Translating from American MIL drawings to ISO 10110

Reference to interpret ISO 10110 drawings

Full standard contains complete descriptions and explanations for proper use

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Surface Form Tolerances and Evaluation[5, 19]

- Written as 3/ A(B/C) RMSx < D; λ = E
  - A = PV power in fringes by default, but can be specified in nm or µm
  - B = PV irregularity in fringes by default, but can be specified in nm or µm
  - C = PV rotational invariant irregularity in fringes by default, but can be specified in nm or µm
  - D = rms deviation
    - t = total rms surface deviation
    - i = rms surface deviation with power removed
    - a = asymmetric variant rms surface irregularity
  - E = wavelength (λ) in nm
    - If wavelength is not indicated in the title block, it must be specified in the tolerance
- When a dash or nothing is listed in place of one of the tolerances, that type of tolerance will not be applied
- Further forms of surface form tolerances can be applied, such as surface slope or Zernike coefficients
  - Zernike coefficients written specifically as 3/ Z(n, m) (PV < O; RMS < P)
    - Z(n, m) = Zernike radial polynomial
    - O = PV surface form deviation
    - P = rms surface form deviation

Surface Texture[8]

- Polish code above the texture symbol is either P (polished), G (ground) or P1-P4 (polish grades) which indicate a default specified texture
- Texture requirements written as follows
  - Each requirement on its own line, showing a spatial wavelength band and a surface texture specification separated by a /
  - Spatial wavelengths are given in mm
  - Rq indicates rms surface roughness in microns
  - Wq indicates rms surface waviness in microns
  - RDq indicates rms surface slope in microradians
  - PSD indicates the maximum value of the power spectrum over the specified spatial wavelength band, given as a power coefficient and an intercept in nm^2 mm
- When upper and lower limits are provided they are indicated with a U or an L
- When the lay of the measurement is provided it is indicated as R (radial), C (circumferential), ⊥ (vertical) or = (horizontal).

Surface Centering Error Due to Tilt[6]

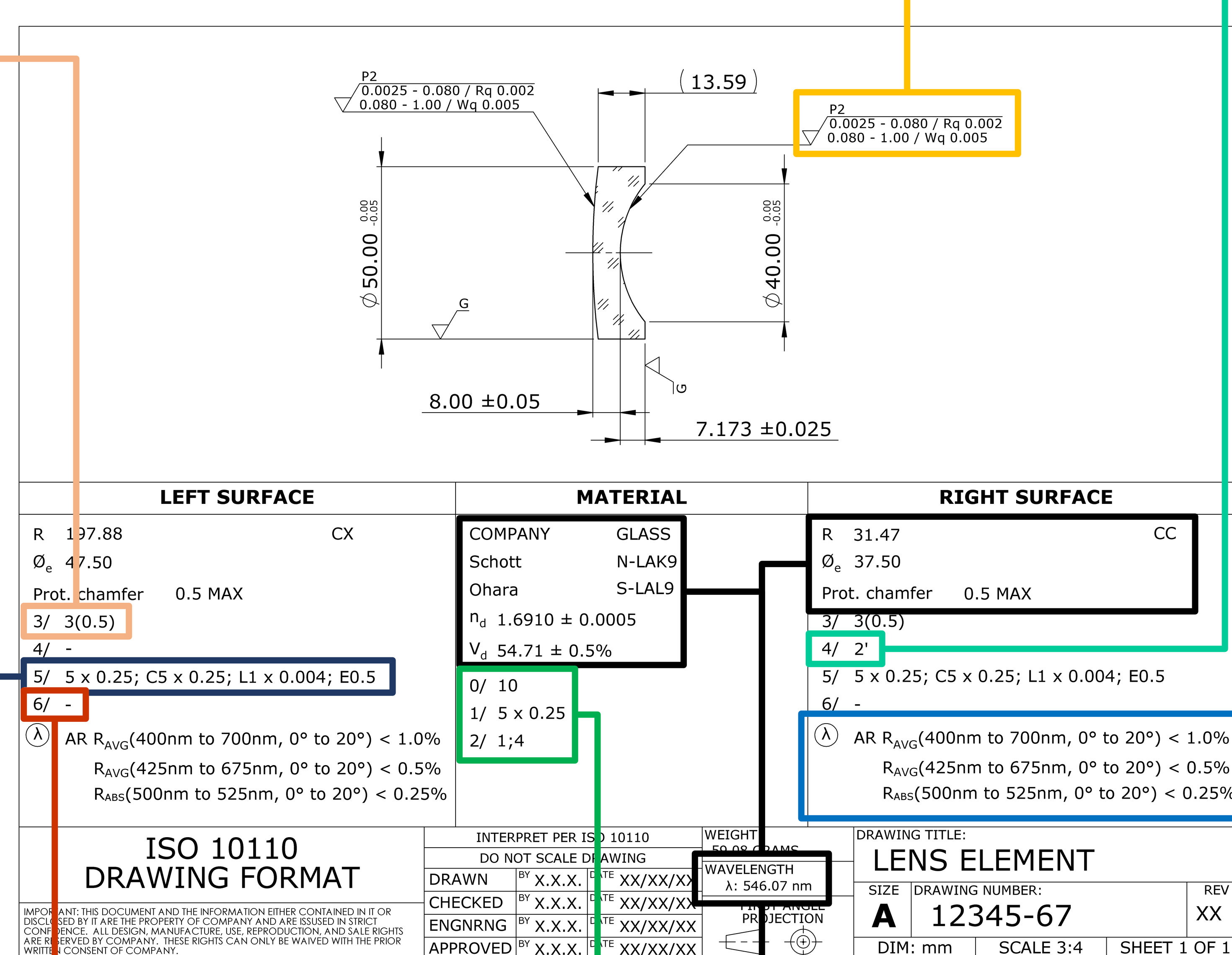
- Default datums exist for typical, centered, spherical elements. If datum axis is unclear, one must be specified
- Written as follows:
  - Spherical Surface: 4/σ
    - σ = maximum tilt relative to either the surface edge (lens edge) or datum axis (optical axis)
  - Aspheric Surfaces or Rotationally Non-Variant Subassemblies: 4/σ(L)
    - σ = maximum tilt
    - L = maximum lateral displacement
  - Surface tilt can alternatively be specified by runout (e.g. lens edge measurement):
    - 4/a < A or 4/c < B
      - A = axial runout at the clear aperture
    - 4/a < A or 4/c < B
      - B = circular runout at the surface edge
- Tolerances can be applied as both angular and linear dimensions at single element or assembly level
- When a dash or nothing is listed in place of a tolerance, that type of tolerance will not be applied

