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Geometrical product specifications (GPS) — Surface texture: Areal —

Part 604:
Design and characteristics of non-contact (coherence scanning interferometry) instruments

Spécification géométrique des produits (GPS) — État de surface: Surfacique —

Partie 604: Conception et caractéristiques des instruments sans contact (à interférométrie par balayage à cohérence)

Reference number
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Foreword

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This document was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 290, *Dimensional and geometrical product specification and verification,* in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 25178-604:2013), which has been technically revised.

The main changes are as follows:

— removal of the terms and definitions now specified in ISO 25178-600;

— revision of all terms and definitions for clarity and consistency with other ISO standards documents;

— addition of Clause 4 for instrument requirements, which summarizes normative features and characteristics;

— addition of Clause 5 on metrological characteristics;

— addition of Clause 6 on design features, which clarifies types of instruments relevant to this document;

— addition of an information flow concept diagram in Clause 4;

— revision of Annex A describing the principles of instruments addressed by this document;

— addition of Annex B on metrological characteristics and influence quantities; replacement of the normative table of influence quantities with an informative description of common error sources and how these relate the metrological characteristics in ISO 25178-600.

A list of all parts in the ISO 25178 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user’s national standards body. A complete listing of these bodies can be found at www.iso.org/members.html

Introduction

This document is a geometrical product specification (GPS) standard and is to be regarded as a general GPS standard (see ISO 14638). It influences chain link F of the chains of standards on profile and areal surface texture.

The ISO GPS matrix model given in ISO 14638 gives an overview of the ISO GPS system of which this document is a part. The fundamental rules of ISO GPS given in ISO 8015 apply to this document and the default decision rules given in ISO 14253-1 apply to the specifications made in accordance with this document, unless otherwise indicated.

For more detailed information on the relation of this document to other standards and the GPS matrix model, see Annex C.

This document includes terms and definitions relevant to the coherence scanning interferometry (CSI) instrument for the measurement of areal surface topography. Annex A briefly summarizes CSI instruments and methods to clarify the definitions and to provide a foundation for Annex B, which describes common sources of uncertainty and their relation to the metrological characteristics of CSI.

NOTE Portions of this document, particularly the informative sections, describe patented systems and methods. This information is provided only to assist users in understanding the operating principles of CSI instruments. This document is not intended to establish priority for any intellectual property, nor does it imply a license to proprietary technologies described herein.

Geometrical product specifications (GPS) — Surface texture: Areal —

Part 604: Design and characteristics of non-contact (coherence scanning interferometry) instruments

1 Scope

This document specifies the design and metrological characteristics of coherence scanning interferometry (CSI) instruments for the areal measurement of surface topography. Because surface profiles can be extracted from surface topography data, the methods described in this document are also applicable to profiling measurements.

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 25178-600:2019, *Geometrical product specifications (GPS) — Surface texture: Areal — Part 600: Metrological characteristics for areal topography measuring methods*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 25178-600 and the following apply.

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

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

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

3.1
coherence scanning interferometry
CSI
surface topography measurement method wherein the localization of *interference fringes* (3.7) during a scan of optical path length provides a means to determine a surface topography map

Note 1 to entry: The optical path length difference is the difference in optical path length, including the effect of geometry and refractive index, between the measurement and reference paths of an interferometer (see ISO 10934:2020, 3.3.1).

Note 2 to entry: CSI uses a broad illumination spectral bandwidth or the illumination geometry, or both, to localize the interference fringes.

Note 3 to entry: CSI uses either fringe localization alone or in combination with *interference phase* (3.8) evaluation, depending on the surface type, desired surface topography repeatability and software capabilities.

Note 4 to entry: Table 1 provides a list of alternative terms for CSI that are within the scope of this document.

Table 1 — Summary of common alternative terms for CSI

Term	Bibliography
Coherence probe microscopy Coherence radar Coherence correlation interferometry	References [13], [14], [15], [16], [17] and [18]
White light interferometry White light scanning interferometry Scanning white light interferometry	References [19], [20] and [21]
Vertical scanning interferometry Height scanning interferometry	References [22] and [23]
Full-field optical coherence tomography	Reference [24]

[SOURCE: ISO 25178-6:2010, 3.3.5, modified — Note 1 to entry has been replaced by Notes 1 to 4 to entry.]

3.2
coherence scanning interferometry scan
CSI scan
mechanical or optical scan which varies the optical length of either the reference path or measurement path to vary the optical path difference

Note 1 to entry: The imaging optics is nominally parallel to the axial scan axis of the microscope (see ISO 25178-607:2019, 3.5).

