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INTERNATIONAL STANDARD

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colour inside

**Fibre optic interconnecting devices and passive components – Basic test and measurement procedures –
Part 3-38: Examinations and measurements – Group delay, chromatic dispersion and phase ripple**

**Dispositifs d'interconnexion et composants passifs à fibres optiques –
Procédures fondamentales d'essais et de mesures –
Partie 3-38: Examens et mesures – Retard de groupe, dispersion chromatique et fluctuation de phase**

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CONTENTS

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**FIBRE OPTIC INTERCONNECTING DEVICES
AND PASSIVE COMPONENTS –
BASIC TEST AND MEASUREMENT PROCEDURES –**

**Part 3-38: Examinations and measurements –
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International Standard IEC 61300-3-38 has been prepared by subcommittee 86B: Fibre optic interconnecting devices and passive components, of IEC technical committee 86: Fibre optics.

This first edition cancels and replaces the IEC/PAS 61300-3-38 published in 2007. This edition constitutes a technical revision.

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

FDIS	Report on voting
86B/3394/FDIS	86B/3438/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.

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

The list of all parts of IEC 61300 series, published under the general title, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures* can be found on the IEC website.

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

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FIBRE OPTIC INTERCONNECTING DEVICES AND PASSIVE COMPONENTS – BASIC TEST AND MEASUREMENT PROCEDURES –

Part 3-38: Examinations and measurements – Group delay, chromatic dispersion and phase ripple

1 Scope

This part of IEC 61300 describes the measurement methods necessary to characterise the group delay properties of passive devices and dynamic modules. From these measurements further parameters like group delay ripple, linear phase deviation, chromatic dispersion, dispersion slope, and phase ripple can be derived. In addition, when these measurements are made with resolved polarization, the differential group delay can also be determined as an alternative to separate measurement with the dedicated methods of IEC 61300-3-32.

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 60050-731, *International Electrotechnical Vocabulary – Chapter 731: Optical fibre communication*

IEC 61300-3-29, *Fibre optic interconnecting devices and passive components – Basic test and measurement procedures – Part 3-29: Examinations and measurements – Measurement techniques for characterizing the amplitude of the spectral transfer function of DWDM components*

3 Terms and abbreviations

For the purposes of this document, the terms and definitions given in IEC 60050-731 and IEC 61300-3-29 apply, together with the following.

BW	Bandwidth: the spectral width of a signal or filter.
CD	Chromatic dispersion (in ps/nm): change of group delay over wavelength: CD=d(GD)/dλ
D	Detector
DGD	Differential group delay (in ps): difference in propagation time between two orthogonal polarization modes
DUT	Device under test
DWDM	Dense wavelength division multiplexing
δ	Step size of the VWS during a wavelength swept measurement
f_{RF}	Modulation frequency
GD	Group delay (in ps): time required for a signal to propagate through a device
GDR	Group delay ripple (in ps): the amplitude of ripple of GD
LN	$LiNbO_3$

LPV	Linear phase variation (in deg)
λ_c	Centre channel or nominal operating wavelength for a component
MPS	Modulation phase shift
PBS	Polarising beam splitter
PMD	Polarization mode dispersion (in ps): average value of DGD over wavelength
PPS	Polarization phase shift
PSP	Principle state of polarization
Φ	Phase delay
RBD	Reference branching device
SOP	State of polarization
SSE	Source spontaneous emission
SWI	Swept wavelength interferometry
$\Delta\theta$	Phase ripple
TDC	Tunable dispersion compensator
TJ	Temporary joint
TLS	Tunable laser source
VWS	Variable wavelength source

4 General description

This document covers transmission measurements of the group delay properties of passive devices and dynamic modules. In order to interpret the group delay properties, it is essential to also have the amplitude spectral measurement available. For this reason, loss measurements are also covered to the extent that they are required to make proper dispersion measurements.

The methods described in this procedure are intended to be applicable in any wavelength band (C, L, O, etc.) although examples may be shown only in the C band for illustrative purposes.

This document is separated into two sections, one concentrating on measurement methods, and one concentrating on analysis of the measurement data. The measurement methods covered in this document are the modulation phase shift method, the swept-wavelength interferometry method and the polarization phase shift method. The modulation phase shift method is considered the reference method. The methods are selected particularly because of their ability to provide spectrally resolved results, which are often necessary for passive components and especially for wavelength-selective devices.

