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

**Part 1:
Terms, definitions and fundamental
relationships**

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

Partie 1: Termes, définitions et relations fondamentales



PDF disclaimer

This PDF file may contain embedded typefaces. In accordance with Adobe's licensing policy, this file may be printed or viewed but shall not be edited unless the typefaces which are embedded are licensed to and installed on the computer performing the editing. In downloading this file, parties accept therein the responsibility of not infringing Adobe's licensing policy. The ISO Central Secretariat accepts no liability in this area.

Adobe is a trademark of Adobe Systems Incorporated.

Details of the software products used to create this PDF file can be found in the General Info relative to the file; the PDF-creation parameters were optimized for printing. Every care has been taken to ensure that the file is suitable for use by ISO member bodies. In the unlikely event that a problem relating to it is found, please inform the Central Secretariat at the address given below.

This document is a preview generated by EVS

© ISO 2005

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either ISO at the address below or ISO's member body in the country of the requester.

ISO copyright office
Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
Web www.iso.org

Published in Switzerland

Contents

Page

Foreword.....	iv
Introduction	v
1 Scope.....	1
2 Wave propagation and some topics on electromagnetic theory	1
2.1 Parameters, symbols, units and constants, operators and computational procedures	1
2.2 Maxwell's equations.....	2
2.3 Electromagnetic fields in a medium.....	3
2.4 Velocity of the wave.....	3
2.5 Refractive index	3
2.6 Scalar wave equation.....	3
2.7 Amplitude, angular frequency, wavelength, wave number	4
2.8 Complex notation, complex amplitude	4
2.9 Irradiance	5
2.10 Poynting vector	5
2.11 Propagation of plane waves	6
2.12 Propagation of spherical wave	8
2.13 Propagation of waves with limited extent	9
2.14 Propagation of aspherical waves	10
3 General description of interference and different types of interferometers	12
3.1 Interference between two waves	12
3.2 Coherence.....	14
3.3 Different arrangements of interference between two beams	19
3.4 Characteristic features for interferometer structures	25
4 Coupled ray-paths in interferometers.....	33
4.1 Aperture stops and field stops; telecentric imaging.....	33
4.2 Coupled ray-path.....	34
4.3 Difference of coherent/incoherent optical imaging.....	34
4.4 Principal layout of an interferometer	35
4.5 Consequences of not properly imaging the test piece onto the detector	39
5 Random and systematic error sources	39
Annex A (informative) Visibility of fringes	41
Bibliography	42

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 14999-1 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 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. which 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 Technical Report 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 Technical Report 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 CO₂-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 are 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.

This document is a preview generated by EVS

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

Part 1: Terms, definitions and fundamental relationships

1 Scope

This part of ISO/TR 14999 gives terms, definitions and fundamental physical and technical relationships for interferometric measurements of optical wavefronts and surface form of optical elements.

It explains why some principles of the construction and use of interferometers are important due to the wave nature of the wavefronts to be measured.

Since all wavefronts with the exception of very extended plane waves do alter their shape when propagating, this part of ISO/TR 14999 also includes some basic information about wave propagation.

In practice, interferometric measurements can be done and are done by use of various configurations; this part of ISO/TR 14999 outlines the basic configurations for two-beam interference.

The mathematical formulation of optical waves by the concept of the complex amplitude as well as the basic equations of two-beam interference are established to explain the principles of deriving the phase information out of the measured intensity distribution, either in time or in space.

Both random and systematic errors may affect the results of interferometric measurements and error types to be clearly differentiated are therefore described in this part of ISO/TR 14999.

2 Wave propagation and some topics on electromagnetic theory

2.1 Parameters, symbols, units and constants, operators and computational procedures

Basic parameters, symbols, units and constants are given in Table 1.

Operators and computational procedures are given in Table 2.