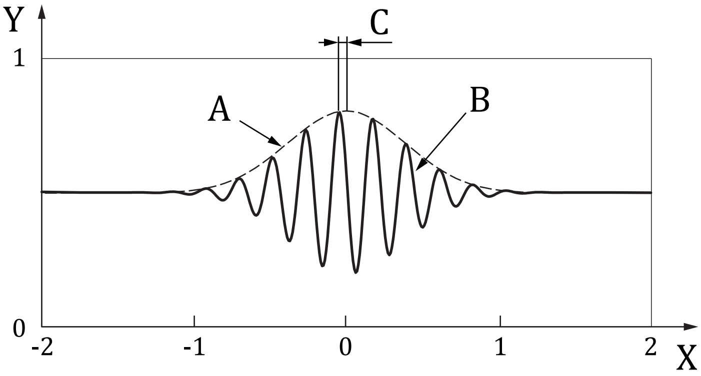
Note 2 to entry: A *CSI signal* (3.3) can correspond to a sequence of electronic camera detections of intensity values during a CSI scan (see Annex A).

Note 3 to entry: In CSI, the most common (but not exclusive) scanning means is a physical adjustment of the path length of an interferometer (see ISO/TR 14999-2).

Note 4 to entry: Mechanical means for performing the CSI scan can be motorized or piezo-electrically driven stages or others, depending on the instrument design, the linearity and consistency of the CSI scan, or the desired maximum *CSI scan length* (3.5).

3.3
coherence scanning interferometry signal
CSI signal
correlogram
white light interferometry signal
intensity data recorded for an individual image point or camera pixel as a function of *CSI scan* (3.2) position

Note 1 to entry: See Figure 1 for a simulated example CSI signal for an *equivalent wavelength* (3.12) of 450 nm and a measurement optical bandwidth of 110 nm at full width half maximum (see ISO 25178-600:2019, 3.3.2) and a low illumination numerical aperture (see ISO 10934:2020, 3.1.10.4 and ISO 25178-600:2019, 3.3.6).



Key

X CSI scan position expressed in micrometres
Y intensity
A modulation envelope (calculated)
B interference fringes
C phase gap

Figure 1 — Defined features of a CSI signal

3.4
coherence scanning interferometry scan increment
CSI scan increment
distance travelled by the *CSI scan* (3.2) between data captures

Note 1 to entry: A data capture can be a single image point or a camera frame.

Note 2 to entry: The CSI scan increment is most often small enough to sample each *interference fringe* (3.7) at several points, e.g. four camera frames per fringe, consistent with the Nyquist criterion. Sub-Nyquist sampling is also possible for higher data acquisition speeds, at the cost of higher measurement noise.

3.5
coherence scanning interferometry scan length
CSI scan length
total range of physical path length traversed by the *CSI scan* (3.2)

Note 1 to entry: The CSI scan length should normally be sufficiently long so as to capture the desired surface topography range plus at least a portion of the modulation envelope width.

3.6
coherence scanning interferometry scanning rate
CSI scanning rate
CSI scan speed
speed at which the *CSI scan* (3.2) is executed

Note 1 to entry: For a linear CSI scan, the CSI scanning rate is the camera frame rate multiplied by the *CSI scan increment* (3.4).

3.7
interference fringe
<coherence scanning interferometry> modulating portion of the *CSI signal* (3.3), related to the interference effect and generated by the variation of optical path length during the *CSI scan* (3.2)

Note 1 to entry: The interference fringes are approximately sinusoidal as a function of scan position.

Note 2 to entry: See Figure 1 for an illustration of the interference fringes of a CSI signal.

Note 3 to entry: The term "interferogram" is often used to describe the image of an interference fringe pattern recorded by a single camera frame (see ISO/TR 14999-2:2019, 6.2). An interference fringe in an interferogram is an attribute of the interference pattern; whereas an interference fringe in *CSI* (3.1) refers to an attribute of a scan-dependent signal, as illustrated in Figure 1.

3.8
interference phase
<coherence scanning interferometry> phase corresponding to the sinusoidal form of the *interference fringes* (3.7) in the *CSI signal* (3.3)

3.9
modulation amplitude
interference fringe visibility
interference fringe contrast
<coherence scanning interferometry> one-half the peak-to-valley variation or equivalent measure of the amplitude of the *interference fringes* (3.7)

Note 1 to entry: See ISO/TR 14999-2:2019, 4.1.2 and 5.2.5, for example uses of the terms “visibility” and “contrast” as synonyms, respectively.

Note 2 to entry: The modulation amplitude of a *CSI signal* (3.3) varies as a function of scan position.

