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Information technology — Digitally recorded media for information interchange and storage — 120 mm Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per 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 Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Recordable disk

Technologies de l'information — Supports enregistrés numériquement pour échange et stockage d'information — Disques BD enregistrables de 120 mm simple couche (25,0 Go par disque) et double couche (50,0 Go par disque)

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CP 401 • Ch. de Blandonnet 8
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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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 ISO documents 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 30190:2016), which has been technically revised. It also incorporates the Amendment ISO/IEC 30190:2016/Amd 1:2019.

The main change compared to the previous edition is the addition of requirements for physical access control (PAC) 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 Part1 in April 2008, which enabled the recording velocity up to 6x.

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 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 February and January 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 for 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. They are 120 mm single layer (25,0 Gbytes per disk) and dual layer (50,0 Gbytes per disk) BD Recordable disks, 120 mm single layer (25,0 Gbytes per disk) and dual layer (50,0 Gbytes per disk) BD Rewritable disks, 120 mm triple layer (100,0 Gbytes per disk) and quadruple layer (128,0 Gbytes per disk) BD Recordable disks and a 120 mm triple layer (100,0 Gbytes per disk) BD Rewritable disk.

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 systems 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.

ISO and IEC take no position concerning the evidence, validity and scope of this patent right.

The holder of this patent right has assured ISO and IEC that he/she is willing to negotiate licences under reasonable and non-discriminatory terms and conditions with applicants throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO and IEC. Information may be obtained from the patent database available at www.iso.org/patents.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights other than those in the patent database. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

NOTE Blu-ray™, Blu-ray Disc™ and the logos are trademarks of the Blu-ray Disc Association.

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 Single Layer (25,0 Gbytes per disk) and Dual Layer (50,0 Gbytes per disk) BD Recordable disk

1 Scope

This document specifies mechanical, physical and optical characteristics of a 120 mm recordable optical disk with a capacity of 25,0 Gbytes or 50,0 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 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 9352, *Plastics — Determination of resistance to wear by abrasive wheels*

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

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
in-groove
geometry where grooves are farther from the entrance surface of a disk than the lands

4 Symbol and abbreviated terms

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

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EDC	error detection code
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
LAA	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
LTH	low-to-high
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
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.

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 all three types of optical disk according to 5.1.

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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 Conventions and notations

6.1 Levels of grouping

Data is often 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 are 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 $0{,}30 < x_{measured} < 0{,}35$: $x_{rounded} = 0{,}3$);
- 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:

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- 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 notation 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 sequences 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 $8n$ 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 one, this is indicated as: i, (i + step) .. j (e.g. $k = 1, 4$ .. 16, where step = 3).

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, Add_0 .. Add_{255}).

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:

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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

The 120 mm optical disk that is the subject of this document consists of a substrate of about 1,1 mm nominal thickness. Clamping is performed in the clamping zone.

The recording layer of the disk may use high-to-low (HTL) or low-to-high (LTH) technology. Recorded HTL marks have lower reflection than the unrecorded layer(s), recorded LTH marks have higher reflection than the unrecorded layer(s).

This document provides for three types of such disks.

Type SL/HTL disk the substrate is covered with an HTL recording layer, consisting of several films. On top of this recording layer, a transparent cover layer of 0,1 mm is applied with precisely defined optical characteristics (see Figure 1). The capacity is 25,0 Gbytes.

Type DL/HTL disk the substrate is covered with two HTL recording layers, each consisting of several films. The two recording layers are separated by a transparent spacer layer of about 0,025 mm. The first recording layer seen from the read-out side of the disk shall be semi-transparent. On top of this recording layer, a transparent cover layer of about 0,075 mm is applied. Both the spacer layer and the cover layer shall have precisely defined optical characteristics (see Figure 2). The capacity is 50,0 Gbytes.

Type SL/LTH disk the substrate is covered with an LTH recording layer, consisting of several films. On top of this recording layer, a transparent cover layer of 0,1 mm is applied with accurately defined optical characteristics (see Figure 3). The capacity is 25,0 Gbytes.

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

Data can be written on 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 that enable 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, first recording layer and spacer layer, depending on which recording layer is involved.

For reference purposes all layers that the light beam passes through when accessing a certain recording layer is called the transmission stack of that specific recording layer (see Figures 1, 2 and 3).

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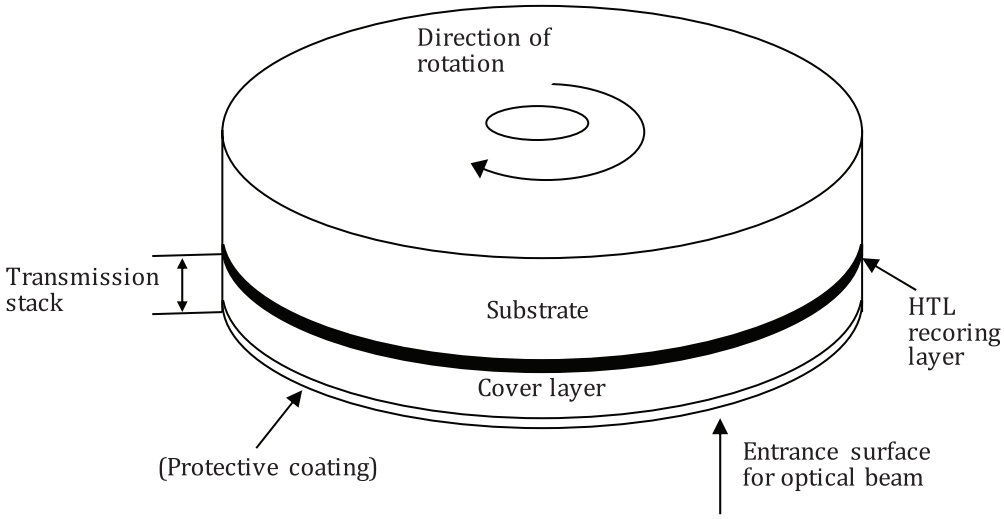

Figure 1 — Outline of type SL/HTL disk

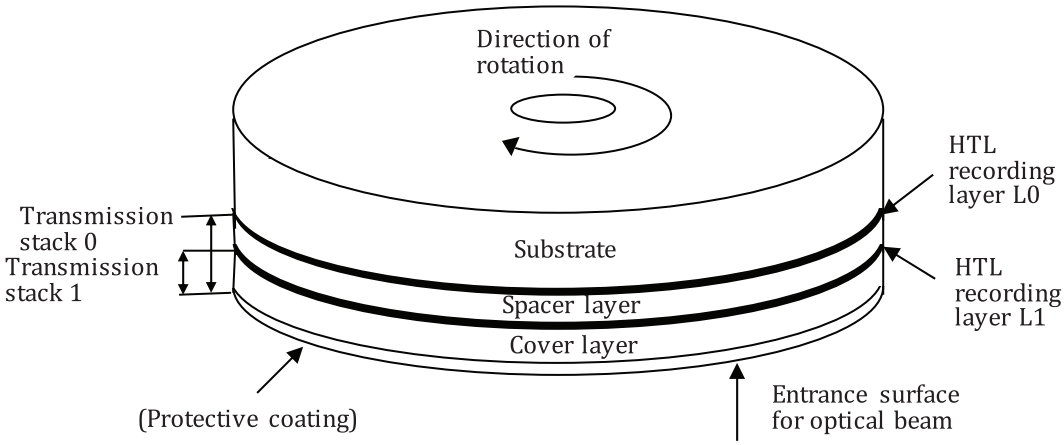

Figure 2 — Outline of type DL/HTL disk

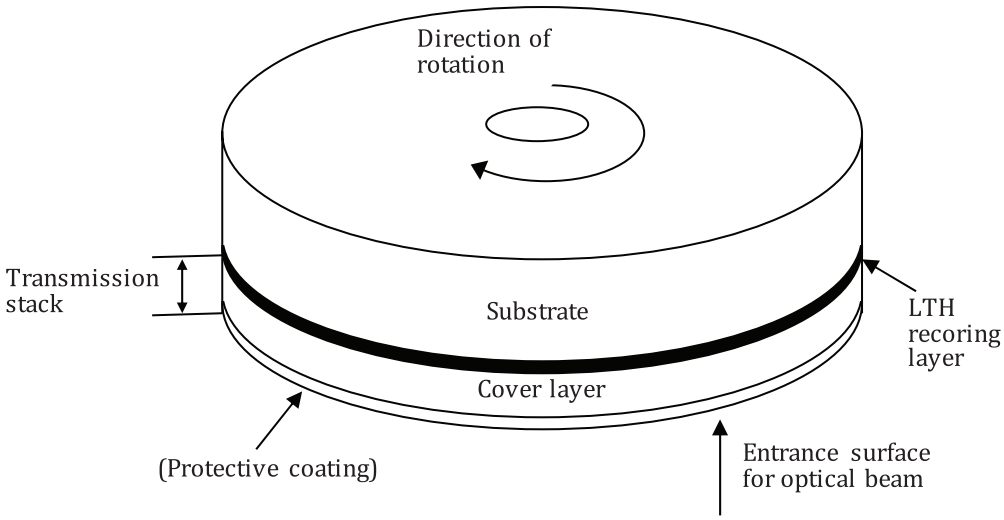

Figure 3 — Outline of type SL/LTH disk

This document specifies four kinds of recording velocity: 1x, 2x, 4x, 6x.

