Draft Minutes
ASC OP/TF 3 Optics and Electro-Optical Instruments – Optical Elements and Assemblies – Wavefront Standard
Tuesday, October 21, 2008, 8:30 a.m. – 12:00 noon
Rochester Plaza Hotel, River Room
70 State St., Rochester, NY 14614

Attending	Committee Members (10 of 22 w/1 alt.)	Representing
☐	David Aikens	Savvy Optics Corp.
☒	Gordon Boultbee (Alternate)	JDSU
☐	Andre Brunfeld	Xyratex
☒	Benjamin Catching (by phone	JDSU
☐	Walter Czajkowski	APOMA (Edmund Optics)
☒	Marla Dowell	IEEE/LEOS (NIST)
☐	Lincoln Endelman	SPIE (Endelman Enterprises)
☒	Chris Evans	Zygo Corporation
☐	Krishna Gupta	Zygo Corporation
☐	John M. Hamilton	Northrop Grumman Corporation
☐	Hal Johnson	Harold Johnson Optical Lab
☒	Allen Krisiloff	Triptar Lens Company, Inc.
☐	Gene Martin	
☐	Jonathan McGuire	Northrop Grumman Laser Systems
☒	Wayne McKinney	Lawrence Berkeley National Lab
☐	Michael Morrill	Lockheed Martin Space Systems Co.
☒	Bruce Netherton	Lockheed Martin Coherent Technologies
☐	William Royall	Eastman Kodak Company (Retired)
☒	Peter Z. Takacs	Brookhaven National Lab
☐	Trey Turner	Research Electro-Optics, Inc.
☐	Steven VanKerkhove	Corning Tropel
☒	Ray Williamson	Ray Williamson Consulting
☒	Dr. Valeriy V. Yashchuk	Lawrence Berkeley National Lab
	Observers (5)	
☒	Jessica DeGroote	Optimax Systems, Inc.
☒	James E. Harvey	CREOL
☒	Gene Kohlenberg	OEOSC
☒	Stephen Martinek	4D Technology
☒	Alan Tourtlotte	OSA

Auditor's Summary of Meeting

P. Takacs chaired the meeting since S. VanKerkhove was unable to participate. P. Takacs had been unable to devote any time to the development of BSR/OEOSC OP1.004 since the meeting in January, but he would have time from the current meeting and the upcoming January 2009 meeting.

The Task Force discussed nomenclature and definitions and decided that work under ASME B46.1 covering surface roughness standards should be reviewed to determine its impact on the current project.

Surface micro-defects ands their effects upon the analysis of an optical surface were discussed. P. Takacs decided that this standard should deal with the evaluation of surface data, and measurement techniques would be excluded.

The Task Force revisited the outline of BSR/OEOSC OP1.005 that had been presented by S. VanKerkhove at the previous January meeting, and discussed the proper order of items in the outline. There was no scope for the draft standard, so C. Evans of Zygo agreed to create a draft scope with the assistance of J. DeGroote of Optimax by January 15, 2009.

The Task Force agreed to meet again during the SPIE Photonics West Conference the last week of January 2009.

1. Welcome and Introductions

G. Kohlenberg opened the meeting at 8:35 a.m. with a round of introductions. S. VanKerkhove was unable attend the meeting so P. Takacs agreed to chair the meeting.

2. Adoption of Agenda

C. Evans moved to adopt the agenda. R. Williamson seconded the motion, which carried unanimously.

3. Approval of draft minutes of the Sunday, January 20, 2008 meeting

J. Harvey said that in paragraph 5 under **Slope** "D. Aikens said that the stray-light programs are the ones that deal with surface scatter. He presumed that the computer program ASAP would already allow an engineer to enter a PSD value for a surface." J. Harvey continued saying that ASAP requires BRDF not PSD. C. Evans moved that the minutes be approved. M. Dowell seconded the motion, which carried unanimously.

4. Wavefront Standards

a) OP1.004 – statistical methods for measuring wavefronts and surfaces

P. Takacs said that he had no time to work on the OP1.004 draft since the January meeting. He said that his time is free from this meeting date until the January meeting, and he will pick up this draft again. He said that he will have to recast everything in the proper form. One of his projects this year was the x-ray optics metrology section of the revised Handbook of Optics. A lot of the material he prepared for the handbook is directly applicable to this standard.

