TECHNICAL REPORT

ISO/TR 21477

First edition
2017-08

Optics and photonics — Preparation of drawings for optical elements and systems — Surface imperfection specification and measurement systems

Optique et photonique — Préparation des plans pour les éléments et systèmes optiques — Spécification des imperfections de surface et systèmes de mesure

Reference number
ISO/TR 21477:2017(E)

ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

Contents

Page

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental standards*.

Introduction

ISO 10110-7 provides a notation for the indication of the level of acceptability of surface imperfections of optical elements and optical assemblies. It provides two systems of drawing notations for permissible imperfections: one based on area and size of imperfections and the other based on the visibility or appearance of imperfections.

ISO 14997 provides test methods for these two systems of drawing notation.

These two systems of specification and verification are totally different, with different accumulation and acceptance rules. As a result, a user who is only familiar with one of the systems can become confused when needing to interpret specifications in the other system. There is no way to translate a specification in one system into a specification in the other system because their criteria for acceptability are not interchangeable. The size or area of an imperfection is not correlated with its visibility or brightness.

It is, however, possible to provide a specification in each system which results in practically the same yield loss for large numbers of optical components.

Optics and photonics — Preparation of drawings for optical elements and systems — Surface imperfection specification and measurement systems

1 Scope

This document intends to guide the user to understand the origins, meanings and differences between the two systems of specifying and evaluating surface imperfections in ISO 10110-7 and ISO 14997, specifically the dimensional method and the visibility method, and to provide information on how to use them. Tables are provided to show specifications of roughly equivalent yield loss for imperfections in the two systems.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10110-7, *Optics and photonics — Preparation of drawings for optical elements and systems — Part 7: Surface imperfections*

ISO 14997, *Optics and photonics — Test methods for surface imperfections of optical elements*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10110-7 and ISO 14997 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

4 General discussion of surface imperfection specification and measurement systems

ISO 10110-7 specifies the indication of the level of acceptability of surface imperfections within the test region of individual optical elements and optical assemblies. These include localized surface imperfections, edge chips and long scratches. It provides two systems of drawing notations for permissible imperfections: one based on area and size of imperfections, referred to as the dimensional method, and the other based on the visibility or appearance of imperfections, referred to as the visibility method.

ISO 14997 provides test methods for these two systems of drawing notation. For imperfections specified using the dimensional method, three test methods are described. The first is visual evaluation of the surface without any comparison standard (IV_D). The second is a dimensional assessment of a surface imperfection when compared with a dimensional comparison standard comprised of a series of artefacts of known size (IS_D). The third is the dimensional measurement of a surface imperfection using magnification and either a dimensional comparison standard or a reticle or ruler (IM_D).

For imperfections specified using the visibility method, two inspection methods are described. The first is visual evaluation of the surface without any comparison standard (IV_V). The second is a visibility assessment of a surface imperfection when compared with a brightness comparison standard comprised of a series of artefacts of known brightness (IS_V).

These two systems of specification and verification are totally different, with different accumulation and acceptance rules. There is no way to translate a specification in one system into a specification in the other system because their criteria for acceptability, including the specification, the measurement principle, and the measurement geometry are not interchangeable. There are many factors which contribute to visibility, including surface area, shape, width, depth, morphology and material type. As a result, there is almost no correlation between any single attribute such as imperfection area or scratch width and an imperfection's visibility or brightness. Nevertheless, it is possible to develop some rules of thumb to show specifications which, when applied to a large number of components, will have similar yield loss.

5 Dimensional system of surface imperfection specifications

5.1 General

Since ISO 10110-7 was first published in 1996, the ISO 10110 series has employed a dimensional method of describing surface imperfections, with grades based on the square root of the allowed area of the imperfection. This dimensional method is appropriate for high-value parts where the function of the component could be affected by surface imperfections, but is often found to be too expensive or time consuming for cosmetic imperfections, which have little influence on the optical performance of the optical elements.

5.2 Origin of the dimensional system

The origin of the dimensional system used in ISO 10110-7 traces back to a German drawing standard published by DIN, the Deutsches Institut für Normung. The entire ISO 10110 drawing system is based largely on the 1976 revision of DIN 3140, which uses a number-slash (#/) indication for each of the optics tolerances and/or allowances on an optical component. DIN 3140 was first published in 1958 and was a codification of an internal system of notations used by the company Carl Zeiss in the 1940s or before and at other optics companies in Germany as early as the 1950s. The dimensional imperfection system specifically originated in DIN 3140-7[9], which was withdrawn when ISO 10110-7 was adopted.

