TECHNICAL REPORT

IEC TR 62000

First edition
2005-11

Single-mode fibre compatibility guidelines

Reference number
IEC/TR 62000:2005(E)

Publication numbering

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Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE J

For price, see current catalogue

CONTENTS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

SINGLE-MODE FIBRE COMPATIBILITY GUIDELINES

FOREWORD

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IEC 62000, which is a technical report, has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
86A/1022/DTR	86A/1026/RVC

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

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

The committee has decided that the contents of this publication will remain unchanged until the maintenance result 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- withdrawn;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.

A bilingual version of this publication may be issued at a later date.

SINGLE-MODE FIBRE COMPATIBILITY GUIDELINES

1 Scope

This technical report provides guidelines indicating the items that should be taken into account when planning to connect

a) different implementations of single-mode fibres of the same type, e.g. different implementations of type B single-mode fibres, and

b) single-mode fibres of different types, e.g. B1.1 with B4.

See IEC 60793-2-50 for the attributes and definitions of single-mode fibres, summarised in Table 1 below.

A given type of single-mode fibre, for example B4, may 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 and cable cut-off wavelength.

Table 1 – Attributes and definitions of single-mode fibres

Common name	Use (IEC 60793-2-50)	IEC category/ type	ITU-T Recommendation
Dispersion unshifted single-mode fibre	Optimised for use in the 1 310 nm region but can be used in the 1550 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	Intended to extend the range of possible transmission signals, using 1 310 nm band power budgets, to portions of the band above 1 360 nm and below 1 530 nm	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 nm – 1625 nm with the positive value of the chromatic dispersion coefficient that is greater than some non-zero value over the same wavelength range.	B5	G.656
NOTE The ITU-T recommendation references are for information. There can be slight variations in these requirements due to the evolution of standards over time.			

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

2 Acronyms

For the purposes of this document, the following acronyms apply.

OTDR: Optical Time Domain Reflectometer

PMD: Polarisation Mode Dispersion

DWDM: Dense Wavelength Division Multiplexing

NRZ: Non-Return to Zero

RZ: Return to Zero

3 System issues

The different characteristics of B type fibres can be explicitly combined to optimise system performance in terms of the dispersion characteristics (global dispersion coefficients, slope) of the link. It is in fact possible to combine fibres with an opposite sign 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 a different effective area 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 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 vs. fibres with smaller effective area are critical issues in system design.

Splice loss considerations (see section 4.2) should also be taken into account when fibres with different effective area or mode field diameter are combined.

4 Fibre issues

4.1 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 could occur.

It is however to be considered that the cut-off wavelength is 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 nanometers (depending on the fibre type). Cable cut-off wavelength is therefore specified in individual standards. See IEC 60793-2-50 and IEC 60793-1-44.

These considerations should be applied when connecting different fibre types, e.g. type B4 with B1, in order to avoid multimodal operation and noise, which could affect the system performance, depending on the source wavelength.

4.2 Splicing issues

The very different mode field diameter ranges for the different fibre categories in the family specifications of 60793-2-50 have an effect on splice loss when fibres of different categories are spliced together. Care must be taken to properly adjust splicing equipment and to correctly evaluate the splicing losses among different fibre families, which can show very large increases in comparison with conventional splice losses.

The optimal set-up parameters of fusion splicers are not the same for the different types of fibres (e.g. B1 versus B4 fibres) or combinations of different implementations of fibres.

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 the group velocity for the different fibres may not be the same. For accurate length measurements, the OTDR length calibration setting must be adjusted according to the section and type of fibre that is present.

4.3 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 to complete the calculations for the overall chromatic dispersion 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. The design and implementation of dispersion managed links is a complex process that requires the co-operation of the system designer, the cable supplier, and the maintenance department of the operating company.

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 61282-9 for more information on PMD generalities and theory.

4.4 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.