Dietrich Schüller

Keep Our Sounds Alive: Principles and Practical Aspects of Sustainable Audio Preservation

(including a glance on video)

Part 3
Audio and Video Carriers
Following IASA-TC 05

Technology, Composition, Life Expectancy, Handling and Storage

With Contributions by Albrecht Häfner and Nadja Wallaszkovits

Workshop at Inforum 2016

Prague 23 May

IASA Technical Committee

Standards, Recommended Practices and Strategies

IASA-TC 03 The Safeguarding of the Audio Heritage: Ethics, Principles and Preservation Strategy, Version 3, December 2005, edited by Dietrich Schüller

IASA-TC 04 Guidelines on the Production and Preservation of Digital Audio Objects, second edition 2009, edited by Kevin Bradley,

IASA-TC 05 Handling and Storage of Audio and Video Carriers. Edited by Albrecht Häfner and Dietrich Schüller. 2014

IASA-TC 06 Guidelines on the Production and Preservation of Digital Audio Objects. Forthcoming

www.iasa-web.org

Part 1:
Audio and video carriers grouped by types (mechanical – magnetic – optical):

- Technology
- Composition
- Life Expectancy
- Deterioration by normal replay

Part 2:
Passive preservation – environmental factors, storage and handling

Part 1:
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Part 2:
Passive preservation – environmental factors, storage and handling

Mechanical carriers (audio)
- Cylinders
- Coarse groove discs (shellacs)
- Instantaneous discs
- Microgroove discs (vinyls, LPs)

Magnetic tape (audio and video)
- Open reel tape and cassettes

Optical carriers (audio, video, data)
- Compact Disc (CD) family
- Digital Versatile Disc (DVD) family
- Blue laser discs (disks)
- MiniDisc (MD) replicated

Magneto-optical carriers (audio, data)
- MiniDisc recordable (re-writable)

Cylinders – Composition and Life Expectancy (LE)
Self recorded cylinders: wax
Replicated cylinders: wax and celluloid (nitrate cellulose) on plaster core

All cylinders extremely fragile and vulnerable

However: under good storage conditions – dry and cool – cylinders have survived for more than 100 years

Prone to deterioration by replay

NB Cylinder replay must be left to experts

Replicated cylinders

wax celluloid wax “Pathe”

Self recorded cylinders

wax, affected by mould

Edison Concert

Coarse groove discs – Composition and LE 1

Replicated discs – “shellacs”

Mineral powders bound by organic substances
Fragile

However: under good storage conditions – dry and cool – shellacs have survived for more than 100 years

Master (stamper, negative) of a shellac (78 rpm) disc

Shellac of the 1950s

Coarse groove discs – Composition and LE 2

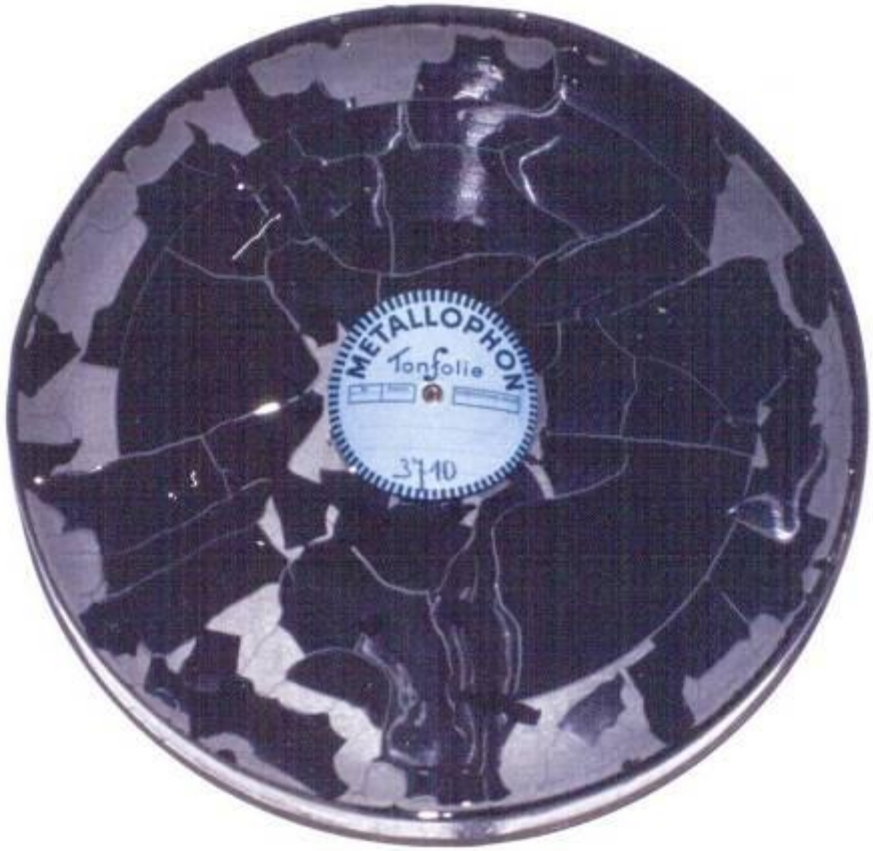
Instantaneous discs

Lacquer discs (“acetates”): cellulose nitrate coating on metal or glass body - Chemically extremely unstable

Various other materials of different kind – waxed carton, gelatin, metal - most of them chemically/physically unstable

NB Instantaneous disc replay must be left to experts

Lacquer disc 1990 2001



Micro groove discs (“Vinyls”, LPs) – Composition and LE

Polyvinyl chloride/polyvinyl acetate (PVC/PVA) co-polymer - vulnerable

To date no systematic chemical deterioration
Possible chemical interaction between discs and sleeves: plasticizer migration – use chemically inert sleeves only

Prone to deterioration by replay

Magnetic tape – Composition and LE

Base film

- Cellulose acetate mid1930s – early 1970s
- PVC 1944 – 1972 (mainly German manufacturers)
- Polyester (PE) since late 1950s

Magnetic pigments

- Fe_2O_3
- CrO_2 and substitutes
- Metal powder (MP), metal evaporated (ME)