- **Reconciliation of definitions with ISO/DIS 25178-2 and ASME B46.1**

  The big issues are nomenclature and definitions. He needs to select a symbol for slope error. Some authors use **Z'** and some use **m** or **Δ**. He found one document that uses **G** for gradient. That might be the solution because he does not know of any other surface wavefront metrology use for **G**. A. Krisiloff asked what is the problem if **m** is used. P. Takacs said that **M** is better used to represent **transfer function**. A. Krisiloff responded that a capital **M** is used in that case. P. Takacs said he prefers that capital letters be used. **Z** is the function for the surface profile. An equivalent symbol is needed for surface slope. If **Z'** were used for slope, the prime may get lost. **G** would stand for gradient. C. Evans asked about ISO 3D Surface Roughness Standards 25178-2, which may handle such terms.

  S. Martinek suggested that the Task Force temporally use **G** as a place holder, and then look at other standards to make sure that this standard will be consistent.

  C. Evans said that ASME is now adopting ISO standards; the ISO surface roughness standards are being developed under ISO/TC 213. Ted Vorburger is in charge of the ASME B46.1 standard. M. Dowell will contact him to see the status of B46.1.

- **Address micro-defects (defined both in 3.4 and 3.14)**

  S. Martinek said that S. VanKerkhove was taking this from another document. It was a recognition that the process does leave defects. Unless these defects degrade the measurement then the statistical impact is not that great. The intent was to think of ways to define lateral size in a normalized way, while not constraining it to a physical size. What may be important on a 6 mm size part may be insignificant on a 60 cm part.

  C. Evans said it is important to decide how filtering is done in large-aperture metrology. The surface roughness community is dealing with standardizing filters and physical lengths. That does not make sense in wavefront metrology. However the optics community uses detectors ranging from Polaroid photos to 2 K-pixel CCD imagers, and defining space in terms of pixels isn't very conducive to having agreement between measurements made on different instruments by different operators.

  P. Takacs asked if both wavefront specifications are geared for describing wavefronts or how to measure wavefronts. In other words what are OP1.004 and OP1.005 trying to describe?

  J. Harvey asked if these micro-defects are handled differently than dust or particulate contamination. S. Martinek said that they could be treated in the same manner.

  P. Takacs asked if the standard should deal with how data is processed rather than how to set up for measurement. S. Martinek said that these documents were started as a result of ISO 14999, "Interferometric measurement of optical

elements and optical systems." C. Evans continued that Part 1 starts with Maxwell's equations, which is not the most useful place to start a standard. There are several parts to the document that he does not find particularly useful. In his humble opinion, Part 5 is an abomination. There are a lot of problems with Part 5; it deals with measurement procedure.

P. Takacs concluded that the OP documents will not deal with procedure, but will assume that the data is obtained using proper procedures. S. Martinek said that early in the discussions about the OP documents there was consideration for an informative section describing proper measurement procedures.

A. Krisiloff said that a good standard would provide guidelines for solving the problem of comparing measurements between different instruments and operators. The standard should not be a theoretical exercise. J. DeGroote said that guidelines are important for the manufacturer.

A. Krisiloff said the other problem is to properly describe what is needed when a part is ordered. C. Evans said that the purpose of a standard is to facilitate trade. J. Harvey said that often a purchaser does not know what he or she needs.

J. Harvey said that P. Takacs is in the process of writing a document for analyzing data. Micro-defects should be handled differently than problems with maintaining a clean surface. S. Martinek said that micro-defects and dust should be ignored. P. Takacs said that the user is really interested in the underlying surface shape. R. Williamson said that each instrument will treat micro-defects differently. S. Martinek said that the instrument transfer function will determine how the data is recorded. R. Williamson gave an example of the hi-fi industry which defined harmonic distortion, it but did not describe how to measure it.

A. Krisiloff asked if some of the measurement problems can be side-stepped while writing the standard so that it helps solve the communication problem.

S. Martinek said that the Task Force is fixating on impact of the problems rather than how to enumerate a wavefront. The Task Force cannot solve instrument problems in the standard. It needs to define a wavefront using nomenclature that can be written on a drawing. C. Evans said that there should be some default values. The user can look at the default values to see if they meet his or her needs. If not, then other values could be specified.

