BRITISH STANDARD

BS 6493-1.5:
1992
IEC 60747-5:
1992

Incorporating Amendments Nos. 1 and 2 and Corrigendum No. 1

Semiconductor devices —

Part 1: Discrete devices —

Section 1.5 Recommendations for optoelectronic devices

ICS 31.260

British Standards

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the Electronic Components Standards Policy Committee (ECL/-) to Technical Committee ECL/24, upon which the following bodies were represented:

EEA (the Association of Electronics, Telecommunications and Business Equipment Industries)

Electronic Components Industry Federation

GAMBICA (BEAMA Ltd.)

Ministry of Defence

National Supervising Inspectorate

Society of British Aerospace Companies Limited

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

British Telecommunications plc

Engineering Equipment and Materials Users' Association

This British Standard, having been prepared under the direction of the Electronic Components Standards Policy Committee, was published under the authority of the Standards Board and comes into effect on 15 September 1992

First published August 1985
Second edition September 1992

The following BSI references relate to the work on this standard:
Committee reference ECL/24
Draft for comment 87/31843 DC

ISBN 0 580 21005 7

Amendments issued since publication

Amd. No.	Date	Comments
8704	November 1995	
8957	May 1996	Indicated by a sideline in the margin
14242 Corr. No. 1	27 March 2003	Addition of supersession details to national foreword

Contents

[1)] See national foreword for details of textual error.

National foreword

This British Standard has been prepared under the direction of the Electronic Components Standards Policy Committee. It is identical with IEC Publication 747-5:1993 *Semiconductor devices. Discrete devices and integrated circuits — Part 5: Optoelectronic devices* as amended by Amendment 1:1994 and Amendment 2:1995, published by the International Electrotechnical Commission (IEC).

When preparing IEC Amendment 2 for incorporation into this document, an error was discovered in the Section numbering of the new material that it introduced. Pending the publication of a new edition of IEC 747-5, this material has been termed "Section X" and introduced at the end of Chapter 3.

This British Standard constitutes Section 1.5 of the British Standard for semiconductor devices (BS 6493). (See national foreword of BS 6493-1.1:1984.) It supersedes BS 6493-1.5:1985 which is withdrawn. It is partiallly superseded by BS EN 62007-1:2000 and BS EN 62007-2:2000.

Cross-references

The British Standards which implement international publications referred to in this document may be found in the *BSI Catalogue* under the section entitled "International Standards Correspondence Index", or by using the "Search" facility of the *BSI Electronic Catalogue* or of British Standards Online.

The Technical Committee has reviewed the provisions of IEC 306-1:1969, to which normative reference is made in the text, and has decided that they are acceptable for use in conjunction with this standard.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to vi, pages 1 to 129 and a back cover.

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Chapter I. General

1 Introductory note

As a rule, it will be necessary to use Publication 747-1 together with the present standard. In 747-1, the user will find all basic information on:

— terminology;
— letter symbols;
— essential ratings and characteristics;
— measuring methods;
— acceptance and reliability.

2 Scope

This standard applies to the following categories or sub-categories of devices:

- Semiconductor photoemitters, including:
  — light-emitting diodes (LEDs);
  — infrared-emitting diodes (IREDs);
  — laser diodes and laser-diode modules;
  — optoelectronic displays (under consideration).
- Semiconductor photoelectric detectors, including:
  — photodiodes;
  — phototransistors.
- Semiconductor photosensitive devices, including:
  — photoresistors, photoconductive cells;
  — photothyristors (under consideration).
- Semiconductor devices utilizing optical radiation for internal operation, including:
  — photocouplers, optocouplers.

The sequence of the different chapters is in accordance with Publication 747-1, Chapter III, subclause **2.1**.

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Chapter II. Terminology and letter symbols

NOTE A number of additional terms of interest for optoelectronic devices, e.g. for radiometric, photometric and spectrophotometric quantities, appear in chapter 845 of the IEV, which supersedes chapter 45.

1 Physical concepts

1.1 (Electromagnetic) radiation (IEV 845-01-01)

1) Emission or transfer of energy in the form of electromagnetic waves with the associated photons.

2) These electromagnetic waves or these photons.

1.2 Optical radiation (IEV 845-01-02)

Electromagnetic radiation of wavelengths lying between the region of transition to X-rays ($\approx$ 1 nm) and the region of transition to radio waves ($\approx$ 1 nm).

1.3 Visible radiation (IEV 845-01-03)

Any optical radiation capable of causing a visual sensation directly.

NOTE There are no precise limits for the spectral range of visible radiation since they depend upon the amount of radiant power available and the responsivity of the observer. The lower limit is generally taken between 360 nm and 400 nm and the upper limit between 760 nm and 830 nm.

1.4 Infrared radiation (IEV 845-01-04, specialized)

Optical radiation for which the wavelengths are longer than those for visible radiation.

1.5 Ultraviolet radiation (IEV 845-01-05, specialized)

Optical radiation for which the wavelengths are shorter than those for visible radiation.

1.6 Light (IEV 845-01-06, without note 2 which is not relevant)

1.6.1 *Perceived light* (see IEV 845-02-17)

1.6.2 *Visible radiation* (see IEV 845-01-03)

NOTE Concept 2 is sometimes used for optical radiation extending outside the visible range, but this usage is not recommended.

1.7 Photoelectric effect (from IEV 845-05-33: photoelectric detector)

Interaction between optical radiation and matter resulting in the absorption of photons and the consequent generation of mobile charge carriers, thereby generating an electric potential or current, or a change in electrical resistance, excluding electrical phenomena caused by temperature changes.

1.8 Liquid crystal display devices

1.8.1 *Alignment layer*

A thin layer deposited over the patterned electrodes that determines the direction of the director at the surface. This layer produces the desired ordering. Alignment such as homeotropic alignment (**1.8.14**) or planar alignment (**1.8.15**) are achieved by the co-operative ordering of the liquid crystal molecules locally affected by the surface forces. The alignment layer is generating the pretilt angle (**1.8.20**).

1.8.2 *Chiral phase*

A liquid crystal phase exhibiting a spontaneous twist.

1.8.3 *Cholesteric phase*

A liquid crystal phase that exhibits planar nematic ordering in which the directors form a helix that has its axis perpendicular to the plane.

1.8.4 *Clearing point*

The phase transition temperature of a liquid crystal for transition toward the isotropic phase.

1.8.5 *Dichroic liquid crystal*

A liquid crystal exhibiting dichroism, i.e. the property of anisotropic absorption of light.

1.8.6 ***Director***

The axial unit vector describing the local axis of symmetry for the orientational distribution function of any chosen molecular axis of a liquid crystal. The director co-ordinates define the local alignment of the liquid crystal.

1.8.7 ***Disclination***

A localized alignment defect (appearing generally under the form of closed or open lines) forming the border between areas exhibiting different alignment states.

1.8.8 ***Discotic mesophase***

A liquid crystal phase of disc-like shaped molecules exhibiting a long range ordering with respect to the short molecular axis.

1.8.9 ***Dynamic scattering***

An electro-optical effect showing a light scattering caused by turbulent motion in a liquid crystal layer induced by an electro-hydrodynamic effect.

1.8.10 ***Electrically controlled birefringence***

An electro-optical effect caused by the birefringence of a liquid crystal layer which can be modulated (varied) by an electric field. It is also called "tunable birefringence".

1.8.11 ***Electrode layer***

An electrically conductive layer, usually transparent (e.g. made of indium tin oxide, "ITO"), covering the support plates and patterned to establish the display and electrical contact configuration.

1.8.12 ***Ferroelectric liquid crystal***

A liquid crystal phase exhibiting a spontaneous electric polarization.

NOTE This effect is commonly exhibited in chiral smectic liquid crystal.

1.8.13 ***Guest-host effect***

An anisotropic optical absorption effect occurring in a dichroic liquid crystal layer containing a dissolved dye.

1.8.14 ***Homeotropic alignment***

The alignment state of a liquid crystal layer for which the director is everywhere nominally perpendicular to a support plate surface.

1.8.15 ***Planar alignment***

The alignment state of a liquid crystal layer for which the director is everywhere nominally parallel to a support plate surface. This alignment is also referred to as homogeneous.

1.8.16 ***Liquid crystal***

A liquid crystal is a material that exhibits a mesophase consisting of elongated (rod-like) or disc-like (discotic) molecules and that possesses at least one long range orientational ordering with respect to one molecular axis.

1.8.17 ***Liquid crystal cell***

A flat structure consisting of a minimum of two support plates with liquid crystal contained in the space between them. These plates are usually separated by a distance of several micrometers.

1.8.18 ***Mesophase (mesomorphic phase)***

An ordered state of matter between the crystalline and isotropic liquid phases, exhibiting some of the properties of the neighbouring phases, as for example fluidity and birefringence.

1.8.19 ***Nematic phase***

Molecules in this liquid-crystalline phase possess a long range orientational ordering of one molecular axis (uniaxial nematic LC) or two molecular axes (biaxial nematic LC).

1.8.20 ***Pretilt angle***

The angle between the plane of a support plate and the adjacent liquid crystal director.

1.8.21 ***Sealing layer***

A layer situated between the support plates and surrounding the liquid crystal to ensure the hermeticity and integrity of the liquid crystal cell.

1.8.22 ***Smectic phase***

A liquid crystalline phase characterized by at least a one-dimensional long range transitional ordering of the molecules and a long range orientational ordering for one molecular axis.

1.8.23 ***Spacer***

A material incorporated into a liquid crystal cell (e.g. calibrated spheres or cylinders) to ensure a constant distance between the support plates.

1.8.24 ***Support plate***

Plate, generally transparent, made of e.g. glass or plastic sheet, covered with several layers (electrodes, sealing and surface alignment layers), forming the mechanical structure of a liquid crystal cell.

1.8.25 ***Twist angle***

The oriented angle between the projections of the respective surface directors at the support plates on to one of the support plates of a twisted nematic cell.

1.8.26 ***Twisted nematic structure***

A nematic liquid crystal state characterized by a twisted structure.

2 Type of devices

2.1 Semiconductor optoelectronic device

1) A semiconductor device that emits or detects or that is responsive to coherent or non-coherent optical radiation.

2) A semiconductor device that utilizes such radiation for its internal purposes.

2.2 Semiconductor photoemitter

A semiconductor optoelectronic device that directly converts electric energy into optical radiant energy.

2.3 Semiconductor optoelectronic display

A semiconductor photoemitter designed for the presentation of visual information.

2.4 Semiconductor laser

2.4.1 ***(Semiconductor) laser diode***

A semiconductor diode that emits coherent optical radiation through stimulated emission resulting from the recombination of free electrons and holes when excited by an electric current that exceeds the threshold current of the diode.

NOTE The laser diode is mounted on a submount or in a package with or without coupling means (e.g. lens, pigtail).

2.4.2 ***Laser-diode module***

A module containing, together with the laser diode, means for an automatic optical and/or thermal stabilization of the radiant output power.

2.5 Light-emitting diode (LED)

A semiconductor diode, other than a semiconductor laser, capable of emitting visible radiation when excited by an electric current.

2.6 Infrared-emitting diode (IRED)

A semiconductor diode other than a semiconductor laser capable of emitting infrared radiation when excited by an electric current.

2.7 (Semiconductor) photosensitive device

A semiconductor device that utilizes the photoelectric effect for detection of optical radiation.

2.8 (Semiconductor) photoelectric detector

A semiconductor device that utilizes the photoelectric effect for detection of optical radiation.

2.9 (Semiconductor) photoresistor, photoconductive cell (IEV 845-05-37, specialized)

A semiconductor photoelectric detector that utilizes the change of electric conductivity produced by the absorption of optical radiation.

2.10 Photoelement, photovoltaic cell (IEV 845-05-38)

A photoelectric detector that utilizes the electromotive force produced by the absorption of optical radiation.

2.11 Photodiode (IEV 845-05-39)

A photoelectric detector in which a photocurrent is generated by absorption of optical radiation in the neighbourhood of a PN junction between the semiconductors, or of a junction between a semiconductor and a metal.

2.12 Avalanche photodiode (IEV 845-05-40, specialized)

A photodiode operating with a reverse bias such that the primary photocurrent undergoes amplification within the diode.

2.13 Phototransistor

A transistor in which the current produced by the photoelectric effect in the neighbourhood of the emitter-base junction acts as base current, which is amplified.

2.14 Photothyristor

A thyristor that is designed to be triggered by optical radiation.

2.15 Photocoupler, optocoupler

A semiconductor optoelectronic device designed for the transfer of electrical signals by utilizing optical radiation to provide coupling with electrical isolation between the input and the output.

3 General terms

3.1 Optical axis

A line about which the principal radiation or sensitivity pattern is centered.

NOTE Unless otherwise stated, the optical axis coincides with the direction of maximum radiation or sensitivity.

3.2 Optical port (of a semiconductor optoelectronic device)

A geometrical configuration, referenced to an external plane or surface of the device, that is used to specify the optical radiation emitted from an emitting device or accepted by a detecting device.

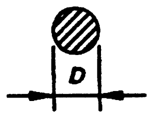
NOTE The geometrical configuration shall be specified by the manufacturer by means of geometrical information, e.g.:

— location, shape and size of the area of emission or acceptance;
— angle of emission or acceptance;
— other parameters, e.g. numerical aperture of optical fibre;
— orientation of optical axis.

Examples:

Signification of annotations in the figures:

α = emission of acceptance angle



= optical port with diameter *D*

Ref. = reference locus for the definition of the optical port.

Example I: *Devices with pigtail (emitter or detector)*

Ia *Device with bare fibre pigtail*

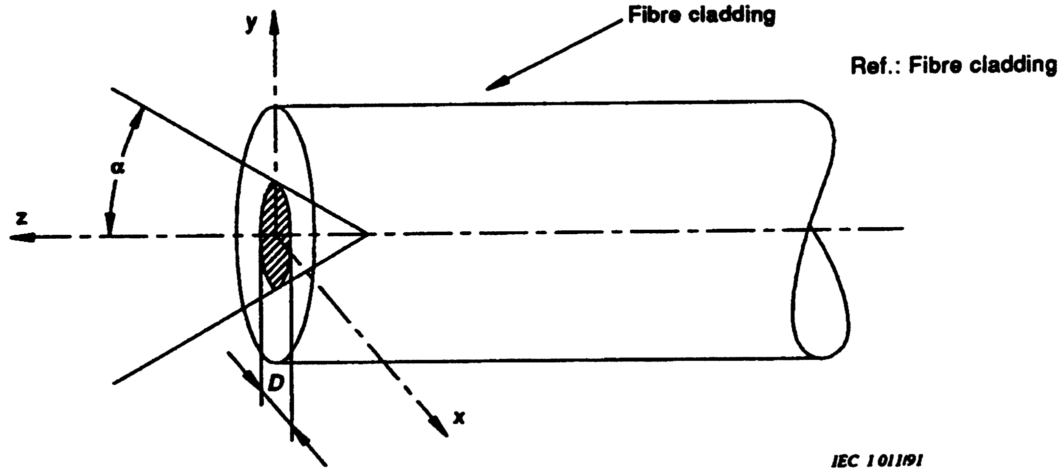


Figure 1a

Ib *Device with fibre pigtail connector attached*

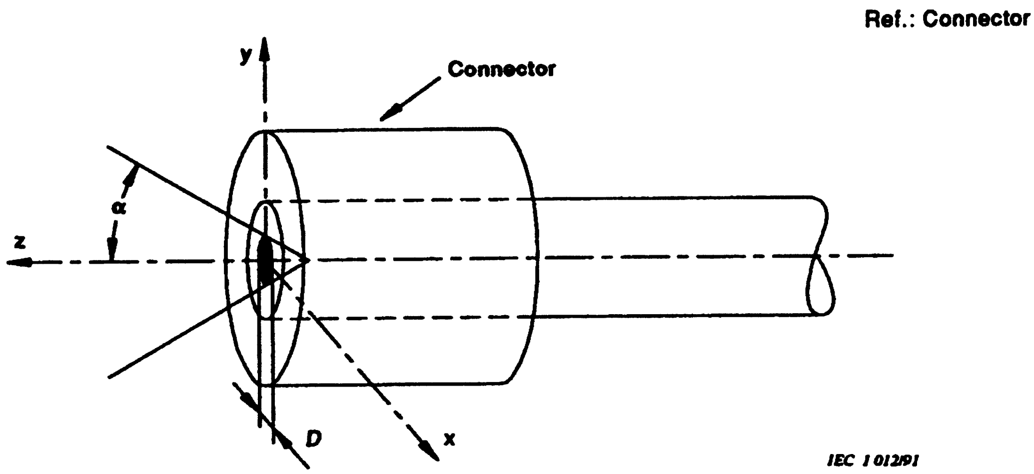


Figure 1b

Example II: *Packaged devices (emitter or detector), without pigtail*

IIa *Device with window, but without lens*

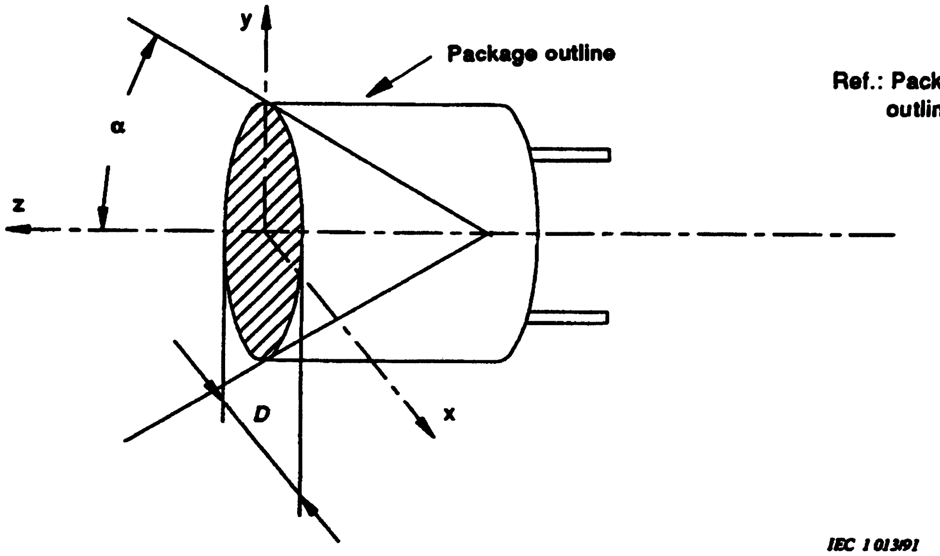
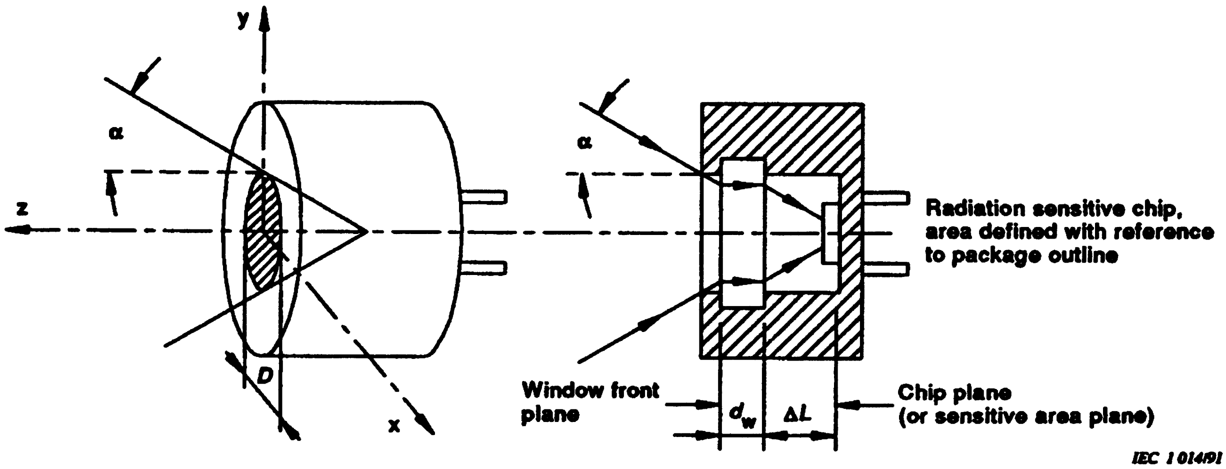


Figure 2a

IIb *Detector with window, but without lens (chip referenced)*



d_w = window thickness

α = aperture angle

n = refractive index of window material

ΔL = distance between window back plane and chip plane

Figure 2b

IIc *Detector with lens*

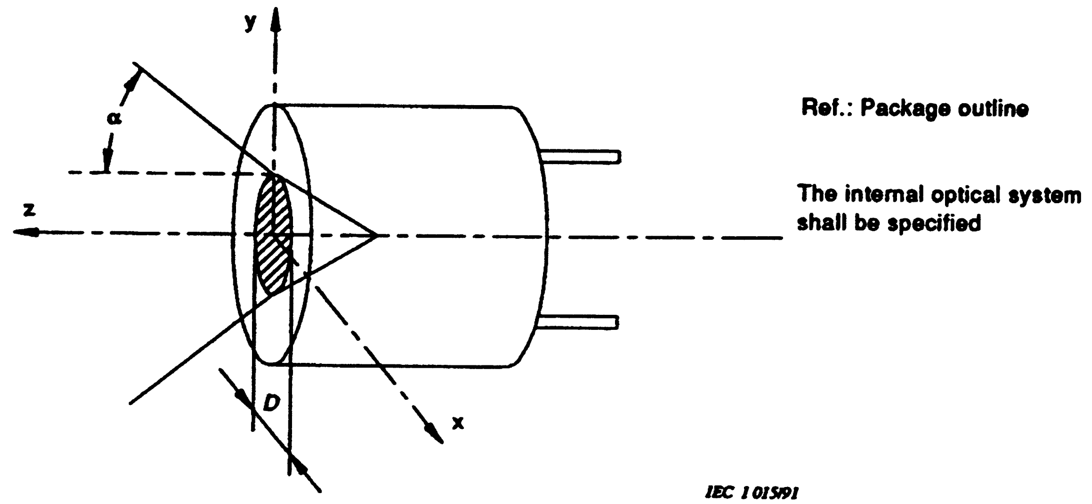


Figure 2c

IId *IRED with optical port that is not located on the output window of the package*

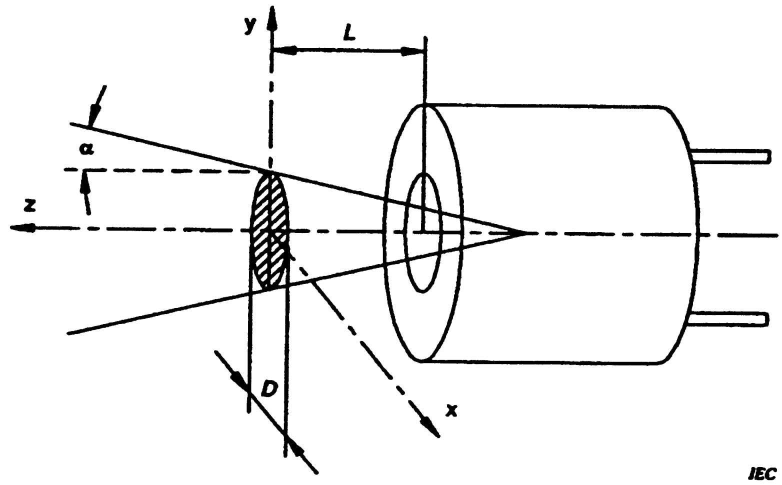
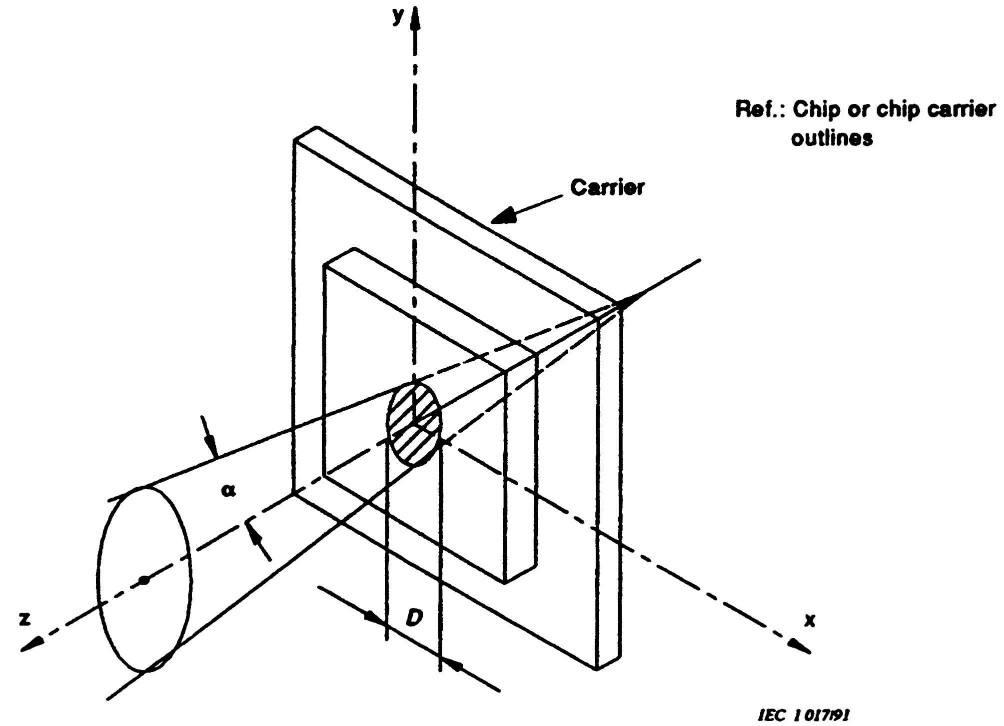


Figure 2d

Example III: *Non-packaged devices (emitter or detector) without pigtail*



NOTE Angle α may not be required for detectors.

Figure 3

3.3 (Optical) cladding (IEV 731-02-05)

That dielectric material of an optical fibre surrounding the core.

3.4 Liquid crystal display devices

3.4.1 ***Active area***

Part of a display screen area delimited by picture elements.

3.4.2 ***Active matrix-addressed display***

A matrix-addressed display device in which each picture element has at least one switching element (e.g. diode or transistor).

3.4.3 ***Alphanumeric display***

A display device that is able to present a limited set of characters including at least letters and numerals.

3.4.4 ***Emissive display***

A display that contains its own source(s) of light. This light can be produced by the transducer itself or provided by one or more internal light source(s) modulated by the transducer.

3.4.5 ***Grey scale***

Display is said to have grey scale capability if it can display images providing more than two luminance levels.

3.4.6 ***Liquid crystal display cell***

Liquid crystal cell that is used to modulate light to present information.

3.4.7 ***Liquid crystal display module***

A display unit combining a liquid crystal display cell with drive electronics. Additional options are possible such as backlight, mounting brackets, etc.

3.4.8 ***Matrix display***

A display device consisting of regularly distributed pixels arranged in rows and columns.

3.4.9 ***Monochrome display***

A display using only one colour or black and white contrast.

3.4.10 ***Pixel***

Smallest element that is capable of generating full functionality of a display.

3.4.11 ***Reflective display***

A display device that modulates light from an external source by reflection.

3.4.12 ***Segment***

A segment is a special purpose dedicated pixel, e.g. a specific portion of an alphanumeric symbol, or a sign by itself.

3.4.13 ***Storage effect***

The property of a picture element in which the visual information is retained after the activation has been removed.

3.4.14 ***Transflective display***

A display device that modulates light from an external source by reflection or from another source by transmission through a semitransmissive reflector.

3.4.15 ***Transmissive display***

A display device that modulates light from an external source by transmission.

3.4.16 ***Viewing angle range***

The viewing angular direction range over which the visual specification is satisfied.

3.4.17 ***Viewing area***

The active area (**3.4.1**) plus any contiguous areas that display permanent visual information or a display background.

4 Terms related to ratings and characteristics

4.1 General

4.1.1 ***Switching times***

NOTE The specified lower and upper limit values referred to in concepts **4.1.1.1** to **4.1.1.6** are usually 10 % and 90 % of the amplitude of the pulses (see Figure 4).

4.1.1.1 *Turn-on delay time* $t_{d(on)}$

The time interval between the lower specified value on the leading edge of the applied input pulse and the lower specified value on the leading edge of the output pulse.

4.1.1.2 *Rise time* t_r

The time interval between the lower specified value and the upper specified value on the leading edge of the output pulse.

4.1.1.3 *Turn-on time* t_{on}

The time interval between the lower specified value on the leading edge of the applied input pulse and the upper specified value on the leading edge of the output pulse.

$$t_{on} = t_{d(on)} + t_r$$

4.1.1.4 *Turn-off delay time* $t_{d(off)}$

The time interval between the upper specified value on the trailing edge of the applied input pulse and the upper specified value on the trailing edge of the output pulse.

NOTE If the turn off delay time is mainly due to carrier storage (e.g. in the output transistor of a photocoupler), the term "(carrier) storage time" and the letter symbol t_s are in use.

4.1.1.5 *Fall time* t_f

NOTE The time interval between the upper specified value and the lower specified value on the trailing edge of the output pulse.

4.1.1.6 *Turn-off time* t_{off}

The time interval between the upper specified value on the trailing edge of the applied input pulse and the lower specified value on the trailing edge of the output pulse.

$t_{off} = t_{d(off)} + t_f$

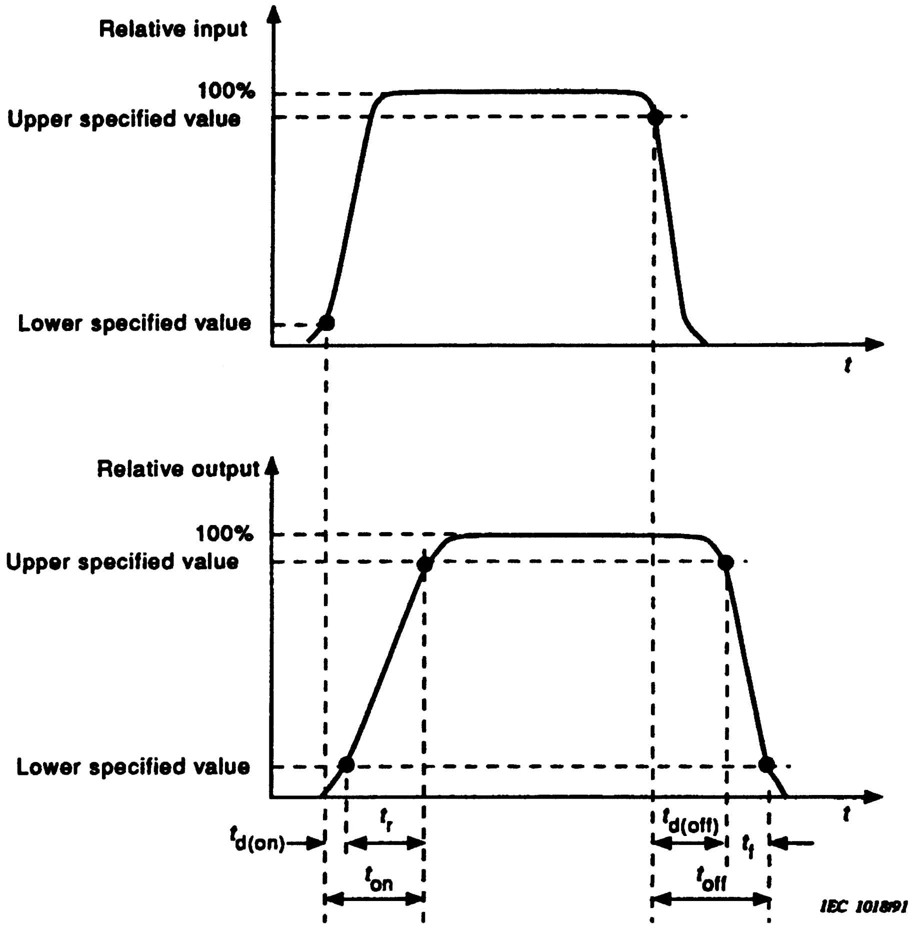


Figure 4 — Switching times

4.2 Photoemitters

4.2.1 *Radiant power, luminous flux*

4.2.1.1 *Radiant power (of a photoemitter)* ϕ_e

The radiant power emitted from the optical port of the device.

4.2.1.2 *Luminous flux (of a photoemitter)* ϕ_v

The luminous flux emitted from the optical port of the device.

4.2.2 *Efficacies*

4.2.2.1 *Radiant power efficacy* η_e, η *radiant efficacy* (of an infrared-emitting diode or a laser diode)

The quotient of the emitted radiant power ϕ_e, by the forward current I_F:

$\eta_e = \phi_e/I_F$

NOTE If no ambiguity is likely to occur, particularly with the term IEV 845-01-54: "radiant efficiency" $\eta_e = \phi_e/(I_F \cdot V_F)$, the term may be shortened to "radiant efficacy" or "efficacy". This is nearly always possible.

4.2.2.2 *Radiant intensity efficacy* η_{ei} (of an infrared-emitting diode or a laser diode)

The quotient of the emitted radiant intensity I_e, by the forward current I_F:

$\eta_{ei} = I_e/I_F$

4.2.2.3 *Luminous flux efficacy* η_v *luminous efficacy* (of a light-emitting diode)

The quotient of the emitted luminous flux ϕ_v, by the forward current I_F:

$\eta_v = \phi_v/I_F$

NOTE If no ambiguity is likely to occur, particularly with the terms IEV 845-01-55: "luminous efficacy of a source" $\eta_v = \phi_v/(I_F \cdot V_F)$, or IEV 845-01-56: "luminous efficacy of a radiation" $K = \phi_v/\phi_e$, the term may be shortened to "luminous efficacy" or "efficacy". This is nearly always, possible.

4.2.2.4 *Luminous intensity efficacy* η_{vi} (of a light-emitting diode)

The quotient of the emitted luminous intensity I_v, by the forward current I_F:

$\eta_{vi} = I_v/I_F$

4.2.2.5 *Differential radiant power efficacy* η_{ed}, η_d *differential radiant efficacy* (of an infrared-emitting diode or a laser diode)

The radiant power efficacy for small-signal modulation:

$\eta_{ed} = d\phi_e/dI_F$

NOTE 1 If no ambiguity is likely to occur, the shorter term and letter symbol may be used.

NOTE 2 The term "small-signal modulation efficacy" is in use as synonym.

4.2.2.6 *Differential radiant intensity efficacy* η_{eid} (of an infrared-emitted diode or a laser diode)

The radiant intensity efficacy for small-signal modulation:

$\eta_{eid} = dI_v/dI_F$

4.2.2.7 *Differential luminous flux efficacy* η_{vd}, η_d *differential luminous efficacy* (of a light-emitting diode)

The luminous flux efficacy for small-signal modulation:

$\eta_{vd} = d\phi_v/dI_F$

NOTE 1 If no ambiguity is likely to occur, the shorter term and letter symbol may be used.

NOTE 2 The term "small-signal modulation efficacy" is in use as synonym.

4.2.2.8 *Differential luminous intensity efficacy* η_{vid} (of a light-emitting diode)

The luminous intensity efficacy for small-signal modulation:

$\eta_{vid} = dI_v/dI_F$

4.2.2.9 *Large-signal radiant power efficacy* η_{EL}, η_L *large-signal radiant efficacy* (of an infrared-emitting diode or a laser diode)

The radiant power efficacy for large-signal modulation:

$\eta_{EL} = \Delta\phi_e/\Delta I_F$

NOTE If no ambiguity is likely to occur, the shorter term and letter symbol may be used.

