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Optics and photonics — Optical transfer function — Principles and procedures of measurement

Optique et photonique — Fonction de transfert optique — Principes et procédures de mesure

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 9335 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental standards*.

This second edition cancels and replaces the first edition (ISO 9335:1995), of which it constitutes a minor revision. It also incorporates the Technical Corrigendum ISO 9335:1995/Cor.1:2005.

Introduction

The optical transfer function is an important aid to objective evaluation of the image-forming capability of optical, electro-optical and photographic systems.

In order that optical transfer function measurements achieved using different measuring principles or obtained from measuring instruments in different laboratories can be compared, it is necessary to ensure equivalence of measurement parameters such as focus setting and spatial frequency range. For this reason, an agreed terminology has been defined in order for the measurement parameters used in this International Standard to be understood by all users. This International Standard gives guidance for the construction and operation of equipment for optical transfer function measurement.

The specifications in this International Standard form the basic requirements of measurement instrumentation and procedures for guaranteeing a defined accuracy of measurement of the optical transfer function.

Optics and photonics — Optical transfer function — Principles and procedures of measurement

1 Scope

This International Standard gives general guidance for the construction and use of equipment for measurement of the optical transfer function (OTF) of imaging systems.

This International Standard specifies important factors that can influence the measurement of the OTF, and gives general rules for equipment performance requirements and environmental controls. It specifies important precautions that should be taken to ensure accurate measurements and correction factors to be applied to the collected data.

The OTF measuring equipment described in this International Standard is restricted to that which analyses the radiation distribution in the image plane of the optical imaging system under test. Interferometer-based instruments are outside the scope of this International Standard.

2 Normative references

The following referenced documents are indispensable for the application 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 9334, *Optics and photonics — Optical transfer function — Definitions and mathematical relationships*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9334 apply.

4 Measuring equipment and environment

4.1 General aspects

4.1.1 Measuring conditions

Any measured OTF depends on the imaging state (I-state) of the imaging system. Thus, before making measurements, those parameters which form the I-state of the system shall be identified and the degree to which the I-state depends on those parameters determined. The complete set of parameters that form the I-state shall be set to fixed values. The fixed values represent a particular I-state and are called the measuring conditions.

4.1.2 Accuracy of measurement

The measuring equipment, and the environment in which it is used, shall allow the prescribed measuring conditions to be set and maintained to a precision which is consistent with the required accuracy of measurement (see ISO 11421, which describes the various parameters which have an impact on the accuracy of measurement). The accuracy of an OTF measurement may be considered as the combination of measurement uncertainties arising from the many separate parameters in the I-state. When a required accuracy of OTF measurement is stated, it shall be apportioned among the known contributing parameters such that a tolerance can be set for each parameter of the I-state. Thus, an overall requirement to an accuracy of measurement of ±0,05 of the modulation transfer function (MTF) might require, among other factors, a temperature stability of the measuring equipment of ±1 °C and focal plane setting to ±5 µm. The discussion of instrumental and environmental settings in the following subclauses relates to tolerances apportioned from the required OTF measurement accuracy in this manner.

4.2 Environment

4.2.1 General

The ambient conditions of the OTF equipment shall be kept sufficiently free from influences that can lead to climatic, mechanical or electromagnetic disturbances. The measuring equipment and the atmosphere in the measuring room shall be kept free from dust, moisture and smoke. All optical surfaces shall be protected from the incidence of scratches and finger prints.

4.2.2 Temperature and humidity control

The temperature shall be kept constant within a stated tolerance and at a suitable value. Humidity shall also be kept within acceptable limits. Both temperature and humidity shall be recorded. Air turbulence and stratification may affect the measurement and shall be minimized through the use of shielding.

4.2.3 Vibration

Vibration shall be kept to a minimum and the use of basement space is recommended if vibration, caused for example by machinery, cannot otherwise be avoided. The degree of vibration isolation for a given measuring accuracy depends on the characteristics of the vibration, the measuring method, and the spatial frequency range. If the method consists of measuring the line spread function, a suitable tolerance might be that the movement of the image and the analyser caused by vibrations should not exceed, for example, 1/20 of the width at half the maximum intensity of the test slit image.

4.2.4 Electromagnetic disturbances

For some systems, it can be necessary to monitor power supply vibrations and keep these to a tolerable minimum. The influence of external electromagnetic fields and the level of ambient light shall be reduced until they do not affect the measured OTF significantly.

4.3 Measuring equipment

4.3.1 Optical mounts

The basis of any measuring equipment shall be a sturdy optical bench or plate, to which mountings for the test target unit, test specimen, image analyser and other auxiliary units can be attached and brought into position, with respect to each other, to the required accuracy.

Depending on the imaging systems to be tested, different requirements can arise regarding the linearity of adjustments and/or the parallelism of equipment slideways. Deviations from ideal linearity and parallelism requirements shall not cause a greater change of the measured MTF than 1/3 of the permitted or specified measurement accuracy.

