IEC 60793-1-60

Edition 1.0 2017-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Optical fibres –
Part 1-60: Measurement methods and test procedures – Beat length

Fibres optiques –
Partie 1-60: Méthodes de mesure et procédures d'essai – Longueur de battement

IEC 60793-1-60:2017-02(en-fr)

Documents
Document Sharing Hub

Full document details: IEC 60793-1-60-2017

THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2017 IEC, Geneva, Switzerland

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 IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

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

Tel.: +41 22 919 02 11
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 corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform
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 It also gives information on projects, replaced and withdrawn publications.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 once a month by email.

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: sales@iec.ch.

IEC online collection - oc.iec.ch
Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org
The world's leading online dictionary on electrotechnology, containing more than 22 000 terminological entries in English and French, with equivalent terms in 18 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

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.

Recherche de publications IEC - webstore.iec.ch/advsearchform
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 une fois par mois par email.

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

IEC online collection - oc.iec.ch
Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

Electropedia - www.electropedia.org
Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Documents
Document Sharing Hub

Full document details: IEC 60793-1-60-2017

IEC 60793-1-60

Edition 1.0 2017-02

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Optical fibres –
Part 1-60: Measurement methods and test procedures – Beat length

Fibres optiques –
Partie 1-60: Méthodes de mesure et procédures d'essai – Longueur de battement

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 33.180.10

ISBN 978-2-8322-9363-8

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.

® Registered trademark of the International Electrotechnical Commission
Marque déposée de la Commission Electrotechnique Internationale

Documents
Document Sharing Hub

Full document details: IEC 60793-1-60-2017

CONTENTS

FOREWORD 3
1 Scope 5
2 Normative references 5
3 Terms and definitions 5
4 Testing conditions 6
5 Reference test method 6
6 Specimen 6
7 Test methods 6
7.1 Phase beat length measurement methods 6
7.1.1 General 6
7.1.2 Monitoring of output power using an electromagnet 6
7.1.3 Monitoring of SOP using a lateral force 9
7.2 Group beat length measurement method 11
7.2.1 General 11
7.2.2 Apparatus and procedure 12
7.2.3 Calculation 12
8 Results 12
8.1 Information available with each measurement 12
8.2 Information available upon request 13
Annex A (informative) Difference of beat lengths by measurement method (phase beat length and group beat length) 14
A.1 Phase modal birefringence and phase beat length 14
A.2 Group modal birefringence and group beat length 14
Annex B (informative) Correlation between results obtained by the two methods (phase beat length and group beat length) 17
B.1 General 17
B.2 Example of correlation between phase and group beat lengths in the case of PANDA fibres 17
B.3 Example of correlation between phase and group beat lengths in the case of elliptical core fibres 18
Annex C (informative) Electromagnet for Faraday rotation 19
Bibliography 20

Figure 1 – Apparatus of phase beat length measurement using an electromagnet 7
Figure 2 – Example of measurement profile by electromagnet 9
Figure 3 – Set-up for measuring $L_{B(\text{phase})}$ when monitoring SOP together with a moving lateral force 9
Figure 4 – SOP measured at different levels of lateral force 11
Figure 5 – Example of SOP evolution and normalized Stokes vector components 11
Figure B.1 – Wavelength dependence of $B_{\text{group}}/B_{\text{phase}}$ [3] 17
Figure C.1 – Schematic of the electromagnet 19

Table B.1 – $B_{\text{group}}/B_{\text{phase}}$ of elliptical core fibres 18

Documents
Document Sharing Hub
Full document details: IEC 60793-1-60-2017

INTERNATIONAL ELECTROTECHNICAL COMMISSION

_____

OPTICAL FIBRES –

Part 1-60: Measurement methods and test procedures – Beat length

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 60793-1-60 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

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

CDV	Report on voting
86A/1737/CDV	86A/1782/RVC

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 60793 series, published under the general title *Optical fibres*, can be found on the IEC website.

AVA Documents Document Sharing Hub

Full document details: IEC 60793-1-60-2017

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
- 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.

Documents
Document Sharing Hub

Full document details: IEC 60793-1-60-2017

OPTICAL FIBRES –

Part 1-60: Measurement methods and test procedures – Beat length

1 Scope

This part of IEC 60793 defines test methods for both the phase beat length, and the group beat length. These two parameters are defined differently, and will give different results depending on the type of polarization-maintaining (PM) fibre.

