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# Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 Gbytes single sided disk and 200,0 Gbytes double sided disk) and Quadruple Layer (128,0 Gbytes single sided disk) BD Recordable disk

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# National foreword

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# Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 Gbytes single sided disk and 200,0 Gbytes double sided disk) and Quadruple Layer (128,0 Gbytes single sided disk) BD Recordable disk

*Technologies de l'information — Supports enregistrés numériquement pour échange et stockage d'information — 120 mm de couche triple (100,0 Go disque unique face et 200,0 Go disque double face) et quadruple couche (128,0 Go disque unique face) sur disque enregistrable BD*

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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information Technology*, Subcommittee SC 23, *Digitally recorded media for information interchange and storage*.

This third edition cancels and replaces the second edition (ISO/IEC 30191:2015), which has been technically revised. It also incorporates the Amendment ISO/IEC 30191:2015/Amd.1 :2019.

The main change compared to the previous edition is the addition of requirements for physical access control and reserved area of BD application.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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# Introduction

In March 2002, the Blu-ray Disc Founders, or BDF, came together to create optical disk formats with the large capacity and high-speed transfer rates that would be needed for recording and reproducing high-definition video content.

The Blu-ray Disc Association (BDA) issued the first version of the Blu-ray Disc™ Recordable Format Part1 in October 2005, and Version 1.3 of the Blu-ray Disc™ Recordable Format Part 1 in April 2008, which enabled the recording velocity up to 6x. In June 2010, the BDA issued Blu-ray Disc™ Recordable Format Part 1 Version 2.0, which specifies the TL and QL of BD recordable disk.

To keep the compatibility of the removable medium in the market, just to make a standard is not enough, and it is necessary to check that the disks and devices can satisfy the specifications.The BDA also conducts verification activities for the disks and devices and has established more than 10 testing centers in Asia, Europe and the USA.

Blu-ray™ disks, players, recorders and PC drives/software based on BDA standards became popular all over the world. The BDA gave consumer applications the highest priority in the first few years. But it was known, of course, that international standardization would be required before many government entities and their contractors would be allowed to use Blu-ray Disc™. In January and February 2011, the BDA was formally requested to consider international standardization. The reason for this was to enable the inclusion of writable BDs, along with DVDs and CDs, in an International Standard specifying test methods for the estimation of lifetime of optical storage media for long-term data storage. In October 2011, the BDA responded that it had decided to pursue international standardization of the basic physical formats for the Recordable and Rewritable Blu-ray™ Format.

In December 2011, the BDA sent project proposals for international standardization of four formats. ISO/IEC 30190, ISO/IEC 30191, ISO/IEC 30192 and ISO/IEC 30193 were published in 2013.

A few additional specifications are required in order to write and read video-recording applications, such as the BDMV and BDAV formats, which have been specified by the BDA for use on BD recordable disks. These specifications, which are related to the BD application, the file system or the content protection system, are required for the disk, the generating system and the receiving system[1)].

The International Organization for Standardization (ISO) and International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of a patent.

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1) For more information of the BD application, the content-protection system and the additional requirements for the Blu-ray™ Format specifications, see http://www.blu-raydisc.info.


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# Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 Gbytes single sided disk and 200,0 Gbytes double sided disk) and Quadruple Layer (128,0 Gbytes single sided disk) BD Recordable disk

## 1 Scope

This document specifies the mechanical, physical and optical characteristics of a 120 mm recordable optical disk with a capacity of 100,0 Gbytes, 128,0 Gbytes or 200,0 Gbytes. It specifies the quality of the recorded and unrecorded signals, the format of the data and the recording method, thereby allowing for information interchange by means of such disks. User data can be written once and read many times using a non-reversible method. This disk is identified as BD recordable disk.

This document specifies the following:

— three related but different types of this disk;

— the conditions for conformance;

— the environments in which the disk is to be operated and stored;

— the mechanical and physical characteristics of the disk, so as to provide mechanical interchange between data processing systems;

— the format of the information on the disk, including the physical disposition of the tracks and sectors;

— the error correcting codes and the coding method used;

— the characteristics of the signals recorded on the disk, enabling data processing systems to read the data from the disk.

This document provides for interchange of disks between disk drives. Together with a standard for volume and file structure, it provides for full data interchange between data processing systems.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 646, *Information technology — ISO 7 bit coded character set for information interchange*

ISO 9352, *Plastics — Determination of resistance to wear by abrasive wheels*

ISO/IEC 30193, *Information technology — Digitally recorded media for information interchange and storage — 120 mm Triple Layer (100,0 Gbytes per disk) BD Rewritable disk*

IEC 60068-2-2, *Environmental testing — Part 2-2: Tests — Test B: Dry heat*

IEC 60068-2-30, *Environmental testing — Part 2-30: Tests — Test Db: Damp heat, cyclic (12 h + 12 h cycle)*

IEC 60950-1, *Information technology equipment — Safety — Part 1: General requirements*

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## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 30193 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

**3.1**
**case**
housing for an optical disk, that protects the disk and facilitates disk interchange

**3.2**
**mark polarity**
polarity of reflectivity change when marks are recorded

## 4 Symbol and abbreviated terms

| | | | |
|---|---|---|---|
| ac | alternating current | MSB | most significant byte |
| ADIP | address in pre-groove | msb | most significant bit |
| APC | automatic power control | MSK | minimum shift keying |
| AU | address unit | MW | monotone wobble |
| AUN | address unit number | NA | numerical aperture |
| BCA | burst-cutting area | NRZ | non-return-to-zero |
| BIS | burst-indicating subcode | NRZI | non-return-to-zero inverting |
| BPF | band-pass filter | NWA | next writable address |
| CAV | constant angular velocity | NWL | nominal wobble length |
| cbs | channel bits | OPU | optical pick-up unit |
| CNR | carrier-to-noise ratio | PAA | physical ADIP address |
| dc | direct current | PIC | permanent information and control data |
| DCZ | drive calibration zone | PLL | phase-lock loop |
| DDS | disk definition structure | PoA | post-amble |
| DFL | defect list | PP | push-pull |
| DI | disk information | pp | peak-to-peak |
| DL | dual layer | PrA | pre-amble |
| DMA | disk management area | PSN | physical sector number |
| DMS | disk management structure | QL | quadruple layer |
| DSV | digital sum value | $R_H$ | relative humidity |


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| | |
|---|---|
| EB | emergency brake |
| ECC | error correction code |
| EDC | error detection code |
| EQ | equalizer |
| FAA | first ADIP address (of data zone) |
| FS | frame sync |
| FWHM | full width at half maximum |
| HF | high frequency |
| HFM | high frequency modulated |
| HMW | harmonic modulated wave |
| HPF | high-pass filter |
| HTL | high-to-low |
| $I_{NHWS}$ | normalized HFM wobble signal amplitude |
| $I_{NWS}$ | normalized wobble signal amplitude |
| GLAA | last ADIP address (of data zone) |
| LDC | long-distance code |
| LPF | low-pass filter |
| LRA | Last recorded address |
| LSB | least significant byte |
| lsb | least significant bit |
| $L_{SHD}$ | second harmonic distortion level |
| $L_{SHL}$ | second harmonic level |
| LSN | logical sector number |
| MM | MSK mark |
| RIN | relative intensity noise |
| RMTR | repeated minimum transition run length |
| RS | Reed-Solomon (code) |
| $R_T$ | relative thickness |
| RUB | recording unit block |
| SER | symbol error rate |
| SL | single layer |
| $S/N$ | signal-to-noise ratio |
| SRM | sequential recording mode |
| SRR | sequential recording range |
| SRRI | sequential recording range information |
| STW | saw-tooth wobble |
| Sync | synchronization |
| TDDS | temporary disk definition structure |
| TDFL | temporary defect list |
| TDMA | temporary disk management area |
| TDMS | temporary disk management structure |
| TL | triple layer |
| TL/D | triple layer double-sided |
| TP | track pitch |
| TS | transmission stack |
| $V_{ref}$ | reference velocity |
| wbs | wobbles |

# 5 Conformance

## 5.1 Optical disk

A claim of conformance with this document shall specify the type implemented. An optical disk shall be in conformance with this document if it meets all mandatory requirements specified for its type.

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### 5.2 Generating system

A generating system shall be in conformance with this document if the optical disk it generates is in accordance with 5.1.

### 5.3 Receiving system

A receiving system shall be in conformance with this document if it is able to handle both a type TL disk and a type QL disk according to 5.1. Handling of a type TL/D disk is optional for a receiving system. See Clause 7 for the types of disk.

### 5.4 Compatibility statement

A claim of conformance by a generating or receiving system with this document shall include a statement listing any other standards supported. This statement shall specify the numbers of the standards, the optical disk types supported (where appropriate) and whether support includes reading only or both reading and writing.

## 6 Convention and notations

### 6.1 Levels of grouping

Many times data is collected into groups, where these groups of data can be collected into higher level groups. For the clarity of the grouping hierarchy, in this document the following levels of hierarchy is used:

Frame: the lowest level of grouping. Generally, frames contain bytes of information.

Block: the second level of grouping. Generally, blocks consist of a number of frames.

Cluster: the highest level of grouping. Clusters consist of several blocks.

Fragment: a level of grouping that can be applied by the application. A certain amount of data is allocated to a (fixed) number of consecutive clusters.

### 6.2 Representation of numbers

A measured value $x_{measured}$ may be rounded off to the least significant digit of the corresponding specified value $x$ before being compared with this specified value.

EXAMPLES

— The specification is: $x = 1{,}26^{+0{,}01}_{-0{,}02}$:
(nominal value = 1,26 with a positive tolerance of +0,01 and a negative tolerance of –0,02)
  — a measured value in the range $1{,}235 \leq x_{measured} < 1{,}275$ fulfills this specification.

— The specification is: $x \leq 0{,}3$:
  — a measured value $x_{measured} < 0{,}35$ fulfills this specification
(rounding off is applied for $0{,}30 < x_{measured} < 0{,}35$: $x_{rounded} = 0{,}3$);


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— The specification is: $x < 0{,}3$:

  — a measured value $x_{measured} = 0{,}299$ fulfills this specification (no rounding off needs to be applied);

  — a measured value $x_{measured} = 0{,}3$ exactly does not fulfil this specification.

In case the specified value is given as “maximum *x* units” or “minimum *x* units”, the measured value shall not be rounded off before comparing to the specified value. Parameters given in this way shall not violate the specified limits set by the exact value of *x*.

EXAMPLES

— The specification is maximum 0,3 mm:

  — a measured value of 0,300 mm fulfills this specification;

  — a measured value of 0,301 mm does not fulfil this specification;

— The specification is minimum 3 dB:

  — a measured value of 3,00 dB fulfills this specification;

  — a measured value of 2,99 dB does not fulfil this specification.

Numbers in decimal notation are represented by the digits 0 to 9. The decimal symbol is “,” (comma). In large numbers the “ ” (space) can be used as digit grouping symbol.

Numbers in hexadecimal notation are represented by the hexadecimal digits 0 to 9 and A to F in parentheses or followed by lowercase “h”. The character *x* in hexadecimal numbers represents any digit 0 to 9 or A to F.

Numbers in binary notations and bit patterns are represented by strings of digits 0 and 1, with the most significant bit shown to the left. The character *x* in binary numbers represents a digit 0 or 1.

Negative values of numbers in binary notation are given as two's complement.

In a pattern of n bits, bit $b_{(n-1)}$ shall be the most significant bit (msb) and bit $b_0$ shall be the least significant bit (lsb). Bit $b_{(n-1)}$ shall be recorded first.

An uninterrupted sequence of *m* 0s in a bit pattern can be represented by $[0^m]$.

The setting of bits is denoted by ZERO and ONE.

In data fields composed of bytes, the data is recorded so that the most significant byte (MSB), identified as byte 0, shall be recorded first and the least significant byte (LSB) last.

In a field of 8*n* bits, bit $b_{(8n-1)}$ shall be the most significant bit (msb) and bit $b_0$ the least significant bit (lsb). Bit $b_{(8n-1)}$ shall be recorded first.

In data fields composed of nibbles, the data is recorded so that the most significant nibble, identified as nibble 0, shall be recorded first and the least significant nibble last.

In a field of 4n bits, bit $b_{(4n-1)}$ shall be the most significant bit (msb) and bit $b_0$ the least significant bit (lsb). Bit $b_{(4n-1)}$ shall be recorded first.

A range of values is indicated as $x \sim y$, where *x* and *y* are included in the range.

A list of integers is indicated as *i* .. *j*. The list contains all numbers between *i* and *j*, including *i* and *j* (e.g. $k = 0$ .. 7). If the step size is different from 1, this is indicated as: *i*, (*i*+step) .. *j* (e.g. $k = 1, 4$ .. 16, where step=3).

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A group of parameters is indicated as param $m$ .. $n$ or $P_m$ .. $P_n$. The group contains all parameters with an index between $m$ and $n$, including $m$ and $n$ (e.g. byte 16 .. 31, bit 7 .. 4).

If $x$ is nearly equal to $y$, then it is expressed as $x \approx y$.

### 6.3 Integer calculus

div($n$,$d$) represents the integer part of the division of $n$ by $d$.

mod($n$,$d$) represents the remainder of the division of $n$ by $d$: mod($n$,$d$) = $n - d \times$ div($n$,$d$).

For example:

| | | | |
|---|---|---|---|
| div(+11, +3) = +3 | div(–11, +3) = –3 | div(+11, –3) = –3 | div(–11, –3) = +3 |
| mod(+11, +3) = +2 | mod(–11, +3) = –2 | mod(+11, –3) = +2 | mod(–11, –3) = –2 |

floor(x) represents the largest integer number ≤$x$.

For example:

floor(+3,7) = +3 floor(–3,7) = –4

## 7 General description of disk

This document provides for three types of disks.

The recording layer of the disk uses high-to-low (HTL) technology. Recorded HTL marks have lower reflection than the unrecorded layer(s).

Type TL disk**:** The 120 mm optical disk consists of a substrate of about 1,1 mm nominal thickness. The substrate is covered with three recording layers. The recording layers consist of several layers. The three recording layers are separated by two transparent spacer layers whose thicknesses are about 25,0 µm and 18,0 µm, respectively in this order from the substrate. On top of these recording layers, a transparent cover layer of about 57,0 µm is applied with accurately defined optical characteristics (see Figure 1).

