Optical Engineering

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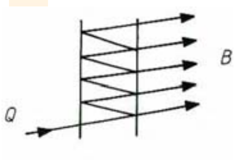
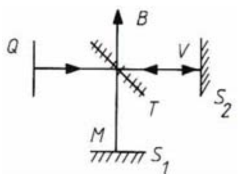
Course outline

Interferometric distance measurement

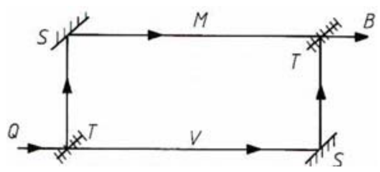
- Interferometer
  - Light split into at least two beams
  - Beams propagate different optical paths
  - Superposition of beams at exit
- Interference effect occur for coherent superposition
  - Interference pattern depends on optical path difference that beams incur before superposition.
- Precision measurement possible by evaluation of optical interference pattern
- Examples for interferometers



Fabry-Perot



Michelson

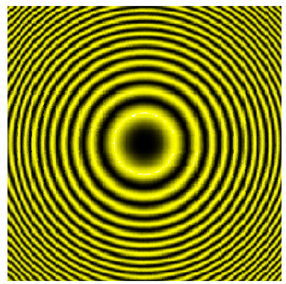


Mach-Zehnder

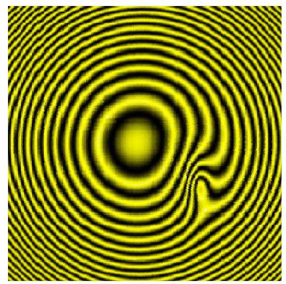
Source: Naumann/Schröder, *Bauelemente der Optik*, 1992

Newton's rings

- Newton's rings due to interference of light reflected on lens and light reflected on glass plate



Without lens error

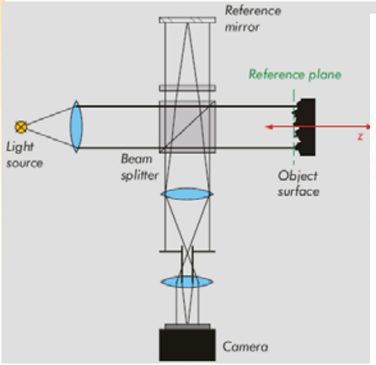


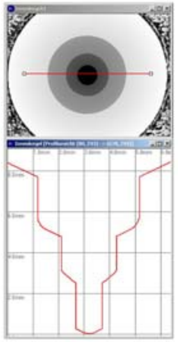
With lens error

Source: wwwex.physik.uni-ulm.de

White light interferometer

- Interference of broad band light source (white light) used
  - White light has small coherence
  - Interference phenomena only visible if optical length of both paths in interferometer identical within coherence length (~λ)
  - Object scanned in z-direction by movement relative to reference plane
- „Depth image“ of object with small measurement uncertainty generated
  - Setup needs to be very stable

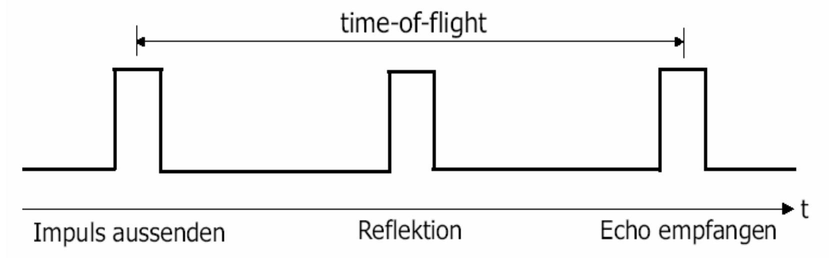




Source: www.3d-shape.com

Time of flight distance measurement

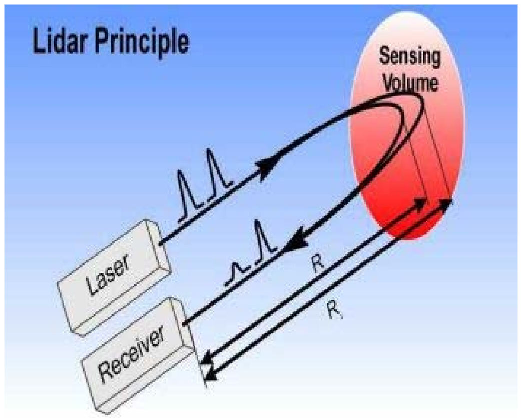
- Emit laser pulse and determine time difference until detection of reflected pulse
- Calculation of distance using propagation velocity



- Problem: Light is fast
  - Propagation time for distance of 1 m is 3 ns
- Short laser pulses and fast electronics necessary

LIDAR (Light Detection and Ranging)

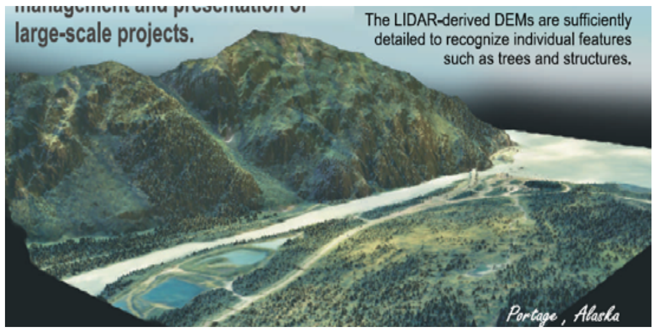
- Compare to Radar:
  - Electromagnetic wave emitted and reflected signal analyzed



Source: http:// www.dlr.de/schoollab/

LIDAR applications

- Coordinate measurement using time of flight
- Dynamics of gas turbulences by time of flight measurement and Doppler shift
- Chemical analysis (Pollutant concentration in atmosphere) by time of flight measurement and spectral measurement (Raman signal)

