THIC Inc.

The Premier Advanced Recording Technology Forum

Overview of Optical Data Storage Technology

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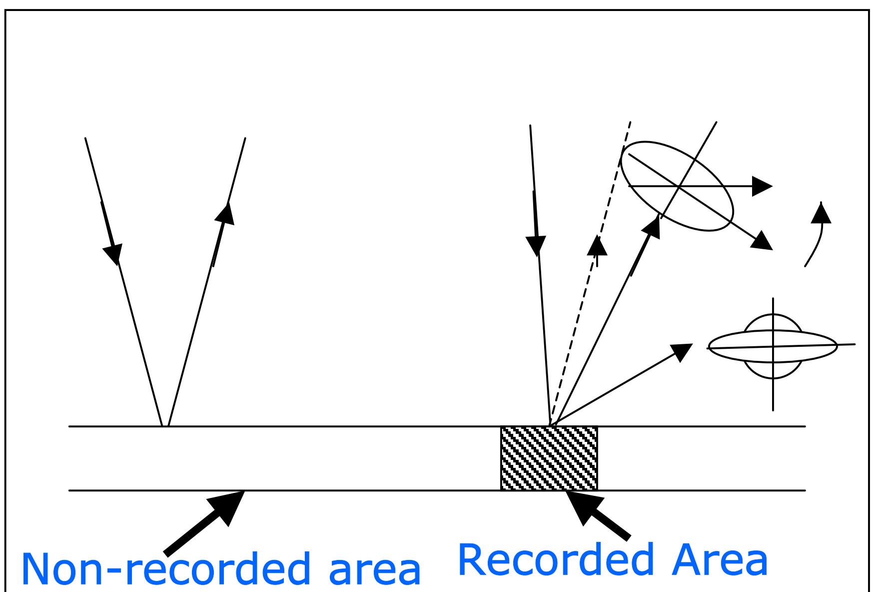
Overview of Optical Data Storage Technology

- Technology Basics
- Recording Process
  - Mass Replicated Read Only Memory, ROM
  - Organic Dye Decomposition, WORM
  - Magneto-optical recording
  - Phase Change recording
- Future Outlook
  - Road to 100 GB+ disc
- True Measure of Storage Density/Efficiency

Optical Data Storage Technology

Reading Data by Laser Beam

- Recording process produces physical, chemical and/or magnetic changes in or on the recording medium
- Reading laser beam, its characteristics changed as it is reflected off the medium surface, is collected by the data detection system
- Detector produces data signal output by comparing the characteristics of the beam returned from the recorded area (pit) and the beam returned from the non-recorded area (land)



Return Beam Characteristics Change

1. Greatly reduced intensity
2. Polarized Plane Angle Shift
3. Beam cross-section ellipticity change

Technology and Applications

Recoding Process	Data Recovery	Application	Products
	Read-only Memory, ROM		
Replication from master by injection molding	Return Beam Intensity Difference Detection	Pre-recorded Video, Audio, Data	CD, DVD, CD-ROM
	Write Once Read Many WORM		
•Organic dye irreversibly decomposed by heat •Substantially less light returns from recorded area	As above As above	Individual and small lot production Video, Audio, Data Storage	CD-R DVD-R

Technology and Applications (contd)

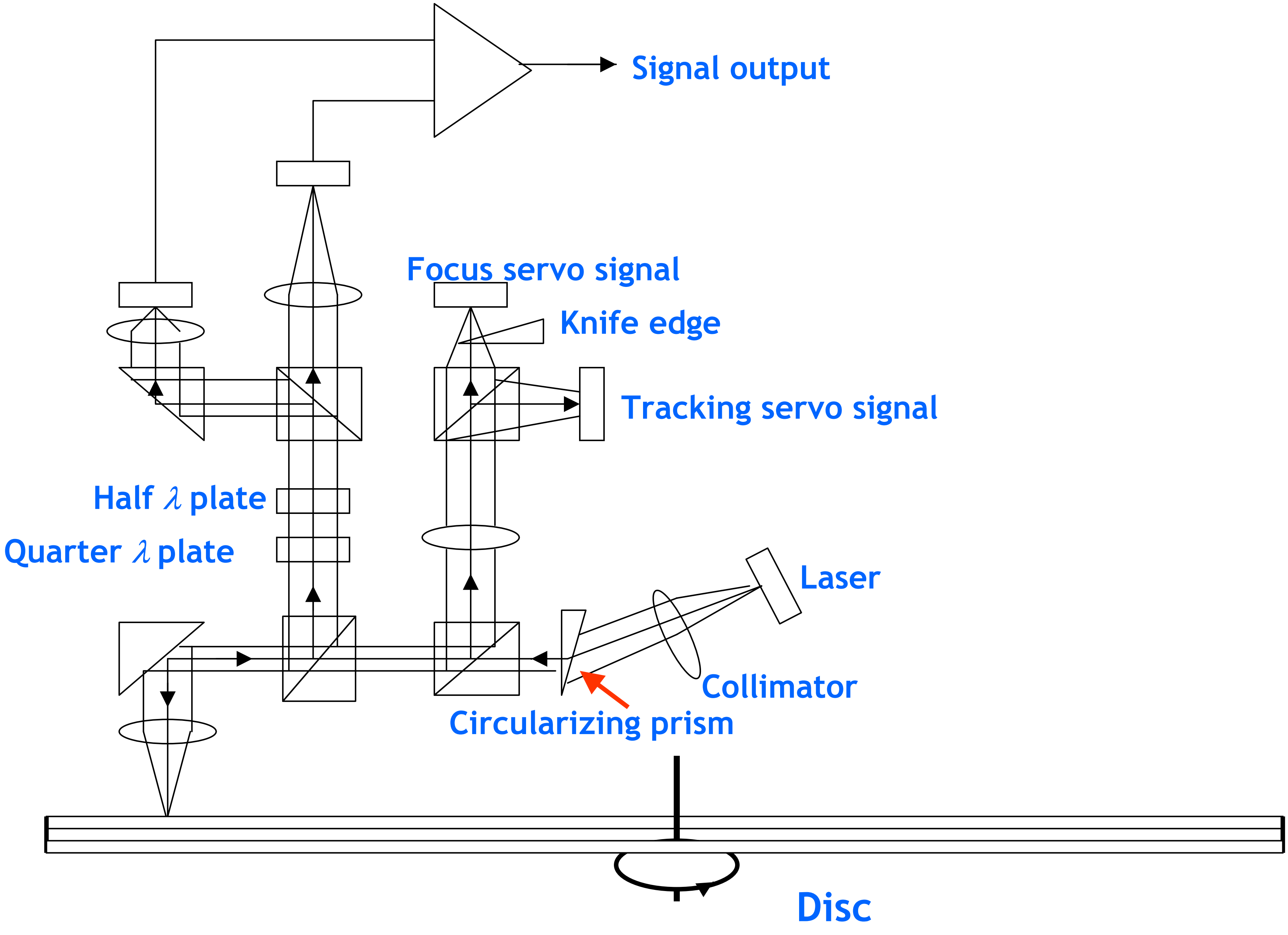
Recording Process	Data Recovery	Application	Products
Record-Erase-Record (Phase Change)			
•Thermally reversible crystalline-amorphous phase change on chalcogen alloy •Amorphous (recorded) area returns less light	Return beam intensity difference detection	General Purpose data storage	DVD-RAM DVD-RW

Technology and Applications (contd)

Record-Erase-Record (Magneto-optics)

Recording Process	Data Recovery	Application	Products
•Thermally assisted magnetic recording •Use polarized light for reading	Return beam polarization angle shift	General purpose data storage	ISO standardized 3.5”, 5.25” MO drive ID-Photo

Typical System Configuration



Areal Recording Density

d = beam spot diameter

$\mathbf{D}$ = Effective lens diameter (aperture)