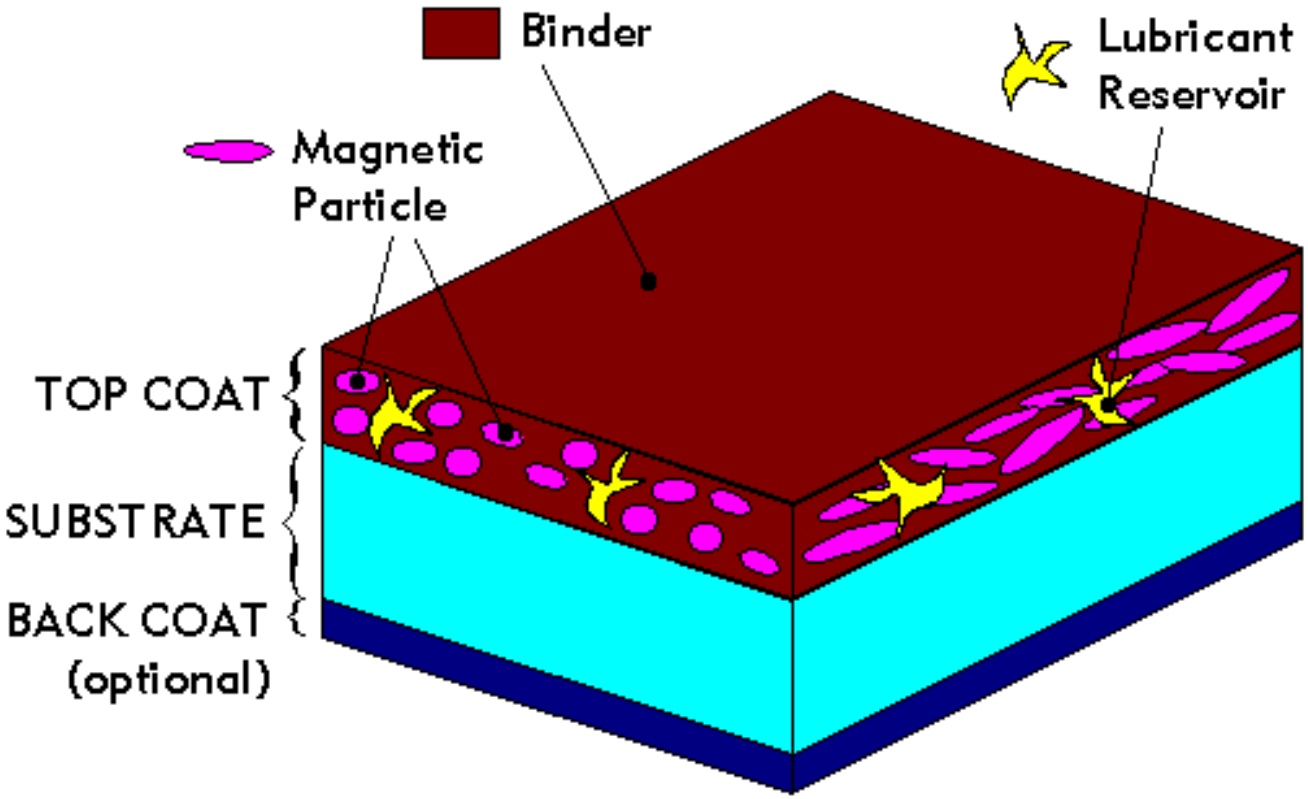
Pigment Binders

- Cellulose acetate (on early CA tapes)
- Mainly polyurethane (PU) since 1970s

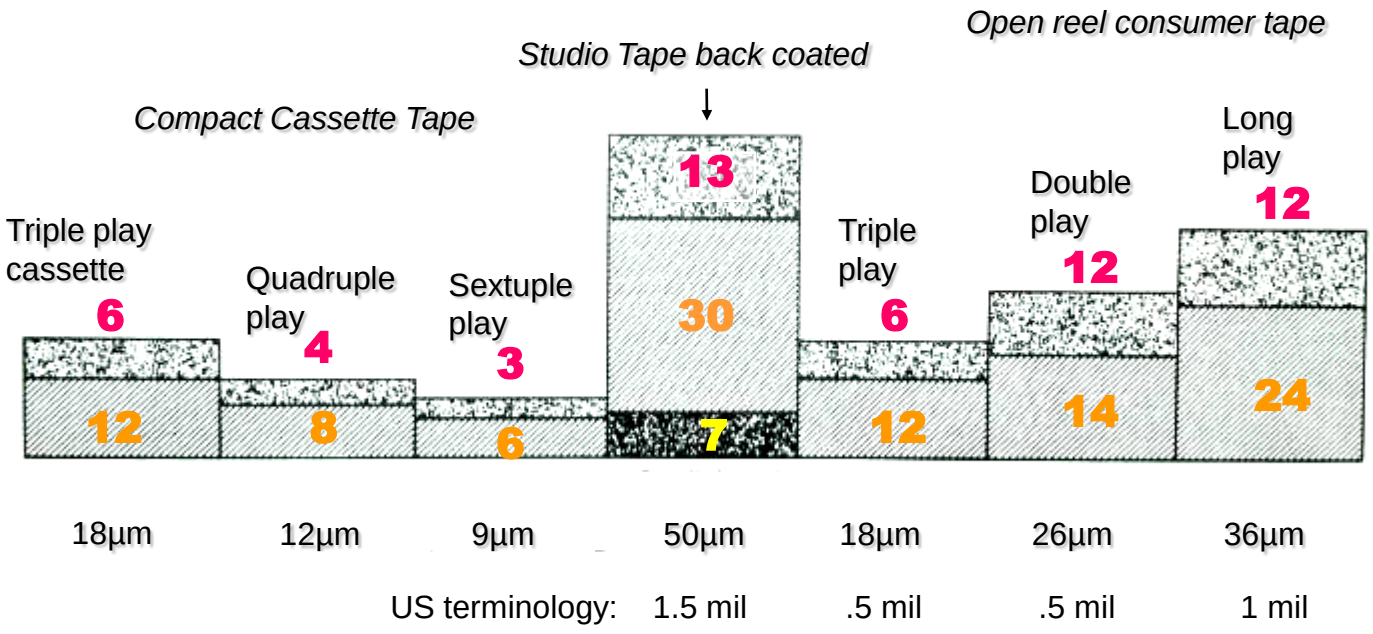
Pigment-Binder Schicht

Träger

Rückseitenmattierung



Cross section of analogue audio tapes



Top coat - „magnetisierbare“ Schicht

Substrate - Träger

Back coat (optional) - Rückseitenmattierung

Most endangered

- Historical tapes 1940s-1960s: cellulose acetate tapes – brittle, replay problems*
- Modern tapes 1970s-1990s: ”Sticky Shed Syndrome”, binder hydrolysis and other reasons
- MP, ME magnetic particles – long term resistance to oxidation unknown

Deterioration by replay low, provided equipment is well adjusted and maintained

*reconditioning possible by process developed by Nadja Wallaszkovits

Cellulose acetate tape used from 1950s to 1970s from Eastern Germany to Vietnam

Bittle and - if at all possible - very difficult to replay

Tape on reel after re-conditioning

Optical disks - confusing spelling

Technically standardized: ***disk***
But: trade names Compact Disc, MiniDisc
Library world prefers: ***disc***
IASA spelling: *analogue discs vs digital disks*

Optical disks - confusing terminology

Originally only replicated CDs existed, mass produced from a master by injection molding:

- CD Audio (CD-A)
- CD-ROM (Read Only Memory) for non-audio contents in various file formats (“data”)

With advent of recordable and re-writable CDs this terminology became inconsistent

A more systematic approach:

ROM (=replicated) – recordable – re-writable
All three types may contain:
Audio, video, data

Optical disks

CD, DVD, blue laser disk families

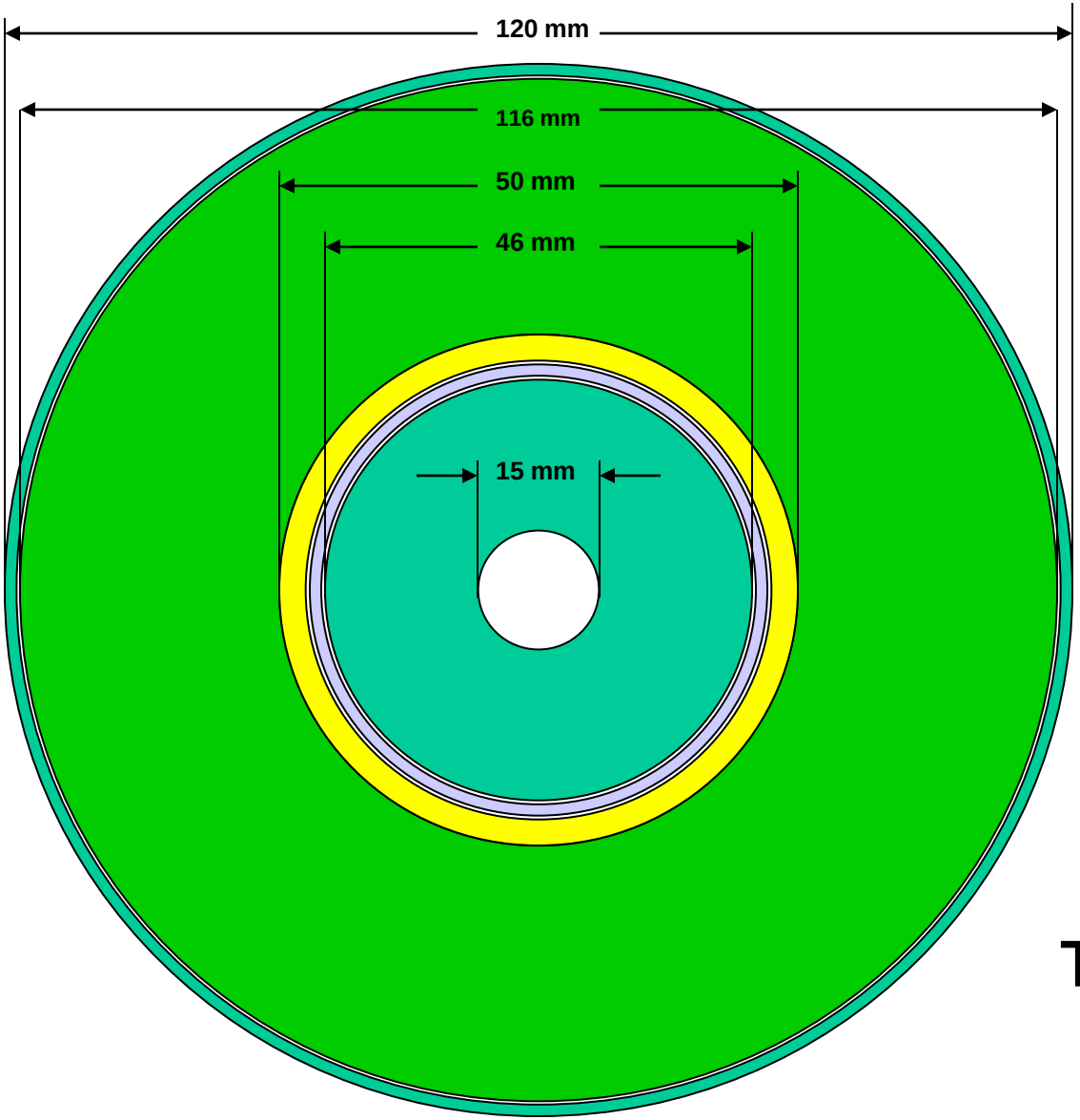
- replicated (CD/DVD-ROM)
- recordable (CD-R, DVD+/-R)
- re-writable (CD-RW, DVD+/-RW, DVD-RAM)
- blue laser disks (Blu-ray, HD-DVD†)