4.2.2.10 *Large-signal radiant intensity efficacy* η_{EIL} (of an infrared-emitting diode or a laser diode)

The radiant intensity efficacy for large-signal modulation:

$\eta_{EIL} = \Delta I_e/\Delta I_F$

4.2.2.11 *Large-signal luminous flux efficacy* η_{VL}, η_L *large-signal luminous efficacy* (of a light-emitting diode)

The luminous flux efficacy for large-signal modulation:

$\eta_{VL} = \Delta\phi_v/\Delta I_F$

NOTE If no ambiguity is likely to occur, the shorter term and letter symbol may be used.

4.2.2.12 *Large-signal luminous intensity efficacy* η_{VIL} (of a light-emitting diode)

The luminous intensity efficacy for large-signal modulation:

$\eta_{VIL} = \Delta I_v/\Delta I_F$

4.2.3 ***Cut-off frequency***

4.2.3.1 *Small-signal (modulation) cut-off frequency* f_{cd}, f_c (of a photoemitting diode)

The frequency at which, for constant modulation depth of the forward current, the demodulated a.c. optical radiant power has decreased to 1/2 of its low-frequency value.

4.2.3.2 *Large-signal (modulation) cut-off frequency* f_{CL}, f_C (of a photoemitting diode)

Under consideration.

4.2.4 ***Threshold current*** (of a laser diode) $I_{(TH)}$

The forward current at which the second derivative of the cure showing radiant power ϕ_e versus forward current I_F has its first maximum (see Figure 5).

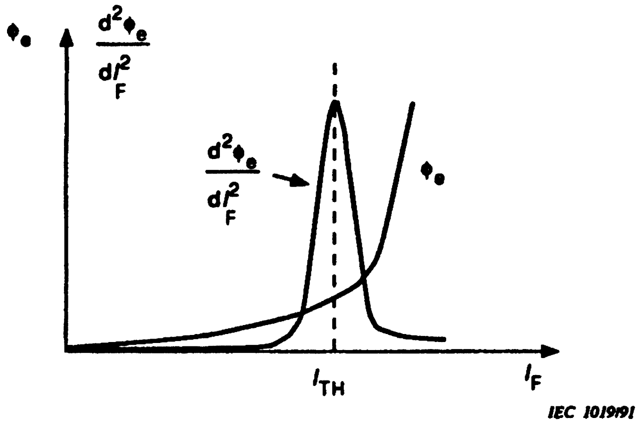


Figure 5 — Threshold current of a laser diode

4.2.5 ***Spatial radiation diagram and related characteristics*** (of a photoemitter)

4.2.5.1 *Radiation diagram*

A diagram that characterizes the distribution of radiant (or luminous) intensity:

I_e (or I_v) = $f(\theta)$ (see Figure 6a and Figure 6b)

NOTE 1 Unless otherwise stated, the distribution of the radiant (or luminous) intensity should be specified in a plane. This plane includes the mechanical axis z.

NOTE 2 If the radiation pattern has a rotational symmetry of the z axis, the radiation diagram shall be specified for one plane only.

NOTE 3 If the radiation pattern has no rotational symmetry to the z axis, radiation diagrams for various angles ϕ shall be specified. Then the x, y and z directions shall be defined by a drawing in the detail specification.

4.2.5.2 *Half-intensity angle* $\theta_{1/2}$

In a radiation diagram, the angle within which the radiant (or luminous) intensity is greater than or equal to half of the maximum intensity (see Figure 6b).

4.2.5.3 *Misalignment angle* $\Delta\theta$

In a radiation diagram, the angle between the direction for maximum radiant (or luminous) intensity (optical axis) and the mechanical axis z (see Figure 6b).

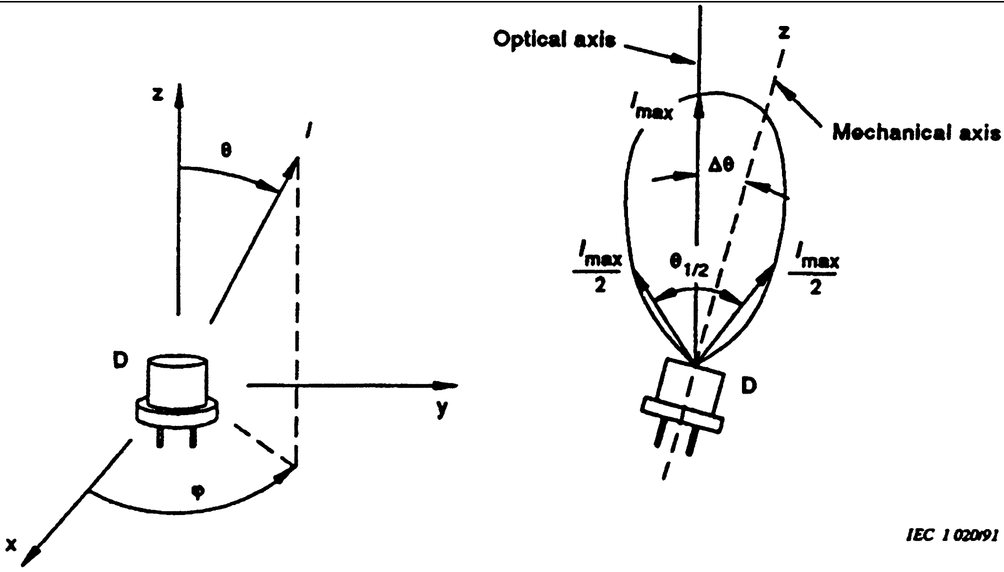


Figure 6 — Radiation diagram and related characteristics

4.2.6 ***Spectral characteristics*** (of light-emitting diodes and infrared-emitting diodes) (see Figure 7)

4.2.6.1 *Peak-emission wavelength* λ_p

The wavelength at which the spectral radiant power is a maximum.

4.2.6.2 *Spectral bandwidth* $\Delta\lambda$

The wavelength interval in which the spectral radiant power is greater or equal to half of its maximum value.

4.2.6.3 *(Relative) parasitic radiant power* $\phi_{e(par)}$ *or luminous flux* $\phi_{v(par)}$

The value of undesired spectral radiant power (or luminous flux) in two specified wavelength ranges that lie below and above the peak-emission wavelength, expressed as a percentage of the radiant power (or luminous flux) at peak-emission wavelength.

NOTE Specified values refer to the maximum value within each of the specified wavelength ranges.

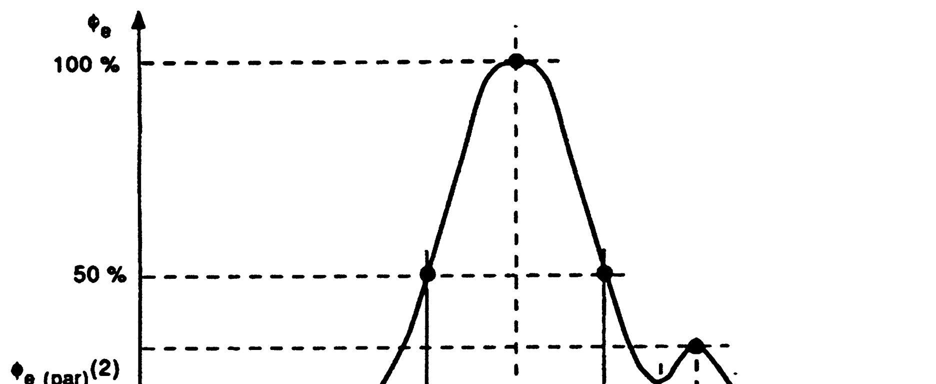


Figure 7 — Spectral characteristics of light-emitting diodes and infrared-emitting diodes

4.2.7 ***Spectral characteristics*** (of laser diodes and laser-diode modules) (see Figure 8)

4.2.7.1 *Peak-emission wavelength* λ_p

The wavelength at the peak value of the mode with the maximum spectral radiant power.

4.2.7.2 *Spectral radiation bandwidth* $\Delta\lambda$

The bandwidth that includes all wavelengths at which the radiant power is equal to or greater than a specified percentage of the power at the peak-emission wavelength.

NOTE 1 Unless otherwise stated, the specified percentage is 50 %.

NOTE 2 The definition allows peak values lower than the specified percentage to be present within this bandwidth.

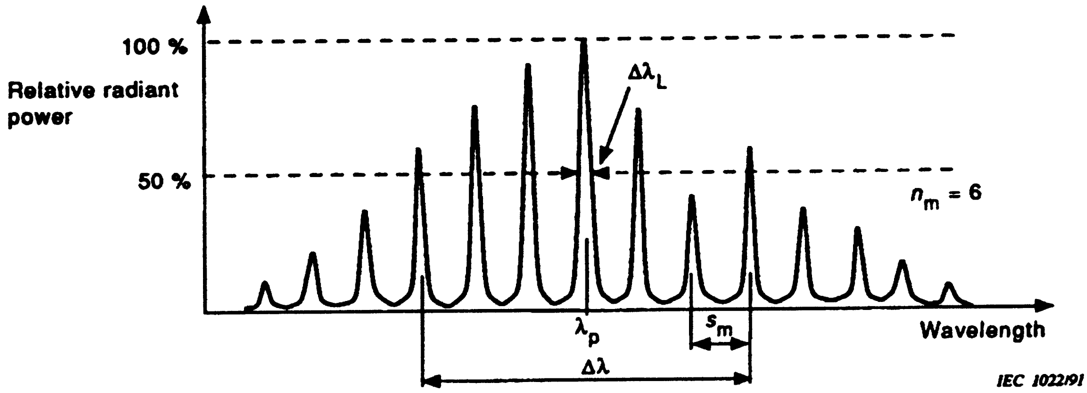


Figure 8 — Spectral characteristics of laser diodes and laser-diode modules

4.2.7.3 *Line width* $\Delta\lambda_L$

The wavelength interval between those points of an emission line at which the spectral radiant power is half of its maximum value.

4.2.7.4 *Central wavelength* $\bar{\lambda}$

The weighted average of the mode wavelengths:

$$\bar{\lambda} = \frac{\sum_{i=-\infty}^{i=+\infty} a_i \times \lambda_i}{\sum_{i=-\infty}^{i=+\infty} a_i}$$

where

λ_i is the wavelength } of the i^{-th} spectral line with $i = 0$ for λ_p
a_i is the amplitude }

4.2.7.5 *RMS bandwidth* $\Delta\lambda_{rms}$

The RMS bandwidth is defined by the expression:

$$\Delta\lambda_{rms} = \sqrt{\frac{\sum_{i=-\infty}^{i=+\infty} a_i \times (\lambda_i - \bar{\lambda})^2}{\sum_{i=-\infty}^{i=+\infty} a_i}}$$

where

λ_i is the wavelength } of the i^{-th} spectral line, with $i = 0$ for λ_p
a_i is the amplitude }
$\bar{\lambda}$ is the central wavelength

4.2.7.6 *Number of longitudinal modes* n_m

The number of longitudinal modes within spectrum bandwidth, including the modes at the band limits.

4.2.7.7 *Mode spacing* s_m

The difference in wavelength for two neighbouring longitudinal modes.

4.2.7.8 *Side-mode suppression ratio SMS*

The ratio of:

— the radiant power at the peak-emission wavelength ϕ_{ep}; to

— the radiant power of the next most intense mode ϕ_{es} (see Figure 9).

NOTE Side-mode suppression ratio is normally expressed as:

$$SMS = 10 \cdot \log \left(\frac{\phi_{ep}}{\phi_{es}}\right) \quad [\text{dB}]$$

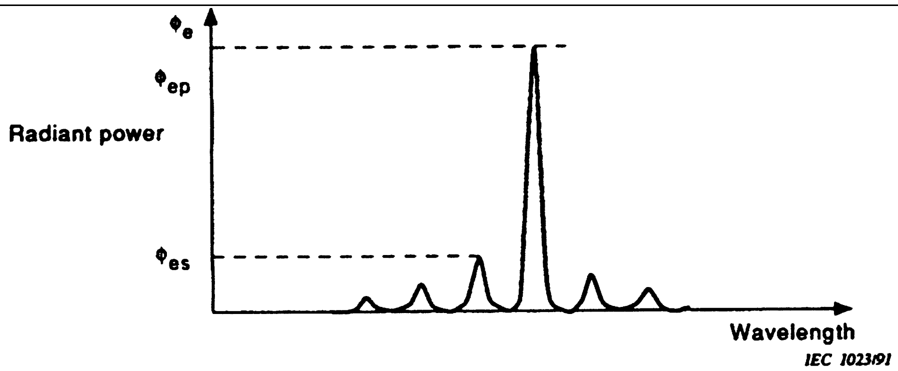


Figure 9 — Side-mode suppression ratio

4.2.7.9 *Spectral shift* (versus current or temperature) $\Delta\lambda_c$

Under consideration.

4.2.7.10 *Input reflection coefficient* s_{11}

Under consideration.

4.2.7.11 *Radiant power* (of a laser chip or submount) ϕ_{eoo}

See Chapter III, Section 8, subclause **6.1**.

4.2.8 ***Emission source*** (of a laser diode)

4.2.8.1 *Emission source width* s_w

On the facet of the laser diode, in the direction of the major axis, the width within which the radiant intensity is larger than or equal to a specified percentage of the maximum value (see Figure 10).

NOTE 1 The direction of the major axis is the direction parallel to the PN junction plane.

NOTE 2 Unless otherwise stated, the specified percentage is 50 %.

4.2.8.2 *Emission source height* s_h

On the facet of the laser diode, in the direction of the minor axis, the height within which the radiant intensity is larger than or equal to a specified percentage of the maximum value (see Figure 10).

NOTE 1 The direction of the minor axis is the direction perpendicular to the PN junction plane.

NOTE 2 Unless otherwise stated, the specified percentage is 50 %.

4.2.8.3 *Astigmatism* d_A

An astigmatism of the emitted radiation that comes from a difference in curvature of the wave front in the directions of the major and minor axis, respectively, whereby usually the centre of the curvature in the direction of the major axis is farther behind the facet than in the other direction.

NOTE 1 The astigmatism can be represented by the curvature $d_A = a - b$ of a convex virtual emission source (see Figure 10).

NOTE 2 The value of d_A is calculated from the difference in position of the focussing lens when the focussed beam diameter is minimum in each of the two directions.

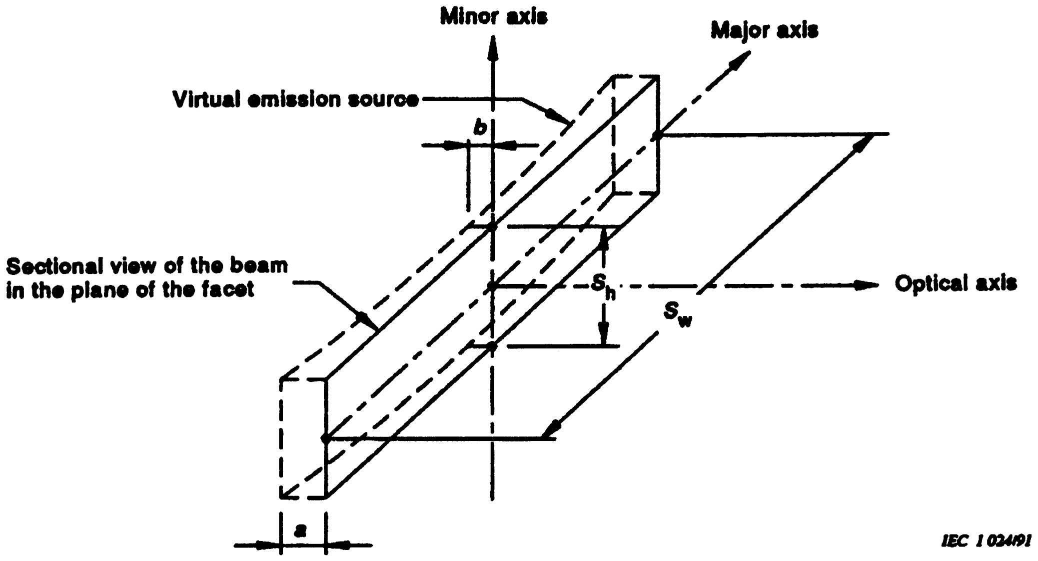


Figure 10 — Emission source of a laser diode

4.2.9 ***Noise characteristics*** (of laser diodes)

4.2.9.1 *Relative intensity noise RIN*

Under consideration.

4.2.9.2 *Carrier-to-noise ratio C/N*

The quotient of:

— the mean square radiant power at the specified frequency; to

— the mean square radiant power fluctuations normalized to a frequency band of unit width centered on the carrier frequency.

4.2.9.3 *K-factor; mode partition noise*

Under consideration.

4.2.10 ***Additional characteristics*** (of laser-diode modules)

4.2.10.1 *Tracking error*

Under consideration.

4.3 Photosensitive devices

4.3.1 ***Output currents*** (of a photodiode)

NOTE The subscripts D for dark and P for photo are still under consideration.

4.3.1.1 *Reverse current* (under optical radiation) $I_{R(H)}$ *or* $I_{R(e)}$, I_R

The total reverse current when the photodiode is exposed to incident optical radiation.

4.3.1.2 *Dark current* $I_{R(D)}$

The reverse current in the absence of incident optical radiation.

4.3.1.3 *Photocurrent* I_p

That part of the reverse current that is caused by incident optical radiation:

$I_p = I_{R(H)} - I_{R(D)}$

4.3.2 ***Output currents*** (of a phototransistor)

4.3.2.1 *Collector current* (under optical radiation) $I_{C(H)}$ *or* $I_{C(e)}$, I_c

The total collector current when the phototransistor is exposed to incident optical radiation.

4.3.2.2 *Collector-emitter dark current* I_{CEO}

The collector current in the absence of incident optical radiation.

4.3.3 ***Sensitivity***

4.3.3.1 *(Diode) sensitivity* S_D, S (of a photodiode)

The quotient of

— the photocurrent I_p, by

— the irradiance E_e (or illuminance E_v) at the optical port of the photodiode.

$$S_D = \frac{I_P}{E_e} \quad \text{or} \quad S_D = \frac{I_P}{E_v}$$

NOTE If no ambiguity is likely to occur, the shorter term and letter symbol may be used.

4.3.3.2 *(Fibre-input) sensitivity* S_{FD}, S (of a photodiode irradiated [illuminated] from the front end of an optical fibre) (see Figure 11)

The quotient of

— the photocurrent I_p, by

— the radiant power ϕ_e (or luminous flux ϕ_v) emitted from the optical fibre, for specified values of the radial displacement r and the distance z of the front end of the optical fibre, relative to the optical port of the photodiode.

$$S_{FD} = \frac{I_P}{\phi_e} \quad \text{or} \quad S_{FD} = \frac{I_P}{\phi_v}$$

NOTE 1 If no ambiguity is likely to occur, the shorter term and letter symbol may be used.

NOTE 2 In specifications, usually curves are given showing S_{FD} as a function of r and z.

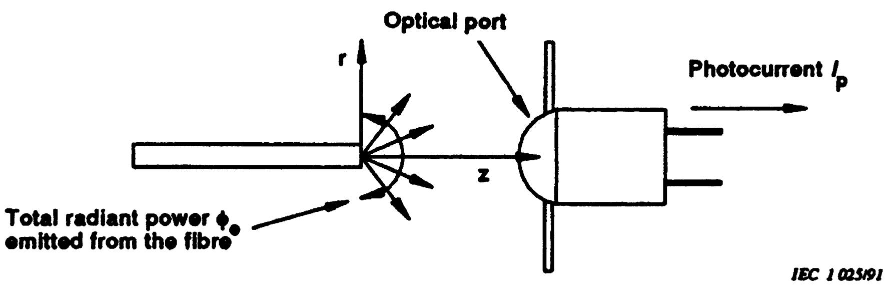


Figure 11 — Fibre-input sensitivity S_{FD}

4.3.4 ***Cut-off frequency*** (of a photodiode)

4.3.4.1 *Small-signal cut-off frequency* f_{cd}, f_c

The frequency at which, for constant small signal modulation depth of the input radiant power, the demodulated signal power has decreased to 1/2 of its low-frequency value.

NOTE When, for the measurement of f_c, the photocurrent of the photodiode is observed, a 1-to-2 decrease in radiant power corresponds to a 1-to-2 decrease in photocurrent. Therefore, when the latter is measured as a voltage drop across a load resistance, the criterion of a 1-to-2 decrease applies also to the voltage, provided the load resistance is small compared with the output resistance of the photodiode.

4.3.4.2 *Large-signal cut-off frequency* f_{CL}, f_C

The frequency at which, for constant large signal modulation depth of the input radiant power, the demodulated signal power has decreased to 1/2 of its low-frequency value.

NOTE The note to subclause **4.3.4.1** applies accordingly.

4.3.5 ***Spatial sensitivity diagram and related characteristics*** (of photosensitive devices)

4.3.5.1 *Sensitivity diagram*

As diagram that characterizes the distribution of sensitivity:

$S = f(\theta)$ (see Figure 12a and Figure 12b)

NOTE 1 Unless otherwise stated, the distribution of sensitivity should be specified in a plane. This plane includes the mechanical axis z.

NOTE 2 If the sensitivity pattern has a rotational symmetry to the z axis, the sensitivity diagram shall be specified for one plane only.

NOTE 3 If the sensitivity pattern has no rotational symmetry to the z axis, sensitivity diagrams for various angles θ shall be specified. Then the x, y and z directions shall be defined by a drawing in the detail specification.

4.3.5.2 *Half-sensitivity angle* $\theta_{S/2}$

In a sensitivity diagram, the angle within which the sensitivity is greater than or equal to half of the maximum sensitivity (see Figure 12b).

4.3.5.3 *Misalignment angle* $\Delta\theta$

In a sensitivity diagram, the angle between the direction for maximum sensitivity (optical axis) and the mechanical axis z (see Figure 12b).

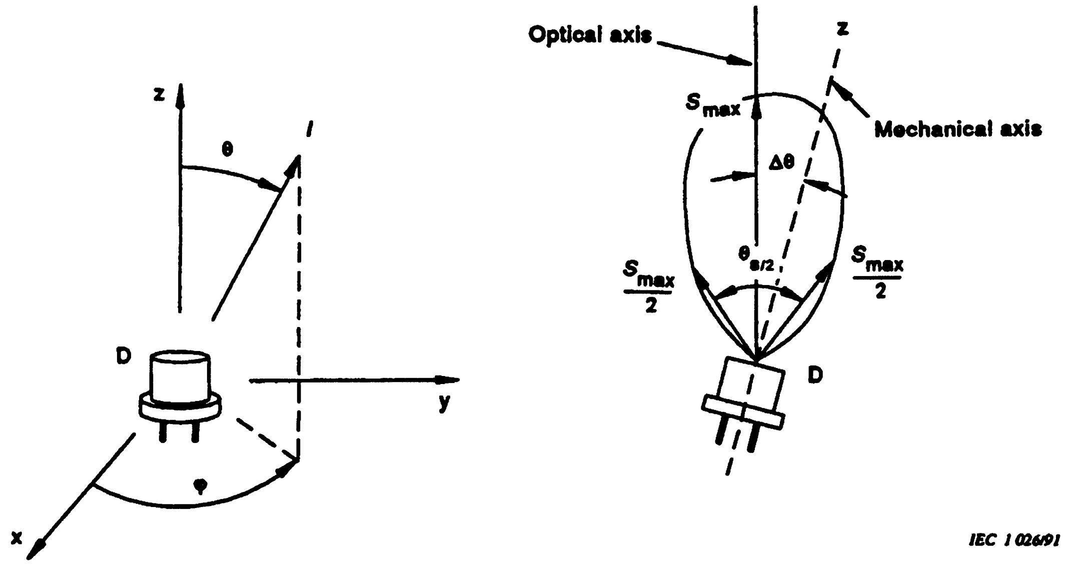


Figure 12 — Sensitivity diagram and related characteristics

4.3.6 ***Spectral characteristics*** (of photosensitive devices)

4.3.6.1 *Peak-sensitivity wavelength* λ_p

The wavelength at which the spectral sensitivity is a maximum.

4.3.7 ***Multiplication factor M*** (of an avalanche photodiode)

The ratio of:

— the photocurrent under a condition at which carrier multiplication takes place (I_{R1} at V_{R1}); to

— the photocurrent under a condition at which no carrier multiplication takes place (I_{R2} at V_{R2});

— $M = \frac{I_{R1}}{I_{R2}}$ (see Figure 13)

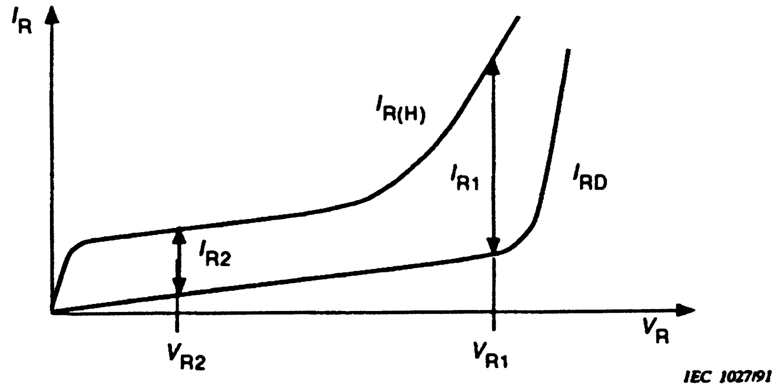


Figure 13 — Multiplication factor of an avalanche diode

4.3.8 ***Excess noise factor*** (of an avalanche photodiode)

Under consideration.

4.4 Photocouplers, optocouplers

4.4.1 ***Current transfer ratio***

4.4.1.1 *Static value of the (forward) current transfer ratio* $h_{F(ctr)}$, h_F

The ratio of the d.c. output current to the d.c. input current, the output voltage being held constant.

NOTE The abbreviation CTR(d.c.) is sometimes used instead of a symbol.

4.4.1.2 *Small-signal short-circuit (forward) current transfer ratio* $h_{f(ctr)}$, h_f

The ratio of the a.c. output current to the a.c. input current, the output being short-circuited to a.c.

NOTE The abbreviation CTR(a.c.) is sometimes used instead of a symbol.

4.4.2 ***Cut-off frequency*** f_{ctr}

The frequency at which the modulus of the small-signal current transfer ratio has decreased to $1/\sqrt{2}$ of its low-frequency value.

4.4.3 ***Input-to-output capacitance*** C_{IO}

The total capacitance between all input terminals connected together and all output terminals connected together.

4.4.4 ***Isolation resistance*** R_{IO}

The resistance between all input terminals connected together and all output terminals connected together.

4.4.5 ***Isolation voltage***

The voltage between any specified input terminal and any specified output terminal.

4.4.5.1 *D.C. isolation voltage* V_{IO}

The value of the constant isolation voltage.

4.4.5.2 *Repetitive peak isolation voltage* V_{IORM}

The highest instantaneous value of the isolation voltage including all repetitive transient voltages, but excluding all non-repetitive transient voltages.

NOTE A repetitive transient voltage is usually a function of the circuit. A non-repetitive transient voltage is usually due to an external cause and it is assumed that its effect has completely disappeared before the next non-repetitive voltage transient arrives.

4.4.5.3 *Surge isolation voltage* V_{IOSM}

The highest instantaneous value of an isolation voltage pulse of short time duration and of specified waveshape.

4.5 Liquid crystal display devices

4.5.1 ***Addressing***

Selecting the pixels in space and/or time for activation or deactivation.

4.5.2 ***Contrast [IEV 45-25-265]***

Subjective assessment of the difference in appearance of two parts of a field of view seen simultaneously or successively.

4.5.3 ***Contrast ratio***

The ratio between the higher, L_H and lower, L_L luminances that define the feature to be detected, measured by contrast ratio (CR), defined as:

$$CR = \frac{L_H}{L_L}$$

(see **2.22** of ISO 9241-3).

4.5.4 ***Direct addressing***

A method of addressing by applying a signal to a terminal that corresponds to one pixel only. Hence, all pixels can be addressed individually, in groups or simultaneously.

4.5.5 ***Driver***

A device that transforms the address information into driving signals suitable for selecting a pixel. The same signals may also activate the pixel.

4.5.6 ***Duty ratio***

The reciprocal value of the number of pixel groups which are addressed in a multiplex addressing scheme (e.g. the reciprocal of the number of rows for a row-at-a-time matrix addressing scheme).

4.5.7 ***Electro-optic characteristic***

The variation of a photometric property (e.g. luminance or contrast) as a function of electrical drive quantities (voltage or current).

4.5.8 ***Image polarity***

The relationship between background brightness and image brightness.

The presentation of brighter images on a darker background is designated by negative polarity, and darker images on a brighter background is designated by positive polarity.

4.5.9 ***Matrix addressing***

A method of addressing in which a pixel is selected by applying signals to the terminals that correspond to its row and column. Hence, an individual pixel is addressed by selecting groups in space and time.

NOTE A typical example is a panel with row and intersecting column electrodes.

4.5.10 ***Multiplex driving***

A method of temporal driving in which a first set of pixel groups is selected in a sequence once in a time frame and a second set of intersecting pixel groups is selected according to the pattern to be displayed.

NOTE A typical example is a cell with row and intersecting column electrodes in which one row is selected at a time.

4.5.11 ***Static driving***

A method of driving in which all pixels are addressed simultaneously and constantly.

5 Letter symbols

Under consideration.

Chapter III. Essential ratings and characteristics Section 1. Light-emitting diodes

(Excluding devices for fibre optic systems or subsystems dealt with in Section 7)

1 Type

Ambient-rated or case-rated light-emitting diode.

2 Semiconductor material

Gallium arsenide-phosphide, etc.

3 Colour

4 Details of outline and encapsulation

4.1 IEC and/or national reference number of the outline drawing.

4.2 Method of encapsulation: glass/metal/plastic/other.

4.3 Terminal identification and indication of any connection between a terminal and the case.

5 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

5.1 Minimum and maximum storage temperatures (T_{stg}).

5.2 Minimum and maximum operating ambient or case temperature (T_{amb} or T_{case}).

5.3 Maximum reverse voltage (V_R).

NOTE Not applicable to dual-diode devices connected anode-to-cathode and cathode-to-anode.

5.4 Maximum continuous forward current (I_F) at an ambient or case temperature of 25 °C and derating curve or derating factor.

5.5 Where appropriate, maximum peak forward current (I_{FM}) at an ambient or case temperature of 25 °C, under specified pulse conditions.

6 Electrical characteristics

For multiple diodes, the characteristics should be given for each diode. For special applications, additional characteristics may be required.

Ref.	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
6.1	Forward voltage	I_F specified (d.c. or pulse)		V_F		Max.
6.2	Reverse current	V_R specified	1	I_R		Max.
6.3	luminous intensity along the defined mechanical axis	I_F specified (d.c. or pulse)	2, 3	I_v	Min.	
6.4	Peak emission wavelength	I_F specified (d.c. or pulse)		λ_p	Min.	Max.
6.5	Spectral radiation bandwidth (where appropriate)	Half value of peak emission, with I_F as specified in subclause **6.4**		$\Delta\lambda$		Max.
6.6	Switching times (where appropriate)					Max.
6.7	Half-intensity angle (where appropriate)					Max.

NOTE 1 Not applicable to dual-diode devices connected anode-to-cathode and cathode-to-anode.

NOTE 2 If the included solid angle over which the intensity is measured is not negligible, it should be specified.

NOTE 3 For diodes intended for use in multi-diode arrays, maximum luminous intensity is also required.

7 Supplementary information

7.1 Radiation diagram

A diagram graphically expressing typical luminous intensity versus viewing angle, and using either polar or rectangular co-ordinates.

7.2 Spectral diagram (where appropriate)

A diagram graphically expressing typical luminous intensity versus wavelength.

7.3 Mechanical information

Mounting and soldering conditions, where appropriate.

Section 2. Infrared-emitting diodes

(Excluding devices for fibre optic systems or subsystems dealt with in Section 7)

1 Type

Ambient-rated or case-rated infrared-emitting diode.

2 Semiconductor material

Gallium arsenide, etc.

3 Details of outline and encapsulation

3.1 IEC and/or national reference number of the outline drawing.

3.2 Method of encapsulation: glass/metal/plastic/other.

3.3 Terminal identification and indication of any connection between a terminal and the case.

4 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

4.1 Minimum and maximum storage temperature (T_{stg}).

4.2 Minimum and maximum operating ambient or case temperature (T_{amb} or T_{case}).

4.3 Maximum reverse voltage (V_R).

4.4 Maximum continuous forward current (I_F) at an ambient or case temperature of 25 °C and derating curve or derating factor.

4.5 Where appropriate, maximum peak forward current (I_{PM}) at an ambient or case temperature of 25 °C, under specified pulse conditions.

5 Electrical characteristics

For special applications, additional characteristics may be required.

Ref.	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
5.1	Foreward voltage	I_F specified (d.c. or pulse)		V_F		Max.
5.2	Reverse current	V_R specified		I_R		Max.
5.3	Radiant power output or radiant intensity along the defined mechanical axis	I_F specified (d.c. or pulse)	1	ϕ_e I_e	Min. Min.	
5.4	Peak emission wavelength	I_F specified (d.c. or pulse)		λ_p	Min.	Max.
5.5	Spectral radiation bandwidth (where appropriate)	Half value of peak emission, with I_F as specified in subclause **5.4**		$\Delta\lambda$		Max.
5.6	Switching times (where appropriate)					Max.
5.7	Half-intensity angle (where appropriate)					Max.
5.8	Capacitance (where appropriate)					Max.

NOTE If the included solid angle over which the intensity is measured is not negligible, it should be specified.

6 Supplementary information

6.1 Radiation diagram

A diagram graphically expressing typical radiant power output or radiant intensity versus angle with respect to the defined mechanical axis, and using either polar or rectangular coordinates.

6.2 Spectral diagram (where appropriate)

A diagram graphically expressing typical radiant power output or radiant intensity versus wavelength.

6.3 Mechanical information

Mounting and soldering conditions, where appropriate.

Section 3. Photodiodes

(Excluding devices for fibre optic systems or subsystems)

1 Type

Ambient-rated or case-rated photodiode intended for small-signal and switching applications.

2 Semiconductor material

Silicon, etc.

3 Details of outline and encapsulation

3.1 IEC and/or national reference number of the outline drawing.

3.2 Method of encapsulation: glass/metal/plastic/other.

3.3 Terminal identification and indication of any connection between a terminal and the case.

4 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

4.1 Minimum and maximum storage temperatures (T_{stg}).

4.2 Minimum and maximum operating ambient or case temperature (T_{amb} or T_{case}).

4.3 Maximum reverse voltage (V_R).

4.4 Where appropriate:

— maximum total power dissipation (P_{tot}) up to ambient or case temperature of 25 °C; and
— derating factor above 25 °C (K_t) or derating curve.