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Figure 4 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	1x	2x	4x	6x
Type SL/HTL	HTL	On-groove	SL	M	M	O	O
Type DL/HTL	HTL	On-groove[a]	DL	M	M	O	O
Type SL/LTH	LTH	In-groove	SL	M	M	O	O
M mandatory O optional [a] Groove geometry is on-groove for both layer L0 and layer L1 (see 15.2).							

Figure 4 — Recording velocity requirements for disk type

Figure 5 shows the recording velocity requirements for the disk (see 15.8.3.7).

	Type SL/HTL				Type DL/HTL				Type SL/LTH			
	1x	2x	4x	6x	1x	2x	4x	6x	1x	2x	4x	6x
2x disk	M	M	—	—	M	M	—	—	M	M	—	—
4x disk	M	M	M	—	M	M	M	—	M	M	M	—
6x disk	M	M	M	M	M	M	M	M	M	M	M	M
M mandatory — not allowed in this document.												

Figure 5 — Recording velocity requirements for disk

8 General requirements

8.1 Environments

8.1.1 Test environment

8.1.1.1 General

During measurements for testing conformance of a 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 a sufficient time.

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8.1.1.2 Test conditions for sudden change in operating environment

Some parameters can be rather sensitive to 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 6).

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 6).

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:

— 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 h before use.

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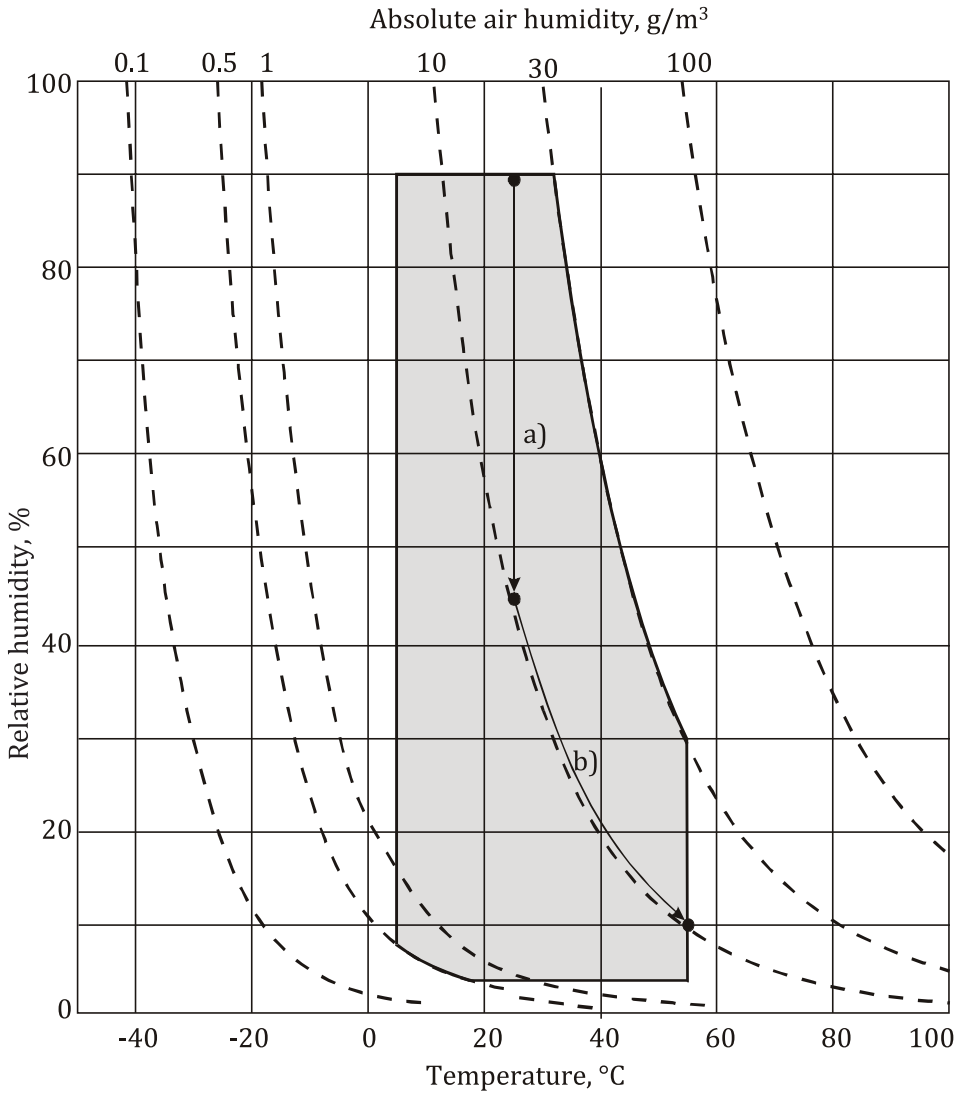

Figure 6 — Operating environment

8.1.3 Storage environment

8.1.3.1 General

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

— 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;

— maximum temperature variation: 15 °C/h;

— maximum relative humidity variation: 10 %/h.

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8.1.3.2 Climate storage tests

To check 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 temperature 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.

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.

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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 7. Different components and locations of components are permitted, provided that the performance remains the same as that of the set-up in Figure 7.

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.

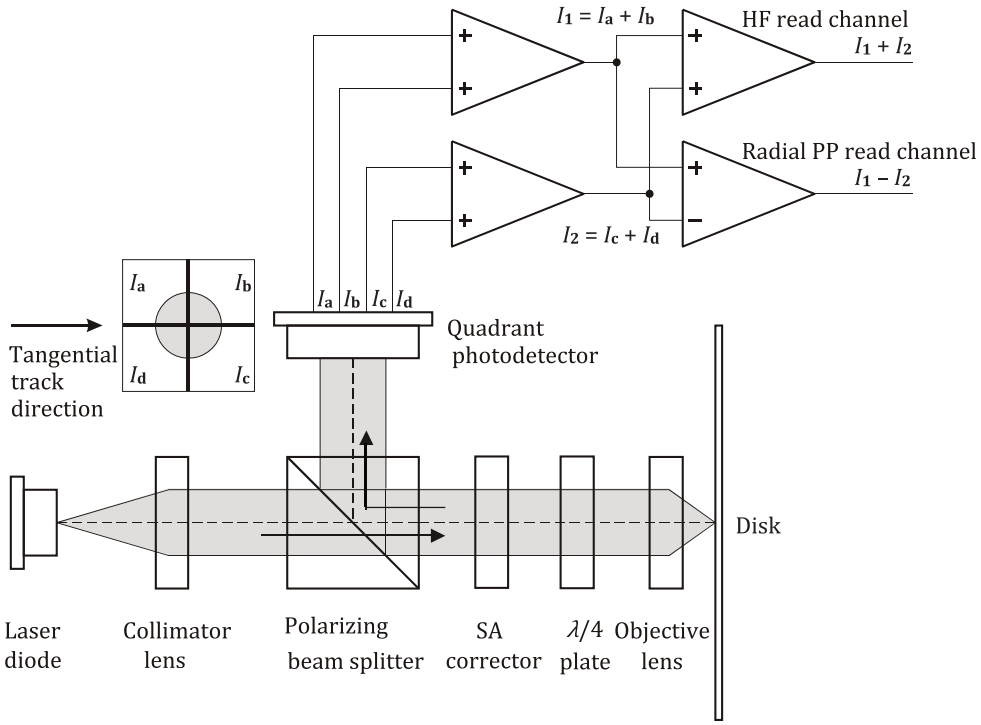

Figure 7 — Optical system of reference drive

A 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 toward 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.

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During measurements on one layer of a dual-layer disk, light reflected from the other layer can influence the measurements on the layer under investigation. To cope with these effects, the photodetector shall have limited 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.

9.4 Optical beam

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

— wavelength (λ) 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): (after correction of tilt and spherical aberrations)	0,033 × λ rms;
— maximum relative intensity noise of the laser diode: $\left[10\times\lg\left(\frac{P_m}{P_{dc}}\right)\right]$ where P_m is the ac light density, in Hz; P_{dc} is the dc light power.	–125 dB/Hz;
— normalized detector size:	$S/M^2 \leq 25$ µm^2 where S is the total surface of the 4-quadrant photodetector;
— read power for disk testing (average):	
— SL disk:	(0,35 ± 0,1) mW;
— DL disk:	(0,70 ± 0,1) mW;
— write power and pulse shape:	For write power, see 29.4.2 for the 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 the 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.

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In the frequency range from dc to 22 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 2 ns pp in the frequency range from 3 MHz to 22 MHz.

For measurement of jitter, the characteristics of the signal processing, the data slicer and the PLL, etc., are specified in Annex H.

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 the dc gain from dc to 8 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 (Figure 8).

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 8).

The top angle, θ_a, of the tapered cone for centering of the disk shall be 40,0° ± 0,5°.