J. Harvey said that the optics industry needs to characterize and measure the surface over relevant spatial frequencies. What is relevant is determined by the image quality requirement, the size of the optic, and on the wavelength.

A. Krisiloff asked P. Takacs what he did not like about his first draft. He replied that it is at too high a level. It does not deal with practical information. C. Evans agreed with P. Takacs opinion. A. Krisiloff asked if the problem is word smithing or are there issues that the members of the Task Force may have different opinions. W. McKinney said that there are two major problems, one is education, and the second is that one cannot measure the required frequency range with one instrument. The work to combine results from multiple instruments into one data set has not been done. In a sense, there is nothing to standardize. C. Evans said that the Task Force could specify a figure morphology over some bandwidth and a finish morphology over some bandwidth. Then the PSD could be specified separately. He has seen some drawings that do that. The drawings specify the RMS over a particular bandwidth, and another RMS over a different bandwidth.

P. Takacs said that his goal is to write the standard so that when PSD is calculated from two different instruments the results are the same.

S. Martinek said that the standard should not force PSD down the throats of the optics industry.

J. Harvey said that for a long time he has been advocating the use of PSD and he is encouraged that people are finally beginning to see it used on drawings. P. Takacs said that PSD is essential to determine if the measurements from different instruments correlate. Unfortunately no commercial software, as yet, computes PSD properly.

J. DeGroote said that her company has not received a PSD spec, yet, and it would take a lot of computing time to get the PSD.

J. Harvey said that he would be presenting a paper on "Just Good Enough Optical Manufacturing"the next day at the optical fabrication portion of the OSA conference. He thinks that he can outline a strategy for solving the problem.

- **Expanded 2D PSD definitions**

P. Takacs asked what coordinate system should be used for the presentation of 2D PSD. What does it mean in an R-theta system? W. McKinney said that there is some attraction for cylindrical coordinate systems. But pixels are square so leave it a square coordinate system for now.

W. McKinney said that he would give a 2D PSD talk the next day.

- **rms, rms slope, PSD in the foreword**

P. Takacs said that there are instruments that measure slope directly. Then it is practical to measure the PSD of the slope in the same way that it is calculated for height. Once the data is calculated then statistics can be computed. It is possible to move back and forth from slope and height using PSD.

A. Krisiloff suggested that some members of the Task Force could write down items that need to be included in the standard. Then the group could take that information and begin to integrate it into text for a standard. P. Takacs suggested that V. Yashchuk look at PSD, C. Evans look at filtering in real space as seen in other standards, and J. DeGroote put down questions concerning what she would want to see from a user point of view.

The Task Force took a break at 10:42 a.m. until 10:58 a.m.

- **Bandwidth limits**
  This topic was covered above.

b) OP1.005 – deterministic methods for measuring wavefronts and surfaces

- **Background**
  The secretary projected and read the OP1.005 draft outline that was originally presented to the Task Force at the January 2008 meeting to those assembled at the meeting.

- **Annex**
  A. Krisiloff suggested that in the interest in completing the standard in a timely fashion, the subject of non-circular apertures be delayed until a future revision. C. Evans respectfully disagreed. There is a substantial volume of non-circular parts that have to be dealt with. A. Krisiloff asked if other bases than Zernike polynomials should be included. C. Evans said that the process of adding them would be straight forward. A. Krisiloff asked where they would be included in the standard. C. Evans replied that while there are a significant number of non-circular optics, the majority of parts are circular and can be treated using Zernike polynomials. Therefore, the Task Force does not need to include all other fitting functions, but should provide guidance about dealing with non-circular optics. R. Williamson suggested that a cautionary note be included so that the user does not assume that other polynomial sets are addressed elsewhere in the standard. C. Evans continued that Zernike Polynomials are not required to compute RMS wavefront. But in order to subtract a well known shape from the data, or use coefficients on the drawing, then the user can get into trouble.

  - **Non-Circular Apertures**
    R. Williamson said that the scope could restrict the standard to circular apertures. C. Evans said that the standard should also cover prisms. A. Krisiloff asked if there was a particular rectangular basis that C. Evans would want to see described for prisms. C. Evans replied that certain measurands, such as PD, rms, can be computed straightforwardly by using the Cartesian polynomials to remove piston and tilt.