$\mathbf{F}$ = Focal Length of Lens

λ = laser wavelength

ρ = laser beam energy distribution profile

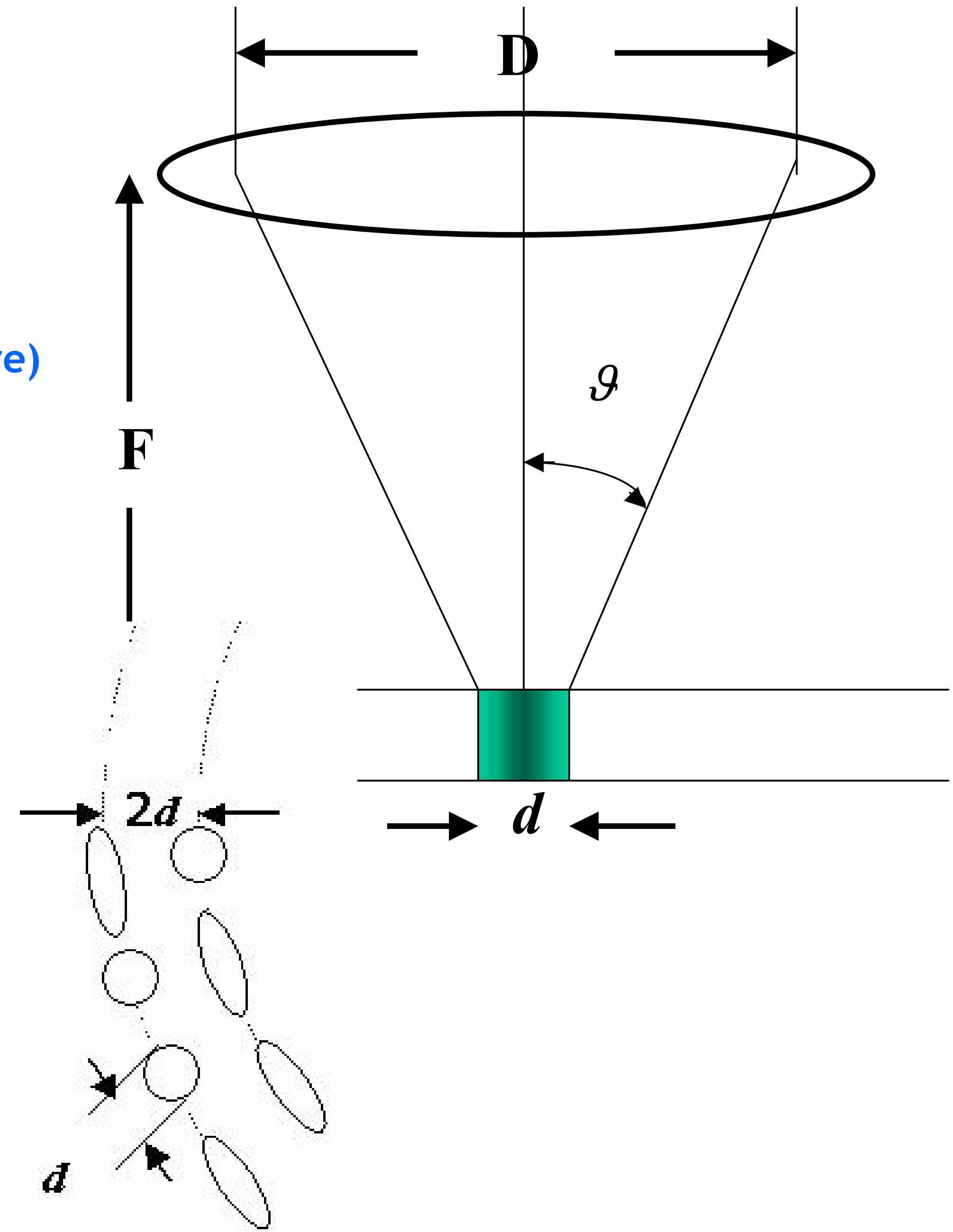
NA = Numerical aperture = $sin\ \theta$

$d = \rho\lambda/\text{NA}$

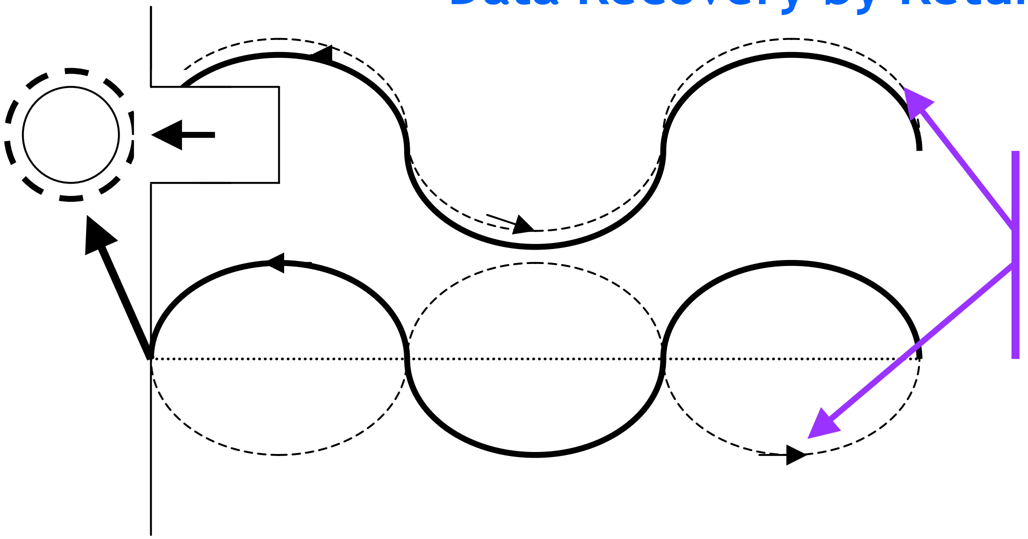
Minimum mark length = d

Track pitch = 2 d

Area/bit = Track pitch X 2 mark lengt
= $(2\ d)^2$



Data Recovery by Return Beam Intensity

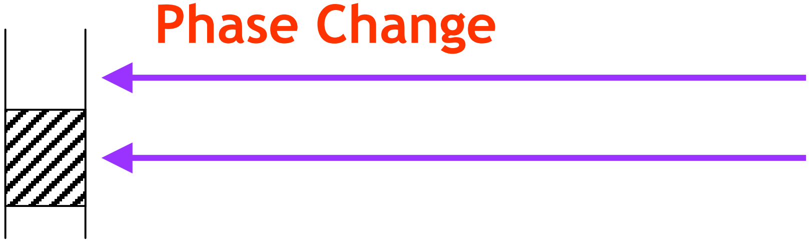


λ/4 Pit elevation

Main return beam from pit and reflections from surrounding area are out of phase; this interference reduces intensity of returned beam

Return beam from land area maintains high intensity

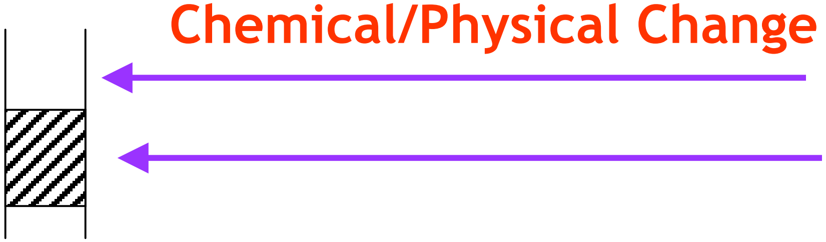
Phase Change



High reflectivity of crystalline phase in no-recorded area (land)

Low reflectivity of amorphous phase recorded area (pit)

Chemical/Physical Change

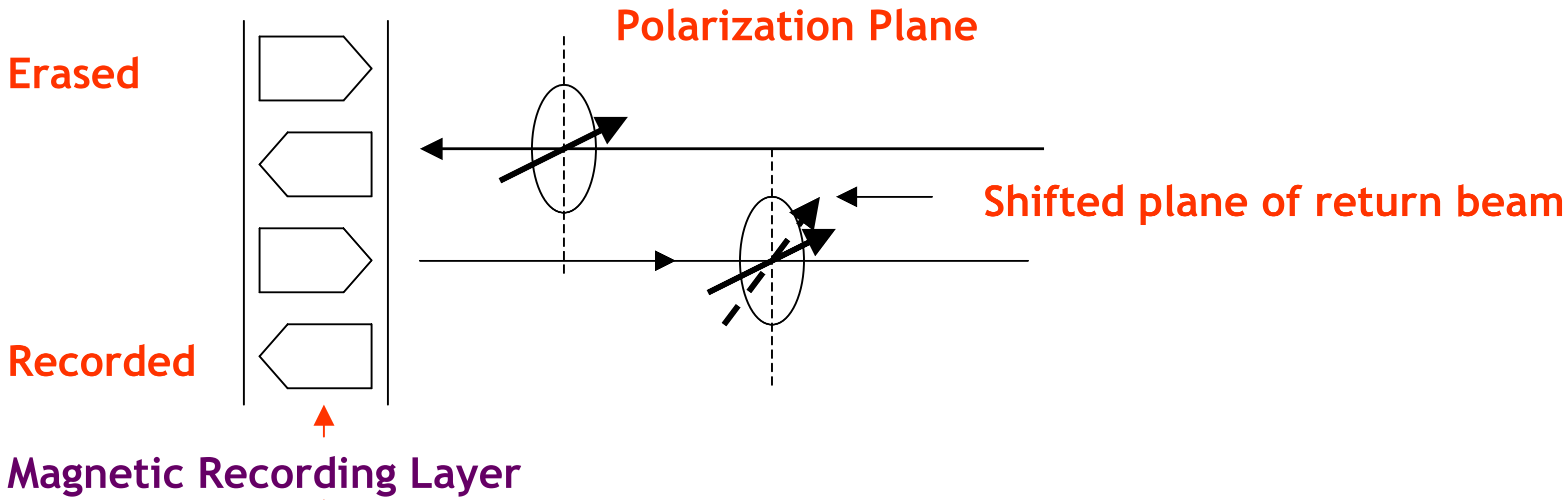


High reflectivity of organic polymer dye

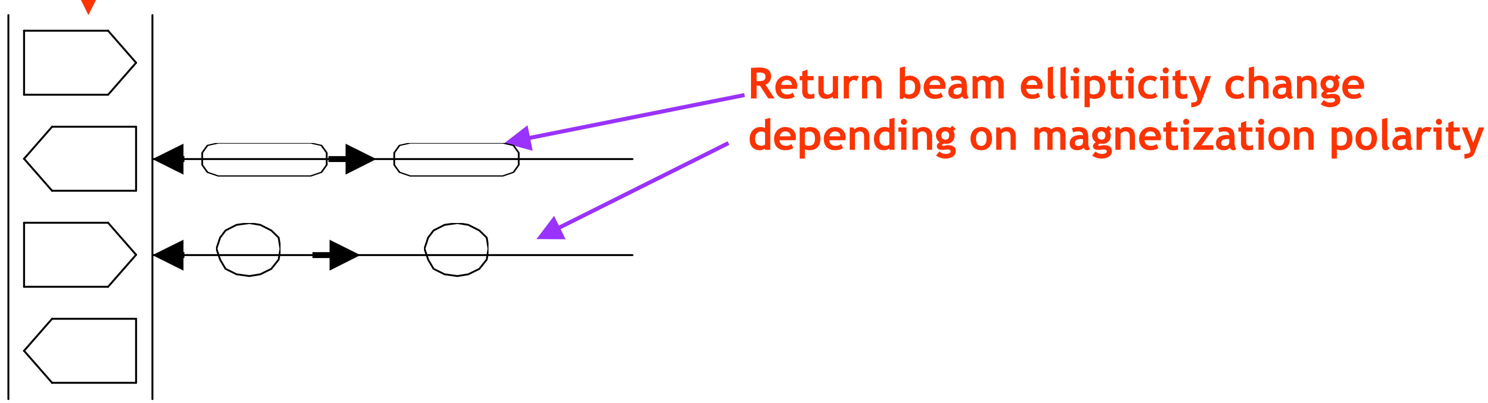
Low reflectivity of recorded (thermally induced chemical change) area