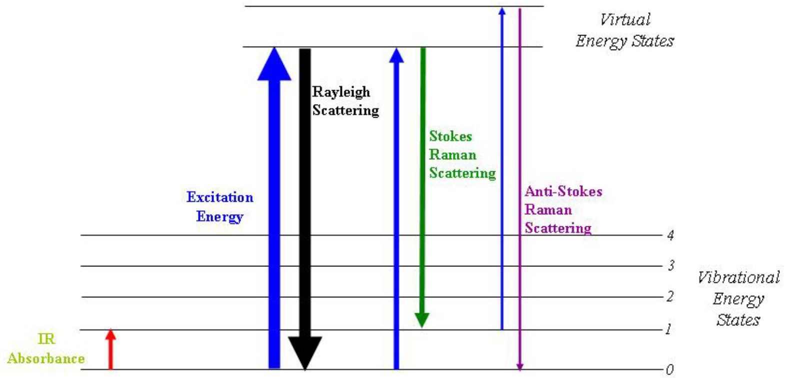


DEM: Digital elevation model

Raman scattering

6.9

- Raman signal provides fingerprint of molecules as vibrational states specific for chemical bonds
  - Fingerprint region of organic molecules typically 500-2000 cm^{-1}
- In solid state physics Raman signal used to, e.g., characterize materials and measure temperature
- Difficulty is to separate weak Raman signal from background



Source: en.wikipedia.org

LIDAR-System (Example Univ. Baltimore)

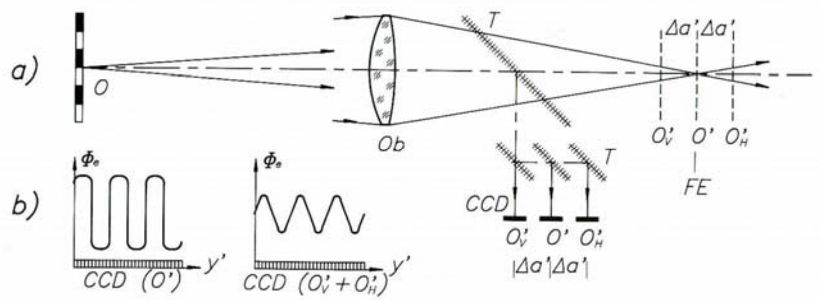
6.10

Laser	Q-switched Nd-YAG with 320mJ at 1064nm (additional wavelengths: 532nm and 355nm); 30Hz repetition rate; 8ns pulse; 1.8 mrad beam divergence; BigSky laser model CFR 400
Telescope	25.4 cm (10 in) diameter, Cassegrain f/10, 5mrad FOV (Meade LX50)
Detector	IR-enhanced Si avalanche photodiode (Analog Modules)
Digitizer	12-bit 100MHz, dual channel (Signatec PDA 12)
Scanning system	Azimuth rotary stage (180:1), stepper motors & encoders, elevation right angle reducer (100:1), i.e. from 90º to -10º, AT6400 controller (Compumotor)
Maximum range resolution	1.5m
Data acquisition	Pentium 133 MHz laptop

Distance measurement by contrast evaluation

6.11

- Modification of objective position until image focused
- Reading of distance on objective scale
- Called contrast measurement as image contrast maximum in focus
- Auto-focus of digital camera works using contrast evaluation
  - Processor of camera calculates spatial frequency distribution of image
  - Image closer to focus if fraction of high frequencies larger
  - Multiple images with different focusing necessary to evaluate contrast
  - Alternatively, beam splitting may be used

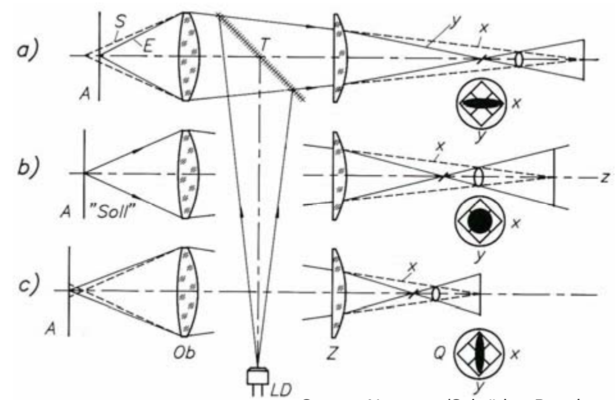


Source: Naumann/Schröder, *Bauelemente der Optik*, 1992

Auto-focus using astigmatic imaging

6.12

- Illumination spot A imaged via objective and cylindrical lens astigmatically onto quadrant diode
- For correct focusing signals on x-diode and y-diode identical
- Setpoint tracing obtained from difference signal
  - Used in CD- und DVD-players

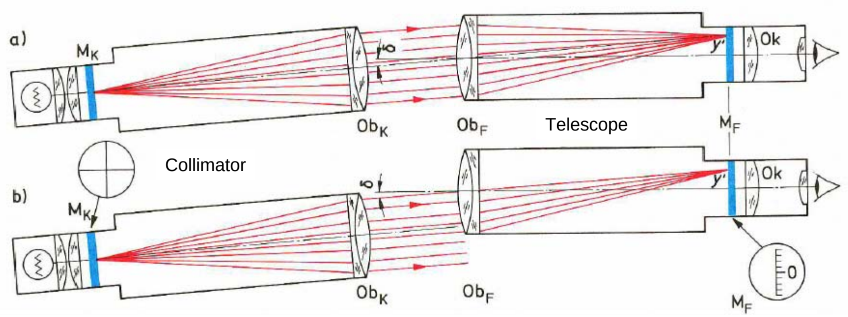


Source: Naumann/Schröder, *Bauelemente der Optik*, 1992

Course outline

Angle measurement using collimator and telescope

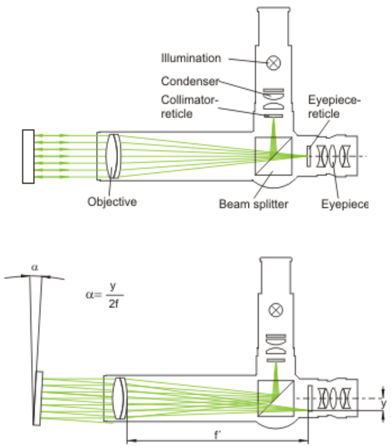
- Collimator: Projector that images illuminated reticle to infinity
- Telescope with reticle used for evaluation
- Sensitive measurement of direction differences
- Setup insensitive vertical alignment (Parallel displacement)



Source: Schröder, *Technische Optik*, 1990

Autocollimator

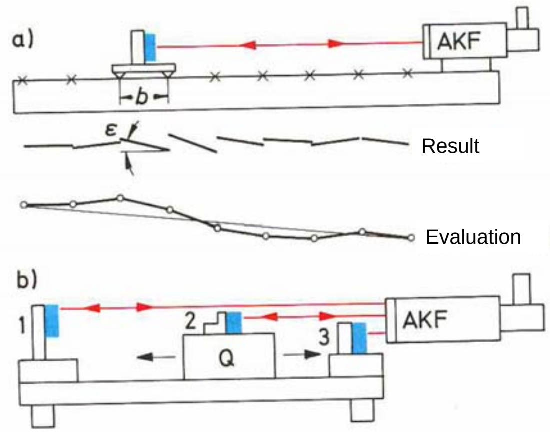
- Instrument combines collimator and telescope
  - Collimator reticle and telescope reticle both placed at focal plane of autocollimator objective



