BS EN IEC 61757-1-1:2020

BSI Standards Publication

Fibre optic sensors

Part 1-1: Strain measurement — Strain sensors based on fibre Bragg gratings

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National foreword

This British Standard is the UK implementation of EN IEC 61757-1-1:2020. It is identical to IEC 61757-1-1:2020. It supersedes BS EN 61757-1-1:2017, which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee GEL/86/3, Fibre optic systems and active devices.

A list of organizations represented on this committee can be obtained on request to its secretary.

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EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN IEC 61757-1-1

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Supersedes EN 61757-1-1:2017 and all of its amendments and corrigenda (if any)

English Version

Fibre optic sensors - Part 1-1: Strain measurement - Strain sensors based on fibre Bragg gratings (IEC 61757-1-1:2020)

Capteurs fibroniques - Partie 1-1: Mesure de déformation - Capteurs de déformation basés sur des réseaux de Bragg à fibres
(IEC 61757-1-1:2020)

Lichtwellenleitersensoren - Teil 1-1: Dehnungsmessungen - Dehnungssensoren basierend auf Faser-Bragg-Gitter
(IEC 61757-1-1:2020)

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European foreword

The text of document 86C/1642/FDIS, future edition 2 of IEC 61757-1-1, prepared by SC 86C "Fibre optic systems and active devices" of IEC/TC 86 "Fibre optics" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61757-1-1:2020.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2021-02-01
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2023-05-01

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The text of the International Standard IEC 61757-1-1:2020 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60793-1-30	NOTE	Harmonized as EN 60793-1-30
IEC 60793-1-31	NOTE	Harmonized as EN IEC 60793-1-31
IEC 60793-1-33	NOTE	Harmonized as EN 60793-1-33
ISO 527-4	NOTE	Harmonized as EN ISO 527-4
ISO 7500-1	NOTE	Harmonized as EN ISO 7500-1
ISO 14125	NOTE	Harmonized as EN ISO 14125

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Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

Publication	Year	Title	EN/HD	Year
IEC 60050	series	International Electrotechnical Vocabulary	-	-
IEC 60068-2	series	Environmental testing - Part 2: Tests	EN 60068-2	series
IEC 60793-2	-	Optical fibres - Part 2: Product specifications - General	EN IEC 60793-2	-
IEC 60793-2-50	-	Optical fibres - Part 2-50: Product specifications - Sectional specification for class B single-mode fibres	EN IEC 60793-2-50	-
IEC 61300-2	series	Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Part 2: Tests	EN 61300-2	series
IEC 61754	series	Fibre optic interconnecting devices and passive components - Fibre optic connector interfaces	EN 61754	series
IEC 61757	-	Fibre optic sensors - Generic specification	EN IEC 61757	-
IEC/TR 61931	-	Fibre optic - Terminology	-	-
IEC 62129-1	-	Calibration of wavelength/optical frequency measurement instruments - Part 1: Optical spectrum analyzers	EN 62129-1	-
IEC 62129-2	-	Calibration of wavelength/optical frequency measurement instruments - Part 2: Michelson interferometer single wavelength meters	EN 62129-2	-
IEC 62129-3	-	Calibration of wavelength/optical frequency measurement instruments - Part 3:Optical frequency meters internally referenced to a frequency comb	EN IEC 62129-3	-

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Publication	Year	Title	EN/HD	Year
ISO/IEC Guide 99	-	International vocabulary of metrology - Basic and general concepts and associated terms (VIM)	-	-

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FIBRE OPTIC SENSORS –

Part 1-1: Strain measurement – Strain sensors based on fibre Bragg gratings

FOREWORD

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International Standard IEC 61757-1-1 has been prepared by subcommittee SC 86C: Fibre optic systems and active devices, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2016. This edition constitutes a technical revision.

This edition includes the following technical changes with respect to the previous edition:

a) update of cited standards;
b) clarification of definitions and test specifications.

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
86C/1642/FDIS	86C/1650/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 61757 series, published under the general title *Fibre optic sensors*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
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INTRODUCTION

The IEC 61757 series is published with the following logic: the sub-parts are numbered as IEC 61757-M-T, where M denotes the measure and T, the technology.

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FIBRE OPTIC SENSORS –

Part 1-1: Strain measurement – Strain sensors based on fibre Bragg gratings

1 Scope

This part of IEC 61757 defines detail specifications for fibre optic sensors using one or more fibre Bragg gratings (FBG) as the sensitive element for strain measurements. Generic specifications for fibre optic sensors are defined in IEC 61757.