Data Recovery by Return Beam Optical Characteristics

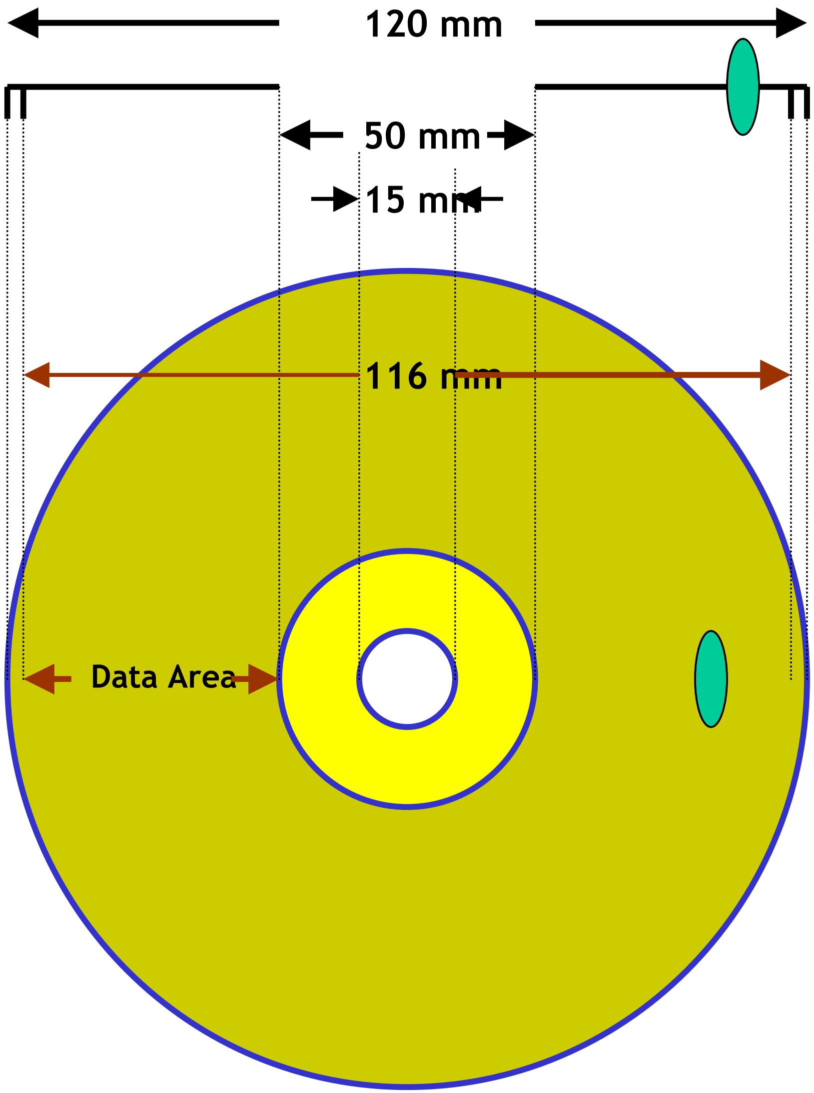
Polarized Beam Plane Angle Shift (Kerr Effect)

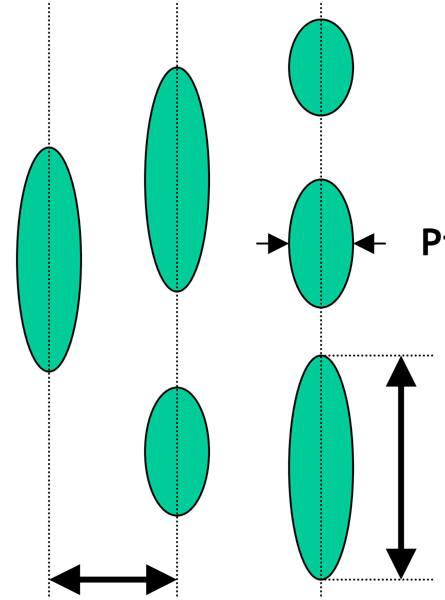


Return Beam Ellipticity Change

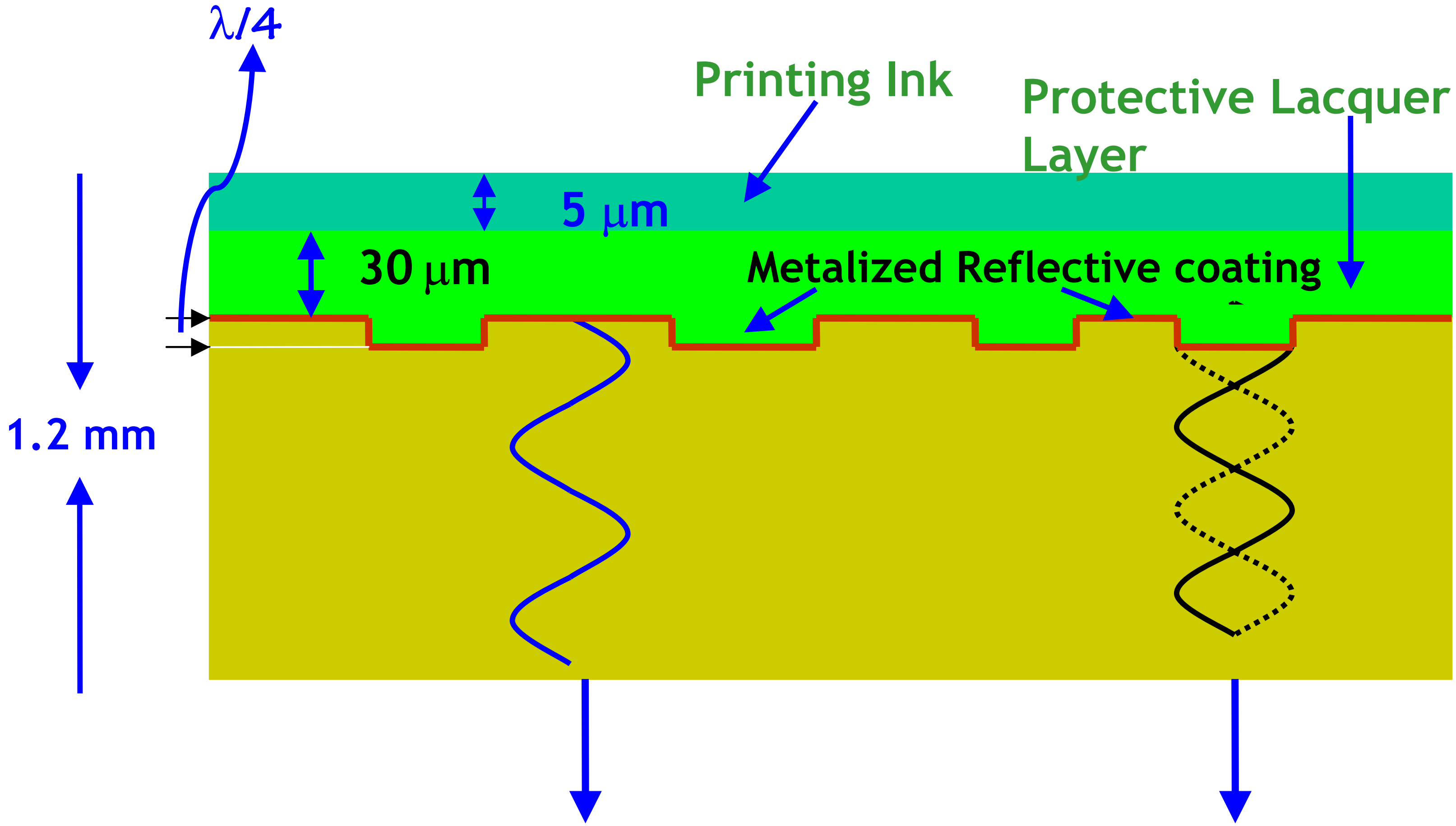


Structure of Compact Disc





Compact Disc Structure



90% reflection from land

20% reflection from pit

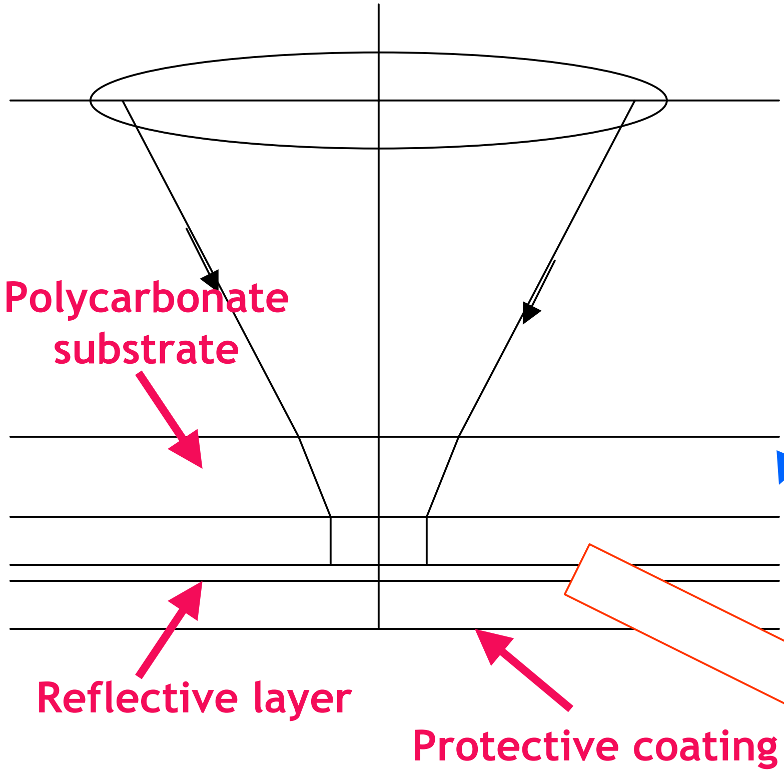
Organic Dye Decomposition Recording

Recording layer, 1/2λ thick

Phthalocyanine, cyanine, azo, etc

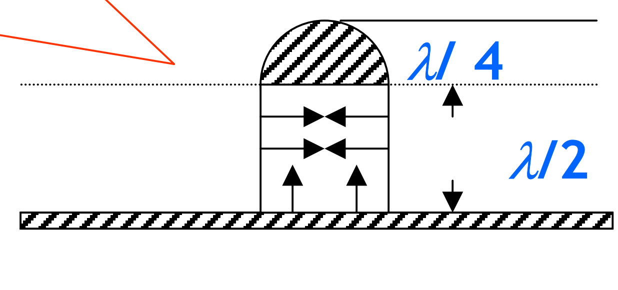
High light transparency before recording