5 Electrical characteristics

Ref.	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
5.1	Reverse current under irradiation	V_R specified E_v or E_e specified	1	$I_{R(H)}$ or $I_{R(e)}$	Min.	
5.2	Dark current	V_R specified, $E_e = 0$		I_R		Max.
5.3	Dark current	V_R specified, $E_e = 0$ at a specified high temperature T_{amb} or T_{case}		I_R		Max.
5.4	Where appropriate, spectral sensitivity	V_R specified, E_e specified, at a short wavelength λ_1 specified		S	Min.	
		and at a longer wavelength λ_2 specified		S	Min.	
5.5	Switching times (where appropriate):	Specified circuit				
	rise time and fall time	specified value of V_R, E_v or E_e specified		t_r t_t		Max. Max.
	or: turn-on time and turn-off time	Specified circuit, specified value of V_R, E_v or E_e specified		t_{on} t_{off}		Max. Max.

NOTE Illumination by standard illuminant A (according to IEC Publication 306-1) emitted from a filament tungsten lamp with a colour temperature T = 2 855,6 K or with radiation from a defined monochromatic source.

6 Supplementary information

6.1 Diagram of typical sensitivity

6.2 Typical spectral diagram

A diagram graphically expressing relative spectral sensitivity versus wavelength.

Section 4. Phototransistors

(Excluding devices for fibre optic systems or subsystems)

1 Type

Ambient-rated or case-rated phototransistor intended for small-signal and switching applications.

2 Semiconductor material

Silicon, etc.

3 Polarity

NPN/PNP.

4 Details of outline and encapsulation

4.1 IEC and/or national reference number of the outline drawing.

4.2 Method of encapsulation: glass/metal/plastic/other.

4.3 Terminal identification and indication of any connection between a terminal and the case.

5 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

5.1 Minimum and maximum storage temperature (T_{stg}).

5.2 Minimum and maximum operating ambient or case temperatures (T_{amb} or T_{case}).

5.3 Maximum collector-emitter voltage with zero base current (V_{CEO}).

5.4 Where an external base connection is present:

5.4.1 Maximum collector-base voltage with zero emitter current (V_{CBO}).

5.4.2 Maximum emitter-base voltage with zero collector current (V_{EBO}).

5.5 Where no external base connection is present:

Maximum emitter-collector voltage (V_{ECO}).

5.6 Maximum continuous collector current (I_C).

5.7 Where appropriate:

— maximum total power dissipation (P_{tot}) up to ambient or case temperature of 25 °C; and
— derating factor above 25 °C (K_t) or derating curve.

6 Electrical characteristics

Ref.	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
6.1	Collector current under irradiation	V_{CE} specified, $I_B = 0$ E_V or E_e specified	1	$I_{C(H)}$ or $I_{C(e)}$	Min.	Max.[a]
6.2	Collector-emitter dark current	V_{CE} specified, $I_B = 0$ $E_e = 0$		I_{CEO}		Max.
6.3	Collector-emitter dark current	V_{CE} specified, $I_B = 0$ $E_e = 0$, at a specified high temperature T_{amb} or T_{case}		I_{CEO}		Max.
6.4	Collector-emitter breakdown voltage	I_c specified, $I_B = 0$, $E_e = 0$		$V_{(BR)CEO}$	Min.	
6.5	Emitter-base breakdown voltage or, where no base connection is present, emitter-collector breakdown voltage	I_E specified, $E_e = 0$		$V_{(BR)EBO}$ $V_{(BR)ECO}$	Min. Min.	
6.6	Collector-emitter saturation voltage	I_c specified, $I_B = 0$, E_v or E_e specified, preferably as in subclause **6.1**	1	V_{CEsat}		Max.
6.7	Where appropriate, spectral sensibility	$I_B = 0$, E_e specified, at a short wavelength λ_1 specified and at a longer wavelength λ_2 specified		S S	Min. Min.	
6.8	Switching times (where appropriate): rise time and fall time	Specified circuit, specified values of V_{CE} and I_C, E_v or E_e specified		t_r t_f		Max. Max.
	or turn-on time and turn-off time	Specified circuit, specified values of V_{CE} and I_C, E_v or E_e specified		t_{on} t_{off}		Max. Max.

NOTE Illumination at standard illuminant *A* (according to IEC Publication 306-1) emitted from a tungsten filament lamp with a colour temperature T = 2 855,6 K or with radiation from a defined monochromatic source.

[a] Where appropriate.

7 Supplementary information

7.1 Diagram of typical sensitivity

7.2 Typical spectral diagram

A diagram graphically expressing relative spectral sensitivity versus wavelength.

Section 5. Photocouplers, optocouplers

(with output transistor)

1 Type

Ambient-rated or case-rated photocouplers, optocouplers, with transistor output, for signal-isolation applications.

2 Semiconductor material

input diode: gallium arsenide, aluminium arsenide, etc.

output transistor: silicon, etc.

3 Polarity of the output resistor

4 Details of outline and encapsulation

4.1 IEC and/or national reference number of the outline drawing.

4.2 Method of encapsulation: glass/metal/plastic/other.

4.3 Terminal identification and indication of any connection between a terminal and the case.

5 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

Indicate any qualifications such as time, frequency, pulse duration, humidity, etc.

5.1 Minimum and maximum storage temperatures (T_{stg}).

5.2 Minimum and maximum ambient or reference-point operating temperatures (T_{amb} or T_{ref}).

5.3 Maximum soldering temperature (T_{sld}).

Maximum soldering time and minimum distance to case should be specified.

5.4 Maximum continuous (direct) reverse input voltage (V_R).

5.5 Maximum collector-emitter voltage, with the base open-circuited (V_{CEO}).

5.6 Maximum collector-base voltage, where an external base connection is present, with the emitter open-circuited (V_{CBO}).

5.7 Maximum emitter-base voltage, where an external base connection is present, with the collector open-circuited (V_{EBO}).

or:

5.8 Maximum emitter-collector voltage, where no external base connection is present (V_{ECO}).

5.9 Maximum continuous (direct) or repetitive peak isolation voltage (V_{IO} or V_{IORM}).

The waveshape and repetition rate should be specified.

5.10 Where appropriate, maximum surge isolation voltage (V_{IOSM}).

This should be specified for pulses of both polarities having the waveshape shown in Figure 14.

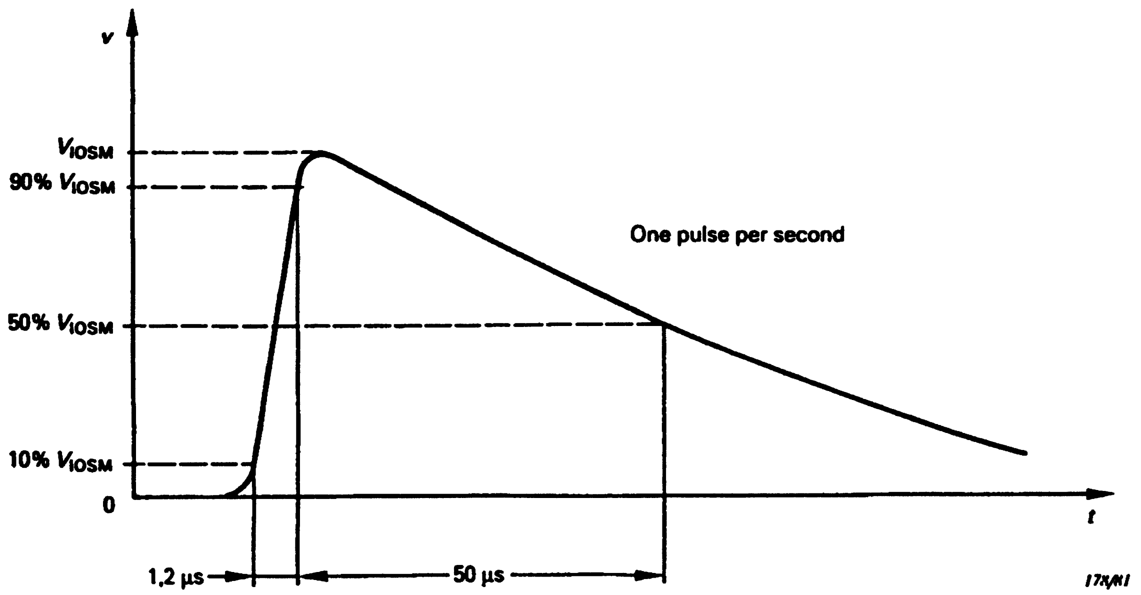


Figure 14 — Test voltage

5.11 Maximum continuous collector current (I_C).

5.12 Maximum continuous forward input current (I_F) at an ambient or reference-point temperature of 25 °C and derating curve or derating factor.

5.13 Maximum peak forward input current (I_{FRM}) at an ambient or reference-point temperature of 25 °C and under specified pulse conditions.

5.14 Maximum power dissipation (P_{trn}) of the output transistor at an ambient or reference-point temperature of 25 °C and a derating curve or derating factor.

5.15 Maximum total power dissipation of the package (P_{tot}) at an ambient or reference-point temperature of 25 °C and derating curve or derating factor.

6 Electrical characteristics

Ref.	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
6.1	Input diode forward voltage	I_F specified		V_F		Max.
6.2	Input diode reverse current	V_R specified		I_R		Max.
6.3	Collector-emitter dark current	V_{CE} specified, $I_F = 0$ $I_B = 0$ (base open circuit)		I_{CEO}		Max.
	or, where appropriate[a], collector-base dark current	V_{CB} specified, $I_F = 0$, $I_E = 0$		I_{CBO}		Max.
6.4	Collector-emitter dark current	V_{CE} specified, I_F and $I_B = 0$, T_{amb} or T_{ref} specified		I_{CEO}		Max.
	or, where appropriate[a], collector-base dark current	V_{CB} specified, $I_F = 0$, $I_E = 0$				
		T_{amb} or T_{ref} specified		I_{CBO}		Max.
6.5	Collector-emitter saturation voltage	I_F and I_C specified, $I_B = 0$		V_{CEsat}		Max.
	or, where appropriate[a], collector-base voltage	I_F and I_C specified, $I_B = 0$		V_{CB}		Max.
6.6	Current transfer ratio	I_F or I_C and V_{CE} specified, $I_B = 0$		h_F or CTR (d.c.)	Min.	Max.
6.7	Where appropriate, differential current transfer ratio	I_F or I_C and V_{CE} specified, $I_B = 0$, frequency specified		h_f or CTR (a.c.)	Min.	Max.
6.8	Isolation resistance between input and output	V_{IO} specified	1	r_{IO}	Min.	
6.9	Where appropriate, input-to-output capacitance	f = 1 MHz, $I_F = 0$, $I_c = 0$	1	C_{io}		Max.
6.10	Where appropriate, switching times:					
	turn-on time and turn-off time	Specified V_{CC}, I_F and R_L, and nominal I_c, test circuit specified		t_{on} t_{off}		Max. Max.
	or: rise time and fall time	Specified V_{CC}, I_F and R_L, nominal I_C test circuit specified		t_r t_f		Max. Max.
6.11	Where appropriate, cut-off frequency	I_f or I_C et V_{CE} specified, $I_B = 0$	2	F_{ctr}	Min.	

NOTE 1 All input terminals should be connected together and all output terminals should be connected together.

NOTE 2 The cut-off frequency is the lowest frequency at which the magnitude of the a.c. current transfer ratio is 0,707 times its value at very low frequency.

[a] For operation in the diode mode.

7 Supplementary information

Under consideration.

Section 6. Laser diodes

1 Type

Ambient-rated or case-rated laser diodes for the following applications:

Type A: general
Type B: focussed laser beam
Type C: optical digital transmission
Type D: optical analogue transmission

2 Semiconductor

2.1 Material

Material such as GaAs, GaAIAs, InGaAsP.

2.2 Structure

Structure such as gain guiding, index guiding, distributed feed-back.

3 Details of outline and encapsulation

3.1 IEC and/or national reference number of the outline drawing.

3.2 Method of encapsulation: glass/metal/plastic/other.

3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

3.4 Characteristics of the optical port: orientation relative to mechanical axes, position relative to mechanical axes, area, numerical aperture.

3.5 Information on the pigtail fibre (where appropriate): type of fibre, kind of protection, connector, length.

4 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

4.1 Minimum bend radius of the pigtail, where appropriate.

4.2 Maximum pull force pigtail (fibre or cable), where appropriate, in the direction of the axis of the input pigtail (fibre or cable).

4.3 Minimum and maximum storage temperatures (T_{stg})

4.4 Minimum and maximum operating temperatures.

4.4.1 Ambient or case temperature (T_{amb} or T_{case}).

4.4.2 Submount temperature, where appropriate (T_{sub}).

4.5 Maximum soldering temperature (soldering time and minimum distance to case) (T_{sld}).

4.6 Maximum reverse voltage (V_R).

4.7 One or more of the following at an ambient or case temperature of 25 °C together with a derating curve or derating factor with temperature:

— Maximum continuous forward current (I_{FM}).
— Maximum continuous radiant power (ϕ_{eM}).
— Maximum pulsed forward current at stated frequency and pulse duration (I_{FM}).
— Maximum pulsed radiant power at stated frequency and pulse duration (ϕ_{eM}).

5 Electrical and optical characteristics

Radiant power shall be specified as continuous or pulsed as appropriate to the device. ΔI_F indicates a forward current above the measured threshold current $I_{(TH)}$ of the device being measured.

Ref.	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Symbols	Types				
				A	B	C	D	Requirements
5.1	Forward voltage	I_F or ϕ_e specified	V_F	×	×	×	×	Max.
5.2	Threshold current		$I_{(TH)}$	×	×	×	×	Min. & max.
5.3	Radiant power at threshold	$I_{(TH)}$	$\phi_{e(TH)}$	×	×	×	×	Max.
5.4.1	Forward current above threshold	ϕ_e specified	ΔI_F (1)	×	×	×	×	Max.
5.4.2	Forward current above threshold	ϕ_e specified, $T = T_{case}$ max. or T_{amb} max.	ΔI_F (2)	×	×	×	×	Max.
5.5	Differential efficiency	ϕ_e or ΔI_F specified	η_d	×	×	×	×	Min. & max.
5.6	Peak emission wavelength	ΔI_F or ϕ_e specified	λ_p	×	×	×	×	Min. & max.
5.7.1	Spectral radiation bandwidth or:	ΔI_F or ϕ_e specified	$\Delta\lambda$	×	×	×	×	Min. & max.
5.7.2	Number of longitudinal modes and mode spacing	ΔI_F or ϕ_e specified	n_m	×	×	×	×	Min. & max.
			s_m	×	×	×	×	Min. & max.
5.7.3	Spectral linewidth, where appropriate	ΔI_F or ϕ_e specified	(Under consideration)			×	×	Max.
5.8	Half-intensity angle in two specified planes (without pigtail)	ΔI_F or ϕ_e specified	θ (1), θ (2)	×	×			Max.
5.9	Misalignment angle	ΔI_F or ϕ_e specified	Δ_θ		×			Max.
5.10.1	Emission source size (without pigtail), width and height	ΔI_F or ϕ_e specified, references axes specified	s_w and s_h		×			Min. & max.
5.10.2	Astigmatism (without pigtail)	ΔI_F or ϕ_e specified, reference axes specified	d_A		×			Max.
5.11	Differential resistance	ΔI_F or $\Delta\phi_e$ specified	r_d			×	×	Max.
5.12	Switching times	Bias conditions εΔI_F or $\Delta\phi_e$) specified						
5.12.1	Rise time and fall time or:		t_r, t_f			×	×	Max.
5.12.2	Turn-on time and turn-off time	Input pulse current, width and duty specified	t_{on}, t_{off}			×	×	Max.
5.13	Small-signal cut-off frequency	ΔI_F or ϕ_e specified	f_c				×	Min.
5.14.1	Relative intensity noise (without pigtail)	ϕ_e, f_o, Δf_N specified	*RIN*		×			Max.
5.14.2	Carrier to noise ratio	ϕ_e, f_o, Δf, f_m, m specified	C/N			×	×	Max.

NOTES

1 CW operation.

2 Modulated.

6 Supplementary information

6.1 Spectral shift as a function of temperature.

6.2 Total capacitance.

6.3 Total inductance.

6.4 S_{11} parameter.

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Section 7. Light-emitting diodes and infrared-emitting diodes for fibre optic systems or subsystems

1 Type

Ambient-rated or case-rated light-emitting or infrared-emitting diode with or without optical fibre pigtail for fibre optic systems or subsystems.

2 Semiconductor material

GaAs, GaAlAs, InGaAs, InP, etc.

3 Details of outline and encapsulation

3.1 IEC and/or national reference number of outline drawing.

3.2 Method of encapsulation: glass/metal/plastic/other.

3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

3.4 Characteristics of the optical port: Orientation relative to mechanical axis, position relative to mechanical axis, area, numerical aperture.

3.5 For devices with pigtail: Information on the pigtail fibre, kind of protection, connector, length.

3.6 Information on the heat sink of the package.

4 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

Reference	Characteristics	Letter symbols	Requirement	
			Min.	Max.
4.1	Storage temperature	T_{stg}	×	×
Either **4.2.1**	Ambient temperature	T_{amb}	×	×
or **4.2.2**	Case temperature	T_{case}	×	×
4.3	Soldering temperature at maximum soldering time and minimum distance to case specified	T_{sld}		×
4.4	Reverse voltage	V_R		×
4.5	Continuous forward current Derating curve or derating factor	I_F		×
4.6	Repetitive peak forward current at specified pulse conditions (where appropriate) Derating curve or derating factor (where appropriate)	I_{FRM}		×
4.7	Power dissipation Derating curve or derating factor (where appropriate)	P_{tot}		×
4.8	For case-rated devices: Virtual junction temperature (where appropriate)	$T_{(vj)}$		×
4.9	For devices with pigtail: Bend radius of pigtail (at specified distance from the case)	r	×	
4.10	Shock			×
4.11	Vibration			×
4.12	Tensile force on devices with pigtail:			
4.12.1	Untight structure:			
	— Tensile force on fibre along its axis	F		×
	— Tensile force on cladding along its axis	F		×
4.12.2	Tight structure:			
	— Tensile force on pigtail along its axis	F		×

5 Electrical and optical characteristics

Reference	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Letter symbol	Requirement	
				Min.	Max.
5.1	Forward voltage	I_F or Φ_e specified	V_F		×
5.2	Reverse current	V_R specified	I_R		×
5.3	Differential resistance	I_F or Φ_e specified	r_d		×
5.4	Total capacitance	V_R, f specified	C_{tot}		×
Either **5.5.1**	Relative intensity noise (where appropriate)	I_F ou Φ_e, f_o, ΔF_N specified	*RIN*		×
or **5.5.2**	Carrier-to-noise ratio (where appropriate)	I_F ou Φ_e, f_o, Δf_N, f_m, m specified	C/N		×
Either **5.6.1**	Radiant output power	I_F specified (d.c. or pulse, or both)	Φ_e	×	×[a]
or **5.6.2**	Forward current	Φ_e specified	I_F	×	×
5.7	For devices without pigtail: Half-intensity angle (where appropriate)	I_F or Φ_e, angle ϕ specified	$\theta_{½}$		×
5.8	For devices without pigtail: Misalignment angle (where appropriate)	I_F or Φ_e, angle ϕ specified	$\Delta\theta$		×
5.9	Spectral radiation bandwidth	I_F or Φ_e specified	$\Delta\lambda$		×
Either **5.10.1**	Switching times: — Rise time — Fall time — Delay times (where appropriate) — Peak emission wavelengths	D.C. current, input pulse current pulse width and duty cycle specified	 t_r t_f $t_{d(on)}/t_{d(off)}$		× × × ×
or **5.10.2**	Cut-of frequency	I_F or Φ_e specified	f_c	×	

[a] Where appropriate.

6 Supplementary information

Either

6.1.1 Typical curve or coefficient of radiant power versus temperature and typical curve of radiant output power versus forward current (d.c. or pulse, as specified).

or

6.1.2 Typical curve or coefficient of radiant intensity versus temperature and typical curve of radiant intensity versus forward current (d.c. or pulse, as specified).

6.2 Typical curve or coefficient of change in peak emission wavelength versus temperature.

6.3 Typical radiation diagram.

6.4 Thermal resistance, ambient-rated or case-rated.

Ref.	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Notes	Symbols	Requirements	
5.16	Parasitic emission levels between specified wavelengths (where appropriate)	I_F specified (d.c. or pulse)				Max.
5.17	Typical radiation diagram					

NOTES

1 Terms or letter symbols are under consideration.

2 Where appropriate.

3 Half value of peak emission with I_F as specified in subclause **5.12**.

6 Supplementary information

Under consideration.

blank

Section 8. Laser module with pigtails

1 Type

The laser module consists of following basic parts:

laser diode
pigtail
photodiodes }
thermal sensor } where appropriate
Peltier element }

2 Semiconductor

2.1 Material

laser diode e.g. GaAs, GaAlAs, InGaAsP, InP

photodiode e.g. Ge, Si, GaInAs }
thermal sensor } where appropriate
Peltier element }

2.2 Structure

Laser diode, e.g: gain guided, index guided, distributed feedback, etc.

3 Details of outline and encapsulation

3.1 IEC and/or national reference number of the outline drawing.

3.2 Method of encapsulation: glass/metal/plastic/other.

3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

3.4 Information on the pigtail fibre, e.g.: type of fibre, kind of protection, connector, length.

3.5 Information on the heatsinking of the package.

4 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

General conditions

4.1 Minimum and maximum storage temperatures (T_{stg}).

4.2 Minimum and maximum operating case temperatures (T_{case}).

4.3 Minimum and maximum operating submount temperature (T_{sub}).

4.4 Maximum soldering temperature (soldering time and minimum distance to case) (T_{sld}).

4.5 Minimum bend radius of pigtail (at specified distance from the case) (r).

4.6 Shock (maximum acceleration and pulse duration).

4.7 Vibration (maximum acceleration and frequency range).

4.8 Tensile force along cable axis:

4.8.1 Untight structure:

— Maximum tensile force on fibre (F);
— Maximum tensile force on cable (F).

4.8.2 Tight structure:

— Maximum tensile force on cable (*F*).

Laser diode

For laser module without Peltier cooler, derating curve or derating factor must be given for one of the following parameters, **4.10** to **4.13**. For laser module with Peltier cooler, T_{sub} equals to 25 °C.

4.9 Maximum reverse voltage (V_R).

4.10 Maximum continuous forward current (I_F).

4.11 Maximum continuous radiant power (Φ_e).

4.12 Maximum pulsed forward current at stated frequency and pulse duration (I_{FP}).

4.13 Maximum pulsed radiant power at stated frequency and pulse duration (Φ_{eP}).

Photodiode

4.14 Maximum reverse voltage (V_R).

4.15 Maximum forward current (I_F).

Thermal sensor (where appropriate)

4.16.1 ***Maximum power dissipation (P)***

or

4.16.2 Maximum voltage supply (*V*).

Thermal electric cooler (where appropriate)

4.17 Maximum cooler current under cooling and heating (I_{PE}).

5 Electric and optical characteristics

Ref.	Characteristics	Conditions at T_{sub} = 25 °C for laser with Peltier cooler, T_{amb} or T_{case} = 25 °C for laser module without Peltier cooler unless otherwise stated	Symbols	Requirements	
Laser diode					
5.1	Forward voltage	ϕ_e or I_F specified	V_F		Max.
5.2	Threshold current		$I_{(TH)}$	Min.	Max.
5.3	Radiant power at threshold	$I_F = I_{TH}$	$\phi_{e(TH)}$		Max.
5.4	Forward current above threshold (for laser module without Peltier cooler)	ϕ_e specified T = T_{case} max. or T_{amb} max.	ΔI_F		Max.
5.5	Differential efficacy (for laser module without Peltier cooler)	ϕ_e or ΔI_F specified $T = T_{case}$ max. or T_{amb} max.	η_d	Min.	Max.
5.6	Spectral characteristics				
5.6.1.1	Peak emission wavelength	ϕ_e or ΔI_F specified λ_p (1) CW-operation	Min.	Max.	
5.6.1.2	Spectral radiation bandwidth FWHM	ϕ_e or ΔI_F specified CW-operation	$\Delta\lambda$ (1)		Max.
or					
5.6.1.3	Mode spacing and number of longitudinal modes	ϕ_e or ΔI_F specified CW-operation	 ηm		Max. Max.
5.6.1.4	Peak emission wavelength under modulation	ϕ_e or ΔI_F specified modulation condition specified	λ_p (2)	Min.	Max.
5.6.1.5	Spectral radiation bandwidth under modulation	ϕ_e or ΔI_F specified modulation condition specified	$\Delta\lambda$ (2)		Max.
and/or					
5.6.2.1	Central wavelength	ϕ_e or ΔI_F specified CW-operation	$\bar{\lambda}$ (1)	Min.	Max.
5.6.2.2	Spectral radiation RMS bandwidth	ϕ_e or ΔI_F specified	$\Delta\lambda_{(rms)}$ (1)		Max.
or					
5.6.2.3	Mode spacing and number of longitudinal modes	ϕ_e or ΔI_F specified	ηm		Max.
5.6.2.4	Central wavelength under modulation	ϕ_e or ΔI_F specified modulation condition specified	λ (2)	Min.	Max.
5.6.2.5	Spectral radiation RMS bandwidth under modulation	ϕ_e or ΔI_F specified modulation condition specified	$\Delta\lambda_{rms}$ (2)		Max.
5.7	Single spectral mode laser module under specified direct modulation				
5.7.1	Spectral mode width	ϕ_e or ΔI_F specified modulation condition specified	$\Delta\lambda_L$		Max.
5.7.2	Side-mode suppression ratio	ϕ_e or ΔI_F specified modulation condition specified	*SMS*	Min.	

NOTES

1 CW-operation.

2 In modulation.

Ref.	Characteristics	Conditions at T_{sub} = 25 °C for laser module with Peltier cooler, T_{amb} or T_{case} = 25 °C for laser module without Peltier cooler unless otherwise stated	Symbols	Requirements	
5.8.1	Spectral shift	ΔI_{F1}, ΔI_{F2} or ϕ_{e1}, ϕ_{e2}	$\Delta\lambda_c$		Max.
5.8.2	Spectral shift for laser module without Peltier cooler	T_{amb} (1) or T_{case} (1), T_{amb} (2) or T_{case} (2)	$\Delta\lambda_c$		Max.
5.9.1	Rise time, fall time	Bias current ΔI_F or ϕ_e input pulse current, width and duty cycle specified	t_r, t_f		Max.
and/or					
5.9.2	Turn-on time, turn-off time		t_{on}, t_{off}		Max.
5.10	Cut-off frequency	ϕ_e or ΔI_F specified	f_c	Min.	Max.
5.11	Carrier-to-noise ratio	ΔI_F or ϕ_e, Δ_f, f_m, m and f_0 specified	C/N	Min.	
Monitor photodiode					
5.12	Dark current	$\phi_e = 0$ V_R specified	$I_{r(0)}$		Max.
5.13	Reverse current under optical radiation	ϕ_{er} or ΔI_F specified V_R specified	$I_{R(e)}$	Min.	Max.
either					
5.14.1	Diode capacitance	V_R and f specified	C_{tot}		Max.
or					
5.14.2	Rise time, fall time	ϕ_e or ΔI_F specified V_R specified	t_r, t_f		Max.
5.15.1	Tracking error	ϕ_e or ΔI_F and V_R specified, temperature range: 25 °C to T_{case} min. or T_{amb} min.	E_{R1}		Max.
and/or					
5.15.2	Tracking error	ϕ_e or ΔI_F and V_R specified, temperature range: 25 °C to T_{case} max. or T_{amb} max.	E_{R2}		Max.
Thermistor (where appropriate)					
5.16	Resistance	Thermistor current I_{tc} specified	R	Min.	Max.
5.17	Slope of resistance	Thermistor current I_{tc} specified Temperature range: T_{sub} (1), T_{sub} (2)	ΔR/R	Min.	Max.
Peltier current (where appropriate)					
5.18	Peltier current	ϕ_e or ΔI_F specified Temperature range: T_{case} min., T_{case} max.	I_{PE}		Max.
5.19	Peltier voltage	ϕ_e or ΔI_F specified Temperature range: T_{case} or T_{amb}, min. and max.	V_{PE}		Max.

NOTES

1 CW-operation.

2 In modulation.

Section 9. Pin photodiodes for fibre optic systems or subsystems

1 Type

Ambient-rated or case-rated PIN photodiodes with or without optical fibre pigtail for fibre optic systems or subsystems.

2 Semiconductor material

Si, Ge, InGaAs, etc.

3 Details of outline and encapsulation

3.1 IEC and/or national reference number of outline drawing.

3.2 Method of encapsulation: glass/metal/plastic/other.

3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

3.4 Characteristics of the optical port: orientation relative to mechanical axis, position relative to mechanical axis, area, numerical aperture.

3.5 For devices with pigtail: information on the pigtail fibre, type of fibre, kind of protection, connector, length.

3.6 Information on the heat sink of the package.

4 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

Reference	Characteristics	Letter symbol	Requirement	
			Min.	Max.
4.1	Storage temperature	T_{stg}	×	×
Either **4.2.1** or **4.2.2**	 Ambient temperature Case temperature	 T_{amb} T_{case}	 × ×	 × ×
4.3	Soldering temperature at maximum soldering time and minimum distance to case specified	T_{sld}		×
4.4	Reverse voltage	V_R		×
4.5	Power dissipation	P_{tot}		×
4.6	Radiant power on the sensitive area	Φ_e		×
4.7	For devices with pigtail: Bend radius of pigtail (at specified distance from the case)	r	×	
4.8	Shock			×
4.9	Vibration			×
4.10	Tensile force on devices with pigtail:			
4.10.1	Untight structure: — Tensile force on fibre along its axis — Tensile force on cladding along its axis	 F F		 × ×
4.10.2	Tight structure: — Tensile force on pigtail along its axis	 F		 ×

5 Electrical and optical characteristics

NOTE The specified voltage V_R shall be the same for all the characteristics, unless otherwise stated

Reference	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C unless otherwise stated	Letter symbol	Requirement	
				Min.	Max.
5.1.1 **5.1.2**	Dark current Dark current at high temperature	V_R specified, $\Phi_e = 0$ V_R specified, $\Phi_e = 0$ T_{amb} or T_{case} specified	$I_{R(D)}$[a] $I_{R(D)}$[b]		× ×
5.2	Total capacitance	V_R, f specified, $\Phi_e = 0$	C_{tot}		×
5.3	Noise current	V_R, $I_{R(e)}$, f_0, Δf_N, R_L, λ_P, $\Delta\lambda$ specified	I_n		×
5.4 **5.4.1** **5.4.2**	For devices without pigtail: Sensitivity along the specified mechanical axis Spatial uniformity of sensitivity (where appropriate)	 V_R, λ_p, $\Delta\lambda$, Φ_e specified V_R, λ_P, $\Delta\lambda$, or Φ_e specified	 S_{FD}, S ΔS	 ×	 ×[a] ×
5.5	For devices with pigtail: Sensitivity	 V_R, λ_P, $\Delta\lambda$, Φ_e specified	 S_{FD}, S	 ×	 ×[a]
Either **5.6.1**	Switching times: — Rise time — Fall time — Delay times (where appropriate) — Storage time	 V_R, λ_P, $\Delta\lambda$, pulse base Φ_{e1}, pulse top Φ_{e2}, R_L specified	 t_r t_f $t_{d(on)}/t_{d(off)}$ t_s		 × × × ×
or **5.6.2**	Cut-off frequency	V_R, λ_P, $\Delta\lambda$, Φ_e, R_L specified	f_c	×	

[a] Where appropriate
[b] Term and/or letter symbol under consideration

6 Supplementary information

6.1 Typical curve of dark current versus voltage, at different temperatures

6.2 Typical curve of total capacitance versus reverse voltage

6.3 Relative sensitivity versus wavelength

6.4 Relative sensitivity versus temperature

6.5 Derating curve or derating factor of maximum dissipation

Section 10. Avalanche photodiodes (APDs) with or without pigtails

1 Type

Ambient-rated or case-rated avalanche photodiode for fibre optic systems or subsystems.

2 Semiconductor

2.1 Material

Si, Ge, InGaAs, etc.

2.2 Structure.

3 Details of outline and encapsulation

3.1 IEC and/or national reference number of outline drawing.

3.2 Method of encapsulation: glass/metal/plastic/other.

3.3 Terminal identification and indication of any electrical connection between a terminal and the case.

3.4 Characteristics of the optical port: orientation relative to the mechanical axes, position relative to mechanical axes, area, numerical aperture.

3.5 Information on the pigtail fibre (where appropriate): type of fibre, kind of protection, connector, length.

4 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

4.1 Minimum bend radius of the pigtail, where appropriate.

4.2 Minimum and maximum storage temperature (T_{stg}).

4.3 Minimum and maximum operating ambient or case temperatures (T_{amb} or T_{case}).

4.4 Maximum soldering temperature (T_{sld}) (soldering time and minimum distance to case to be specified).

4.5 Maximum power dissipation at ambient or case temperature of 25 °C (P_{tot}) and derating curve or derating factor.

4.6 Maximum pull force for pigtail (fibre or cable), where appropriate, in the direction of the axis of the input pigtail (fibre or cable).

4.7 Maximum reverse current (I_R).

4.8 Maximum forward current (I_F).

5 Electrical and optical characteristics

V_R shall be the same for all characteristics; it shall be equal to 0,9 of the individually measured value of $V_{(BR)}$, unless otherwise specified.

Ref.	Characteristics	Conditions at T_{amb} or T_{case} = 25 °C, unless otherwise stated	Symbols	Requirements	
5.1	Breakdown voltage	E_e or $\phi_e = 0$, I_R specified	$V_{(BR)}$	Min.	Max.
5.2.1	Reverse dark current (Note 1)	E_e or $\phi_e = 0$, V_R specified	I_R (1)		Max.
5.2.2	Reverse dark current (Note 2)	E_e or $\phi_e = 0$, V_R specified $T = T_{amb}$ max. or T_{case} max.	I_R (2)		Max.
5.3.1	Sensitivity (Note 1)	V_{R1} (Note 2), ϕ_e λ_{pp}, $\Delta\lambda$ specified	$S^{(1)}$	Min.	Max. Note 1
5.3.2	Sensitivity (Note 2)	V_R, ϕ_e, λ_p, $\Delta\lambda$ specified	$S^{(2)}$	Min.	Max. Note 1
5.4	Multiplication factor	V_{R1} (Note 2), λ_p, $\Delta\lambda$, ϕ_e specified	M	Min.	
5.5	Total capacitance	E_e or $\phi_e = 0$; V_R, f specified	C_{tot}		Max.
5.6					
5.6.1	Turn-on time and turn-off time	V_R, $\Delta\lambda$, R_L, ϕ_{e1}: peak radiant power ϕ_{e2}: offset radiant power	t_{on} t_{off}		Max. Max.
5.6.2	Small signal cut-off frequency	V_R, λ_p, $\Delta\lambda$, ϕ_e and R_L specified	f_c	Min.	
5.7	Excess noise factor	V_{R1} (Note 2), V_R, I_{PO}, λ_P, $\Delta\lambda$, M, f_0, Δ_{fn} specified	F_e		Max.
5.8	Noise current (where appropriate)	V_R, λ_P, $\Delta\lambda$, f, Δf_N specified	I_n		Max.

NOTES

1 Where appropriate.

2 V_{R1} should be a small value at which negligible carrier multiplication takes place, or the voltage at which the device is fully depleted and has achieved its rated speed.