The appropriate measurement parameter to evaluate the group delay ripple, and the method of estimating the phase ripple from the measurement result of GDR are shown in 7.4. The phase ripple is important as a measure of the influence that GD of an optical device has on the transmission quality since many tunable dispersion compensators use the interference effect where ripple is a significant effect.

5 Apparatus

5.1 Modulation phase shift method

5.1.1 General

The measurement set-up for the characterisation of the group delay (GD) properties of optical components is shown in Figure 1. A detailed explanation of the various components of this system and their functions is contained in 5.1.2 to 5.1.13.

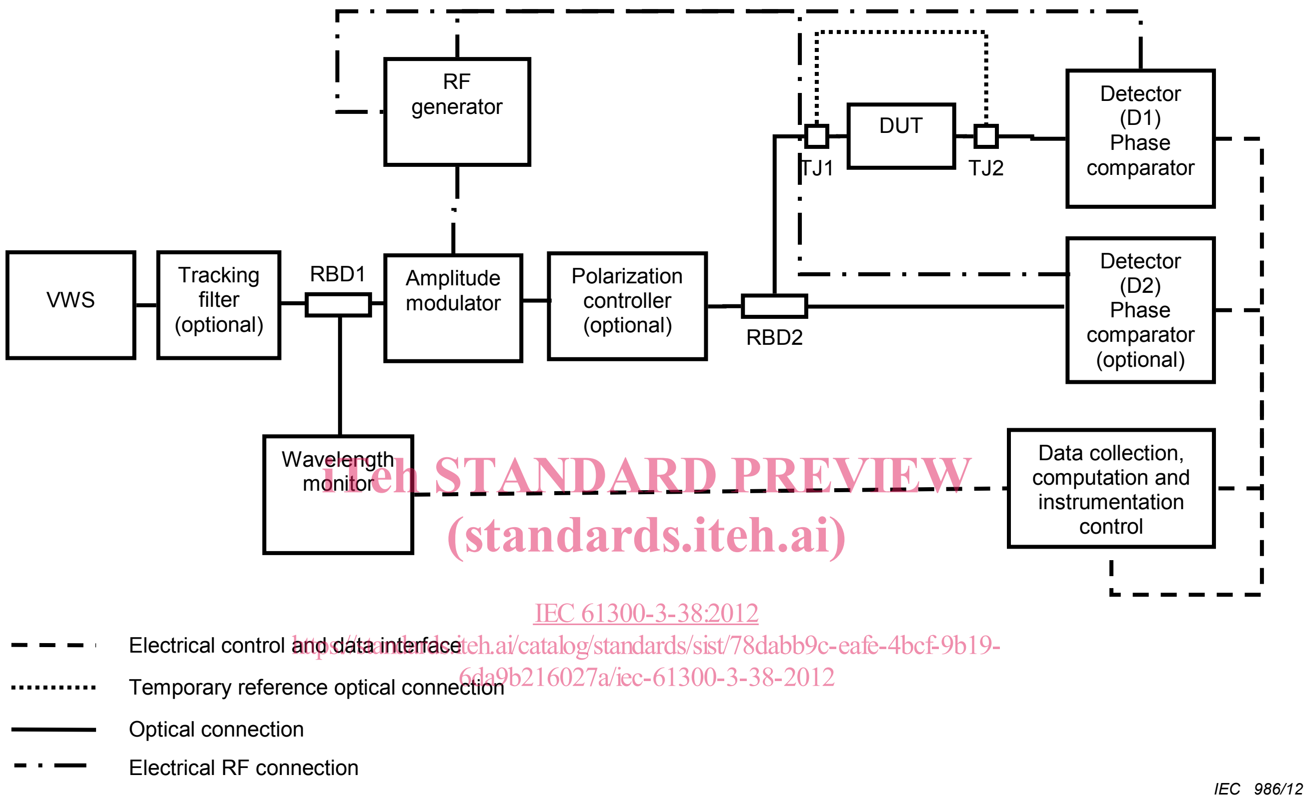


Figure 1 – MPS measurement method apparatus

5.1.2 Variable wavelength source VWS

The variable wavelength source (VWS) is a polarized light source that can select a specific output wavelength and can be tuned across a specified wavelength range. The power stability at any of the operating wavelengths shall be sufficient so as not to cause significant errors in the phase comparators. The relative accuracy and repeatability of wavelength, as determined by the VWS and wavelength monitor together, shall be accurate to 3 pm for each point in the measuring range and the absolute wavelength accuracy should satisfy the wavelength specifications of the device under test. The linewidth of the source shall be less than 100 MHz. The tuning range of the VWS shall cover the entire spectral region of the device and the source shall also be free of mode hopping over the tuning range. The output power of the VWS shall be sufficient to provide enough signal to ensure good comparison of the phase.