Becomes near opaque after recording

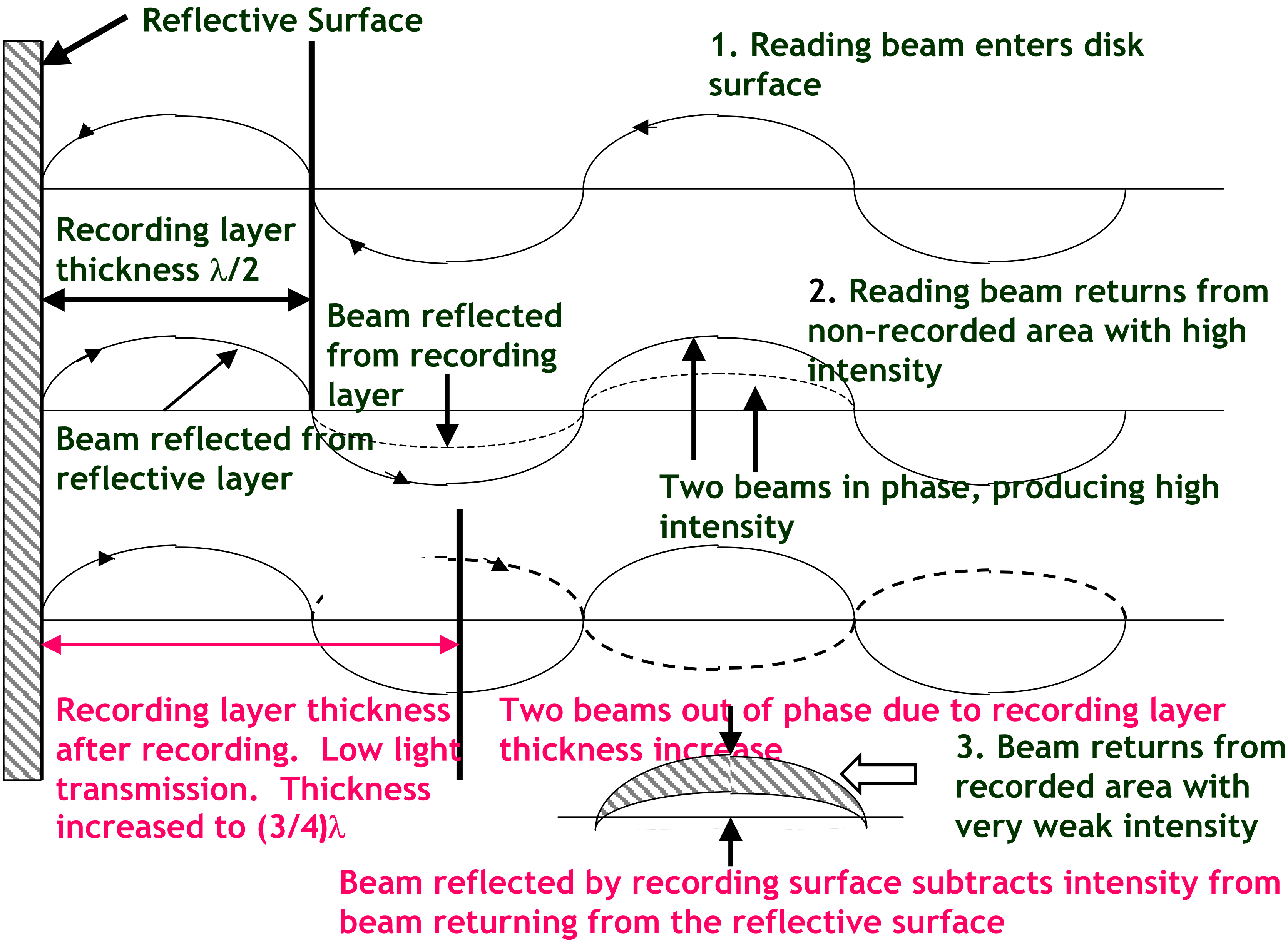


Polycarbonate substrate absorbs heat generated in recording layer, forming light-absorbing substance approximately ¼ λ thick

Heat concentrated in illuminated area due to poor lateral heat conductivity of recording layer and heat reflected from metallic reflective layer

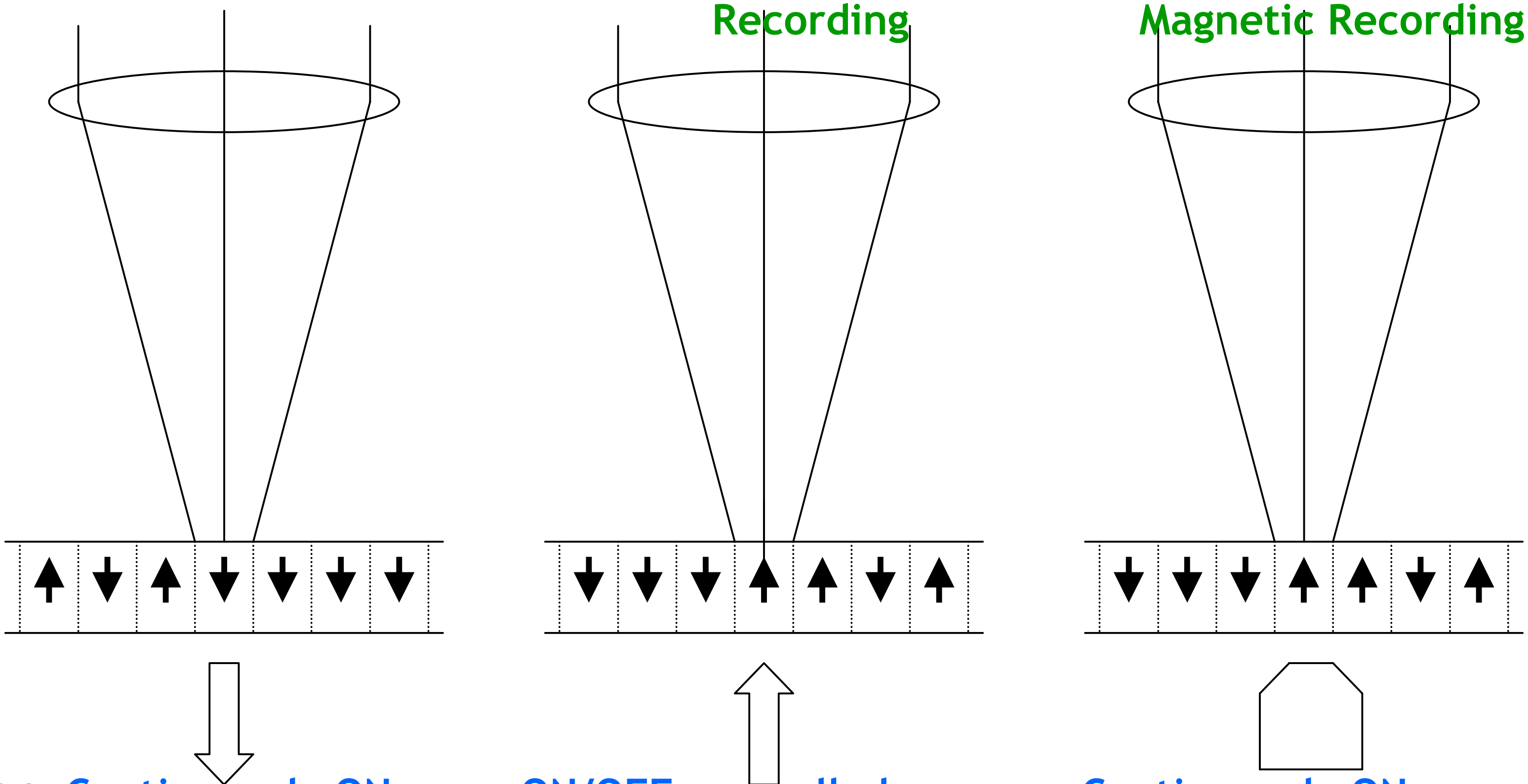


Return Beam Intensity Modulation - Complex Technique



Magneto-optical Recording

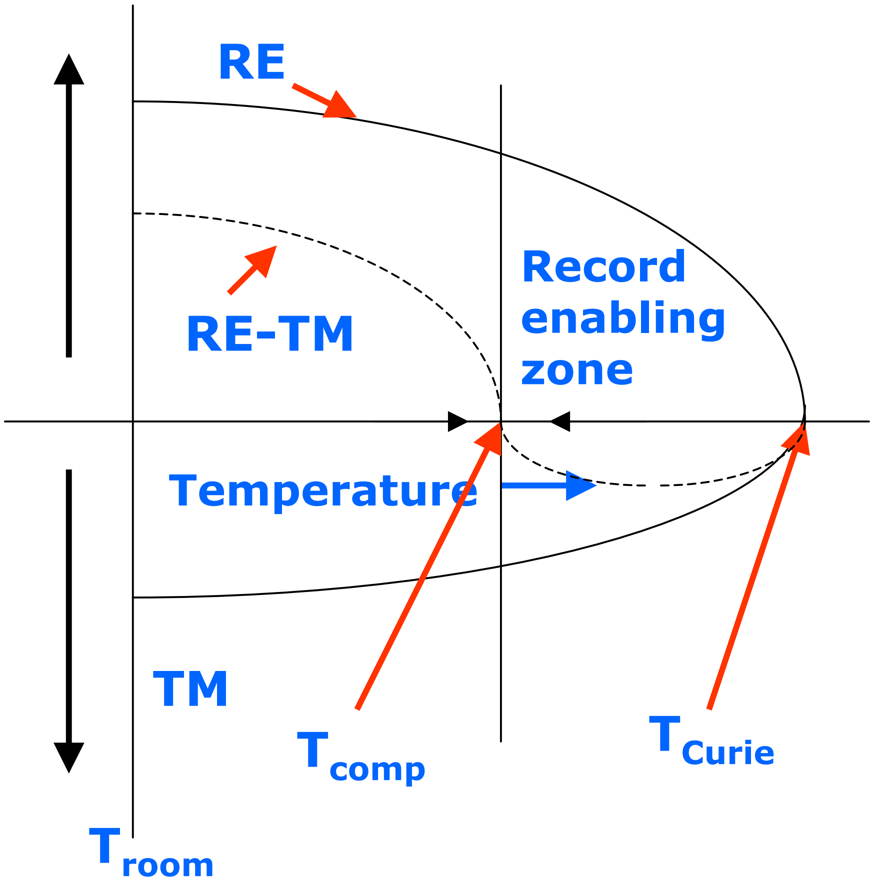
Erase	Conventional M-O Recording	Thermally assisted Magnetic Recording