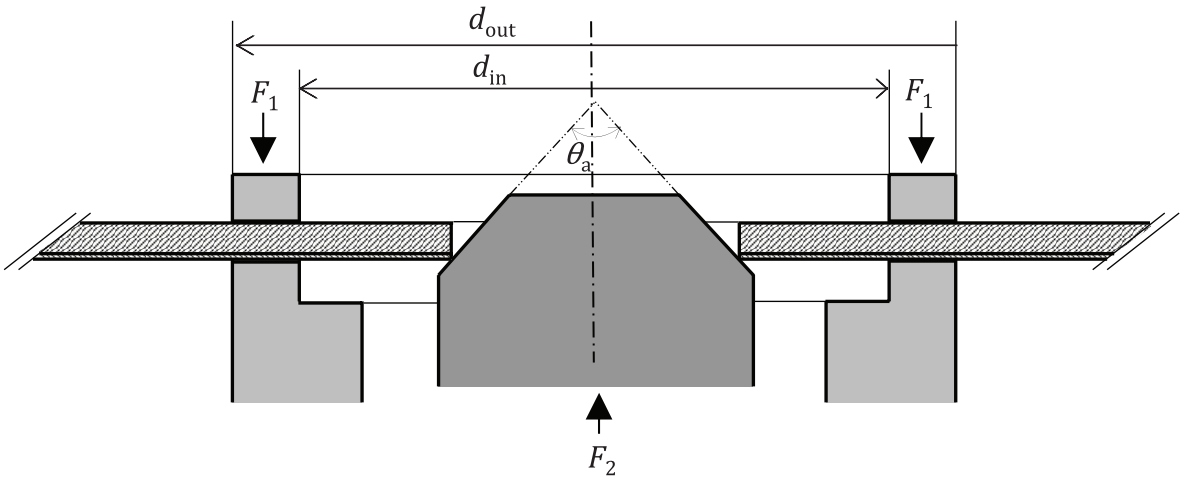

Figure 8 — Clamping conditions for measurement

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 reference velocity, unless otherwise specified. This corresponds to a constant linear velocity of 4,917 m/s.

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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 (iω) is used. It specifies the nominal values of the open-loop transfer function H of the reference servo(s) as Formula (1):

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

where

ω = 2π × f;

ω_0 = 2π × f_0;

ω_{int} = 2π × f_{int};

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+ω_{int}/iω) 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_{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 velocity of the disk under testing:

— a reference servo for 2x disks to be measured at 1x measurement velocity (see 9.10.2);

— a reference servo for 4x disks and for 6x disks at radii up to 36 mm to be measured at 2x measurement velocity (see 9.10.3);

— a reference servo for 6x disks at radii 36 mm and higher to be measured at 3x measurement velocity (see 9.10.3).

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

9.10.2 Reference servo for axial tracking for 1x measurement velocity

Regarding the open-loop transfer function $H(f)$ of the reference servo for axial tracking, $|1+H_N(f)|$ is shown schematically by the shaded area in Figure 9:

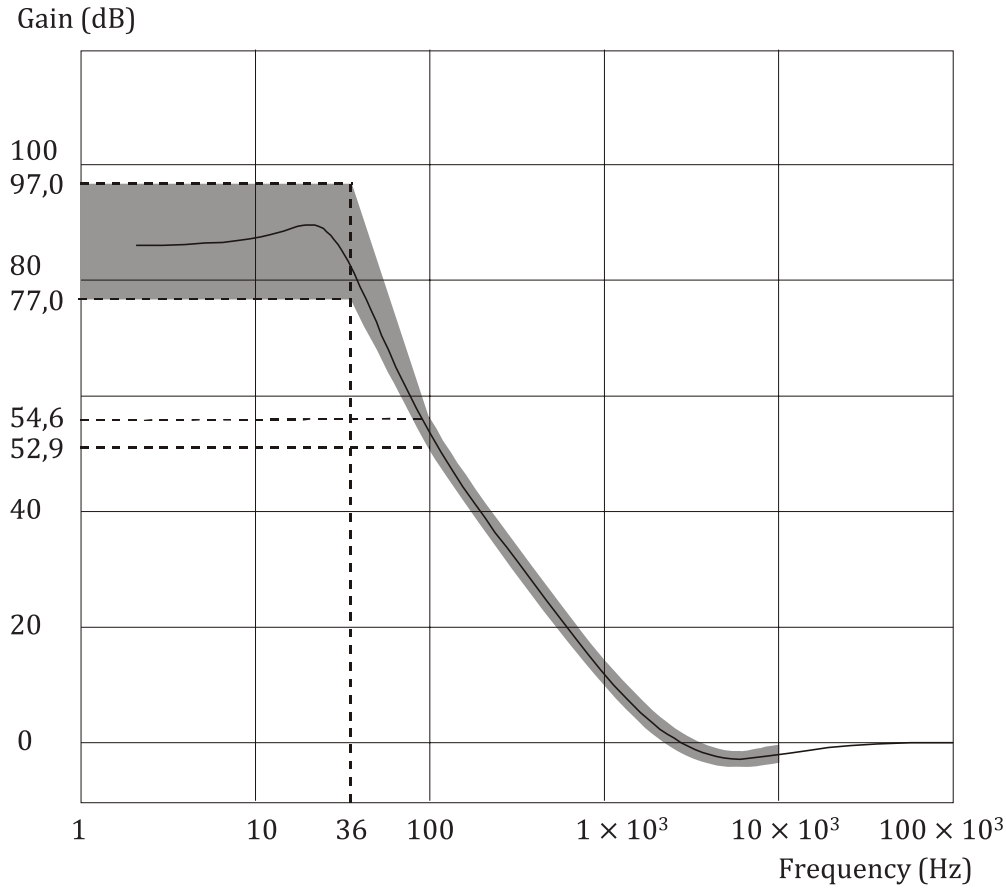

Figure 9 — Servo characteristic for axial tracking at 1x measurement velocity

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 Formula (3), where α_{max} = 6,0 m/s^2 is the maximum expected axial acceleration due to local disturbances, and α_{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:

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

In the frequency range 36 Hz to 100 Hz:

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

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

$$77{,}0 \leq |1+H(f)| \leq 97{,}0 \quad (6)$$

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

$$f_x = \frac{1}{2\pi}\sqrt{\frac{\alpha_{\max}}{e_{\max}}} = \frac{1}{2\pi}\sqrt{\frac{6{,}0}{55\times10^{-9}}} \approx 1{,}6 \quad (7)$$

9.10.3 Reference servo for axial tracking for 2x measurement velocity and 3x measurement velocity

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

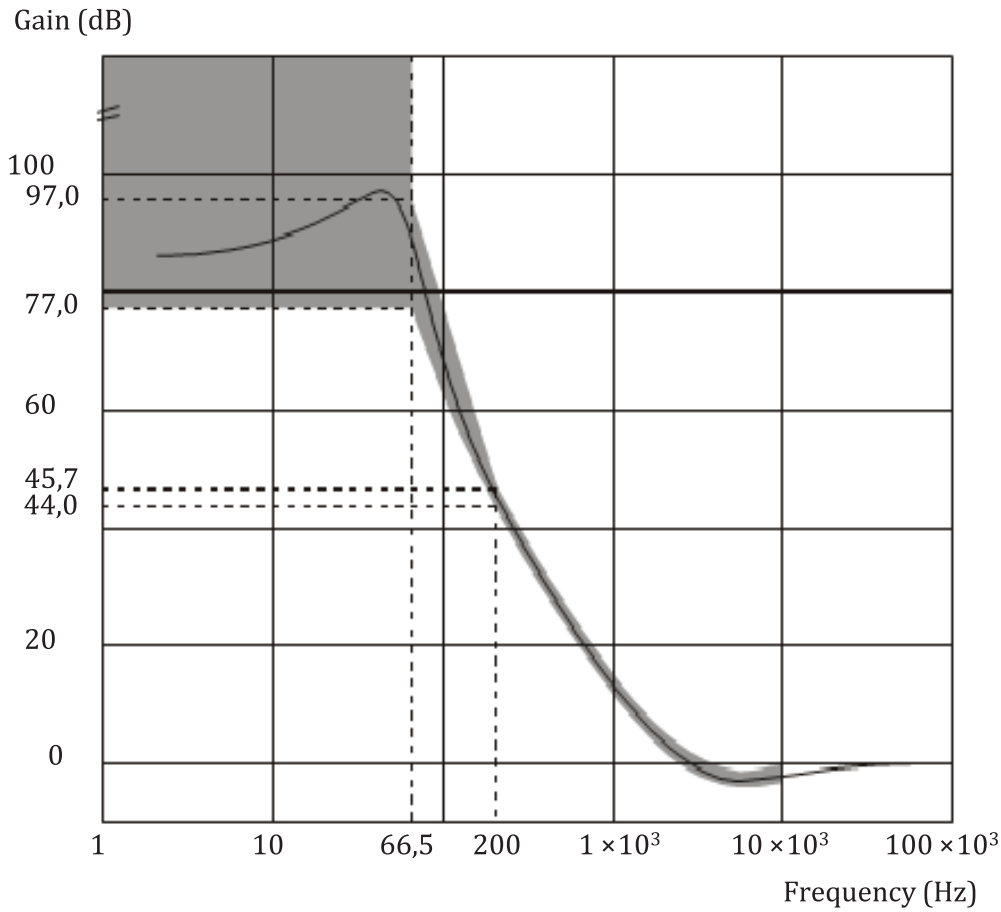

Figure 10 — Servo characteristics for axial tracking at 2x measurement velocity and 3x measurement velocity

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

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

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

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

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

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:

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

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

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

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

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

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 velocity of the disk under testing:

— a reference servo for 2x disks to be measured at 1x measurement velocity (see 9.11.2);