Surface Imperfections and Evaluation[7, 20]

- Imperfections can be described by two methods
  - Visibility imperfections (MIL historical standard): 5/ S-D; CS’-D’; EA_e
    - Each group represents different types of imperfections
      - S-D = general surface scratch and dig designation
      - CS’-D’ = coated aperture scratch and dig designation
      - EA_e = edge chips
    - Accumulation and concentration rules apply
  - Dimensional imperfections (DIN historical standard):
    $N_g \times A_g$; $CN_c \times A_c$; $LN_l \times A_l$; EA_e
    - Each group with a different prefix designation classifies types of imperfections
      - No Prefix = general surface imperfections
      - C = imperfections on across a coating
      - L = long scratches outside of general surface grades
      - E = edge chips
    - Each designation is listed in two methods
      - $N_y \times A_y$
        - N = Number of imperfections within a grade class
        - A = Grade class to characterize imperfections
    - Accumulation and concentration rules apply

Surface Treatment and Optical Coatings[9, 21, 22]

- Functional coatings are indicated by a λ inside a circle
- As defined in ISO 9211 descriptions and applications of an optical coating must precede the specifications for spectral characteristics (e.g. Antireflecting [AR] or Filtering [FI])
  - Coatings specifications can primarily be broken down into three designations
    - τ(λ) or T(λ) = transmission for a waveband
    - ρ(λ) or R(λ) = reflectance for a waveband
    - α(λ) or A(λ) = absorptance for a waveband
  - Additional methods are possible to describe an optical coating past the waveband
    - Angle of incidence (AOI)
    - Aperture size
    - Polarization orientation
    - Phase
- Surface treatments
  - Indicated on the optic by a thick chain line adjacent to the treated region
  - Specifications are written in a box with a leader line to the treated region
  - Surface treatment applications
    - mitigate damage to the optic (i.e. handling, environmental effects)
    - Provide functional uses outside main use of the optic (e.g. stray light control)



Laser Damage Threshold[17, 25, 26]