The minimum increment of the wavelength of the VWS should be adjusted to one tenth of expected GDR period of the DUT.

5.1.3 Tracking filter (optional)

The tracking filter may be used for any DUT measurements if the dynamic range of the VWS and the detector does not allow for measuring dynamic range of at least 40 dB due to the shape of the DUT and the broadband source spontaneous emission (SSE) of the VWS. The filter shall track the VWS so as to provide the maximum SSE suppression and the maximum transmitted power as the VWS is scanned across the measurement region. The spectral shape of the filter shall provide enough out of band attenuation to allow for 40 to 50 dB dynamic range at the transmission detector.

5.1.4 Reference branching device RBD1, RBD2

The configuration of the RBD is 1 × 2 or 2 × 2. If its configuration is 2 × 2, one port of the RBD shall be terminated to have a return loss better than 50 dB. The splitting ratio of the RBD shall be stable with wavelength. It shall also be insensitive to polarization. The polarization sensitivity of transmission attenuation shall be less than one tenth of the device wavelength dependency of attenuation or less than 0,1 dB. The directivity shall be at least 10 dB higher than the maximum return loss. The split ratio shall be sufficient to provide the dynamic range for the measurement of the transfer function and the power necessary for the wavelength monitor to operate correctly.

5.1.5 Wavelength monitor (optional)

In this test procedure, the wavelength accuracy of the source needs to be closely monitored. If the tuning accuracy of the VWS is not sufficient for the measurement, a wavelength monitor is required. For this measurement method, it is necessary to measure the spectral peak of any input signal within the device BW to an accuracy of 3 pm. Acceptable wavelength monitors include an optical wavelength monitor or a gas absorption cell (such as an acetylene cell). If a gas absorption cell is used, the wavelength accuracy of the VWS must be sufficient to resolve the absorption lines. The VWS must be sufficiently linear between the absorption lines.

Included under this specification, is the wavelength repeatability of the VWS + monitor. It should be understood by the operator that if the test apparatus has 0,1 ps of ripple with a 30 pm period, then a random 3 pm wavelength variation from reference scan to device scan can result in as much as 0,03 ps of GD noise.

5.1.6 Device under test DUT

For the purposes of this document, the test ports shall be a single “input-output” path. The method described can be extrapolated to obtain a single measurement system capable of handling an m x n device. The device shall be terminated on either pigtails or with connectors. Because this measurement set up is very sensitive to reflections, and is useful for detecting reflections in the DUT it is important that reflections are not introduced by the measurement system.

In many cases, the characteristics of DWDM components are temperature dependent. This measurement procedure assumes that any such device is held at a constant temperature throughout the procedure. The absolute accuracy of the measurement may be limited by the accuracy of any heating or cooling device used to maintain a constant temperature. For example, if a device is known to have a temperature dependence of 0,01 nm / C, and the temperature during the procedure is held to a set temperature ± 1 °C; then any spectral results obtained are known to have an total uncertainty of 0,02 nm due to temperature.

5.1.7 Detectors D1, D2

The detectors consist of an optical detector, the associated electronics, and a means of connecting to an optical fibre. The use of a detector (D2) is considered optional, but provides correction for any instability in the GD of the instrument setup between the modulator and the DUT between Step 3 and Step 4 of 6.1.3. The optical connection may be a receptacle for an optical connector, a fibre pigtail, or a bare fibre adapter. The back-reflection from detectors D1 and D2 shall be minimised. The preferred option would be to use an APC connector. It should be noted that the use of an APC connector would contribute approximately 0,03 dB of PDL to the measurement if terminated in air.

The dynamic range and sensitivity of the detectors shall be sufficient for the required measurement range, given the power level provided by the modulated source. The linearity of the detectors shall be sufficient to provide accurate representation of the modulated signal. The detector shall transfer the optical modulation phase to the RF output phase with good stability and little dependence on the optical signal level.

Where during the sequence of measurements a detector shall be disconnected and reconnected the coupling efficiency for the two measurements shall be maintained to at least the accuracy of the mated connector.

