that the issue of non-circular apertures could explain why a different polynomial is being adopted. S. VanKerkhove said that Zernike polynomials are embedded in the optical design and measurement infrastructure, and it is not practical to change to a different polynomial. S. Martinek countered that those in the industry who manufacture rectangular components want a better method for describing them. D. Aikens said that the first step could be a treatise that could be added to OP1.005 as an annex addressing Legendre polynomials for rectangular apertures.

V. Yashchuk said that the standard must address the statistics of the residuals that result from the polynomial approximation. D. Aikens said that that subject could be a technical note. The scientific community should tell the user how many terms in the polynomial he should use.

At this point the task force began examining the draft of OP1.005 that was stored on the OEOSC web site. S. VanKerkhove said the scope statement was created to give the task force a talking point. He said that he was looking for guidance concerning the structure of the document. D. Aikens asked if the task force wanted to add methods of evaluating the surface for surface form error? Are we going to treat metrology in this document, or will it be a separate document? He would recommend including a cohesive description of the measurement used in the standard rather than separating metrology as ISO does. S. VanKerkhove asked what we would do when different measurement techniques are used, such as Shack-Hartman, rather than an interferometer? There are also contact and non-contact profilometry measurement techniques. That is why he didn't delve into the area of measurement technique. D. Aikens said that the standard needs to include rules for validating the measurements indicated by this notation. S. VanKerkhove said a lot of that information appears in text books, etc. D. Aikens replied that the notation is not the problem, the validation of the wavefront error is the problem. S. VanKerkhove said that he did not understand why NIST does not certify reference surfaces so that manufacturers could have a known reference sample. There are NIST certified flats. D. Aikens said that he thought the standard still needed an annex that describes some of the fundamental boundary conditions for validating to this standard. The scope should consider how far the process is detailed beyond notation. Does the user need a way to annotate filtering, for example. The scope should tell the user that he needs to have some knowledge of his uncertainty. Should there be a notation for the k-value for the uncertainty that he wants the value to be measured to? Should there be default values?

D. Aikens suggested that Fizeau interferometry is the industry standard method for evaluating surface form. When aspheres are dropped from consideration, then the Shack-Hartman method could be eliminated. When statistical processes are not used, then profilers can also be eliminated. Representatives from 4D and Zygo were attending the meeting; D. Aikens said that if those two companies can agree to the content, then the task force can assume that the document will be relatively safe to use.

S. Martinek suggested that the standard would not have to worry about what equipment was used to generate the data, but the standard should be concerned with the array of data that will be processed to give the values used with the notation. The standard needs to define the conditions required to have confidence in the data. NIST did document processes for radiometry, but have not done the something comparable for optical measurements. D. Aikens agreed that there is no book that describes how to do digital interferometry.

The task force agreed that peak-to-valley measurements are no longer sufficient, but since many manufacturers still use it, the standard will have to include it.

S. VanKerkhove proposed that the Zernike polynomial section of ISO 24517 be added to the definitions for OP1.005. Then the nomenclature can indicate how many terms to use. Then in the section covering types of deviations and specification of tolerances, the user has the opportunity to define a PVQ, PV, or PVR.

S. VanKerkhove asked the task force to look at section 3.6 of the draft. He proposed to add the gradient value, which is not in the current ISO document, because the description is gaining momentum in the industry. D. Aikens said that the task force could help the optics industry by putting in a default filtering to be used for processing these types of data when the user has not specified his own filtering.

V. Yashchuk said that Fourier analysis could be a better approach for determining a slope than polynomial fitting. S. Martinek said that he worries about Fourier transform artifacts. He was also concerned with polynomial fitting because there may be surface structure that cannot be fitted. D. Aikens said that when Fourier transforms are used, windowing has to be considered.

S. VanKerkhove said that he borrowed sections 3.7.4 (tilt approximation) and 3.7.5 (spherical approximation) from ISO 10110-5;1996, with some material from the current version. He prefers the 1996 version as contrasted with the 2006 version. He said that he introduced a new concept in 3.7.6, "rotationally invariant approximation." He pointed out that none of these require polynomial fitting.

S. VanKerkhove said that Section 3.8 comes directly from ISO 14999-4.

In section 3.11 and 3.12 the polynomial functions are called out in general terms.

D. Aikens suggested that the Zernike expansion should be defined very early in the document so that fitting can be defined. Then more meaningful definitions can be created. The terms needed to establish filtering techniques should also be defined early. Filtering is also very important to the definition of other terms. S. Martinek said that perhaps section 4 could include the machine parameters that affect how the terms are calculated. Perhaps it should be an annex. D. Aikens said that he would want to see uncertainty defined with reference to the national standard. He suggested that the task force go straight to the indications so that they know what terms need to be defined. S. VanKerkhove said that he would take a crack at the indication on drawings for the next meeting. He will first look at what the outline of the document should look like, before attacking the indications.

**5. Time and Place for next OP1 Wavefront Meeting**

S. Martinek moved that the group meet next in San Diego, CA . J. Harvey seconded the motion. The motion carried unanimously.

**6. Adjournment**

J. Harvey moved that the meeting be adjourned. S. Martinek seconded the motion. The meeting was adjourned at 4:50 p.m.