Source: www.moeller-wedel-optical.com

Example: Determination of track way profile

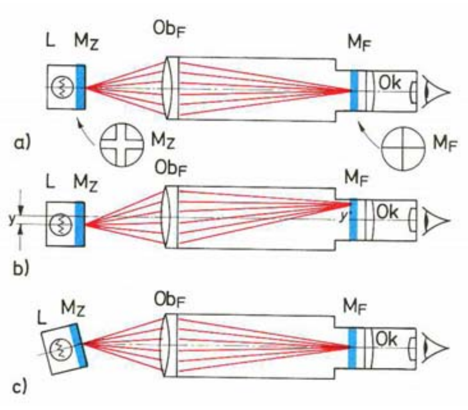
- Measurement of angle while slide moves



Source: Schröder, *Technische Optik*, 1990

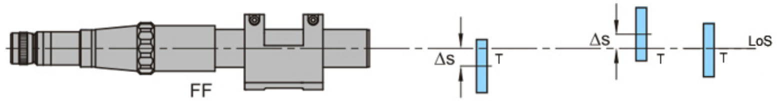
Alignment telescope

- Precision instruments for the alignment of objects to a reference line, which is defined by the line of sight of the system
- Alignment telescope focuses target to determine lateral displacement with regard to reference line
  - Setup insensitive against rotation



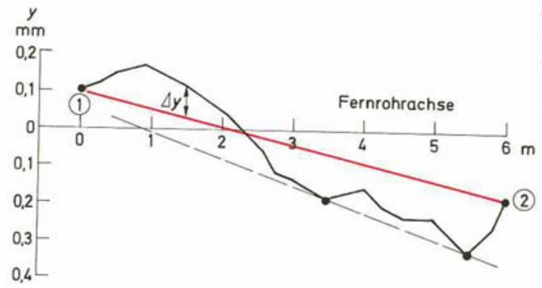
Source: Schröder, *Technische Optik*, 1990

Example: Evaluation of alignment



FF	alignment telescope
T	target
LoS	line of sight
ΔS	deviation of line of sight

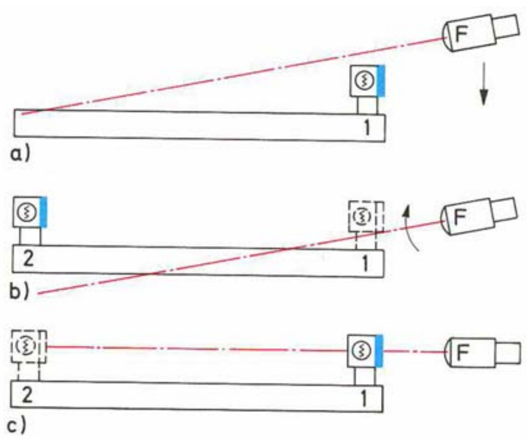
Source: www.moeller-wedel-optical.com



Source: Schröder, *Technische Optik*, 1990

Adjustment of telescope axis

- Before use telescope axis needs to be aligned with track way
  - Adjust height to front target
  - Adjust direction to rear target
  - Repeat if necessary
- Identical procedure for adjustment of alignment laser with two iris apertures

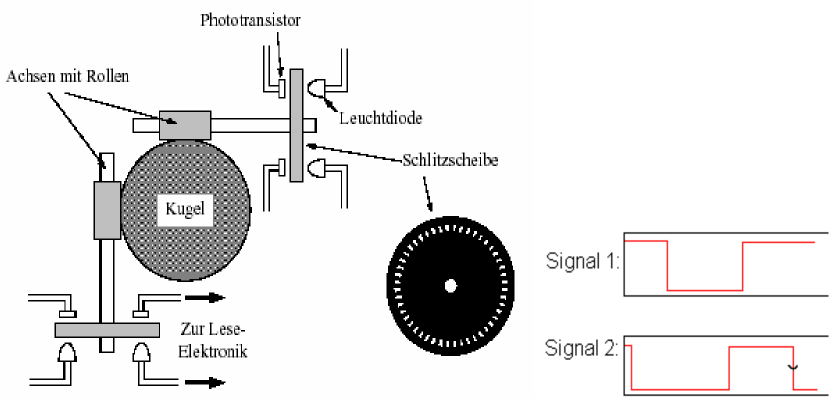


Source: Schröder, *Technische Optik*, 1990

Course outline

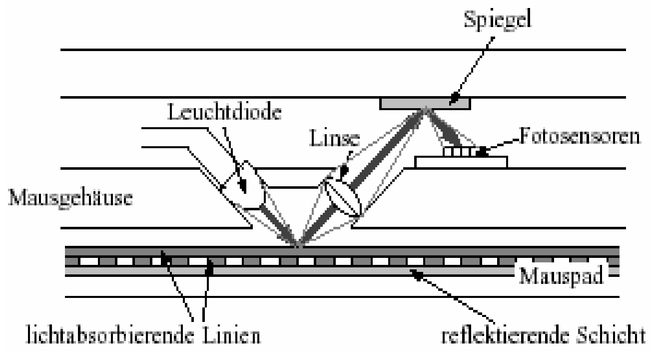
Opto-mechanical mouse (since 1984)

- Direction obtained from time sequence of signals



Optical mouse (old – since 1968)

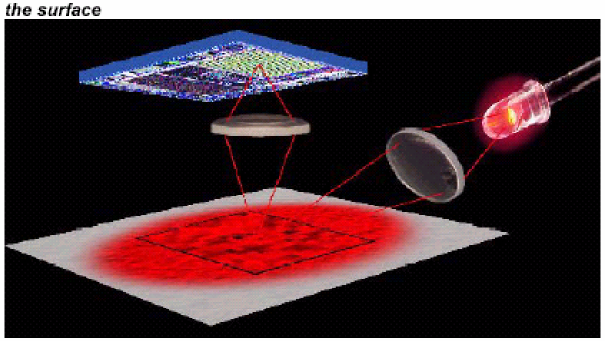
- Special pattern on mouse pad used for modulated reflection during movement