4.3.2 Defocusing tolerance

For photographic lenses, the defocusing effects caused by bench misalignment result in errors in the measured MTF which increase with rising spatial frequency or with decreasing *f*-number and reduced wavefront aberration. Table 1 gives the defocusing tolerances of a diffraction-limited lens with circular pupil and incoherent illumination that leads to a ±0,05 MTF change. The wavelength of the light is assumed to be 500 nm.

Table 1 — Defocusing tolerances

Dimensions in micrometres

f-number	Defocusing tolerance for spatial frequency mm^{-1}					
	1	5	10	20	50	100
1	45	9	4,5	2,3	1,0	0,5
1,4	62	12,5	6,3	3,2	1,4	0,8
2	89	18	9	4,7	2,0	1,1
4	180	36,5	18,8	9,8	4,6	3
8	360	74	39	21,5	12	12,2
16	720	157	86	54	49	468

NOTE For a change of 0,10 in MTF, defocusing tolerances are twice those shown in this table.

4.3.3 Provision of measuring scales

The measuring equipment shall provide adequate means for determining the positions of test target, system or device under test (test specimen), image analyser and auxiliary systems. These include scales, spindles and dial gauges. Furthermore, means shall be provided to monitor, set or determine all other parameters that form the I-state of the specimen.

4.4 System components

4.4.1 General

The following subclauses give details concerning the measuring arrangement and its basic elements including the test target unit, test specimen, image analyser and auxiliary imaging systems.

4.4.2 Optical benches

4.4.2.1 General

Several arrangements of the measuring equipment are possible, but those in 4.4.2.2 to 4.4.2.5 are recommended.

4.4.2.2 Object and image at finite conjugates

For tests in which object and image are at finite distances from the test specimen, the configurations shown in Figure 1 or 2 shall be used. In these arrangements, two of the three basic units (test specimen, test target unit and image analyser) are moved along slideways parallel to one another and perpendicular to the reference axis. Usually, the test specimen is fixed and the other two units moved as shown in Figures 1 and 2.

When electro-optical components such as image intensifiers are to be tested, auxiliary imaging systems are used to produce an image of the test pattern at the input of the test specimen. The image at the output of the test specimen is then relayed to the image analyser. The corresponding arrangement is shown in Figure 2.

4.4.2.3 Nominal infinite object conjugate

For tests in which the object conjugate is infinite (i.e. the test target is at the principal focus of a collimator), arrangements similar to that shown in Figure 3 shall be used. When off-axis measurements are to be made, the collimator may be rotated by an angle ω about an axis passing through the entrance pupil of the test specimen and perpendicular to the reference axis (see Figure 3).

Alternatively, the collimator may be fixed and the test specimen and image analyser rotated together about the entrance pupil. In this case, the mounting fixture for the test specimen and the image analyser slideway are both rigidly fixed to a rotating baseplate (this arrangement is consequently often referred to as the “rotary table” type).

4.4.2.4 Nominal infinite image conjugate

The same arrangement as described in 4.4.2.3 (see Figure 3) shall be used, with the image analyser and test target unit interchanged.

4.4.2.5 Object and image at nominal infinite conjugates

For systems which are tested with both the object and image at infinite conjugates, arrangements similar to those shown in Figure 4 shall be used. When off-axis measurements are to be made, the object side collimator with the test target unit should be rotated by an angle ω about an axis passing through the entrance pupil and perpendicular to the reference axis of the test specimen. The image side decollimator, together with the image analyser, shall be rotated by an angle ω' about an axis passing through the exit pupil and perpendicular to the reference axis and shall be refocused according to the test criteria.