MiniDisc (MD)

- replicated

Magneto-optical disks

- MiniDisc recordable (actually: re-writable)
- Various other professional (historical) formats



Lead out area

Programme area

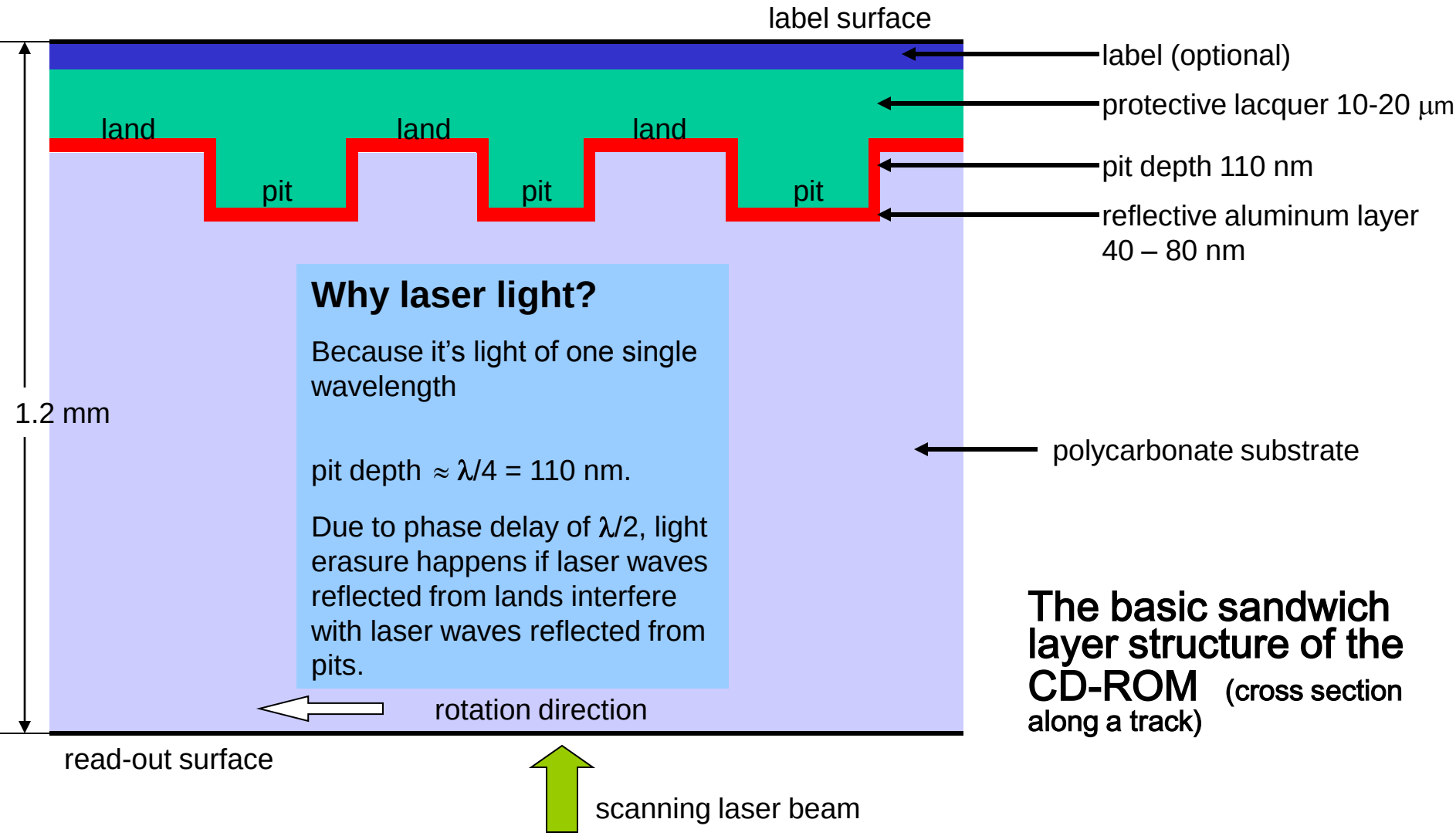
TOC (Table of Content)

Lead-in area

Clear inner hub, clamping area

The partition of a CD

Recording technology CD replicated (CD-ROM)



Why laser light?

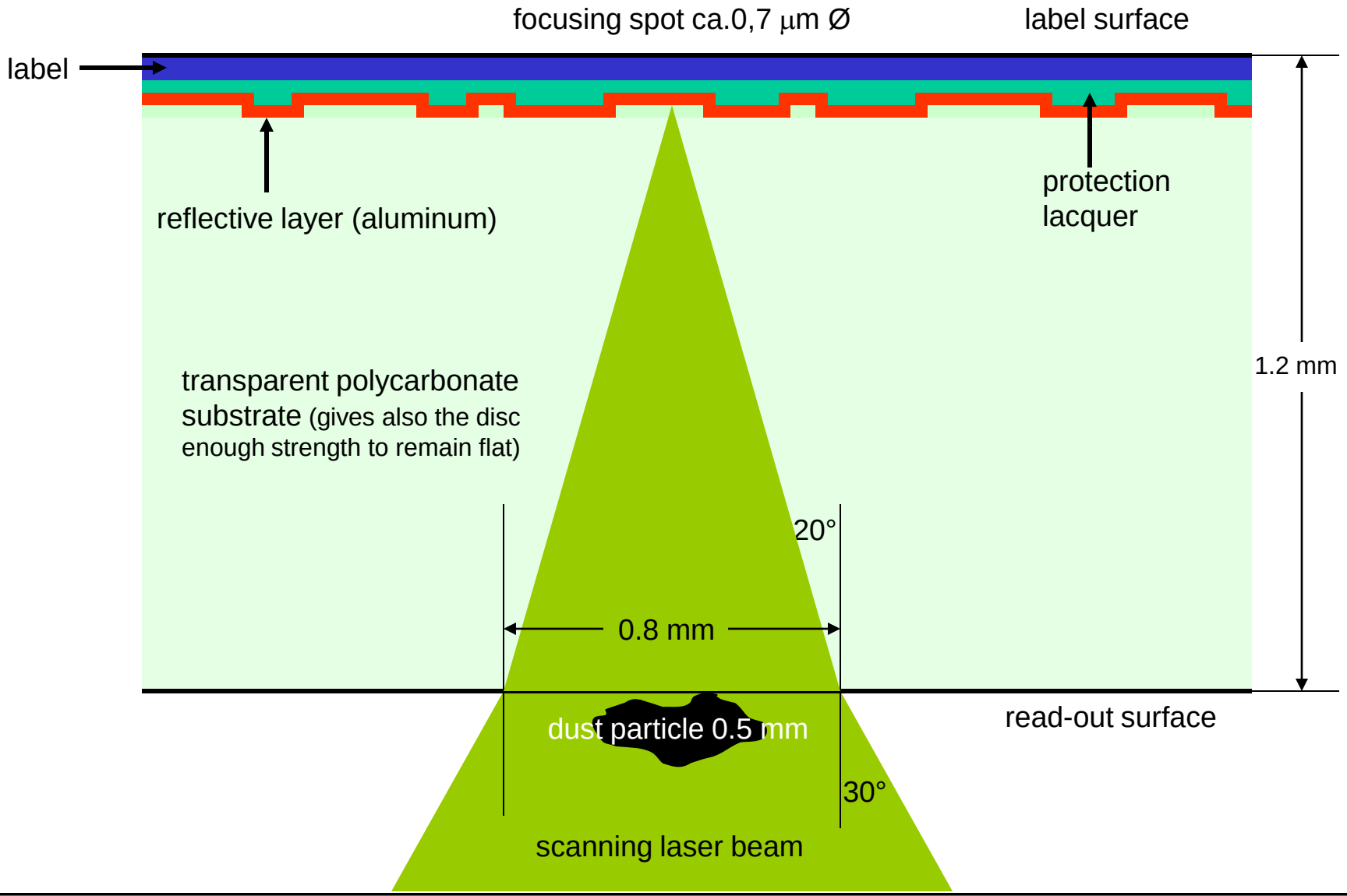
Because it's light of one single wavelength

pit depth ≈ λ/4 = 110 nm.

Due to phase delay of λ/2, light erasure happens if laser waves reflected from lands interfere with laser waves reflected from pits.