Optical mouse (new)

- Image scanned (as in digital camera) and displacement calculated

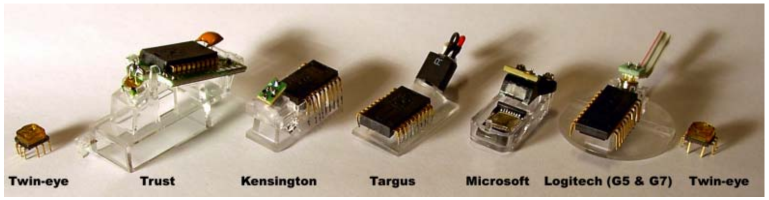
Figure 2: An optical mouse works by reading a reflected light beam on the surface



Source: http://www.logitech.com/lang/pdf/laser_techbrief-04.pdf

Examples for optical mouse systems

- Different systems:



Source: http://www.mstarmetro.net/~rlowens/OpticalMouse/

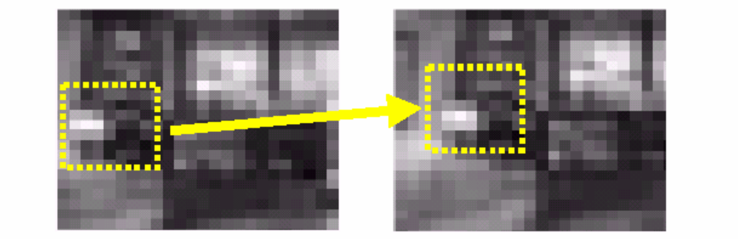
- Example of image from bottom

Source: http://www.howstuffworks.com

Laser mouse (very new – since November 2004)

- Illumination with IR-laser
- Image taken with camera
- Movement of speckle-pattern evaluated

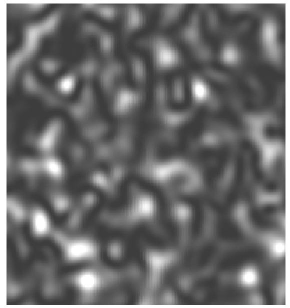
Figure 3: Interpreting differences in image fingerprints can be translated to movement of the mouse



Source: http://www.logitech.com/lang/pdf/laser_techbrief-04.pdf

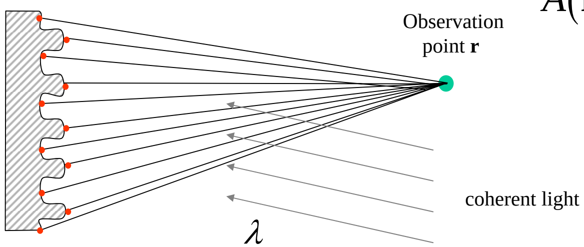
What is speckle?

- Speckle (laser light-granulation) occurs upon reflection or transmission of coherent light on rough surfaces or distributed scatterers

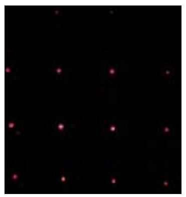


Diffraction on grating

- Interference effect of large number *N* of scattering points *k* with fixed phase difference φ_k between 0..2π
- Each scattering point is origin of spherical wave. Waves superpose at observation point **r**

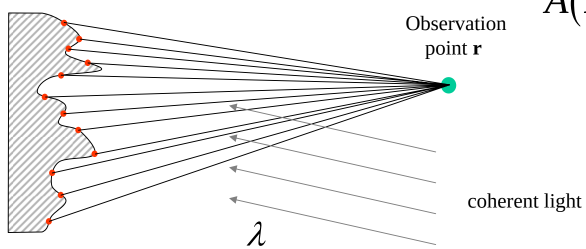


$$A(\mathbf{r}) = \sum_{k=1}^{N} \frac{a_k e^{i\varphi_k}}{\sqrt{N}}$$



How does speckle form?

- Interference effect of large number *N* of scattering points *k* with random phase difference φ_k between 0..2π
- Each scattering point is origin of spherical wave. Waves superpose at observation point **r**



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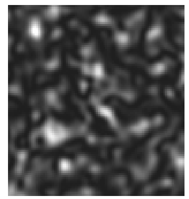
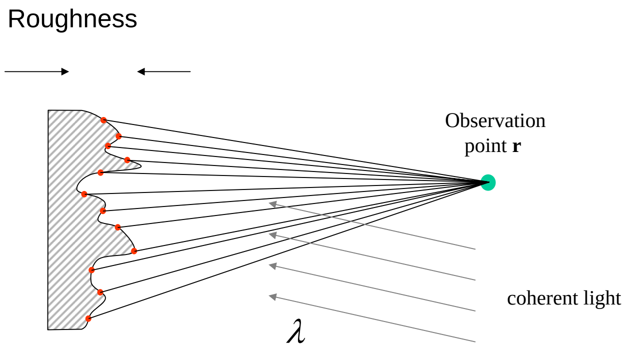


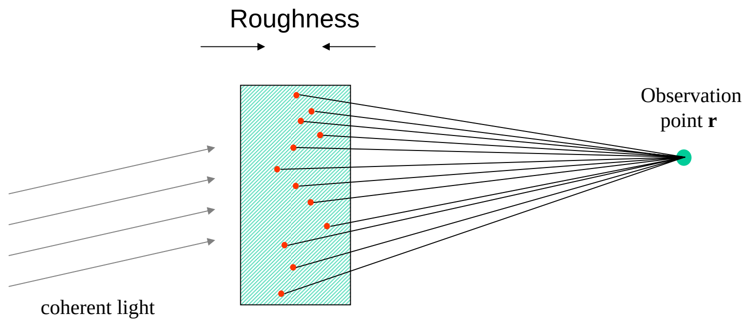
Speckle: influence of surface

- Speckle occurs if roughness of surface larger than wavelength of light



Speckle: influence of scattering particles

- Speckle occurs in transmission if scattering particles are distributed in volume with distance larger than wavelength of light
- Possible difference to scattering on surface:
  - Multiple scattering (random walk) increases effective roughness to more than layer thickness



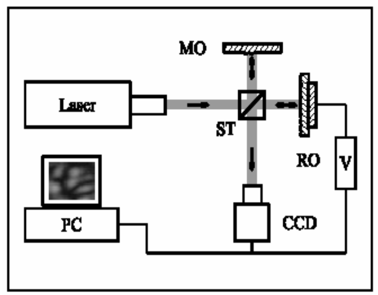
Problems caused by speckle

- Holograms
  - Besides desired object and reference wave speckle exists due to rough objects
- Laser projection displays
  - Roughness of projection screen causes speckle and blurred images
- Astronomy
  - Wave front are disturbed in atmosphere and limit resolution (“Seeing”)