6 Supplementary information

6.1 Curve of breakdown voltage versus temperature.

6.2 Curve of sensitivity versus wavelength.

6.3 Curve of capacitance versus reverse voltage.

6.4 Curve of multiplication factor versus reverse voltage at different temperatures.

6.5 Curve of reverse dark current versus reverse voltage at different temperatures.

6.6 Location of sensitive area by reference to the package (without pigtail).

6.7 Curve of excess noise factor versus reverse voltage (where appropriate).

6.8 Curve of noise current versus reverse voltage (where appropriate).

Section 11. Visual inspection of monochrome matrix liquid crystal display modules

(Excluding all active matrix liquid crystal display modules)

1 General

The criteria for the acceptance of specimens assessed by visual inspection depend on:

— dimension and mode of operation of the display;
— dimension, quantity and position of picture elements;
— application;
— temperature range;
— inspection requirements.

Because of this dependence, it is not possible in general to specify these criteria, and reference is made to detail specifications and reference samples.

NOTE The inspection is made on displays without protection sheet either with unaided eyes or by an automatic test set-up.

2 Visual inspection of displays

2.1 Display not activated

Test conditions

To be specified in detail specification:

— viewing direction range;
— illumination from above or through the device (depending on the application);
— duration;
— viewing distance;
— ambient temperature.

Procedure

Devices shall be inspected for the following visual defects:

Defect	*Rejection criteria*
— Spots (see Figure 63), bubbles, foreign particles: light/dark stains on light background, light/dark stains on dark background	To be specified in detail specification
— Scratches on the liquid crystal cell and on the polarizer within the specified viewing direction range	To be specified in the detail specification
— Mechanical damage outside of viewing area	To be specified in the detail specification
— Accumulation of above-listed visible defects	Reference samples
— Visible structure of the electrodes within the viewing area	Reference samples
— Non-uniformity of luminance and colours within the viewing area of the display and within the specified viewing direction range	Reference samples
— Dirt on surface, e.g. finger prints, adhesive residue	Reference samples

2.2 Display activated

2.2.1 ***Overall geometrical aspect of the display*** (see Figure 64 and Figure 65)

Test conditions

To be specified in detail specification:

— electrical driving conditions;
— illumination;
— ambient temperature.

Procedure

Devices shall be inspected to conformity with detail specification.

Property	*Rejection criteria*
— Dimension on picture elements	Not in conformity with the detail specification
— Shape of picture elements	Not in conformity with the detail specification
Defect	*Rejection criteria*
— Missing picture elements	Not in conformity with the detail specification
— Unwanted picture elements	Not in conformity with the detail specification
— Activation of the picture elements	Not in conformity with the detail specification
— Seal edge within viewing area	Not in conformity with the detail specification

2.2.2 ***Visible defects of the viewing area***

Test conditions

To be specified in detail specification:

— electrical driving conditions;
— viewing direction range;
— illumination from above or through the device depending on the application;
— duration;
— viewing distance;
— ambient temperature.

Procedure

Devices shall be inspected for the following visual defects:

Defect	*Rejection criteria*
— A pin-hole within the picture element	To be specified in the detail specification (see Figure 66)
— Accumulation of pin holes the size of which is smaller than specified above	Reference samples
— Pin-holes within the non-activated surrounding area of the picture elements	To be specified in the detail specification
— Difference of contrast ratio between different picture elements	To be specified in the detail specification
— Uniformity of luminance within the viewing area	To be specified in the detail specification
— Uniformity of contrast within the viewing area	To be specified in the detail specification
— Non-uniformity of luminance and colours within the viewing area and within the specified viewing direction range	Reference samples

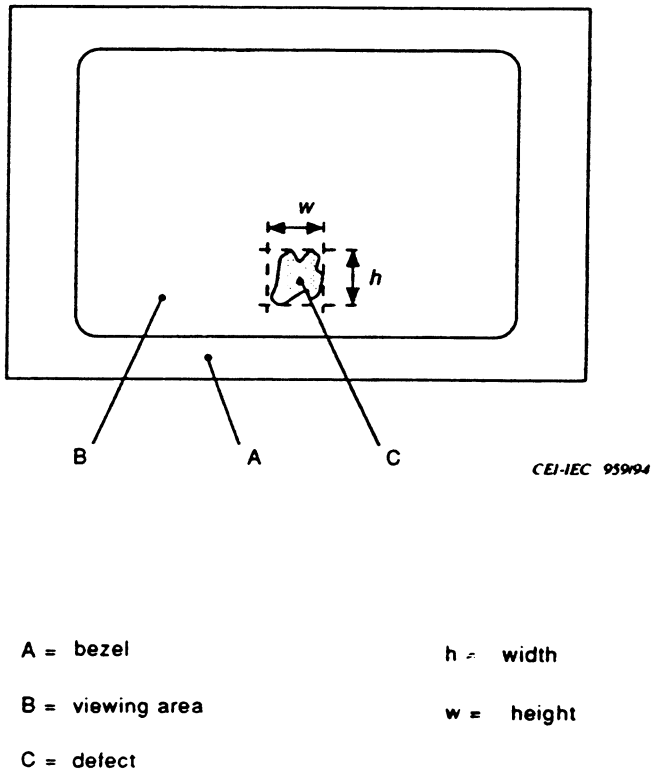

Figure 63 — Defects within the viewing area

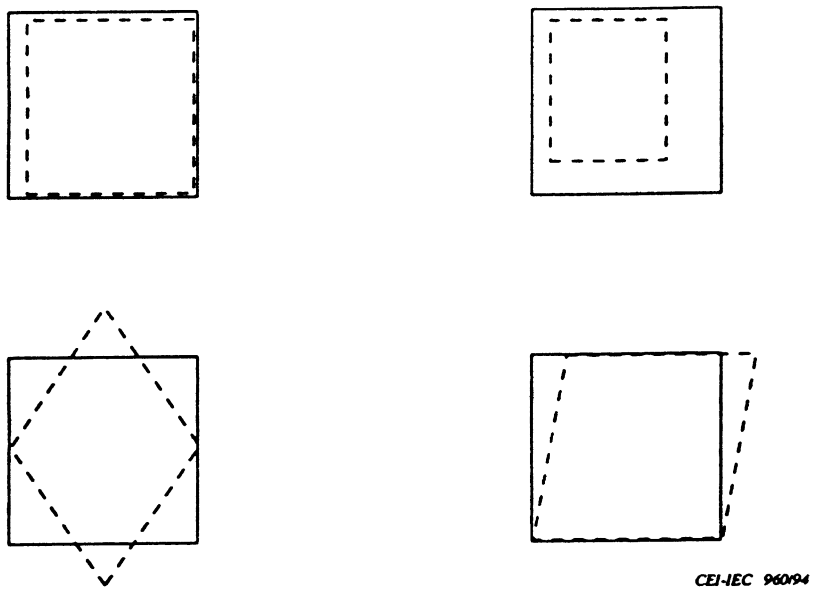

Figure 64 — Deviations and misshapes of a square picture element

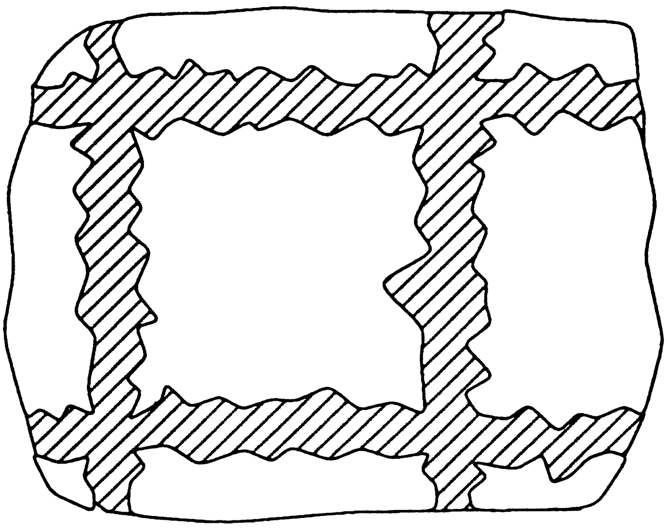

Figure 65 — Notched edges of picture elements

w = width *h* = height

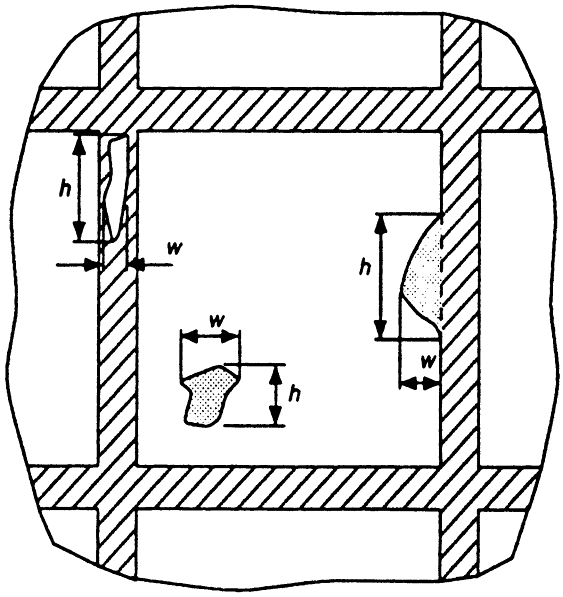

Figure 66 — Defects within picture elements and their surroundings

Section 12. Liquid crystal display cells (LCD cells)

(Excluding active matrix LCD and multicolour cells)

1 Type

Liquid crystal display device without any electronic circuit.

2 Principle and material used

Example: twisted nematic cell.

3 Modes of operation

3.1 Optical mode of operation

— illumination mode: e.g. reflective, transmissive, transflective;
— light symbol on dark background or vice-versa.

3.2 Electrical mode of operation

Static mode or multiplex mode.

4 Details of outline

4.1 Mechanical description

Example: glass or plastic

4.2 Method of connection

4.3 Outline drawing

Dimensions and display pattern.

4.4 Pinout table and/or connection diagram

4.5 LCD cell reference axis for definition of viewing angle

4.6 Recommended viewing direction

5 Limiting values (absolute maximum system) over the operating temperature range, unless otherwise stated

5.1 Minimum and maximum storage temperatures (T_{stg})

5.2 Minimum and maximum operating temperatures (T_{op})

5.3 Maximum ambient humidity (RH)

5.4 Minimum and maximum atmospheric pressure outside

5.5 Maximum mechanical shock

5.6 Maximum vibration

5.7 Maximum acceleration

5.8 Maximum bending strength of the cell (under consideration)

5.9 Maximum torsional strength of the cell (under consideration)

5.10 Maximum r.m.s. value of applied driving voltage

5.11 Maximum peak to peak value of applied voltage

5.12 Maximum d.c.-voltage component of the applied driving voltage

5.13 Maximum soldering temperature and time, where appropriate

6 Electrical and optical characteristics

The following parameters should be specified:

— viewing direction and contrast condition;
— electrical mode of operation.

Reference	Characteristics	Conditions at T = 25 °C unless otherwise stated	Symbols	Requirements	
6.1	Driving voltage			Min.	Max.
6.2	Driving frequency			Min.	Max.
6.3	Threshold voltage	At specified frequency	V_{th}	Min.	Max.
6.4	Saturation voltage	At specified frequency	V_{sat}	Min.	Max.
6.5	Total current: All picture elements activated at MPX. ratio = 1	At specified voltage and frequency			
6.6	Total capacitance: All picture elements activated at MPX. ratio = 1	At specified voltage and frequency			Max.
6.7	Contrast ratio	At specified viewing direction. Diffuse light and/or direct beam	CR_{dir} and/or CR_{diff}	Min.	
6.8	Turn-on time		t_{on}		Max.
6.9	Turn-off time		t_{off}		Max.
6.10	Where appropriate, regular and/or diffuse transmittance		τ_t and/or τ_d	Min.	
6.11	Where appropriate, regular and/or diffuse reflectance		ρ_t and/or ρ_d	Min.	Max.

7 Supplementary information

7.1 Angular dependence of contrast ratio

7.2 Switching times versus temperature

7.3 Operating range:

— threshold voltage versus temperature;
— operating voltage range as a function of temperature at specified contrast ratio.

7.4 Total picture element area

(Sum of all single picture element areas, e.g. segments, symbols or dots.)

7.5 Handling and operation information

7.6 Precautions

7.7 Chromaticity coordinates

7.8 Uniformity characteristics

Section X. Visual inspection of monochrome liquid crystal display cells[2)]

1 Scope

This section applies to visual inspection of monochrome liquid crystal display cells. This section does not apply to active matrix liquid crystal display cells.

2 General

The criteria for the acceptance of specimens assessed by visual inspection depend on:

— dimension and mode of operation of the display;

— dimension, quantity and position of picture elements;

— application;

— temperature range;

— inspection requirements.

Because of this dependence, it is not possible in general to specify these criteria, and reference is made to detail specifications and reference samples.

NOTE The inspection is made on displays without a protection sheet either with the unaided eye or by an automatic test set-up.

3 Visual inspection of displays

3.1 Display not activated

3.1.1 *Test conditions to be specified in the detail specification:*

— viewing direction range;

— illumination from above or through the device (depending on the application);

— duration;

— viewing distance;

— ambient temperature.

3.1.2 ***Procedure***

Devices shall be inspected for the following visual defects:

Defect	*Rejection criteria*
Spots (see Figure 1), bubbles, foreign particles	To be specified in the detail specification
Light/dark stains on light background	To be specified in the detail specification
Light/dark stains on dark background	To be specified in the detail specification
Scratches on the liquid crystal cell and on the polarizer within the specified viewing direction range	To be specified in the detail specification
Mechanical damage outside of viewing area (see Figure 3 and Figure 4)	To be specified in the detail specification
Accumulation of above-listed visible defects	Reference samples

Defect	*Rejection criteria*
Visible structure of the electrodes within the viewing area	Reference samples
Non-uniformity of luminance and colours within the viewing area of the display and within the specified viewing direction range	Reference samples
Dirt on surface, e.g. finger prints, adhesive residue	Reference samples

[2)] See national foreword for details of textual error.

3.2 Display activated

3.2.1 ***Overall geometrical aspect of the display*** (see Figure 5 and Figure 6)

3.2.1.1 *Test conditions to be specified in the detail specification:*

— electrical driving conditions;
— illumination;
— ambient temperature.

3.2.1.2 *Procedure*

Devices shall be inspected to be in conformity with the detail specification.

Property	*Rejection criteria*
Dimension of picture elements	Not in conformity with the detail specification
Shape of picture elements	Not in conformity with the detail specification
Defect	*Rejection criteria*
Missing picture elements	Not in conformity with the detail specification
Unwanted picture elements	Not in conformity with the detail specification
Seal edge within viewing area	Not in conformity with the detail specification

3.2.2 ***Visible defects of the viewing area***

3.2.2.1 *Test conditions to be specified in the detail specification:*

— electrical driving conditions;
— viewing direction range;
— illumination from above or through the device (depending on the application);
— duration;
— viewing distance;
— ambient temperature.

3.2.2.2 *Procedure*

Devices shall be inspected for the following visual defects:

Defect	*Rejection criteria*
A pin-hole within the picture element	To be specified in the detail specification
Accumulation of pin-holes whose size is smaller than specified above	Reference samples
Pin-holes within the non-activated surrounding area of the picture elements	To be specified in the detail specification
Difference of contrast ratio between different picture elements	To be specified in the detail specification
Uniformity of luminance within the viewing area	To be specified in the detail specification
Uniformity of contrast within the viewing area	To be specified in the detail specification
Non-uniformity of luminance and colours within the viewing area and within the specified viewing direction range	Reference samples

4 Seal inspections (see Figure 2)

4.1 Test conditions:

— optical magnification (e.g. 10 ×);
— illumination (e.g. vertical illumination).

4.2 Procedure

The seal shall be inspected for the following defects:

Defect	*Rejection criteria*
Cracks	To be specified in the detail specification
Inclusions (e.g. bubbles, foreign particles)	To be specified in the detail specification
Differences of seal width	To be specified in the detail specification

5 Visual inspection of contact pad area (see Figure 3)

5.1 *Test conditions to be specified in the detail specification:*

— viewing direction;
— illumination from above or through the device (depending on the application);
— viewing distance.

5.2 Procedure

The devices given below shall be inspected for the following visual defects:

5.2.1 *Contact pads*

Defect	*Rejection criteria*
Dirt on contact pad area e.g. residue of liquid crystal material or adhesive	Not allowed
Cracks	a) Complete breaks not allowed b) Reference samples for partial breaks
Damage to contact pad area.	To be specified in the detail specification

5.2.2 *Pins*

Defect	*Rejection criteria*
Dirt on pins	To be specified in the detail specification
Missing pins	Not allowed
Bent pins	To be specified in the detail specification

5.2.3 *Flexible leads*

Defect	*Rejection criteria*
Missing electrical contact	Not allowed

6 Visual inspection for chipped material at the borders and edges of the support plates of cells (see Figure 3 and Figure 4)

6.1 Procedure

The support plates shall be inspected for mechanical damage at borders and edges.

Defects	*Rejection criteria*
Damage to the support plates	To be specified in the detail specification

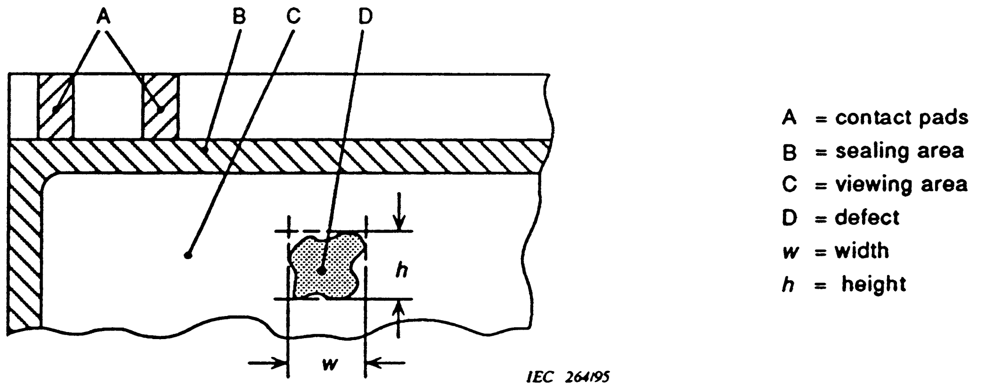

Figure 1 — Defects within the viewing area

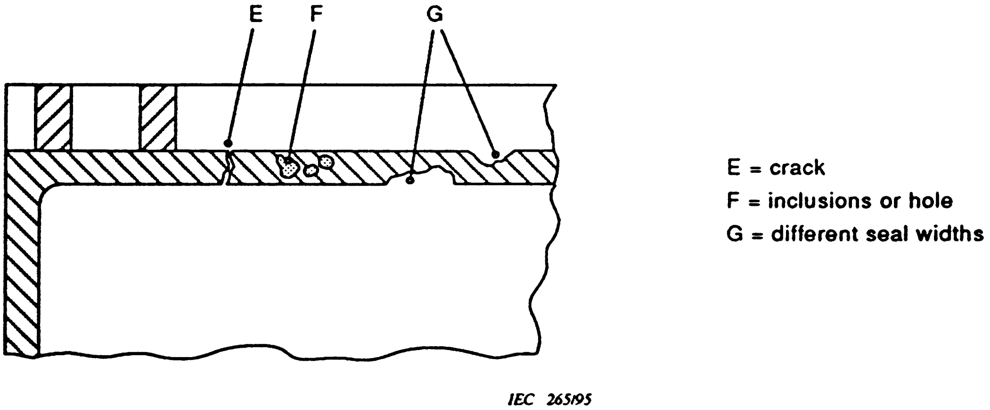

Figure 2 — Defects within the sealing area

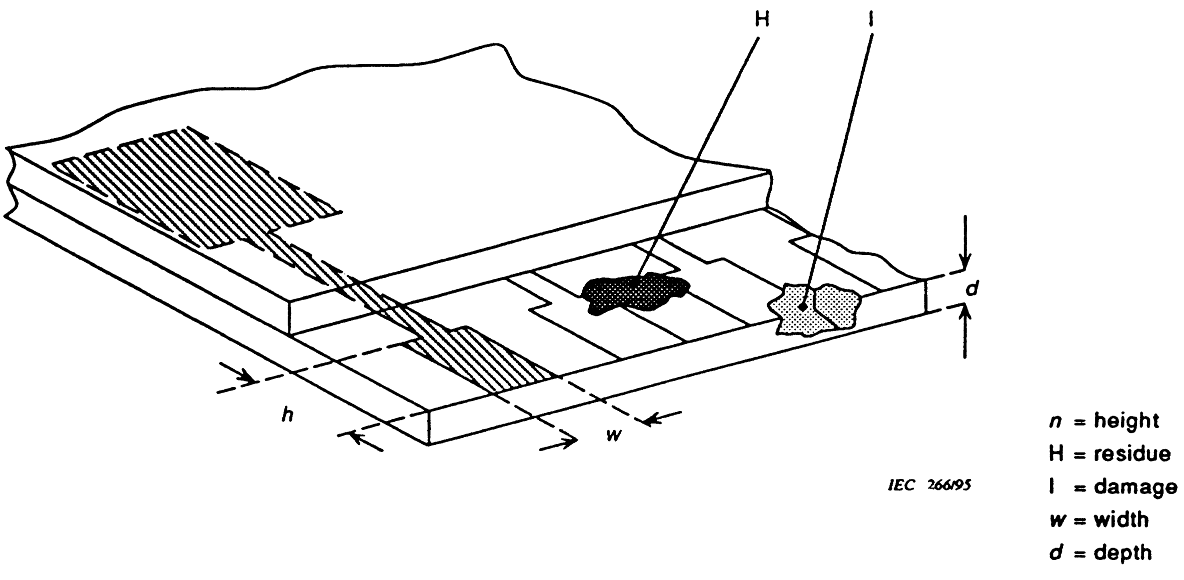

Figure 3 — Defects of contact pad area

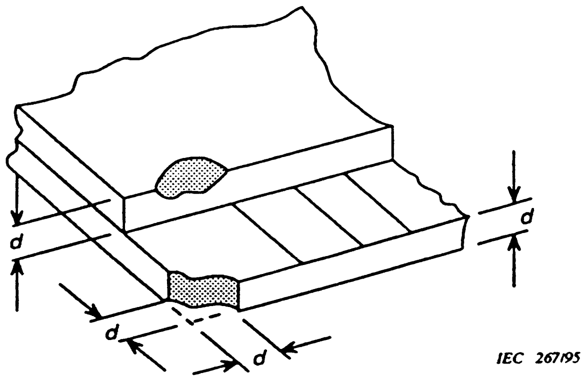

Figure 4 — Damage of a corner and of an edge

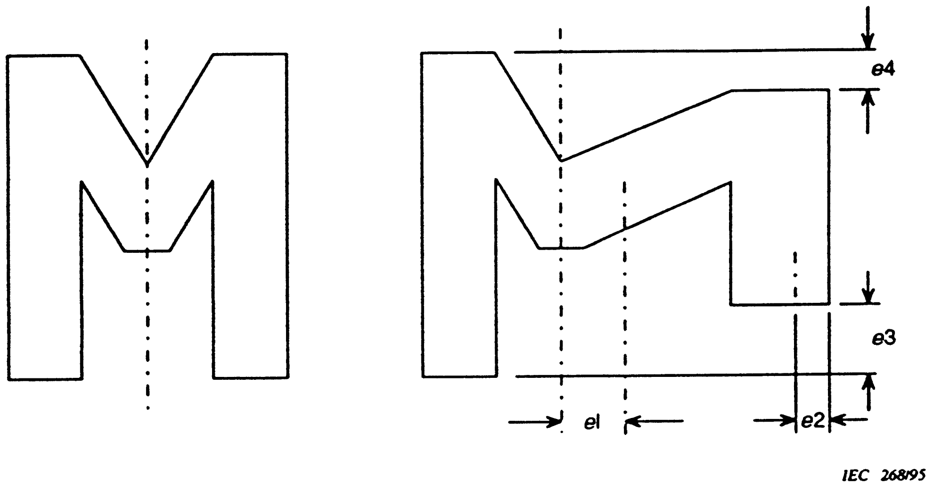

Figure 5 — Deviations of dimensions and shape e1...e4: deviations

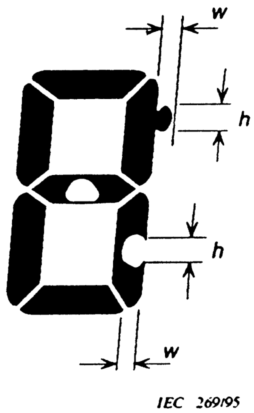

Figure 6 — Defects within segments

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Chapter IV. Measuring methods

1 Measuring methods for photoemitters

1.1 Luminous intensity of light-emitting diodes (I_v)

a) *Purpose*

To measure the luminous intensity of semiconductor light-emitting diodes.

The method can be applied to three possible measurement variants:

Variant 1

Rotation of the diode around its mechanical axis for an accurate location of the minimum and/or maximum value.

Variant 2

Alignment of the diode optical axis with that of the optical bench.

Variant 3

Positioning according to a reference corresponding to the type of the diode envelope and allowing a reproducible mechanical orientation.

b) *Circuit diagram*

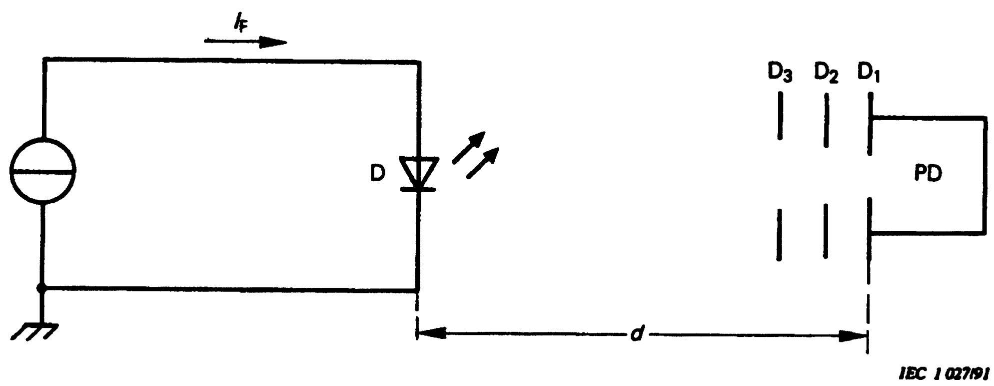


Figure 15

c) *Circuit description and requirements*

G = current source

D = light-emitting diode being measured

PD = photodetector including the diaphragm D_1 of area A

D_2, D_3 = Diaphragms intended to suppress parasitic radiations. D_2 and D_3 shall not limit the solid angle

d = distance between the diode being measured and D_1.

The spectral sensitivity of the photometer shall be adjusted to the CIE (International Commission on Illumination) standard observers curve in the wavelength region of the light emitted by the diode. The photometer shall be calibrated in candelas at the distance d, with diaphragm D_1 in place.

The distance d shall be such that the solid angle viewed by the light source at the diaphragm D_1 ($= A/d^2$) is less than 0,01 sr.

For pulse measurements, the current generator should provide current pulses of the required amplitude, duration and repetition rate. The photodetector should have a rise time sufficiently small in comparison with the pulse duration; it should be a peak-reading instrument.

d) *Measurement procedure*

The diode being measured is positioned according to the variant chosen.

The specified current is applied and the luminous intensity is measured on the photodetector.

e) *Specified conditions*

— Ambient temperature and, where appropriate, the atmospheric conditions.
— Forward current in the diode and, where applicable, duration and repetition rate.
— Variant: 1, 2 or 3.

1.2 Radiant intensity of infrared-emitting diodes (I_e)

a) *Purpose*

To measure the radiant intensity of semiconductor infrared-emitting diodes.

The method can apply to three possible measurement variants:

Variant 1

Rotation of the diode around its mechanical axis for an accurate location of the minimum and/or maximum value.

Variant 2

Alignment of the diode optical axis with that of the optical bench.

Variant 3

Positioning according to a reference corresponding to the type of the diode envelope and allowing a reproducible mechanical orientation.

b) *Circuit diagram*

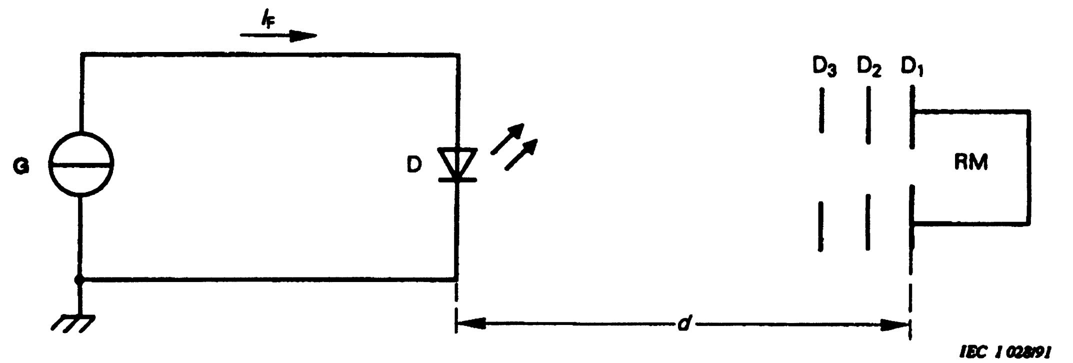


Figure 16

c) *Circuit description and requirements*

G	= current source
D	= infrared-emitting diode being measured
RM	= radiometer including the diaphragm D_1 of area A
D_2, D_3	= diaphragms intended to suppress parasitic radiations. D_2 and D_3 shall not limit the solid angle
d	= distance between the diode being measured and D_1.

The radiant intensity I_e in the direction of the case axis should be measured by a wavelength-independent detector (for example, a thermocouple element) and the radiometer shall be calibrated in W/sr at the distance d with diaphragm D_1 in place.

The distance d shall be such that the solid angle viewed by the infrared source at the diaphragm D_1 ($= A/d^2$) is less than 0,01 sr.

For pulse measurements, the current generator shall provide current pulses of the required amplitude, duration and repetition rate. The radiometer shall have a rise time sufficiently small in comparison with the pulse duration; it shall be a peak-reading instrument.

d) *Measurement procedure*

The diode being measured is positioned according to the variant chosen.

The specified current is applied to the diode and the radiant intensity is measured on the radiometer.

e) *Specified conditions*

— Ambient temperature and, where appropriate, the atmospheric conditions.
— Forward current in the diode and, where applicable, duration and repetition rate.
— Variant: 1, 2 or 3.

1.3 Radiant power or forward current of light-emitting diodes (LED), infrared-emitting diodes (IRED) and laser diodes with or without pigtails

a) *Purpose*

To measure the radiant power ϕ_e or the forward current I_F of light-emitting diodes (LED), infrared-emitting diodes (IRED) and laser diodes, with or without pigtails, under specified conditions.

b) *Measuring equipment*

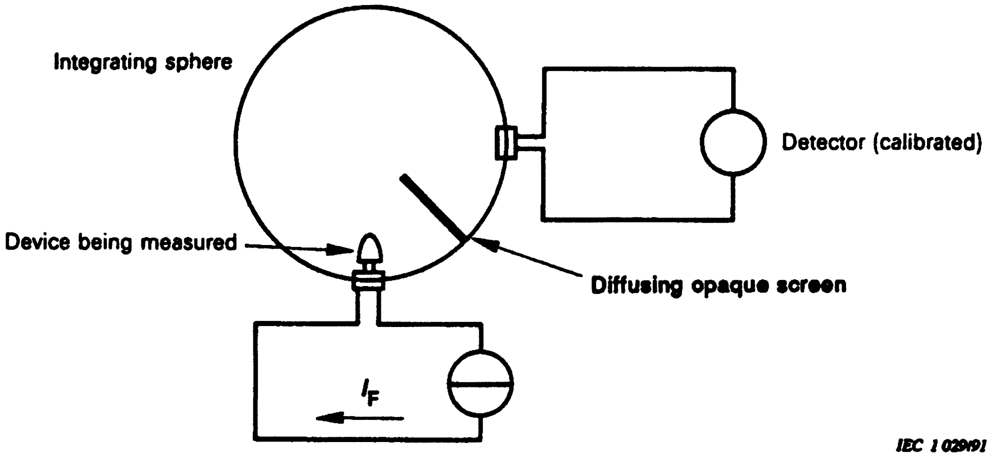


Figure 17

c) *Equipment description and requirements*

The radiation emitted by the device is submitted to multiple reflections from the walls of the integrating sphere; this leads to a uniform irradiance of the surface proportional to the emitted flux. A detector located in the walls of the sphere measures this irradiance. An opaque screen shields the detector from the direct radiation of the device being measured.

d) *Precautions to be observed*

The device being measured, the screen and the apertures shall be small compared to the sphere surface.

The inner surface of the sphere and screen shall have a diffusing coating having a high uniform reflection coefficient (0,8 minimum).

The sphere and detector assembly shall be calibrated.

Change in peak-emission wavelength and flux due to power dissipation shall be taken into account.

When the device being measured is pulsed, the detector shall average the measured radiation.

e) *Measurement procedures*

The emitting device is set at the entrance of the integrating sphere, so that no direct radiation will reach the detector.

For measurement of radiant power, the specified forward current I_F is applied to the device and the radiant power is measured on the photodetector.

For measurement of forward current, a current is applied to the device until the specified radiant power (ϕ_e) is achieved. The value of current is recorded.

f) *Specified conditions*

— Ambient or case temperature.

— Radiant power (when measuring forward current).

— Forward current (when measuring radiant power).

1.4 Peak-emission wavelength (λ_p) **spectral radiation bandwidth** ($\Delta\lambda$) **and number of longitudinal modes** (n_m)

a) *Purpose*

To measure the peak-emission wavelength and the spectral radiation bandwidth of emitting devices and to determine the number of longitudinal modes of laser diodes.

b) *Circuit diagram*

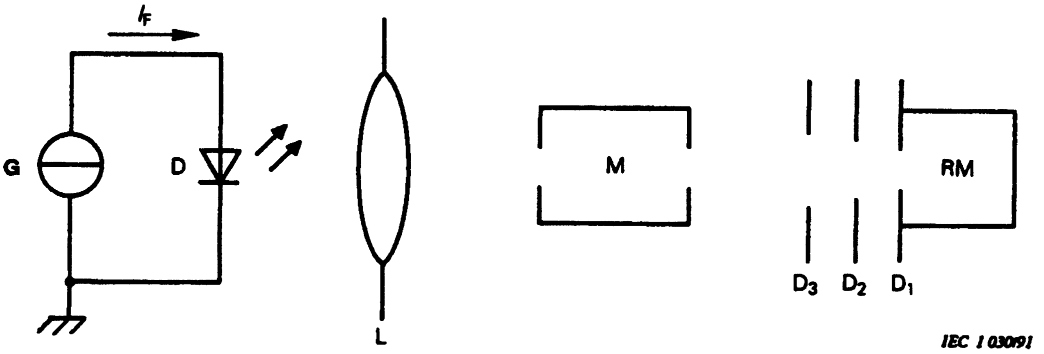


Figure 18 — Basic circuit

c) *Circuit description and requirements*

D	=	device being measured
L	=	focusing lens systems
G	=	generator (pulsed or d.c.)
M	=	monochromator
D_2, D_3	=	diaphragms intended to suppress parasitic radiations, where appropriate
RM	=	radiometer (including diaphragm D_1).