This document specifies the most important features and characteristics of a fibre optic sensor for strain measurements, based on use of an FBG as the sensitive element, and defines the procedures for their determination. Furthermore, it specifies basic performance parameters and characteristics of the corresponding measuring instrument to read out the optical signal from the FBG. This document refers to the measurement of static and dynamic strain values in a range of frequencies.

A blank detail specification is provided in Annex B.

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.

IEC 60050 (all parts), *International Electrotechnical Vocabulary* (available at www.electropedia.org)

IEC 60068-2 (all parts), *Environmental testing – Part 2: Tests*

IEC 60793-2, *Optical fibres – Part 2: Product specifications – General*

IEC 60793-2-50, *Optical fibres – Part 2-50: Product specifications – Sectional specification for class B single-mode fibres*

IEC 61300-2 (all parts), *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 2: Tests*

IEC 61754 (all parts), *Fibre optic interconnecting devices and passive components – Fibre optic connector interfaces*

IEC 61757, *Fibre optic sensors – Generic specification*

IEC TR 61931, *Fibre optic – Terminology*

IEC 62129-1, *Calibration of wavelength/optical frequency measurement instruments – Part 1: Optical spectrum analyzers*

IEC 62129-2, *Calibration of wavelength/optical frequency measurement instruments – Part 2: Michelson interferometer single wavelength meters*

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IEC 62129-3, *Calibration of wavelength/optical frequency measurement instruments – Part 3: Optical frequency meters internally referenced to a frequency comb*

ISO/IEC Guide 99, *International vocabulary of metrology – Basic and general concepts and associated terms (VIM)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61757, IEC 60050 (all parts), IEC TR 61931, ISO/IEC Guide 99 (VIM), and the following apply.

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

- ISO Online browsing platform: available at https://www.iso.org/obp
- IEC Electropedia: available at http://www.electropedia.org/

NOTE Long period gratings, non-uniform gratings, angled gratings, and FBG in polarization maintaining fibre are not considered.

3.1
fibre Bragg grating
FBG
phase diffraction grating integrated in optical single-mode silica-based fibres, according to category B of IEC 60793-2-50, to selectively reflect a very narrow range of wavelengths while transmitting others

Note 1 to entry: To achieve this characteristic, periodically spaced zones in the fibre core are altered to have different refractive indexes slightly higher than the core.

Note 2 to entry: This note applies to the French language only.

3.2
FBG strain sensor
device that uses one or more fibre Bragg gratings (3.1) as a sensitive element for strain measurements

Note 1 to entry: Different configurations are possible (see 5.2).

3.3
Bragg wavelength
λ_{Bref}
wavelength of the FBG (3.1), generally corresponding to the Bragg reflection peak or transmission minimum, without applied strain under reference ambient conditions

Note 1 to entry: If referred to as an FBG strain sensor (see 3.2), it refers to the configuration prior to its installation.

Note 2 to entry: λ_B is the wavelength of the FBG strain sensor indicated by the manufacturer without any further mechanical and ambient specification.

3.4
reference wavelength
λ_0
wavelength response of an FBG after installation or at the beginning of measurement to the affecting loading and ambient conditions

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3.5
FBG reflectivity
R_{FBG}
ratio of the incident optical power P_0 to the reflected optical power $P_{\lambda B}$ at Bragg wavelength λ_B in a defined spectral window

Note 1 to entry: The power transmitted to the FBG strain sensor is less than the incident (input) optical power due to losses in the fibre at the connector and even in the grating. The definition of the FBG reflectivity should therefore use the incident optical power P_0 (see the equations in 7.4.2) that represents the measurable part at the connector of a fibre optic sensor.

Note 2 to entry: P_0 depends on the measurement device and has no absolute characteristic value. From the user's point of view, the reflectivity is important if operational or installation conditions exist that influence the reflective characteristic.

3.6
transmission loss of an FBG sensor
loss of power of the transmitted optical signal passing along the optical fibre, the fibre Bragg grating and the components to connect an FBG strain sensor outside the FBG spectrum

Note 1 to entry: When considering transmission loss in an FBG sensor configuration, all parts that contribute to the reduction of power, for example transmission losses due to joining and connecting techniques, have to be considered. The transmission spectra of the grating can show a reduction of the grating transmissivity due to influences on grating performance. Such propagation losses in the grating should be considered separately. The entry only applies to wavelength multiplexed FBG strain sensors double-ended for in-series connection.

3.7
FBG spectral width
full width at half maximum (FWHM) of the reflection peak or transmission minimum at Bragg wavelength

Note 1 to entry: The FWHM of an FBG spectrum is the wavelength range of the spectrum over which the amplitude is greater than 50 % (3 dB) of its reflectance maximum value at λ_B (see Figure 1).

Note 2 to entry: This note applies to the French language only.