Type QL disk**:** The 120 mm optical disk consists of a substrate of about 1,1 mm nominal thickness. The substrate is covered with four recording layers. The four recording layers are separated by three transparent spacer layers whose thickness are about 15,5 µm, 19,5 µm and 11,5 µm, respectively in this order from the substrate, and on top of these recording layers, a transparent cover layer of about 53,5 µm is applied (see Figure 2).

Type TL/D disk**:** The 120 mm optical disk consists of a substrate of about 1,0 mm nominal thickness. The substrate is covered with three recording layers on each side. The recording layers of each side have the same characteristics and structure as a type TL disk (see Figure O.1). The three recording layers on each side of a disk can be accessed from the side only. Requirements specific for a type TL/D disk are defined in Annex O. All requirements for a type TL disk including Annex O shall be applied to a type TL/D disk unless otherwise described. See Annex P for bonding.

The first (layer L2) and second (layer L1) recording layers of a type TL disk and a type TL/D disk and the first (layer L3), second (layer L2) and third (layer L1) recording layers of a type QL disk seen from the read-out side of the disks shall be semi-transparent.

To improve the scratch resistance, the cover layer optionally can be protected with an additional hard coating.

Clamping is performed in the clamping zone.


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Data can be written onto the disk with a high power focused optical beam. The data can be read with a low power focused optical beam, using the difference in the reflectivity of the marks and the spaces.

The recording layer(s) contain wobbled groove (s) with addresses, which serve as a speed control and navigation system for the data to be written to the recording layer concerned.

Recording and read-out of the data is accomplished through the cover layer or through the total stack of cover layer, recording layers and spacer layers, depending on which recording layer is involved.

Depending on which recording layer is to be accessed, the optical beam passes through the transparent cover layer (reading/writing layer L2 on a type TL disk or a type TL/D disk, or layer L3 on a type QL disk) or through the transparent cover layer, the semi-transparent recording layer(s) and the transparent spacer layer(s) (reading/writing layer L0 and layer L1 on a type TL disk or a type TL/D disk, or layer L0, layer L1 and layer L2 on a type QL disk).

For reference purposes, all layers together, passed through by the light beam when accessing a certain recording layer, are called the transmission stack of that specific recording layer.

A TL disk and a QL disk also denote a type TL disk and a type QL disk respectively in this document.

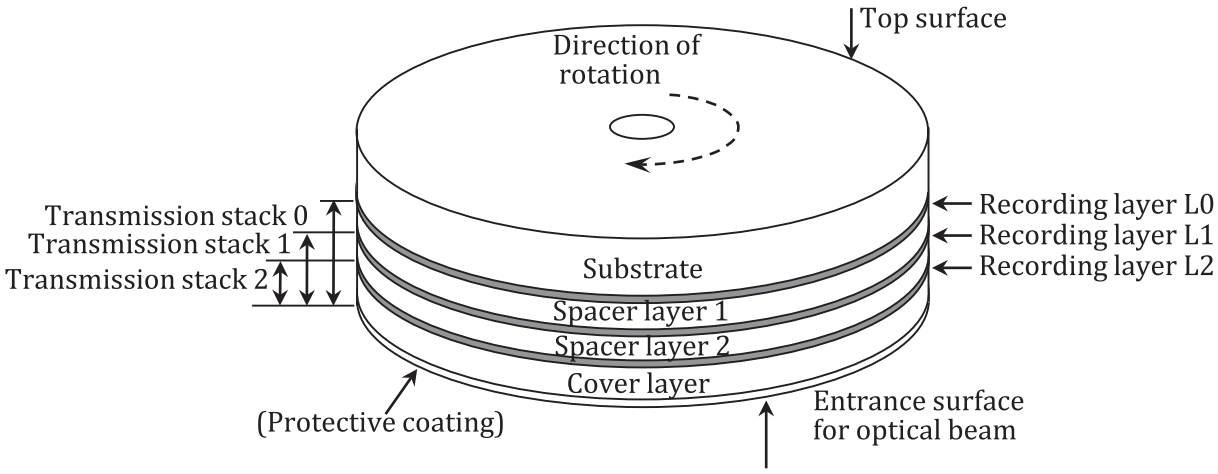



**Figure 1 — Outline of type TL disk**

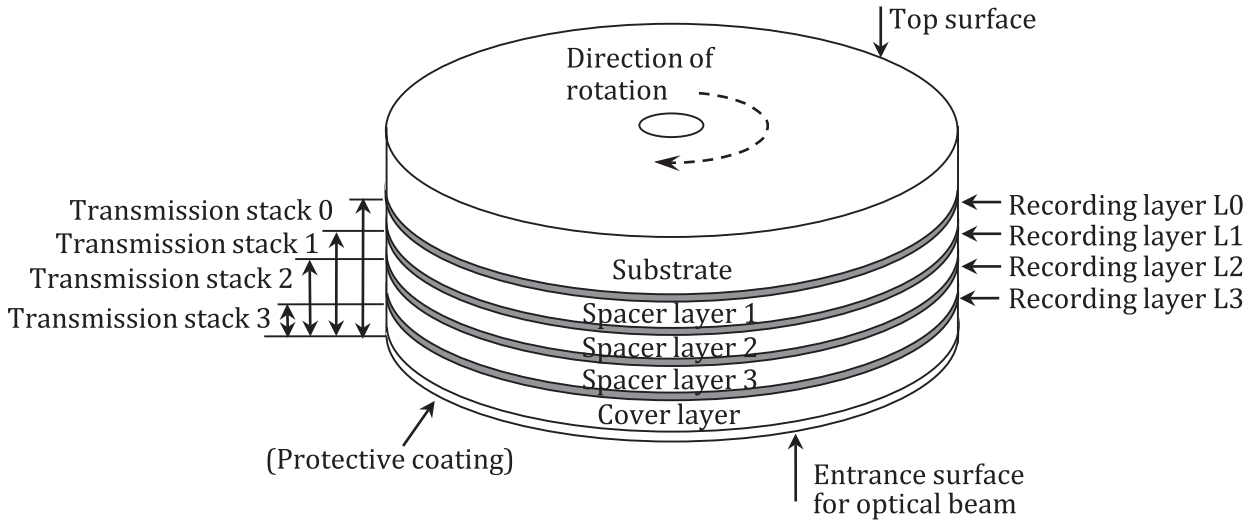



**Figure 2 — Outline of type QL disk**

This document specifies two kinds of recording velocity 2x, 4x.

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Figure 3 shows the recording velocity requirements for each disk type.

| Disk type | Disk type parameters | | | Recording velocity | |
|---|---|---|---|---|---|
| | Mark polarity | Push-pull polarity (see 26.1) | Layer type | 2x | 4x |
| Type TL<br>Type TL/D | HTL | On-groove [a] | TL | M | M |
| Type QL | HTL | On-groove [a] | QL | M | M |
| M mandatory<br>[a] Groove geometry is on-groove for all layers (see 15.2). | | | | | |

**Figure 3 — Recording velocity requirements for disk type**

# 8 General requirements

## 8.1 Environments

### 8.1.1 Test environment

#### 8.1.1.1 General

During measurements for testing the conformance of the disk with this document, the disk shall be in the test environment. The test environment is the environment where the air immediately surrounding the disk shall have the following properties:

— temperature, $T$: (23 ± 2) °C;

— relative humidity, $R_H$: 45 % to 55 %;

— atmospheric pressure: 86 kPa to 106 kPa.

No condensation on the disk shall occur. Before testing, the disk shall be conditioned in this environment for sufficient time.

#### 8.1.1.2 Test conditions for sudden change in operating environment

Some parameters can be rather sensitive for changes in the operating environment. Where specified, the following two tests shall be performed. In both cases the required specifications shall be fulfilled during the time it takes for the disk to acclimatize to the new environment.

a) Apply a sudden change in relative humidity, while keeping the temperature at a constant level: $R_H$ = 90 %, $T$ = 25 °C ⇒ $R_H$ = 45 %, $T$ = 25 °C (see Figure 4);

b) Apply a sudden change in temperature, while keeping the absolute humidity at a constant level (about 10,4 g/m$^3$): $T$ = 25 °C, $R_H$ = 45 % ⇒ $T$ = 55 °C, $R_H$ = 10 % (see Figure 4).

### 8.1.2 Operating environment

A disk in conformance with this document shall provide data interchange over the specified ranges of environmental parameters in the operating environment. The operating environment is the environment where the air immediately surrounding the disk shall have the following properties:


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— temperature, $T$: 5 °C to 55 °C;

— relative humidity, $R_H$: 3 % to 90 %;

— absolute humidity: 0,5 g/m$^3$ to 30 g/m$^3$;

— atmospheric pressure: 60 kPa to 106 kPa.

There shall be no condensation of moisture on the disk. If a disk has been exposed to conditions outside those specified above, it shall be acclimatized in an operating environment for at least 2 hours before use.

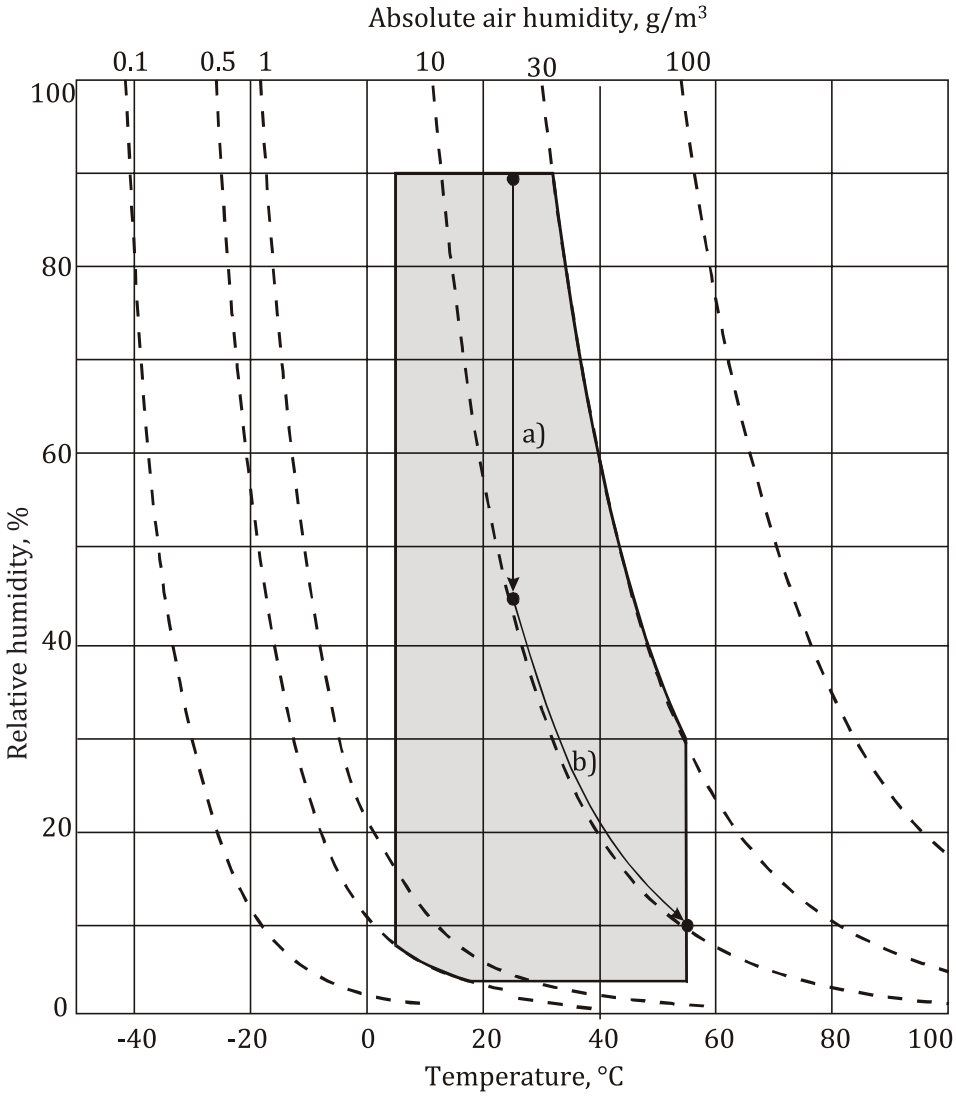



**Figure 4 — Operating environment**

### 8.1.3 Storage environment

#### 8.1.3.1 General

The storage environment is the environment where the air immediately surrounding the optical disk shall have the following properties:

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— temperature, $T$: –10 °C to 55 °C;

— relative humidity, $R_H$: 5 % to 90 %;

— absolute humidity: 1 g/m$^3$ to 30 g/m$^3$;

— atmospheric pressure: 60 kPa to 106 kPa;

— temperature variation max.: 15 °C/h;

— relative humidity variation max.: 10 %/h.

#### 8.1.3.2 Climatic storage tests

To check the environmental stability of the disk, it shall be exposed to the following environments:

— dry heat test according to IEC 60068-2-2 Ba: $T$ = 55 °C, $R_H$ = 50 %, 96 h;

— damp heat cycle test according to IEC 60068-2-30 Db: $T_{high}$ = 40 °C, $T_{low}$ = 25 °C, $R_H$ = 95 %, cycle time = (12 + 12) h, 6 cycles.

After exposure to these environmental conditions, one should allow for some recovery time before measuring [(24 or 48) h].

### 8.1.4 Transportation

#### 8.1.4.1 General

As transportation occurs under a wide range of temperatures and humidity variations, for differing periods, by many methods of transport and in all parts of the world, it is not possible to specify mandatory conditions for transportation or for packaging.

#### 8.1.4.2 Packaging

##### 8.1.4.2.1 General

The form of packaging should be agreed between sender and recipient. In absence of such an agreement, it is the responsibility of the sender. It should take into account the following hazards.

##### 8.1.4.2.2 Temperature and humidity

Insulation and wrapping should be designed to maintain the conditions for storage over the estimated period of transportation.

##### 8.1.4.2.3 Impact loads and vibrations

a) Avoid mechanical loads that would distort the shape of the disk.

b) Avoid dropping the disk.

c) Disks should be packed in a rigid box containing adequate shock-absorbent material.

d) The final box should have a clean interior and a construction that provides sealing to prevent the ingress of dirt and moisture.