The phase beat length is the relevant parameter for the fibres ability to maintain a high extinction ratio. This is described in more details in Annexes A and 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 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60793-1-1, *Optical fibres – Part 1-1: Measurement methods and test procedures – General and guidance*

IEC 60793-1-48, *Optical fibres – Part 1-48: Measurement methods and test procedures – Polarization mode dispersion*

IEC 60793-2-70[1], *Optical fibres – Part 2-70: Product specifications – Sectional specifications for polarization-maintaining fibres*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60793-1-1 and the following apply.

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

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

3.1
phase beat length
$L_{B(\text{phase})}$
distance over which two orthogonal polarization modes are delayed by one cycle (2_{π})

[1] Under preparation. Stage at the time of publication: IEC CCDV 60793-2-70:2017.

Documents
Document Sharing Hub
Full document details: IEC 60793-1-60-2017

3.2
group beat length
$L_{B(group)}$
distance over which the group delay difference is one cycle (2_{π})

Note 1 to entry A group delay is based on group refractive index.

4 Testing conditions

Unless otherwise specified, the test shall be conducted under the standard conditions specified in IEC 60068-1. However, when it is difficult to make measurements in the standard conditions, the test may be conducted in conditions other than the standard conditions provided that no doubts will arise about judgments.

5 Reference test method

Since the phase beat length is the parameter specified in the product specification, IEC 60793-2-70, both phase beat length test methods described in 7.1 are defined as the reference test method (RTM). Test method for group beat length described in 7.2 can be used as an alternative test method (ATM) when the correlation between phase and group beat lengths is confirmed in advance (as shown in Annex B).

6 Specimen

A specimen length should be the minimum necessary to set up the test apparatus. If the specimen is extra long, take care that no stresses will be induced in the specimen.

7 Test methods

7.1 Phase beat length measurement methods

7.1.1 General

The phase beat length measurement method is based on applying a point-like perturbation along a short length of the fibre under test, and either monitor the changes in output power, or monitor changes in output state of polarization (SOP) at one wavelength versus travel distance.

The perturbation can either be a lateral force or an electromagnet.

In this document, the test methods where output power is monitored using an electromagnet, and where SOP is monitored using a lateral force, are both described.

7.1.2 Monitoring of output power using an electromagnet

7.1.2.1 Apparatus

7.1.2.1.1 General apparatus

See Figure 1 for a diagram of the test set-up.

An electromagnet is moved along the optical fibre longitudinal axis for Faraday rotation.

Documents
Document Sharing Hub
Full document details: IEC 60793-1-60-2017

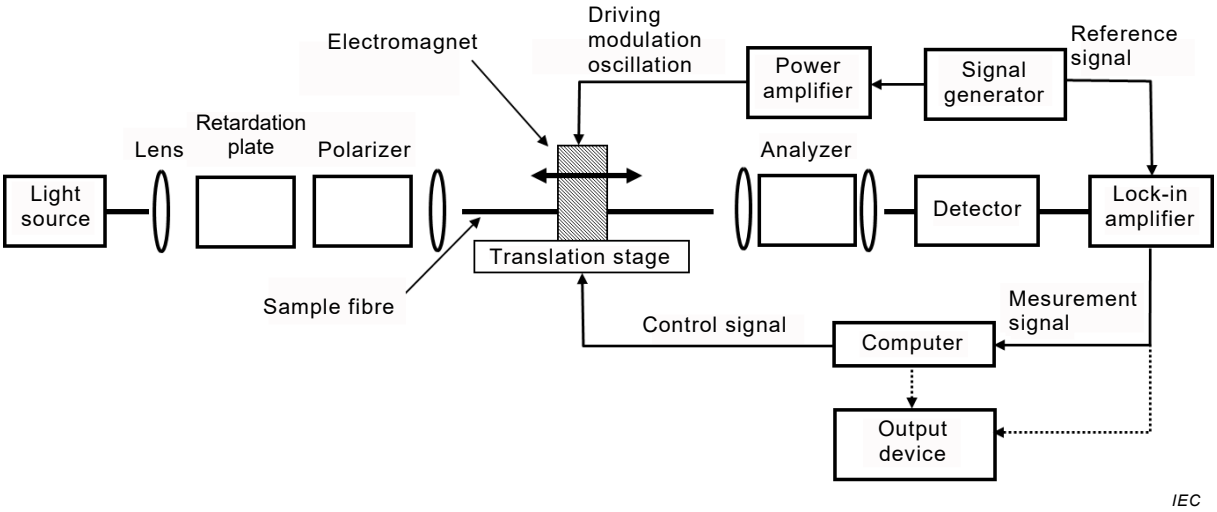

Figure 1 – Apparatus of phase beat length measurement using an electromagnet

7.1.2.1.2 Light source

A light source which has a narrow spectrum line-width such as a DFB laser shall be used.