— a reference servo for 4x disks and for 6x disks at radii up to 36 mm to be measured at 2x measurement velocity (see 9.11.3);

— a reference servo for 6x disks at radii 36 mm and higher to be measured at 3x measurement velocity (see 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 for 1x measurement velocity

For the open-loop transfer function $H(f)$ of the reference servo for radial tracking, $|1 + H(f)|$ is shown schematically by the shaded area in Figure 11:

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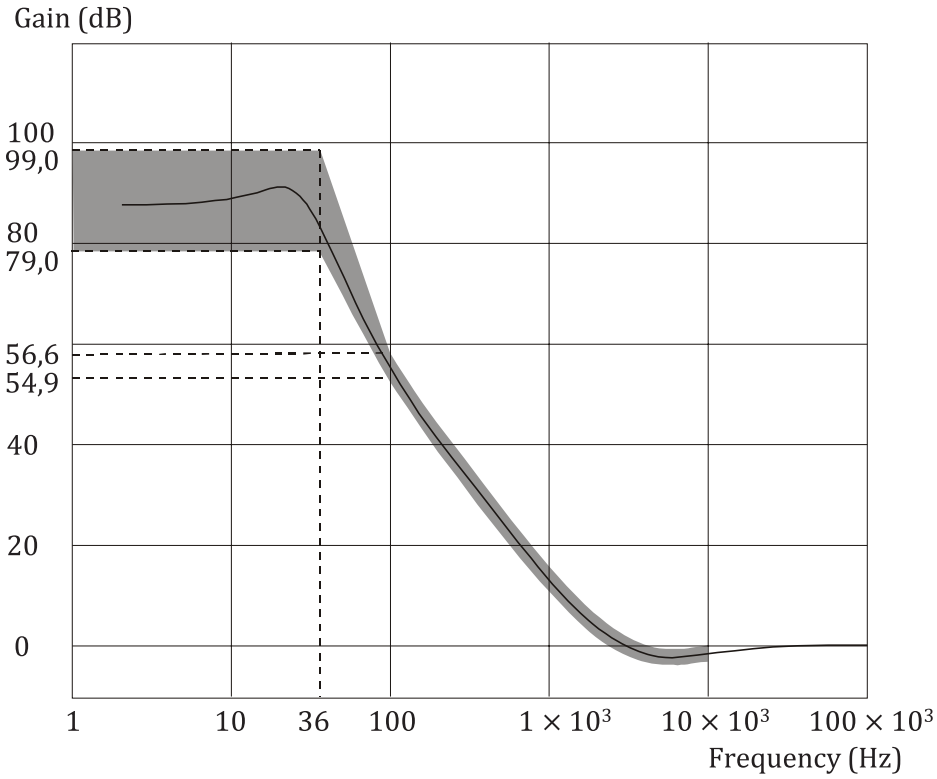

Figure 11 — Servo characteristics for radial tracking at 1x measurement velocity

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 α_{max} = 2,2 m/s^2 is the worst-case maximum expected radial acceleration due to local disturbances, and α_{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:

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

In the frequency range 36 Hz to 100 Hz:

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

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

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

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 for 2x measurement velocity and 3x measurement velocity

For the open-loop transfer function $H(f)$ of the reference servo for radial tracking, $|1 + H(f)|$ is shown schematically by the shaded area in Figure 12:

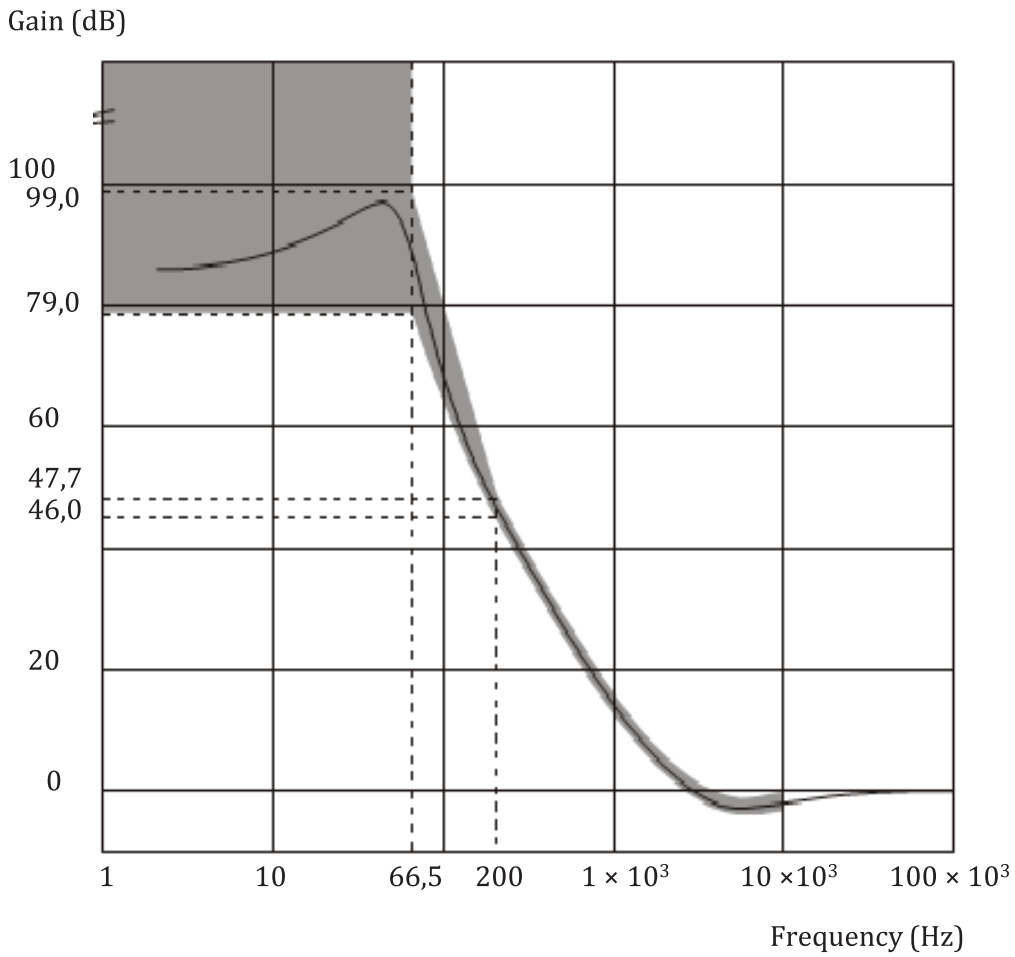

Figure 12 — Servo characteristics for radial tracking at 2x measurement velocity and 3x measurement velocity

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, α_{max} in m/s^2, as per Formula (18):

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

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:

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

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

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

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

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

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. Figure 13 shows the dimensional requirements in summarized form. The different parts of the disk are described from the centre hole to the outside rim.

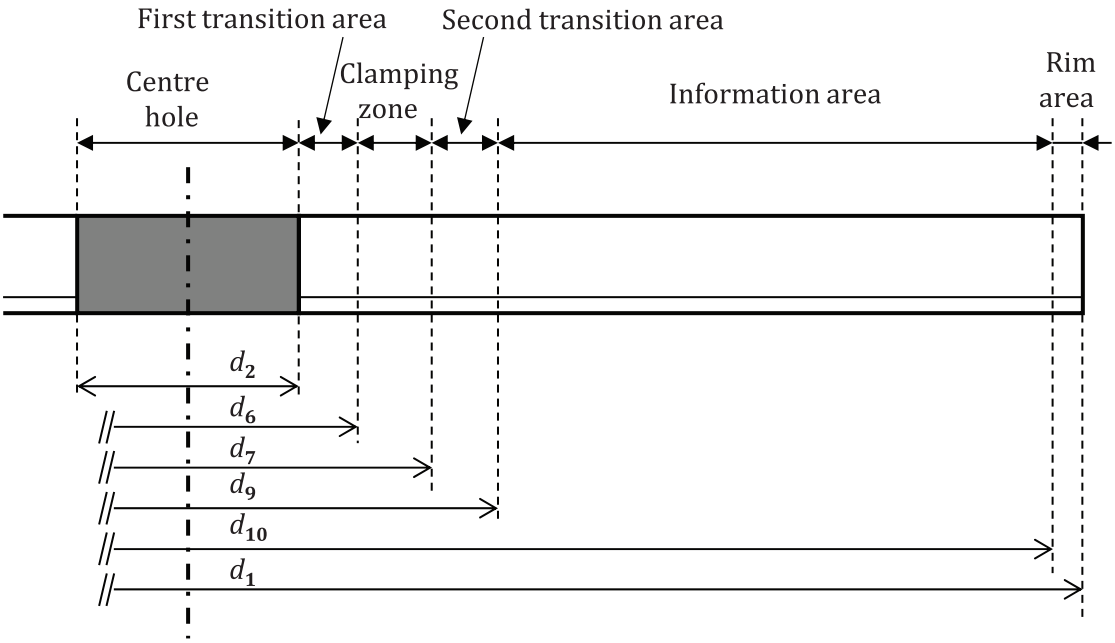

Figure 13 — Overview of disk dimensions

10.2 Disk reference planes and reference axis

For disk reference planes, see also Figure 14 and Figure 15.

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.

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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 Figures 14 and 15).

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 only recording layer on an SL disk or the deepest recording layer on a DL disk).