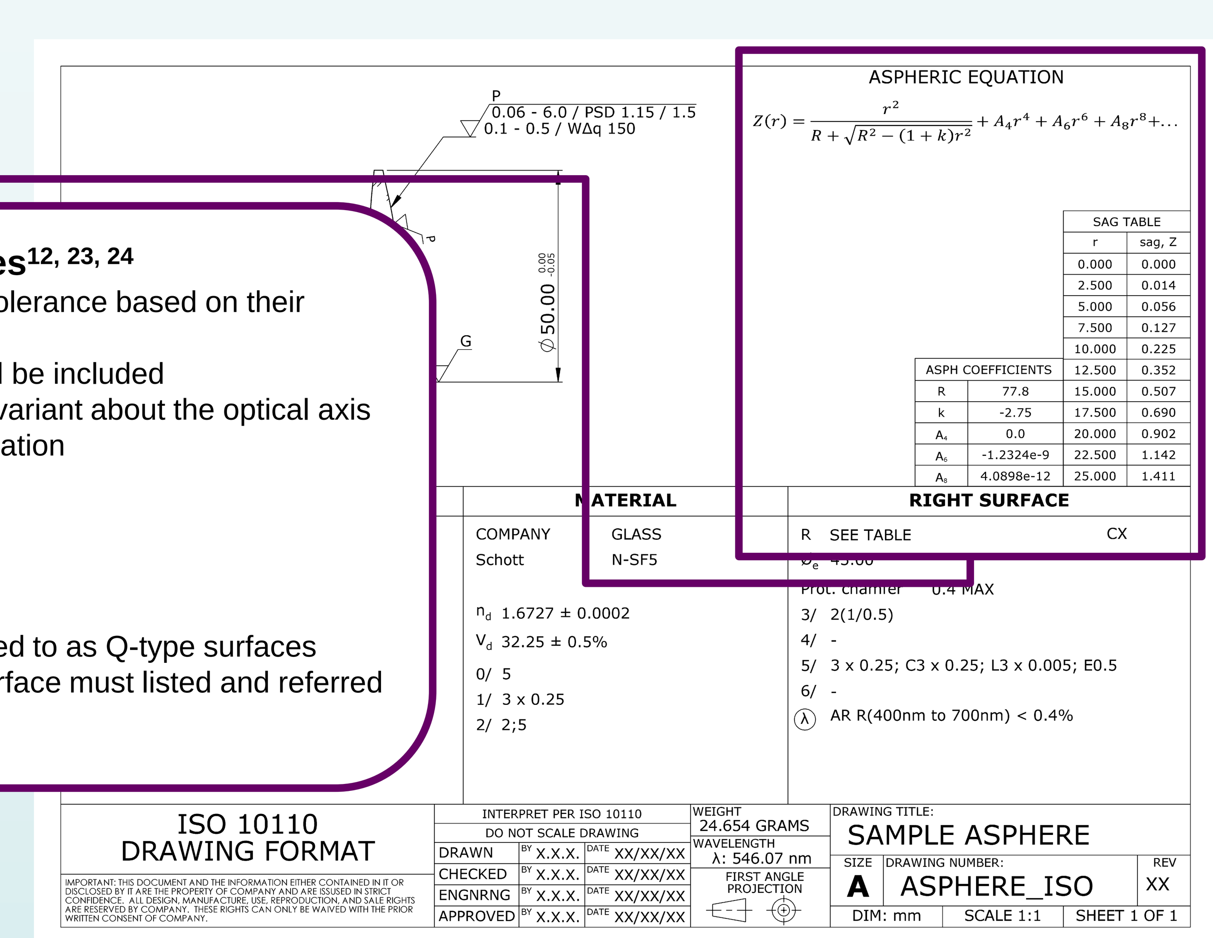
- Written as 6/ X_{th}; λ; τ_{th}
  - X can either be one of three conditions depending on the type of laser irradiation
  - Pulsed laser irradiation:
    - H_{th} = Threshold energy density in units of J/cm^2
    - E_{th} = Threshold power density in units of W/cm^2
  - Long pulse or CW laser irradiation
    - F_{th} = Threshold linear power density in units of W/cm
    - A pulse is considered long when the thermal transit distance, $(2\,D\,\tau_{eff})^{1/2}$, is on the order of the size of the test spot $d_{T,\,eff}$
      - D = Thermal diffusivity
  - In both cases, τ_{eff} = Effective pulse duration in units of s
- When a dash is present following 6/, or the 6/ is not included, the laser damage threshold is not defined and will not be tested

General Notation[1]

- Drawings can be prepared for an optical element or subassembly
- Default conditions unless stated otherwise:
  - Temperature = 20°C
  - Dimensional Units = mm
- Each tolerance property is applied for multiple cases:
  - X/ = element tolerance
  - 1X/ = subassembly tolerance
  - 0X/ = raw material tolerance
- Fundamental dimensions for a rotationally invariant optical element
  - Radius = dimensional value preceded by an R and the curvature orientation (cx or cc)
  - Thickness = dimensional value including tolerance unless specified otherwise
  - Diameter (Ø) = dimensional value including tolerance
    - Effective diameter ($Ø_e$) = sub-aperture where optical tolerances apply
  - Edge corners
    - Bevel = functional corner specified with a dimension, tolerance, and angle
    - Chamfer = nonfunctional corner specified as the maximum or minimum allowed width
- Unless stated within each tolerance where a wavelength is necessary, the title block must include default wavelength
- The following optical material information needs to be listed; either
  - Manufacturer and optical material type
    - Multiple manufacturers may be listed for a given element
  - International glass code
  - The index and Abbe information
    - Material specifications occur at n_d and V_d or n_e and V_e
  - However the glass is specified, the tolerance on the index and dispersion must be indicated