	Erase	Conventional M-O Recording	Thermally assisted Magnetic Recording
Laser	Continuously ON	ON/OFF controlled by recording data	Continuously ON
Magnetic Field	Continuously ON	Continuously ON	ON/OFF controlled by recording data(Note)

Note:Perpendicular magnetic recording head placed in close proximity (10-20 μm)to recording layer

Magneto-optical recording - Compensation point writing



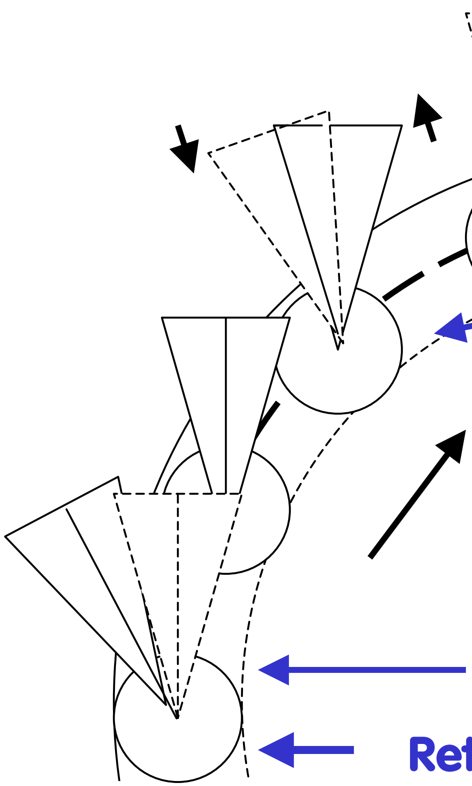
- Ferrimagnetic recording layer
- Ferrimagnetic material composed of: RE (rare earth material)

  TM (Transition Metal)
- T_{comp} = compensation temperature where net magnetization from RE and TM approaches zero
- T_{curie} = Curie temperature

Magneto-optical Recording - Use of Laser as Heat source

- laser power focused on recording layer elevates its temperature to near compensation point where coercivity is very low
- Weak magnetic field placed below recording medium reverses polarity of recording layer magnetization

Data Recovery Technique



Magnetization direction reversed by recording

Returned beam polarization plane rotated

Direction of Recording

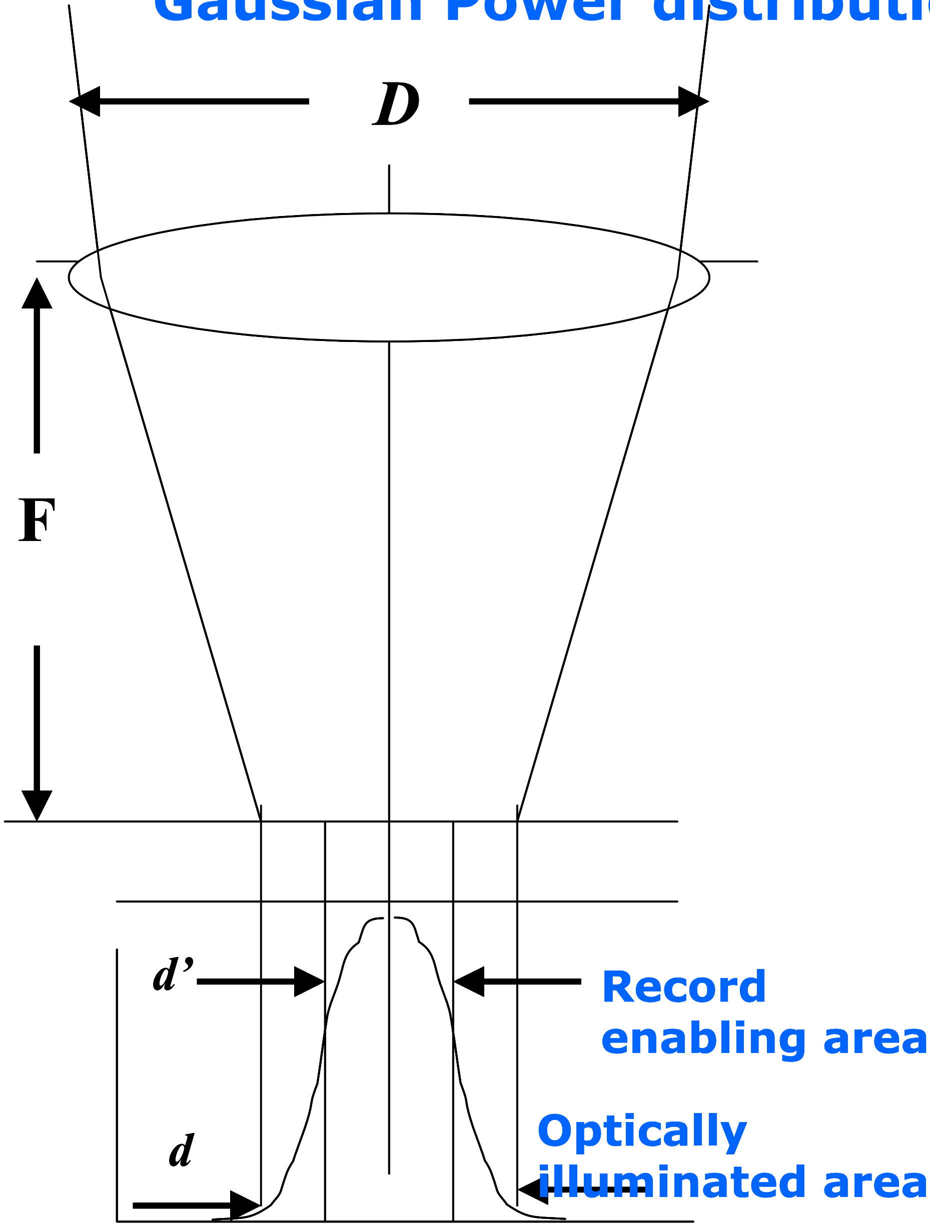
Pre-erased track magnetized to one direction

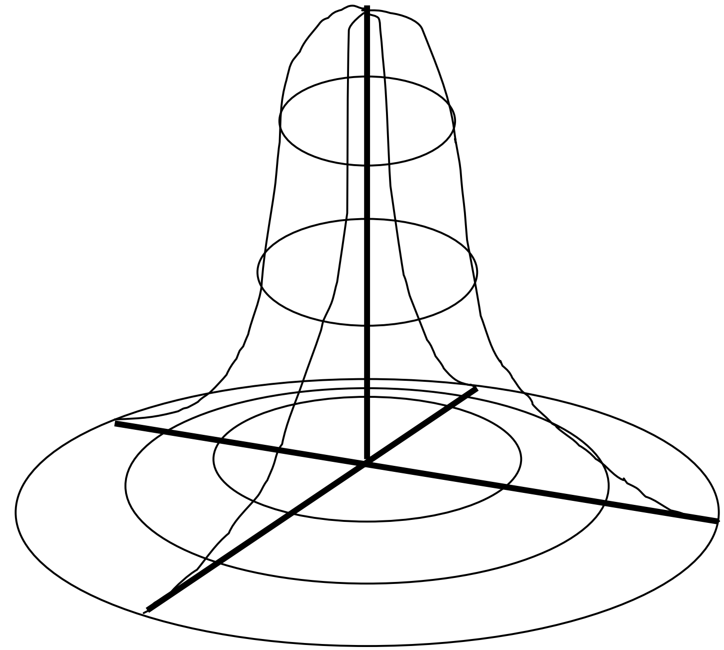
Returned beam polarization plane unchanged

Polarization Plane Angle Rotation, Kerr Effects

- Angle of rotation depends on reading laser wavelength and composition of recording layer
- Round trip return increases rotation
- Differential Signal detection technique used to improve recovered signal S/N