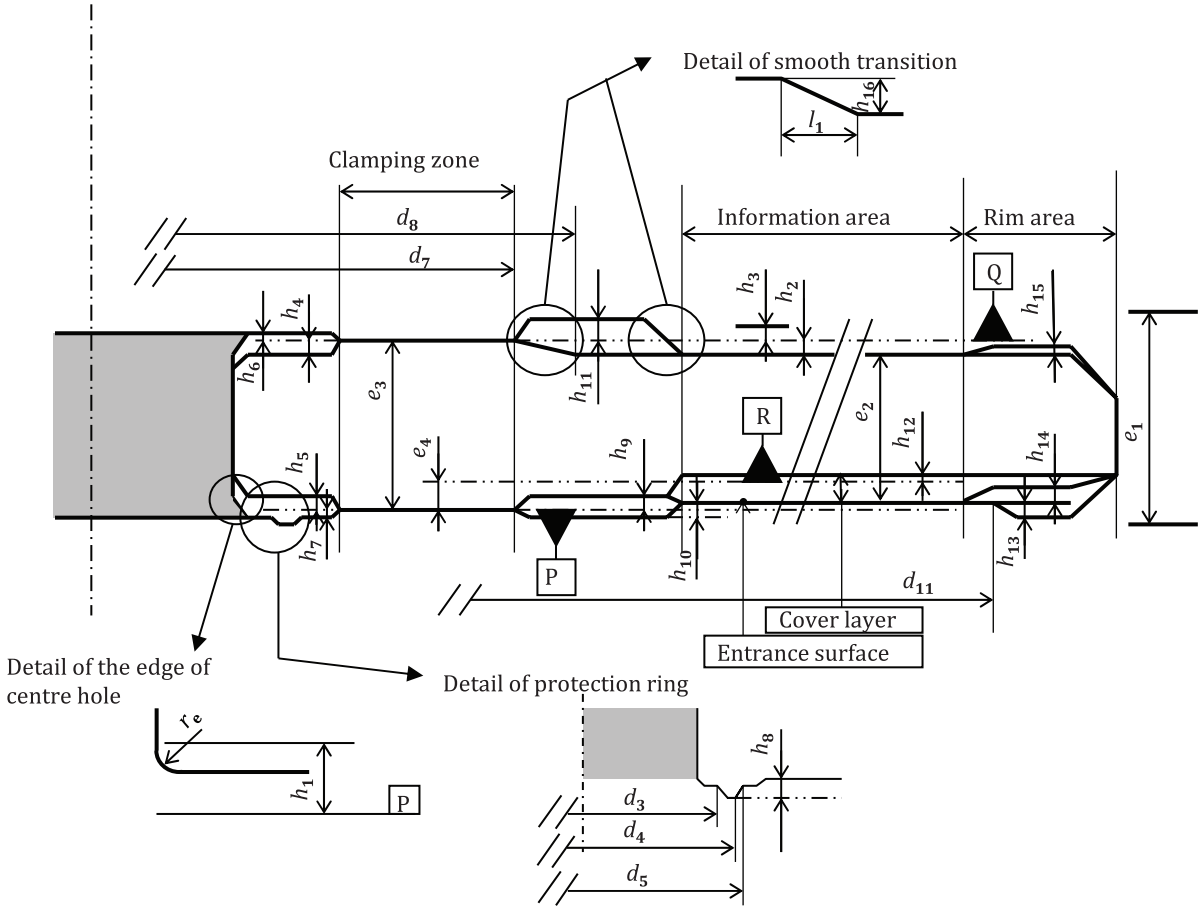

Figure 14 — Details of disk dimensions

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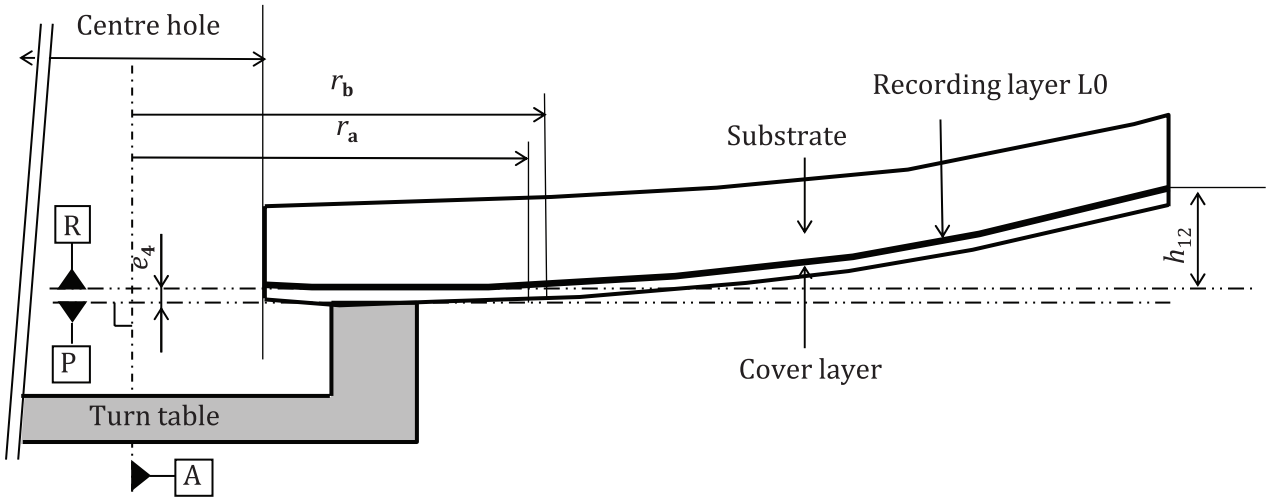

Figure 15 — Details of disk reference planes P and R and recording layer L0

10.3 Overall dimensions

The overall outer diameter of the disk shall be d_1 = (120,0 ± 0,3) mm (see Figure 13).

The diameter of the centre hole shall be $d_2 = 15{,}00^{+0{,}10}_{0{,}00}$ mm (see Figure 13).

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 centering 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 14).

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 the cover layer, protective coating and label printing at any radius shall be e_1 = 1,40 mm (see Figure 14).

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 14).

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 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 Figures 13 and 14).

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.

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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 14).

10.6 Clamping zone

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

The outer diameter of the disk clamping zone shall be $d_7 \geq 33{,}0$ mm (see Figure 13).

The thickness of the disk within the clamping zone shall be $e_3 = 1{,}20^{+0{,}10}_{-0{,}05}$ mm (see Figure 14).

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 13).

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 14).

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 $l_1 > 1{,}8$ mm as indicated in Figure 14. If the top surface in the information area is stepped down from the top surface in the second transition area, then the step shall end within diameter d_8 = 40,0 mm.

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 Figures 13 and 16).

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

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 16).

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

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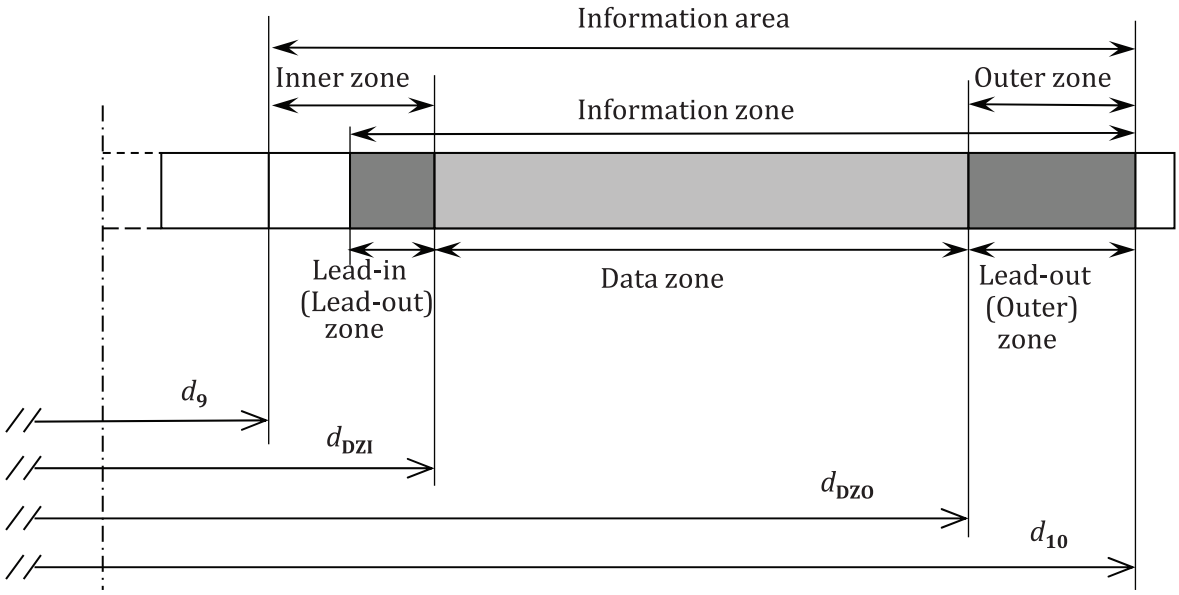

Figure 16 — Division of information area

10.8.2 Subdivision of information zone on SL disks

The information area is used to record the information zone.

The information zone is subdivided into the following main parts (see Figure 17):

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

— a data zone;

— a lead-out zone (outer zone).