## 8.2 Safety requirements

The disk shall satisfy the requirement of IEC 60950-1, when used in the intended manner or in any foreseeable uses in an information system.


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### 8.3 Flammability

The disk shall be made from materials that comply with the flammability class for HB materials, or better, as specified in IEC 60950-1.

## 9 Reference drive

### 9.1 General

A reference drive shall be used for the measurement of optical and electrical signal parameters for conformance with the requirements of this document. The critical components of this device have the characteristics specified in Clause 9.

### 9.2 Measurement conditions

During tests, the disk shall be in a test environment as defined in 8.1.1, unless stated otherwise.

### 9.3 Optical system

The basic set-up of the optical system of the reference drive used for measuring specified write and read parameters is shown in Figure 5. Different components and locations of components are permitted, provided that the performance remains the same as that of the set-up in Figure 5.

The optical system shall be aligned such that the focused optical beam is perpendicular to the recording layer on which the beam is focused at the radius where the measurement is to be performed.

The optical system shall be such that the detected light reflected from the entrance surface of the disk is minimized so as not to affect the accuracy of the measurements.

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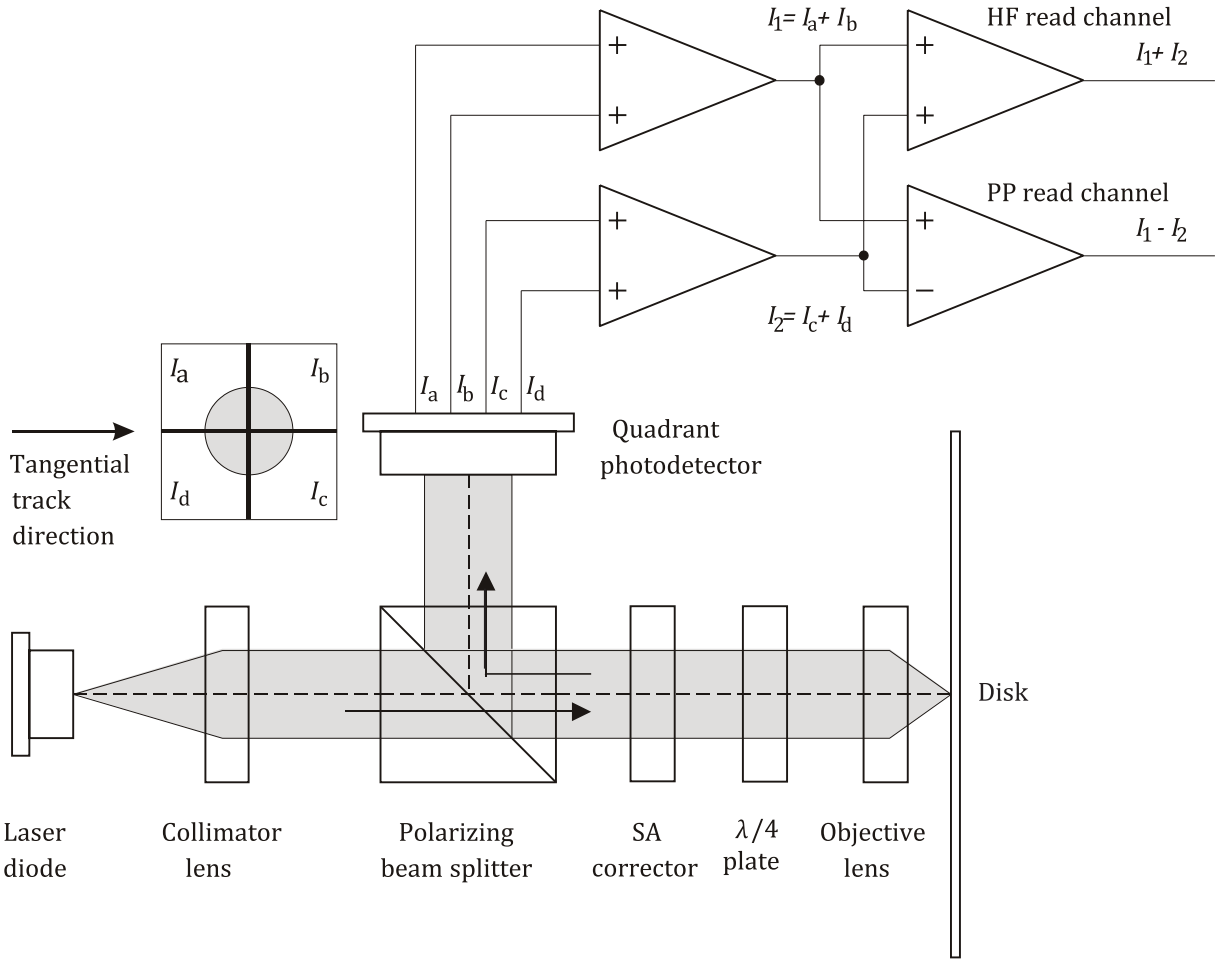



**Figure 5 — Optical system of reference drive**

A combination of polarizing beam splitter and a quarter-wavelength plate shall be used to separate the entrance light beam, coming from the laser diode, and light beam reflected by the optical disk going towards the photodetector. The light beam transmitted through the splitter shall have a p:s intensity ratio of at least 100:1.

The optical beam shall be compensated for spherical aberrations (SA) such that these aberrations are minimized for the thickness of the transmission stack of the recording layer on which the beam is focused at the radius where the measurement is to be performed.

During measurements on one layer of a multi-layer disk, light reflected from the other layers can influence the measurements on the layer under investigation. To cope with these effects, the photodetector shall have defined dimensions. Its length and width shall be smaller than $M \times 5$ µm, where $M$ is the transversal optical magnification from the disk to its conjugate plane near the quadrant photodetector. For a TL disk or a QL disk, however, the effect cannot be neglected even if length and width of the photodetector is smaller than $M \times 5$ µm. Therefore, observed reflectivity shall be compensated using the procedure shown in B.4.

## 9.4 Optical beam

The focused optical beam used for writing and reading data shall have the following properties:


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— wavelength ($\lambda$) of the laser beam: (405 ± 5) nm;

— polarization: circular;

— NA: 0,85 ± 0,01;

— light intensity at the rim of the pupil of the objective lens relative to the maximum intensity:

  — in the tangential direction: (60 ± 5) %;

  — in the radial direction: (65 ± 5) %;

— maximum wave-front aberration at the recording layer(s): 0,033 × $\lambda$ rms;

  (after correction of tilt and spherical aberrations)

— maximum relative intensity noise of the laser diode: –125 dB/Hz;

$$\left[10\times\lg\left(\frac{P_m}{P_{\mathrm{dc}}}\right)\right]$$

where

$P_{\mathrm{m}}$ is the ac light density, in Hz;

$P_{\mathrm{dc}}$ is the dc light power.

— normalized detector size: $S/M^2 \leq 25\ \mu m^2$

  where $S$ is the total surface of the 4-quadrant photodetector;

— read power for disk testing (average):

  — layer L0 and layer L1 for a TL disk: (1,20 ± 0,10) mW;

  — layer L2 for a TL disk: (1,10 ± 0,10) mW;

  — layer L0, layer L1 and layer L2 for a QL disk: (1,20 ± 0,10) mW;

  — layer L3 for a QL disk: (1,10 ± 0,10) mW;

— write power and pulse shape: For write power, see 29.4.2 for detailed specifications.

  The pulse shape shall follow Annex F.

## 9.5 HF read channel

The HF read channel is provided to supply a signal from which user data can be retrieved. This signal is generated by summing the currents from all four elements of the photodetector ($I_a + I_b + I_c + I_d$). These currents are modulated by the user-written information, due to the difference in reflectivity of the marks and spaces.

In the frequency range from dc to 44 MHz, the HF read channel, including the photodetectors, shall have a flat amplitude response within ±1,0 dB relative to its dc gain. The group delay variation shall be maximum 1,5 ns pp in the frequency range from 6 MHz to 44 MHz.

For measurement of i-MLSE, the characteristics of the signal processing and the PLL, etc., are specified in Annex H.

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## 9.6 Radial PP read channel

The radial PP read channel provides the tracking error signal to control the servo for radial tracking of the optical beam. It also provides a wobble signal from which the information modulated on the grooves can be retrieved.

The radial tracking error is generated as a signal $[(I_a + I_b) - (I_c + I_d)]$ related to the difference in the amount of light in the two halves of the exit pupil of the objective lens.

The read amplifiers including the photodetectors in the radial PP read channel shall have a flat amplitude response within ±1,0 dB relative to their dc gain from dc to 16 MHz.

## 9.7 Disk clamping

While its parameters are being measured, the disk shall be clamped between two concentric rings covering most of the clamping zone (see 10.6). The top clamping area shall have the same inner and outer diameters as the bottom clamping area (see Figure 6).

Clamping shall occur between $d_{in}$ = (23,5 ± 0,5) mm and $d_{out}$ = (32,5 ± 0,5) mm.

The total clamping force shall be $F_1$ = 2,0 N ± 0,5 N.

In order to prevent warping of the disk under the moment of force generated by the clamping force and the chucking force $F_2$, which is exerted by the tapered cone on the rim of the centre hole of the disk, $F_2$ shall not exceed 0,5 N (see Figure 6).

The top angle, $\theta_a$, of the tapered cone for centring of the disk shall be 40,0° ± 0,5°.

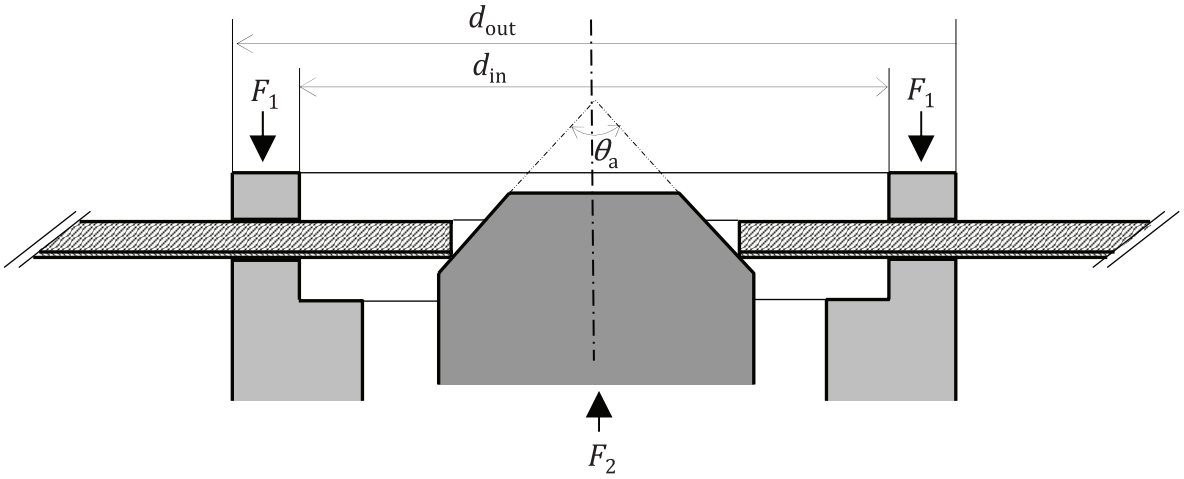



**Figure 6 — Clamping conditions for measurement**

## 9.8 Rotation of disk and measurement velocity

The direction of rotation shall be counter-clockwise as viewed from the objective lens.

All specifications are based on a tangential speed during reading that is equal to the 2x reference velocity unless otherwise specified. This corresponds to a constant linear velocity as follows:

— 7,375 m/s for a TL disk with a user data capacity of 33,368 GB per layer, and

— 7,690 m/s for a QL disk with a user data capacity of 32,000 GB per layer.


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## 9.9 Normalized servo transfer function

In order to specify the servo systems for axial and radial tracking, a function $H_N$ (i$\omega$) is used. It specifies the nominal values of the open-loop transfer function $H$ of the reference servo(s) as Formula (1):

$$H_N(\mathrm{i}\omega) = \frac{1}{3} \times \left( \frac{\omega_0}{\mathrm{i}\omega} \right)^2 \times \frac{1 + \frac{3 \times \mathrm{i}\omega}{\omega_0}}{1 + \frac{\mathrm{i}\omega}{3 \times \omega_0}} \times \left( 1 + \frac{\omega_{\mathrm{int}}}{\mathrm{i}\omega} \right)^K \tag{1}$$

where

$\omega$ = $2\pi \times f$;

$\omega_0$ = $2\pi \times f_0$;

$\omega_{\mathrm{int}}$ = $2\pi \times f_{\mathrm{int}}$;

$\mathrm{i}^2$ = –1;

$K$ = order of integrator.

Here, $f_0$ is the 0 dB crossover frequency of the open-loop transfer function. The crossover frequencies of the lead-lag network of the servo are given by:

— lead break frequency: $f_1 = f_0 / 3$;

— lag break frequency: $f_2 = f_0 \times 3$.

The term $(1+\omega_{\mathrm{int}}/\mathrm{i}\omega)$ in Formula (1) represents an integrator function. Such an integrator or equivalent function is used to further reduce low-frequency components, especially those due to deviations with frequencies equal to the rotational frequency of the disk or its harmonics.

Also, $f_{\mathrm{int}}$ is the crossover frequency of the integrator function.

Another frequency of importance is the frequency $f_X$ at which a sinusoidal displacement with an amplitude equal to the maximum allowed residual tracking error, $e_{\max}$, corresponds to the maximum expected acceleration, $\alpha_{\max}$. This frequency can be calculated with Formula (2):

$$f_x = \frac{1}{2\pi} \sqrt{\frac{\alpha_{\max}}{e_{\max}}} \tag{2}$$

Because the tracking error signals from the disk can have rather large variations, the tracking error signal fed into each reference servo loop shall be adjusted to a fixed level (effectively calibrating the total loop gain), which guarantees the specified bandwidth.

## 9.10 Measurement velocities and reference servos for axial tracking

### 9.10.1 General

The applicable reference servo and conditions for measuring residual axial errors depend on the following measurement velocities under testing:

— measurement velocities for axial residual errors shall be a half of the recording velocities,

— a reference servo for 1x disks measurement velocity refers to 9.10.2, and

— a reference servo for 2x disks measurement velocity refers to 9.10.3.

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The servo for all these conditions has the same basic characteristics with, however a modified integrator.