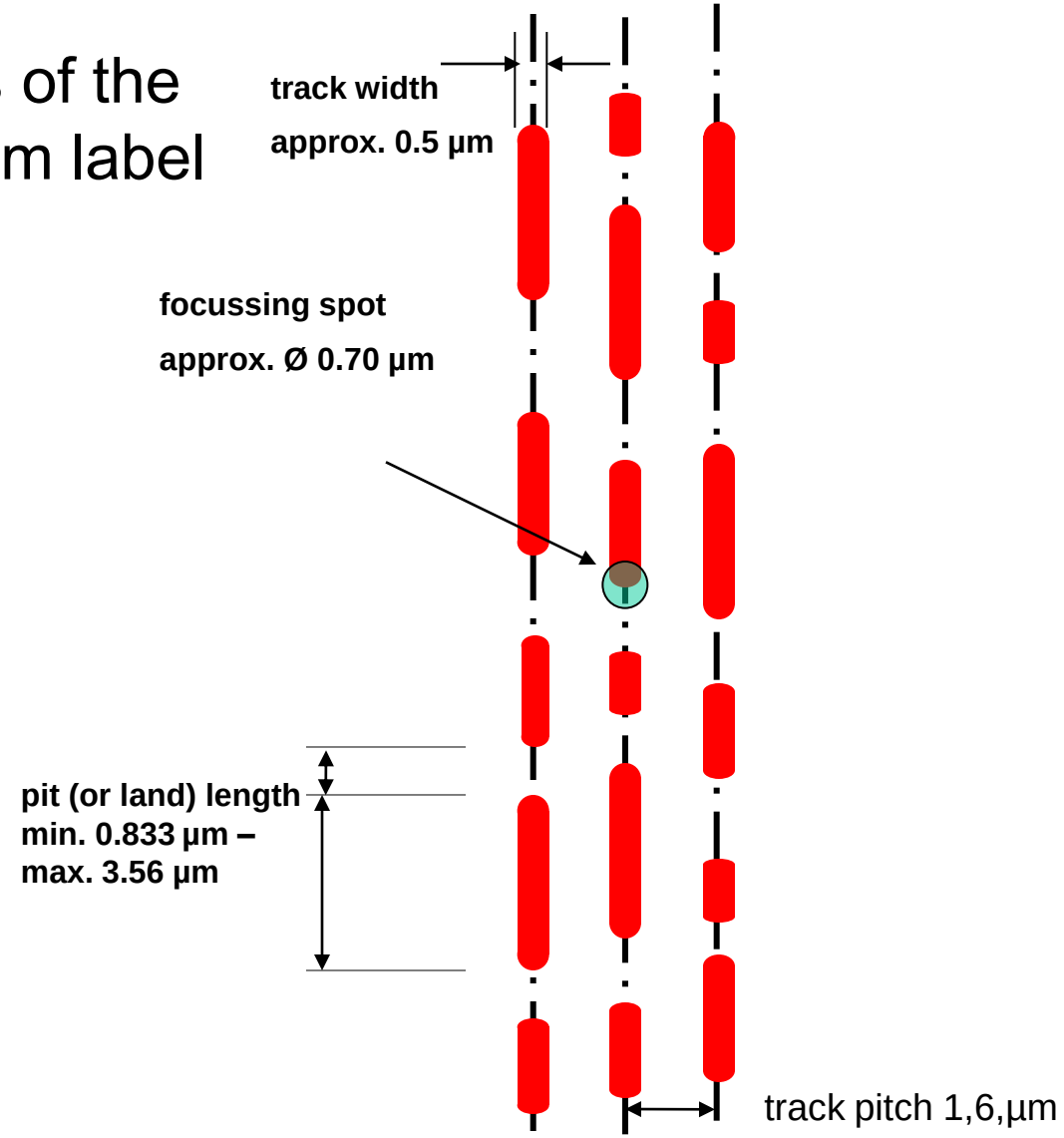
The basic sandwich layer structure of the CD-ROM (cross section along a track)

Replay technology CD replicated (CD-ROM)



Replay technology CD replicated (CD-ROM) and CD-R(W)

Track details of the CD, seen from label side

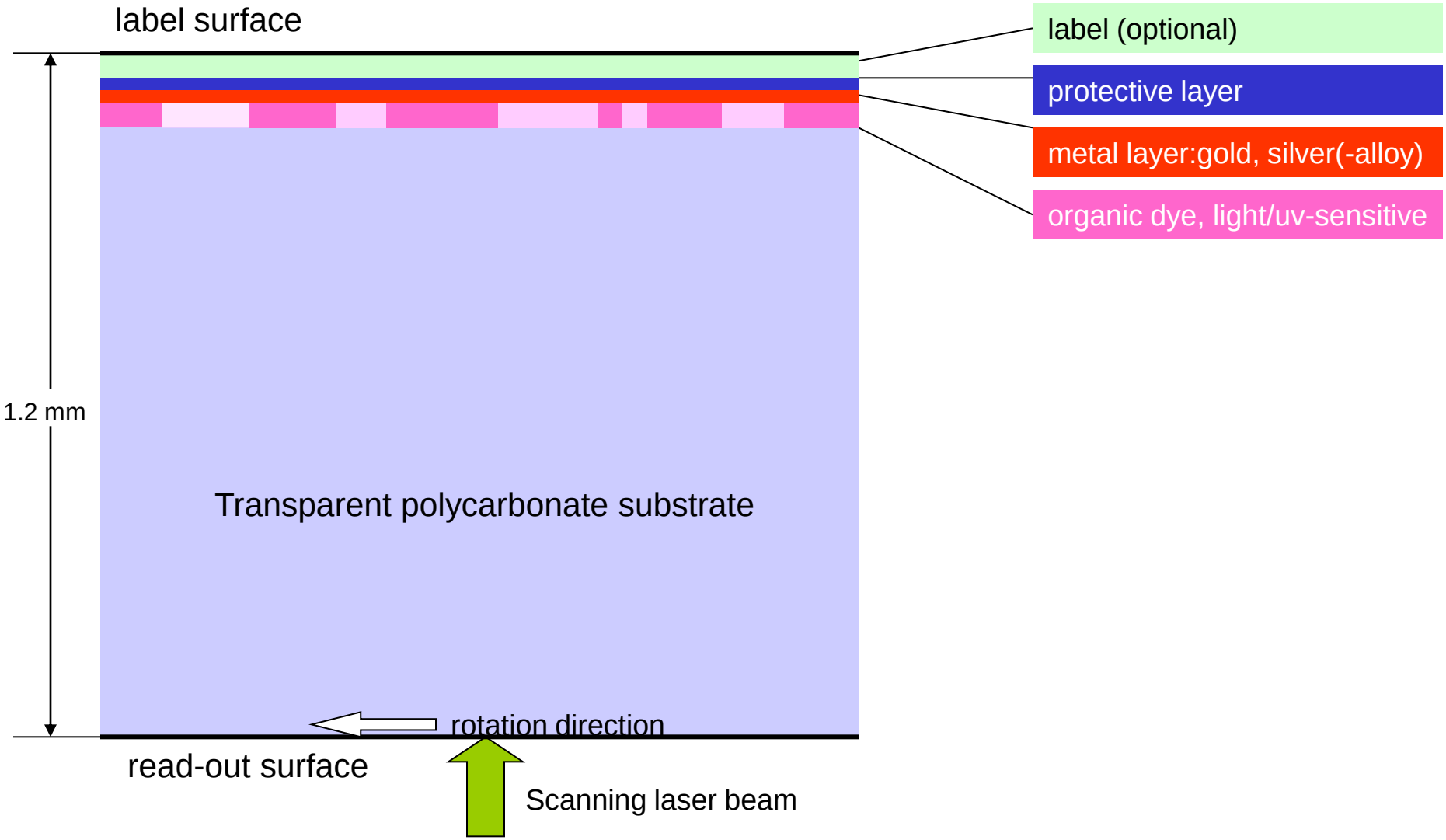


Principle of coding / information retrieval

Change from pit to land or vice versa - change of reflectivity = **1**

Pit or land - no change of reflectivity = **0**

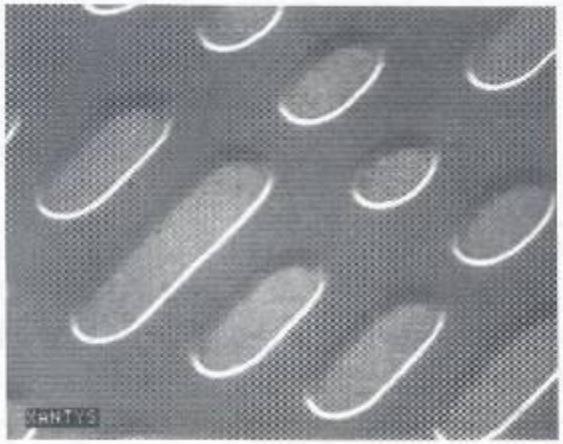
The sandwich layer structure of the CD-R