    C. Evans said that he feels that the Zernike Polynomials are too prominently presented in the standard. A. Krisiloff suggested that the Secretary move the Zernike Polynomials to the bottom of the standard. The Secretary replied that there are two sections dealing with the Zernike Polynomials: 'Definitions' and 'Terms and Functions'. In which section should the Zernikes be demoted? After some discussion, A. Krisiloff suggested that they be dropped to the bottom of the definitions. A. Krisiloff asked if there is a preferred embodiment of the Zernike Polynomials. S. Martinek said that there has been a defacto formalism for ten years that came out of a paper by John Loomis at the Optical Sciences Center, University of Arizona in the 1970s. It was adopted fairly early by Zygo, Code V, Wyko, and others.

    C. Evans said that users have to be careful because there are two different fringe sets. The two sets are different in the numbering of the coefficients. This is an artifact of early computers when subscripts and superscripts were difficult to code. A. Krisiloff asked if the different formalisms should be enumerated. C. Evans said that the description found in ISO DIS 24157 is sufficient.

    R. Williamson and A. Krisiloff suggested that section 4 of the outline be shortened to 'Functions'. A. Krisiloff asked if the item 'Zernike Polynomial Terms' should be expanded to say 'Standard Zernike Polynomial Terms'. S. Martinek said that ISO DIS 24157 should determine the heading. A. Krisiloff suggested that extracts from ISO DIS 24157 would be inserted into this outline as an annex.

    C. Evans said that until the scope of the standard is clearly delineated, then word smithing the outline is a waste of time. The Secretary was asked if there is a written scope. He looked back at documents for OP1.005 and determined that there was no written scope. A. Krisiloff asked if anyone in the room would be willing to draft a scope for OP1.005. C. Evans said that he has a strong opinion concerning what the Task Force is trying to achieve, so he volunteered to draft a scope with help from J. DeGroote.

    A. Krisiloff asked what would be done with the scope when when it is completed. The Task Force has no standard means for communicating during a project. He asked if the Secretary were to open a Yahoo discussion group, and the draft of the scope were uploaded by December 1st, would members of the Task Force be interested in logging in to participate in a

discussion. P. Takacs said that he would forget about it, and finds it more useful to get an e-mail from the Secretary that a document is available on the web. J. DeGroote said that she was part of another group that used Yahoo. She found that it was inconvenient to have to go through the login process. She agrees that it is much easier to get an e-mail that documents are available on the website. C. Evans said that it is easier to turn on track changes so that each person can add his or her comments. Then the author can see what the suggested changes are right in the document.

A. Krisiloff said that currently S. VanKerkhove has not been able to manage the document so that he could take suggestions from others. Also, each person on the Task Force is very busy. That is why he was asking if there is some hi-tech way to help the process along. C. Evans said that his experience is when you have several persons commenting in a document, you get a morass of multi-colored comments that quickly gets complicated. The secretary said that if each person were to send him his or her commented documents, he could put them up sequentially on the web for all to review.

C. Evans said that there are others in Zygo that he could include in reviewing his scope draft, and he would act as an Interim Project Leader for OP1.005. After each meeting someone else could take a turn as the project leader. A. Krisiloff asked if the Secretary could create a separate page for OP1.005. The Secretary confirmed that he could. The Secretary asked for confirmation that this project group would consist of C. Evans, J. DeGroote, and P. Takacs. A. Krisiloff wanted to be included so that he could read the document even though he may not comment. G. Boultbee suggested that everyone at the meeting should be included on the distribution.

PSD will be covered in OP1.004, so does not need to be included here.

5. Time and Place for next OP/TF 3 Wavefront Meeting

The Task Force agreed to meet in San Jose, CA during SPIE's Photonics West Conference. The Secretary said that he would check to see if the room could be available all day on Monday, January 26 so that there could be time for this project. He would re-arrange the other meetings to fit the extended time period.

6. Adjournment

G. Boultbee moved that the meeting be adjourned. R. Williamson seconded the motion. The meeting was adjourned at 12:06 p.m..