### 9.10.2 Reference servo for axial tracking at 1x measurement velocity

Regarding the open-loop transfer function $H(f)$ of the reference servo for axial tracking, $|1+H_N(f)|$ is limited as shown schematically by the shaded area in Figure 7:

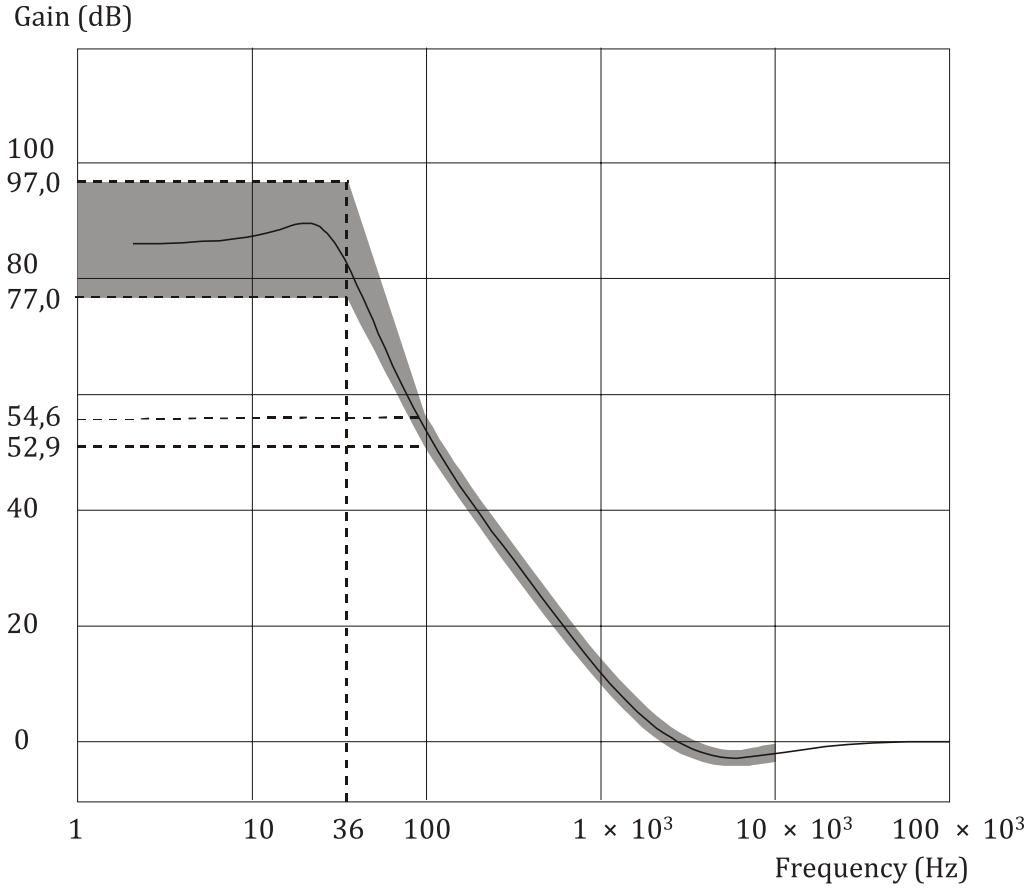



**Figure 7 — Servo characteristic for axial tracking at 1x measurement velocity**

The crossover frequency, $f_0$ of $H_N(f)$ (see 9.9), in kHz, used to define the limits of $|1+H(f)|$ is specified by the following Formula (3), where $\alpha_{max}$ = 6,0 m/s² is the maximum expected axial acceleration due to local disturbances, and $\alpha_{max}$ is multiplied by a factor $m$ = 1,25 for servo margin. The tracking error $e_{max}$, caused by this $m \times \alpha_{max}$, shall be 55 nm. Thus, the 0 dB crossover frequency shall be as follows:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3 \times m \times \alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{3 \times 1{,}25 \times 6{,}0}{55 \times 10^{-9}}} = 3{,}2 \qquad (3)$$

The integrator shall be first order ($K$ = 1) with the crossover frequency of $f_{int}$ = 100 Hz [see Formulae (4) to (6)].


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In the frequency range 100 Hz to 10 kHz:

$$0,9\times|1+H_N(f)|\leq|1+H(f)|\leq1,1\times|1+H_N(f)| \tag{4}$$

In the frequency range 36 Hz to 100 Hz:

$$0,9\times|1+H_N(f)|\leq|1+H(f)|\leq1,1\times|1+H_N(f_{\text{int}})|\times\left(\frac{f_{\text{int}}}{f}\right)^{4,78} \tag{5}$$

In the frequency range up to 36 Hz (in dB):

$$77,0\ \leq|1+H(f)|\leq97,0 \tag{6}$$

The frequency, $f_x$, in kHz, has the value determined by Formula (7):

$$f_x=\frac{1}{2\pi}\sqrt{\frac{\alpha_{\max}}{e_{\max}}}=\frac{1}{2\pi}\sqrt{\frac{6,0}{55\times10^{-9}}}\approx1,6 \tag{7}$$

### 9.10.3 Reference servo for axial tracking at 2x measurement velocity

For the open-loop transfer function $H(f)$ of the reference servo for axial tracking, $|1+H(f)|$ is limited as shown schematically by the shaded area of Figure 8.

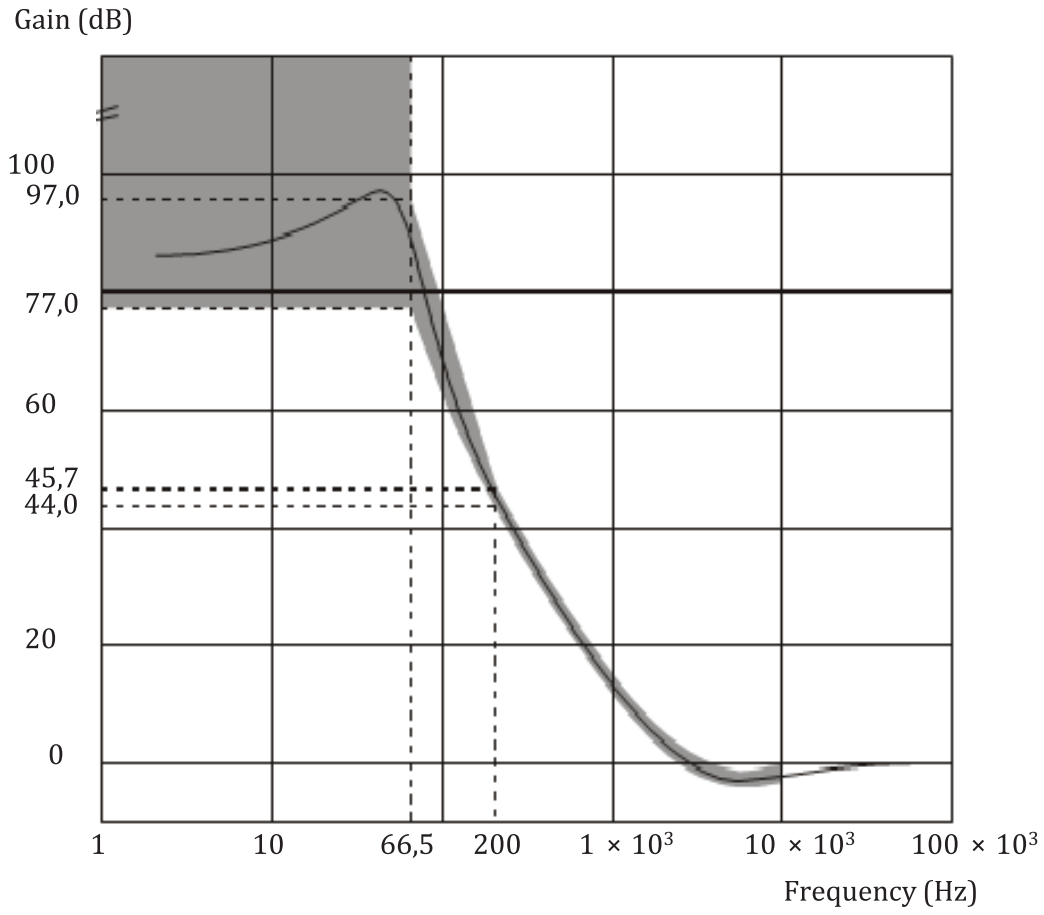



**Figure 8 — Servo characteristic for axial tracking at 2x measurement velocity**

The 0 dB crossover frequency, $f_0$, shall be 3,2 kHz, the same as the measurement condition for the 1x measurement velocity.

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For the maximum residual tracking error of 80 nm (see 11.4.3), this corresponds to an acceleration, $\alpha_{max}$ in m/s$^2$, as per Formula (8):

$$\alpha_{max} = \frac{(2\pi \times f_0)^2}{3} \times e_{max} = \frac{(2\pi \times 3{,}2 \times 10^3)^2}{3} \times 80 \times 10^{-9} = 10{,}8 \quad (8)$$

For the maximum residual tracking error of 110 nm (see 11.4.4), this corresponds to an acceleration, $\alpha_{max}$ in m/s$^2$, as per Formula (9):

$$\alpha_{max} = \frac{(2\pi \times f_0)^2}{3} \times e_{max} = \frac{(2\pi \times 3{,}2 \times 10^3)^2}{3} \times 110 \times 10^{-9} = 14{,}8 \quad (9)$$

The integrator shall be second order ($K$ = 2) with the crossover frequency of $f_{int}$ = 200 Hz [see Formulae (10) to (12)].

In the frequency range 200 Hz to 10 kHz:

$$0{,}9 \times |1 + H_N(f)| \leq |1 + H(f)| \leq 1{,}1 \times |1 + H_N(f)| \quad (10)$$

In the frequency range 66,5 Hz to 200 Hz:

$$0{,}9 \times |1 + H_N(f)| \leq |1 + H(f)| \leq 1{,}1 \times |1 + H_N(f_{int})| \times \left(\frac{f_{int}}{f}\right)^{5{,}36} \quad (11)$$

In the frequency range up to 66,5 Hz (in dB):

$$|1 + H(f)| \geq 77{,}0 \quad (12)$$

## 9.11 Measurement velocities and reference servos for radial tracking

### 9.11.1 General

The applicable reference servo and conditions for measuring residual radial errors depend on the following measurement velocities:

— measurement velocities for radial residual errors shall be a half of the recording velocities;

— a reference servo for 1x disks measurement velocity refers to 9.11.2; and

— a reference servo for 2x disks measurement velocity refers to 9.11.3.

The servo for all conditions has the same basic characteristics, however with a modified integrator.

### 9.11.2 Reference servo for radial tracking at 1x measurement velocity

For the open-loop transfer function $H(f)$ of the reference servo for radial tracking, $|1 + H(f)|$ is limited as shown schematically by the shaded area in Figure 9.


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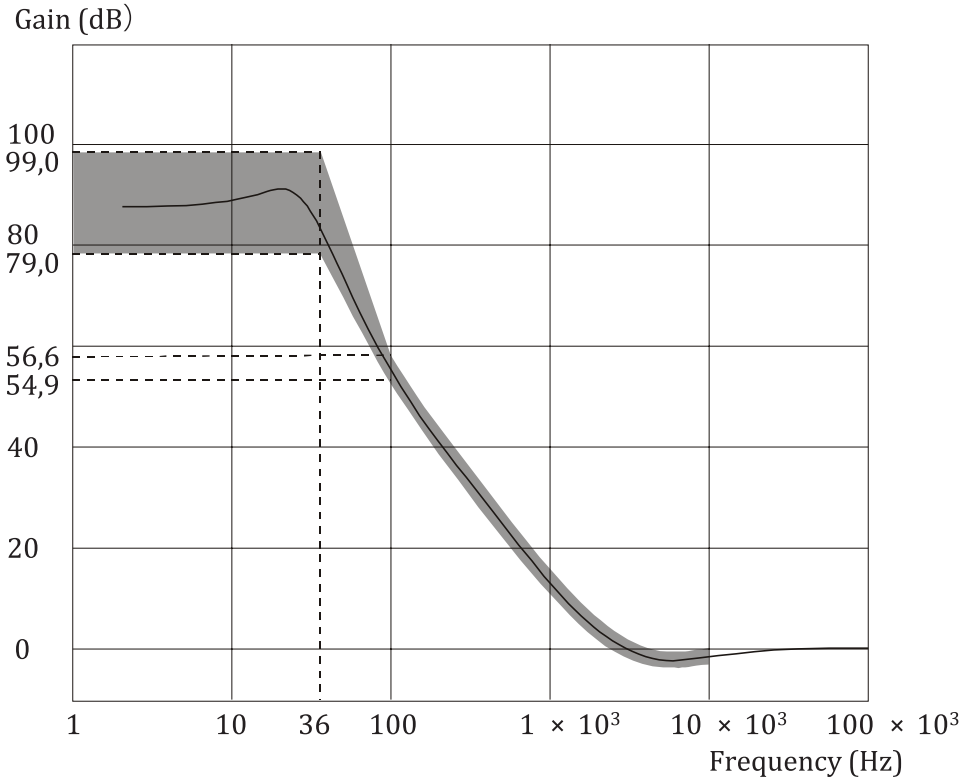



**Figure 9 — Servo characteristic for radial tracking at 1x measurement velocity**

The crossover frequency $f_0$ of $H_N(f)$ (see 9.9), in kHz, which is used to define the limits of $|1+H(f)|$ is specified by Formula (13), where $\alpha_{max}$ = 2,2 m/s$^2$ is the worst-case maximum expected radial acceleration due to local disturbances, and $\alpha_{max}$ is multiplied by a factor $m$ = 1,25 for servo margin. The tracking error, $e_{max}$, caused by this $m \times \alpha_{max}$ shall be 16 nm. Thus, the 0-dB crossover frequency shall be as follows:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{3\times m\times \alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{3\times 1{,}25\times 2{,}2}{16\times 10^{-9}}} = 3{,}6 \tag{13}$$

The integrator shall be first order with crossover frequency of $f_{int}$ = 100 Hz [see Formulae (14) to (16)].

