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REDLINE VERSION

TECHNICAL REPORT

colour inside

Guidelines for combining different single-mode ~~fibres types~~ fibre sub-categories

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GUIDELINES FOR COMBINING DIFFERENT SINGLE-MODE ~~FIBRES TYPES~~ FIBRE SUB-CATEGORIES

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition IEC TR 62000:2010. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

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.

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GUIDELINES FOR COMBINING DIFFERENT SINGLE-MODE ~~FIBRES TYPES~~ FIBRE SUB-CATEGORIES

1 Scope

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

A given ~~type~~ category of single-mode fibre, for example ~~B4~~ B-655, ~~may~~ 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 ~~should be~~ are taken into account when planning to connect

1) different implementations of single-mode fibres of the same ~~type~~ category, for example different implementations of ~~type~~ Class B single-mode fibres, and
2) single-mode fibres of different ~~types~~ sub-categories, for example ~~B1.1~~ B-652.B with ~~B4~~ 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 6079-2-50)~~	~~IEC Class~~	~~ITU-T Recommendation~~
~~Dispersion unshifted single-mode fibre~~	~~Optimised for use in the 1 310 nm region but can be used in the 1 550 nm region~~	~~B1.1~~	~~G.652 A, B~~
~~Cut-off shifted single-mode fibre~~	~~Optimised for low loss in the 1 550 nm region, with cut-off wavelength shifted above the 1 310 nm region~~	~~B1.2~~	~~G.654~~
~~Extended band dispersion unshifted single-mode 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).~~	~~B1.3~~	~~G.652 C, D~~
~~Dispersion shifted single-mode fibre~~	~~Optimised for single channel transmission in the 1 550 nm region. Multiple channels can only be transmitted if care is taken to avoid the effects of four wave mixing by, for example, moderating the power levels or appropriate spacing or placement of the channels~~	~~B.2~~	~~G.653~~
~~Non-zero dispersion-shifted single-mode fibre~~	~~Optimised for multiple channel transmission in the 1 550 nm region with a cut-off wavelength that may be shifted above the 1 310 nm region~~	~~B4~~	~~G.655~~
~~Wideband non-zero dispersion-shifted single-mode fibre~~	~~Optimised for multiple channel transmission in the wavelength range of 1 460 to 1 625 nm with the positive value of the chromatic dispersion~~	~~B5~~	~~G.656~~

~~Common name~~	~~Use (IEC 6079-2-50)~~	~~IEC Class~~	~~ITU-T Recommendation~~
	~~coefficient that is greater than some non-zero value over the same wavelength range.~~		
~~Bend loss optimised~~	~~Bending loss insensitive single-mode fibre suitable for use in the access networks, including inside buildings at the end of these networks.~~ ~~B6_a fibres 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 meet the requirements of B1.3 fibres.~~	~~B6_a~~	~~G.657.A~~
	~~Bending loss insensitive single-mode fibre suitable for use in the access networks, including inside buildings at the end of these networks.~~ ~~B6_b fibres are suitable for transmission at 1 310 nm, 1 550 nm, and 1 625 nm for restricted distances that are associated with in-building transport of signals.~~	~~B6_b~~	~~G.657.B~~

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 ~~implementation~~ 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 ~~type~~ 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 ~~may~~ 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 ~~are~~ can be critical issues in ~~system~~ design of the highest performing optical networks.

Splice loss considerations (see 5.3) ~~should~~ 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 ~~shall~~ 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 ~~must~~ 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.

~~It should however be considered that~~ 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 ~~should~~ need to be applied when connecting different fibre ~~types~~ categories, for example ~~type B4 with B1~~ 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 ~~must~~ needs to be taken to properly adjust splicing equipment and to correctly evaluate the splicing losses among different fibre ~~families~~ categories, which can show increases in comparison with ~~conventional~~ same-category splice losses.

The optimal set-up parameters of fusion splicers are not the same for the different ~~types~~ categories of fibre (e.g. ~~B1~~ B-652 versus ~~B6~~ B-657 fibres) or combinations of different ~~implementations~~ categories of fibres.

Some ~~B6_b~~ B-657.B3 fibres ~~may~~ 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 ~~may~~ is not ~~be~~ the same. For accurate length measurements, the OTDR length calibration setting ~~must~~ 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 ~~recommended~~ 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 ~~shall~~ 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).