Gaussian Power distribution of focused beam





$d' = \rho\lambda/\mathrm{NA}$

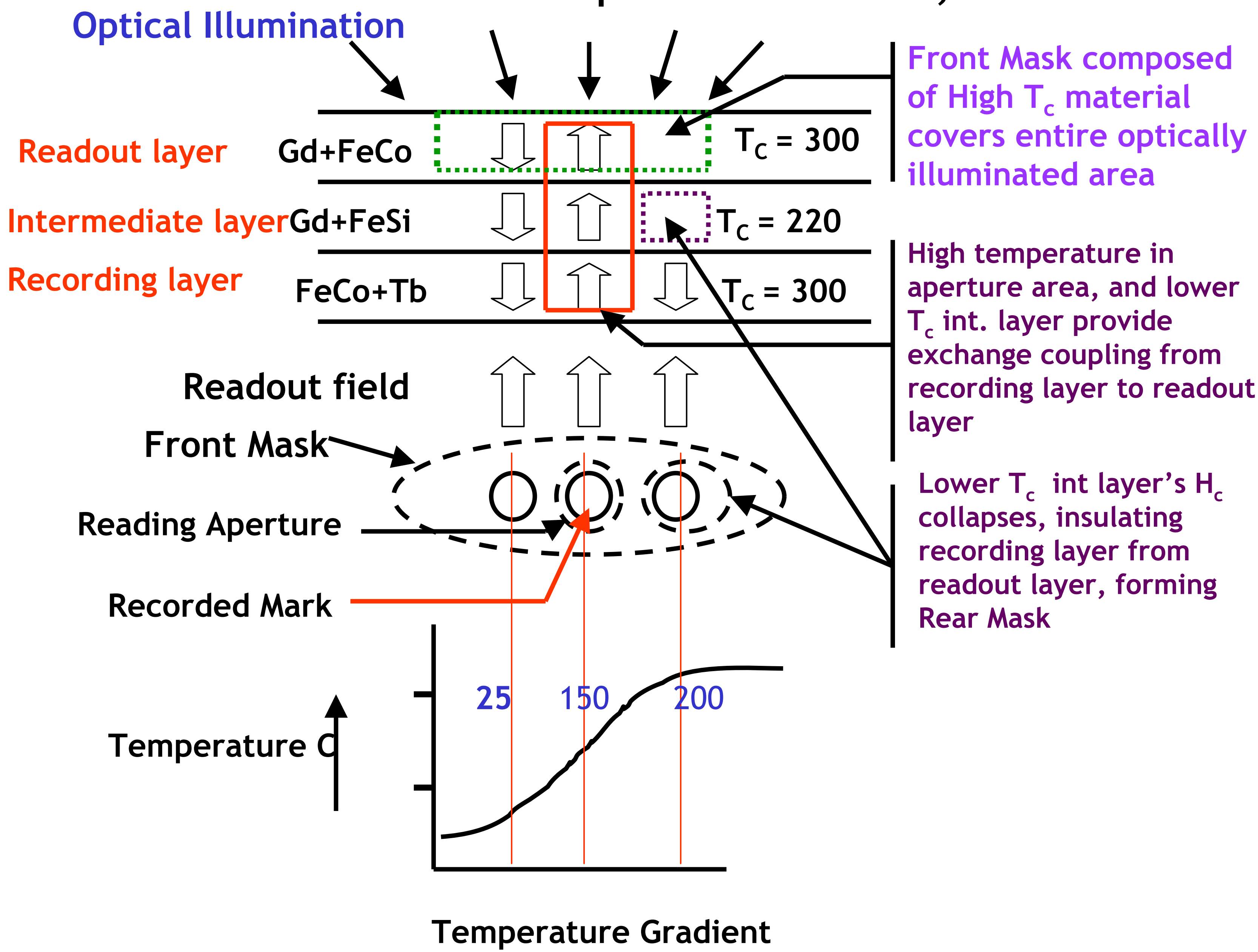
$d = \lambda/\mathrm{NA}$

λ = laser wavelength

NA = Numerical aperture of lens

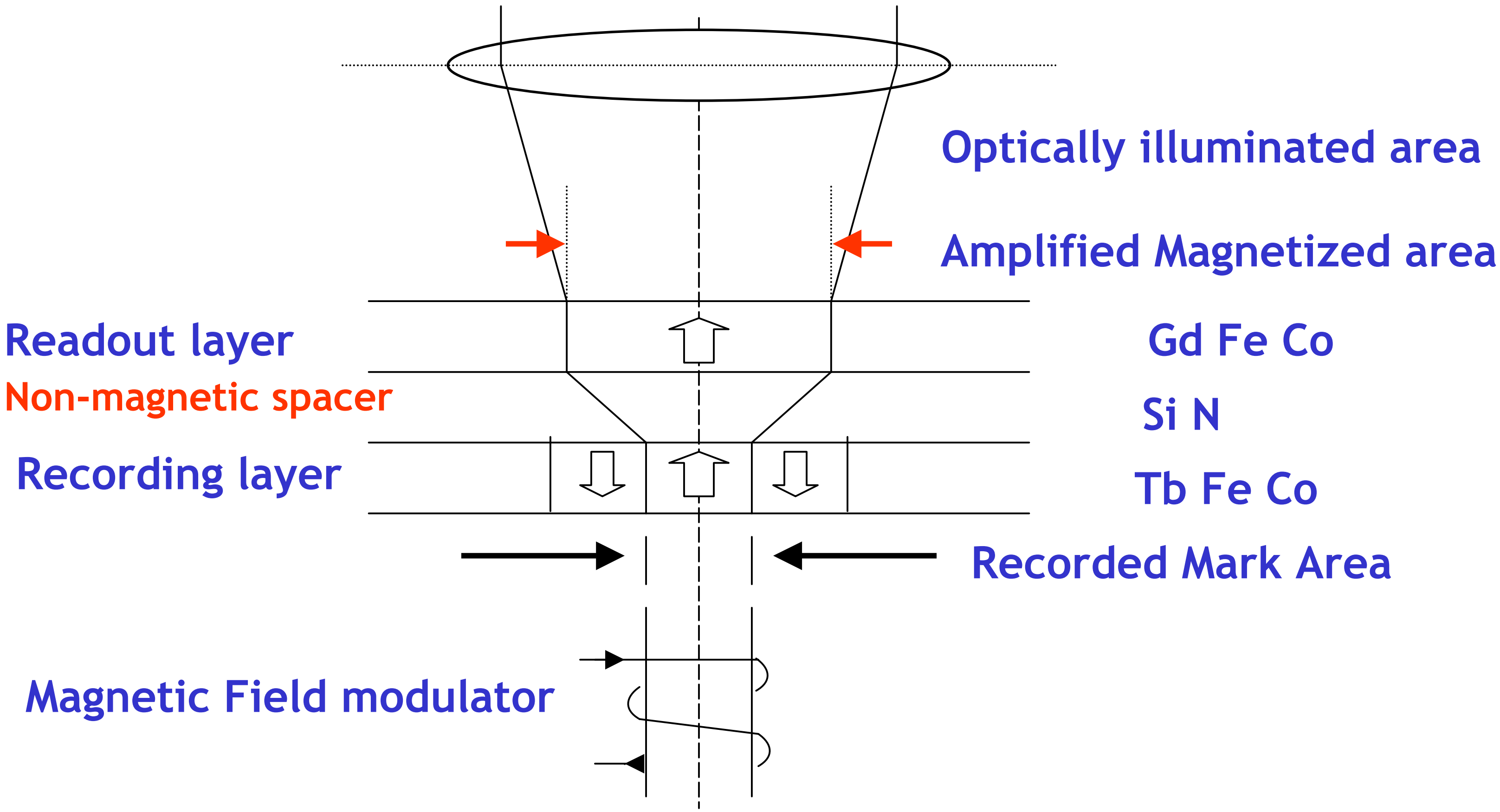
Magnetic Super Resolution MSR

Double Mask Rear Aperture Detection, RAD



Magnetic Super Resolution (MSR)

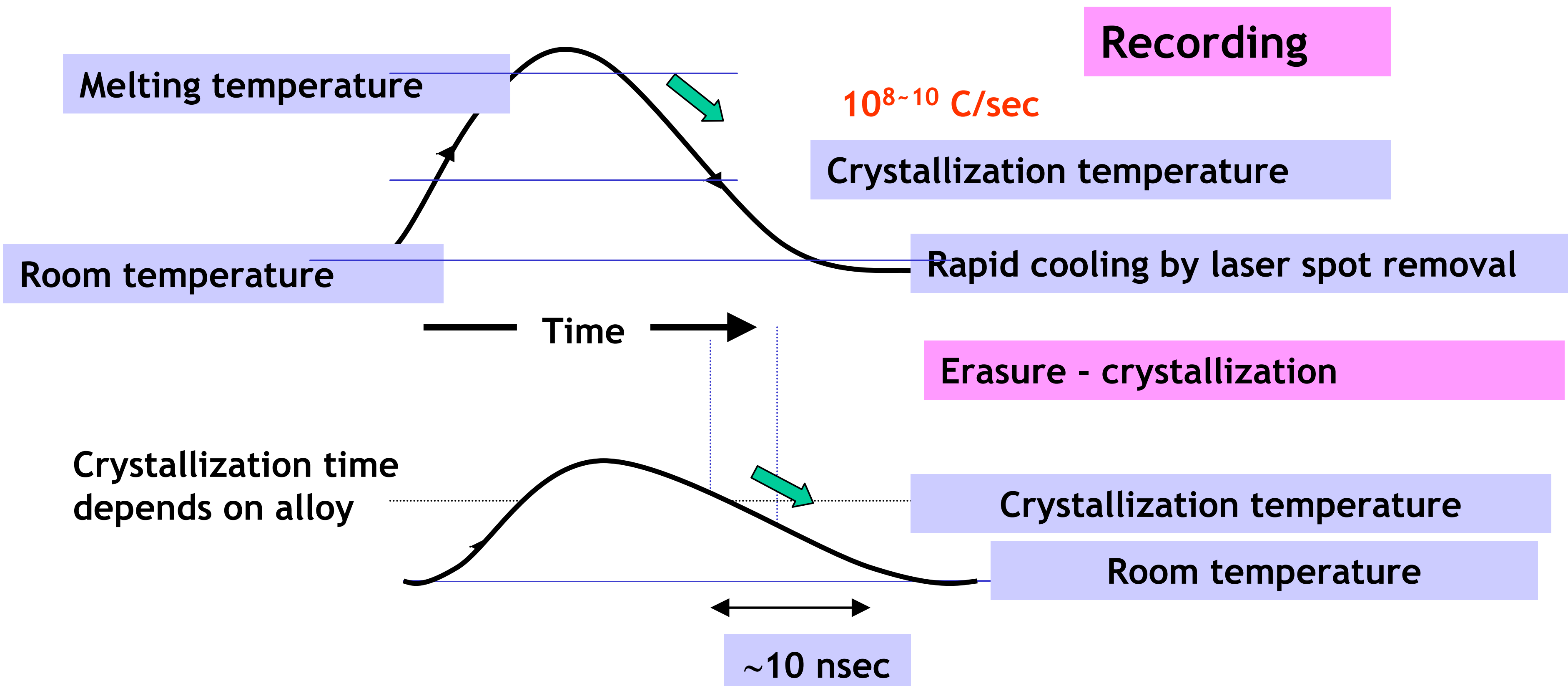
Center Aperture Detection (CAD*)



* Magnetic Amplifying Magneto Optical System (MAMMOS)

Recording Process (Phase Change)