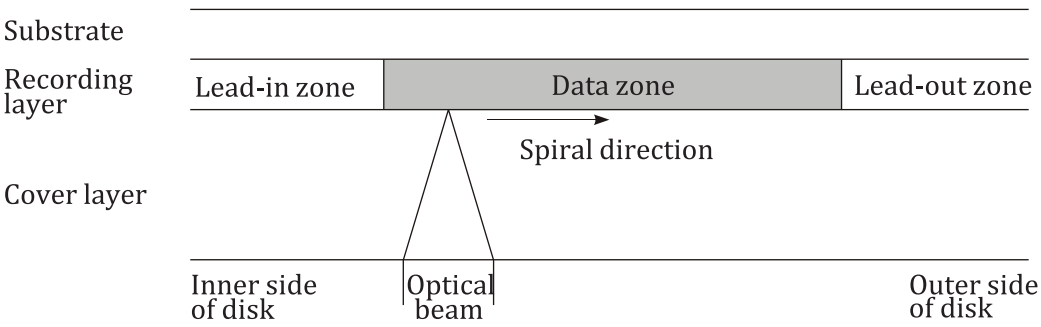

Figure 17 — Subdivision of information zone on SL disk

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 at diameter d_{DZI}.

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

10.8.3 Subdivision of information zone on DL disks

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

The information zone is subdivided into the following main parts (see Figure 18):

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On recording layer L0:

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

— a data zone 0;

— an outer zone 0;

On recording layer L1:

— an outer zone 1;

— a data zone 1;

— a lead-out zone (part of the inner zone 1).

On layer L0, the spiral groove 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.

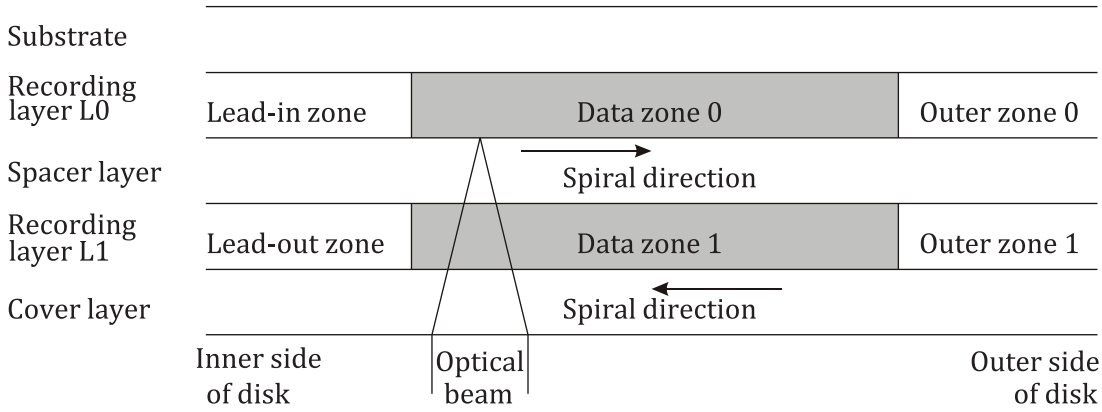

Figure 18 — Subdivision of information zone on DL disk

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 ofminimum 117 mm and shall end at the beginning of data zone 1 at diameter d_{DZO1}.

The lead-out zone shall start at the end of the data zone 1 at diameter d_{DZI1} and shall end in the area extending from diameter 44,0 mm to diameter 44,4 mm.

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 13).

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.

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 14).

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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 14).

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.

11.4 Axial run-out

11.4.1 General

When measured by an optical system using the reference servo for axial tracking and with the disk rotating at a scanning velocity of 4,917 m/s (for all capacities), the distance between each recording layer and the disk reference plane R (see Figures 14 and 15) 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.

At the inner side of the disk, rotating at a velocity of 4,917 m/s, this corresponds to a maximum acceleration of about 4,6 m/s^2, based on a sinusoidal deviation at the rotational frequency of the disk.

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, 11.4.3 and 11.4.4, 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 1 × V_{ref}.

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.

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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 9.10.2, 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 2 × V_{ref}.

Spikes in the residual axial tracking error signal due to local defects, such as dust and scratches, shall be excluded. For 2x measurement velocity, local defects that cause large axial tracking errors shall be taken into account as described in Annex I.

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 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.

11.4.4 Residual axial tracking error for 3x measurement velocity

The residual axial tracking error of each recording layer for frequencies below 4,8 kHz, measured using the reference servo for axial tracking as specified in 9.10.3, shall be as follows:

— 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 3 × V_{ref}; or

— maximum 110 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 3 × V_{ref} if the jitter performance at ±10 % power window meets the requirements.

Spikes in the residual axial tracking error signal due to local defects, such as dust and scratches, shall be excluded. For 3x measurement velocity, local defects that cause large axial tracking errors shall be taken into account as described in Annex I.

The measuring filter shall be a Butterworth LPF with f_{-3dB} = 4,8 kHz and slope = –60 dB/decade.

This means that, for frequencies <4,8 kHz, the maximum local acceleration of the recording layer in the direction of the reference axis A does not exceed 14,8 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 4,8 kHz to 30 kHz, measured with an integration time of 10 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} = 4,8 kHz with slope = +60 dB/decade, to f_{-3dB} = 30 kHz with slope = –60 dB/decade.

11.5 Radial run-out

11.5.1 General

The run-out of the outer edge of the disk shall be maximum 0,3 mm pp.

The radial run-out of the tracks in each recording layer (including eccentricity and non-roundness) shall be measured by an optical system using the reference servo for radial tracking, while the disk is rotating at a scanning velocity of 4,917 m/s (for all capacities).

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The radial run-out shall be maximum 75 µm pp (SL and DL disks).

At the inner side of the disk, rotating at a velocity of 4,917 m/s, this corresponds to a maximum acceleration of about 1,7 m/s^2, based on a sinusoidal deviation at the rotational frequency of the disk.

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, 11.5.3, 11.5.4 and 11.5.5 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 7.

11.5.2 Residual radial tracking error for 1x measurement velocity on SL disks

The residual radial tracking error 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 9 nm with the disk rotating at 1 × V_{ref}.

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 local acceleration of the tracks in the radial direction does not exceed 1,5 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 and using the reference servo for radial tracking, shall be maximum 6,4 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 for 1x measurement velocity on DL disks

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 1 × V_{ref}.

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 does 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 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} = 1,8 kHz with slope = +60 dB/decade to f_{-3dB} = 10 kHz with slope = –60 dB/decade.

11.5.4 Residual radial tracking error for 2x measurement velocity on SL and DL disks

The residual radial tracking error in each recording layer for frequencies below 3,6 kHz, measured using the reference servo for radial tracking as specified in 9.11.3, shall be maximum 20 nm with the disk rotating at 2 × V_{ref}.

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.

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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.

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.

11.5.5 Residual radial tracking error for 3x measurement velocity on SL and DL disks

The residual radial tracking error in each recording layer at frequencies below 3,6 kHz, measured using the reference servo for radial tracking as specified in 9.11.3, shall be maximum 20 nm with the disk rotating at 3 × V_{ref}.

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.

The rms noise value of the residual error signal in the frequency band from 3,6 kHz to 30 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} = 30 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 the 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 the 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 the 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 e.g. gluing layers in case of foils, the spacer layer and the semi-transparent recording layer of layer L1 in case of TS0, the cover layer and possibly a protective coating).

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12.2 Refractive index of transmission stacks (TS)

If the layers making up the total TS have different refractive indices, 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 SL disks

The average thickness between radius r_a and radius r_b is called the reference thickness of the transmission stack (TS) on the disk. (see 10.2 and Figure 15).

The thickness of the TS, measured over the whole disk, shall fulfil the following two requirements:

a) The thickness of TS as determined by its refractive index shall be within the upper shaded area in Figure 19 (in case of a refractive index of 1,6 the thickness shall be between 95 µm and 105 µm, and the dashed line indicates the nominal thickness as a function of the refractive index);

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

12.3.2 Thickness of transmission stacks of DL disks

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

The thickness of TS0 and TS1, measured over the whole disk, shall fulfil the following four requirements:

a) The thickness of TS0 (all layers on top of layer L0) as determined by its refractive index shall be within the upper shaded area in Figure 19 (In case of a refractive index of 1,6 the thickness shall be between 95 µm and 105 µm, and the dashed line indicates the nominal thickness as a function of the refractive index);

b) The thickness of TS1 (all layers on top of layer L1) as determined by its refractive index shall be within the lower shaded area in Figure 19 (In case of a refractive index of 1,6 the thickness shall be between 70 µm and 80 µm, and the dashed line indicates the nominal thickness as a function of the refractive index);

c) The thickness of spacer layer shall be between 20 µm and 30 µm;

d) The maximum deviation, ΔD, of the thicknesses of TS0 and TS1 from their respective reference thicknesses shall meet the requirement $|\Delta D| \leq 2{,}0$ µm.

