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Optics and photonics — Holography —

Part 2: Methods for measurement of hologram recording characteristics

Optique et photonique — Holographie —

Partie 2: Méthodes de mesurage des caractéristiques d'enregistrement holographique

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Contents

Page

Foreword

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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information.

The committee responsible for this document is ISO/TC 172, *Optics and Photonics*, Subcommittee SC 9, *Electro-optical systems*.

ISO 17901 consists of the following parts, under the general title *Optics and photonics — Holography*:

— *Part 1: Methods of measuring diffraction efficiency and associated optical characteristics of holograms*

— *Part 2: Methods for measurement of hologram recording characteristics*

Introduction

A hologram is an optical device utilizing interference and applied in numerous fields. In order to know the exposure characteristics of materials on which the hologram is to be recorded, it is enough to initially record the hologram under common conditions and subsequently establish the numeral values representing exposure characteristics by measuring the diffraction efficiency. Though the hologram-related terms and the measurement method of critical evaluation parameters (diffraction efficiency, angular selectivity, wavelength selectivity) pertinent to optical characteristics are specified in ISO 17901-1, there is no stipulation as to the conditions concerning hologram recording or the way to calculate the numeral values. Therefore, the purpose of this part of ISO 17901 is to provide the terms and measurement method concerning the hologram exposure characteristics. This part of ISO 17901 does not intend to restrict manufacturing process.

Optics and photonics — Holography —

Part 2: Methods for measurement of hologram recording characteristics

1 Scope

This part of ISO 17901 specifies the terms and measurement method concerning exposure characteristics (exposure characteristic curve, exposure at half-maximum, R-value, amplitude of refractive index modulation) for the hologram recorded by double-beam interference. The materials of hologram to be measured are not restricted to any particular ones. This part of ISO 17901 does not intend to restrict manufacturing process.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15902, *Optics and photonics — Diffractive optics — Vocabulary*

ISO 17901-1:2015, *Optics and photonics — Holography — Part 1: Methods of measuring diffraction efficiency and associated optical characteristics of holograms*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 15902, ISO 17901-1, and the following apply.

3.1
exposure
product of the laser beam irradiance and exposure time on the recording material surface, when the hologram is to be recorded on the recording material

Note 1 to entry: Exposure is represented in Joules per square meter (J/m^2) in the SI unit system, but may also be expressed in micro-Joules per square centimetre ($\mu J/cm^2$) or milli-Joules per square centimetre (mJ/cm^2).

Note 2 to entry: If the object wave or reference wave enters the detector obliquely in the course of the measurement of the irradiance, the value of irradiance might not be measured correctly because of reflection on the surface of the detector. In such an event, it is enough to allow the object wave or reference wave to enter the detector in an approximately vertical direction to measure the radiant flux and then to divide the obtained value by the flux sectional area on the recording material surface.

3.2
exposure characteristics curve
<of the hologram> curve of measured values plotted with the exposure taken on the axis of abscissa and the diffraction efficiency taken on the axis of ordinate, which indicate the characteristics of hologram recording materials

Note 1 to entry: This curve is also called η -E characteristics curve.

3.3
exposure at half-maximum
<of the hologram> smallest exposure that can achieve 50 % of the highest diffraction efficiency in the exposure characteristics curve

Note 1 to entry: This term is a measure to indicate the sensitivity of the hologram recording material. The smaller the exposure at half-maximum, the smaller the light quantity required for hologram recording.

3.4
R-value
diffraction efficiency of the hologram that has recorded the interference fringes of a certain spatial frequency

Note 1 to entry: For the spatial frequency of interference fringes, the value measured in air is used.

Note 2 to entry: This is an index to indicate the resolution of a recording material in terms of the fine detail of the interference fringes identified spatially in the hologram. For the finer interference fringes, the recording material that can achieve the high R-value (diffraction efficiency) can be the recording material that ensures the high resolution in the hologram. For example, R (1000) is equal to 30 when the diffraction efficiency of hologram recorded with the spatial frequency of interference fringes being 1 000 lines/mm is assumed to be 30 %.

3.5
spatial frequency
<of the hologram> number of interference fringes per unit length

Note 1 to entry: This indicates the density of a periodic pattern of interference fringes and is expressed by the number of interference fringes repeated per unit length (lines/mm). This is proportional to the reciprocal of the spacing of interference fringes.

3.6
amplitude of refractive index modulation
<of the hologram> amount of modulation of the refractive index and equivalent to the contrast of interference fringes and the mean refractive index in the recording material of a phase hologram in which the phase is modulated according to the difference in the refractive indices of the recording material.