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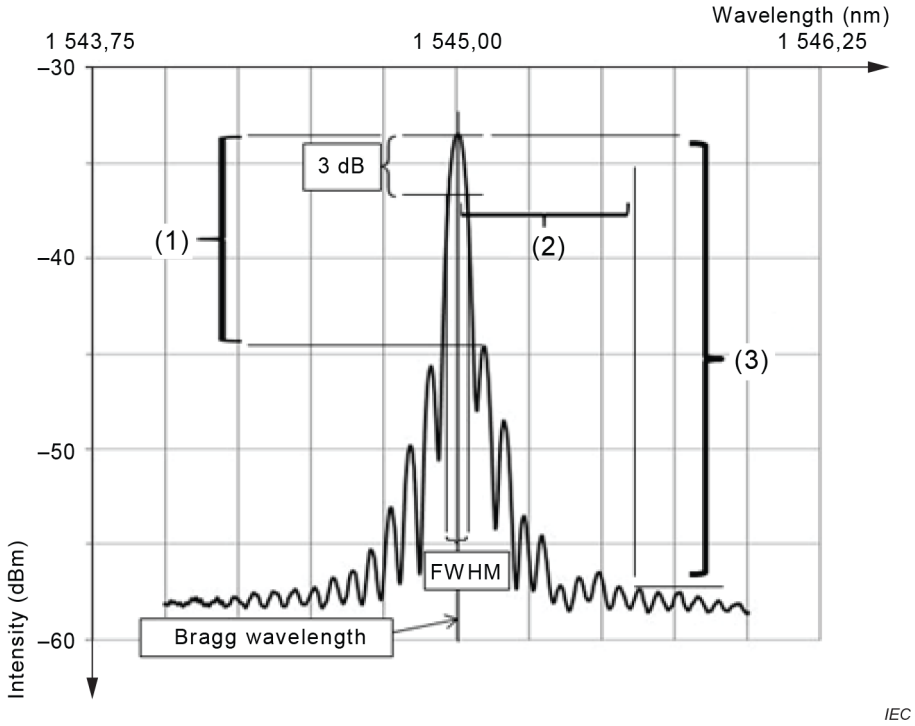

Key

(1) difference in intensity between Bragg peak and largest side-lobe (called "relative side-lobe level")

(2) recorded spectral distance (see 3.12) from the maximum value of one or both sides of the Bragg wavelength

(3) FBG signal-to-noise ratio SNR_{FBG} for (2)

Figure 1 – Characteristics of the Bragg grating reflectance spectrum

3.8
side-lobes
reflection peaks on each side of the Bragg wavelength peak λ_B

Note 1 to entry: Side-lobes are also called "side modes".

Note 2 to entry: Side-lobes shall be considered according to conditions of use (see Figure 1 and Clause A.2).

Note 3 to entry: To describe the transmission characteristics, the following features should be reported:

– maximum attenuation of the transmission spectrum due to parasitic optic effects (in dB);

– maximum attenuation of the transmission spectrum within the wavelength range λ_B ± 1 nm.

Note 4 to entry: The quality of the wanted signal is expressed by the signal-to-noise ratio (SNR). The wavelength range reported can deviate from those usually related to the SNR. In this case, it shall be explicitly reported.

3.9
relative side-lobe level
ratio of the maximum value of the amplitude of the specified field component in a side-lobe to the maximum value in a reference lobe

Note 1 to entry: The reference lobe of an FBG is the peak power at the Bragg wavelength λ_B; peak power of the largest side-lobe in the FBG spectrum is the related field component (see Figure 1).

Note 2 to entry: Relative side-lobe level is usually expressed in decibels.

Note 3 to entry: Some manufacturers indicate this term as side-lobe suppression ratio (SLSR).

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3.10
width level
relative amplitude difference between a local maximum and a specified amplitude, at which a spectral feature is evaluated for a two-sided threshold crossing for purposes of defining that local maximum as either a fundamental peak or as a side-lobe

Note 1 to entry: The width level is applied as an evaluative relative threshold to a local maximum.

Note 2 to entry: Width level is expressed in decibels.

3.11
peak width
width over which a local maximum exhibits a two-sided spectrum crossing over a threshold defined by the width level parameter

Note 1 to entry: The quantity FBG spectral width is defined as the spectral width of the FBG fundamental mode and will be equal to or greater than the peak detection algorithm's peak width requirement when the width level is defined as 3 dB.

Note 2 to entry: The peak width requirement is applied in conjunction with the width level parameter to distinguish fundamental peaks from side-lobes in an array spectrum where side-modes may be at an absolute amplitude higher than adjacent fundamental peaks.

