TECHNICAL REPORT

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Optics and photonics — Interferometric measurement of optical elements and optical systems —

Part 2: Measurement and evaluation techniques

Optique et photonique — Mesurage interférométrique de composants et systèmes optiques —

Partie 2: Mesurage et techniques d'évaluation

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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.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

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/TR 14999-2 was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 1, *Fundamental standards*.

ISO 14999 consists of the following parts, under the general title *Optics and photonics — Interferometric measurement of optical elements and optical systems*:

— *Part 1: Terms, definitions and fundamental relationships* (Technical Report)

— *Part 2: Measurement and evaluation techniques* (Technical Report)

— *Part 3: Calibration and validation of interferometric test equipment* (Technical Report)

— *Part 4: Interpretation and evaluation of tolerances specified by ISO 10110*

Introduction

A series of International Standards on *Indications in technical drawings for the representation of optical elements and optical systems* has been prepared by ISO/TC 172/SC 1, and published as ISO 10110 under the title *Optics and photonics — Preparation of drawings for optical elements and systems*. When drafting this standards series and especially its Part 5, *Surface form tolerances* and Part 14, *Wavefront deformation tolerance*, it became evident to the experts involved that additional complementary documentation is required to describe how the necessary information on the conformance of the fabricated parts with the stated tolerances can be demonstrated. Therefore, the responsible ISO Committee ISO/TC 172/SC 1 decided to prepare an ISO Technical Report on *Interferometric measurement of optical wavefronts and surface form of optical elements*.

When discussing the topics which had to be included into or excluded from such a Technical Report, it was envisaged that it might be the first time, where an ISO Technical Report or Standard is prepared which deals with wave-optics, i.e. that is based more in the field of physical optics than in the field of geometrical optics. As a consequence only fewer references than usual were available, which made the task more difficult.

Envisaging the situation, that the topic of interferometry has so far been left blank in ISO, it was the natural wish to now be as comprehensive as possible. Therefore there was discussion, whether important techniques such as interference microscopy (for characterizing the micro-roughness of optical parts), shearing interferometry (e.g. for characterizing corrected optical systems), multiple beam interferometry, coherence sensing techniques or phase conjugation techniques should be included or not. Other techniques, which are related to the classical two beam interferometry, like holographic interferometry, Moiré techniques and profilometry were also mentioned as well as Fourier transform spectroscopy or the polarization techniques, which are mainly for microscopic interferometry.

In order to complement ISO 10110 the guideline adopted was to include what presently are common techniques used for the purpose of characterizing the quality of optical parts. Decision was made to complete a first Technical Report, and to then up-date it by supplementing new parts, as required. It is very likely that more material will be added in the near future as more stringent tolerances (two orders of magnitude) for optical parts and optical systems become mandatory when dealing with optics for the EUV range (wavelength range 6 nm to 13 nm) for microlithography. Also, testing optics with EUV radiation (the same wavelength as they are later used, e.g. at-wavelength testing) can be a new challenge, and is not covered by any current standards.

This part of ISO 14999 should cover the need for qualifying optical parts and complete systems regarding the wavefront error produced by them. Such errors have a distribution over the spatial frequency scale; in this part of ISO 14999 only the low- and mid-frequency parts of this error-spectrum are covered, not the very high end of the spectrum. These high-frequency errors can be measured only by microscopy, measurement of the scattered light or by non-optical probing of the surface.

A similar statement can be made regarding the wavelength range of the radiation used for testing. ISO 14999 considers test methods with visible light as the typical case. In some cases, infrared radiation from CO_2-lasers in the range of 10,6 µm is used for testing rough surfaces after grinding or ultraviolet radiation from excimer-lasers in the range of 193 nm or 248 nm is used for at-wavelength testing of microlithography optics. However, these are still rare cases, which are included in standards, that will not be dealt with in detail. The wavelength range outside these borders is not covered.

Optics and photonics — Interferometric measurement of optical elements and optical systems —

Part 2: **Measurement and evaluation techniques**

1 Scope

This part of ISO 14999 gives fundamental explanations to interferometric measurement objects, describes hardware aspects of interferometers and evaluation methods, and gives recommendations for test reports and calibration certificates.

2 Measurement objects

2.1 Surfaces

2.1.1 Mirrors: boundary surfaces of optical components in transmission

A common task in interferometry is measurement of the shape of a surface. This can be accomplished in two different ways. Either reflected light or the light transmitted through the surface could be used for the measurement.

Interferometric measurement is achieved by comparing the difference of two optical path lengths $\int nd$. Usually one path is called the reference path, the other the measurement path.

The resulting wave aberration, ΔW, for a displacement d of the surface, if measured in reflection, is $\Delta W = 2nd$. The same displacement measured in transmission results in the wave aberration $\Delta W = \left(n_2 - n_1\right)d$.

2.1.2 Reflection degree

The Fresnel reflection from the boundary between two different media, R, can be calculated from the refractive index n_1 and n_2 at the boundary surface.

$$R = \left(\frac{n_2 - n_1}{n_2 + n_1}\right)^2 \quad (1)$$

For most optical glasses this value is between 4 % and 6 %, so an average of 5 % is usually a good estimate.

This reflection causes a loss of light from the transmitted wavefront at every surface. On the other hand, this reflection is often used for the measurement itself. To obtain maximum fringe visibility, or contrast, the two interfering beams should have approximately the same intensity. Changing the reflectivity of the beam splitter within an interferometer only changes the amount of light in the interference pattern and does not change the beam intensity ratio of the two beams because the light in both arms is transmitted through and reflected by the beam splitter once. If the measurement path and reference path are separated, as in a Mach-Zehnder or Twyman-Green set-up, it is usually possible to adjust the intensities of the light in both arms.