Note 1 to entry: This is an index to indicate the phase modulation capacity of recording material and expressed also in Δn.

4 Symbols and abbreviated terms

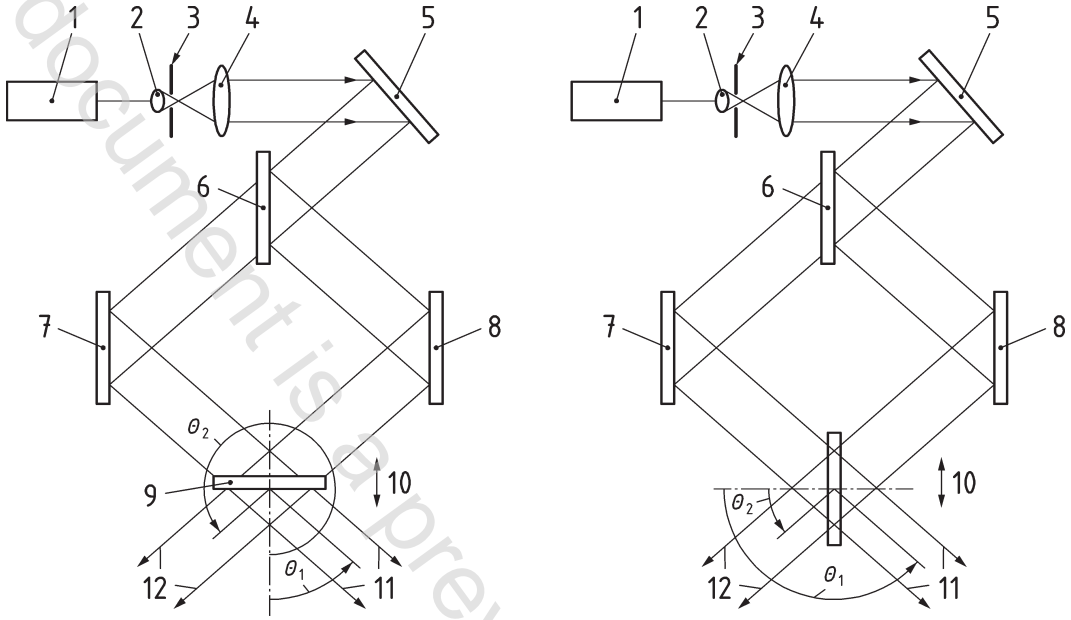
NA	Numerical aperture of objective
λ	Laser wavelength in air (μm)
η	Diffraction efficiency (%)
T	Thickness of hologram (μm)
θ'_B	Bragg diffraction angle (angle inside the hologram) (radian)

5 Principles

Holograms are recorded through mutual double-beam interference of plane waves. Examples of hologram recording optical systems are shown in Figure 1. The measurement is made of the diffraction efficiency of each hologram according to any one of measurement methods specified in ISO 17901-1:2015, 6.5. The exposure characteristics curve, exposure at half-maximum, R-value, or amplitude of refractive index modulation is derived from the relationship between the measured diffraction efficiency value and exposure conditions.

To derive the exposure characteristics curve or exposure at half-maximum, multiple holograms are recorded while changing the exposure and the diffraction efficiency is then measured for each

hologram. To derive the R-value, one or multiple holograms are recorded while adjusting the incident angle of double beams in such a manner that the interference fringes with specific spatial frequency are obtained and subsequently, the diffraction efficiency of each hologram is measured. To derive the amplitude of refractive index modulation, the diffraction efficiency is measured according to any one of measurement methods specified in ISO 17901-1:2015, 6.5. Finally, the amplitude of refractive index modulation can be obtained from the Formula (2) or Formula (3) described in 6.8 to substitute values of the wavelength of light used for the measurement of diffraction efficiency, volume of the hologram, double-beam incident angle, mean refractive index of hologram, and the measured diffraction efficiency.



a) Transmission hologram **b) Volume reflection hologram**

Key

1	laser	7	mirror 2
2	objective	8	mirror 3
3	pinhole	9	hologram recording material
4	collimating lens	10	holder
5	mirror	11	reference wave
6	half mirror	12	object wave

Figure 1 — Example of optical arrangements for hologram recording

6 Measurement methods

6.1 General

The exposure characteristics (exposure characteristics curve, exposure at half-maximum, R-value, and amplitude of refractive index modulation) as specified in this part of ISO 17901 are measured as follows on the basis of the diffraction efficiency as specified in ISO 17901-1. It should be noted that, according to this part of ISO 17901, the exposure characteristics during a hologram recording is derived by measuring the diffractive efficiency of holograms recorded through double-beam interference of plane waves.