In the frequency range 100 Hz to 10 kHz:

$$0{,}9\times|1+H_N(f)| \le |1+H(f)| \le 1{,}1\times|1+H_N(f)| \tag{14}$$

In the frequency range 36 Hz to 100 Hz:

$$0{,}9\times|1+H_N(f)| \le |1+H(f)| \le 1{,}1\times|1+H_N(f_{int})|\times\left(\frac{f_{int}}{f}\right)^{4{,}78} \tag{15}$$

In the frequency range up to 36 Hz (in dB):

$$79{,}0 \le |1+H(f)| \le 99{,}0 \tag{16}$$

The frequency $f_x$, in kHz, has the following value determined by Formula (17):

$$f_x = \frac{1}{2\pi}\sqrt{\frac{\alpha_{max}}{e_{max}}} = \frac{1}{2\pi}\sqrt{\frac{2{,}2}{16\times 10^{-9}}} \approx 1{,}8 \tag{17}$$

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### 9.11.3 Reference servo for radial tracking at 2x measurement velocity

For the open-loop transfer function $H(f)$ of the reference servo for radial tracking, $|1+H(f)|$ is limited as schematically shown by the shaded area of Figure 10.

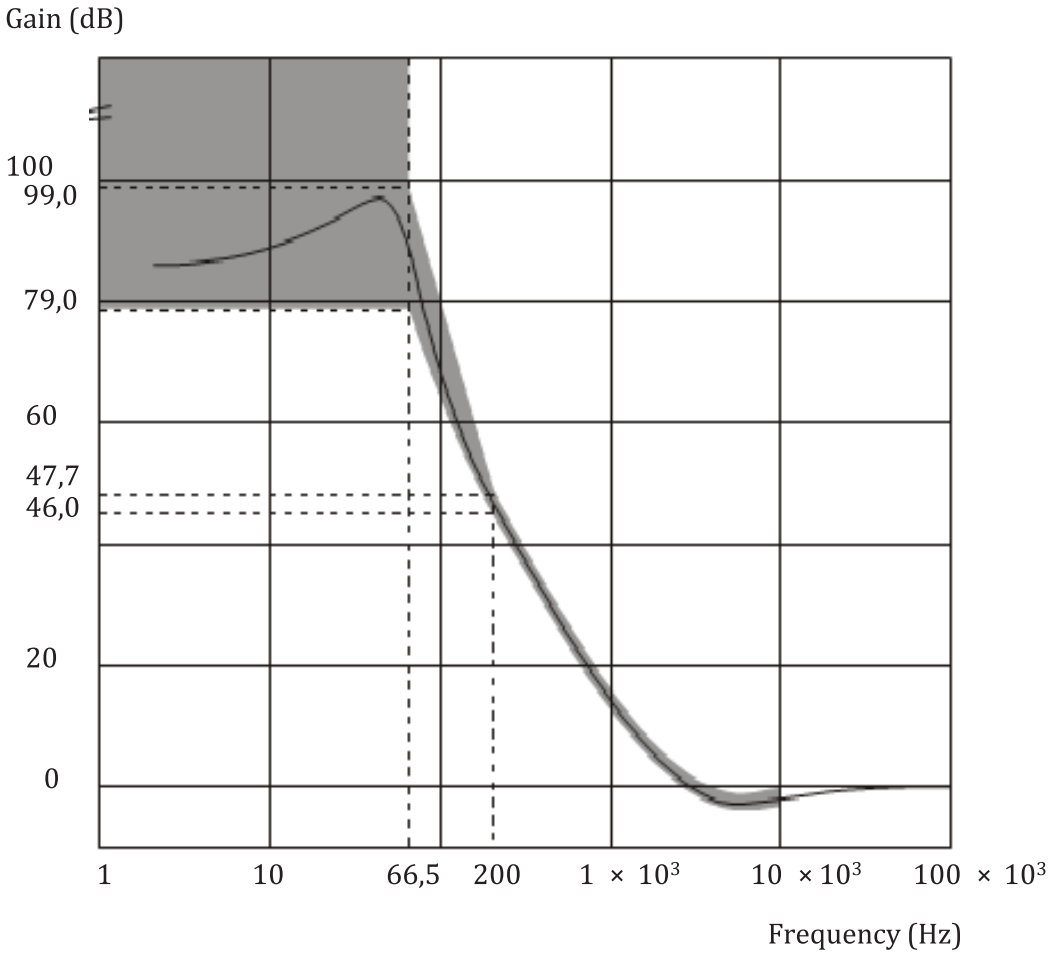



**Figure 10 — Servo characteristic for radial tracking at 2x measurement velocity**

The 0 dB crossover frequency, $f_{0,}$ shall be 3,6 kHz, the same as the measurement condition for the 1x measurement velocity. For the maximum residual tracking error of 20 nm (see 11.5.4), this corresponds to an acceleration, $\alpha_{max}$ in m/s$^2$, as per Formula (18):

$$\alpha_{max} = \frac{(2\pi \times f_0)^2}{3} \times e_{max} = \frac{(2\pi \times 3{,}6 \times 10^3)^2}{3} \times 20 \times 10^{-9} = 3{,}4 \quad (18)$$

The integrator shall be second order ($K$ = 2) with the crossover frequency of $f_{int}$ = 200 Hz [see Formulae (19) to (21)].


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In the frequency range 200 Hz to 10 kHz:

$$0,9\times\left|1+H_N(f)\right|\leq\left|1+H(f)\right|\leq 1,1\times\left|1+H_N(f)\right| \tag{19}$$

In the frequency range 66,5 Hz to 200 Hz:

$$0,9\times\left|1+H_N(f)\right|\leq\left|1+H(f)\right|\leq 1,1\times\left|1+H_N(f_{\text{int}})\right|\times\left(\frac{f_{\text{int}}}{f}\right)^{5,36} \tag{20}$$

In the frequency range up to 66,5 Hz (in dB):

$$\left|1+H(f)\right|\geq 79,0 \tag{21}$$

# 10 Dimensional characteristics

## 10.1 General

Dimensional characteristics are specified for those parameters deemed mandatory for interchange and compatible use of the disk. Where there is freedom of design, only the functional characteristics of the elements described are indicated. The enclosed drawing, Figure 11 shows the dimensional requirements in summarized form. The different parts of the disk are described from the centre hole to the outside rim.

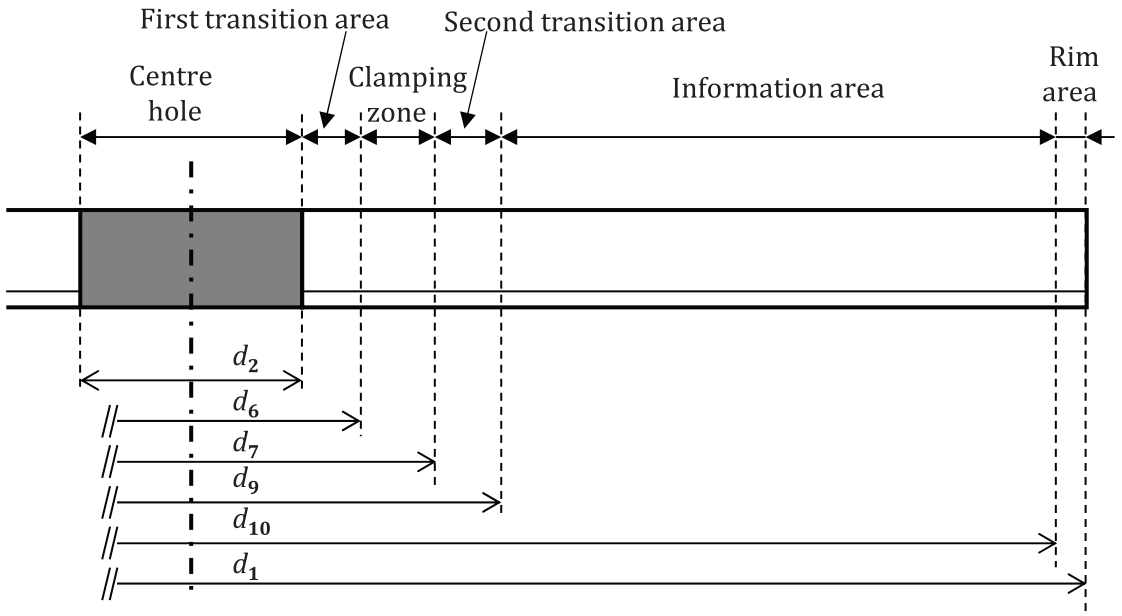



**Figure 11 — Overview of disk dimensions**

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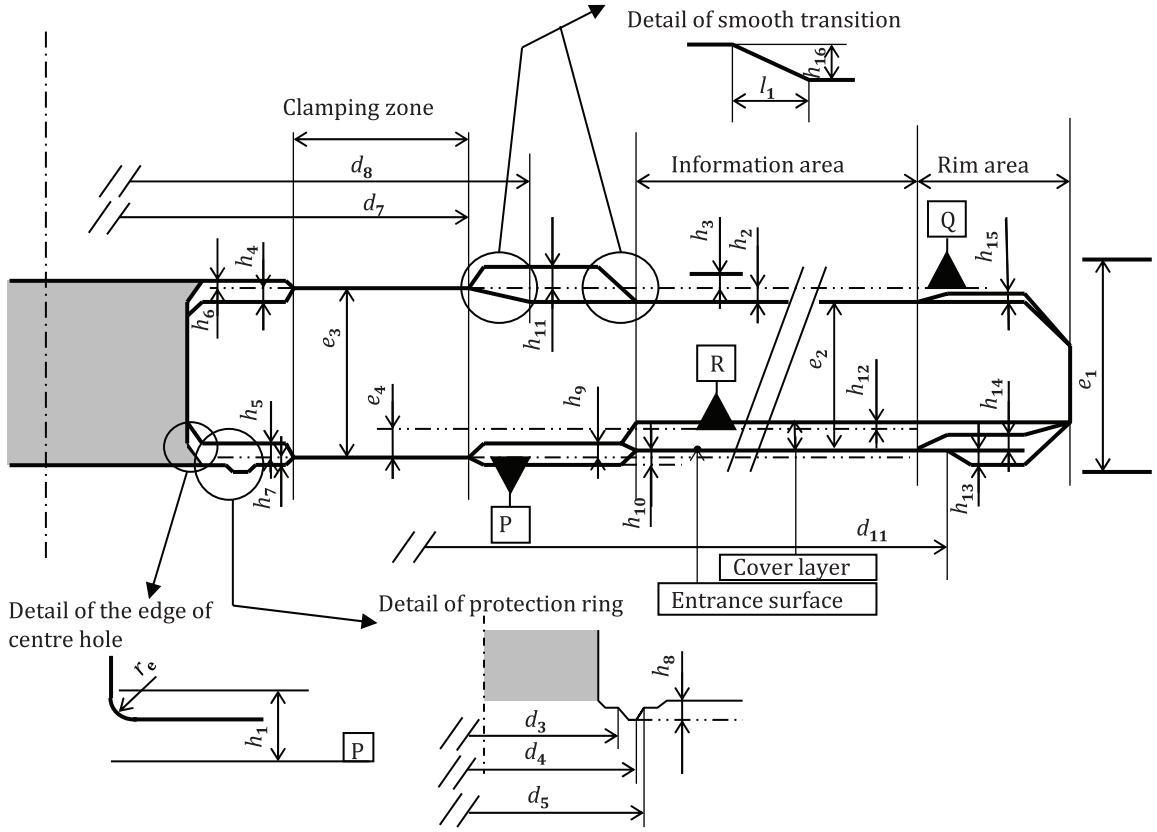



**Figure 12 — Details of disk dimensions for type TL disk and type QL disk**

## 10.2 Disk reference planes and reference axis

For disk reference planes, see also Figure 12, Figure 0.2 and Figure 13.

The disk reference plane P is the plane determined by the surface of the clamping zone (see 10.6) at the read-out side of the disk.

The disk reference plane Q is the plane determined by the surface of the clamping zone at the substrate side of the disk.

The reference axis A is the axis through the middle of the centre hole, perpendicular to the disk reference plane P.

The disk reference plane R is a plane parallel to the disk reference plane P. The distance between disk reference plane R and disk reference plane P shall be $e_4$ = (100 ± 25) µm towards the inside of the disk (see Figure 12, Figure 0.2 and Figure 13).

The disk reference plane R shall intersect with recording layer L0 at layer L0's average position between radius $r_a$ = 23 mm and radius $r_b$ = 24 mm (layer L0 is the deepest recording layer on a TL disk and a QL disk).


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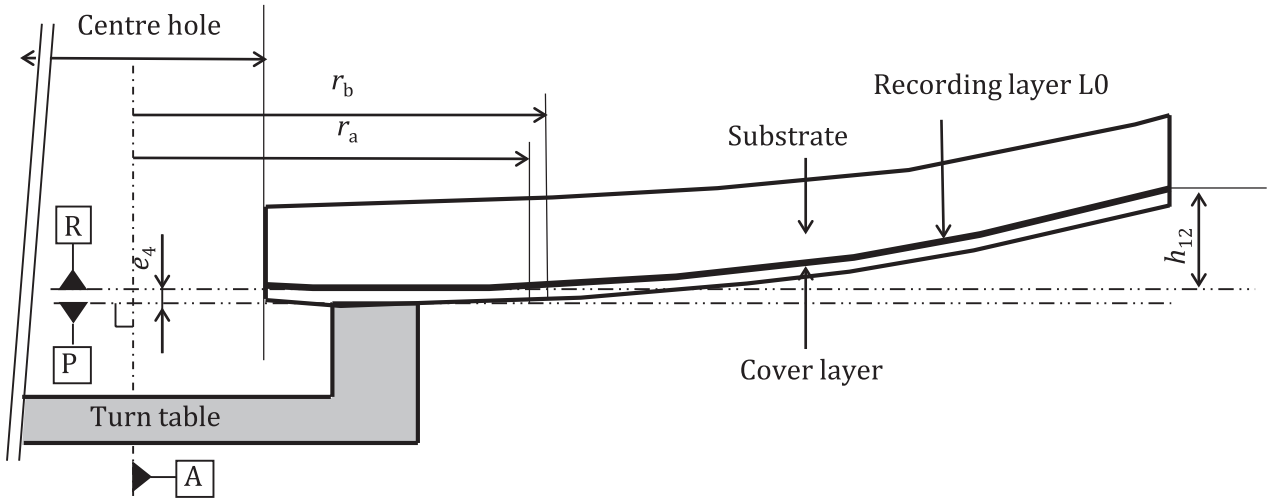



**Figure 13 — Details of disk reference planes P and R and recording layer L0**

## 10.3 Overall dimensions

The overall outer diameter of the disk shall be $d_1$ = (120,0 ± 0,3) mm (see Figure 11).