7.1.2.1.3 Retardation plate

A retardation plate ($\lambda/4$ retarder) shall be provided to enable the input of certain level of optical power into the fibre even when the polarizer is rotated. The retardation plate converts the polarization of incident light from linear polarization into circular polarization.

7.1.2.1.4 Polarizer and analyser

A polarizer and an analyser shall be capable of outputting linearly polarized light having a certain direction of electric field vector when they have received light in a state of polarization.

7.1.2.1.5 Detector

A detector to be used shall have a light receiving area that can detect all the optical power emitted from the output end of the optical fibre.

7.1.2.1.6 Electromagnet for Faraday rotation

An electromagnet for Faraday rotation rotates the polarization of the light in a fibre by applying an electromagnetical field along the fibre longitudinal axis. The polarization rotation shall be modulated by an electrical signal from outside to improve measurement sensitivity. The interaction length should be smaller than the specified beat length (for example, around 1 mm) enough for detecting the beat length with appropriate accuracy. The applied electromagnetical field should be large enough for detecting the beat length with appropriate accuracy. Annex C describes the examples of electromagnet equipment for Faraday rotation.

7.1.2.1.7 Translation stage

A translation stage shall be able to move the electromagnet along the fibre longitudinal axis. The translation stage shall have the moving range and pitch which are sufficient to measuring the beat length of the sample fibre.

Documents
Document Sharing Hub
Full document details: IEC 60793-1-60-2017

7.1.2.1.8 Lock-in amplifier

A lock-in amplifier shall be used to improve measurement sensitivity. The lock-in amplifier shall have response time enough to respond to the modulation speed of the electromagnet.

7.1.2.1.9 Signal generator

A signal generator provides modulated signal to the lock-in amplifier and the electromagnet.

7.1.2.1.10 Power amplifier

A power amplifier may be used as necessary. The power amplifier shall provide enough power for the electromagnet.

7.1.2.1.11 Computer

A computer should control the pulse stage and process the output signal from the lock-in amplifier.

7.1.2.1.12 Output device

An output device is used to output a measurement profile processed by the computer. The output device may directly output the signal level of the lock-in amplifier by such as a plotter.

7.1.2.2 Procedure

7.1.2.2.1 Preparation and adjustment

Prepare a V-groove or bare fibre adapter to connect the sample fibre under test to the polarizer and analyser. Remove the primary coating from both ends of the fibre under test, and cleave the ends into mirror surfaces perpendicular to the axis of the fibre. Connect one end of the fibre to the polarizer, either the V-groove or the bare fibre adapter. Connect the other end of the fibre to the analyser, and connect the analyser with the detector, so that all the input light can be received.

Rotate the polarizer and analyser to minimize the optical output power through the analyser. Next, adjust the analyser to maximize the output voltage of the lock-in amplifier.

7.1.2.2.2 Measurement

Move the electromagnet by driving the pulse stage. Memorize a relationship between the electromagnet travel distance Z and the lock-in amplifier output V. The relationship as shown in Figure 2 can be obtained. Measure N times of the travel distances, ΔZ_i which is a half period of the sequence of V.

