IEC 61757-1-1

Edition 1.0 2016-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

Capteurs à fibres optiques –
Partie 1-1: Mesure de déformation – Capteurs de déformation basés sur des réseaux de Bragg à fibres

IEC 61757-1-1:2016-02(en-fr)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

About the IEC
The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications
The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

IEC Catalogue - webstore.iec.ch/catalogue
The stand-alone application for consulting the entire bibliographical information on IEC International Standards, Technical Specifications, Technical Reports and other documents. Available for PC, Mac OS, Android Tablets and iPad.

IEC publications search - www.iec.ch/searchpub
The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished
Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and also once a month by email.

Electropedia - www.electropedia.org
The world's leading online dictionary of electronic and electrical terms containing 20 000 terms and definitions in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary
65 000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

IEC Customer Service Centre - webstore.iec.ch/csc
If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: csc@iec.ch.

A propos de l'IEC
La Commission Electrotechnique Internationale (IEC) est la première organisation mondiale qui élabore et publie des Normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications IEC
Le contenu technique des publications IEC est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

Catalogue IEC - webstore.iec.ch/catalogue
Application autonome pour consulter tous les renseignements bibliographiques sur les Normes internationales, Spécifications techniques, Rapports techniques et autres documents de l'IEC. Disponible pour PC, Mac OS, tablettes Android et iPad.

Recherche de publications IEC - www.iec.ch/searchpub
La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,…). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished
Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et aussi une fois par mois par email.

Electropedia - www.electropedia.org
Le premier dictionnaire en ligne de termes électroniques et électriques. Il contient 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary
65 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.

Service Clients - webstore.iec.ch/csc
Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: csc@iec.ch.

IEC 61757-1-1

Edition 1.0 2016-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

Capteurs à fibres optiques –
Partie 1-1: Mesure de déformation – Capteurs de déformation basés sur des réseaux de Bragg à fibres

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.180.99

ISBN 978-2-8322-5166-9

Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

FIBRE OPTIC SENSORS –

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

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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 bilingual version (2017-12) corresponds to the English version, published in 2016-02.

The text of this standard is based on the following documents:

FDIS	Report on voting
86C/1322/FDIS	86C/1353/RVD

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

The French version of this standard has not been voted upon.

This publication 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.

This International Standard is to be used in conjunction with IEC 61757-1:2012.

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

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

It has been decided to restructure the IEC 61757 series, with the following logic. From now on, the sub-parts will be renumbered as IEC 61757-*M*-*T*, where *M* denotes the measure and *T*, the technology.

The existing part IEC 61757-1:2012 will be renumbered as IEC 61757 when it will be revised as edition 2.0 and will serve as an umbrella document over the entire series.

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 61757-1:2012.

This standard 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 standard 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, 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.

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

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

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

IEC 60874-1, *Fibre optic interconnecting devices and passive components – Connectors for optical fibres and cables – Part 1: Generic specification*

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

IEC 61757-1:2012, *Fibre optic sensors – Part 1: Generic specification*

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*

IEC TS 62129-3, *Calibration of wavelength/optical frequency measurement instruments – Part 3: Optical frequency meters using optical frequency combs*

IEC TR 61931, *Fibre optic – Terminology*

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 definitions given in IEC 61757-1:2012, the IEC 60050 series, IEC TR 61931, ISO/IEC Guide 99 (VIM), as well as the following apply.

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

3.1
FBG
fibre Bragg grating
phase diffraction grating integrated in optical single-mode silica-based fibres, according to category B of IEC 60793-2, 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
λ_B
Bragg wavelength
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.

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

3.5
R_{FBG}
FBG reflectivity
ratio of the incident optical power P_0 to the reflected optical power P_{λ_B} at Bragg wavelength λ_B

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 formulas in 7.4.2,) that represents the measurable part at the connector of a fibre optic sensor.

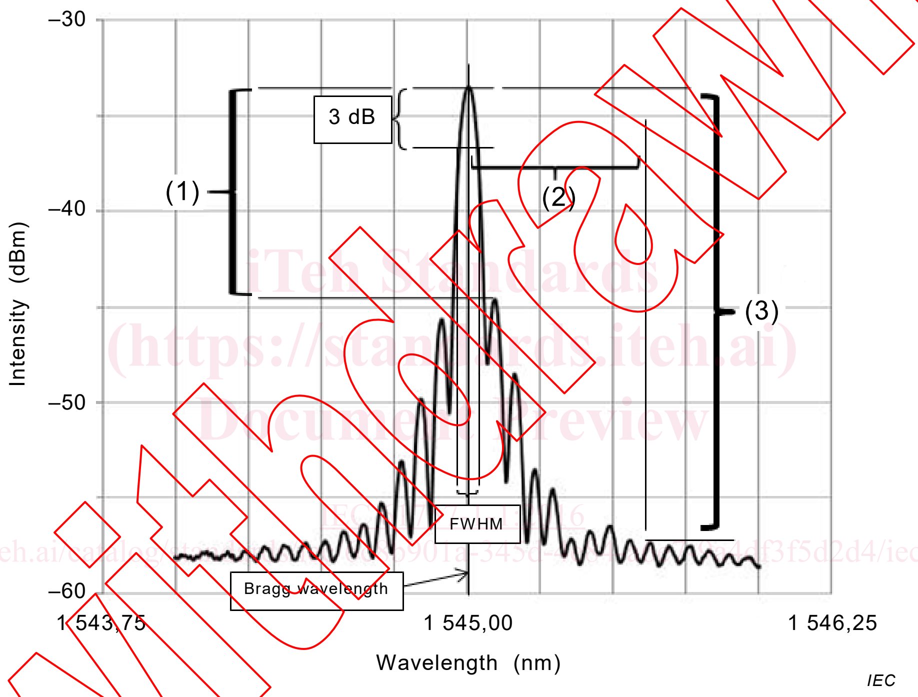
Note 2 to entry: P_0 depends on the measurement device and has no absolute characteristic value. From the user's point of view, the reflectivity is important if operational or installation conditions exist that influence the reflective characteristic.

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
FWHM of the reflection peak or transmission minimum at Bragg wavelength

Note 1 to entry: 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).



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 aside the Bragg wavelength peak of an FBG spectrum

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).

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.

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 3dB.

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: Peak width is expressed in nanometres.

3.12
SNR_{FBG}
FBG signal-to-noise ratio
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 grid number, grid 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.

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
k
gauge factor
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
FBG sensor strain range
maximum strain range that the FBG can measure being 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 range, the FBG strain sensor may not be physically damaged, but the specified measurement performance may be affected.

3.18
Λ
FBG period
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

$$\Lambda = \frac{\lambda_B}{2 \cdot n_{eff}}$$