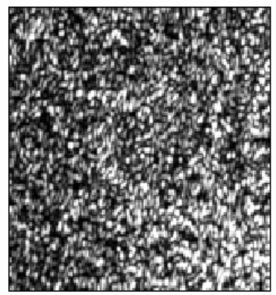
- Wireless microphone
  - Lecturer with wireless microphone cannot be heard at certain position in auditorium (dead spots)
- Ultrasonic imaging
  - Granulated image due to speckle

Possibilities by using speckle

- Speckle metrology
  - Superposition of pattern 1 from measurement object and pattern 2 from reference object results in pattern 3 that depends on phase difference at given wavelength
  - Surface analysis by comparison to reference surface

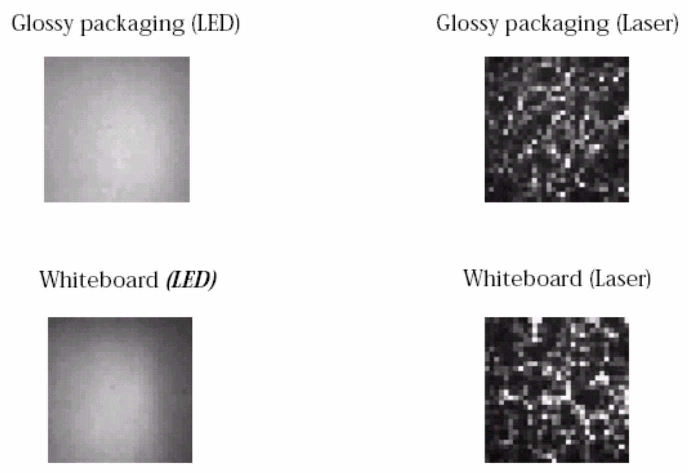


b)



Laser mouse

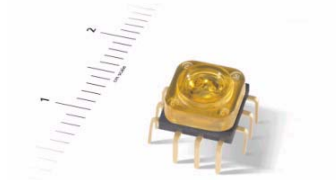
Figure 4: Laser uncovers surface features not detected by LED.

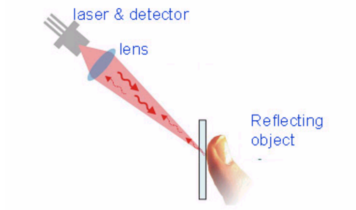


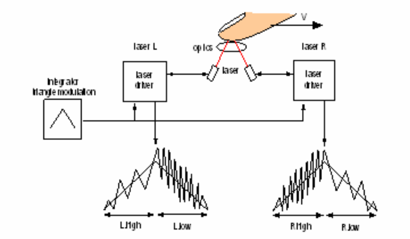
Source: http://www.logitech.com/lang/pdf/laser_techbrief-04.pdf

Laser mouse (very new – since November 2004)

- Other laser properties may be used as well
  - e.g., Philips Twin-Eye laser sensor: Input device based on laser Doppler effect







Source: http://www.business-sites.philips.com/lasersensors/about/article-15031.html

Course outline

1. Imaging optics
2. Optical sensors
3. Optics in data storage
   - 6.1 Copier and laser printer
   - 6.2 CD-/DVD-player
   - 6.3 Magneto-optical discs (MO), MiniDisc (MD)
3. Introduction to displays -> Presentation by BARCO (end of semester)
4. Fourier optics (starts 13.12.2007)
5. Diffractive optics and holograms
6. Integrated optics
7. Computerized imaging

Early data storage systems

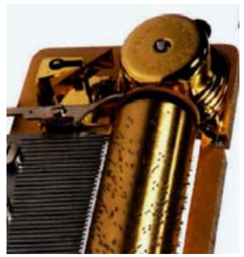
- Data storage is used to save and distribute information independent of humans

cuneiform writing

cave-painting

letterpress

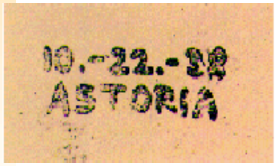
music box



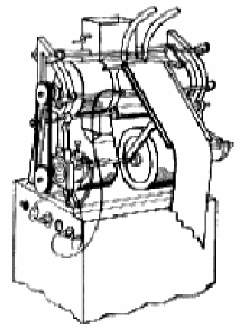
Photocopier

- 1938: Effect discovered by Carlson
- 1947: Technology licensed to Haloid
- 1949: First commercial photocopier
- 1961: Company was renamed from Haloid to Xerox

