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Implementation of ISO 10110 optics drawing standards for the National Ignition Facility

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Abstract

LLNL plans to specify optical components for the National Ignition Facility according to ISO 10110, the new international standard for preparation of optics drawings. The standards have been approved by the international optics community and represent a fairly comprehensive language for describing optical components. We will describe our plan for implementation and experience to date in doing so.

Keywords

Optics drawings, ISO 10110, National Ignition Facility (NIF)

1. Introduction

The international community has recently approved ISO 10110, Preparation of drawings for optical elements and systems, Parts 1–13. This standard is a comprehensive and thorough method for indicating the characteristics, especially the tolerances, of optical elements and systems on a drawing. In the next decade this new standard will become widely accepted and used in the U.S and around the world.

The National Ignition Facility (NIF) comprises 192 separate beam lines, each with 39 or 40 precision optical elements. The clear aperture is approximately 40 cm square. In addition, there are about 40–50 smaller (< 15 cm diameter) laser optical components in the front end. We will specify these components according to the form and function described in ISO 10110.

There are a number of practical issues that we must address in implementing this new standard. The first is knowledge and understanding of the standard itself, both by our staff and by the optics vendors. By means of in-house training, explaining to vendors, and practical application to real components, we are coming to understand the standard and its implications.

An equally important issue is the technical application of ISO 10110 specifications to actual parts. Determination of surface and material imperfections is an example that elucidates the issue. Optics shops do not yet have comparison plates for ISO 10110 scratches and digs; glass suppliers do not grade their blanks by ISO numerology. It's one thing to generate a drawing according to ISO 10110; it's quite another to buy material according to the drawing.

2. ISO 10110

The structure of the standard is shown in Table 1 below. All 13 parts have been approved by the voting member bodies of the ISO and will be published later this year. The standard is metric based and all linear dimensions are in millimeters. (A comma is used instead of a decimal point.) ISO R1101, Technical drawings – Tolerances of form and position, is the applicable mechanical drawing standard. We note that ANSI Y14.5M-1982, Dimensioning and tolerancing, is in general agreement with ISO standards.

Table 1. ISO 10110 structure

Part	Title	Indication
1	General	n/a
2	Material imperfections - Stress birefringence	0/
3	Material imperfections - Bubbles and inclusions	1/
4	Material imperfections - Inhomogeneity and striae	2/
5	Surface form tolerances	3/
6	Centring tolerances	4/
7	Surface imperfection tolerances	5/
8	Surface texture	√
9	Surface treatment and coating	(λ)
10	Table representing data of a lens element	n/a
11	Non-toleranced data	n/a
12	Aspheric surfaces	n/a
13	Laser irradiation damage threshold	6/

3. Translation example: bubbles and inclusions

Using a new standard requires some amount of re-training and re-thinking. The initial reaction of optical engineers and fabricators ranges from reluctance to resistance. The new standard has much to offer, though, and is relatively easy to use after a short period of study. An example is helpful to understand how current language and specifications 'translate' into the ISO format.

Corning Incorporated sells fused silica by inclusion class. The inclusion class is defined by the total inclusion cross section and the maximum inclusion cross section. The total inclusion cross section "defines the sum of the cross-section in mm^2 of inclusions per 100 cm^3 of glass. Inclusions with a cross-section equal to, or less than 0.08 mm diameter are disregarded." The maximum inclusion cross section "refers to the diameter of the largest single inclusion in any single 100 cm^3 of glass."[1]

Table 2 below shows a translation for inclusion classes 0–3 into ISO format, assuming the subaperture test volume call out shown in Fig. 1. For a 35 mm thick blank, this subaperture test volume is about 100 cm^3.

To arrive at these results, we used the following approach. If the total cross-section is A, and the maximum cross-section is d, then the ISO format is 1/NxM, where $\pi(d/2)^2 = M^2$ and $A=NM^2$. The resulting values for N were rounded to the nearest whole number; the values for M were rounded to the nearest preferred ISO class.