5.1.8 RF generator

The RF Generator delivers an electrical signal that is used for driving the intensity modulator. In addition, the signal is delivered to the phase comparator in detectors D1 and D2 as a reference signal. The RF Generator produces a waveform with a single dominant Fourier component, for example, a sinusoidal wave modulation. Typically, a sinusoidal signal with a frequency in the range of 100 MHz up to 3 GHz is used. The RF generator shall have sufficient frequency accuracy and stability for the required measurement accuracy, considering that the frequency provides the time base for the GD measurement.

5.1.9 Amplitude modulator

The amplitude modulator uses the modulated signal from the RF generator to induce the equivalent amplitude modulation on a continuous wave optical signal. The modulator converts the modulated signal from the RF generator to a modulated optical signal. The modulator shall have sufficient linearity to produce a good sinusoidal modulation. The modulation amplitude should be matched to the dynamic range of the detector system.

5.1.10 Phase comparator

The phase comparator is built into the detectors D1 and D2, which compare the phase of the modulated optical signal and the RF reference signal. Typically, a network analyser, or lock-in amplifier is used as a phase comparator. A method known as phase sensitive detection is used to single out the component of the signal at a specific reference frequency and phase. Noise signals at frequencies other than the reference frequency are rejected and do not affect the phase measurement. The RF signal level shall not affect the phase measurement.

5.1.11 Temporary joints TJ1, TJ2

Temporary joints are specified to connect the test input signal to the device under test to the device output to the transmission detector (D1).

Examples of temporary joints are typically connectors or splices. However other methods such as vacuum chucks, or micromanipulators may be applied. Due to the high sensitivity to back reflections, it is necessary to ensure that all of these joints have back-reflection <-50 dB.

5.1.12 Polarization controller (optional)

The modulated laser signal is optionally sent to a polarization controller, wherein the polarization can be adjusted to the 4-Mueller-states located on the surface of the Poincaré sphere, three of them on the equator of the Poincaré sphere and separated by 90 degree consisting of the 0°, 45° and 90° linear polarization states, and the fourth state on the pole of the Poincaré sphere for circular polarization. If the DUT exhibits polarization mode dispersion, averaging results from orthogonal polarization states allows the GD average over all input polarization states to be determined. From a set of GD measurements at all the 4-Mueller-states, the differential group delay (DGD) can be calculated. The polarization controller shall be able to provide satisfactory polarization stability over the wavelength range of the measurement.

5.1.13 Reference jumper

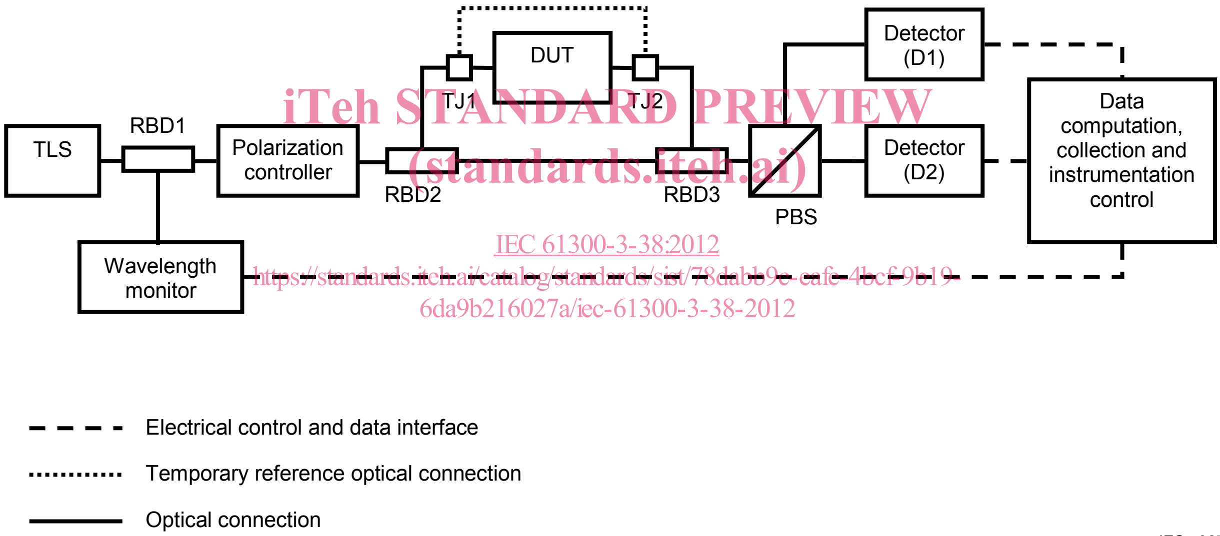
The reference jumper is a single-mode fibre. The optical connection may be an optical connector, a fibre pigtail, or a bare fibre. The reference jumper must have the same optical connection as the DUT.