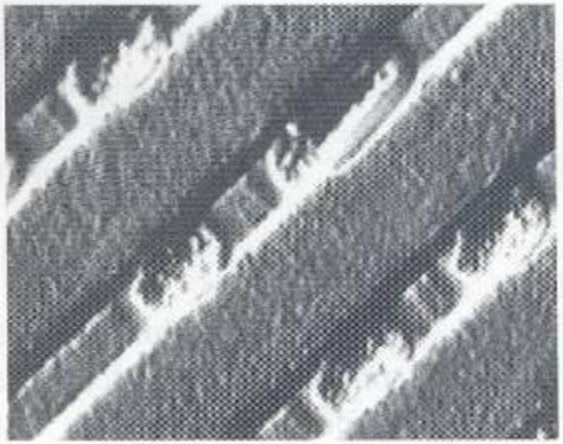


CD: Pits und Lands

CD-ROM – replicated

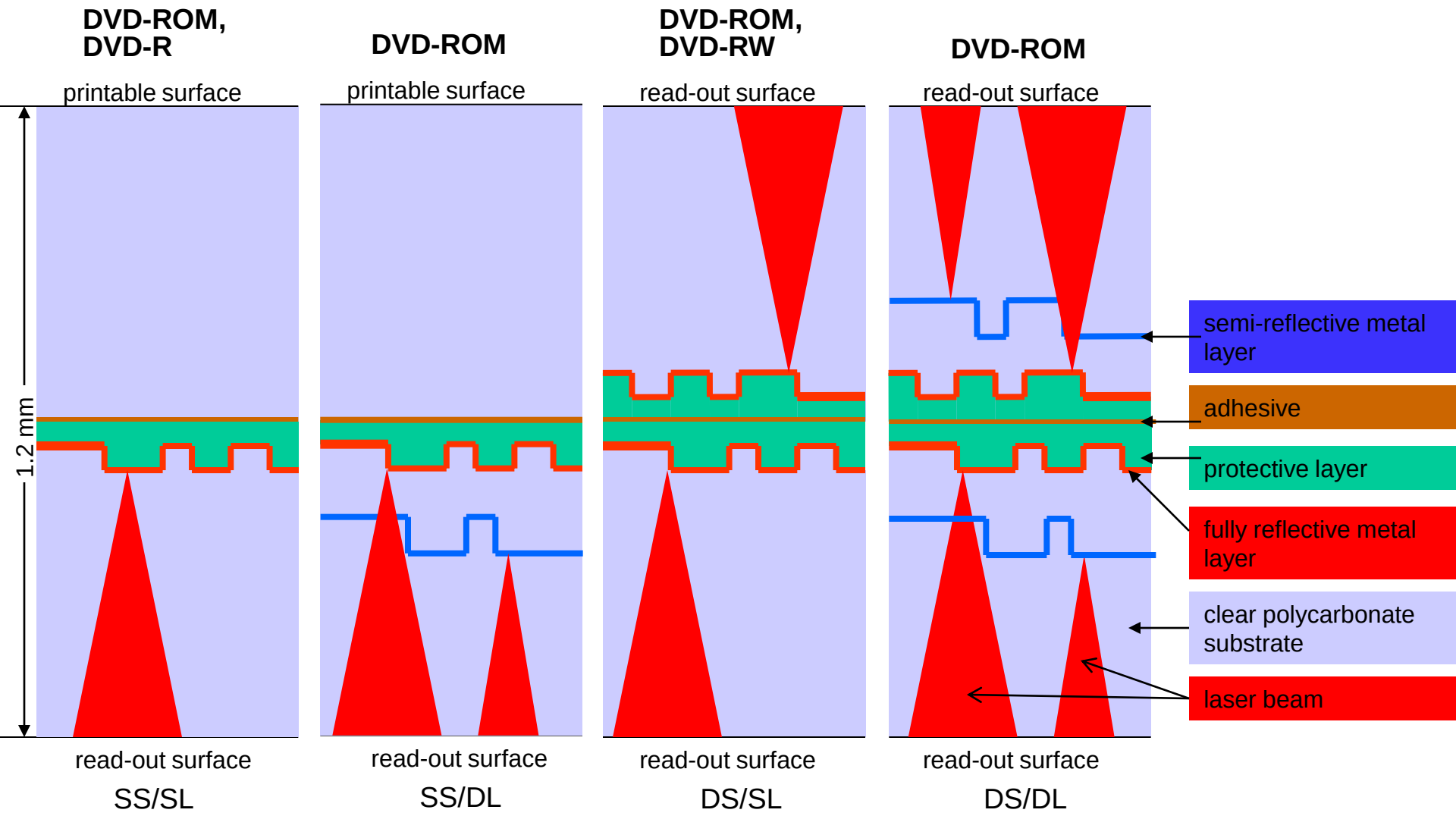
CD-R – burned





Photographs: Jean-Marc Fontaine

Recording technology: DVD family



SS=**S**ingle-**S**ided, DS=**D**ouble-**S**ided. SL=**S**ingle **L**ayer, DL=**D**ual **L**ayer