Table 2. Current inclusion class and ISO designation

Inclusion Class No.	Total Inclusion Cross Section	Maximum Inclusion Cross Section	ISO Equivalent
0	0.00 – 0.03 mm^2	0.10 mm	1/4x0,10
1	0.03 – 0.10 mm^2	0.25 mm	1/2x0,25
2	0.10 – 0.25 mm^2	0.50 mm	1/1x0,40
3	0.25 – 0.50 mm^2	0.76 mm	1/1x0,63

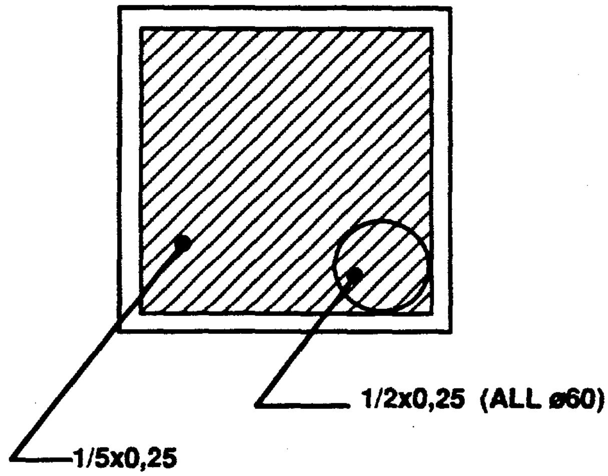


Fig. 1. Bubble and inclusion indication for a fused silica blank that is 35 mm thick. One indication specifies no more than 2 bubbles of class 0,25* within any and all 60 mm diameter subapertures within the clear aperture [1/2x0,25 (ALL ø60)]. Since the part is 35 mm thick, this latter specification applies to volumes that are about 100 cm^3. Since the optical components for NIF are large, we also specify a maximum total number of inclusions permitted in the entire clear aperture. The other indication specifies no more than 5 bubbles of class 0,25* within the clear aperture [1/5x0,25].

(*or any combination of smaller bubbles with the same total area)

A few comments are worth noting. The exclusion of inclusions < 0.080 mm is not strictly consistent with ISO 10110, which states that inclusions < 1/6 of the grade number shall be excluded. Secondly, it is not clear from Corning's product information whether their approach to treating concentrations would be consistent with the ISO 10110 prohibition against concentrations. (A concentration occurs if 20% of the number of allowed bubbles fall within 5% of the test area.) These are, perhaps, relatively minor points, and we believe that over the next few years, even such minor inconsistencies will be addressed.

4. Preliminary NIF specifications

Other papers in this session discussed the origin and technical basis for the optical specifications for NIF. Although the specifications are not yet finalized, it is instructive to see how they are described in ISO 10110 form.

In Table 3 we show the preliminary specifications for a transport spatial filter lens. In NIF the transport lens is an equi-convex, fused silica lens, 435 mm x 437 mm x 26 mm thick with a focal length of 32.5 m. The table includes the optical parameters relating to the material and the optical surfaces. Other mechanical features (e.g., shape, size, radius of curvature, chamfers) would be indicated on a formal drawing.

Implementation of the material call-outs in ISO 10110 are relatively straightforward. A note must be included describing what is meant by striae class 5 (per ISO 10110). The centering, scratch and dig, coating, and damage threshold call-outs are also straightforward.

The surface form and surface texture indications require some additional explanation. The optical surface requirements for NIF are divided into three characteristic spatial frequency regimes: form, waviness, and roughness (definitions to follow). Permissible surface form or long-scale deviations (surface features with characteristic scale lengths > 33 mm) are indicated according to a peak-to-value specification (0,17 waves irregularity at 633 nm). No sag tolerance is given because there is a separate tolerance on the radius of curvature or, equivalently, the focal length. A slope deviation tolerance is given in a note.[2]

Table 3. NIF transport spatial filter lens specifications (preliminary) in ISO format