The wavelength resolution and the bandwidth of the monochromator shall be such that the measurement is carried out with adequate accuracy.

The spectral response of the radiometer shall be calibrated. For convenience of measurement, the peak of the curve may represent 100 %.

d) *Precautions to be observed*

If the transmission factor of the monochromator and the radiometer sensitivity are not constant over the required range of wavelength, the recorded values should be corrected.

For measurement of the laser diode, radiant power reflected into the laser diode shall be minimized to ensure that the spectral response is not significantly affected.

e) *Measurement procedure*

1) *Peak emission wavelength and spectral radiation bandwidth of a light-emitting diode, or an infrared-emitting diode, or a single-mode laser diode*

The specified current is applied to the device being measured.

The wavelength of the monochromator is adjusted within the required range until the maximum reading on the radiometer has been achieved. The wavelength corresponding to this peak value is recorded. This is the peak-emission wavelength (λ_p) (see Figure 19).

The wavelength of the monochromator is then adjusted on either side of λ_p until the maximum reading is halved. These two wavelengths (λ_1 and λ_2 on Figure 19) are recorded. Their difference is the spectral radiation bandwidth of the infrared-emitting or light-emitting device (see Figure 19).

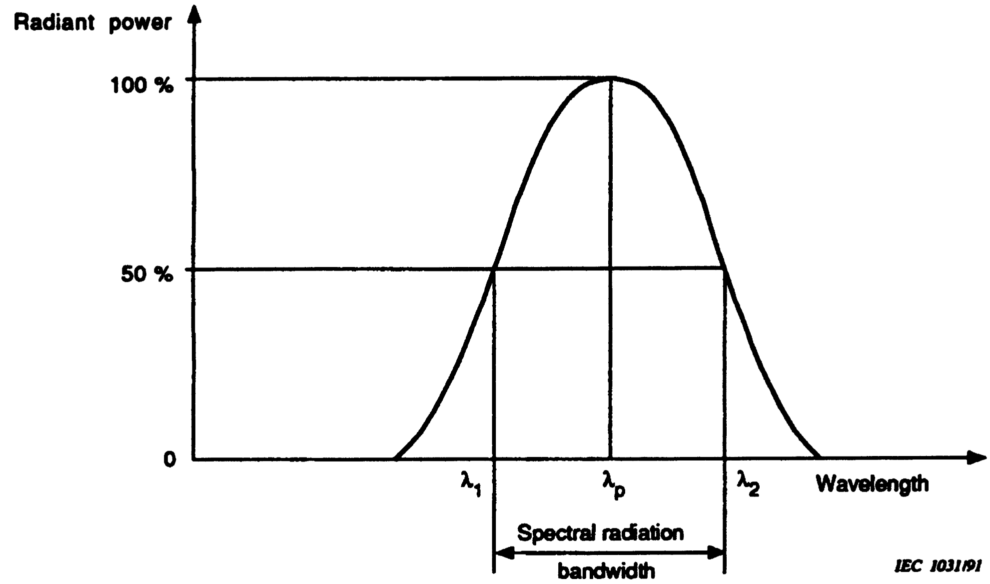


Figure 19 — Radiant power as function of wavelength

2) *Peak-emission wavelength, spectral radiation bandwidth and number of longitudinal modes of a multimode laser diode*

2.1) *Peak-emission wavelength of a multimode laser diode*

A current corresponding to the specified optical power output is applied to the device being measured.

The wavelength of the monochromator is adjusted within the required range until the highest of the various maxima is indicated.

The wavelength corresponding to this value is recorded. This is the peak-emission wavelength (λ_p) (see Figure 20).

2.2) *Spectral radiation bandwidth of a multimode laser diode*

The monochromator is set to a long wavelength and then adjusted progressively to shorter wavelengths. Record the first wavelength at which the specified percentage of the highest reading recorded under e) 2.1) is obtained or exceeded. The monochromator is set to a short wavelength and thus adjusted progressively to longer wavelengths. Record the first wavelength at which the specified percentage of the highest reading recorded under e) 2.1) is obtained or exceeded. The difference between the two recorded values is the spectral radiation bandwidth of the laser diode ($\Delta\lambda$) (see Figure 20).

2.3) *Number of longitudinal modes of a multimode laser diode*

The spectral radiation bandwidth as in e) 2.2) above is measured and then the number of modes (n_m) within that bandwidth including the two modes that define the limit of the bandwidth is counted (see Figure 20).

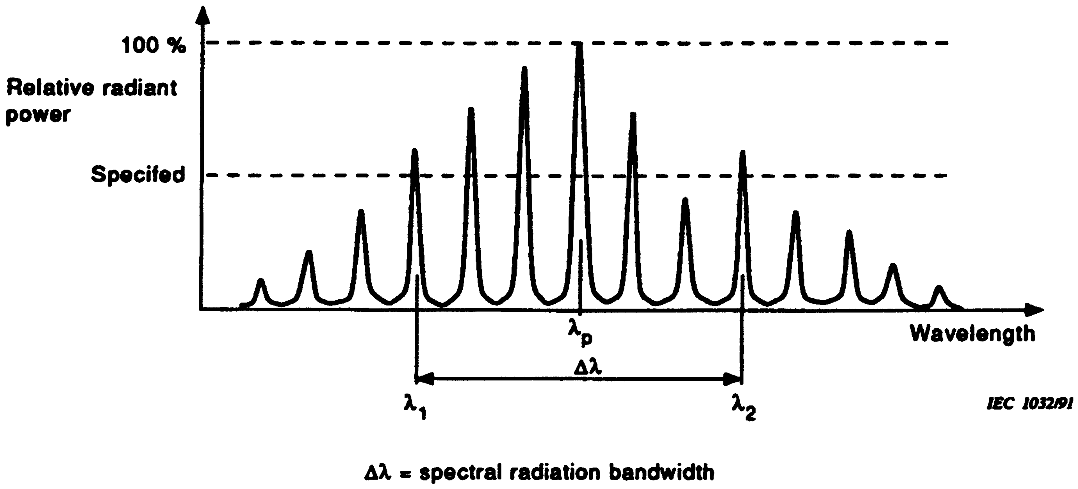


Figure 20

f) *Specified conditions*

— For LED and IRED:

- ambient or case temperature;
- forward current (d.c. or pulse), as specified.

— For laser diodes:

- ambient, case or submount temperature;
- radiant power or forward current;
- percentage of peak emission if other than 50 %.

1.5 Switching times of infrared-emitting diode and light-emitting diode with or without pigtails

a) *Purpose*

To measure the turn-on time t_{on} (turn-on delay time $t_{d(on)}$ + rise time t_r) and turn-off time t_{off} (turn-off delay time $t_{d(off)}$ + fall time t_f) of an infrared-emitting diode and light-emitting diode with or without pigtails.

b) *Circuit diagram*

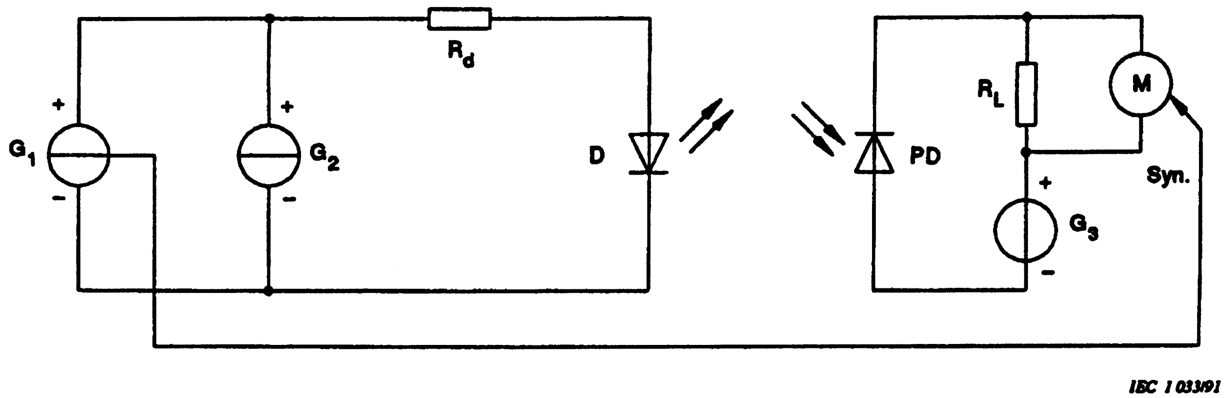


Figure 21

c) *Circuit description*

G_1	=	current pulse generator, with high impedance
G_2	=	d.c. current bias source
G_3	=	d.c. voltage bias source
R_d	=	resistance for matching the impedance with the generator
D	=	device being measured
PD	=	photodiode
R_L	=	load resistance
M	=	measuring instrument
Syn.	=	synchronization signal

d) *Precautions to be observed*

The switching time of the photodiode, the delay time of the test circuit and measuring instrument, the rise and fall times of the input current pulse shall be short enough not to affect the accuracy of the measurement.

The mean output power obtained at the top of the optical pulse (see Figure 22) may not necessarily be equivalent to the c.w. radiant power at a current equal to the sum of the d.c. bias and input pulse current.

Only the optical port of the device being measured shall be considered.

e) *Measurement procedure*

Apply the specified d.c. and pulse current to the device being measured.

Measure the switching times with the measuring instrument M.

The 100 % radiant output power level is the mean output power obtained at the top of the radiant pulse. The 0 % level is the output power obtained at the d.c. bias current.

f) *Specified conditions*

— Ambient or case temperature.
— D.C. bias current.
— Input pulse current, width and duty cycle.
— Optical port.
— Optical configuration.

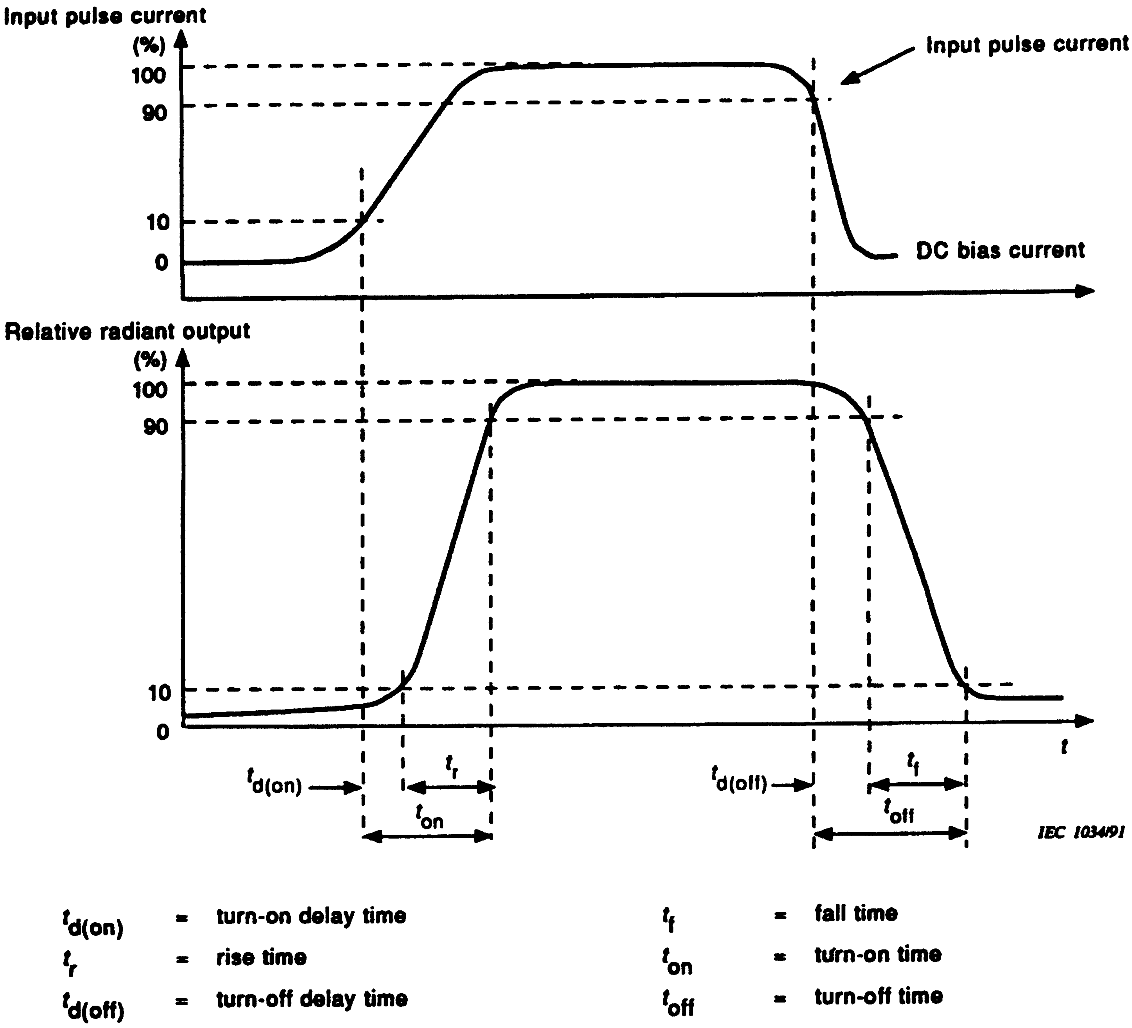


Figure 22

1.6 Small signal cut-off frequency (f_c) of light-emitting diodes (LED), infrared-emitting diodes (IRED) and laser diodes with or without pigtails

a) *Purpose*

To measure the small-signal cut-off frequency (f_c) of light-emitting diodes (LED), infrared-emitting diodes (IRED) and laser diodes with or without pigtails, under specified conditions.

b) *Circuit diagram*

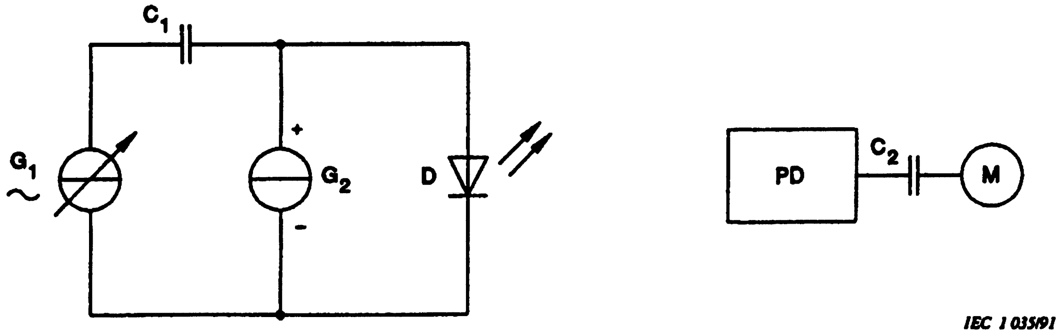


Figure 23

c) *Circuit description and requirements*

D = device being measured
G_1 = adjustable frequency a.c. generator
G_2 = d.c. generator
PD = photodetector
M = measuring instrument for a.c. radiant power
C_1, C_2 = coupling capacitors

d) *Precautions to be observed*

The radiant power reflected back into the laser-diode shall be minimized so as to avoid distortions which could affect the accuracy of the measurements. The photodetector must have a frequency response greater than f_c.

e) *Measurement procedure*

For LED and IRED, the specified direct forward current or the direct forward current required to obtain the specified radiant power is applied to the device being measured.

For laser diodes, the forward current is adjusted to a value equal to the continuous forward current above the threshold or specified radiant power.

The forward current is modulated using generator G_1 at a low frequency (less than $f_c/100$) and the a.c. radiant power is measured on M.

The modulation frequency is increased, keeping the modulation level constant until the output radiant power measured on M has halved.

This frequency is the small-signal cut-off frequency (f_c).

f) *Specified conditions*

For the light-emitting diodes (LED) and infrared-emitting diodes (IRED):

— ambient or case temperature;
— d.c. forward current or radiant power.

For the laser diodes:

— ambient, case or submount temperature;
— difference between (actual) d.c. forward current and threshold current or radiant power.

1.7 Threshold current of laser diodes with or without pigtails

a) *Purpose*

To measure the threshold current of a laser diode, with or without pigtails.

b) *Circuit diagram*

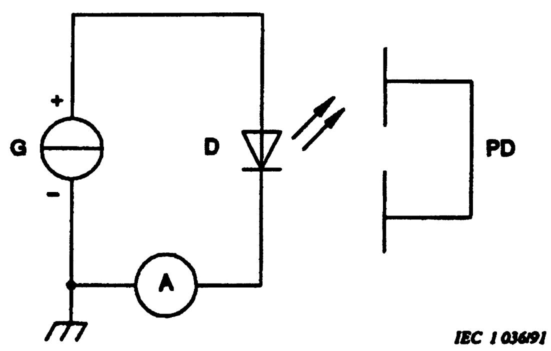


Figure 24

c) *Circuit description and requirements*

D	=	device being measured
PD	=	photodetector measuring incident radiant power
A	=	ammeter
G	=	generator (pulsed or d.c.)

For pulse measurement, the current generator shall provide current pulses of the required amplitude, duration and repetition rate.

d) *Precautions to be observed*

Radiant power reflected back into the laser diode shall be minimized. The limiting values of the laser diode (I_F and ϕ_e) shall not be overstepped.

e) *Measurement procedure*

A forward current is applied to the diode and the relation between the incident radiant power from the diode and the forward current is recorded.

The forward current at which the second derivative of the recorded curve showing incident radiant power versus the forward current has its first maximum is determined (see Figure 25). The forward current at this point is the threshold current I_{TH}.

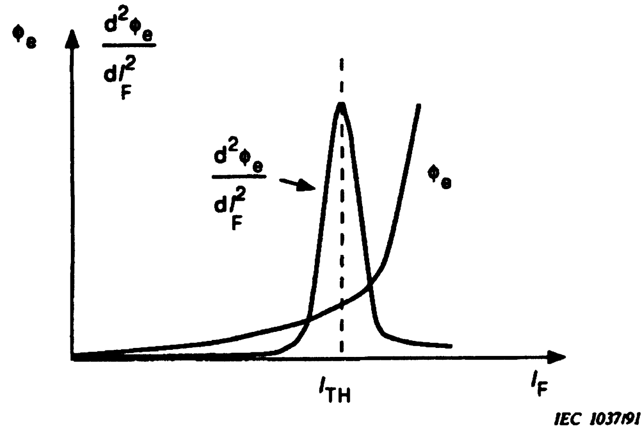


Figure 25

f) *Specified conditions*

— Ambient, case or submount temperature.

— For pulse measurement, repetition frequency and pulse duration of the forward current.

1.8 Relative intensity noise of light-emitting diodes (LED), infrared-emitting diodes (IRED) and laser diodes with or without pigtails

a) *Purpose*

To measure the relative intensity noise (RIN) of LED, IRED and laser diodes, with or without pigtails, under specified conditions.

b) *Circuit diagram*

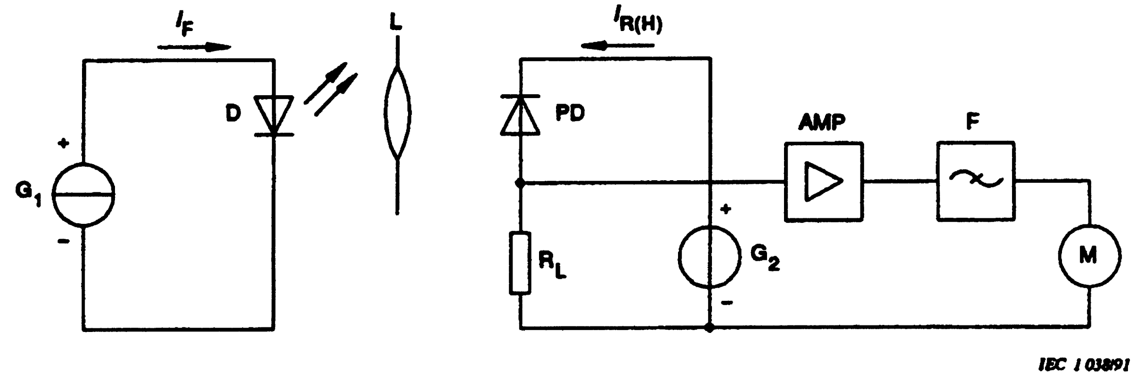


Figure 26

c) *Description of the circuit*

G_1	=	d.c. current generator
D	=	device being measured
L	=	lens system
I_F	=	forward current
PD	=	photodetector
R_L	=	load resistance
$I_{R(H)}$	=	reverse current of the photodetector under optical radiation
G_2	=	d.c. voltage bias generator
AMP	=	a.c. amplifier with gain G
F	=	filter with centre frequency f_o and equivalent noise bandwidth Δf_N
M	=	measuring instrument (for example level meter, etc.)

d) *Precautions to be observed*

Radiant power reflected back into the laser diode shall be minimized to avoid distortions affecting accuracy of the measurements.

e) *Measurement procedure*

A d.c. current corresponding to the specified radiant power ϕ_e is applied to the device. The noise power N_t is measured by the measuring instrument M and is replaced by reverse current $I_{R(H)}$ of the photodetector, under optical radiation is measured simultaneously.

The photo-emitting device being measured is replaced by a radiation source with broad spectral radiation bandwidth in the same wavelength range.

The irradiant power is adjusted to obtain the same reverse current $I_{R(H)}$ of the photodetector under optical radiation as previously measured. The noise power N_d which corresponds to the photodetector shot-noise plus amplifier noise is measured by the measuring instrument.

RIN is calculated using the formula:

$$RIN = (N_t - N_d)/(R_L \,.\, G \,.\, \Delta f_N \,.\, I_{R(H)})$$

It is expressed in Hz^{-1}.

f) *Specified conditions*

— Ambient, case or submount temperature.

— Radiant power.

— Centre frequency and equivalent noise bandwidth.

1.9 Emission source length and width and astigmatism of a laser diode without pigtail

a) *Purpose*

To measure the emission source size on the facet of the laser diode with respect to a defined axis and the astigmatism of the optical beam emitted from the laser diode.

b) *Measuring equipment*

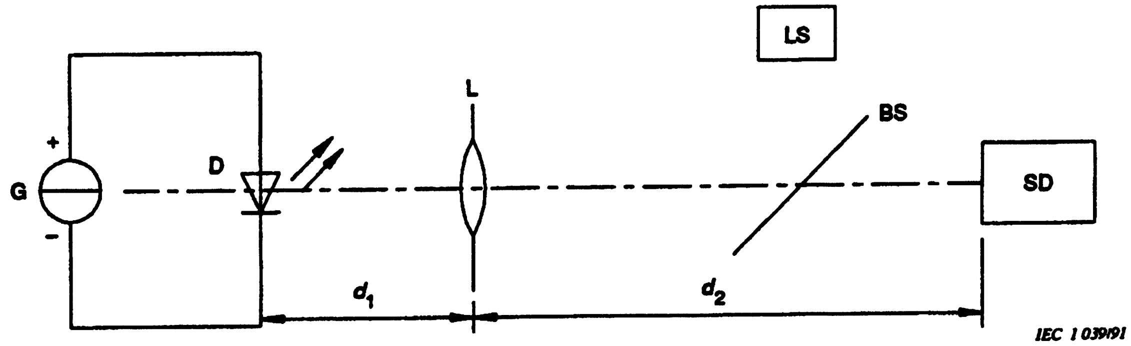


Figure 27

c) *Equipment description and requirements*

G	=	current source
D	=	device being measured
L	=	lens system
SD	=	scanning photodetector with a narrow slit
LS	=	light source with filter or LED the emission wavelength of which is close to that of the device being measured
BS	=	beam splitter

$d_2 >> d_1$

d) *Precautions to be observed*

The lens system L shall be substantially achromatic over the range of wavelengths encompassed by the light source LS and the device D.

e) *Measurement procedure*

Emission source size

The light source LS is turned on and the lens system L adjusted to obtain a focussed image of the front face of the device D on the photodetector SD. Distances d_1 and d_2 are then read.

The specified d.c. current or the d.c. current corresponding to the specified radiant power ϕ_e is applied to the device being measured D.

The scanning direction of the photodetector SD is aligned with the major and minor axes of the focussed image.

The photodetector SD is scanned along the major and the minor axes. The length and width of the emission source are given by the distance between the 3 dB power points along the major and minor axes multiplied by d_1/d_2.

Astigmatism d_A

The light source LS is turned on and the lens system L adjusted to obtain a focussed image of the front facet of the device D on the photodetector SD. Distances d_1 and d_2 are read.

The scanning direction of the photodetectors align with SD the major and the minor axes of the focussed image.

The lens system L is moved along the optical axis toward the device D until the emission source length along the major axis is minimized.

The distance d_3 traversed by the lens system L is measured.

The lens system is returned to the original position. The procedure is repeated for the minor axis. The distance d_4 traversed by the lens system L is measured.

The difference between d_3 and d_4, multiplied by $(1 - d_1^2 / d_2^2)$, is the astigmatism.

f) *Specified conditions*

— Ambient, case or submount temperature.

— Direct forward current or radiant power.

— Reference axes (major and minor axes).

1.10 Switching times of a laser diode with or without pigtails

a) *Purpose*

To measure the switching times (turn-on delay time $t_{d(on)}$, rise time t_r, turn-off delay time $t_{d(off)}$ and the fall time t_f) of a laser diode with or without pigtails under specified conditions.

b) *Circuit diagram*

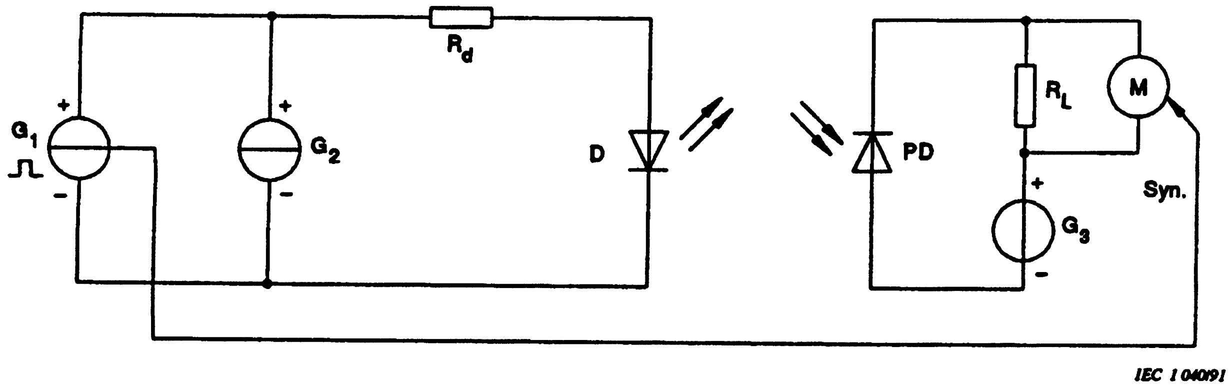


Figure 28

c) *Circuit description*

G_1	=	current pulse generator
G_2	=	d.c. current bias source
G_3	=	d.c. voltage bias source
R_d	=	resistance for matching the impedance with the generator
D	=	device being measured
PD	=	photodiode
R_L	=	load resistance
M	=	measuring instrument capable of measuring input and output waveforms simultaneously
Syn.	=	synchronization signal.

d) *Precautions*

— Radiant power reflected back into the laser diode shall be minimized.

— The pulse width and the duty cycle shall be chosen in order to avoid significant thermal effects.

— A surge current due to switching on/off the circuit, contact with electrostatically charged bodies, etc., shall be avoided.

— The d.c. source G_2 shall have a sufficiently high impedance that does not distort the output of the current pulse generator G_1.

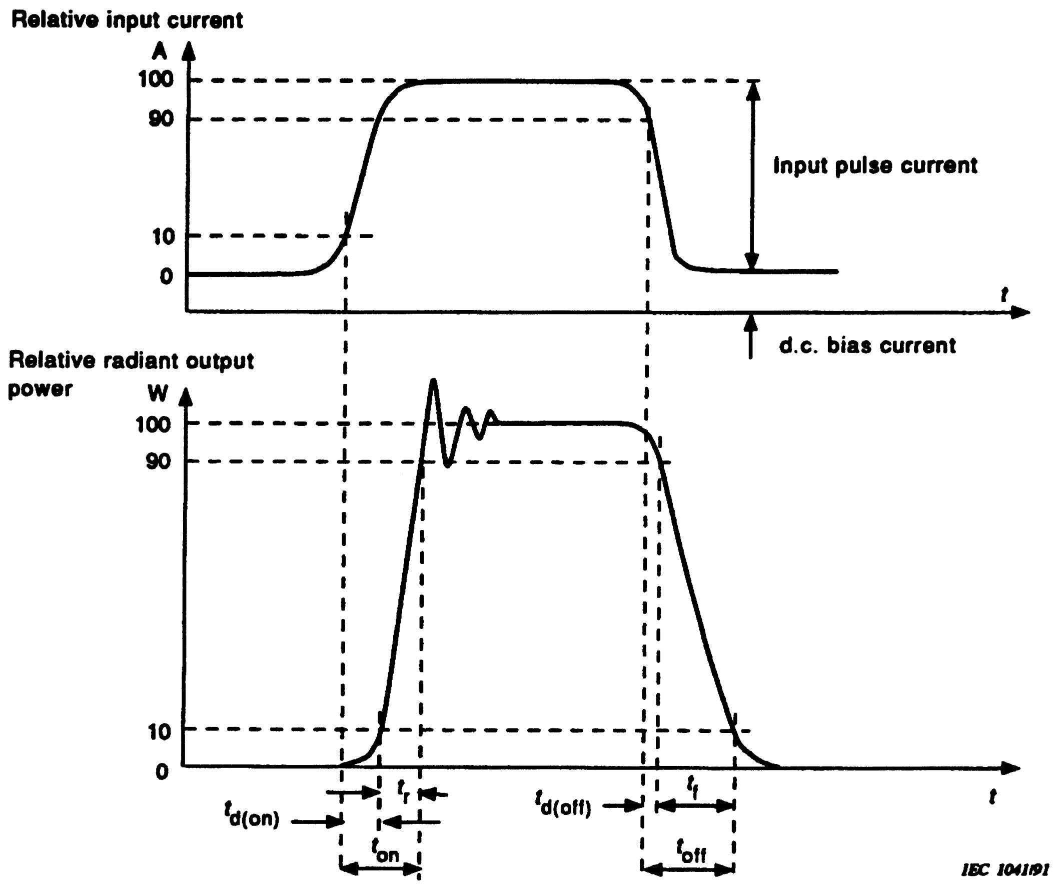
— The switching time of the photodiode PD, and the delay time of the test circuit and measuring instrument should be fast enough not to affect the accuracy of the measurement.

e) *Measurement procedure*

The specified d.c. and pulse current are applied to the device being measured D.

Values of $t_{d(on)}$, t_r, $t_{d(off)}$ and t_f are determined by the measuring instrument.

NOTE Mean output power at the top of the relative radiant output pulse may not necessarily be equivalent to the c.w. optical power at a current equal to the sum of the d.c. bias and input pulse current.



NOTE 1 The switching times are defined in Figure 29 unless otherwise stated. The 100 % level is the mean output power obtained at the top of the optical pulse. The 0 % level is the output power obtained with only the d.c. bias current.

NOTE 2 The switching times t_r and t_f are defined between 10 % and 90 % of the mean radiation output power, unless otherwise stated.

Figure 29

f) *Specified conditions*

— Ambient, case or submount temperature.

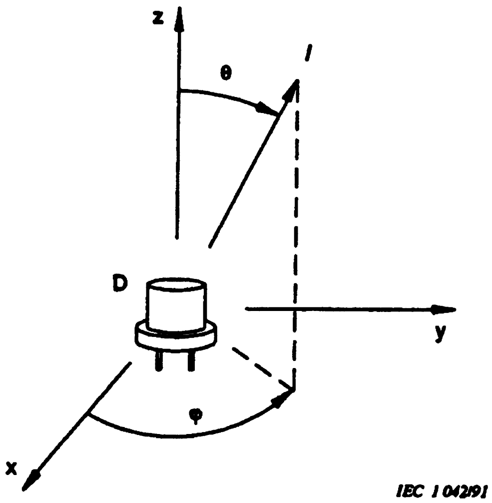
— Bias current or radiant power.

— Input pulse current, width and duty cycles.

1.11 Half-intensity angle and misalignment angle of a photoemitter

a) *Purpose*

To measure the spatial distribution of the radiation from a photoemitter.



Axes X and Y define a mechanical reference plane of the device being measured D, e.g. the mounting face.

The angle φ defines the orientation of the device D in that plane.

Figure 30

The half intensity angle is the angle within which the luminous or radiant intensity is greater than or equal to half of the maximum intensity. This angle is $\theta_{1/2}$ defined for a specified plane which in turn is defined by φ.

The misalignment angle Δθ is the angle between the optical and mechanical axes.

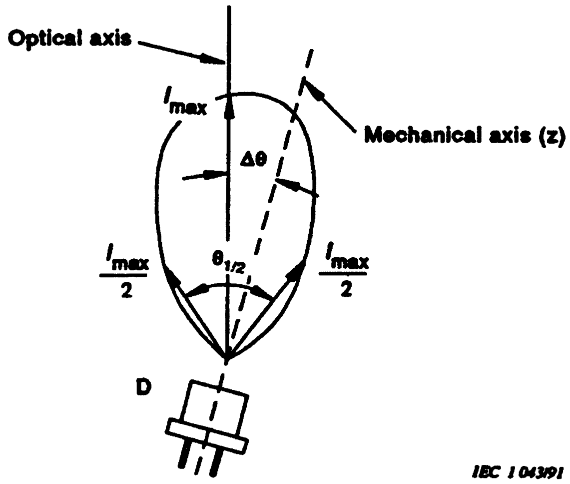


Figure 31

b) *Diagram*

The basic optical arrangement and definition is shown in the following figure:

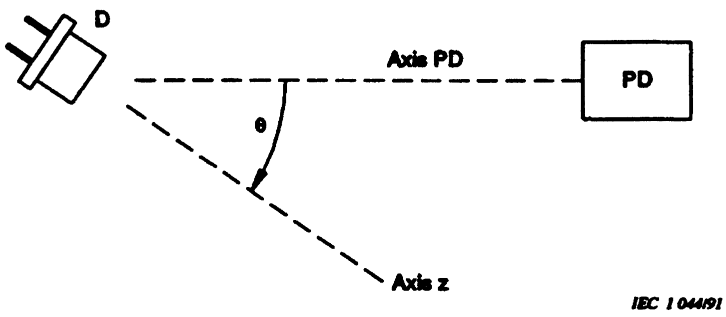


Figure 32

c) *Measurement description and requirements*

D	=	device being measured
PD	=	photodetector
Axis Z	=	defined mechanical axis of the device being measured
Axis PD	=	axis of photodetector
θ	=	inclinaison angle of axis Z to axis PD

NOTE The solid angle, defined by the device being measured and the aperture of the photodiode, shall be small. The solid angle is considered small if the measurement result does not change significantly when the solid angle is halved.

The device being measured D shall be mounted in a fixture which allows:

— precise, reproducible positioning of the device D;
— changes to the angle θ, keeping the centre of the optical port of the device D fixed;
— measurement of the angle of inclinaison θ;
— rotation of the device D around its Z axis;
— measurement of the angle of rotation about the X axis.

d) *Precautions to be observed*

Under consideration.

e) *Measurement procedure*

The specified current is applied to the device being measured D.