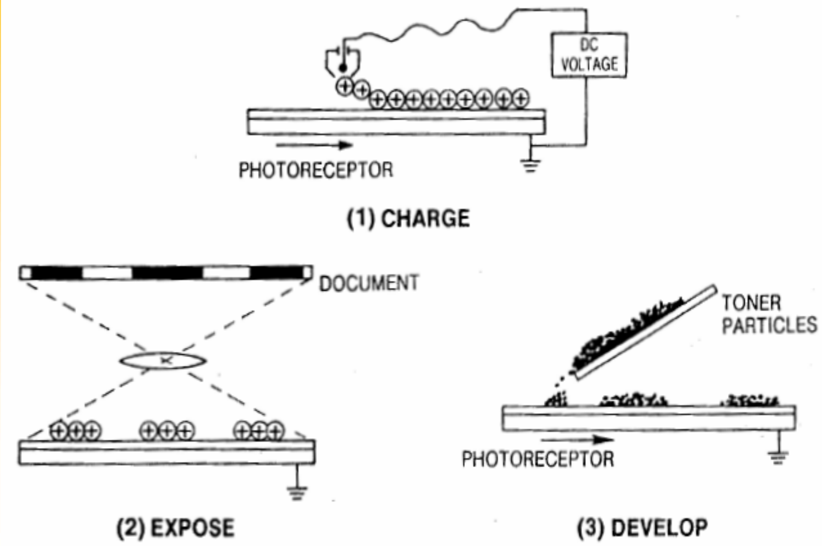
The first photocopy



Source: Xerox

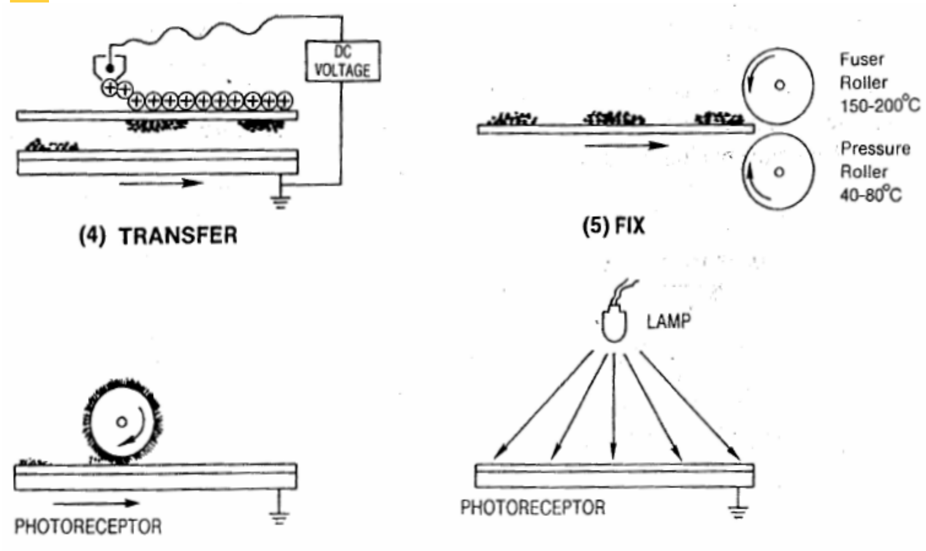


Copying I



Source: Borsenberger, „Organic Photoreceptors for Imaging Systems “

Copying II



Source: Borsenberger

Image drum

- Core of copier is drum coated with photoconductor
- Photoconductor should have small dark conductivity and high photo sensitivity
- Photoconductor needs to be applied onto round or flexible substrates
- Until 1975 selenium mainly used, today organic semiconductor materials are used (see lecture „Plastic Electronics“).

Photo courtesy of Xerox

Toner

- Toner consists of pigments, iron and resin
  - Pigments responsible for color, e.g., soot for black toner
  - Iron particles allow for sticking to electrically charged drum
  - Resin allows for „melting“ toner onto paper in fuser

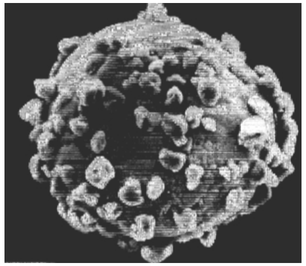
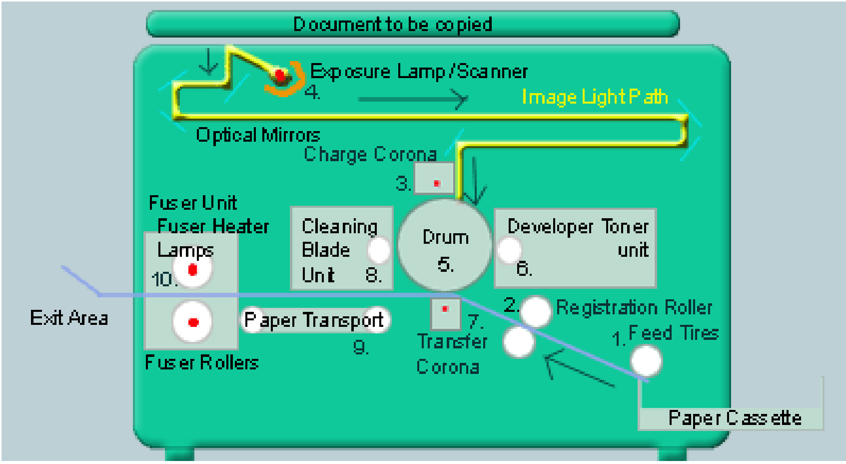


Photo courtesy of Xerox

Photocopier (analog)

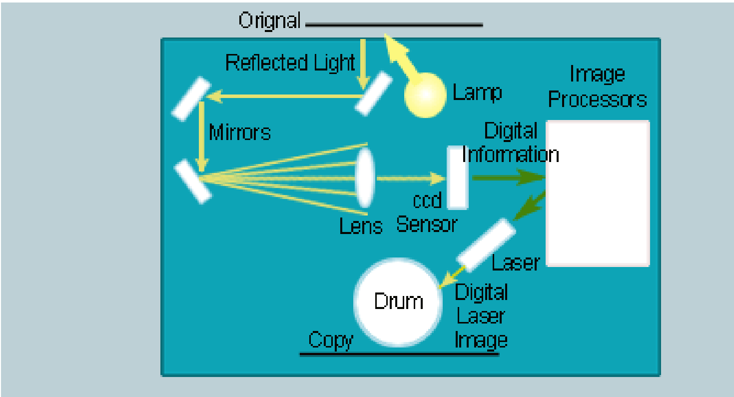
- Imaging of document onto drum using system of lenses and mirrors
- Exposure and development need to be in one instrument



Source: www.compareindia.com/tips/photocopiers_components.htm

Digital copier

- Digital copiers consist of two separate units, the scanner and the printer
- Document digitalized with scanner and saved in digitally (RAM or hard drive)
- Saved image transferred electronically to printer and usually printed with laser printer



Source: www.compareindia.com/tips/photocopiers_components.htm

Advantages and disadvantages of digital copying

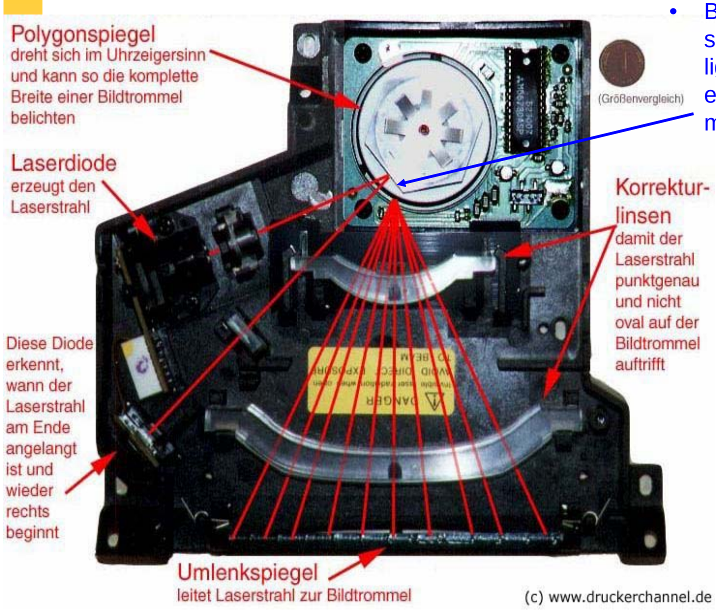
- Advantages
  - Compact and cost-effective construction possible
  - Document may be copied several times without repeated exposure
  - Additional functionality such as print, fax, scan possible
  - Possibility of digital modification of copy before print

- Disadvantages
  - More likely noise on image
  - Grey increments worse

Exercise: Laser scanner unit

- Suggest a layout for the laser scanner unit!