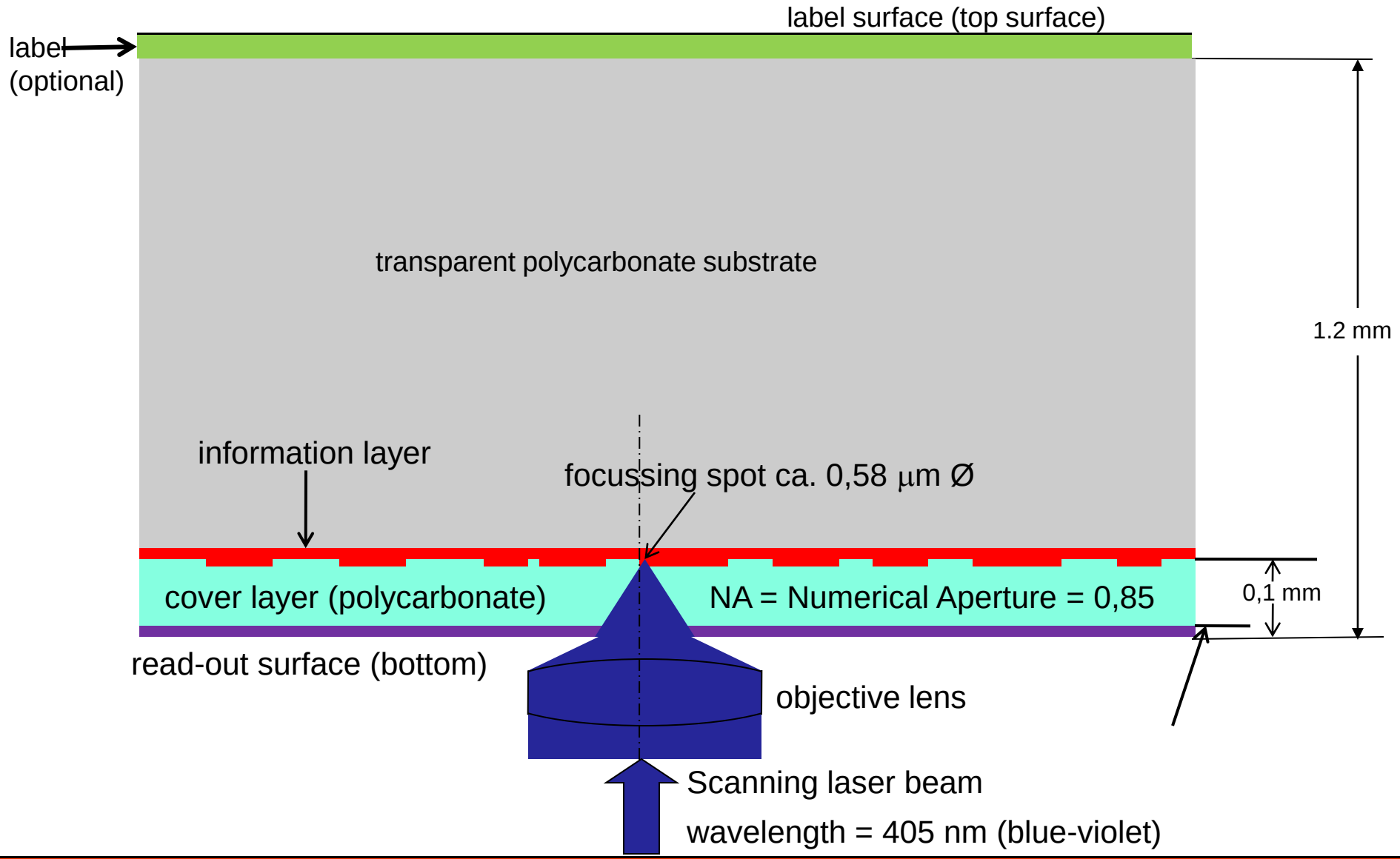
Blue laser disks

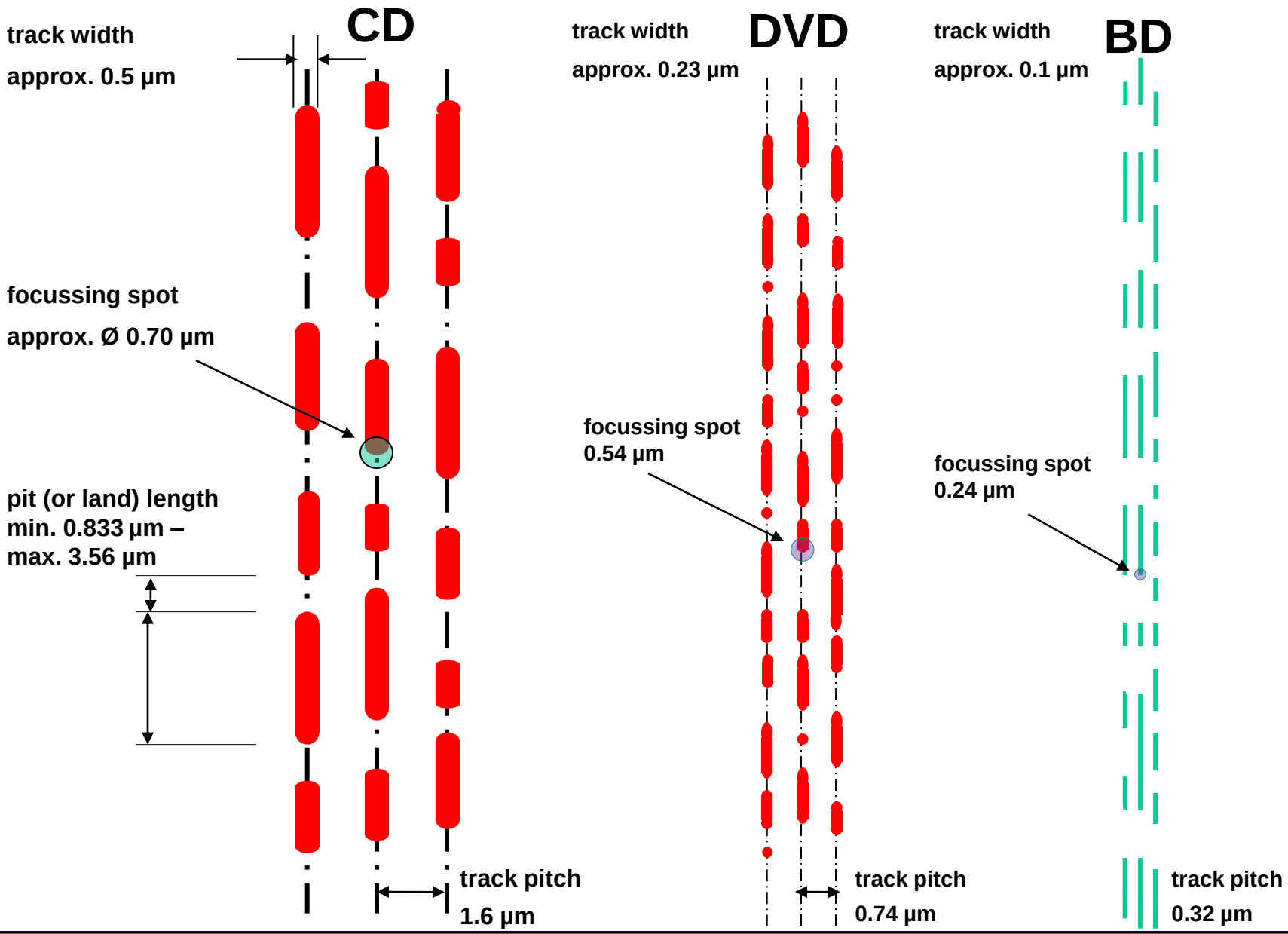
Shorter wavelength of laser – smaller pit/land dimensions – ~ 5 times higher storage capacity than DVDs

Competing, incompatible formats:

- Blu-ray
- HD-DVD discontinued February 2008

Recording technology: Blu-ray




CD
track width
approx. 0.5 µm
focussing spot
approx. Ø 0.70 µm
pit (or land) length
min. 0.833 µm –
max. 3.56 µm
track pitch
1.6 µm
DVD
track width
approx. 0.23 µm
focussing spot
0.54 µm
track pitch
0.74 µm
BD
track width
approx. 0.1 µm
focussing spot
0.24 µm
track pitch
0.32 µm

Optical disk family – Composition and LE

Replicated disks

Polycarbonate substrate – mechanically vulnerable

Reflective layer: mainly aluminum – prone to oxidation

DVD and BD: two polycarbonate layers glued together – stability of bonding unknown

Double layer DVDs and BDs: stability of semi-reflective layer unknown

Protective layer (varnish with label imprint) mechanically vulnerable, chemical stability unknown

No deterioration by replay

Recordable disks ("dye disks") - additional risks

Organic dye: cyanine, phthalo-cyanine and azo – light/uv sensitive, LE "5-100 years"

Reflective layer: gold, silver, silver alloy – prone to oxidization (except gold)

Double layer DVDs and BDs: stability of semi-reflective layer unknown

No deterioration by replay (in practice)

Important factor of recordable disk LE: Quality of recording

Error correction: important factor for the retrievability of digital data

Error correction compensates – within limits – for defects caused by mishandling and deterioration (=ageing)

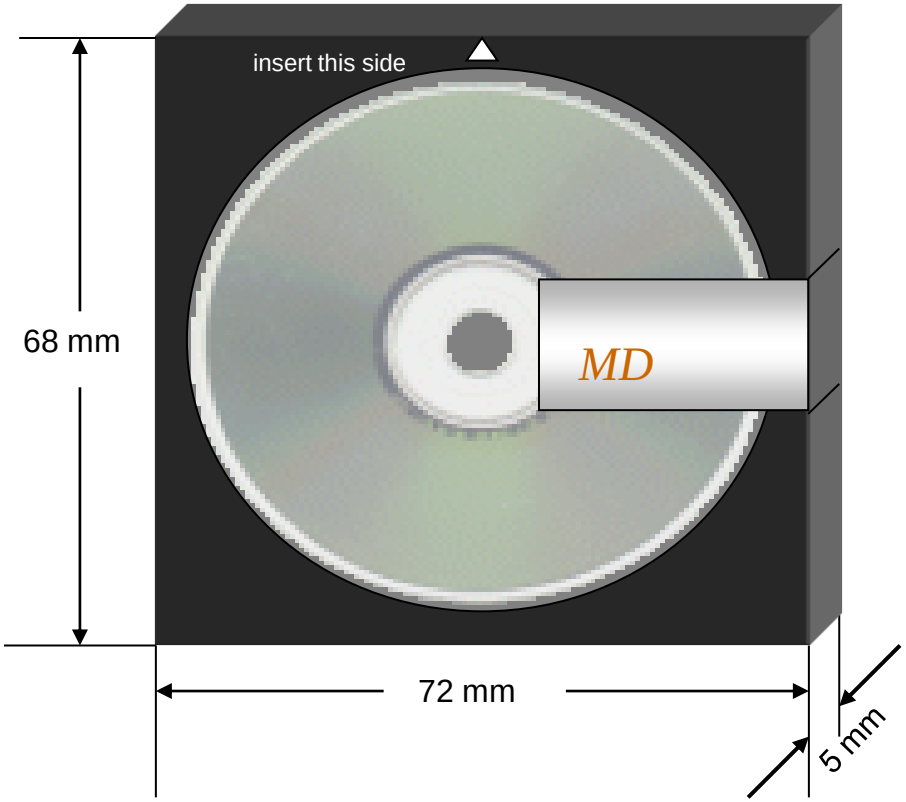
Writer/blank incompatibilities cause bad initial recording quality (= high number of errors), absorbing error correction capacity needed to compensate for defects and ageing

Consequently, recording quality determines LE to high degree

IASA does not recommend recordable disks as preservation media without elaborate testing

Recording technology MiniDisc replicated and recordable

The MiniDisc (MD)



Presented by SONY in 1991 to replace the Compact Cassette, not the CD

Market aimed at young consumers.