The mechanical axis of the device D is aligned along the axis of the photodetector, i.e. θ = 0, and measure the signal on the photodetector.

This value is set at I_0 = 100 %.

The device D is inclinated and the relative intensity I/I_0 versus θ is plotted.

The preferred plot will be in polar diagram form. Other formats e.g. cartesian may be used when defined in the blank detail specification.

The half intensity angle $\theta_{1/2}$ is the angle between the two points at which $I = I_{max/2}$.

The misalignment angle is the angle between the directions corresponding to I_{max} and I_0.

f) *Specified conditions*

— Ambient, case or submount temperature.
— I_F or ϕ_e.
— Mechanical reference plane.
— Angle φ.

1.12 Carrier to noise ratio of light-emitting diodes, infrared-emitting diodes, laser diodes and a laser module with or without pigtails

a) *Purpose*

To measure the carrier to noise ratio at a specified radiant power level (cw) under specified modulation conditions.

b) *Circuit diagram*

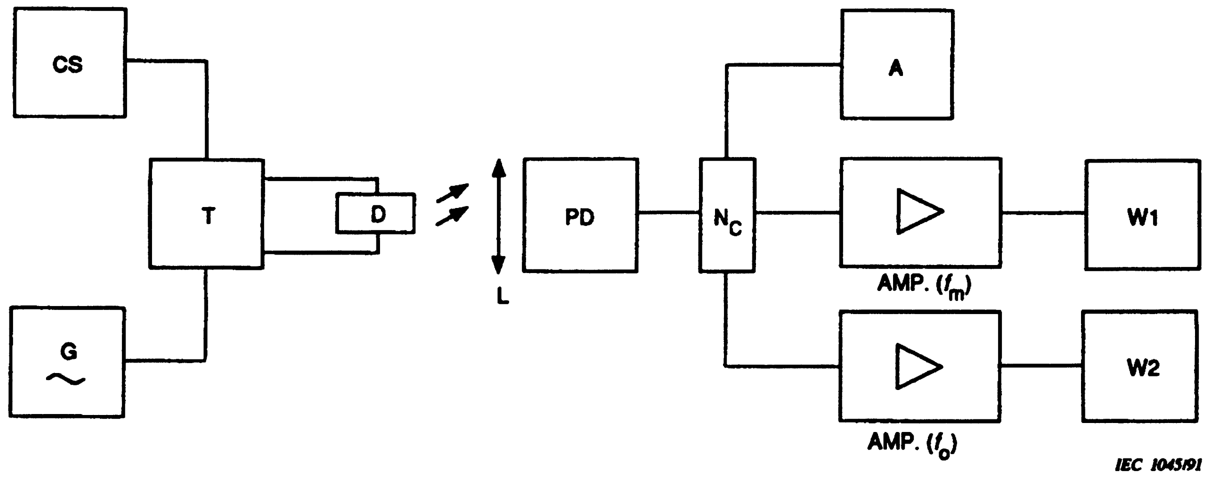


Figure 33

c) *Circuit description and requirements*

CS	=	d.c. current source
D	=	device being measured
G	=	a.c. generator
T	=	bias T or passive biasing circuit
L	=	focusing lens systems
PD	=	photodetector
A	=	current measuring instrument
AMP(f_m)	=	amplifier suitable for use at frequency f_m
W1	=	power meter
AMP(f_o)	=	amplifier and filter suitable for use at frequency f_o
W2	=	power meter
N_C	=	impedance matching and signal dividing network

d) *Precautions to be observed*

The associated "photodetector + ammeter" shall be calibrated as a radiant power meter unit over the wavelength range under consideration.

The focusing systems shall be designed:

— to avoid radiation being reflected back into the laser diode or the laser module;

— to bring into focus the optical port of the device being measured onto the optical port of the photodetector.

e) *Measurement procedure*

The specified supply and drive conditions are applied to the device being measured D.

The photocurrent (I_{ph}) resulting from the illumination (ϕ_e specified) of the photodetector is measured first and noted. R.F. modulation is applied to the device being measured through the biasing circuit: sinewave frequency f_m, modulation depth m. The electrical power P_1 at frequency f_m is measured on the power meter W1. This electrical power P_1 is related to the modulated radiant power squared as follows:

$$(\Delta\phi_m)^2 = \frac{P_1}{S^2 \times R_c}$$

where

S = responsivity on the photodetector PD

R_c = load resistance of PD [input of AMP(f_m)]

The noise electrical power N_{tot} at frequency f_o in the frequency band Δf is measured on the power meter W2 (f_o should be as close as technically possible to f_m). This is the sum of the pure shot noise associated with the photocurrent I_{ph} and the excess noise due to the radiation source intensity fluctuations. The pure shot noise must be measured under the same illumination conditions (same I_{ph}) using a "broad optical spectrum" radiation source. The electrical noise power corresponding to the pure shot noise equivalent radiant power fluctuations can be measured on W2 (N_s):

$$\left(\frac{C}{N}\right)_{lin} = \frac{(\Delta\phi_m)^2}{<\Delta\phi_e^2>} = \frac{P_1}{(N_{tot} - N_s)} \times (\Delta f)$$

or

$$\left(\frac{C}{N}\right) = 10 \log_{10} \left(\frac{C}{N}\right)_{lin}$$

f) *Specified conditions*

— Ambient, case or submount temperature.

— Measurement bias conditions (ϕ_e, I_F or ΔI_F).

— Frequency and bandwidth (f_o, Δf).

— Drive frequency (f_m).

— Modulation depth (m).

1.13 S_{11} parameter of infrared emitting diodes, light-emitting diodes, laser diodes, laser modules with or without pigtails

a) *Purpose*

To measure the real and imaginary parts (or modulus and phase) of the input characteristic of a device at a specified radiant power level and at a specified frequency.

The S_{11} parameter is the ratio of the high-frequency reflected voltage V_{rl} to the high-frequency incident voltage V_{il} at the device electrical input port.

$$S_{11} = \frac{V_{rl}}{V_{il}}$$

The equivalent working equation is the following:

$$S_{11} = \frac{Z_1 - Z_0}{Z_1 + Z_0}$$

In which Z_1 is the input impedance of the device being measured and Z_0 the characteristic impedance of the measuring equipment.

b) *Circuit diagram*

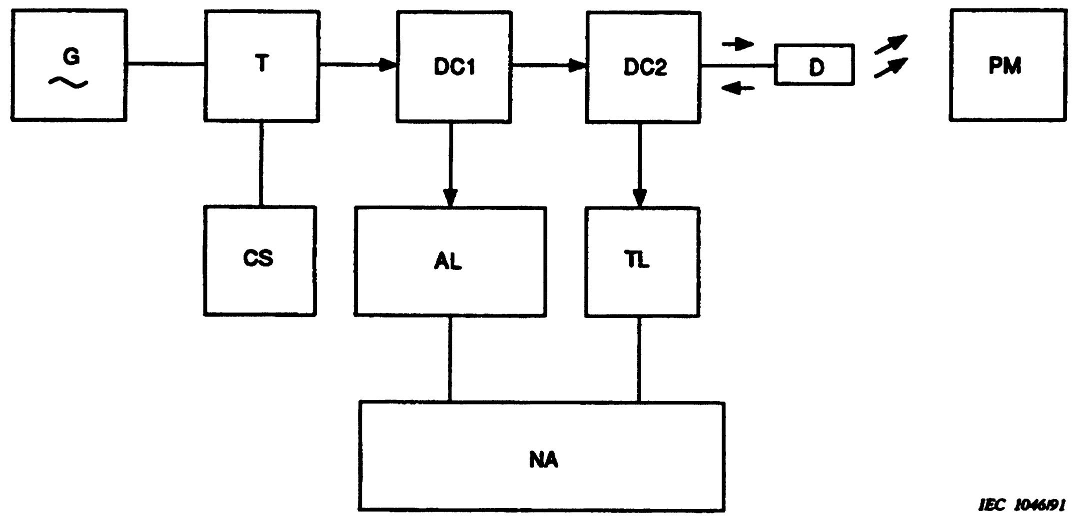


Figure 34

c) *Circuit description and requirements*

G	=	RF generator
T	=	biasing circuit
CS	=	d.c. current source
DC1	=	directional coupler forward
DC2	=	directional coupler reverse
AL	=	adjustable transmission line
NA	=	network analyzer
D	=	device being measured
PM	=	radiant power meter
TL	=	test transmission line

d) *Precautions to be observed*

The characteristic impedance of the transmission lines, generator, attenuators, device measuring socket, T-biasing circuit and loads is matched to a common impedance (usually 50 Ω) over the specified frequency range.

The RF power shall remain low enough to allow for linear operation of the device being measured D.

Ensure that the optical ports of the device D and the meter PM are aligned.

e) *Measurement procedure*

Calibration:

The adjustable line shall balance the test line.

A short circuit is connected to the input line at the location of the device being measured.

The a.c. signal frequency is scanned around the specified frequency *f*, and the adjustable line length is altered in order to obtain one single point S_{11} on the Smith Chart (modulus equal to unity and phase equal to 180°).

Measurement:

The "calibration" short-circuit is replaced by the device being measured D, the bias conditions are applied as specified (ϕ_e, T_{case}, or T_{amb}, T_{sub}), the value of S_{11} corresponding to the reflection coefficient of the device D is read.

f) *Specified conditions*

— Ambient, case of submount temperature.

— Supply and drive conditions: ϕ_e or I_F or ΔI_F, f, m (modulation depth).

1.14 Tracking error for a laser module with pigtails, with or without cooler

a) *Purpose*

To measure the maximum variations of the tracking ratio between the fibre output radiant power and the monitor diode photocurrent of a laser module over a specified temperature range.

b) *Circuit diagrams*

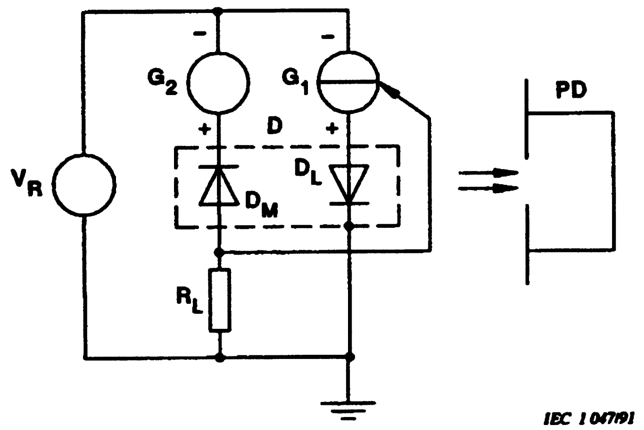


Figure 35a — Laser diode: cathode connected to the package

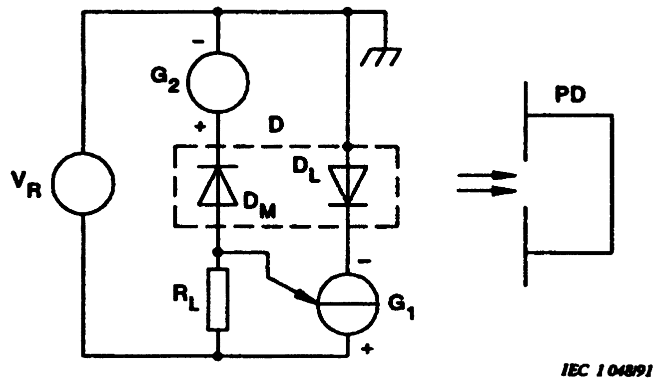


Figure 35b — Laser diode: anode connected to the package

c) *Circuit description and requirements*

D	=	device being measured
PD	=	photodetector calibrated (in watts)
G_1	=	d.c. current source, monitored through negative feedback by the photocurrent delivered by the monitor photodiode
G_2	=	d.c. voltage source
R_L	=	load resistance
V_R	=	d.c. voltmeter
D_L	=	laser diode
D_M	=	monitor photodiodes

d) *Precautions to be observed*

— The optical radiant power reflected back to the laser diode shall be minimized.

— The changes in case temperature should be slow enough to insure that thermal equilibrium takes place inside the module, and in the case of a module with cooler, that the specified T_{sub} is stabilized.

e) *Measurement procedure*

At each measuring point, the current source G_1 is adjusted until the monitor photocurrent is equal to the value obtained with the specified optical radiation at 25 °C.

The case temperature is scanned over the specified range and the plot of the output radiant power is recorded against either time (Figure 36) or case temperature (Figure 37).

The tracking error is then given by:

$$E_{R1} = \frac{\phi_{e\,25\,°C} - \phi_{e\,min}}{\phi_{e\,25\,°C}} \times 100\ (\%)$$

$$E_{R2} = \frac{\phi_{e\,max} - \phi_{e\,25\,°C}}{\phi_{e\,25\,°C}} \times 100\ (\%)$$

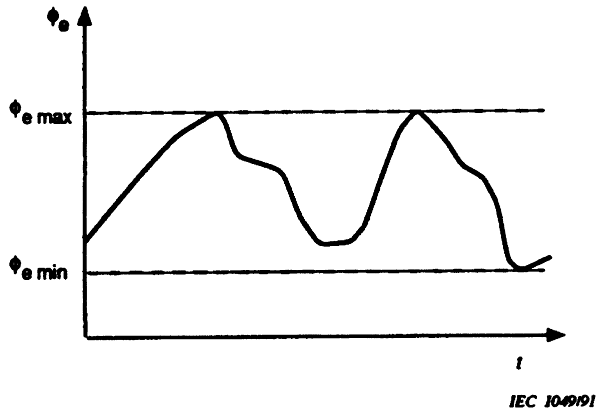


Figure 36

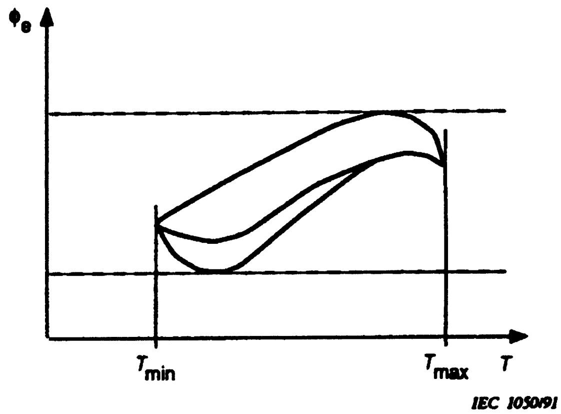


Figure 37

f) *Specified conditions*

— ϕ_e or ΔI_F at 25 °C.

— Case or ambient temperature range $T_{case/amb\,min}$; $T_{case/amb\,max}$.

— Submount temperature (T_{sub}), where appropriate.

— Bias voltage (V_R) of the monitor photodiode (D_M).

1.15 Spectral linewidth of a laser diode with or without pigtails

a) *Purpose*

To measure the spectral linewidth of a laser diode with or without pigtails.

b) *Circuit diagram*

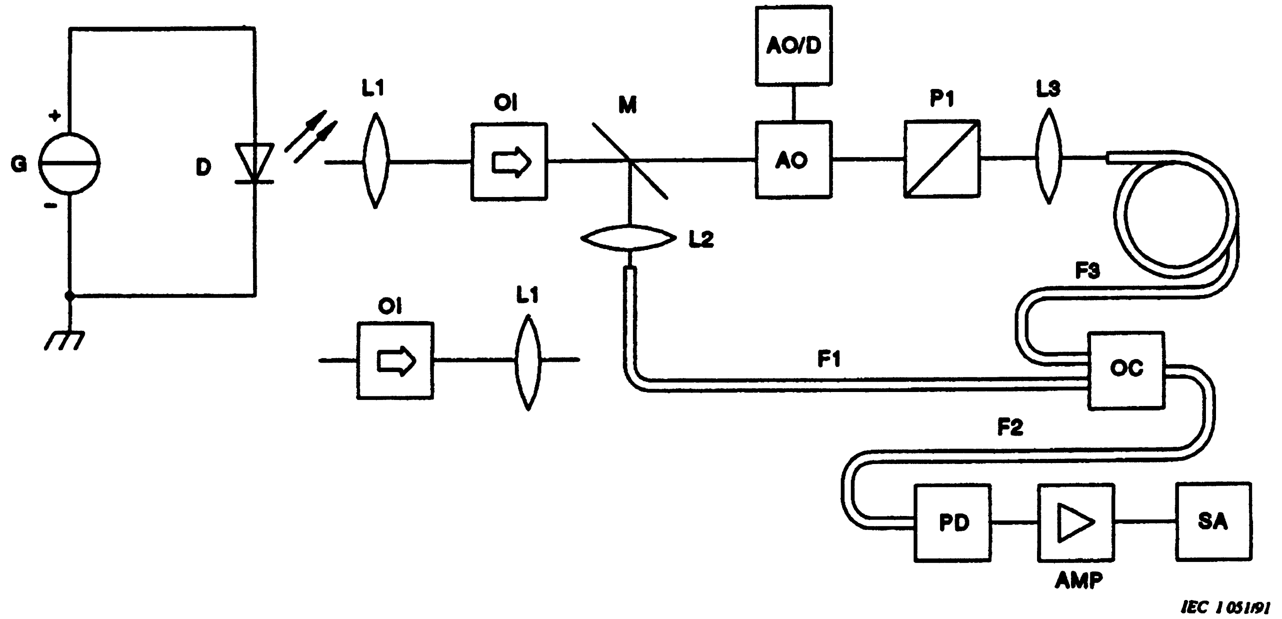


Figure 38

c) *Circuit description*

G	=	d.c. current source
D	=	device being measured
L1, L2, L3	=	lenses
OI	=	optical isolator
AO	=	acousto-optic modulator
AO/D	=	driver for acousto-optic modulator
M	=	mirror
P1	=	polarization adjustment device
F1, F2, F3	=	single mode fibre
OC	=	optical coupler
PD	=	detector
AMP	=	amplifier
SA	=	spectrum analyzer

d) *Precautions to be observed*

— Radiation power reflected back into the laser diode shall be minimized.

— Length of F3 should be sufficiently long to obtain a greater resolution than the spectral linewidth of the device being measured D.

— Modulation frequency should be higher than the spectral linewidth of the device D.

— The specified d.c. current should be sufficiently stabilized so as not broaden the measured linewidth of the device D.

NOTE The fibre length of F3 should be determined by the frequency resolution:

$$\frac{0,75\, c}{\pi L n}$$

where

c is the velocity of light.

L is the length of F3.

n is the refractive index of fibre F3.

e) *Measurement procedure*

The specified d.c. current above threshold (ΔI_F) or the forward current corresponding to the specified radiant power (ϕ_e) is applied to the device being measured D.

The optical port of the device D is aligned to get maximum radiant power into F1 and F3.

A peak corresponding to the modulation frequency of the modulator AO on the spectrum analyzer is observed and P1 is rotated to get the maximum radiant power. Full width at half maximum of the observed peak is measured. The measured value is twice the spectral linewidth of the device D.

f) *Specified conditions*

— Ambient, case or submount temperature.

— Forward current above threshold ΔI_F or radiant power ϕ_e.

1.16 Modulation current at 1 dB efficacy compression ($I_{F(1\ dB)}$) of light emitting diodes (LED) and infrared emitting diodes (IRED)

a) *Purpose*

To measure the modulation current at 1 dB efficacy compression under specified modulation frequency and radiant power output condition.

b) Circuit diagram

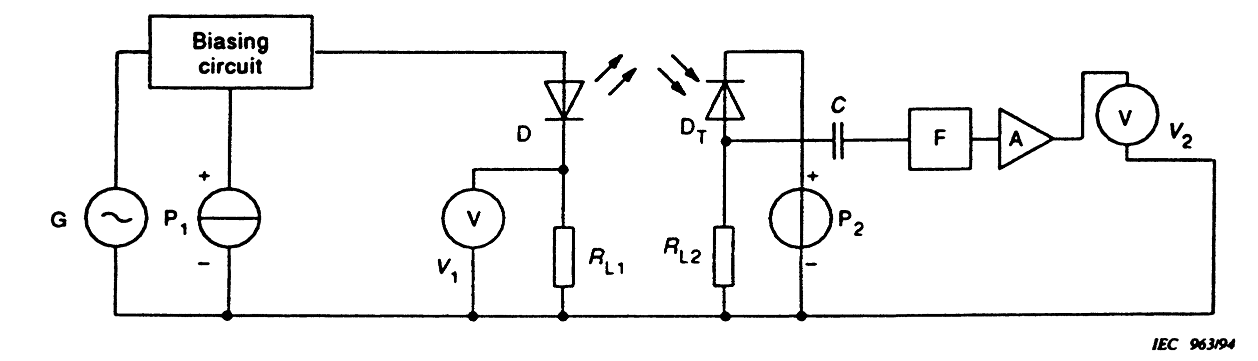


Figure 67

c) *Circuit description and requirements*

D = device being measured
G = sine wave signal source
C = coupling capacitor
P_1 = power supply to provide the specified radiant power (Φ_e to D
V, V_1, V_2 = a.c. voltmeter or broadband voltage measuring equipment
R_{L1} = load resistor for matching the specified electrical impedance of D
D_T = optical signal detector
R_{L2} = load resistor for matching the specified electrical impedance of D_T
P_2 = power supply to provide the operating voltage to D_T
F = filter with passband centre frequency matched to the frequency *f* of the sine wave signal source
A = amplifier

d) *Precautions to be observed*

The optical port of the device being measured shall, as far as possible, be coupled to that of the optical signal detector.

e) *Measurement procedure*

Couple the optical output of D from the optical port to the detector D_T. Apply the supply current generated by P_1 to the appropriate connections of D so as to achieve the specified output radiant power Φ_e from the optical port. Apply modulation current from signal generator G at the specified modulation frequency. Record the detected signal voltage V_2 and the modulation voltage V_1 as the modulation current is increased. The modulation current I_1 ($I_1 = V_1/R_{L1}$) is determined from V_1 using the value of R_{L1}. Identify the region for which there is a linear relationship between log V_2 and log I_1. Record the value of I_1 at which log V_2 is 1 dB below the value resulting from the projected linear region, as shown in Figure 68. This value of I_1 is the modulation current at 1 dB efficacy compression $I_{F(1\ dB)}$.

NOTE The functions of the filters and a.c. voltmeters are typically incorporated in r.f. spectrum analyzer instruments. Such instruments can be used in place of the individual circuit elements shown in the circuit description. With this substitution, the measured quantities are a.c. signal powers in place of signal amplitudes.

f) *Specified conditions*

— Ambient or case temperature (T_{amb} or T_{case});

— Load resistances (R_{L1} and R_{L2});

— Peak-emission wavelength and spectral radiation bandwidth of the light source (λ_p, $\Delta\lambda$);

— Radiant power (Φ_e);

— Modulation frequency (f).

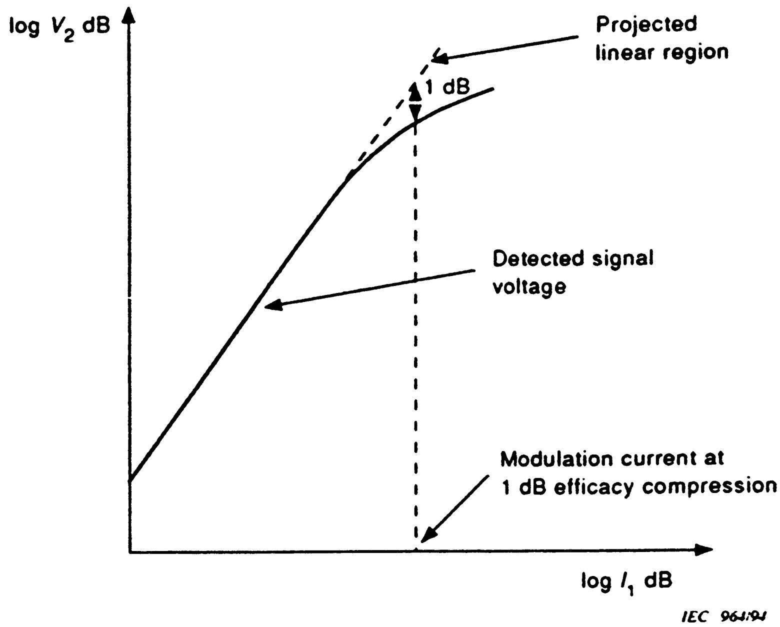


Figure 68

1.17 Two-tone intermodulation distortion (D_{12}, D_{21}) of light emitting diodes (LED) and infrared emitting diodes (IRED)

a) *Purpose*

To measure the two-tone intermodulation distortion of a LED/IRED under specified load resistance and modulation condition.

b) *Circuit diagram*

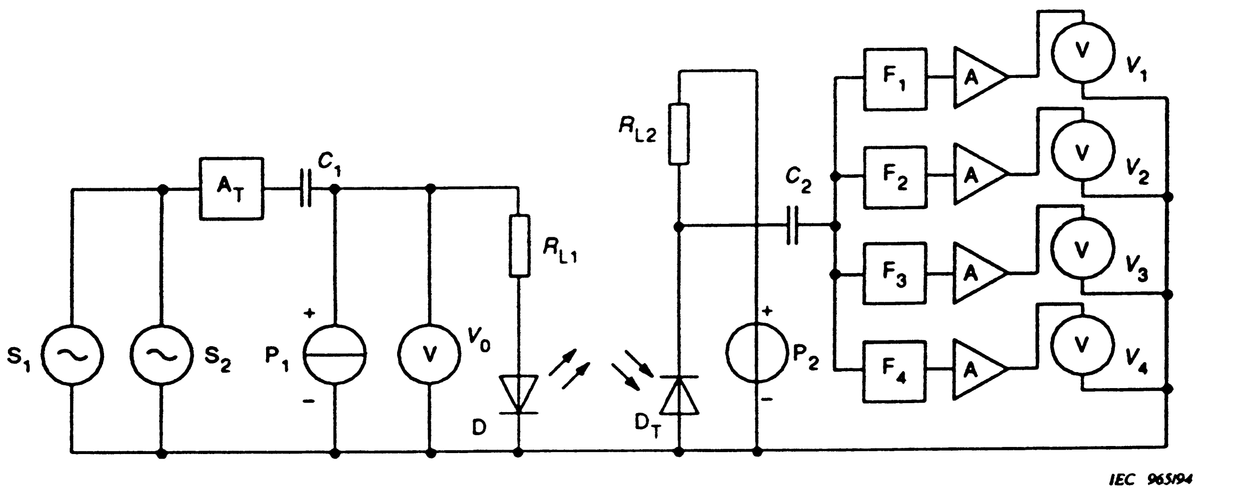


Figure 69

c) *Circuit description and requirements*

D = device being measured
S_1, S_2 = sine wave signal sources at two frequencies (f_1 and f_2)
C_1, C_2 = coupling capacitors
A_T = variable signal attenuator
P_1 = power supply to provide the specified radiant power Φ_e to D
V_0, V_1, V_2, V_3, V_4 = a.c. voltmeters or broadband voltage measuring equipment
R_{L1} = load resistor for matching the specified electrical impedance of D
D_T = optical signal detector
R_{L2} = load resistor for matching the specified electrical impedance of D_T
P_2 = power supply to D_T
F_1, F_2, F_3, F_4 = filters with passband centre frequency matched to the frequencies of the sine wave signal sources (f_1 and f_2) and the appropriate intermodulation frequencies ($2f_1 - f_2$ and $2f_2 - f_1$).
A = amplifier

d) *Precautions to be observed*

The optical port of the device being measured shall, as far as possible, be coupled to that of the optical signal detector.

NOTE The definition of two-tone intermodulation distortion of LED/IRED will be proposed in a later document.

e) *Measurement procedure*

Couple the optical output of D from the specified optical port to the detector D_T. Apply specified supply voltages generated by P to the appropriate connections of D so as to achieve the specified output radiant power from the optical port. Apply modulation current from the two sine wave signal sources S_1 and S_2 so as to create two modulation tones at fundamental frequencies f_1 and f_2. The modulated optical output at the fundamental frequencies are read on V_1 and V_2, and the modulated optical output at the intermodulation frequencies are read on V_3 and V_4. Adjust S_1 and S_2 so that V_1 and V_2 are equal. Vary the signal attenuation with A_T and record the modulation voltage V_0 and the optical signal voltages V_1, V_2, V_3, and V_4. Determine the two-tone intermodulation ratio by taking the ratio of the amplitude of the larger of the modulated optical output intermodulation sidebands (V_3 or V_4) to the amplitude of the fundamental signals (either V_1 or V_2) as a function of the amplitude of the composite input signal (V_0).

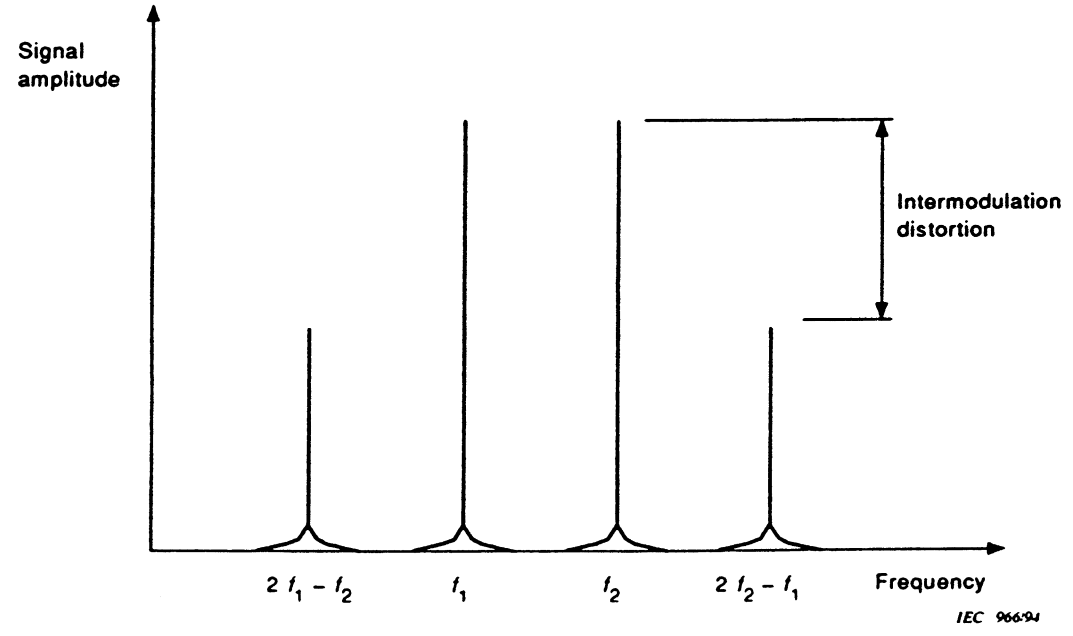


Figure 70

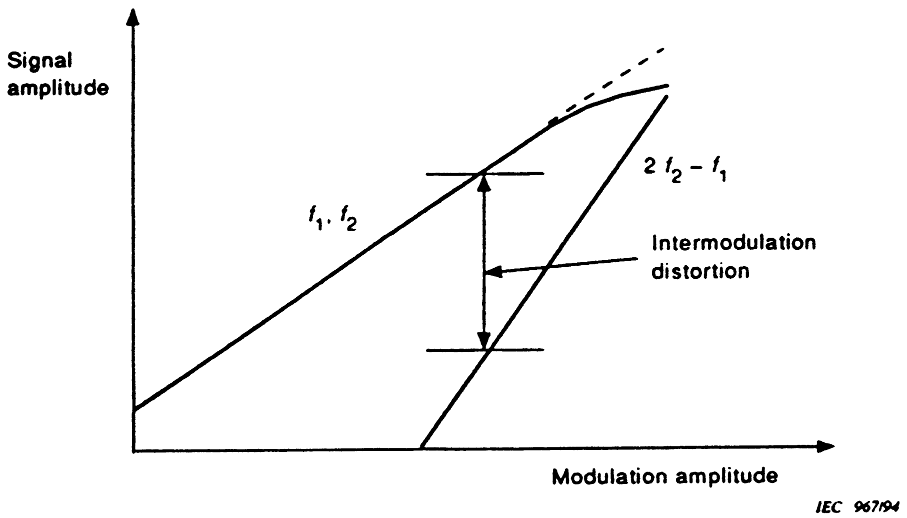


Figure 71

NOTE The functions of the filters and a.c. voltmeters are usually incorporated in r.f. spectrum analyzer instruments. Such instruments can be used in place of the individual circuit elements shown in the circuit description. With this substitution, the measured quantities are a.c. signal powers in place of signal amplitudes.

f) *Specified conditions*

— Ambient or case temperature (T_{amb} or T_{case});
— Radiant power (Φ_e);
— Peak-emission wavelength and spectral radiation bandwidth (λ_p, $\Delta\lambda$);
— Modulation frequencies (f_1, f_2);
— Load resistances (R_{L1} and R_{L2}).

1.18 Central wavelength ($\bar{\lambda}$) and r.m.s. spectrum bandwidth ($\Delta\lambda_{rms}$) of laser diode or laser diode modules

a) *Purpose*

To measure the central wavelength and r.m.s. spectrum bandwidth of a laser diode or laser diode module operated under specified modulation conditions.

b) *Circuit diagram*

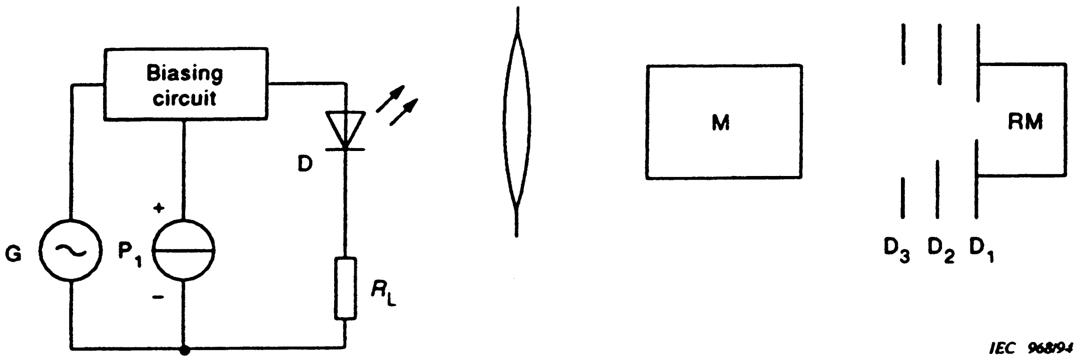


Figure 72

c) *Circuit description and requirements*

D	=	device being measured
P	=	power supply to provide the specified value of forward current above threshold ΔI_Fγ or the specified radiant power Φ_e to 2D
G	=	modulation signal generator providing the specified modulation conditions
R_L	=	load resistor for matching the electrical impedance of D
L	=	focusing lens system
M	=	monochromator
D_3, D_2	=	diaphragms, where appropriate
RM	=	radiometer (including diaphragm D_1)

NOTE M together with RM are typically incorporated in an optical spectrum analyzer. Such equipment can be used in place of M and RM.

d) *Precautions to be observed*

Radiant power reflected into the optical port of D shall be minimized to ensure that the spectral characteristics are not significantly affected.

e) *Measurement procedure*

Apply sufficient forward current to reach the specified value of ΔI_F* or apply the current corresponding to the specified radiant power Φ_e.

Adjust the wavelength of the monochromator within the required range until the maximum reading on the radiometer has been achieved.

Record the reading on the radiometer and the wavelength corresponding to this value. This is the peak emission wavelength (λ_p).