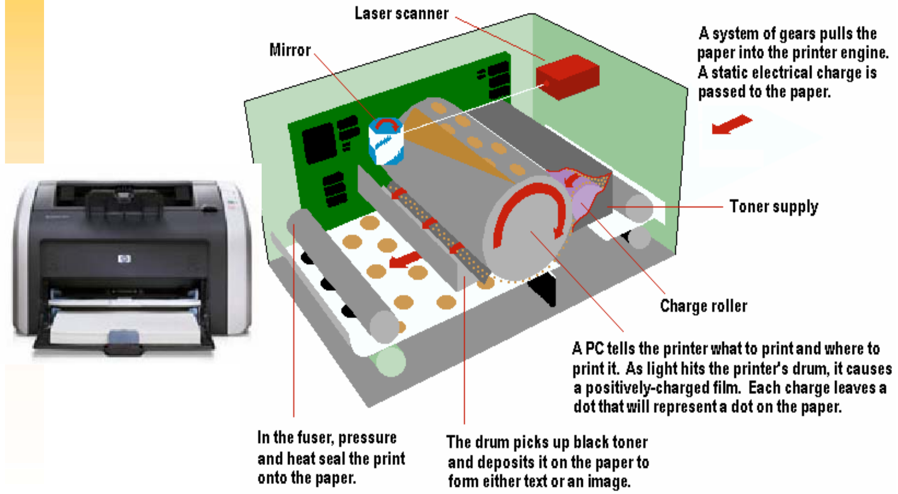
Laser unit of laser printer



- Beam path not shown correctly, light reflects on edge of polygon mirror!

Laser printer

- Laser printer has printer part only
- Image on drum generated by exposure with laser (for LED-printers using row of LEDs).



Source: www.pctechguide.com/12lasers.htm

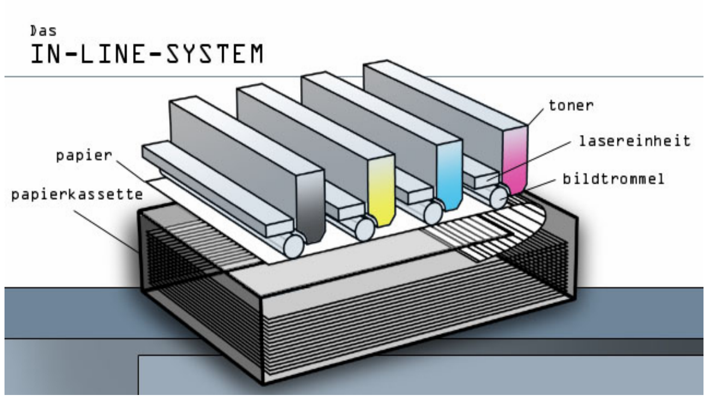
Color laser printer

- Individual toner cartridge for each color (cyan, magenta, yellow and black) necessary
- Laser exposes drum or transfer band four times for each print – once for each color

Source: www.druckerchannel.de

Color laser printer: Inline-technique

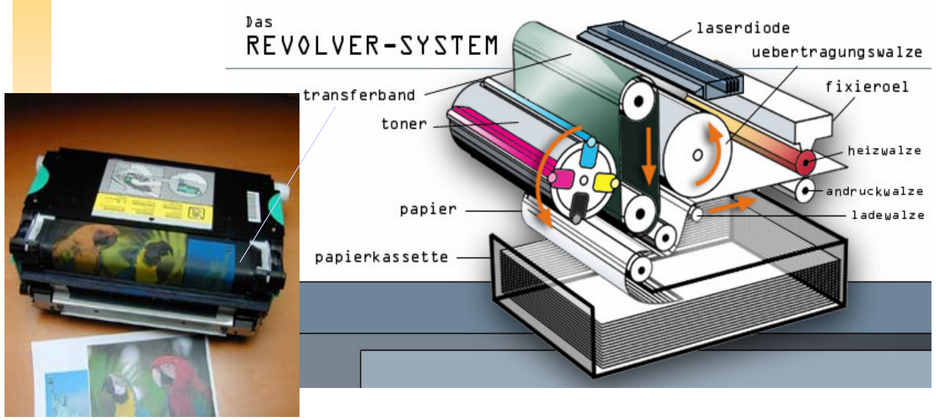
- Individual drum for each color
- Sequential transfer of colors to paper
- Advantage is high print speed



Source: www.druckerchannel.de

Color laser printer: Revolver-technique

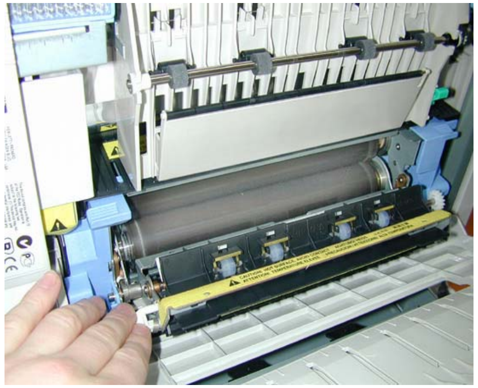
- Only one laser unit used
- Images of individual colors printed on transfer band
- When all colors are on transfer band, image transferred to paper
- Compact construction, but rather slow and loud



Source: www.druckerchannel.de

Fuser

- At the end paper passes fuser rolls: Heat and pressure fuse toner into paper
  - One of the Teflon coated rolls is heated to about 200 degrees Celsius.
  - Other roll necessary for counter pressure
  - Heat and pressure melt toner particles and fixate them on paper
- Small bristles visible at paper ejection. These neutralize electrically charged paper to prevent sticking of pages.