MiniDisc uses a data reduction system (ATRAC)

Late development: Hi-MD, *NO data reduction,* 1GB storage capacity – low market acceptance

Replicated MDs work like replicated CD, recordable (actually re-writable) MDs are magneto-optical disks

MiniDisc – Composition and LE

Replicated MiniDiscs → replicated CDs

Recordable (actually: re-writable) MiniDiscs

Polycarbonate substrate

Magneto-optical layer: LE considered higher than organic dyes

Protective layer

No deterioration by replay (in practice)

Part 2 – Passive preservation

Environmental factors, storage, and handling:

- water - humidity
- temperature
- mechanical deformation
- dust (air) pollution, foreign matter
- light uv radiation, x-rays
- magnetic stray fields

General risks:

- fire
- water

Water - greatest natural enemy of audiovisual carriers – omnipresent in humidity of air

Direct action:

•hydrolysis of polymers: lacquer disc coating, nitrate and acetate base film (film and tape), some modern pigment binders

•oxidation of pure metal magnetic pigments (MP-, ME-tapes) and reflective optical disc layer (except gold)

•adhesion - rotary head systems

•causes dimensional changes of carriers

Secondary action:

•fungus growth beyond 65% RH – affects ALL carriers

Magnetic tapes: Sticky shed syndrome (SSS):

- Squeal during replay
- Deposit sticky shed on tape guides, clogging replay heads

Formerly generally ascribed to binder hydrolysis

Other SSS reasons:

Primer exudation – PVC-based 0.1 µm layers between base film, pigment and back coating

Superfluous dispersion agent

Lubricant exudation often as a result of temperature below 5-6°C

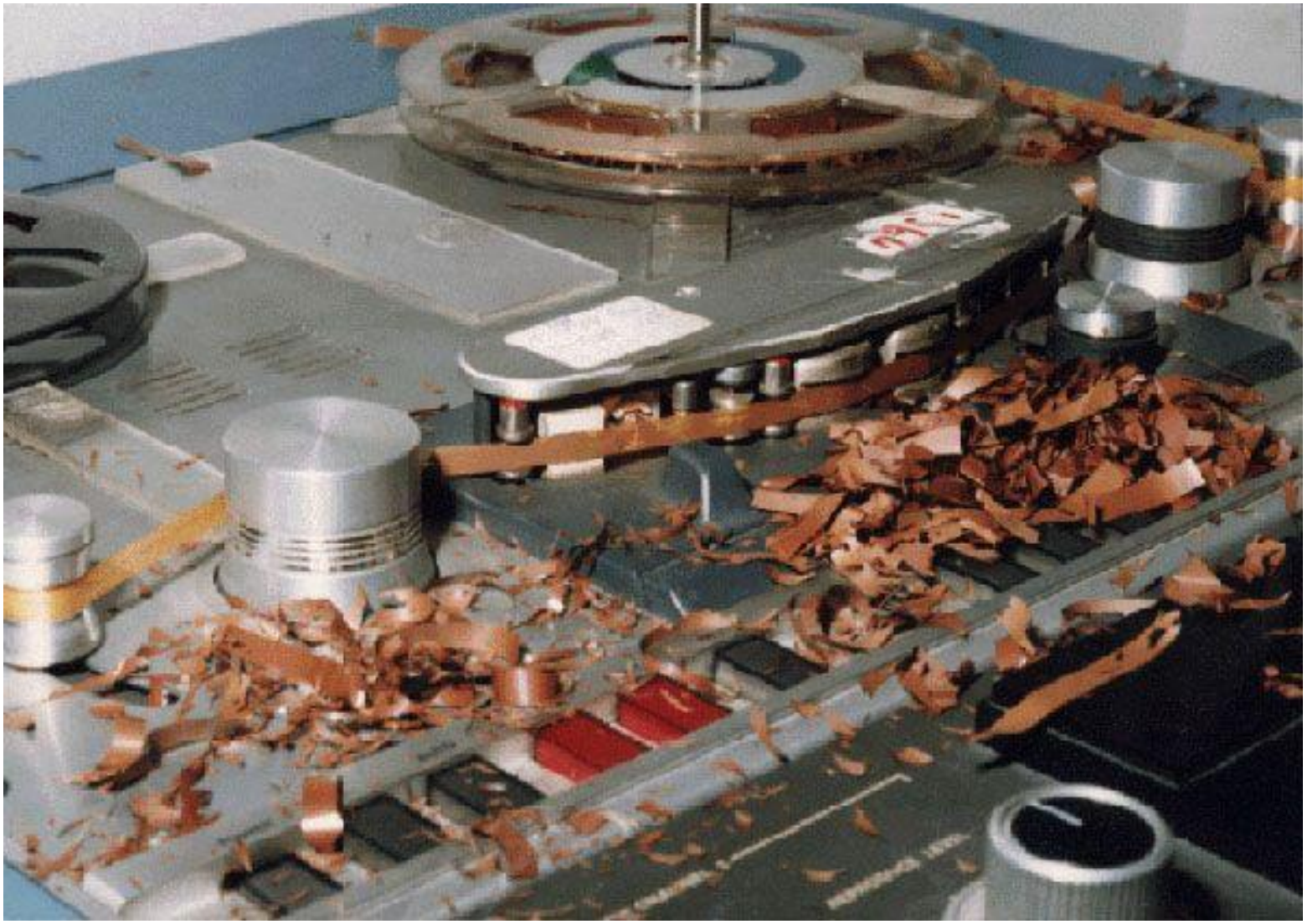
Insufficiently cross linked binder components – high production speeds (up to 1000m/min, for amateur tapes only) called for cross linking binder components during coating on the surface. Irregular spread of components lead to sticky areas.

Most sticky tapes (except insufficiently cross linked) can be reconditioned by cleaning and exposure to elevated temperatures

Nota bene: seek experts advise!

Pigment binder degradation or misproduction ?

Extreme case: misproduction



Temperature

up to 35°C no direct harmful influence on audiovisual carriers

but:

Temperature causes dimensional changes

Temperature determines speed of chemical processes:

•the higher, the faster

•the lower, the slower

...processes of deterioration, ageing

Theoretical ideal: keep temperature and humidity stable and low -

Avoid (cyclic) changes of temperature and RH

And:

Temperature and humidity are interrelated:
- control both parameter simultaneously
- **never** cool storage area without dehumidification (humidity may raise excessively!)

Instead of fixed values, TC 05 defines ranges

Humidity (ranges):

Medium	40-50% RH	
Low	25-35% RH	
Variability	narrow ± 3%RH	relaxed ± 5%RH

Temperature (mean values):

Room:	~20°C (higher in tropical areas)	
Cool:	between 8 and12°C	
Variability	narrow ± 1°C	relaxed ± 3°C

Temperature/humidity ranges and variability must not be added. The chosen mean value should be kept to the permissible variability

Collections	**Humidity**	**Variability**	**Temperature**	**Variability**
Access storage Tape collections in frequent use Mechanical and optical carriers (except lacquer discs)	low medium	narrow relaxed	room room	narrow Relaxed
Preservation storage Tape collections Mechanical and optical carriers (except lacquer discs)	low medium to low	narrow relaxed	cool room to cool	narrow relaxed
Access and preservation storage Lacquer discs	medium	narrow	room	narrow

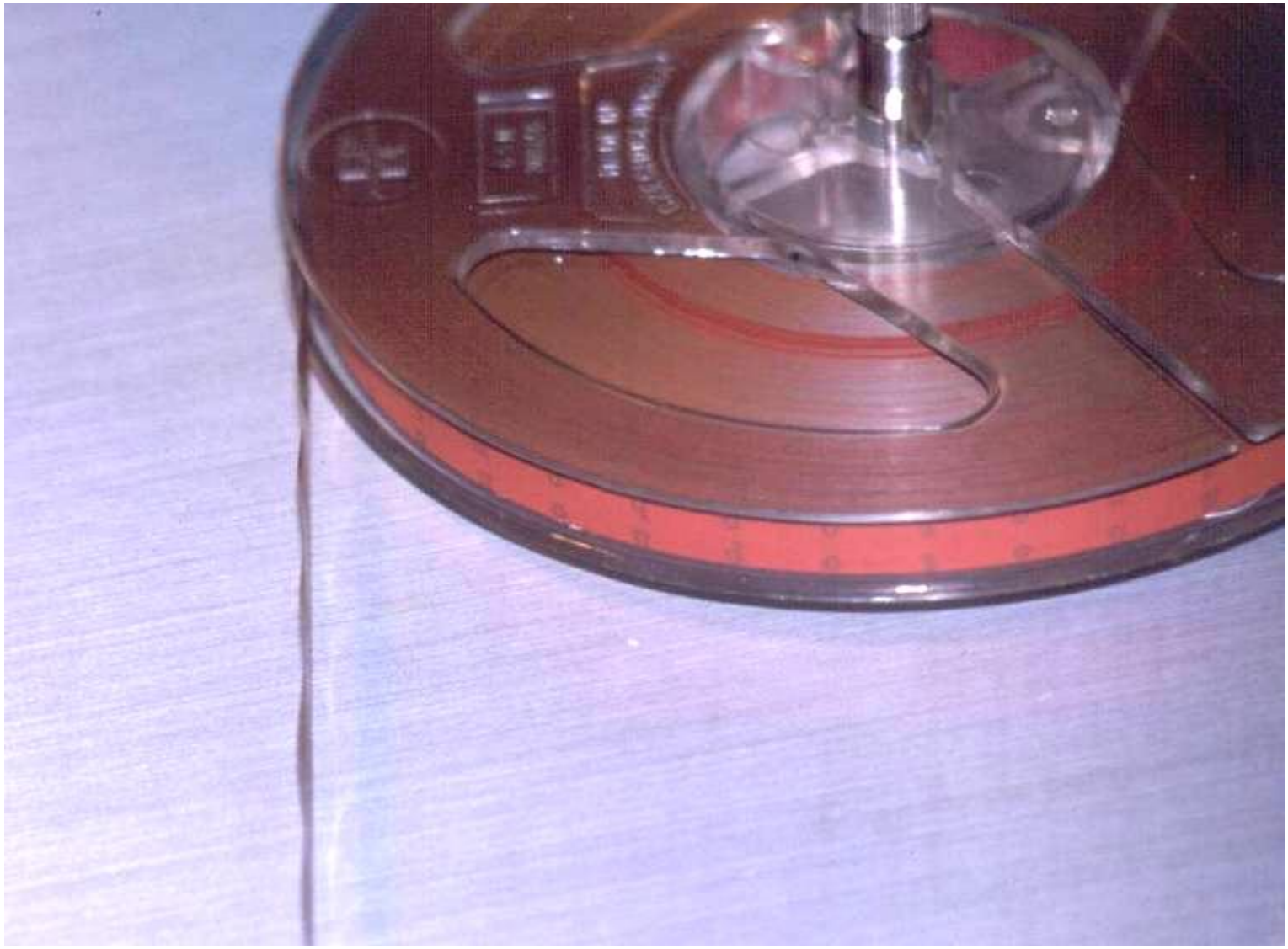
Acclimatise when moving carriers from preservation to access store and **relax tape based carriers**