Set the monochromator to a longer wavelength than λ_p and adjust it to progressively shorter wavelengths. Record the first wavelength (λ_i) at which the power is equal to or higher than the specified percentage of the maximum peak reading.

Record the power reading (a_i) on the radiometer. Adjust the wavelength of the monochromator progressively to shorter wavelength until the maximum reading on the radiometer is obtained and record the wavelengths (λ_i) and the power readings on the radiometer (a_i) corresponding to each spectral line.

Set the monochromator to a shorter wavelength than λ_p and adjust it to progressively longer wavelengths. Record the first wavelength (λ_i) at which the power is equal to or higher than the specified percentage of the maximum peak reading. Record the power reading (a_i) on the radiometer. Adjust the wavelength of the monochromator progressively to longer wavelength until the maximum reading on the radiometer is obtained and record the wavelengths (λ_i) and the power readings on the radiometer (a_i) corresponding to each spectral line.

Calculate the central wavelength from the equation:

$$\overline{\lambda} = \frac{\sum_i a_i \cdot \lambda_i}{\sum_i a_i}$$

where λ_i and a_i are the wavelength and the reading on the radiometer of i-th spectral line. The r.m.s. spectrum bandwidth ($\Delta\lambda_{rms}$) is derived from the equation

$$\Delta\lambda_{rms} = \sqrt{\frac{\sum_i a_i \cdot (\lambda_i - \overline{\lambda})^2}{\sum_i a_i}}$$

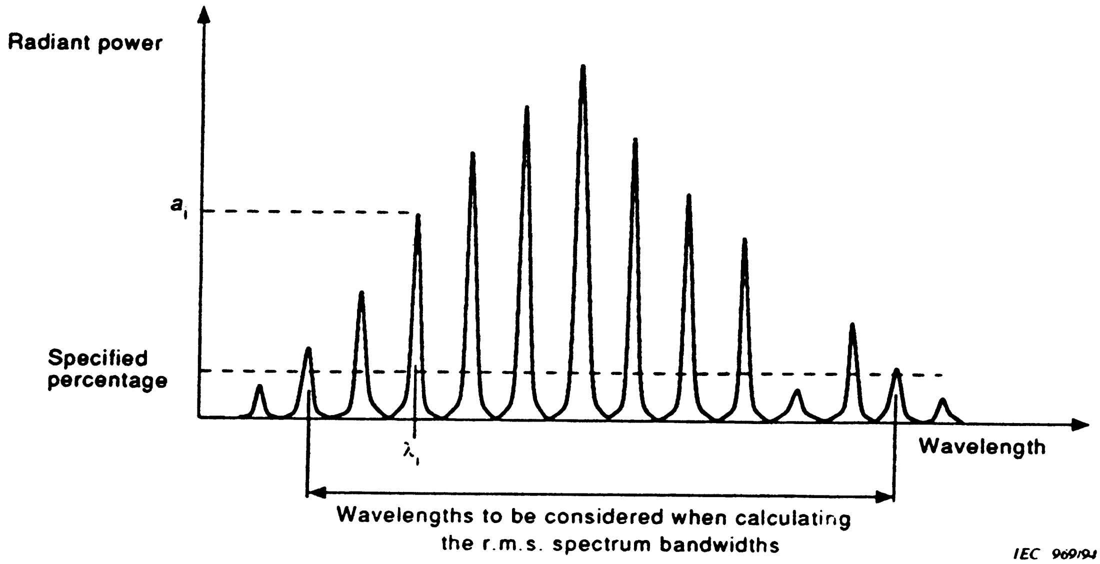


Figure 73

f) *Specified conditions*

— Ambient, case or submount temperature (T_{amb}, T_{case} or T_{sub});
— Radiant power (Φ_e) or forward current above threshold (ΔI_F*);
— Modulation frequency (*f*) and modulation factor (*m*);
— Percentage of the power at λ_p that defines the r.m.s. spectrum bandwidth, if other than 1 %.

2 Measuring methods for photosensitive devices

2.1 Reverse current under optical radiation of photodiodes including devices with or without pigtails ($I_{R(H)}$ or $I_{R(e)}$) and collector current under optical radiation of phototransistors ($I_{C(H)}$ or $I_{C(e)}$)

a) *Purpose*

To measure the reverse current under optical radiation of photodiodes including devices with or without pigtails and the collector current under optical radiation of phototransistors.

b) *Measuring equipment*

One of the four following variants shall be used:

Variant 1

Rotation of the device around its mechanical axis for an accurate location of the maximum value.

Variant 2

Alignment of the device optical axis with that of the optical bench.

Variant 3

Positioning according to a reference specified for the type of device envelope, to obtain a reproducible mechanical orientation.

Variant 4

For devices with pigtails.

Alignment of the optical port of the device to receive the radiant power with focusing means.

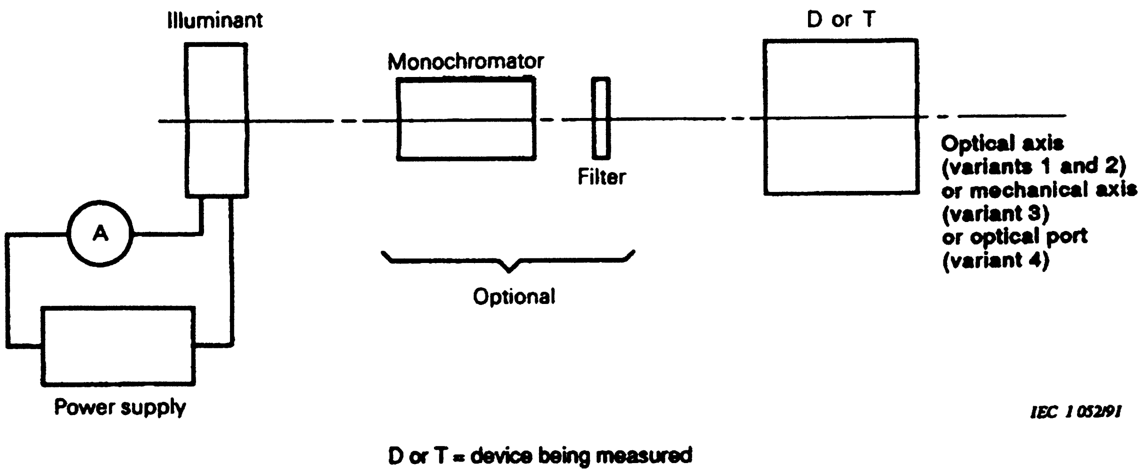


Figure 39

c) *Circuit diagrams*

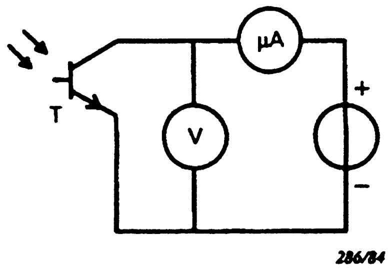


Figure 40a — Phototransistor

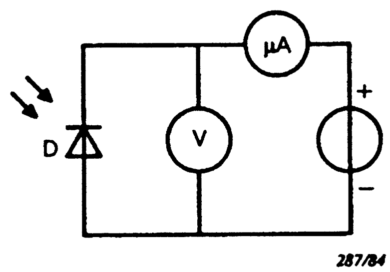


Figure 40b — Photodiode

d) *Equipment description and requirements*

The device being measured is fixed in a measuring socket that is mounted on a calibrated optical bench (variant 1, 2, 3 or 4) or on a calibrated equipment (variant 3).

The illuminant shall be

either:

i) a standard illuminant (not monochromatic), consisting of a calibrated standard lamp, with its regulated power supply and an ammeter;

or:

ii) a monochromatic illuminant consisting of either:

an equipment such as described in item i) above, plus an interference filter or any other system (monochromator, etc.) having a specified or known peak-transmission wavelength and spectral radiation bandwidth;

or:

any other calibrated device (for example a light-emitting diode or an infrared-emitting diode), having a known peak-emission wavelength and spectral radiation bandwidth.

For fibre optic devices with pigtails:

The illuminant such as described in item ii) shall be used.

e) *Precautions to be observed*

— Overheating the device being measured by optical radiation from the source shall be avoided. For levels in excess of 200 W/m^2, a thermal shield arranged as a shutter to limit the duration of exposure is recommended.

— Cleanliness of optical surfaces shall be ensured.

— Light sources shall be stabilized before being used for measurement purposes.

— When a standard illuminant is used as a light source, a diaphragm intended to suppress parasitic radiation shall be placed in front of the device being measured.

For devices with pigtails:

Only the optical port of the device shall be irradiated.

f) *Measurement procedure*

The temperature conditions are set to the specified value.

The socket is placed at a distance from the illuminant corresponding to the specified illuminance (irradiance).

The device to be measured is inserted into its socket and is biased at the specified value.

For variant 1 only, the device is rotated around its mechanical axis. Read the minimum and the maximum values of the current under irradiation on the ammeter.

For variant 2, 3 or 4, the value of the current under optical radiation is read on the ammeter.

g) *Specified conditions*

— Ambient or case temperature.

— Bias of the device being measured (d.c. or pulse).

— Measuring method (variant).

— Illuminance or irradiance.

— Standard illuminant (not monochromatic) or wavelength and spectral radiation bandwidth (monochromatic).

For devices with pigtails:

— ambient or case temperature;

— bias of the device being measured;

— radiant power into the optical port;

— wavelength and spectral radiation bandwidth of the light source.

2.2 Dark current for photodiodes I_R and dark currents for phototransistors I_{CEO}, I_{ECO}, I_{EBO}

a) *Purpose*

To measure the dark current of photodiodes and the dark currents of phototransistors, under specified conditions.

b) *Circuit diagrams*

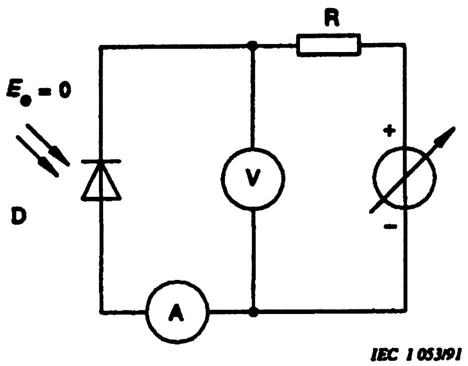


Figure 41a — Dark current of a photodiode I_R

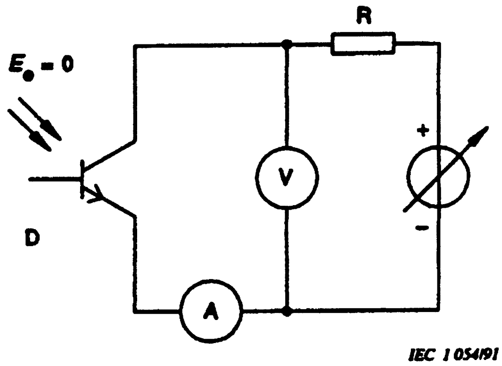


Figure 41b — Collector-emitter dark current of a phototransistor I_{CEO}

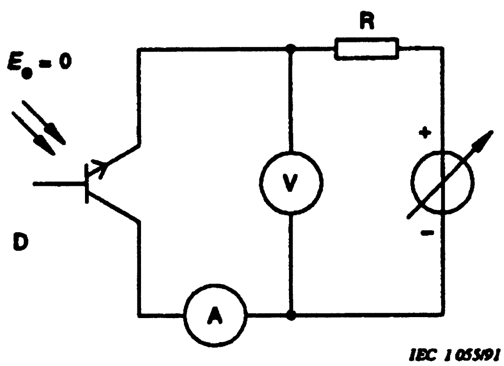


Figure 41c — Emitter-collector dark current of a phototransistor I_{ECO}

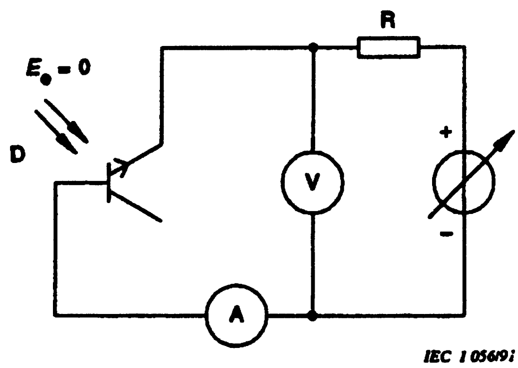


Figure 41d — Emitter-base dark current of a phototransistor I_{EBO}

Figure 41

c) *Circuit description and requirements*

R = current limiting resistor
D = device being measured

d) *Precautions to be observed*

These parameters are very temperature-dependent and the accuracy of the measurement largely depends on that with which the ambient temperature can be maintained. Complete darkness is a necessary condition. Even ordinary daylight illumination of the wire feed-through glass seals would falsify the measurement result.

The device should not be subjected to radiation within the spectral sensitivity range.

e) *Measurement procedure*

The temperature is set to the specified value. The device being in complete darkness, the voltage is progressively increased from zero until the specified value is reached and then the dark current is measured.

The test is stopped when the current reaches a specified limit.

f) *Specified conditions*

— Ambient temperature.

— Voltage to be applied:

V_R for I_R;

V_{CE} for I_{CEO};

V_{EC} for I_{ECO};

V_{EB} for I_{EBO}.

2.3 Collector-emitter saturation voltage $V_{CE(sat)}$ of phototransistors

a) *Purpose*

To measure the collector-emitter saturation voltage of phototransistors under specified conditions.

b) *Circuit diagram*

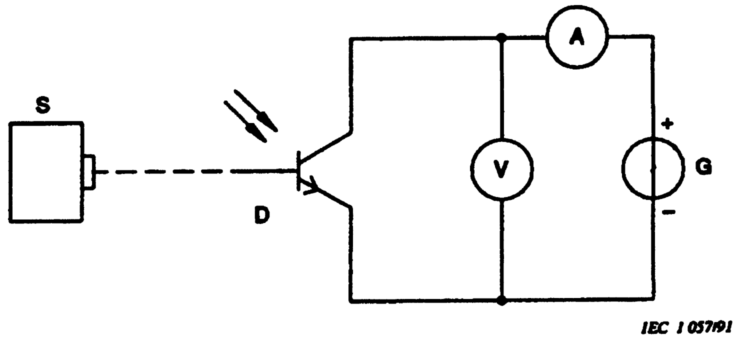


Figure 42

c) *Circuit description and requirements*

S	=	optical radiation source
G	=	collector current generator
D	=	device being measured

d) *Precautions to be observed*

— Avoid overheating the device being measured by irradiation from the source. For levels in excess of 200 W/m^2, a thermal shield arranged as a shutter to limit the duration of exposure is recommended.

— Ensure cleanliness of optical surfaces.

— Optical radiation sources shall be stabilized before being used for measurement purposes.

e) *Measurement procedure*

The temperature is set to the specified value.

The optical radiation source being stabilized to the specified value of E_e or E_v, the collector current is adjusted to the specified value and the collector-emitter saturation voltage is measured.

f) *Specified conditions*

— Ambient temperature.

— Collector current.

— Illuminance or irradiance.

— Reference to standard illuminant (not monochromatic) or wavelength and spectral bandwidth (monochromatic).

— Open base.

2.4 Noise of a PIN photodiode

a) *Purpose*

To measure the noise current, the noise power, the detectivity or the noise equivalent power (NEP) of a PIN photodiode under specified conditions.

b) *Circuit diagram*

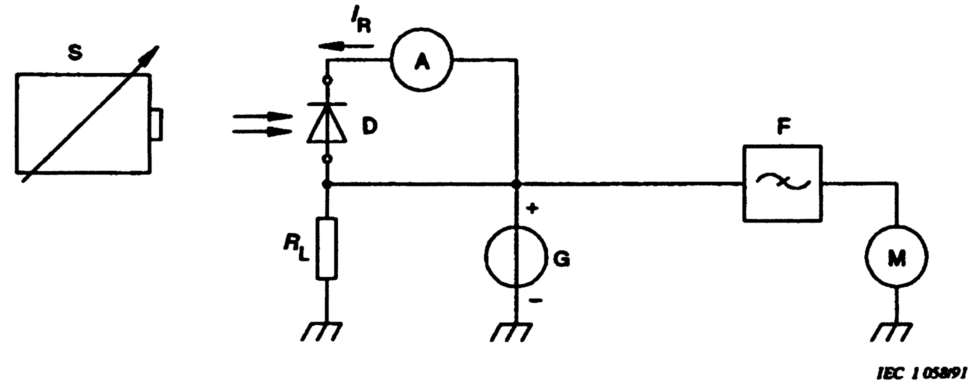


Figure 43

c) *Circuit description and requirements*

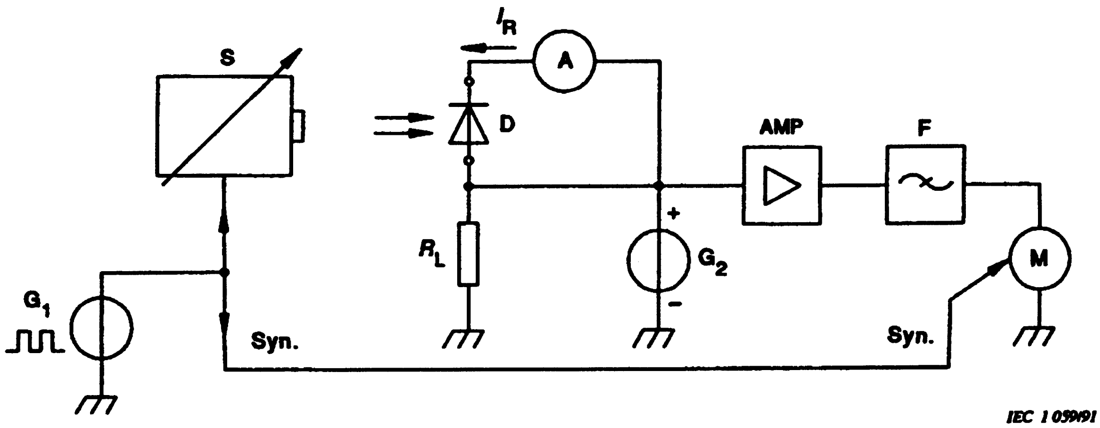
S	=	radiation or light source
D	=	device being measured
I_R	=	reverse current under optical radiation
R_L	=	load resistance (50 Ω preferably)
A	=	ammeter
G	=	reverse-voltage supply
F	=	filter with specified maximum transmission frequency (centre frequency) f_o and specified equivalent noise bandwidth Δf_N
M	=	true r.m.s. reading instrument, calibrated in noise current, noise power, detectivity or equivalent noise power

d) *Precautions to be observed*

1) The bandwidth should be defined by the filter F, taking into account the other parameters, such as the capacitance of D and the input capacitance of the measuring equipment.

2) The noise of the measuring equipment, including the radiation or light source, should be small compared with the noise to be measured or should be taken into account in the measurement result.

3) When the noise level is too low to be measured directly, amplification and synchronous detection techniques may be used as described below:



G_1 = modulation generator, square wave (δ = 0,5), frequency f_1
S = radiation or light source
D = device being measured
R_L = load resistor
A = ammeter
G_2 = reverse voltage supply
AMP = a.c. amplifier
F = filtre (centre frequency f_o, equivalent noise bandwidth Δf_N)
M = true r.m.s. reading instrument
Syn. = synchronization signal

NOTE 1 f_1 is low compared with f_o (centre frequency of the filter F)

NOTE 2 The filtre F rejects the frequency f_1

Figure 44

e) *Measurement procedure*

The measuring equipment being calibrated, the specified reverse voltage V is applied to the device being measured D. The radiant or luminous flux of the source is increased from zero until the specified value of I_R is reached. The noise of the device D is measured on the reading instrument M.

f) *Specified conditions*

— Ambient temperature.

— Characteristics of the radiation of light source: either peak-emission wavelength λ_p and spectral bandwidth $\Delta\lambda$, or spectral distribution (for example illuminant A).

— Reverse voltage source (V).

— Reverse current under optical radiation (I_R).

— Load resistance (R_L) if other than 50 Ω.

— Filter maximum transmission frequency (centre frequency) (f_o) and equivalent noise bandwidth (Δf_N).

2.5 Excess noise factor of an avalanche photodiode with or without pigtails

a) *Purpose*

To measure the excess noise factor F_e of an avalanche photodiode with or without pigtails.

b) *Circuit diagram*

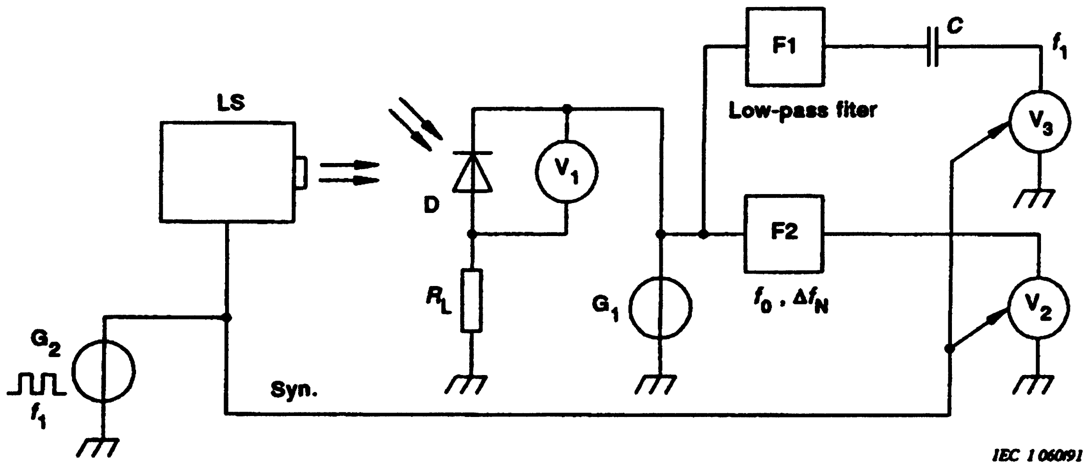


Figure 45

c) *Circuit description and requirements*

LS	=	radiation or light source
D	=	device being measured
R_L	=	load resistance
G_1	=	d.c. voltage source
G_2	=	optical modulation generator with frequency f_1
V_1	=	d.c. voltmeter
V_2	=	true r.m.s. voltage meter with synchronous amplifier at frequency f_1
V_3	=	a.c. voltage meter with synchronous amplifier at frequency f_1
F_1	=	low-pass filter
F_2	=	band-pass filter with specified central frequency f_o and bandwidth Δf_N
C	=	d.c. blocking capacitor
Syn.	=	synchronization signal

NOTE 1 Modulation frequency f_1 should be low compared to f_o and sufficiently low to prevent measuring error due to frequency response of the device being measured D.

NOTE 2 Filter F_2 should reject modulation frequency f_1.

NOTE 3 Filter F_1 should pass modulation frequency f_1 but reject frequencies larger than $f_o - \Delta f_n/2$.

NOTE 4 Capacitor value C should be large enough to pass frequency f_1.

NOTE 5 Only the optical port of the device being measured D should be irradiated and that irradiation should completely fill the port.

d) *Procedure*

1) Apply a low-bias voltage V_{R1} measured by V_1.

V_{R1} should be sufficiently low that negligible carrier multiplication takes place (i.e. multiplication factor M ≈ 1) but sufficiently large that the device is fully depleted and has achieved its rated speed and responsivity. Adjust the input optical power to achieve the specified photocurrent $I_{po(3)}$ as measured by voltage V_{30} on V_3 from the signal modulated at frequency f_1 using the relationship:

$$I_{po} = \frac{1}{k} \times \frac{V_{30}}{R_L}$$

where k is equal to the duty factor of modulation generator G_2 (e.g. for a 50 % duty factor square wave, k = 1/2).

2) Increase bias voltage V_R until the voltage V_{31} read on V_3 reaches the value $M \times V_{30}$:

$$M = \frac{V_{31}}{V_{30}}$$

3) Read the voltage V_{21} on V_2 and calculate the excess noise factor F_e from the relationship:

$$F_e = \frac{V_{21}^{\,2}}{2\,q \times I_{po} \times M^2 \times R_L^{\,2} \times \Delta f_N}$$

where q is the electronic charge.

e) *Precautions to be observed*

This method is not accurate for a device in which unity gain (M ≈ 1) cannot be achieved when the device is fully depleted and has achieved its rated speed and responsivity.

f) *Specified conditions*

— Ambient or case temperature.
— Multiplication factor (M).
— Photocurrent (I_{po}).
— f_o, Δf_N of the filter F_2.
— Peak emission wavelength and spectral radiation bandwidth (λ_p, $\Delta\lambda$).
— V_{R1}.

2.6 Small-signal cut-off frequency of a photodiode with or without pigtails

a) *Purpose*

To measure the small-signal cut-off frequency of a photodiode, with or without pigtails, under specified conditions.

b) *Circuit diagram*

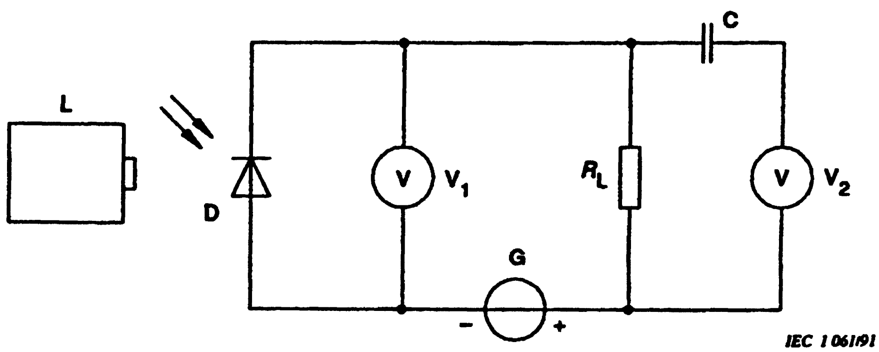


Figure 46

c) *Circuit description and requirements*

D	=	device being measured
L	=	narrowband light source emitting light which is amplitude modulated with a small-signal sinusoidal wave of adjustable frequency
G	=	d.c. voltage source
V_1	=	d.c. voltmeter
V_2	=	broadband voltage measurement instrument
R_L	=	load resistance, low in value compared with the source resistance of the device being measured
C	=	coupling capacitor

d) *Precaution to be observed*

Only the optical port of the device shall be completely irradiated.

e) *Measurement procedure*

The specified direct reverse voltage is applied to the device being measured. The radiation source is adjusted to obtain the average value ϕ_e specified from the optical port. This source is modulated at a low frequency (less than $f_c/100$) and the a.c. output signal is measured on V_2.

The modulation frequency of the radiation source is increased keeping the average value of ϕ_e and the modulation level constant until the output signal measured on V_2 has decreased by $\sqrt{2}$. This frequency is the small-signal cut-off frequency f_c.

f) *Specified conditions*

— Ambient or case temperature.
— Reverse voltage (V_R).
— Load resistance (R_L).
— Peak-emission wavelength and spectral radiation bandwidth of the light source (λ_p, $\Delta\lambda$).
— Radiant power (ϕ_e).

2.7 Multiplication factor of an avalanche photodiode (APD) with or without pigtails

a) *Purpose*

To measure the multiplication factor *M* of an avalanche photodiode (APD) with or without pigtails.

b) *Circuit diagram*

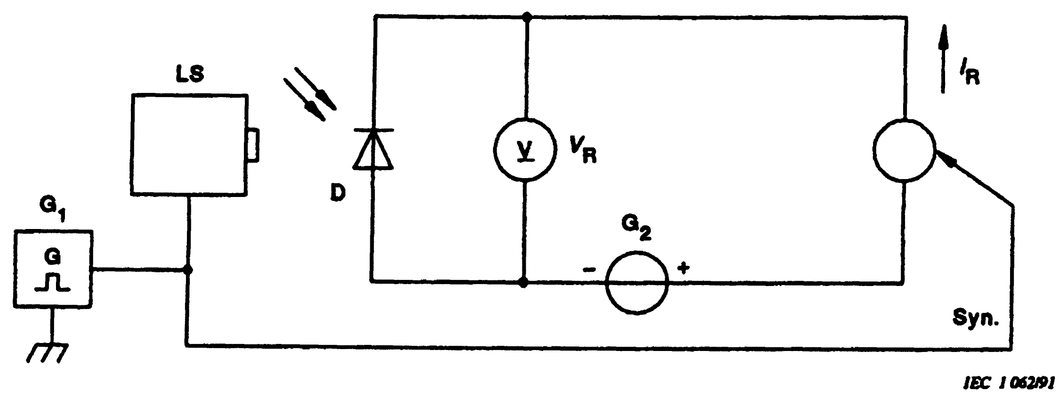


Figure 47

c) *Circuit description and requirements*

LS	=	radiation or light source
D	=	device being measured
G_1	=	modulation generator
G_2	=	d.c. voltage source
SA	=	synchronous ammeter
Syn.	=	synchronization signal

d) *Precautions to be observed*

Only the optical port of the device being measured shall be considered.

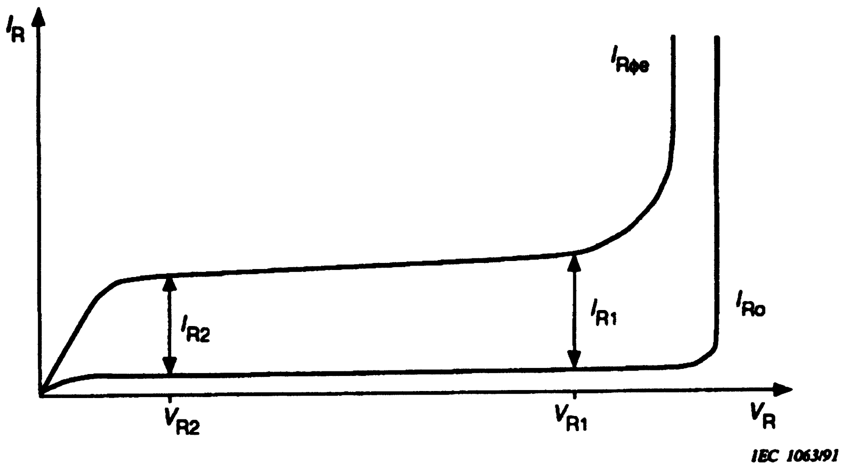
e) *Measurement procedure*

Apply the specified low bias voltage V_{R2} from the generator G_2 to the device being measured. Adjust the radiant power ϕ_e to the specified value. Measure the current I_{R2} on the synchronous ammeter.

Change the d.c. bias voltage applied to the device being measured to the specified value V_{R1}. Measure the current I_{R1} on the synchronous ammeter.

Calculate the multiplication factor M from the equation:

$$M = \frac{I_{R1}}{I_{R2}}$$



I_{Ro} = dark current

$I_{R\phi e}$ = current under optical radiation

Figure 48

f) *Specified conditions*

— Ambient or case temperature.
— Reverse voltages (V_{R1}, V_{R2}).
— Radiant power (ϕ_e).
— Peak emission wavelength (λ_p).
— Spectral radiation bandwidth ($\Delta\lambda$).
— Optical port.
— Optical configuration.

2.8 Switching times of a PIN photodiode or an avalanche photodiode (APD) with or without pigtails

a) *Purpose*

To measure the turn-on time t_{on} (turn-on delay time $t_{d(on)}$ + rise time t_r) and turn-off time t_{off} (turn-off delay time $t_{d(off)}$ + fall time t_f) of a *PIN* photodiode or an avalanche photodiode (APD) with or without pigtails.

b) *Circuit diagram*

The switching parameters of a *PIN* photodiode or an avalanche photodiode (APD) are measured using the circuit of Figure 49.

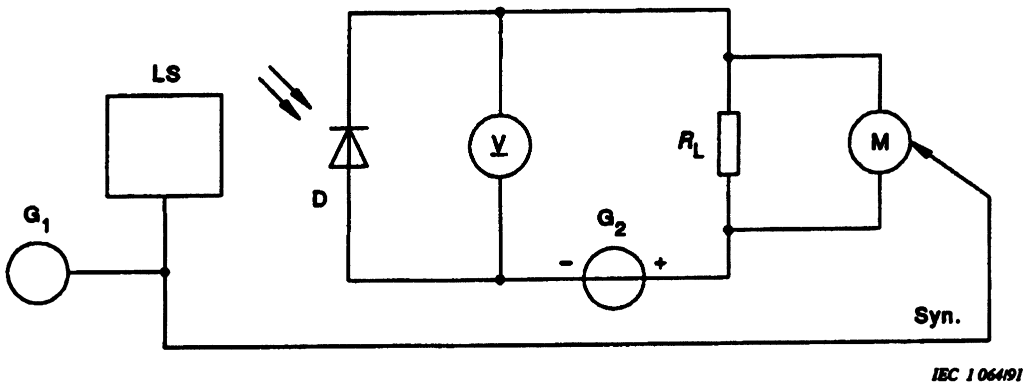


Figure 49

c) *Circuit description and requirements*

G_1	=	modulation generator
G_2	=	direct voltage source
LS	=	radiation source
D	=	device being measured
R_L	=	load resistance
M	=	measuring instrument
Syn.	=	synchronization signal

d) *Precautions to be observed*

The rise and fall times of the input radiant power pulse shall be short enough not to affect the accuracy of the measurement.

Only the optical port of the device being measured shall be considered.

Only the optical radiation falling onto the optical port of the device being measured shall be measured.

e) *Measurement procedure*

The specified voltage from the voltage source G_2 is applied to the device being measured and the radiant power pulses are set to the specified values of peak radiant power (ϕ_{e1}) and offset radiant power (ϕ_{e2}).

The switching times are measured with the measuring instrument M.