The diameter of the centre hole shall be $d_2 = 15{,}00^{+0{,}10}_{0{,}00}$ mm (see Figure 11).

There shall be no burr on the edge of the centre hole at the read-out side.

The edge of the centre hole at the read-out side is the reference for centring the disk and shall be rounded off or chamfered. The rounding radius shall be maximum $r_e$ = 0,1 mm. The height of the chamfer shall be maximum 0,1 mm above the bottom surface of the first transition area. The rounding or chamfer shall be maximum $h_1$ = 0,25 mm from disk reference plane P (see detail in Figure 12 and Figure O.2).

The maximum thickness of the disk is defined as the distance in the direction of the reference axis A between the highest structure protruding from the entrance surface of the disk and the highest structure protruding from the top surface of the disk.

The maximum thickness of the disk, including cover layer, protective coating and label printing, at any radius shall be $e_1$ = 1,40 mm for a type TL disk and a type QL disk (see Figure 12). See Annex O for a type TL/D disk.

The minimum thickness of the disk in the information area shall be $e_2$ = 0,90 mm.

Outside the clamping zone, the top surface may be inside the disk reference plane Q by maximum $h_2$ = 0,4 mm.

Outside the clamping zone, the top surface may be outside the disk reference plane Q by maximum $h_3$ = 0,1 mm (see Figure 12).

The parameters $h_2$ and $h_3$ are only for a type TL disk and a type QL disk.

## 10.4 First transition area

In the inner area inside the clamping zone ($d < d_6$), the surfaces may be inside the disk reference planes P and Q by maximum $h_5$ = 0,20 mm and maximum $h_4$ = 0,12 mm, respectively. These surfaces may be uneven or may have burrs up to maximum $h_7$ = 0,05 mm and maximum $h_6$ = 0,05 mm outside the disk reference planes P and Q, respectively (see Figure 11, Figure 12 and Figure O.2).

The parameters $h_4$ and $h_6$ are only for a type TL disk and a type QL disk.

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## 10.5 Protection ring

An optional ring-shaped protrusion in the inner area of the disk that can prevent full contact between the surface of the disk and a surface on which such a disk is laid down. By applying such a ring, the chance for damage to the read-out side of the disk can be minimized.

When applied, the protection ring shall be located between diameter $d_3$ = 17,5 mm and diameter $d_5$ = 21,0 mm. Between $d_3$ and diameter $d_4$ = 20,5 mm the height of the protection ring shall be maximum $h_8$ = 0,12 mm above the clamping surface.

Between $d_4$ and $d_5$, the height of the protection ring shall sink gradually to the surrounding surface (see Figure 12).

## 10.6 Clamping zone

The inner diameter of the disk clamping zone shall be $d_6 \leq 23{,}0$ mm (see Figure 11).

The outer diameter of the disk clamping zone shall be $d_7 \geq 33{,}0$ mm (see Figure 11, Figure 12 and Figure O.2).

The thickness of the disk within the clamping zone shall be $e_3 = 1{,}20^{+0{,}10}_{-0{,}05}$ mm (see Figure 12 and Figure O.2).

Within the clamping zone ($d_6 < d < d_7$), both sides of the disk shall be flat within maximum 0,1 mm.

Within the clamping zone ($d_6 < d < d_7$), both sides of the disk shall be parallel within maximum 0,1 mm.

## 10.7 Second transition area

The second transition area is an area between the clamping zone and the information area: $d_7 < d < d_9$ (see Figure 11).

In the area, the surface at the read-out side of the disk may be inside the disk reference plane P by maximum $h_9$ = 0,12 mm. This surface may be outside the entrance surface in the information area by maximum $h_{10}$ = 0,01 mm (see Figure 12 and Figure O.2).

In the area, the top surface of the disk may be outside the disk reference plane Q by maximum $h_{11}$ = 0,2 mm.

The step from the top surface in the area to the top surface in the information area is $h_{16}$. The distance between the start and the end diameters of the step is $l_1$. If $h_{16} > 0{,}2$ mm, then the slope down to the top surface of the information area shall be smooth and $l_1$ shall be >1,8 mm as indicated in Figure 12. If the top surface in the information area is stepped down from the top surface in the area, then the step shall end within diameters $d_8$ = 40,0 mm.

The parameters $h_{11}$, $h_{16}$, $l_1$ and $d_8$ are only for a type TL disk and a type QL disk.

## 10.8 Information area

### 10.8.1 General

The information area shall extend from diameter $d_9$ = 42 mm to diameter $d_{10}$ = 117 mm (see Figure 11 and Figure 14).

On each recording layer the data zone shall be located between inner diameter, $d_{DZI}$, and outer diameter, $d_{DZO}$. The data zones on all recording layers shall have the same storage capacity.

The inner diameter, $d_{DZI}$, on recording layer $n$ shall be $d_{DZIn} = 48{,}0^{0{,}0}_{-0{,}2}$ mm and the outer diameter, $d_{DZO}$, on recording layer n shall be $d_{DZOn} \leq 116{,}2$ mm.


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The area between $d_9$ and $d_{DZI}$ is called the inner zone, and the area between $d_{DZO}$ and $d_{10}$ is called the outer zone (see Figure 14).

The total thickness of the disk in the information area is as specified in 10.3.

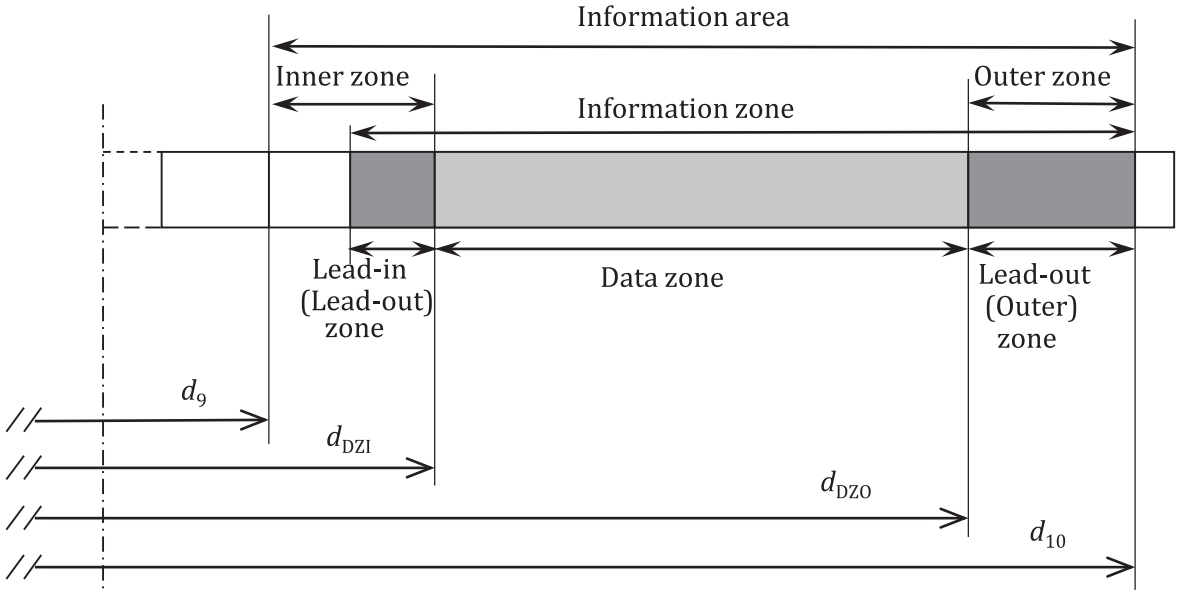



**Figure 14 — Division of information area**

### 10.8.2 Subdivision of information zone on TL disk

The information area is used to record the information zone, divided over the three recording layers.

The information zone is subdivided in the following main parts (see Figure 15):

On recording layer L0:

— a lead-in zone (part of the inner zone 0);

— a data zone 0;

— a outer zone 0.

On recording layer L1:

— a outer zone 1;

— a data zone 1;

— a inner zone 1.

On recording layer L2:

— a inner zone 2;

— a data zone 2;

— a lead-out zone (outer zone 2).

On layer L0 and layer L2, the spiral grooves shall run from the inner side of the disk towards the outer side of the disk.

On layer L1, the spiral groove shall run from the outer side of the disk towards the inner side of the disk.

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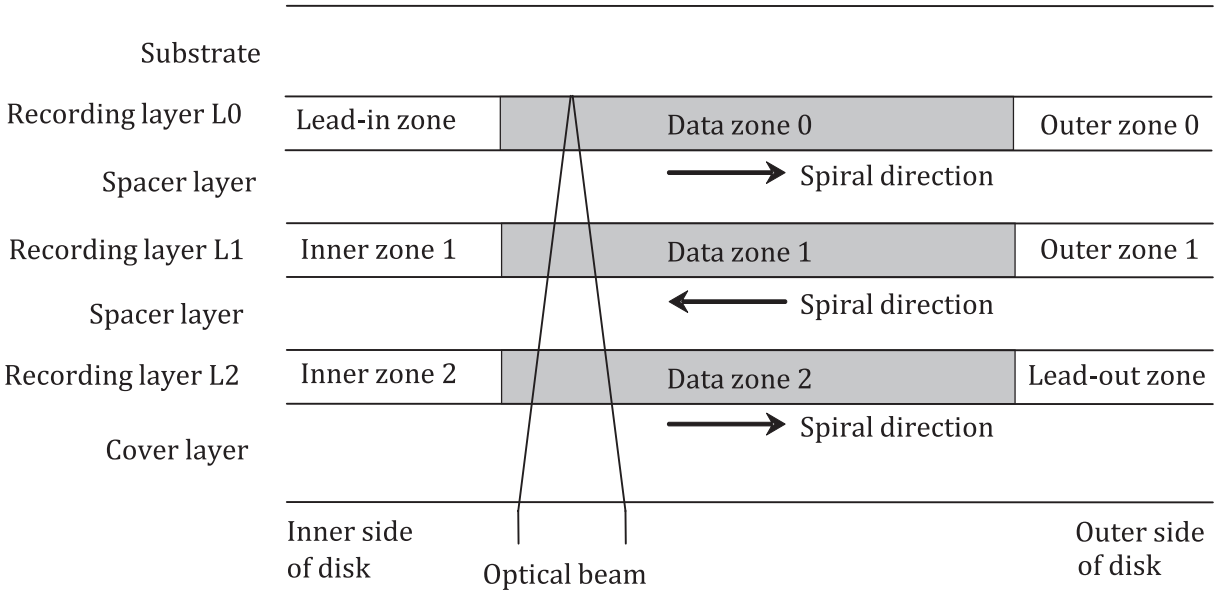



**Figure 15 — Use of information area on TL disk**

The lead-in zone starts in the area extending from diameter 44,0 mm to diameter 44,4 mm and shall end at the beginning of the data zone 0 at diameter $d_{DZI0}$.

The outer zone 0 shall start at the end of the data zone 0 at diameter $d_{DZO0}$ and shall end at diameter minimum 117 mm.

The outer zone 1 shall start at diameter minimum 117 mm and shall end at the beginning of data zone 1 at diameter $d_{DZO1}$.

The inner zone 1 shall start at the end of the data zone 1 $d_{DZI1}$ and shall end at the diameter maximum 44,4 mm.

The inner zone 2 shall start at the diameter maximum 44,4 mm and shall end at the beginning of the data zone 2 at diameter $d_{DZI2}$.

The lead-out zone shall start at the end of the data zone 2 at diameter $d_{DZO2}$ and shall end at diameter minimum 117 mm.

### 10.8.3 Subdivision of information zone on QL disk

The information area is used to record the information zone, divided over the four recording layers.

The information zone is subdivided into the following main parts (see Figure 16):

On recording layer L0:

— a lead-in zone (part of the inner zone 0);

— a data zone 0;

— a outer zone 0.

On recording layer L1:

— a outer zone 1;

— a data zone 1;

— a inner zone 1.


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On recording layer L2:

— a inner zone 2;

— a data zone 2;

— a outer zone 2.

On recording layer L3:

— a outer zone 3;

— a data zone 3;

— a lead-out zone (part of the inner zone 3).

On layer L0 and layer L2, the spiral grooves shall run from the inner side of the disk towards the outer side of the disk.

On layer L1 and layer L3, the spiral grooves shall run from the outer side of the disk towards the inner side of the disk.

The lead-in zone starts in the area extending from diameter 44,0 mm to diameter 44,4 mm and shall end at the beginning of the data zone 0 at diameter $d_{DZI0}$.

The outer zone 0 shall start at the end of the data zone 0 at diameter $d_{DZO0}$ and shall end at diameter minimum 117 mm.

The outer zone 1 shall start at diameter minimum 117 mm and shall end at the beginning of data zone 1 at diameter $d_{DZO1}$.

The inner zone 1 shall start at the end of the data zone 1 at diameter $d_{DZI1}$ and shall end at the diameter maximum 44,4 mm.

The inner zone 2 shall start at the diameter maximum 44,4 mm and shall end at the beginning of the data zone 2 at diameter $d_{DZI2}$.

The outer zone 2 shall start at the end of the data zone 2 at diameter $d_{DZO2}$ and shall end at diameter minimum 117 mm.

The outer zone 3 shall start at diameter minimum 117 mm and shall end at the beginning of data zone 3 at diameter $d_{DZO3}$.

The lead-out zone shall start at the end of the data zone 3 at diameter $d_{DZI3}$ and shall end in the area extending from diameter 44,0 mm to diameter 44,4 mm.