- Erased state ------ Crystalline phase
- Recorded state ------ Amorphous phase

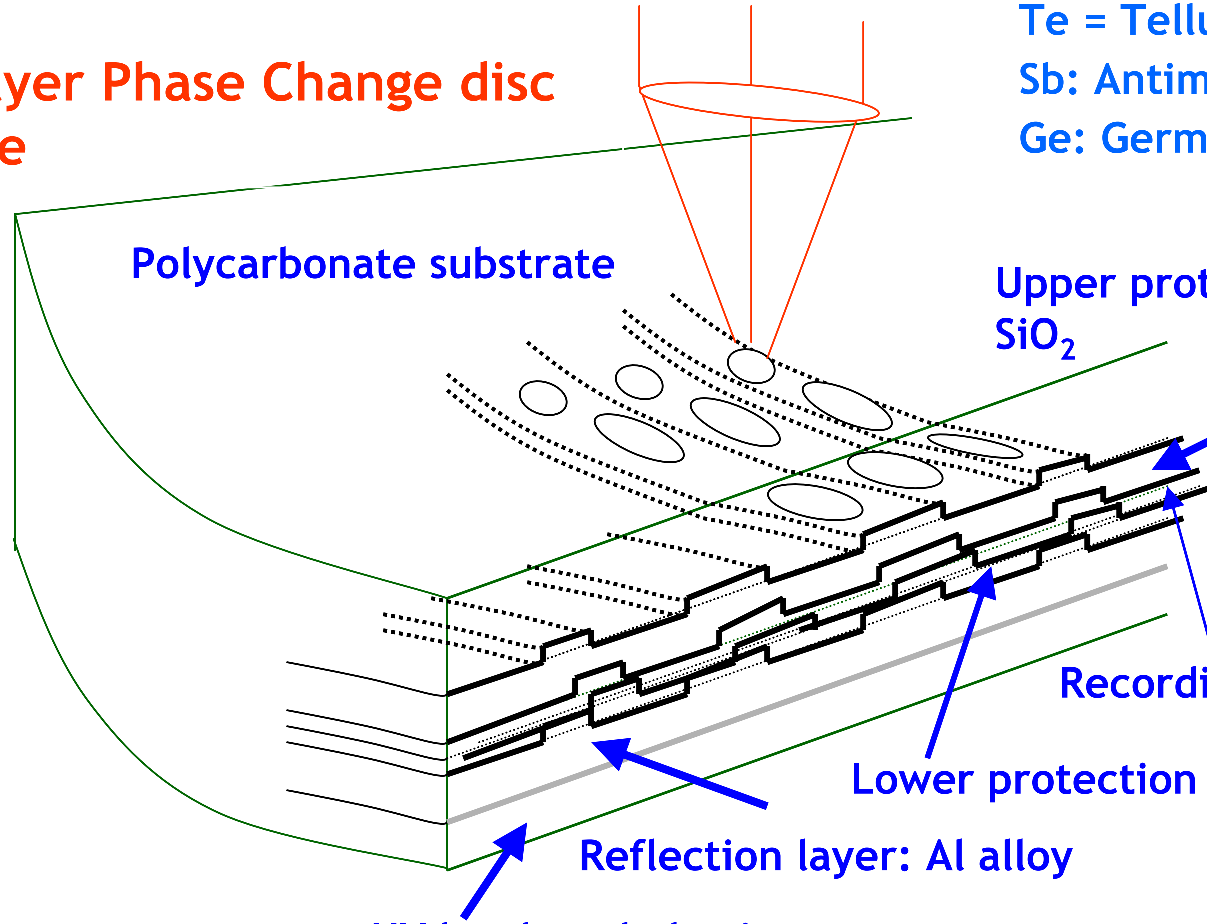


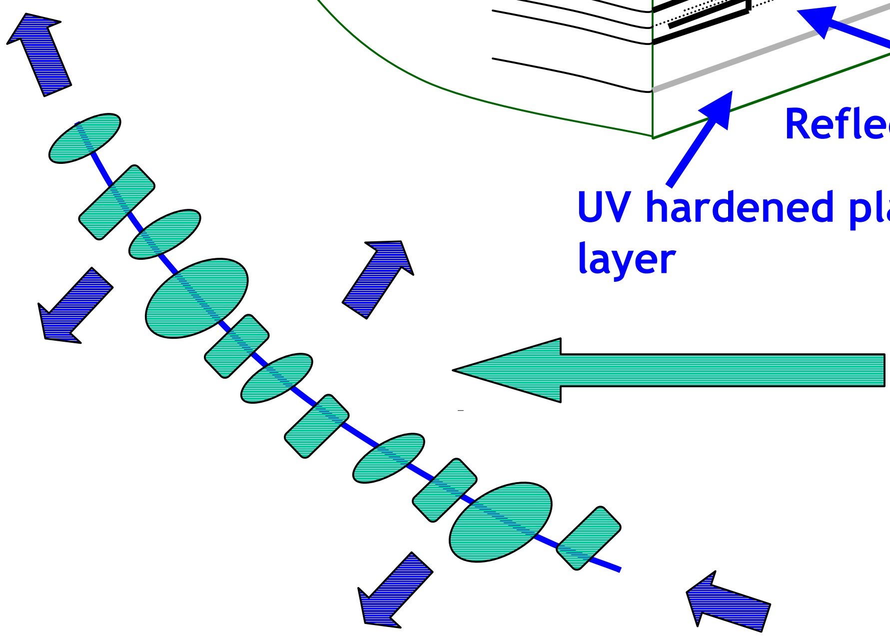
Data rate limited by crystallization time characteristic of the alloy

- Current status --- 8 MB/sec
- Near term objective --- 12 MB/sec

Single layer Phase Change disc structure

Te = Tellurium
Sb: Antimony
Ge: Germanium

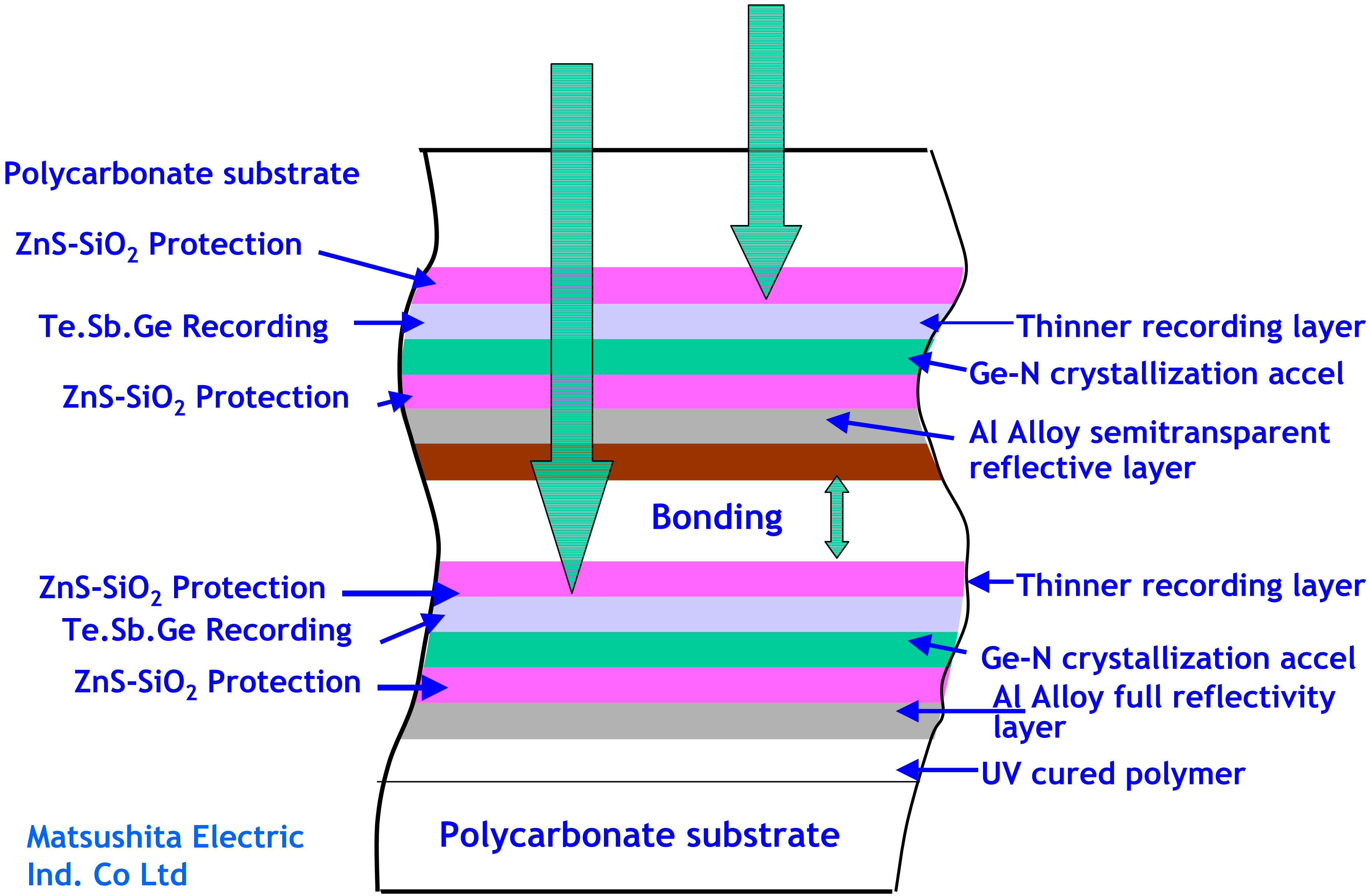




Auto track finding system

Track wobbled from track center line with period equal to 1/232 of sector length

Double Recording Layer Disc Structure



Matsushita Electric Ind. Co Ltd

Next generation Optical Disc Recorder Prototypes

Common attributes

•Phase change recording •laser wavelength 405 nm •Lens NA = 0.85

Demonstration at recent trade exhibitions

Mfr	Capacity/ surface	# of sur-faces	Mb/sec	Track Utiliza-tion	Track Pitch	Min Mark Length	Mod code
Hitachi	25 GB	2[(1)]	33	G	0.35 mm	0.20 mm	8-16
Matsu-shita	25	2[(2)]	33	G	0.32	0.185	D8-15
Pioneer	23	1	35	G	0.32	0.120	(1,7)
SONY/ Sanyo	23	1	35[(3)]	L+G	0.30	0.12	(1,7)
Toshiba	30	1	35		-	-	-

Notes on next slide

Next generation Optical Disc Recorder Prototypes

Notes: (1) Double sides disc construction

(2) Double layer recording surface

(3) TDK Recording Media operates at 100 Mbps

(4) JVC did not demonstrate its 25 GB drive at show

Phase change vs Magneto-optics

Phase Change	2001	Next Generation, 2003-2004		
•Products	DVD-RAM	UDO(1)	NextGen DVD(2)	
•Capacity/surface, GB	4.7	20	25	
•No of surfaces	2	2	2/4	
•Bit area *mm* x *mm* (3)	0.615 x 0.280	0.33 x 0.13	0.32 x 0.185	
•Transfer Rate, MB/sec	1.2	4-8	4-6	
Magneto-Optics				
•Products	3.5” GIGAMO(4)	ID Photo(5)	3.5”GIGAM)	ID Photo
•Capacity	2.3	0.73	10.0	3.0
•No of surfaces	1	1	1	1
•Bit area	0.67x0.233	0.60x0.235		
•Transfer rate	8.38	2.5	20+	10