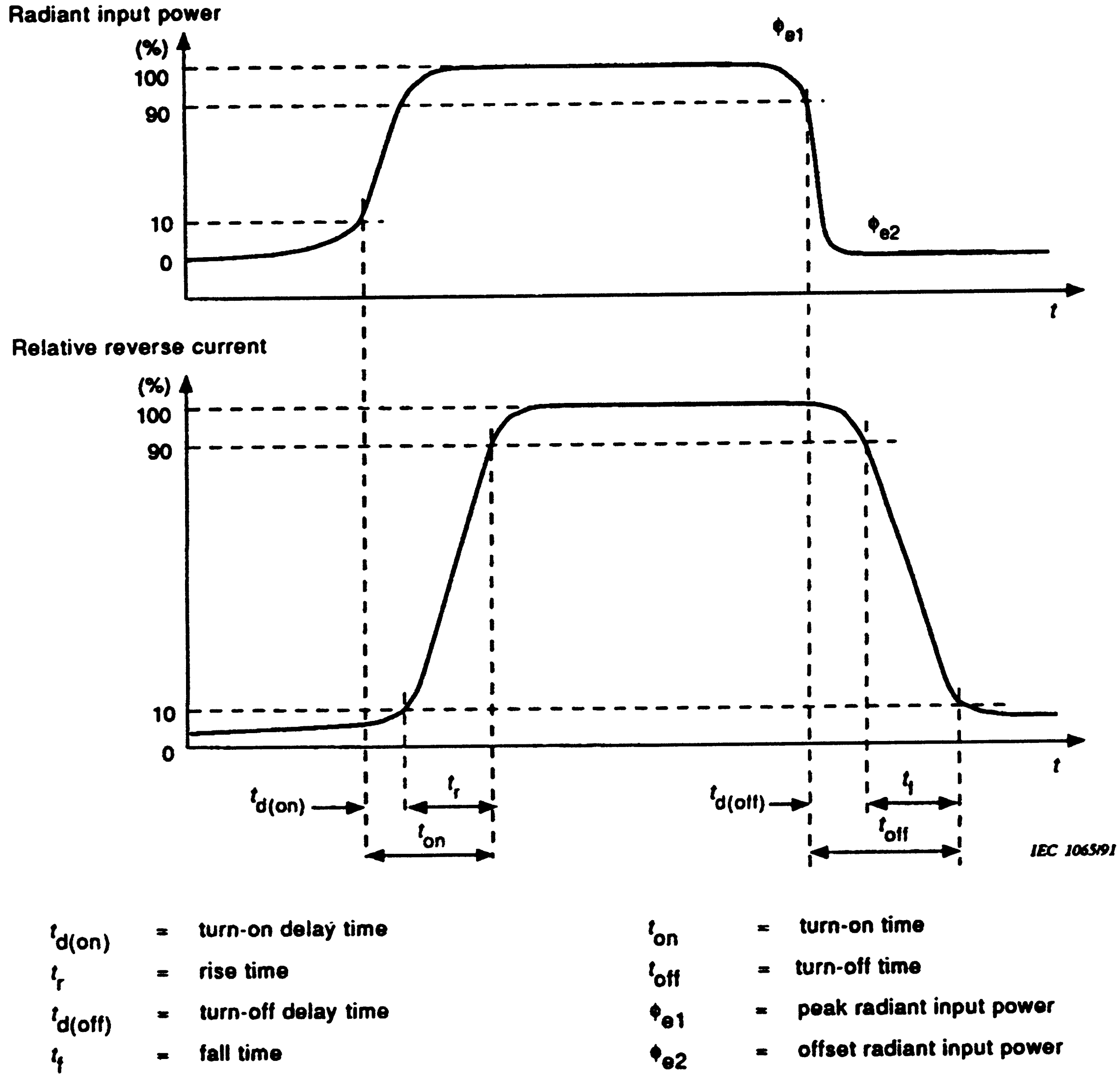


Figure 50

f) *Specified conditions*

— Ambient or case temperature.

— Reverse voltage (V_R).

— Peak radiant power (ϕ_{e1}).

— Offset radiant power (ϕ_{e2}).

— Load resistance (if other than 50 Ω) (R_L).

— Peak-emission wavelength (λ_p).

— Spectral radiation bandwidth ($\Delta\lambda$).

— Optical port.

— Optical configuration.

2.9 Responsivity of a PIN-FET module

a) *Purpose*

To measure the responsivity of a PIN-FET module under specified modulated radiation input condition.

b) *Circuit diagram*

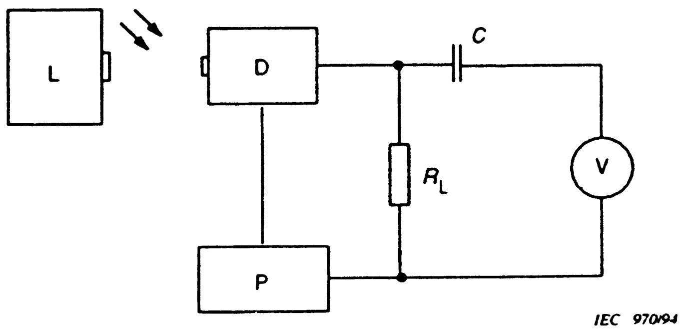


Figure 74

c) *Circuit description and requirements*

D = device being measured
L = narrowband radiation source with adjustable radiant power Φ_e and which is amplitude modulated with a small-signal sinusoidal wave of adjustable frequency and r.m.s. value $\Delta\Phi_{e(rms)}$
P = power supply to provide specified operating voltages and currents to D
R_L = load resistor for matching the specified output impedance of D
C = coupling capacitor
V = r.m.s. voltmeter or broadband voltage measuring instrument

d) *Precautions to be observed*

The optical port of the device being measured shall be completely irradiated.

The value of $\Delta\Phi_{e(rms)}$ shall be sufficiently smaller than the d.c. radiant power Φ_e, and stay constant over the specified band of modulation frequencies f_1 to f_2.

A signal shall be considered small if a two-to-one increase in its magnitude does not produce a change in the measured value of the parameter that is greater than the permitted error of the measurement.

e) *Measurement procedure*

Apply specified supply voltages generated by P to the appropriate connections of D. Adjust L to provide the specified d.c. value of input radiant power Φ_e and the specified modulation frequency. Measure the r.m.s. a.c. output voltage $V_{o(rms)}$ on V. Determine the responsivity S using the following relationship:

$$S = V_{o(rms)}/\Delta\Phi_{e(rms)}$$

Note the maximum (S_{max}) and minimum (S_{min}) values of S measured in the frequency range f_1 to f_2, as well as the mid-band central value S_{mb} defined by:

$$F_{mb} = \sqrt{f_1 \times f_2}$$

or corresponding to a specified value.

NOTE The functions of the load resistor, coupling capacitor and a.c. voltmeter are typically incorporated in r.f. spectrum/network analyzers. Such instruments can be used in place of the individual circuit elements shown in the the circuit description.

f) *Specified conditions*

— Ambient or case temperature (T_{amb} or T_{case});
— Specified supply voltages generated by P;
— Load resistance (R_L);
— Peak-emission wavelength and spectral radiation bandwidth of the light source (λ_p, $\Delta\lambda$);
— d.c. radiant power (Φ_e);
— Modulation frequency (f).

2.10 Frequency response flatness ($\Delta S/S$) of a PIN-FET module

a) *Purpose*

To measure the frequency response flatness of a PIN-FET module over a specified band of modulation frequencies.

b) *Circuit diagram*

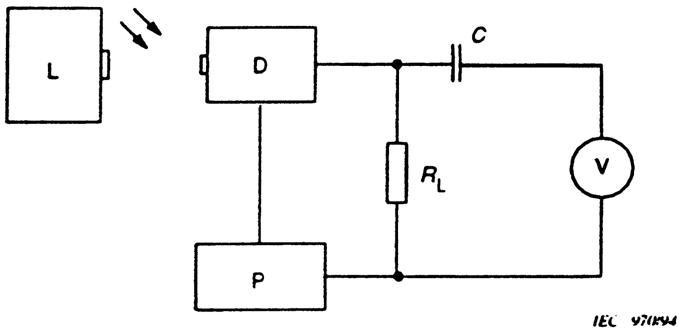


Figure 75

c) *Circuit description and requirements*

D = device being measured
L = narrowband radiation source with adjustable radiant power Φ_e and which is amplitude modulated with a small-signal sinusoidal wave or adjustable frequency and r.m.s. value $\Delta\Phi_{e(rms)}$
P = power supply to provide specified operating voltages and currents to D
R_L = load resistor for matching the specified output impedance of D
C = coupling capacitor
V = a.c. voltmeter or broadband voltage measuring instrument

d) *Precautions to be observed*

The optical port of the device being measured shall be completely irradiated.

The value $\Delta\Phi_{e(rms)}$ shall be sufficiently smaller than the d.c. radiant power Φ_e and substantially constant over the specified band of modulation frequencies f_1 to f_2.

A signal shall be considered small if a two-to-one increase in its magnitude does not produce a change in the measured value of the parameter that is greater than the permitted error of the measurement.

e) *Measurement procedure*

Apply specified supply voltages generated by P to the appropriate connections of D. Adjust L to provide the specified d.c. value of input radiant power Φ_e. Vary the modulation frequency over the specified band of frequencies f_1 to f_2. Measure the a.c. output voltage $V_{o(rms)}$ on V as a function of frequency. Determine the responsivity S using the following relationship:

$$S = V_{o(rms)}/\Phi_{e(rms)}$$

Determine the maximum (S_{max}) and minimum (S_{min}) values of S over the specified band of modulation frequencies, and its value [$S(f_{mb})$] at the mid-band frequency f_{mb}. The frequency response flatness, expressed in decibels, is calculated as:

$$\Delta S/S = 10 \log [(S_{max} - S_{min})/S_{mb})] \text{ [dB]}$$

where f_{mb} is the mid-band frequency defined by $f_{mb} = \sqrt{f_1 \times f_2}$, unless otherwise specified, and $S(f_{mb})$ is the responsivity value at the frequency f_{mb}.

NOTE The functions of the load resistor, coupling capacitor and a.c. voltmeter are typically incorporated in r.f. spectrum/network analyzer instruments. Such instruments can be used in place of the individual circuit elements shown in the circuit description.

f) *Specified conditions*

— Ambient or case temperature (T_{amb} or T_{case});
— Specified bias voltages generated by P;
— Load resistance (R_L);
— Peak-emission wavelength and spectral radiation bandwidth of the light source (λ_p, $\Delta\lambda$);
— D.C. radiant power (Φ_e);
— Modulation frequency range of radiant power (f_1, f_2);
— Mid-band frequency (f_{mb}), if other than $\sqrt{f_1 \times f_2}$.

2.11 Output noise power (spectral) density $P_{no,\lambda}$ of a PIN-FET module

a) *Purpose*

To measure the output noise power spectral density of a PIN-FET module under matched-output conditions.

b) *Circuit diagram*

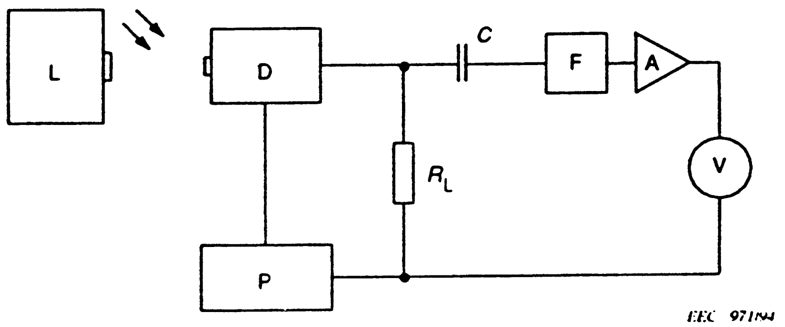


Figure 76

c) *Circuit description and requirements*

D = device being measured
L = narrowband radiation source with adjustable radiant power Φ_e
P = power supply to provide specified operating voltages and currents to D
R_L = load resistor for matching the specified electrical impedance of D
F = high-Q bandpass filter
A = amplifier with voltage gain G_v
V = true r.m.s. noise voltage measuring instrument to measure the output noise voltage V_m at frequency f_m
C = coupling capacitor

d) *Precautions to be observed*

The optical port of the device being measured shall be completely irradiated with the specified input radiant power Φ_e.

The bandwidth of the amplifier shall be sufficiently large to ensure that the overall noise bandwidth is determined by filter F.

The measuring circuit shall be electrically grounded and shielded so as to prevent spurious signals from interfering with the measurement of low level noise signals.

e) *Measurement procedure*

Apply specified supply voltages and currents provided by P to the appropriate connections of D.

Adjust L to provide at the optical port of D the specified input radiant power Φ_e.

Adjust the centre frequency of F to the specified frequency f_m for the measurement of the output noise power (spectral) density.

Read the value V_m of the output r.m.s. noise voltage at voltmeter V.

Calculate the output noise power (spectral) density as

$$P_{no,\lambda} = (V_m/G_v)^2/R_L \cdot B)$$

NOTE The functions of the load resistor, filter, amplifier and r.m.s. noise voltmeter are typically incorporated in r.f. spectrum analyzer instruments. Such instruments can be used in place of the individual circuit elements shown in the circuit diagram.

f) *Specified conditions*

— Ambient or case temperature (T_{amb} or T_{case});
— Specified supply voltages and currents provided by P;
— Load resistance (R_L);
— Peak-emission wavelength and spectral radiation bandwidth of the light source (λ_p, $\Delta\lambda$);
— Input radiant power (Φ_e);
— Centre frequency (f_m) and effective bandwidth (B) of F.

2.12 Low frequency output noise power (spectral) density ($P_{no,\lambda,LF}$) and corner frequency (f_{cor}) of a PIN-FET module

a) *Purpose*

To measure the output noise power (spectral) density of a non-irradiated PIN-FET module in the low frequency region, where it is dominated by the so-called 1/*f* noise, and corner frequency, under matched-output condition.

b) *Circuit diagram*

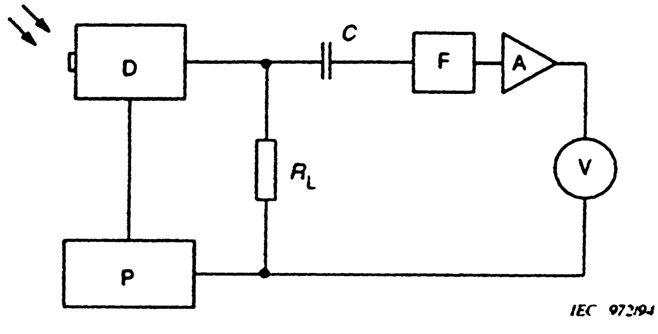


Figure 77

c) *Circuit description and requirements*

D = device being measured (non-irradiated)
P = power supply to provide specified supply voltages and currents to D
R_L = load resistor for matching the specified output impedance of D
F = high-Q bandpass filter with adjustable centre frequency f_m and effective bandwidth B
A = amplifier with voltage gain G_v
V = true r.m.s. voltage measuring instrument to measure the output noise voltage V_m at frequency f_m

d) *Precautions to be observed*

The optical port of D shall not be irradiated.

The bandwidth of the amplifier shall be sufficiently large to ensure that the overall noise bandwidth is determined by F.

The measuring circuit shall be electrically grounded and shielded so as to prevent spurious signals from interfering with the measurement of low level noise signals.

The effective (noise) bandwidth B of F shall be 15 % or less of its centre frequency.

e) *Measurement procedure*

Apply specified supply voltages and currents provided by P to the appropriate connections of D.

Increase the centre frequency of filter F from a very low value at which the noise voltage V_m is still decreasing with increasing frequency up to a value where V_m becomes nearly constant, see Figure 78 which shows V_m in decibels as a function of f. Note the value V_m* at this frequency.

Decrease the frequency until V_m has increased by 3 dB (by a factor $\cong \sqrt{2}$) compared to V_B*. This frequency is the corner frequency F_{cor}.

Decrease the frequency further and measure $V_m(f_m)$ at the specified frequency f_m which refers to a point in nearly linear region of the curve in Figure 78.

Calculate the low frequency output noise power (spectral) density as

$$P_{no,\lambda,LF} = (V_m/G_v)^2/(R_L \cdot B)$$

NOTE The functions of the load resistor, filter, amplifier and r.m.s. noise voltage measuring instrument are typically incorporated in r.f. spectrum analyzer instruments. Such instruments can be used in place of the individual circuit elements shown in the circuit diagram. In that case, particular care should be paid to calibration of spectrum analyzers and to good impedance matching to D.

f) *Specified conditions*

— Ambient or case temperature (T_{amb} or T_{case});
— Supply voltages and currents provided by P;
— Load resistance (R_L);
— Measuring frequency (f_m) for $P_{no,\lambda,LF}$;
— Effective bandwidth (B) of F.

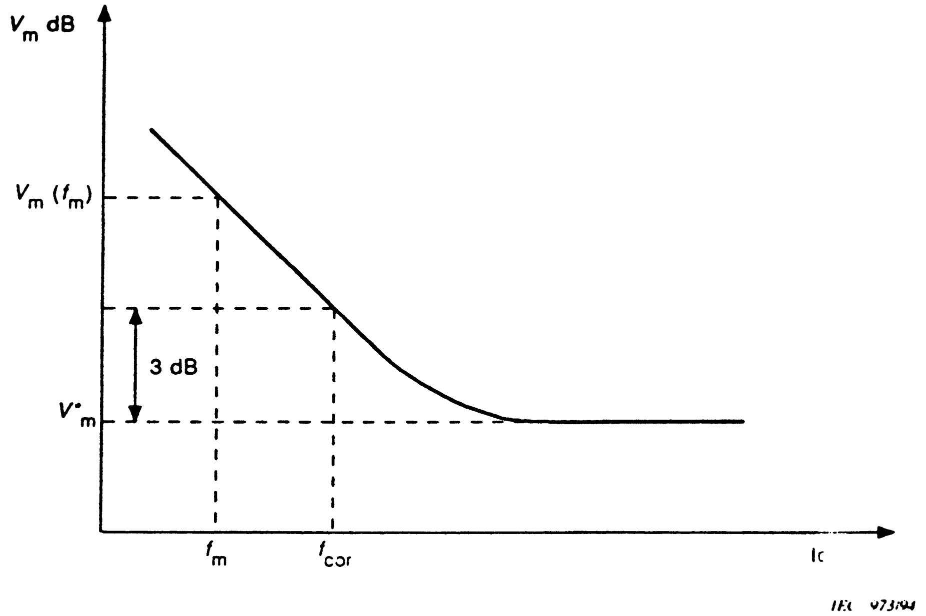


Figure 78

2.13 Minimum detectable power of PIN-FET module

a) *Purpose*

To measure the minimum detectable power of a PIN-FET module at a specified bit-error rate (BER) or carrier-to-noise ratio (*C/N*).

b) *Circuit diagram*

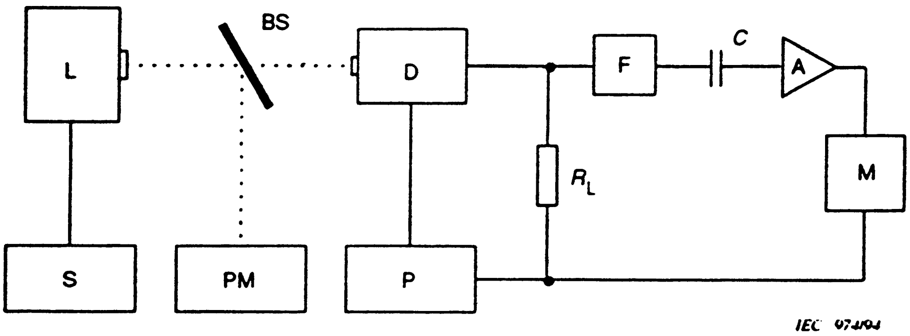


Figure 79

c) *Circuit description and requirements*

L = radiation source with adjustable d.c. and modulated radiant power (Φ_e, $\Delta\Phi_e$)
S = sinusoidal signal source (for analogue measurement) or signal source to generate appropriate digital signal under specified conditions (for digital measurement)
BS = beam splitter
PM = optical signal measuring instrument
D = device being measured
P = power supply to provide specified operating voltages and currents to D
R_L = load resistance
EQ = equalizer, if required
C = coupling capacitor
A = amplifier with centre frequency f_{mb} and bandwidth B (for analogue measurement) or amplifier with variable gain (for digital measurement)
M = r.m.s. voltage meter (for analogue measurement) or bit-error rate counter (for digital measurement)

d) *Precautions to be observed*

Optical power on PM shall be calibrated so that the a.c. irradiated power on the optical port of D can be measured.

The C/N of L shall be high enough to avoid the increase in the detected noise.

Only the optical port of D shall be irradiated.

e) *Measurement procedure*

1) Analogue measurement

Apply specified supply voltages generated by P to D and adjust L to Φ_e.

Measure V_1 on M under specified d.c. radiant power of Φ_e.

Apply sinusoidal modulation with frequency f_{mb} to L, and adjust the a.c. modulation current of S to obtain V_2 on M corresponding to such value that

$$V_2 = (1 + C/N)\ V_1$$

Measure the modulated radiant power $\Delta\Phi_e$ on PM. This is the minimum detectable power of D.

2) *Digital measurement*

Apply specified supply voltages generated by P to D and modulate L by S under the condition of sufficient high extinction ratio.

Adjust the radiant power measured on PM to obtain the specified bit-error rate maintaining the constant extinction ratio of L and appropriate input condition of M by adjusting the gain of A.

Measure the radiant power on PM. This is the minimum detectable power of D.

f) *Specified conditions*

1) Analogue measurement

— Ambient or case temperature (T_{amb} or T_{case});
— Supply voltages of D;
— Radiant power Φ_e;
— Peak emission wavelength and spectral radiation bandwidth of L (λ_p, $\Delta\lambda$);
— Modulation frequency f_{mb};
— Bandwidth B;
— C/N, if other than 3 dB;
— Equalizer parameters, if required.

2) Digital measurement

— Ambient or case temperature (T_{amb} or T_{case});
— Supply voltages of D;
— Peak emission wavelength and spectral radiation bandwidth of L (λ_p, $\Delta\lambda$);
— Signal bit-rate;
— Modulation scheme (RZ or NRZ);
— Bit-error rate;
— Signal pattern (bit sequence and mark density);
— Equalizer parameters, if required.

3 Measuring methods for photocouplers

3.1 Current transfer ratio ($h_{F(ctr)}$)

a) *Purpose*

To measure the static value of the forward current transfer ratio of photocouplers under specified conditions.

b) *Circuit diagram*

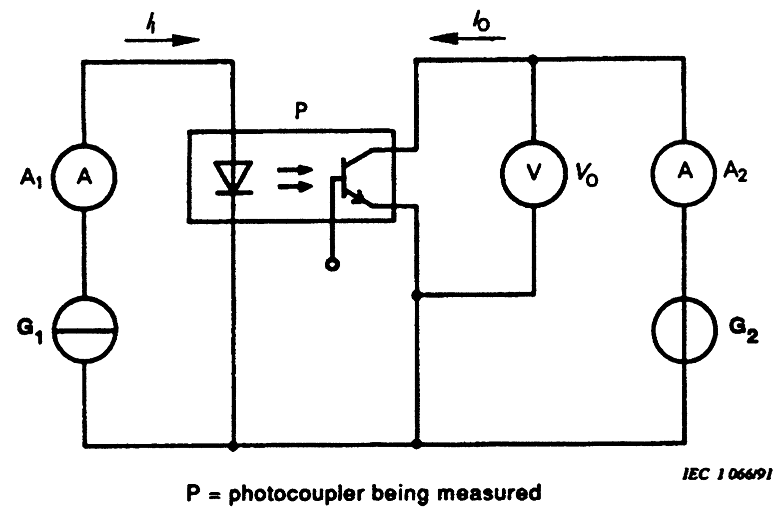


Figure 51 — Basic circuit

c) *Circuit description and requirements*

I_I = input current = forward current I_F of the emitted diode
I_O = output current = reverse current I_R of the photodiode or collector current I_C of the phototransistor
V_O = output voltage = reverse voltage V_R of the photodiode or collector-emitter voltage V_{CE} of the phototransistor
A_1, A_2 = ammeters
G_1 = current source
G_2 = voltage source

d) *Measurement procedure*

The measurement shall be performed under standard atmospheric conditions, unless otherwise specified.

The constant current source G_1 is adjusted to obtain the specified input current through the emitting diode.

The voltage source G_2 is adjusted to the specified value V_R or V_{CE}. The output current I_R or I_C is measured with the ammeter A_2.

The current transfer ratio is calculated by the following formula:

$$h_{F(ctr)} = \frac{I_O}{I_t} \quad (1)$$

hence, for a photocoupler with diode output

$$h_{F(ctr)} = \frac{I_R}{I_F} \quad (2)$$

and, for a photocoupler with transistor output

$$h_{F(ctr)} = \frac{I_C}{I_F} \quad (3)$$

e) *Precautions to be observed*

If the photocoupler is sensitive to external radiation, the precautions to be taken in measurement should be stated and observed.

f) *Specified conditions*

— Ambient temperature.

— Input or output current, d.c. or pulse.

— Output voltage (V_R or V_{CE}).

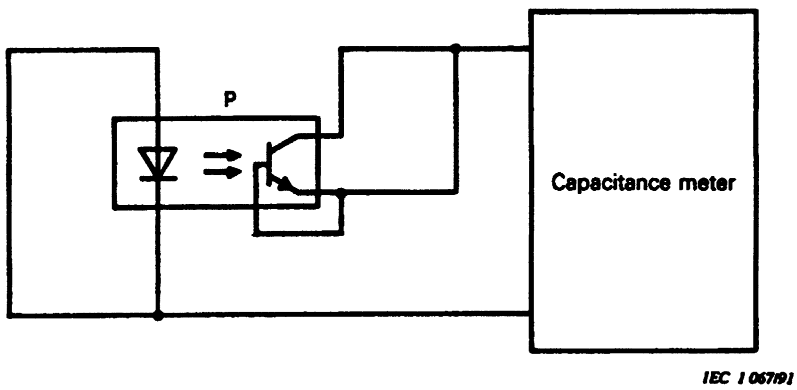
— When appropriate, the atmospheric conditions.

3.2 Input-to-output capacitance (C_{io})

a) *Purpose*

To measure the capacitance between the input and output terminals of a photocoupler under specified conditions.

b) *Circuit diagram*



P = Photocoupler being measured

Figure 52 — Basic circuit

c) *Measurement procedure*

The photoemitter terminals as well as the photodetector terminals are connected together. The capacitance between the photoemitter and the photodetector terminals is measured at a frequency of 1 MHz (unless otherwise specified), using a suitable capacitance meter.

d) *Precautions to be observed*

Allowance should be made for the stray capacitance of the test fixture and the leads.

e) *Specified conditions*

— Ambient temperature.

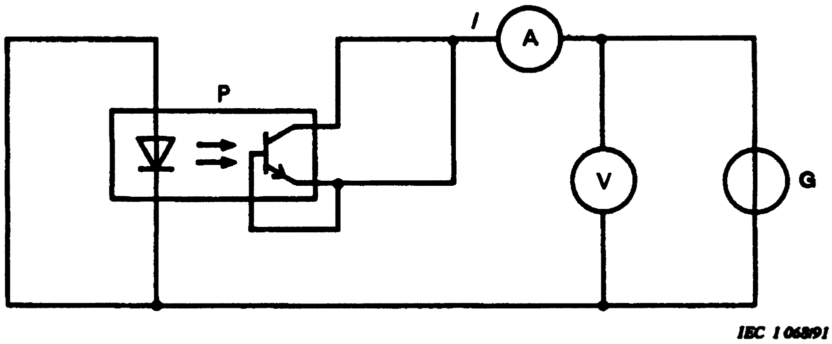
— Measurement frequency, if different from 1 MHz.

3.3 Isolation resistance between input and output (r_{IO})

a) *Purpose*

To measure the isolation resistance between the input and output terminals of a photocoupler when subjected to d.c. voltage, under specified conditions.

b) *Circuit diagram*



P = Photocoupler being measured

G = Voltage source

Figure 53 — Basic circuit

c) *Precautions to be observed*

Allowance should be made for the leakage current of the test fixture and the leads.

d) *Measurement procedure*

The photoemitter terminals, as well as the photodetector terminals, are connected together.

The specified measurement voltage between the photoemitter and photodetector terminals is applied for 60 s. The isolation resistance is calculated as V/I.

e) *Specified conditions*

— Ambient temperature.

— Measurement voltage.

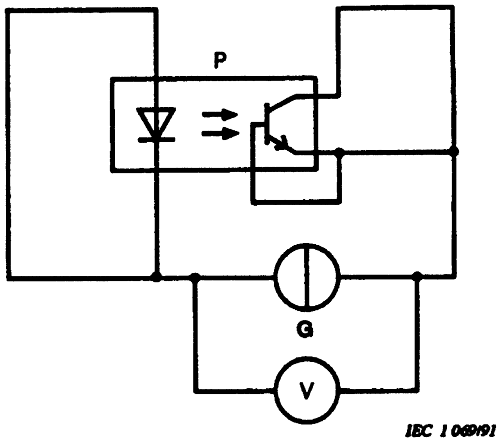
— Time after which the measurement is made, if different from 60 s.

3.4 Isolation test

a) *Purpose*

To verify the ability of the device to withstand the isolation test voltage (V_{IO} or V_{IORM}) under specified conditions.

b) *Circuit diagram*



P = Photocoupler under test
G = Voltage source

Figure 54

c) *Test procedure*

The test should be carried out under the standard atmospheric conditions in IEC Publication 68-1, subclause **5.3.1**.

The device is inserted into the test socket. The photoemitter terminals, as well as the photodetector terminals, are connected together.

The d.c. or a.c. test voltage is increased from zero to the specified value at a rate of about 100 V per second if the specified value is lower than or equal to 1 000 V, and at 500 V per second if the specified value is higher than 1 000 V.

The voltage is maintained for 1 min for qualification testing and for 10 s (minimum) for acceptance testing.

d) *Requirements*

External or internal flash-over shall not occur during the test.

The device shall pass the post-test measurements.

e) *Specified conditions*

— Isolation voltage (V_{IO} or V_{IORM}).
— Test time (if different from 1 min or 10 s, respectively).
— Post-test measurements.

3.5 Partial discharges of photocouplers

a) *Purpose*

To verify the performance of solid insulation between input and output of a photocoupler by measuring the partial discharge level under specified conditions.

This test is non-destructive.

NOTE For the definition of partial discharge see IEC Publication 270, subclause **3.1**. For convenience this definition is repeated hereafter:

"Partial discharge

A partial discharge, within the terms of this standard, is an electric discharge that only partially bridges the insulation between conductors. Such discharges may, or may not, occur adjacent to a conductor.

NOTE Partial discharges in gases around a conductor are sometimes referred to as "corona". This term should not be applied to other forms of partial discharges.

The general term "ionization" should not be used to denote the particular case of partial discharges."

b) *Circuit diagram*

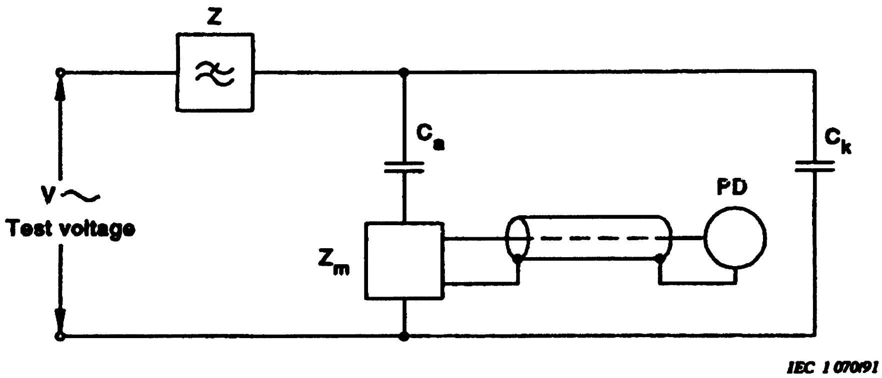


Figure 55 — Partial discharge test circuit

c) *Description of the test circuit and requirements*

(see also Annex A1, Annex A2 and Annex A3).

1) *Test circuit*

The circuit consists mainly of:

C_a = photocoupler under test which can be regarded as a capacitance

C_k = coupling capacitor by passing partial discharge current

Z_m = measuring circuit consisting of the measuring impedance, the connecting lead the surge limiting device and the measuring instrument

PD = partial discharge measuring instrument

Z = a low-pass filter to reduce interference from the source (see also Annex A1)

2) *Equipment characteristics*

The peak value of the test voltage shall be measured. A RMS reading instrument may be used provided the distortion of the sinewave of the test voltage is less than 5 %.

The bandwidth of the partial discharge measuring equipment shall be less than 15 kHz.

The centre frequency shall be between 150 kHz and 2 MHz.

The resonance frequency of the test circuit shall be at least three times the centre frequency used (see also Annex A2).

3) *Coupling capacitor*

The coupling capacitor shall be of a low-inductance design and the coupling capacitor shall not exhibit any partial discharges at the test voltage.

d) *Test procedure*

1) *Calibration*

1.1) *General*

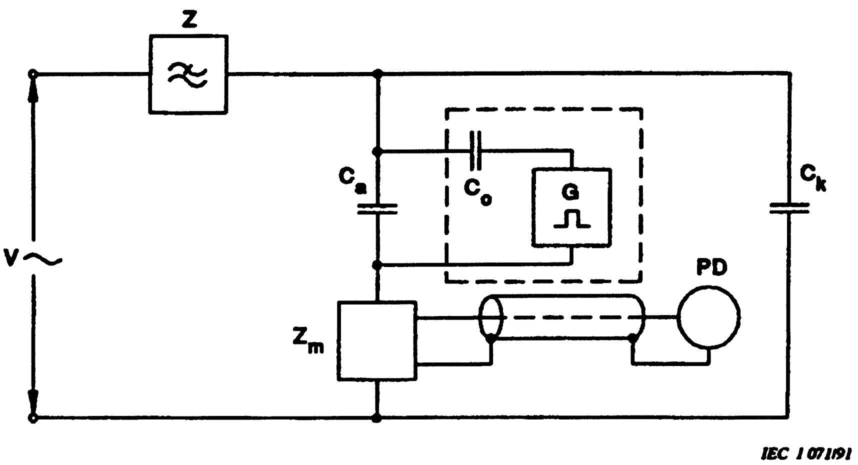
Calibration involves two separate procedures: one is a complete determination of the characteristics of the measuring instrument itself including a detailed calibration and should be performed after major repairs or at least once per year; the other is a routine calibration of the instrument in the complete test circuit and should be performed before every test or, if many identical test objects are being tested, then it may be performed at suitable intervals to be determined by the user. The latter calibration should include a verification that the instrument, as used in the test circuit, shall be able to measure a partial discharge level of 1 pC (minimum).

1.2) *Calibration of partial discharge measuring instrument*

The partial discharge measuring instrument is calibrated according to the instructions of the manufacturer of the instrument.

1.3) *Calibration of the instrument in the complete test arrangement*

The calibration of the instrument in the complete test arrangement is made according to Figure 56, below.



C_0 = Pulse generator capacitance
G = Pulse generator
(For the other elements, see Figure 55)

Figure 56 — Connections for the calibration of the complete test arrangement

The calibration shall be repeated every day and for each device with a different design.

The pulse generator is adjusted so that the outpulse represents a charge of 5 pC.

The pulse of the calibration generator shall have a rise time of less than 50 ns. The delay time shall be between 100 µs and 1 000 µs.

The reading of the instrument should be at least half of full scale.

The pulse generator shall be removed before energizing the test circuit.

The test voltage is set to the highest applicable level relevant to the device under test. The reading of the instrument should be below 1 pC. For this verification of the test circuit noise level, C_a shall be free of partial discharge.

2.2) *Method b)*

Figure 58 — Time interval versus test voltage diagram

The partial discharge test voltage (V_p) is applied. This voltage is maintained for a specified time (t_{st}) and during this time the partial discharge magnitude is measured in a given time interval (t_p).

$V_p = k \, . \, V_{IORM}$

e) *Precautions to be observed*

All applicable test voltages in this standard are peak voltages.

f) *Specified conditions*

Parameter	Method a)	Method b)
Initial time t_{ini}	×	—
Initial voltage V_{IOSM}	×	—
Partial discharge test voltage V_p; $V_p = k \, . \, V_{IORM}$	×	×
Partial discharge measuring time t_p	×	×
Stress time t_{st}	×	×
Settling time t_1, t_2, t_3, t_4	×	×
Ambient temperature T_{amb}	×	×

Annexes

Annex A1: Partial discharges in the test object cause charge transfer in the test circuit giving rise to current pulses through the measuring impedance. This impedance, in combination with the test object and coupling capacitor, determines the duration and shape of the measured voltages pulses. These pulses are further shaped and amplified in order to supply to a measuring instrument a value proportional to the apparent charge quantity.

Annex A2: Measuring impedance