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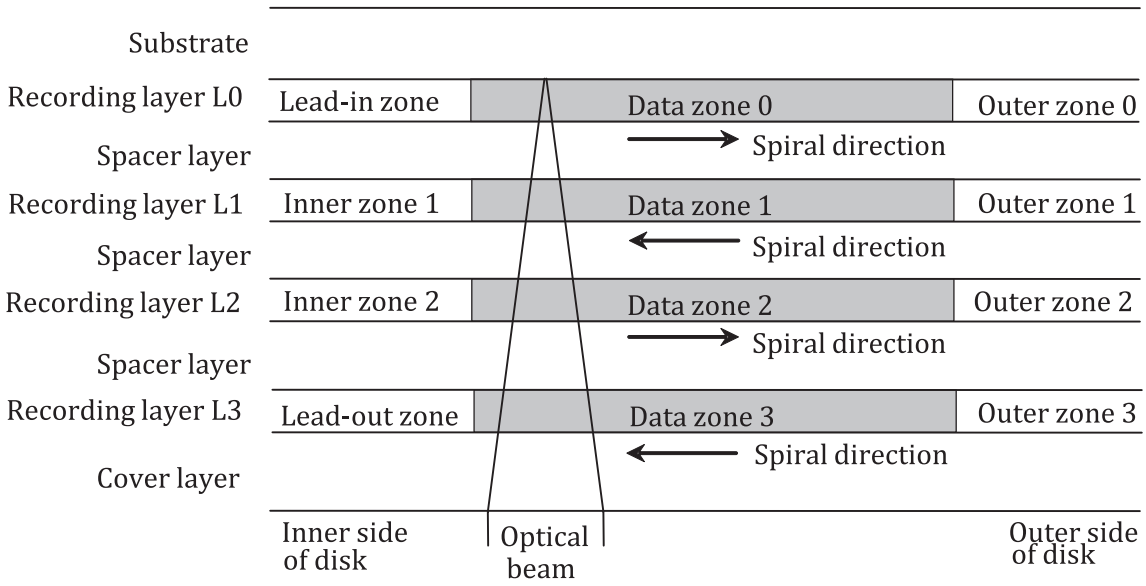



**Figure 16 — Use of information area on QL disk**

### 10.9 Rim area

The rim area is the area outside the information area, starting at $d_{10}$ and extending to the outer diameter of the disk (see Figure 11).

In the first 0,5 mm of the rim area, the surface at the read-out side of the disk shall not be outside the entrance surface in the information area.

In the remainder of the rim area, the surface at the read-out side of the disk shall not be outside the entrance surface in the information area by maximum $h_{13}$ = 0,05 mm (see Figure 12 and Figure 0.2).

In the rim area, the surface at the read-out side of the disk may be inside the entrance surface in the information area by maximum $h_{14}$ = 0,12 mm (see Figure 12 and Figure 0.2).

In the rim area, the top surface of the disk shall not be outside the top surface in the information area by maximum $h_{15}$ = 0,05 mm (see Figure 12).

The parameter $h_{15}$ is only for a type TL disk and a type QL disk.

## 11 Mechanical characteristics

### 11.1 Mass

The mass, $m$, of the disk shall be 12 g ≤ $m$ ≤ 17 g.

### 11.2 Moment of inertia

The moment of inertia of the disk shall be ≤0,032 g·m$^2$.

### 11.3 Dynamic imbalance

The dynamic imbalance of the disk shall be ≤2,5 g·mm.


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## 11.4 Axial runout

### 11.4.1 General

When measured by an optical system using the reference servo for axial tracking, and with the disk rotating at a half of the recording velocity, the distance between each recording layer and the disk reference plane R (see Figure 12, Figure 0.2 and Figure 13) in the direction of the reference axis A shall be maximum $h_{12}$ = 0,3 mm over the entire disk.

Within one track (one revolution), the deviation of each recording layer from its average position in the direction of the reference axis A shall be maximum 0,1 mm.

Due to the integrator function in the reference servo (see 9.10), this component is suppressed sufficiently such that the residual tracking errors as defined in 11.4.2 and 11.4.3 are mainly due to local disturbances.

### 11.4.2 Residual axial tracking error for 1x measurement velocity

The residual axial tracking error of each recording layer for frequencies below 1,6 kHz (equals $f_x$, see 9.10.2), measured using the reference servo for axial tracking as specified in 9.10.2, shall be maximum 45 nm. (displacement of the objective lens needed to move the focal point of the optical beam onto the recording layer) with the disk rotating at 1x reference velocity, 3,688 m/s for a TL disk and 3,845 m/s for a QL disk respectively, and with the read power at (0,70 ± 0,10) mW for any layers for a TL and a QL disk. It is recommended to measure the residual axial tracking error signal in a short period to avoid the deterioration of the read stability at 1x reference velocity.

Spikes in the residual axial tracking error signal due to local defects, such as dust and scratches, shall be excluded.

The measuring filter shall be a Butterworth LPF, with $f_{-3dB}$ = 1,6 kHz and slope = –60 dB/decade.

This means that, for frequencies <1,6 kHz, the maximum local acceleration of the recording layer in the direction of the reference axis A does not exceed 6,0 m/s$^2$.

The rms noise value of the residual error signal in the frequency band from 1,6 kHz to 10 kHz, measured with an integration time of 20 ms, and using the reference servo for axial tracking, shall be maximum 32 nm. The measuring filter shall be a Butterworth BPF, from $f_{-3dB}$ = 1,6 kHz with slope = +60 dB/decade, to $f_{-3dB}$ = 10 kHz with slope = –60 dB/decade.

### 11.4.3 Residual axial tracking error for 2x measurement velocity

The residual axial tracking error of each recording layer for frequencies below 3,2 kHz, measured using the reference servo for axial tracking as specified in 9.10.3, shall be maximum 80 nm (displacement of the objective lens needed to move the focal point of the optical beam onto the recording layer) with the disk rotating at 2x reference velocity, 7,375 m/s for a TL disk and 7,690 m/s for a QL disk respectively, and with the read power (see 9.4).

Spikes in the residual axial tracking error signal due to local defects, such as dust and scratches, shall be excluded. For 4x measurement velocity local defects that cause large axial tracking errors shall be taken into account as described in I.10.

The measuring filter shall be a Butterworth LPF, with $f_{-3dB}$ = 3,2 kHz and slope = –60 dB/decade.

This means that, for frequencies <3,2 kHz, the maximum local acceleration of the recording layer in the direction of the reference axis A does not exceed 10,8 m/s$^2$ (see 9.10.3). However, due to the additional reduction of low-frequency components by the second order integrator function, the maximum acceleration at frequencies below about 400 Hz can reach values up to 45 m/s$^2$.

The rms noise value of the residual error signal in the frequency band from 3,2 kHz to 20 kHz, measured with an integration time of 10 ms, and using the reference servo for axial tracking, shall be maximum

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32 nm. The measuring filter shall be a Butterworth BPF, from $f_{-3dB}$ = 3,2 kHz with slope = +60 dB/decade, to $f_{-3dB}$ = 20 kHz with slope = –60 dB/decade.

## 11.5 Radial runout

### 11.5.1 General

The runout of the outer edge of the disk shall be maximum 0,3 mm pp.

The radial runout of the tracks in each recording layer (including eccentricity and unroundness) shall be measured by an optical system using the reference servo for radial tracking, while the disk is rotating at a half of the recording velocity.

The radial runout shall be maximum 75 µm pp.

Due to the integrator function in the reference servo (see 9.11), this component is suppressed sufficiently such that the residual tracking errors as defined in 11.5.2 and 11.5.3 are mainly due to local disturbances.

The residual tracking error shall be determined by applying the radial PP read channel ($I_1 - I_2$) signal for both measurement and radial servo control purposes as indicated in Figure 5.

### 11.5.2 Residual radial tracking error on 1x measurement velocity

The residual radial tracking error in each recording layer for frequencies below 1,8 kHz (equals $f_x$, see 9.11.2), measured using the reference servo for radial tracking as specified in 9.11.2 shall be maximum 13 nm with the disk rotating at 1x reference velocity, 3,688 m/s for a TL disk and 3,845 m/s for a QL disk respectively, and with the read power at (0,70 ± 0,10) mW for any layers of a TL and a QL disk. It is recommended to measure the residual radial tracking error signal in a short period to avoid the deterioration of the read stability at 1x reference velocity.

Spikes in the residual radial tracking error signal due to local defects, such as dust and scratches, shall be excluded.

The measuring filter shall be a Butterworth LPF with $f_{-3dB}$ = 1,8 kHz and slope = –60 dB/decade.

This means that for frequencies <1,8 kHz the maximum acceleration of the tracks in the radial direction will not exceed 2,2 m/s$^2$.

The rms noise value of the residual error signal in the frequency band from 1,8 kHz to 10 kHz, measured with an integration time of 20 ms, using the reference servo for radial tracking, shall be maximum 9,2 nm. The measuring filter shall be a Butterworth BPF, from $f_{-3dB}$ = 1,8 kHz with slope = +60 dB/decade, to $f_{-3dB}$ = 10 kHz with slope = –60 dB/decade.

### 11.5.3 Residual radial tracking error on 2x measurement velocity

The residual radial tracking error in each recording layer for frequencies below 3,6 kHz, measured using the reference servo at for radial tracking as specified in 9.11.3, shall be maximum 20 nm with the disk rotating at 2x reference velocity, 7,375 m/s for a TL disk and 7,690 m/s for a QL disk, respectively, and with the read power refers to 9.4.

Spikes in the residual radial tracking error signal due to local defects, such as dust and scratches, shall be excluded.

The measuring filter shall be a Butterworth LPF with $f_{-3dB}$ = 3,6 kHz and slope = –60 dB/decade.

This means that for frequencies <3,6 kHz the maximum local acceleration in the radial direction does not exceed 3,4 m/s$^2$ (see 9.11.3). However, due to the additional reduction of low-frequency components by the second-order integrator function, the maximum acceleration at frequencies below about 400 Hz can reach values up to 15 m/s$^2$.


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The rms noise value of the residual error signal in the frequency band from 3,6 kHz to 20 kHz, measured with an integration time of 10 ms, and using the reference servo for radial tracking, shall be maximum 9,2 nm. The measuring filter shall be a Butterworth BPF, from $f_{-3dB}$ = 3,6 kHz with slope = +60 dB/decade, to $f_{-3dB}$ = 20 kHz with slope = −60 dB/decade.

### 11.6 Durability of cover layer

#### 11.6.1 Impact resistance of cover layer

To prevent excessive disk damage in case an object lens hits the entrance surface at the read-out side of the disk, the surface of the disk should have a minimum impact resistance. This impact resistance can be tested by a procedures described in Annex L.

#### 11.6.2 Scratch resistance of cover layer

To prevent excessive scratching, the surface of the disk shall have a minimum hardness. The scratch resistance shall be tested by a procedure described in Annex C.

#### 11.6.3 Repulsion of fingerprints by cover layer

To prevent excessive contamination, the surface of the disk should repel grime as much as possible. The repulsion of grime shall be tested by a procedure described in Annex D.

## 12 Optical characteristics in information area

### 12.1 General

The following requirements shall be fulfilled within the information area of the disk.

These specifications of the transmission stacks (TS) include all possible layers on top of the recording layer concerned (such as gluing layers in case of foils, the spacer layers and all the semi-transparent recording stack layer of layer L*n* in case of TS0, the cover layer and possibly a protective coating).

### 12.2 Refractive index of the transmission stacks (TS)

If the layers making up the total TS have different refractive indexes, then the procedure described in Annex A shall be followed.

The refractive index $n$ of the cover layer and spacer layer of the disk shall be as per Formula (22):

$$1{,}45 \leq n \leq 1{,}70 \tag{22}$$

### 12.3 Thickness of transmission stacks (TS)

#### 12.3.1 Thickness of transmission stack of TL disks

The average thickness between radius $r_a$ and radius $r_b$ is called the reference thickness of the related transmission stack (TS0, TS1 or TS2) on the disk.

The thicknesses of TS0, TS1 and TS2, measured over the whole disk, shall fulfil requirements a) to h).

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In Figure 17, for reference to requirements a) to c), the curves show the thickness of equivalent spherical aberration. The ratio of the thickness with arbitrary refractive index $n$ to that with refractive index 1,60 is expressed approximately by the function of $g(n)$ in Formula (23):

$$g(n) = -1{,}111\ 1n^3 + 5{,}814\ 3n^2 - 9{,}880\ 8n + 6{,}476\ 0 \quad (23)$$

Figure 18 shows a coefficient function for converting the actual thickness to an effective thickness for requirements f). The actual thickness means its physical value. The effective thickness means imaginary value where the refractive index is assumed to be 1,60.

The actual thickness of arbitrary refractive index is converted to an effective thickness of standard refractive index of 1,60. The defocus values of both the actual and effective thickness are the same. In this clause, defocus is defined as the focus position movement of the light going through the transparent medium with each thickness and each refractive index.

The coefficient function of $f(n)$ equals $\tan(\theta_r)/\tan(\theta_o)$, where $\theta_o$ and $\theta_r$ are the converging angles in the transmission stack with each refractive indexes of 1,60 and arbitrary $n$, respectively. The function $f(n)$ is expressed approximately by Formula (24):

$$f(n) = -1{,}088\ 0n^3 + 6{,}102\ 7n^2 - 12{,}042n + 9{,}100\ 7 \quad (24)$$

a) The thickness of the TS0 (all layers on top of layer L0) as determined by its refractive index shall be within the uppermost shaded area in Figure 17 (In case of a refractive index of $n$, the thickness shall be between $94{,}0 \times g(n)$ µm and $106{,}0 \times g(n)$ µm, the dashed curve indicates the nominal thickness as a function of the refractive index).

b) The thickness of the TS1 (all layers on top of layer L1) as determined by its refractive index shall be within the middle shaded area in Figure 17 (in case of a refractive index of $n$, the thickness shall be between $69{,}0 \times g(n)$ µm and $81{,}0 \times g(n)$ µm, the dashed curve indicates the nominal thickness as a function of the refractive index).

c) The thickness of the TS2 (all layers on top of layer L2) as determined by its refractive index shall be within the lowest shaded area in Figure 17 [in case of a refractive index of $n$ the thickness shall be between $52{,}0 \times g(n)$ µm and $62{,}0 \times g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index].

d) The thickness of the spacer layer1 ($S_1$) sandwiched by layer L0 and layer L1 shall be between 20,0 µm and 30,0 µm.

e) The thickness of the spacer layer2 ($S_2$) sandwiched by layer L1 and layer L2 shall be between 13,0 µm and 23,0 µm.

f) The thickness differences shall meet the requirement $C - (S_1 + S_2) \geq 1{,}0$ µm and $S_1 - S_2 \geq 1{,}0$ µm [$C$, $S_1$, $S_2$ shall be converted from their actual thicknesses to effective thicknesses by being multiplied by coefficient $f(n)$ shown in Figure 18, where the thickness of TS2 equals the cover layer thickness ($C$) and $n$ is the refractive index].

g) The maximum deviation $\Delta D$ of the thickness of TS0 and TS1 from their respective reference thicknesses shall meet the requirement $|\Delta D| \leq 2{,}5$ µm.

h) The maximum deviation $\Delta D$ of the thickness of TS2 from its reference thickness shall meet the requirement $|\Delta D| \leq 2{,}0$ µm.