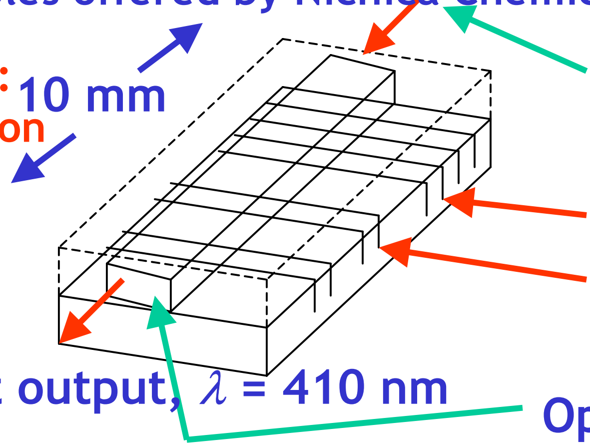
(1) SONY disc diameter = 130 mm (2) Matsushita prototype, two recording layers, both accessible from disc front (3) Track pitch x minimum mark length (4) Disc diameter = 90 mm (5) Disc diameter = 50 mm

Supporting Technology

Short wavelength Laser

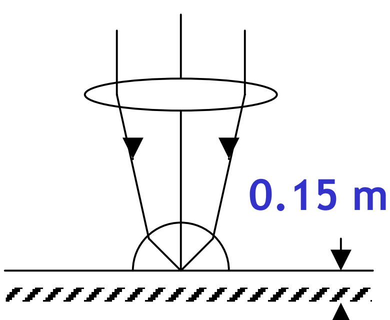
- Gallium Nitride Crystal on Sapphire, Silicon Carbide or Silicon Dioxide
- Required capability: wavelength = 400 nm, output = 30 mW CW at 25 C, life = 3000 hrs minimum, 10000 hours desired
- Engineering samples offered by Nichica Chemical (Japan), Cree Inc (Durham NC)

- Alternate Approach: Wavelength conversion by optical nonlinear element



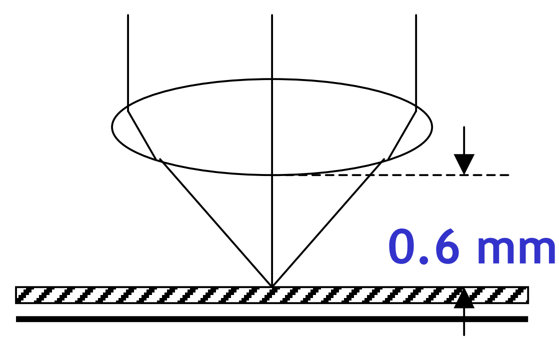
Wide Aperture Objective Lens

Conventional Approach



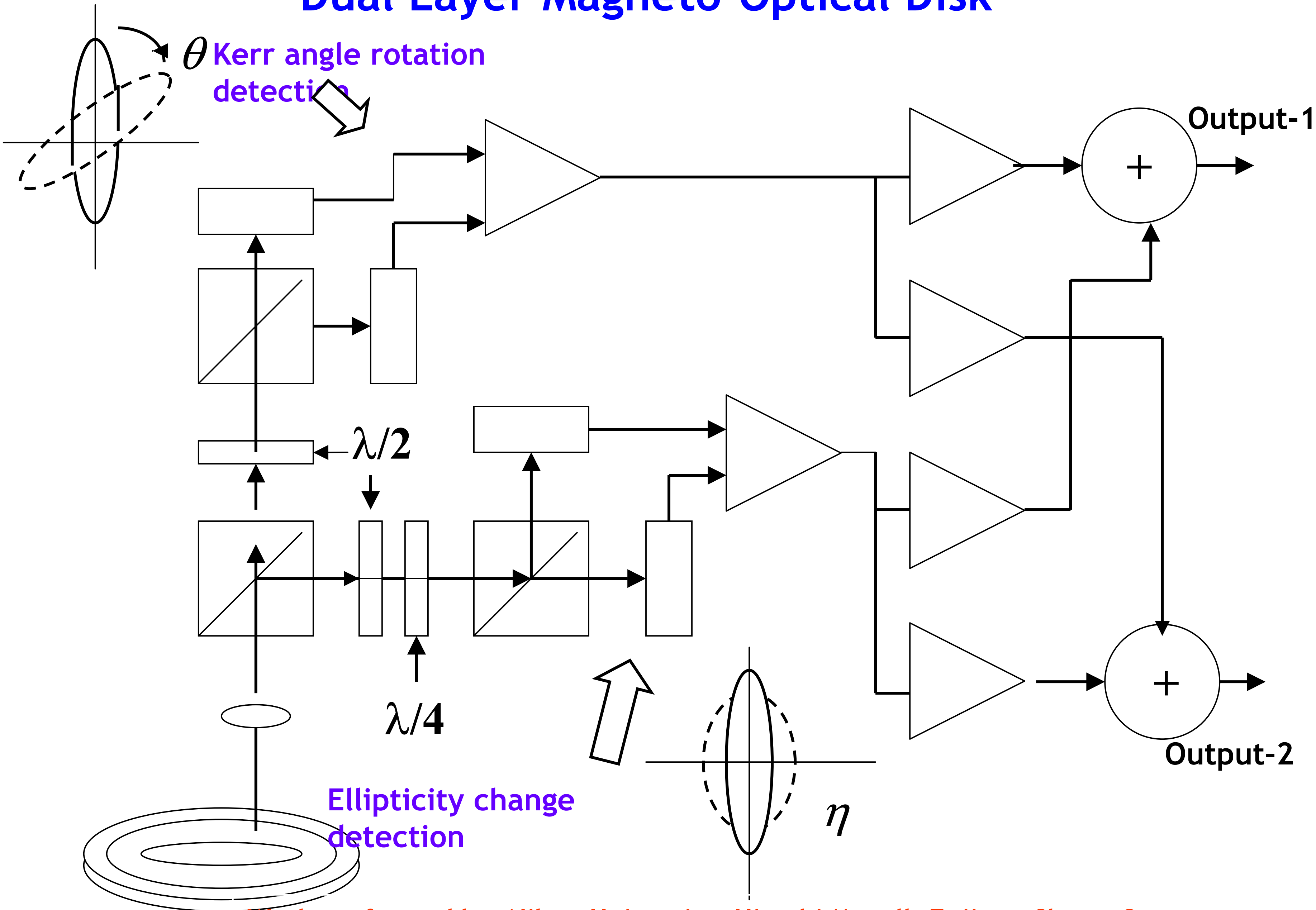
Dual Lens System

New Technique



Single High Refractive Index Glass Lens

Dual Layer Magneto-Optical Disk



Work performed by: Nihon University, Hitachi Maxell, Fujitsu, Sharp, Sanyo

Road to 100 GB+ Disc

Markets

- Consumer HDTV Video Player ---------------- Data rate < 50 Mbps, low cost disc
- Industrial Rec./PB -------------------------------- Data rate > 100 Mbps
- Computer data backup ------------------------- Data rate > 100 Mbps, WORM version also required (Lower Cost Disc)
- Broadcast camcorder -------------------------- Data rate > 100 Mbps

Technology

- Blue laser (λ = 400 nm), Wide aperture lens (NA = 0.85 - 0.9)
- Phase change Recording
    - Per surface capacity = 25 - 35 GB
    - Max 4 recording surfaces (Double layer, double sided)
    - Data transfer rate = upto100 Mbps
- Magneto-optical recording
    - Magnetic Super resolution (MSR) technology
    - Per surface capacity = 30 - 50 GB
    - Two recording surfaces (double sided)
    - Data transfer rate = 150 - 200 Mbps

Road to 100 GB+ Disc (contd)

Commercial Products Introduction

- Technology Development essentially completed
- Standardization ?
- Market driven – possibly 2004 - 2005

Removable Data Storage package and Storage Efficiency

Data Storage Efficiency ε = User Data/Package Volume = MB/cc

Removable Data Storage Package

- Magnetic tape cassette: DVCPRO-HD, 125x78x14.8 mm = 143 cc
  Capacity = 69 GB, ε = 485
- Magnetic tape cartridge: LTO Ultrium[(1)], 125x109x26 mm = 350 cc
  Capacity = 100 GB, ε = 285
- Hard Disc Drive: IBM Travelstar 48GB[(2)], 100x70x12.7 mm = 89 cc
  Capacity = 48 GB, ε = 540
- Recordable Optical Disc: DVD-RAM, Double side, 150x150x3 mm = 67.5 cc[(3)], Capacity = 9.4 GB[(4)], ε = 139

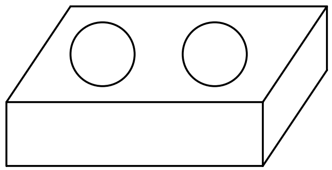
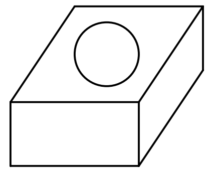
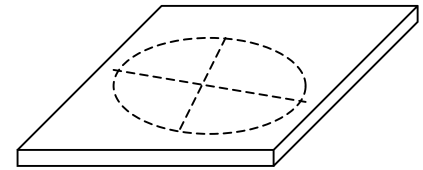
Notes: (1) First generation product

(2) 2.5”, half-height package

(3) Dimensions for disc carrier used in jukebox system

(4) Higher capacity versions in development

Data Storage Efficiency Improvement Trends

Package	Tape Cassette	Tape Cartridge	HDD	Optical Disc
Products	6.35 mm helical Tape	LTO Ultrium	2.5" half-height	120 mm recordable with carrier
Volume, cc	143	350	89	67.5
2001 - $\Gamma^{(1)}$	69/485	100/285	48/540	9.4/139
2004 - $\Gamma^{(1)}$	150/1100	400/1140	150/1650	100/1400

(1) $\Gamma =$ Capacity/Efficiency; Capacity = GB, Efficiency = MB/sec