IEC TR 62000

Edition 3.0 2021-09

TECHNICAL REPORT

Guidelines for combining different single-mode fibre sub-categories

IEC TR 62000:2021-09(en)

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 It also gives information on projects, replaced and withdrawn publications.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.

IEC TR 62000

Edition 3.0 2021-09

TECHNICAL REPORT

colour inside

Guidelines for combining different single-mode fibre sub-categories

INTERNATIONAL ELECTROTECHNICAL COMMISSION

ICS 33.180.10

ISBN 978-2-8322-1021-2

Warning! Make sure that you obtained this publication from an authorized distributor.

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

____

GUIDELINES FOR COMBINING DIFFERENT SINGLE-MODE FIBRE SUB-CATEGORIES

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.

IEC TR 62000 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics. It is a Technical Report.

This third edition cancels and replaces the second edition published in 2010. This edition constitutes a technical revision.

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

a) global uniformity of terminology concerning fibre classes, categories and sub-categories throughout the document;
b) updating and aligning to the new naming convention of IEC 60793-2-50 for class B fibre categories and sub-categories;
c) updating and aligning with IEC 60793-2-50 as per supported fibre sub-categories;
d) additional guidelines concerning combination of fibre parameters: chromatic dispersion and slope, polarization mode dispersion;
e) additional guidelines concerning non-linear affects;
f) updating of bibliographical references.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
86A/2114/DTR	86A/2129/RVDTR

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

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under 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 document 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.

GUIDELINES FOR COMBINING DIFFERENT SINGLE-MODE FIBRE SUB-CATEGORIES

1 Scope

This document provides guidelines concerning single-mode fibre inter-compatibility.

A given category of single-mode fibre, for example B-655, can have different implementations by suitably optimising several of the following parameters: mode field diameter (hence effective area), chromatic dispersion coefficient, slope of the chromatic dispersion curve, cable cut-off wavelength.

These guidelines indicate the items that are taken into account when planning to connect

1) different implementations of single-mode fibres of the same category, for example different implementations of Class B single-mode fibres, and
2) single-mode fibres of different sub-categories, for example B-652.B with B-655.C.

See IEC 60793-2-50 for the attributes and definitions of single-mode fibre. The attributes and definitions of fibres covered in this document are given in Table 1.

Table 1 – Correspondence table of various single-mode fibres

Common name	Use (IEC 60793-2-50)	IEC sub-category	ITU-T Recommendation
Dispersion unshifted fibre	Optimised for use in the 1 310 nm region but can be used in the 1 550 nm region.	B-652.B	G.652.B
Extended band dispersion unshifted fibre	Optimised for use in the 1 310 nm region but can be used in the O, E, S, C and L-band (i.e. throughout the 1 260 nm to 1 625 nm range).	B-652.D	G.652.D
Dispersion shifted fibre	Optimised for single channel transmission in the 1 550 nm region. Multiple channels can only be transmitted if care is taken to avoid non-linear effects such as four wave mixing by, for example, moderating the power levels or appropriate spacing or placement of the channels.	B-653.A	G.653.A
		B-653.B	G.653.B
Cut-off shifted fibre	Optimised for low loss in the 1 550 nm region, with cut off wavelength shifted above the 1 310 nm region.	B-654.A	G.654.A
		B-654.B	G.654.B
		B-654.C	G.654.C
		B-654.D	G.654.D
		B-654.E	G.654.E
Non-zero dispersion-shifted fibre	Optimised for multiple channel transmission in the 1 530 to 1 625 nm region with a positive or negative, non-zero chromatic dispersion and a cut off wavelength that can be shifted above the 1 310 nm region.	B-655.C	G.655.C
		B-655.D	G.655.D
		B-655.E	G.655.E
Wideband non-zero dispersion-shifted fibre	Optimised for multiple channel transmission in the wavelength range of 1 460 nm to 1 625 nm with the positive value of the chromatic dispersion coefficient that is greater than some non-zero value over the same wavelength range.	B-656	G.656

Common name	Use (IEC 60793-2-50)	IEC sub-category	ITU-T Recommendation
Bending loss insensitive fibre	Bending loss insensitive single-mode fibre suitable for use in the access networks, including inside buildings at the end of these networks. They are suitable to be used in the O, E, S, C and L-band (i.e. throughout the 1 260 nm to 1 625 nm range) and, in the case of B-657.A1 and B-657.A2, meet the requirements of B-652.D fibres. Subcategories B-657.B2 and B-657.B3 fibres are intended to be used for restricted distances (less than 1 000 m) at the end of access networks, in particular inside buildings or near buildings (e.g. outside building riser cabling).	B-657.A1	G.657.A1
		B-657.A2	G.657.A2
		B-657.B2	G.657.B2
		B-657.B3	G.657.B3

This document does not consider the connection of fibres with the same category from different manufacturers, which is already considered by the standardisation procedure.

2 Normative references

There are no normative references in this document.

3 Abbreviated terms

OTDR optical time domain reflectometer

PMD polarization mode dispersion

DWDM dense wavelength division multiplexing

NRZ non return to zero

RZ return to zero

4 System issues

The different characteristics of class B optical fibres can be explicitly combined to optimise system performance in terms of the dispersion characteristic (global dispersion coefficients, slope) of the link. It is in fact possible to combine fibres with opposite signs of the dispersion coefficient in a given wavelength range to bring the total link dispersion to near-zero in that range. The final result will however depend on the accuracy of individual fibre dispersion measurements and the ability to match lengths.

The process of combining fibres with different dispersion coefficient characteristics can be one of the ways to make dispersion management in a transmission line (the most common one being the periodical insertion of dispersion compensating modules).