### 12.3.2 Example of target thickness of spacer layers for TL disks

In mass production, simple target values for thicknesses are useful.


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It is recommended that a) to c) are fulfilled. Then, requirements a) to f) of 12.3.1 are always fulfilled for a refractive index of 1,60.

a) The thickness of the spacer layer1 ($S_1$) should be (25,0 ± 2,0) µm.

b) The thickness of the spacer layer2 ($S_2$) should be (18,0 ± 2,0) µm.

c) The thickness of TS2 (equals $C$) should be (57,0 ± 2,0) µm.

### 12.3.3 Thickness of transmission stacks of QL disks

The average thickness between radius 23 mm and 24 mm is called the reference thickness of the related transmission stack (TS0, TS1, TS2 or TS3) on the disk.

The thicknesses of TS0, TS1, TS2 and TS3, measured over the whole disk, shall fulfil the following ten requirements:

In Figure 19, for reference to requirements a) to d), the curves show the thicknesses having equivalent spherical aberration. The ratio of thickness with arbitrary refractive index $n$ to that with refractive index 1,60 is expressed approximately by the function of $g(n)$ in Formula (25):

$$g(n) = -1{,}111\ 1n^3 + 5{,}814\ 3n^2 - 9{,}880\ 8n + 6{,}476\ 0 \quad (25)$$

Figure 18 shows a conversion coefficient for converting the actual thickness to an effective thickness for requirement h). The actual thickness means its physical value. The effective thickness means an imaginary value when refractive index is assumed to be 1,60.

The actual thickness under arbitrary refractive index is converted to an effective thickness with standard refractive index of 1,60. The defocus values of both the actual and effective thicknesses are the same. In this section, defocus is defined as the focus position movement of the light going through the transparent medium with each thickness and each refractive index.

The coefficient function of $f(n)$ equals $\tan(\theta_r)/\tan(\theta_0)$, where $\theta_0$ and $\theta_r$ are converging angle in disk substrate with each refractive index of 1,60 and arbitrary n, respectively. The function $f(n)$ is expressed approximately by Formula (26):

$$f(n) = -1{,}088\ 0n^3 + 6{,}102\ 7n^2 - 12{,}042n + 9{,}100\ 7 \quad (26)$$

a) The thickness of TS0 (all layers on top of layer L0) as determined by its refractive index shall be within the uppermost shaded area in Figure 19 [In case of a refractive index of $n$, the thickness shall be between 94,0 × $g(n)$ µm and 106,0 × $g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index].

b) The thickness of the TS1 (all layers on top of layer L1) as determined by its refractive index shall be within the second uppermost shaded area in Figure 19 [In case of a refractive index of $n$, the thickness shall be between 78,5 × $g(n)$ µm and 90,5 × $g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index].

c) The thickness of the TS2 (all layers on top of layer L2) as determined by its refractive index shall be within the second lowest shaded area in Figure 19 [In case of a refractive index of $n$, the thickness shall be between 60,5 × $g(n)$ µm and 69,5 × $g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index].

d) The thickness of the TS3 (all layers on top of layer L3) as determined by its refractive index shall be within the undermost shaded area in Figure 19 [In case of a refractive index of $n$, the thickness shall be between 50,5 × $g(n)$ µm and 56,5 × $g(n)$ µm, and the dashed curve indicates the nominal thickness as a function of the refractive index].

e) The thickness of the spacer layer1 ($S_1$) sandwiched by layer L0 and layer L1 shall be between 11,0 µm and 20,5 µm.

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f) The thickness of the spacer layer2 ($S_2$) sandwiched by layer L1 and layer L2 shall be between 14,5 µm and 24,5 µm.

g) The thickness of the spacer layer3 ($S_3$) sandwiched by layer L2 and layer L3 shall be between 10,0 µm and 16,5 µm.

h) The thickness differences shall meet the requirement $C - (S_1 + S_2 + S_3) \geq 1{,}0$ µm, $S_1 - S_3 \geq 1{,}0$ µm, $S_2 - S_1 \geq 1{,}0$ µm and $S_3 \geq 10{,}0$ µm [$C$, $S_1$, $S_2$, $S_3$ shall be converted from actual thickness to effective thickness by being multiplied by coefficient $f(n)$ shown in Figure 18, where the thickness of TS3 equals the cover layer thickness ($C$), and n is refractive index].

i) The maximum deviation $\Delta D$ of the thickness of the TS0, TS1 and the TS2 from their respective reference thickness shall meet the requirement $|\Delta D| \leq 2{,}5$ µm.

j) The maximum deviation $\Delta D$ of the thickness of the TS3 from its reference thickness shall meet the requirement $|\Delta D| \leq 2{,}0$ µm.

### 12.3.4 Example of target thickness of spacer layers for QL disks

In mass production, simple target values for the thicknesses are useful.

It is recommended that a) to d) be fulfilled. Then, the requirements a) to h) of 12.3.3 are always fulfilled for a refractive index of 1,60.

a) The thickness of the spacer layer1 ($S_1$) should be (15,5 ± 1,5) µm.

b) The thickness of the spacer layer2 ($S_2$) should be (19,5 ± 1,5) µm.

c) The thickness of the spacer layer3 ($S_3$) should be (11,5 ± 1,5) µm.

d) The thickness of TS3 (equals $C$) should be (53,5 ± 1,5) µm.

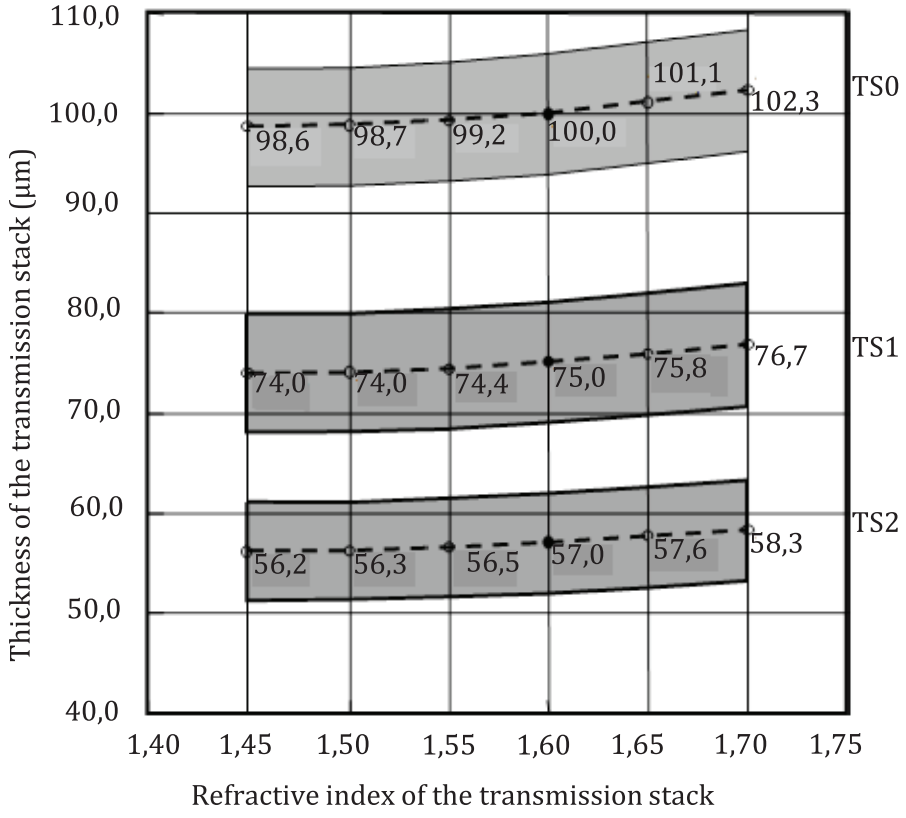



**Figure 17 — Thickness of the transmission stacks as a function of the refractive index**


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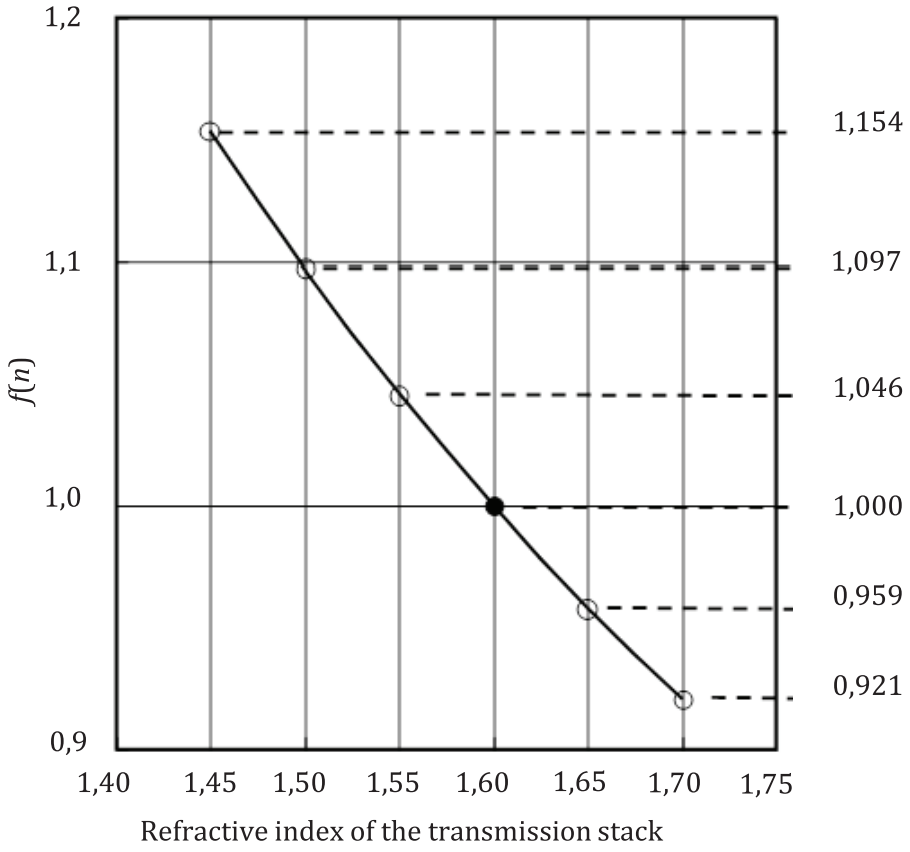



**Figure 18 — Ratio of effective thickness with refractive index 1,60 and that with arbitrary refractive index *n***

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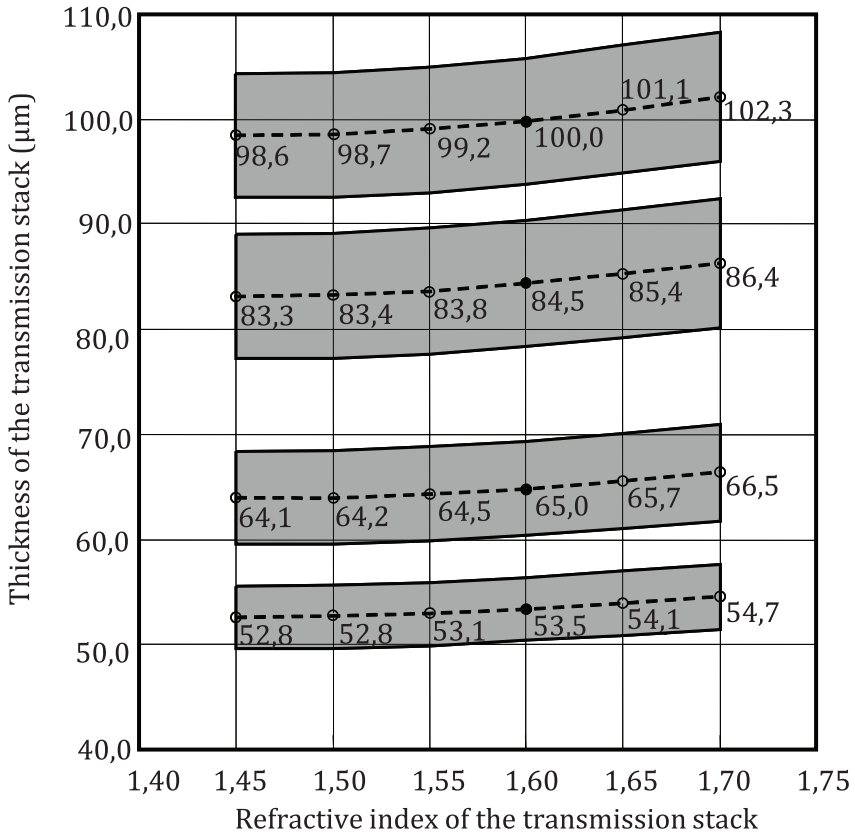



**Figure 19 — Thickness of the transmission stacks as a function of the refractive index**

## 12.4 Reflectivity of recording layers

The reflectivity of each recording layer in the information zone, including the transmission through the cover layer, shall fulfil the following requirements under the measurement conditions of Annex B:

— in unrecorded virgin groove:

  — of layer L0 and layer L1 of a TL disk /layer L0, layer L1 and layer L2 of a QL disk: $R_{g\text{-}v}$ = 1,8 to 4,0 %;

  — of layer L2 of a TL disk / layer L3 of a QL disk: $R_{g\text{-}v}$ = 2,0 to 4,0 %;

— in recorded groove:

  — of layer L0 and layer L1 of a TL disk/ layer L0, layer L1 and layer L2 of a QL disk: $R_{8H}$ = 1,6 to 4,0 %;

  — of layer L2 of a TL disk / layer L3 of QL disk: $R_{8H}$ = 1,8 to 4,0 %;

— at each location on the disk: $0{,}75 \times R_{g\text{-}v} < R_{8H} < 1{,}25 \times R_{g\text{-}v}$.

Written marks shall have a lower reflectivity than the unrecorded layer.


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