Documents
Document Sharing Hub
Full document details: IEC 60793-1-60-2017

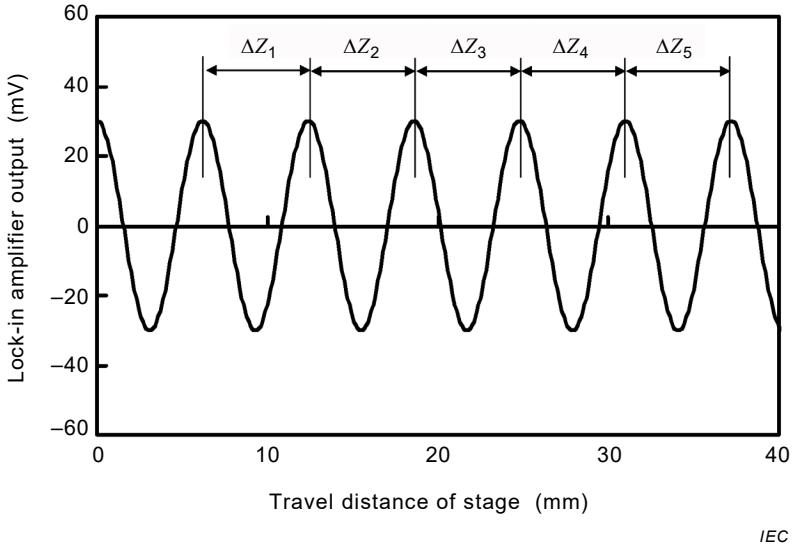

Figure 2 – Example of measurement profile by electromagnet

7.1.2.3 Calculation

The phase beat length $L_{B(\text{phase})}$ is given by:

$$L_{B(\text{phase})} = \frac{2\sum_{i=1}^{N} \Delta Z_i}{N} \quad (1)$$

where

$L_{B(\text{phase})}$ is the phase beat length;

ΔZ_i is the travel distance of the stage where the lock-in amplifier output changes by the half period;

N is the number of the half period.

7.1.3 Monitoring of SOP using a lateral force

7.1.3.1 Apparatus

7.1.3.1.1 General apparatus

See Figure 3 for a diagram of the test set-up.

By applying a lateral force at a point that moves along the fibre axis and simultaneously measure the SOP, the $L_{B(\text{phase})}$ can be obtained.

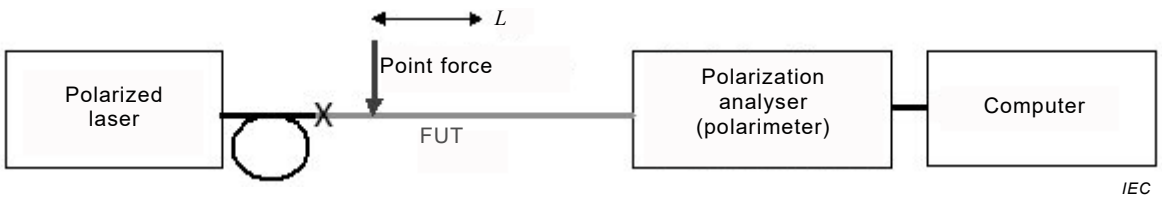

Figure 3 – Set-up for measuring $L_{B(\text{phase})}$ when monitoring SOP together with a moving lateral force

Documents
Document Sharing Hub
Full document details: IEC 60793-1-60-2017

7.1.3.1.2 Light source

A polarized laser source with a narrow spectrum line-width, such as a distributed feedback laser (DFB) shall be used.

7.1.3.1.3 Polarization analyser

Any commercial available polarization analyser (polarimeter) can be used.

7.1.3.1.4 Translation stage

A translation stage shall be able to move the lateral force along the fibre longitudinal axis. The translation stage shall have the sufficient moving range to measure the beat length of the sample fibre. It is recommended to have a range long enough to ensure five to ten periods in order to average the result.

The length of interaction between the lateral force and the sample fibre should be significantly smaller than the specified beat length (e.g. 1/10).

7.1.3.1.5 Computer

A computer should be used to combine the SOP data and the displacement data.

7.1.3.2 Procedure

7.1.3.2.1 Preparation and adjustment

The fibre sample shall be placed straight on a flat and smooth surface. It is important to avoid any twisting of the fibre sample.

Since a specific input SOP is not needed (or needs to be known) [1][2], the input end of the fibre sample can be spliced to any type of pigtail fibre connected to the light source.

The output end of the sample fibre can be connected directly to the polarization analyser by using for example a bare fibre adapter.

7.1.3.2.2 Measurement

Move the lateral force to one end of the fibre sample and lower it onto the fibre sample.

Then move the lateral force slowly along the length of the fibre sample.

Observe the SOP on the polarization analyser. One full circle corresponds to one period.

The diameter of the circle showed on the Poincaré sphere gets larger for increasing lateral force (see Figure 4 below).

---

2 Numbers in square brackets refer to the Bibliography.

Documents
Document Sharing Hub

Full document details: IEC 60793-1-60-2017

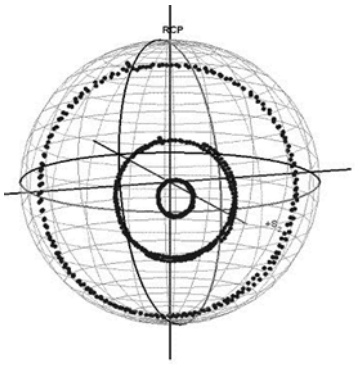

Figure 4 – SOP measured at different levels of lateral force

7.1.3.3 Calculation

The phase beat length is obtained from the periodic variation of the SOP. Examples of SOP evolution on the Poincaré sphere (left) and the three normalized Stokes vector components as function of displacement length from which the $L_{B\ (\text{phase})}$ is determined (right) are shown in Figure 5.