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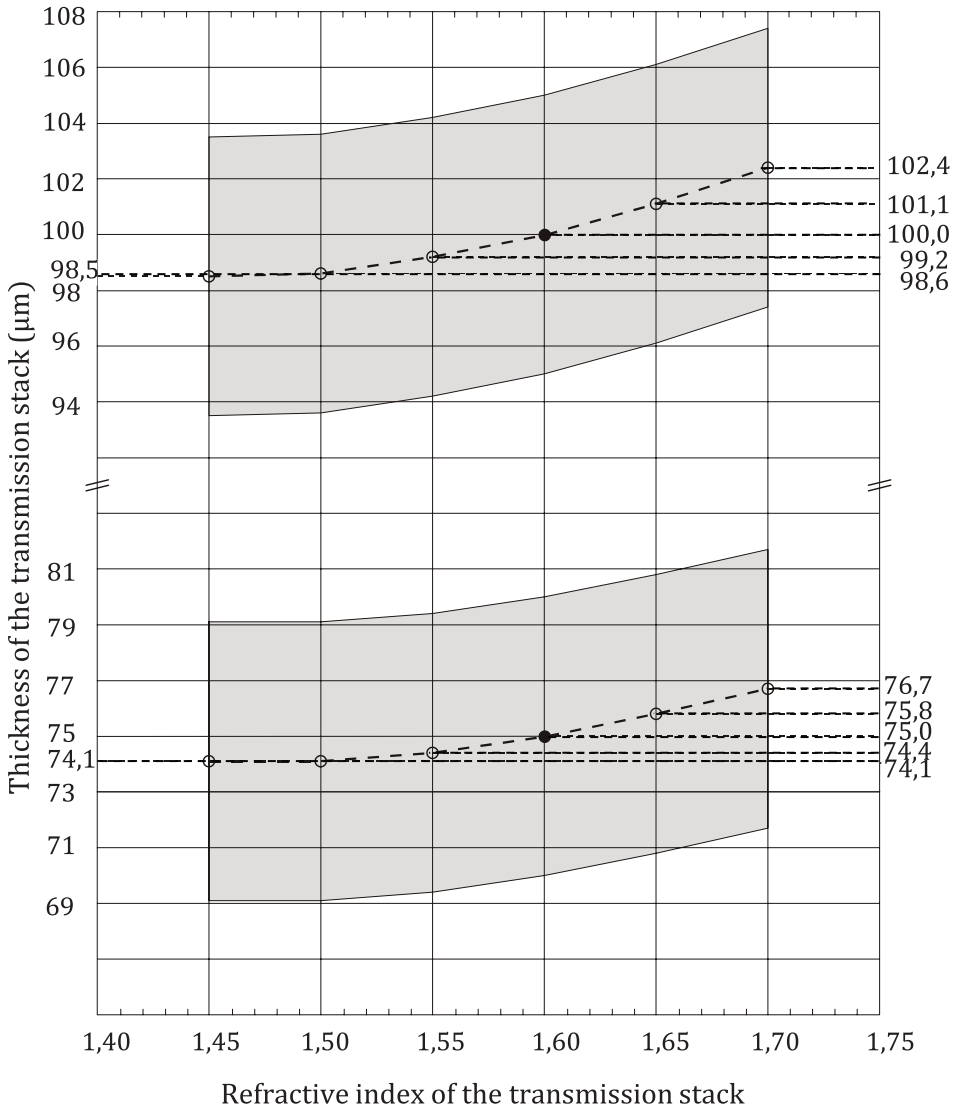

Figure 19 — Thickness of transmission stacks as function of reflective index

12.4 Reflectivity

12.4.1 Reflectivity of recording layer of SL disks

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

- in unrecorded virgin groove: $R_{g\text{-}v}$ = 12 % to 24 %;
- in recorded groove:
  - for HTL disks: R_{8H} = 11 % to 24 %;
  - for LTH disks: R_{8H} = 16 % to 35 %;
- at each location on the disk:
  - for HTL disks: $0{,}75 \times R_{g\text{-}v} < R_{8H} < 1{,}25 \times R_{g\text{-}v}$;
  - for LTH disks: $0{,}75 \times R_{g\text{-}v} < R_{8L} < 1{,}25 \times R_{g\text{-}v}$.

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Written marks shall have a lower reflectivity than the unrecorded layer for HTL disks. Written marks shall have a higher reflectivity than the unrecorded layer for LTH disks.

12.4.2 Reflectivity of recording layers of DL disks

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

— in unrecorded virgin grooves: $R_{g\text{-}v}$ = 4 % to 8 %;

— in recorded grooves: R_{8H} = 3,5 % to 8 %;

— 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.

12.5 Birefringence

The in-plane birefringence of the transmission stacks shall be as per Formula (23) (see Annex J for additional information):

$$\Delta n_{//} \leq 1{,}5 \times 10^{-4} \tag{23}$$

The perpendicular birefringence of the transmission stacks shall be as per Formula (24) (see Annex J for additional information):

$$\Delta n_{\perp} \leq 1{,}2 \times 10^{-3} \tag{24}$$

12.6 Angular deviation

The angular deviation is the angle, θ_a, between a parallel incident beam, perpendicular to the disk reference plane P, and the reflected beam. The incident beam shall have a diameter in the range 0,3 mm to 1,0 mm. The angle, θ_a, includes deflections of the entrance surface and lack of parallelism of the cover layer and/or spacer layer (see Figure 20).

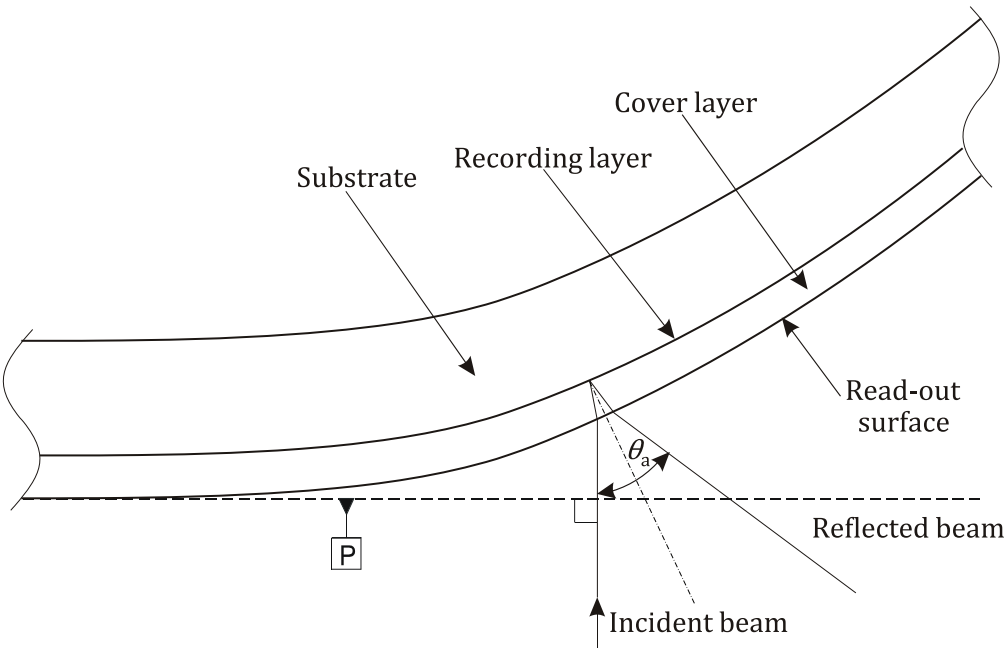

Figure 20 — Definition of angular deviation

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The angle, θ_a, shall fulfil the following requirements:

— in the radial direction:

  — under the normal test conditions specified in 8.1.1: $|\theta_a|_{max} = 0{,}60°$;

  — under the "sudden change" test conditions specified in 8.1.1: $|\theta_a|_{max} = 0{,}70°$;

— in the tangential direction:

  — under the normal test conditions specified in 8.1.1: $|\theta_a|_{max} = 0{,}30°$.

13 Data format

13.1 General

The data received from the source (application or host), called user data frames, are formatted in a number of steps before being recorded on the disk (see Figure 21).