Combining fibres with different effective areas is also a possible way to minimise the overall impact of non-linear effects. For instance, it is possible to place large effective area fibres in the initial section of a link, where the propagating power is relatively large. In this case, the large core reduces the associated non-linear effects. For link sections away from the source, where power levels are reduced, fibres with smaller effective area can be used, to take advantage of a possible reduction of the dispersion slope or to increase the efficiency of Raman amplification. The relative size and placement of fibres with large effective area versus fibres with smaller effective area can be critical issues in design of the highest performing optical networks.

Splice loss considerations (see 5.3) can also be taken into account when fibres with different effective areas or mode field diameter are combined.

5 Optical fibre issues

5.1 General

Most fibre characteristics are wavelength dependent: the actual operating wavelengths of the system need therefore to be taken into account when considering the following comments and suggestions.

The compatibility between fibre specified characteristics (e.g. attenuation and dispersion) and the system operating wavelength needs to be considered.

5.2 Cut-off wavelength

Different fibres have been historically developed for operation in different wavelength ranges: they can therefore have different cut-off wavelengths. If the source wavelength is below the cut-off wavelength, undesirable multi-modal propagation and modal noise could occur.

The cut-off wavelength is however reduced after cabling and installation. The amount of the reduction depends on the refractive index profile, i.e. on the fibre type. If fibre cut-off wavelength is specified, it can be assumed that, after cabling and installation, the cut-off will be down-shifted by several tens of nanometres (depending on the fibre type). Cable cut-off wavelength is therefore specified in international standards. See IEC 60793-2-50 and IEC 60793-1-44.

These considerations need to be applied when connecting different fibre categories, for example B-655 with B-652, in order to avoid multimodal operation and noise, which could affect the system performance, depending on the source wavelength. A launch from another single-mode fibre will typically serve as a mode filter which can significantly reduce or eliminate the potential for multimode transmission.

5.3 Splicing issues

The very different mode field diameter ranges, typical of the several fibre families, have an effect on splice losses when fibres of different categories are spliced together. Care needs to be taken to properly adjust splicing equipment and to correctly evaluate the splicing losses among different fibre categories, which can show increases in comparison with same-category splice losses.

The optimal set-up parameters of fusion splicers are not the same for the different categories of fibre (e.g. B-652 versus B-657 fibres) or combinations of different categories of fibres.

Some B-657.B3 fibres can cause difficulties with the core alignment systems of some fusion splicing machines because the characteristics that provide improved bend loss performance can interact with the splicer alignment field of view. Amended splice programs or specialist fusion splicing technology has eliminated this problem on many fusion splicers. An alternative and recommended approach is to use an outside diameter (OD) or cladding alignment fusion splicing program as is generally used with multimode optical fibres. Since recent advances in fibre manufacturing technology have resulted in improved fibre geometry – with fibre core concentricity errors typically less than 0,5 µm –, the splice losses encountered are usually less than 0,1 dB.

Another factor that has to be taken into account when using an OTDR to measure the splice loss across fibres with different mode field diameters is that the bidirectional method is strictly required. The mismatch of mode fields can make a splice appear to have much more loss from one direction than the other. Negative loss or "gain" can also be apparent with uni-directional OTDR measurements. See IEC TR 62316 for more information.

When using an OTDR to measure the distance between splices of various sections of fibre with different mode field diameters, the apparent distance can be different than the actual distance because it is possible the group velocity for the different fibres is not the same. For accurate length measurements, the OTDR length calibration setting needs to be adjusted according to the section and type of fibre that is present.

Most of the previous considerations also apply to mechanical (temporary or permanent) connections.

5.4 Combination of fibre parameters: chromatic dispersion coefficient and slope, polarization mode dispersion (PMD)

The chromatic dispersion coefficients of two fibres combine linearly on a length-weighted basis. It is possible to combine different fibres or dispersion compensation devices to achieve the desired overall system chromatic dispersion values.

When different fibre families are combined, it is important that the calculations for the overall chromatic dispersion be completed by using the chromatic dispersion of each section, in ps/nm, rather than considering the combination of possibly misleading descriptive parameters such as the zero-dispersion wavelength or slope. In fact, zero-dispersion wavelength and slope are not defined for some fibre families.

Sometimes, the term "slope compensation" is found, referring to a situation where fibres with different wavelength-dependence of the chromatic dispersion coefficient are combined: the resulting dispersion vs. wavelength curve will be the linear combination (on a length weighted basis) of the two original curves.

Details on dispersion accommodation and compensation and on slope compensation can be found in IEC TR 61282-5.

For polarization mode dispersion (PMD), the PMD values combine in quadrature (square root of sum of squares) rather than in the linear fashion that is appropriate for chromatic dispersion. Because PMD is a stochastic attribute, the link characteristics are defined statistically. See IEC 60794-3 for information on the calculations for concatenations of cables and IEC TR 61282-3 for information on the calculation for the combined link, including the effects of other link components such as amplifiers. See IEC TR 61282-9 for more information on PMD generalities and theory.

5.5 Non-linear effects

Non-linear effects come from the interactions of the propagating pulse with the transmission medium that make the propagation sensitive to the channel optical power. They are generated with an efficiency, which is dependent on the concentration of energy in the fibre core (therefore proportional to optical power and inversely proportional to effective area), and on the distance over which the light is propagated.

The local chromatic dispersion of the fibre also has an effect on the impairment due to non-linear effects, depending on, for example, the channel density, bit rate, and modulation format.

See IEC TR 61282-4 for more information.

For high power DWDM systems operating at 10 Gb/s and higher, the local fibre chromatic dispersion needs to be different than zero by an amount that is dependent on the details of the system. The actual values of the optimal chromatic dispersion coefficient and effective area for a given link section are a trade-off depending on the number of optical channels, the powers of the channels in the section, the bit rate, and the modulation format (NRZ versus RZ).