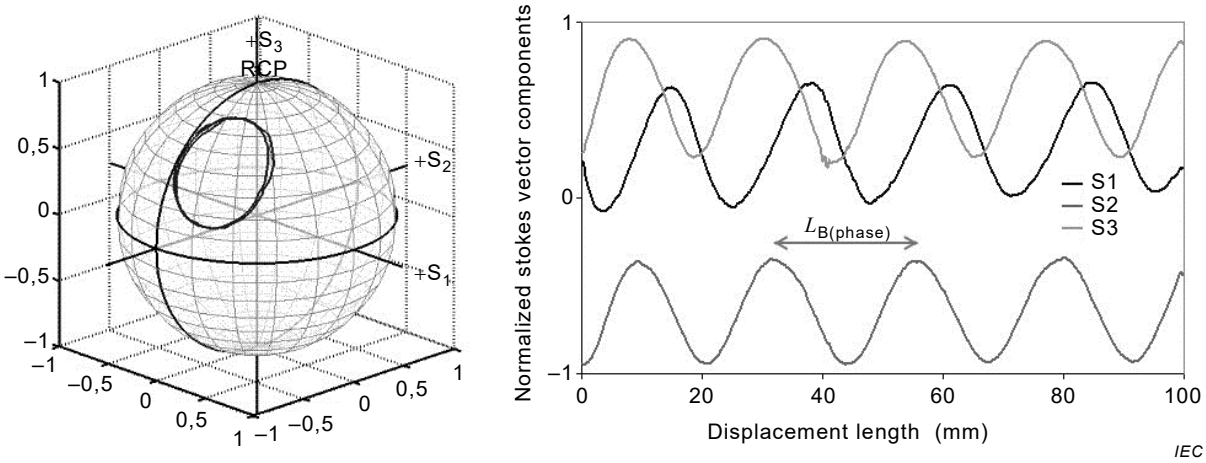

Figure 5 – Example of SOP evolution and normalized Stokes vector components

7.2 Group beat length measurement method

7.2.1 General

In principle, polarization mode dispersion is measured with the group beat length measurement method. A modal birefringence and a beat length are measured by this method, which are defined on the basis of a differential group refractive index, and are different from a modal birefringence and a beat length measured by the methods in 7.1. See Annex A.

As shown in Annex B, there is a correlation between results obtained by the methods in 7.1 and 7.2 in some types of polarization maintaining fibre. If the correlation between both methods is confirmed in advance (as shown in Annex B), the measurement method in 7.2 can be used as an alternative easy-to-use measurement method (ATM), instead of 7.1 (RTM) for phase beat length measurement, with an appropriate correlation factor.

Documents
Document Sharing Hub
Full document details: IEC 60793-1-60-2017

7.2.2 Apparatus and procedure

In the group beat length measurement method, differential group delay (DGD) or group modal birefringence is utilized for calculation of beat length. It should be measured by a method of polarization mode dispersion measurement (i.e. fixed analyser or wavelength scanning, Stokes parameter evaluation, Interferometry). Information pertaining to each individual method appears in IEC 60793-1-48.

7.2.3 Calculation

A group beat length can be calculated from results in method of IEC 60793-1-48.

The group beat length $L_{B(\text{group})}$ is given by:

$$L_{\text{B(group)}} = \frac{\lambda}{B_{\text{group}}} \tag{2}$$

where

$L_{B\ (\text{group})}$ is the group beat length;

B_{group} is the group modal birefringence in 7.2;

λ is the wavelength.

The group modal birefringence B_{group} is given by:

$$B_{\text{group}} = \frac{c}{L} \cdot \Delta\tau \tag{3}$$

where

c is the velocity of light in vacuum [m/s];

L is the fibre length [m];

$\Delta\tau$ is the differential group delay (DGD) [s].

8 Results

8.1 Information available with each measurement

Report the following information on each measurement:

– date and title of measurement;
– length of specimen;
– identification of specimen;
– measurement wavelength;
– beat length;
– measurement method.

Documents
Document Sharing Hub
Full document details: IEC 60793-1-60-2017