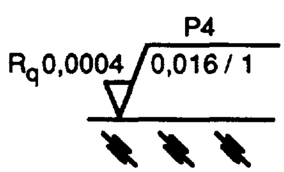
Parameter	ISO indication	Notes
stress birefringence	0/5	
bubbles and inclusions	1/2x0,25 (ALL Ø60) 1/5x0,25	
inhomogeneity and striae	2/4 ; 5	Striations shall not be visible in either a near field shadowgram or in a Schlieren knife-edge test at 633 nm.
surface form	3/– (0,17)	λ is 633 nm. Slope deviation shall be < λ/12/cm with a slope sampling length of 100 mm. Must be verified by measuring the transmitted wavefront (see MEL-xxxxxx).
centering	4/6″	
surface imperfections (scratches and digs)	5/1x0,25 ; L1x0,060 ; E1,0 (ALL Ø50)	Edge chips shall be polished out.
damage threshold	6/ 22 J CM^{-2} ; 1064 NM ; 2 ; 10 HZ ; 10 ; 600	Specification is for a 3 ns, Gaussian-shaped pulse.
surface texture		Surface texture relating to waviness (sampling lengths from 0,12 to 33 mm) is controlled by the transmitted wavefront specification (see table below).
coating	(λ) AR COATING SOL-GEL τ > 99,8% FOR λ = 1053 NM.	Sol-gel coating to be applied at LLNL.

Table 4. Transmitted wavefront specification for NIF transport spatial filter lens

Transmitted wavefront spec #	R_qMAX (in nm)	Min/Max Sampling Lengths (in mm) C / D	Maximum permissible PSD = A/f^B (PSD in nm^2-mm ; f in mm^{-1}) A	B	Test zone diameter (locations indicated on drawing)
1	1,8	1,6 / 33	1,05	1,55	100
2	1,1	0,12 / 2,5	1,05	1,55	7,5

Fine-scale surface structure or roughness (characteristic scale lengths < 0.12 mm) is controlled by the ISO indication for surface texture; this is shown in Table 3 by the check-mark indication. The root-mean-square (rms) roughness, R_qMAX, is in µm, and the minimum/maximum scan lengths are given in mm.

The waviness of the transmitted wavefront arises from intermediate-scale surface features, as well as intermediate-scale material homogeneity variations; these have characteristic scale lengths < 33 mm and > 0.12 mm. The permissible transmitted wavefront deviation is specified in Table 4. Because the spatial frequency bandwidth of the waviness specification is so broad, the band is sub-divided into two bands to match interferometric measurement capabilities (spec # 1 & 2).

The waviness specification has both a maximum permissible value of the rms (R_qMAX) and a maximum permissible value of the power spectral density (PSD) function. R_qMAX is expressed in nm. The PSD curve is given by $PSD = A/f^B$, where the PSD is given in nm^2-mm and f is the spatial frequency in mm^{-1}. Thus, the units for A are (nm^2-mm^{1-B}). The test zone diameter is given in mm.[3]

For NIF it is essential to control the transmitted wavefront of optics used in transmission, such as the lens described in Tables 3 and 4. However, a transmitted wavefront indication is not defined in ISO 10110; parts 5 and 8, describe surface features only (indications are equivalent to a reflected wavefront tolerance). Because a standard has not been established, we developed the description shown in Table 4. It is encouraging that work has begun on parts 14 and 15 of ISO 10110, which will address transmitted wavefront indications on drawings, and we intend to participate in this effort.

5. Conclusion

In conjunction with the derivation and determination of the optical specifications for the NIF, work is progressing on indicating these fabrication requirements on drawings according to ISO 10110. There are some detailed issues to be refined, but the new international standard is a very useful and usable means for precise communication of optical tolerances.

6. Acknowledgements

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7. References

1. "Fused Silica" product brochure, revision 6/93, Corning Incorporated, Advanced Materials Department, Corning, NY 14831.

2. In Table 3, we make reference to a document MEL-xxxxxx. This stands for a measurement document that we will write describing in detail the test configurations, interferometer requirements, data manipulation, and so on. (MEL = Mechanical Engineering Department - Livermore).

3. In the ISO standard for surface texture, part 8, R_qMAX is in µm, the PSD is in μm^3 and the frequency is in μm^{-1}.

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