3.10
modulation envelope
fringe contrast envelope
fringe visibility function
fringe visibility envelope
degree of coherence as a function of CSI scan position
overall variation in the *modulation amplitude* (3.9) of a *CSI signal* (3.3) as a function of scan position

Note 1 to entry: See Figure 1 for an illustration of the modulation envelope of a *CSI signal* (3.3).

Note 2 to entry: The modulation envelope is a consequence of limited optical coherence, which follows from using a spectrally broadband light source (white light) or a spatially extended light source, or both.

Note 3 to entry: The modulation envelope is calculated as a function of scan position that depends on the data analysis method.

3.11
coherence scanning interferometry signal processing option
CSI signal processing option
processing selection that determines whether the software makes use of the *modulation envelope* (3.10), the *interference phase* (3.8), a model-based analysis or other approach to interpreting the *CSI signal* (3.3)

Note 1 to entry: See Clause A.3.

3.12
equivalent wavelength
λ_{eq}
<coherence scanning interferometry> change in surface topography height which corresponds to the scan length between two successive *interference fringes* (3.7) in the *CSI signal* (3.3) near the maximum value of the *modulation envelope* (3.10) of a CSI signal

Note 1 to entry: The equivalent wavelength is a definition in the context of CSI for the measurement optical wavelength, defined in ISO 25178-600:2019, 3.3.3, as the “effective value of the wavelength of the light used to measure a surface”.

Note 2 to entry: The measurement optical wavelength is affected by conditions such as the light source spectrum, spectral transmission of the optical components and spectral response of the image sensor array.

Note 3 to entry: The equivalent wavelength can be calculated from factors related to the instrument design, calibrated experimentally, or determined as part of the CSI signal analysis (see Clause A.3).

3.13
width of the modulation envelope
scan length over which the signal strength represented by the *modulation envelope* (3.10) is greater than a defined value

Note 1 to entry: The width of the modulation envelope is quantifiable in different ways, such as the full width at half maximum (FWHM).

Note 2 to entry: The width of the modulation envelope is related to the coherence length described in ISO 11145:2018, 3.11.4, and is a function of the light source bandwidth (see ISO 25178-600:2019, 3.3.2), the camera spectral sensitivity and geometrical factors such as the numerical aperture of the illumination (see ISO 10934:2020, 3.1.10.4 and ISO 25178-600:2019, 3.3.6).

3.14
phase gap
ϕ_G
<coherence scanning interferometry> offset in units of phase at the *equivalent wavelength* (3.12) between the *CSI scan* (3.2) position for the *interference fringe* (3.7) and the maximum value of the *modulation envelope* (3.10) of a *CSI signal* (3.3)

Note 1 to entry: See Figure 1 for an example CSI signal illustrating the phase gap.

Note 2 to entry: The phase gap is a calculated value that depends on the data analysis method.

Note 3 to entry: The phase gap can vary as a function of optical dispersion in the instrument optics as well as sample surface characteristics such as surface films (see ISO 25178-600:2019, 3.4.1), local slope and optically non-uniform materials (see ISO 25178-600:2019, 3.4.6).

3.15
fringe-order error
2π error
<coherence scanning interferometry> error in the identification of the correct 2π phase interval in a topography map that makes use of the *interference phase* (3.8) as part of the *CSI signal processing option* (3.11)

Note 1 to entry: Fringe-order errors are integer multiples of one-half the *equivalent wavelength* (3.12) in height.

Note 2 to entry: Fringe-order errors can lead to artificial steps within the topography map. On smooth, continuous surfaces, these artificial steps can sometimes be corrected by using phase unwrapping algorithms (see ISO/TR 14999-2:2019, 6.6)

4 Instrument requirements

An instrument according to this document shall perform areal surface topography measurements of a sample surface using CSI. The instrument shall comprise an interferometer (see ISO/TR 14999-2) and means to perform a CSI scan. The instrument shall acquire camera images captured at scan positions determined by a CSI scan increment. The data acquisition proceeds at a CSI scanning rate over a CSI scan length. The CSI signal for a single image point shall comprise interference fringes having an interference phase and modulation amplitudes shaped by a modulation envelope characterized by the width of the modulation envelope. The instrument shall convert acquired data to an areal topography using a CSI signal processing option that uses the interference fringes or modulation envelope, or both. The topography height values shall be inferred from either the CSI scanning rate or the equivalent wavelength, or both. If the final surface topography relies on the interference phase, the CSI signal processing option shall take into account the phase gap when interpreting the interference fringes, so as to avoid fringe-order errors.

Figure 2 shows the information flow between these elements for a CSI microscope, from the real surface to a scale-limited surface. Example CSI hardware, techniques and error sources are given in Annexes A and B.