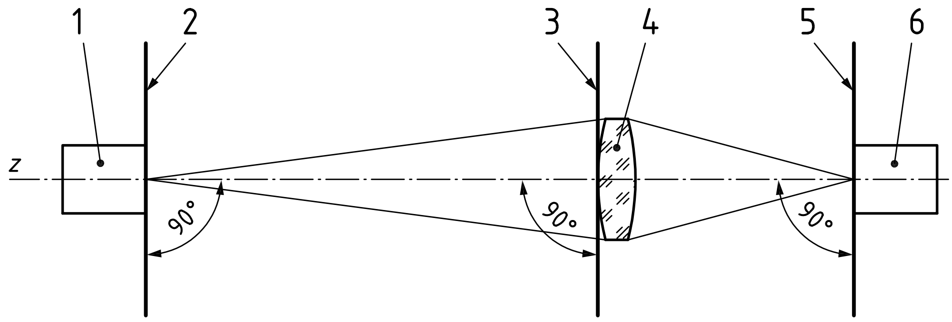
4.4.3 Test target unit

4.4.3.1 General

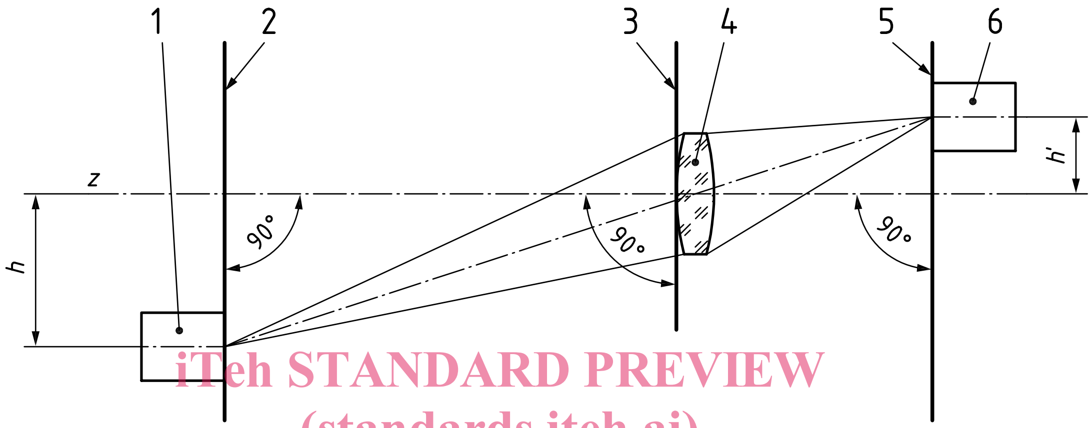
The test target unit shall consist of a source of radiation and a test target.

4.4.3.2 Test target

Depending on the characteristics of the test specimen, several different types of test target may be used. Circular apertures, slits, edges, gratings and self-luminous test targets such as incandescent wires are commonly used. The spatial frequency spectrum of the test target used for the OTF measurement shall be known with an accuracy that is determined by the required measuring accuracy. The actual frequency spectrum of the test target usually differs from its ideal (geometrically predicted) spectrum. If the actual spectrum cannot be measured, precautions shall be taken to ensure that the target is as close as necessary to the specified geometry.



a) On-axis

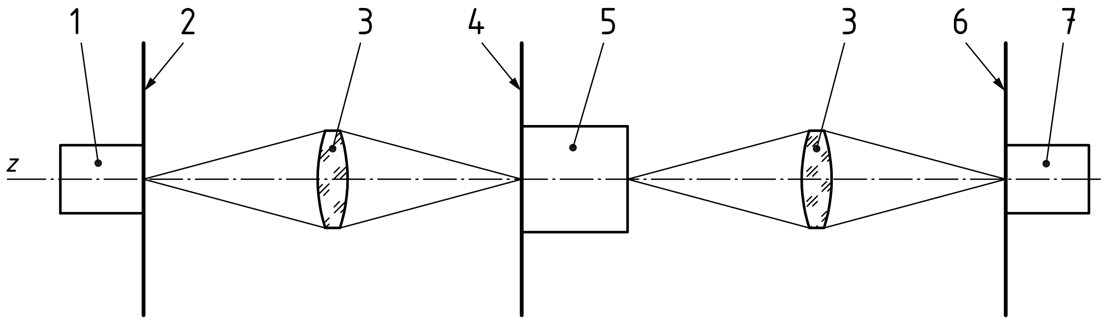


b) Off-axis

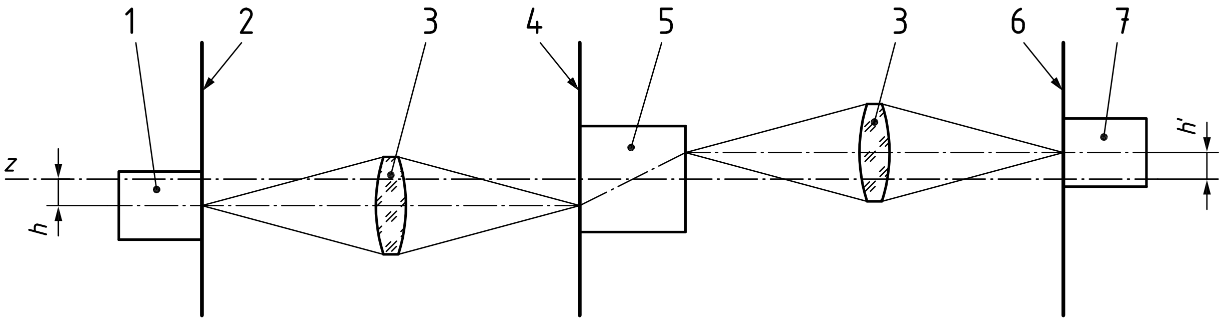
Key

1	test target unit (TTU)
2	TTU slideway
3	fixture for test specimen
4	test specimen
5	image analyser slideway
6	image analyser
z	reference axis
h, h′	object, image heights

Figure 1 — Schematic test setup: object and image at finite conjugates



a) On-axis



b) Off-axis

Key

1 TTU
2 TTU slideway
3 relay lenses
4 fixture for test specimen
5 test specimen
6 image analyser slideway
7 image analyser
z reference axis
h, h' object, image heights

Figure 2 — Schematic setup for image intensifiers