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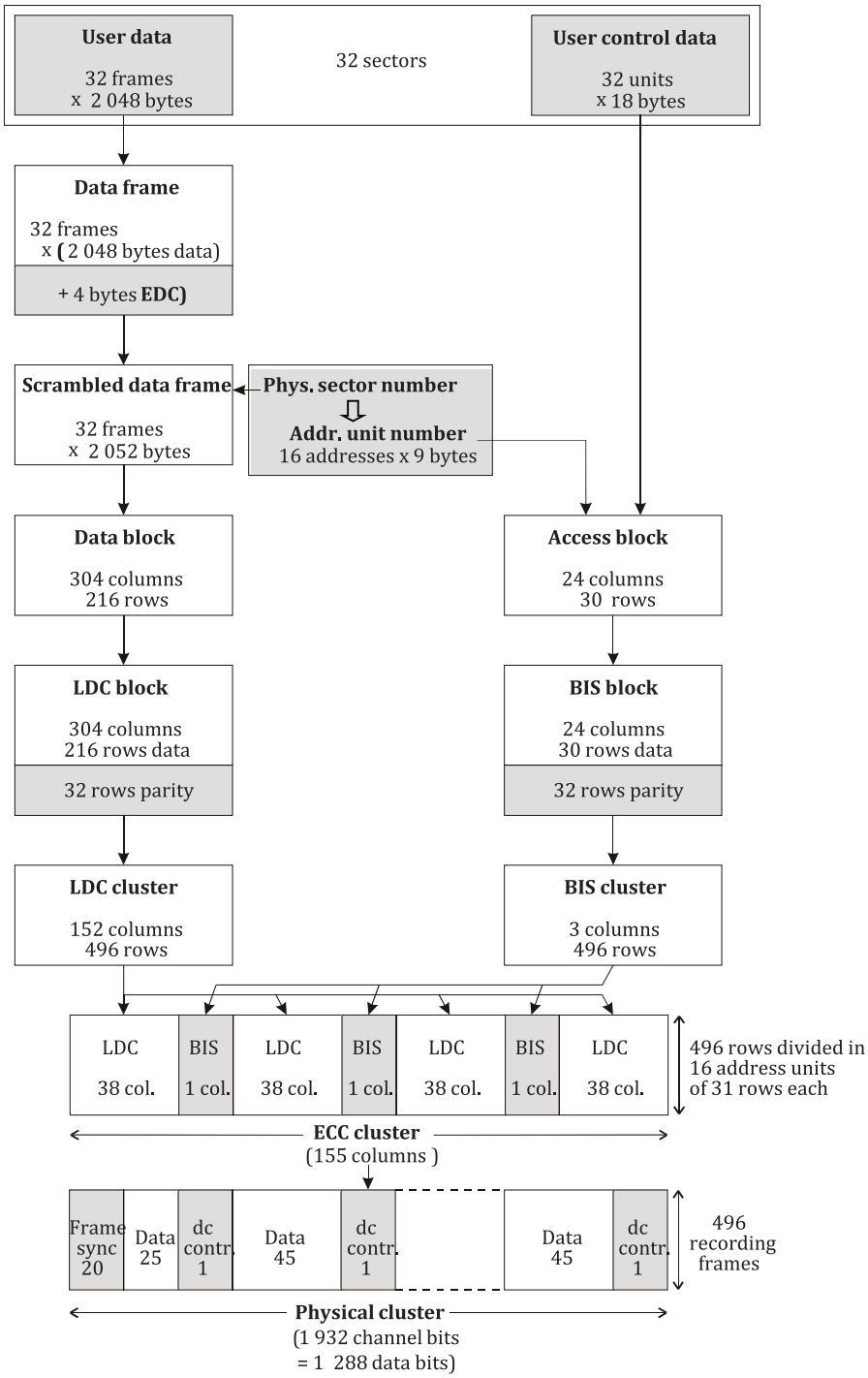

Figure 21 — Schematic representation of encoding process

They are transferred successively into data frames, scrambled data frames, a data block, an LDC block and an LDC cluster.

The address and control data, added by the BD recordable system, are transferred successively into an access block, a BIS block, and a BIS cluster.

The LDC custer and the BIS cluster are multiplexed and modulated into:

— an ECC cluster, subdivided into 16 address units, and

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— a physical cluster, consisting of 496 recording frames.

The data on BD recordable disks is recorded in 64K partitions, called clusters, containing 32 data frames with 2 048 bytes of user data. These clusters are protected by two error correction mechanisms as follows:

— First the data is protected by a long distance (LDC) error correction code, consisting of (248,216,33) Reed-Solomon (RS) code words. This code has ample parities and interleaving length with a good overall efficiency and can correct both random errors and burst errors.

— Secondly, the data is multiplexed with a powerful burst-indicating subcode (BIS), which consists of (62,30,33) Reed-Solomon (RS) code words. These BIS code words carry addresses for allocation purposes and control information belonging to the user data. They can also be used to indicate long burst errors, by means of which the LDC can efficiently perform erasure corrections.

The combination of these two codes is called an "LDC + BIS code" (see Figure 22).

All the data is arranged in an array as indicated in Figure 22. This array is read in the horizontal direction, row after row, and recorded on the disk after insertion of additional dc-control bits, modulation, and insertion of synchronization patterns.

The error correction codes are applied in the vertical direction, which gives a good basic break-up of burst errors on the disk. Additionally, the LDC code words have been interleaved in a diagonal direction.

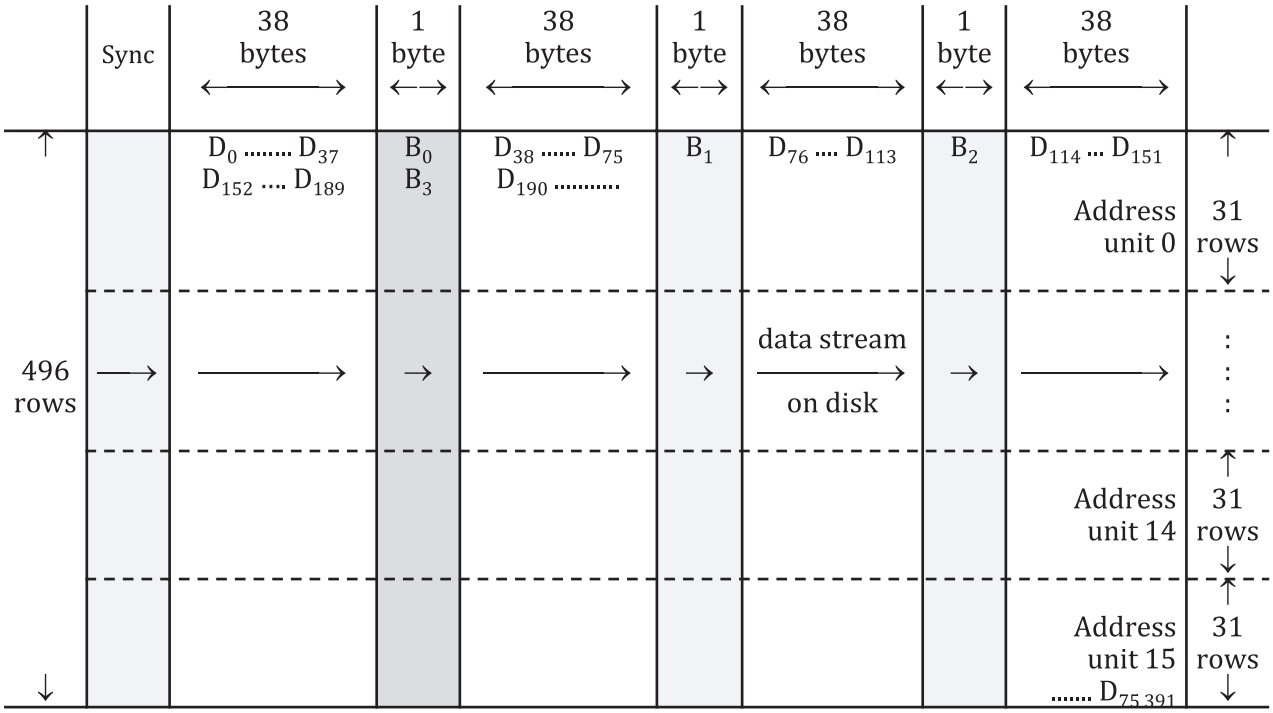

Figure 22 — Schematic representation of physical cluster on disk

Address units, physical sectors and logical sectors are defined as follows.

Address units

For the purpose of allocating the optical pick-up to a certain position on the disk, the physical cluster is subdivided into 16 address units, each consisting of 31 consecutive rows. The address unit numbers (AUN) provide a fast addressing mechanism embedded in the written data.

Physical sectors

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A data frame accompanied by it's control data is called a sector. All sectors in all physical clusters all over the disk (including the inner and outer zones) are called physical sectors. All physical sectors have a virtual number assigned, called the physical sector number (PSN). These PSNs are not recorded onto the disk, however they are synchronized with the AUNs.

Logical sectors

Not all physical sectors are available for storage of user data delivered by the application or host. The inner and outer zones are excluded. The remaining sectors are available for storing user data and are called logical sectors.

13.2 Data frame

A data frame consists of 2 052 bytes: 2 048 bytes of user data and 4 bytes of error detection code (EDC). The 2 048 user data bytes are identified as ud_0 to $ud_{2\,047}$ and the 4 EDC bytes as $ed_{2\,048}$ to $ed_{2\,051}$ (see Figure 23).

↑	ud_0	↑
	:	
2 048	:	
user data	:	
bytes	:	2 052
↓	$ud_{2\,047}$	bytes
↑	$ed_{2\,048}$	
4	$ed_{2\,049}$	
EDC bytes	$ed_{2\,050}$	
↓	$ed_{2\,051}$	↓

Figure 23 — Data frame

13.3 Error detection code (EDC)

The 4-byte field $ed_{2\,048}$ to $ed_{2\,051}$ shall contain an error detection code computed over the 2 048 bytes of user data. Considering the data frame as a single-bit field, starting with the most significant bit of the first user data byte (ud_0) and ending with the least significant bit of the last EDC byte ($ed_{2\,051}$), then the msb is $b_{16\,415}$ and the lsb is b_0.

Each bit b_i of the EDC is shown as Formula (25) for i = 0 to 31:

$$EDC(x)=\sum_{i=31}^{0} b_i x^i = I(x) \bmod G(x) \tag{25}$$

where

$$I(x)=\sum_{i=16\,415}^{32} b_i x^i \text{; and}$$

$$G(x)=x^{32}+x^{31}+x^4+1 .$$

13.4 Scrambled data frame

Each data frame, consisting of 2 052 bytes of user data + EDC, shall be scrambled with the output of the circuit defined in Figure 24, in which bits s_7 (msb) to s_0 (lsb) represent a scrambling byte at each 8-bit shift.

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