5.3 Dimensional comparison standard

Because the dimensional system is based on the size, width or area of the surface imperfections, the imperfections can be measured directly and no comparison artefact is required. Nevertheless, it is often expedient to conduct a visual inspection using a comparison artefact rather than a measurement. ISO 14997 provides a recommended set of comparison artefacts to be used in comparison inspections and several commercial companies offer such a set of artefacts for sale. Since the artefacts are based on size, they are functionally interchangeable and do not need to be called out on the drawing.

6 Visibility system of surface imperfection specifications

6.1 General

Since the 1950s, the de facto standard method of describing surface quality in many parts of the world has been with a pair of numbers referred to as the scratch and dig specification. The scratch and dig specification is a highly subjective visibility standard, which can be adequate for cosmetics, but insufficiently quantitative for performance-based specifications.

When using the visibility system, it is imperative to remember that the test is subjective; different inspectors will inevitably interpret "visibility" differently. Furthermore, the fidelity of the test depends upon both parties using the same or similar brightness comparison standards, and inspecting the parts in strict accordance with ISO 14997.

6.2 Origin of the visibility system

The origin of the visibility system used in ISO 10110-7 and ISO 14997 traces back to an American Military Standard. The scratch and dig specification is found in MIL-PRF-13830B[10], Section 3.5. It, in turn, is based on MIL-O-13830, first released as a military standard in the US in 1954. The surface quality test is based on a visual comparison, under specific darkfield lighting conditions, of a subject surface imperfection and a brightness comparison standard set to determine the visibility or "grade" of the imperfection. The specification references a US Army drawing for surface quality standards, C7641866.

This approach to surface imperfections was first proposed by McLeod and Sherwood in 1945[5]. They offered up brightness comparison standards consisting of artefacts numbered from 10 to 120 to be used in this comparison method. As early as 1945, they recorded that "there is little correlation between the appearance or visibility of a scratch and its measured width". Frankford Arsenal documents dating to the same period declare that "these numbers are arbitrary, and are not to be assumed as denoting the width of the scratch". Scratch morphology is a better predictor of scratch visibility or brightness than width[6].

At Picatinny Arsenal in New Jersey, there is a set of limit standards that date back to 1954 or even earlier. These limit standards are set in pairs, indicating the highest visibility and lowest visibility allowed for a given grade number. These artifacts are the master set from Frankford Arsenal and are still being used to certify submaster comparison standard sets which are sent to the field by the US Army to be used in inspections. The master artifact set has remained intact and virtually unchanged since it was first fabricated in 1945[6].

6.3 Brightness comparison standard

While the scratch and dig system is used all over the world, there is a problem in that the limit standards on which it is based are retained at Picatinny Arsenal for US government use only. Several companies offer comparison standard sets. There are at least two commercial manufacturers: Davidson Optronics and Universal Photonics. There is also a plastic paddle sold by Edmund Optics, Anchor Optics and Thor Laboratories. It is expected that each company does a decent job of certifying them to whatever internal masters they have, but they look different. Figure 1 in Reference [8] shows a comparison of five such scratch sets measured under identical dark-field conditions.

7 Comparison of visibility and dimensional specifications

As has already been discussed, these two systems of specification and verification are totally different, with different accumulation and acceptance rules. There is no way to translate a specification in one system into a specification in the other system because their criteria for acceptability are not interchangeable. The size or area of an imperfection is not directly correlated with its visibility or brightness.

Even so, if a large number of components are manufactured and inspected using the two systems, one can determine a specification which will result in an equivalent yield loss. While the actual components that are rejected can and will be different in the two cases, it is possible to determine an equivalent level of process control and difficulty for the two systems.

Such a comparison is given in Tables 1 and 2. Table 1 shows the various recommended dig grades from the visibility system and an approximately equivalent dimensional specification. Table 2 shows the preferred values of scratch grades and an approximately equivalent long scratch specification using the dimensional method. These tables have been in use by some companies for about 30 years, and are based on historical yield rates for optics manufactured according to the two systems. Tables 1 and 2 only give a reasonable approach which can be used as a guide when a manufacturer is unfamiliar with one or the other system. In no case should these translations be employed as a method of accepting components specified in one system by using the other.