Material Imperfections[18]

- Tolerances for optical materials are determined by three main groups
  - Stress birefringence: 0/A
    - A = maximum allowable optical path difference (OPD) in units of nm/cm
    - Value of stress birefringence is based on quality of annealing and optic size
  - Bubbles and inclusions: 1/N x A
    - A = grade of the bubbles determined by the square root of the projected area
    - N = number of allowable bubbles through a method of accumulation
  - Homogeneity and striae: 2/A;B
    - A = homogeneity grade based on tolerance limits of material
    - B = striae quality based on either the density or the wavefront deviation for a given material path
      - Striae can either be specified by a grade number or the more common shadowgraph class



Aspheric and Rotationally Non-Variant Surfaces[12, 23, 24]

- Both aspheric and rotationally non-variant surfaces are tolerance based on their surface form
  - A sagitta table with Δz (sag) and/or Δs (slope) should be included
- Aspheric surfaces are surfaces that are rotationally non-variant about the optical axis
  - Surface shape is described through a multi-term equation
    - Conic section and a power series
      - $z(h) = \frac{h^2}{R\left[1+\sqrt{1-(1+\kappa)\left(\frac{h}{R}\right)^2}\right]} + \sum_{i=2}^{n} A_{2i} h^{2i}$
    - Conic section and orthogonal polynomials
      - Multiple types of equations commonly referred to as Q-type surfaces
  - Coefficients and equation needed to describe the surface must listed and referred to in the surface radius designation

Wavefront Deformation from an Element of Assembly[14, 19]

- Builds upon surface form tolerance specification where notation changes from 3/ to 13/
  - Written as 13/ A(B/C) RMSx < D; λ = E
- Value specified is needs to be measurable using a single-pass metrology method, typically found to be an interferometer
- Specification would be shown on the drawing view or in a total system specification section of the table
- Assembly deformation example:
  - 13/ - RMSt < 0.04; λ = 632.8 nm
  - Example states that the measured total rms wavefront error needs to be less than 0.04 waves different from the theoretical total rms wavefront error when tested at 632.8 nm
- When a dash or nothing is listed in place of one of the tolerances, that type of tolerance will not be applied

References (Full standard is required for proper use, poster for reference only)

1. ISO 10110-1, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 1: General.” www.iso.org (2018).
5. ISO 10110-5, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 5: Surface form tolerances.” www.iso.org (2015).
6. ISO 10110-6, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 6: Centring tolerances.” www.iso.org (2015).
7. ISO 10110-7, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 7: Surface imperfections.” www.iso.org (2017).
8. ISO 10110-8, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 8: Surface texture.” www.iso.org (2017).
9. ISO 10110-9, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 9: Surface treament and coating.” www.iso.org (2016).
12. ISO 10110-12, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 12: Aspheric surfaces.” www.iso.org (2018).
14. ISO 10110-14, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 14: Wavefront deformation tolerance.” www.iso.org (2018).
17. ISO 10110-17, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 17: Laser irradiation damage threshold.” www.iso.org (2004).
18. ISO 10110-18, “Optics and photonics - Preparation of drawings for optical elements and systems - Part 18: Stress birefringence, bubbles and inclusions, homogeneity, and striae.” www.iso.org (2018).
19. ISO 14999-4, “Optics and photonics - Interferometric measurement of optical elements and optical systems - Part 4: Interpretation and evaluation of tolerances specified in ISO 10110.” www.iso.org (2015).
20. ISO 14997, “Optics and photonics - Test methods for surface imperfections of optical elements.” www.iso.org (2017).
21. ISO 9211-1, “Optics and photonics – Optical coatings – Part 1: Definitions.” www.iso.org (2010).
22. ISO 9211-2, “Optics and photonics – Optical coatings – Part 2: Optical properties.” www.iso.org (2010).
23. Forbes, G. W., “Robust, efficient computational methods for axially symmetric optical aspheres.” Opt. Express **18**, 19700–19712 (2010).
24. Forbes, G. W. & Brophy, C. P., “Asphere, O Asphere, how shall we describe thee?” Proc. SPIE **7100,** 710002 (2008).
25. ISO 11254-1, “Lasers and laser-related equipment - Determination of laser-induced damage threshold of optical surfaces - Part 1: 1-on-1 test.” www.iso.org (2000).
26. ISO 11254-2, “Lasers and laser-related equipment - Determination of laser-induced damage threshold of optical surfaces - Part 2: S-on-1 test.” www.iso.org (2001).