Nota bene:

- any levels between 20 – 65% RH and 8 (for photographic materials lower) – 35°C are without **immediate** risk to AV carriers
- **but:** choice of storage conditions determines speed of degradation
- keeping to tight standards does **not** prevent degradation
- choose parameters which you can afford 24 h/day all year round

Mechanical deformation

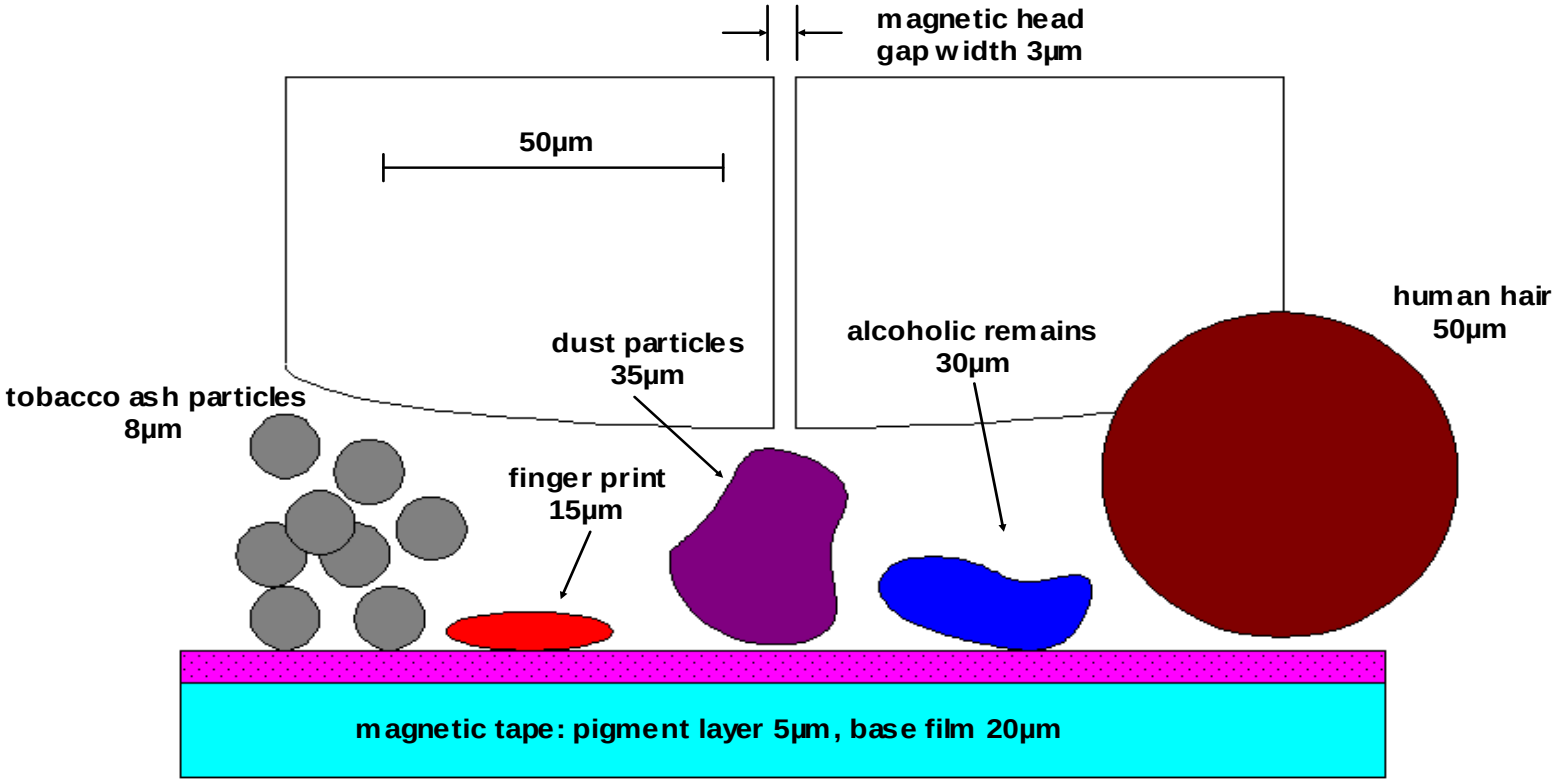
- careful handling of fragile carriers (all mechanical carriers)
- avoid scratches on ALL carriers, keep tape machines in excellent condition
- load/unload cassettes only at *unrecorded* start/end
- store tapes/cassettes with **flat wind** only
- avoid bending optical disks



Dust, (air) pollution, foreign matter

- minimize dust in storage and handling areas, use air filters
- don't use carpeted floors
- never touch recorded areas with fingers
- don't drink, eat or smoke in storage and handling areas

The higher data density, the higher risk of malfunction because of foreign matter


magnetic head
gap width 3µm
50µm
human hair
50µm
alcoholic remains
30µm
dust particles
35µm
tobacco ash particles
8µm
finger print
15µm
magnetic tape: pigment layer 5µm, base film 20µm

Cleaning of carriers

Sequence of action:

- compressed clean air
- gentle mechanical
- distilled water - if permissible
- chemical agents - if permissible

Imperative: seek expert's advise first

Light, uv radiation, x-rays

- avoid prolonged light and uv exposure to all audio and video carriers, especially, and recordable CDs, DVDs and BDs
- high, even lethal doses of x-raying have not shown significant immediate signal deterioration of magnetic carriers – long term effect, however, unknown

Magnetic stray fields 1

most sensitive:

- analogue magnetic audio recordings
- linear audio tracks on analogue video formats

less sensitive:

- FM audio
- analogue video
- all digital recordings
- magneto-optical disks

Magnetic stray fields 2

maximum stray fields for analogue audio tapes:

- 5 Oe AC
- 25 Oe DC

keep recorded tapes 10-15 cm off:

- dynamic microphones and headphones
- loudspeakers
- level meters (moving coil instruments)
- magnetic board stickers, etc
- unclear: transport in electric cars

Keep greatest possible distance to lightning conductors

Storage areas, shelving

- underground storage suboptimal
- avoid wooden shelves
- steel ok, if not part of lightning conductor system
- store all carriers upright, except soft instantaneous discs (Decelith, gelatin, etc.)
- film cans are often stored horizontally

Model of tropical AV archive building

Fire protection and extinguishing

- protect storage areas by fire doors and fire walls
- organise appropriate fire divisions throughout building
- install fire detection and alarm system

- NB: Nitrate film must only be stored in special vaults

Extinguishing agents:

- automated extinguishing system: halon replacement gases or “dry fog”
- hand-held extinguishers: CO_2
- **no water - no foam - no powder !**

Observing all rules, keeping to all parameters, is no guarantee against loss of a given document, therefore:

“one copy is no copy“

Minimal requirements:

1. original
2. archival master copy **plus** back up (safety) copy
3. service/access/working copy

All copies must be handled by trained archive staff only

Thank you!

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