Note 3 to entry: When several sensors are used in a Bragg grating array, special attention shall be paid to the transmission characteristic. If wavelength multiplexing is used, unintentional signal-crosstalk of the Bragg grating pulses is possible. The Bragg grating wavelengths shall be designed with a sufficient distance of the Bragg peaks in the available spectrum to avoid overlapping of the Bragg wavelength. Parasitic reflexions, if relevant, shall be suppressed.

Note 4 to entry: Peak width is expressed in nanometres.

3.12
FBG signal-to-noise ratio
SNR_{FBG}
ratio of the maximum amplitude of the Bragg wavelength peak to that of the coexistent side-lobe amplitude at a wavelength distance of 1 nm under unloaded conditions

Note 1 to entry: SNR_{FBG} shall not be confused with the side-lobes of an FBG caused by the inscription process and depending on the grating number, grating distance Λ and the change in the refractive index of the FBG. Noise is generated by the measurement device; side-lobes are generated during inscription of the grating and have great importance for the use of an FBG as strain sensor (see Figure 1 and 3.7).

Note 2 to entry: The value "1 nm" is still valid even if the central wavelength of an FBG is extended to the visible range.

Note 3 to entry: FBG signal-to-noise ratio is expressed in decibels.

Note 4 to entry: This note applies to the French language only.

3.13
FBG strain sensitivity
ratio of the relative change in wavelength $\Delta\lambda/\lambda_0$ for a given strain change $\Delta\varepsilon$ defined by the equation

$$\frac{\Delta\lambda}{\lambda_0} = (1-p)\Delta\varepsilon$$

Note 1 to entry: FBG strain sensitivity describes the response of an FBG to uniaxial strain deformation $\Delta\varepsilon$ of the grating area. The strain response is represented by the photo-elastic coefficient p. For practical use, the gauge factor k is introduced as a linear approximate for $(1 - p)$. In this case, the sensitivity can be considered as a linear function for a uniformly non-integrated stretched grating area (see 7.6), i.e. only the optical fibre and coating are deformed.

Note 2 to entry: Frequently, this term is defined, for practical reasons, as the peak shift ($\Delta\lambda$ in nm) over the introduced strain change ($\Delta\varepsilon$ in μm/m) related to a specified reference wavelength λ_0.

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Note 3 to entry: Strain sensitivity can be superimposed by temperature-induced deformation of the optical fibre.

Note 4 to entry: If the strain sensitivity gets a non-linear characteristic because of the set-up of for example a strain transducer, higher order terms may be used. The calibration function and the parameters have to be defined.

3.14
gauge factor
k
ratio of the relative change in wavelength $\Delta\lambda/\lambda_0$ to a mechanical strain $\Delta\varepsilon$ introduced to an FBG strain sensor and expressed by the dimensionless gauge factor k measured by the manufacturer

$$k = \frac{\frac{\Delta\lambda}{\lambda_0}}{\Delta\varepsilon}$$

Note 1 to entry: The gauge factor k is used by manufacturers to express the strain response of their products.

Note 2 to entry: The gauge factor k considers all influences of the FBG strain sensor on the strain sensitivity. It can vary with the selected structural form of the strain sensor (e.g. Bragg grating fibre with special protecting layer or FBG strain gauge) and therefore has to be distinguished from the strain sensitivity of the Bragg grating in the optical fibre (see 3.13).

Note 3 to entry: The gauge factor k for an FBG strain sensor assumes a linear characteristic. Considering the whole measurement system (sensor, device, cabling), it can be separately defined for the components of the measurement system. It is only valid for defined conditions. In the case of a non-linear characteristic (e.g. by creeping effect in the strain transfer), the gauge factor k is considered as linear within a defined permissible error.

3.15
gauge length
length within which a strain will cause a change in the measured value of the FBG strain sensor

Note 1 to entry: The gauge length depends on the FBG strain sensor configuration (see 5.2).

3.16
minimum operating radius of curvature
minimum radius that an FBG may be bent without change of the specified performance parameters

3.17
strain range
<FBG sensor> maximum strain range that the FBG can measure when excited according to the stated mechanical conditions without change of the specified performance parameters

Note 1 to entry: This could include axial tensile strain and compression.

Note 2 to entry: Outside the strain range, the FBG strain sensor may not be physically damaged, but the specified measurement performance may be affected.

3.18
FBG period
Λ
distance between the periodically varying refractive index zones (grating planes) in the fibre and expressed by Λ

Note 1 to entry: The FBG period defines the Bragg wavelength (see 3.3) by the equation

$$\Lambda = \frac{k_B \times \lambda_B}{2 \times n_{eff}}$$

where

k_B = 1, 2, 3

Documents
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Full document details: BS EN IEC 61757-1-1:2020