5.2 Swept wavelength interferometry method

5.2.1 General

The measurement set-up for this method is shown in Figure 2. A detailed explanation of the various components of this system and their functions is contained in 5.2.2 to 5.2.7. The setup shown illustrates a transmission measurement of a DUT with two optical ports.

The measurement of GD is usually of interest to determine its dependence on wavelength and polarization. However, the GD of optical fibre and other components of optical fibre networks is also sensitively dependent on outside parameters such as temperature, pressure, mechanical stress, and noise. Therefore a setup for measuring GD should provide for stability against fibre movement and external changes during the measurement. Since the SWI method relies on tracing the optical phase, which is very sensitive to GD and GD changes in a fibre, such provision is particularly important for this method.



IEC 987/12

Figure 2 – SWI measurement method apparatus

5.2.2 Tunable laser source TLS

The SWI method uses coherent interference, so a tunable laser source is necessary to provide the variable wavelength signal. The TLS must be tunable across the required wavelength range. Considering typical coherence and wavelength resolution requirements, the line-width shall be less than 1 MHz. A typical device length of about 10m, including patch cords, will give an interferogram period of about 20 MHz. Accurate characterization of this requires a substantially smaller resolution. Typically closely spaced measurements are required (depending on the length and GD range of the DUT as discussed in 6.2.1), so it is highly recommended to perform the measurements during continuous wavelength scanning by the source. Therefore the setup shall provide specified control and monitoring of the wavelength while sweeping.

5.2.3 Wavelength monitor

If the TLS does not itself provide adequate wavelength accuracy, this shall be achieved with the wavelength monitor. The monitor improves absolute wavelength accuracy and relative wavelength accuracy for each measurement point during the wavelength scan.

5.2.4 Reference branching devices RBD1, RBD2, RBD3

The branching devices, RBD2 and RBD3, are used to establish the interferometer by splitting the optical path so that part of the light passes through the DUT and the other part passes along a reference path. The light from the two paths is then recombined so that it interferes at the detectors. These couplers will typically have a 50:50 coupling ratio. Further branching devices may be used to tap light for monitoring, as for the wavelength monitor. These should be selected to provide adequate signal for the monitoring function. The branching devices have 1 × 2 or 2 × 2 configuration. Unused ports of the RBD shall be terminated to give less than -50 dB back-reflection.

5.2.5 Detectors D1, D2

The detectors are used to trace the optical power with respect to wavelength. As described below, the recommended configuration produces two such traces for light at two orthogonal polarization states. The traces will generally yield oscillations in power with very short wavelength period as explained in 5.2.1, so that a high density of measurements vs. wavelength will be required. Therefore a high-speed data acquisition detection system is recommended. The discussion below assumes that the output signal corresponds to optical power. Since relative changes in power will be evaluated, the detectors should have good linearity, and care should be taken to avoid approaching saturation.

5.2.6 Polarization controller

To obtain sufficient interference signal from the interferometer, it must be assured that light from the two paths combines with the same polarization, since signals with orthogonal polarization will not produce interference. Since in general the polarization state of the light at the DUT output will be unknown, some control of the polarization is required. The polarization controller and polarization analyzer of 5.2.6 combine to satisfy this function, as described in Clause 5. Generally the polarization controller is used to establish the polarization at the DUT input and to “balance” the power at the two detectors from the reference path of the interferometer. The polarization controller shall be able to provide satisfactory polarization stability over the wavelength range of the measurement, for example by using zero-order retarding plates. The combination of polarization controller and analyzer also permits the calculation of DGD from a set of GD measurements at different polarization conditions.

5.2.7 Polarization analyzer

The polarization analyzer is the second part of the configuration to assure favourable interference conditions, based on polarization. A practical realization is to use the polarising beam splitter (PBS) in combination with the two detectors. When the polarization controller of 4.2.5 assures that similar power from the reference arm is present at both detectors, then the light from the DUT will also be split into two respective components with the same polarization at the detector as the reference light. This assures a good interference signal.

5.3 Polarization phase shift method

5.3.1 General

Figure 3 shows a block diagram of the polarization phase shift method (PPS). A detailed explanation of the various components of this system and their functions is contained in 5.3.2 to 5.3.8.