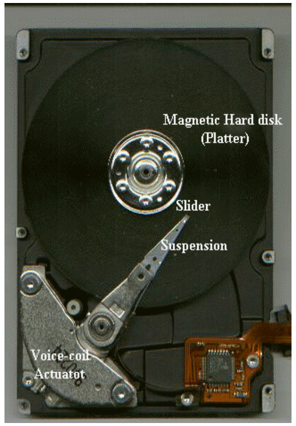
Source: www.druckerchannel.de

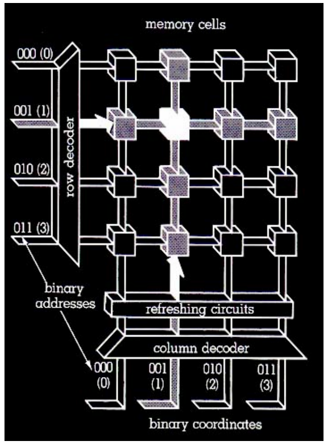
Course outline

1. Imaging optics
2. Optical sensors
3. Optics in data storage
   - 6.1 Copier and laser printer
   - 6.2 CD-/DVD-player
   - 6.3 Magneto-optical discs (MO), MiniDisc (MD)
3. Introduction to displays -> Presentation by BARCO (end of semester)
4. Fourier optics (starts 13.12.2007)
5. Diffractive optics and holograms
6. Integrated optics
7. Computerized imaging

Classification of data storage I

- Mass storage: **Storage medium** and **access unit** separate
- „random-access"-storage: **Storage medium** and **access unit** joined





Classification of data storage II

Mass storage

- One or more access units and information saved on one or more storage units
- Data access by positioning of access unit onto storage unit
- Data exchange using different physical transactions, e.g., mechanical, optical, magnetic fields, electric fields.
- Access times for HDD are a few milliseconds, for CD/DVD/MO ca. 100 milliseconds

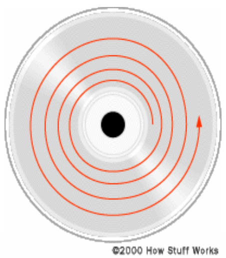
„random-access"-storage

- Access using matrix of conductors. Storage medium located at cross points
- Data access by electrical addressing of rows and columns in random order
- Electronic data exchange.
- Access times of few nanoseconds.

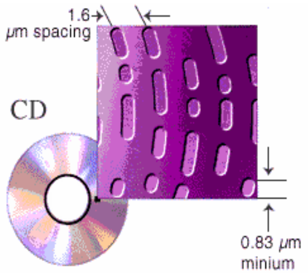
Source: Waser, „Nanoelectronics and Information Technology"

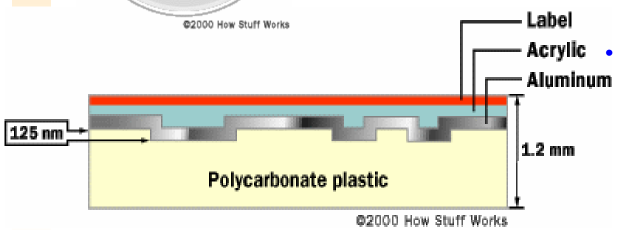
How is data stored on CD?

- Digital data saved in continuous spiral on CD



- Data saved as bits in pits



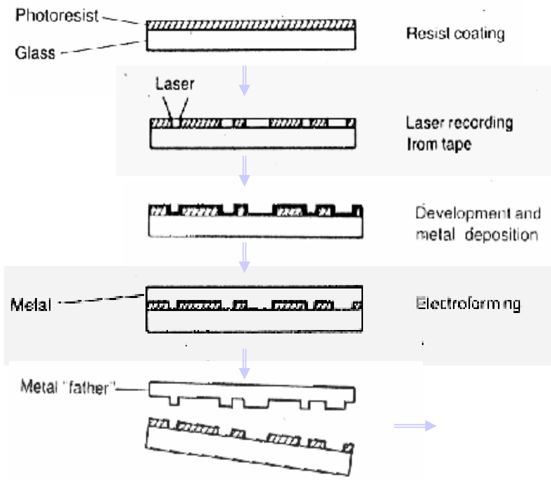


- Height profile coated with reflective layer to increase intensity of reflected light

Sources: www.howstuffworks.com; www.physics.udel.edu/wwwusers/watson/scen103/less-cd.html

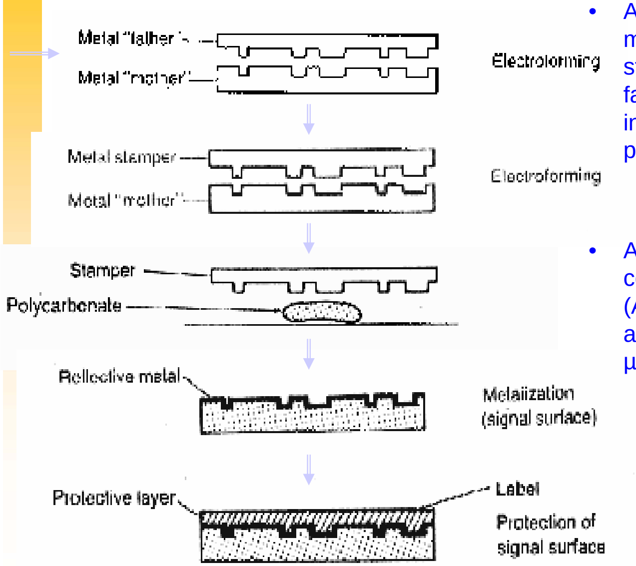
Fabrication of CD I

- Glass master fabricated by exposure of photo resist
- By galvanization (electrochemical process) 3-6 molds are fabricated



Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

Fabrication of CD II

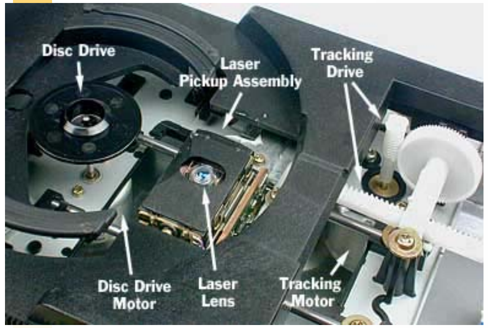


- After two more galvanic molds resulting metal stampers („Sons“) used to fabricate CDs using inexpensive die casting in polycarbonate (1.2 mm).
- At the end surface is coated with metal (Ag,Al,Au,Cu 50-100 nm), and protective layer (1-30 µm). Label is applied.

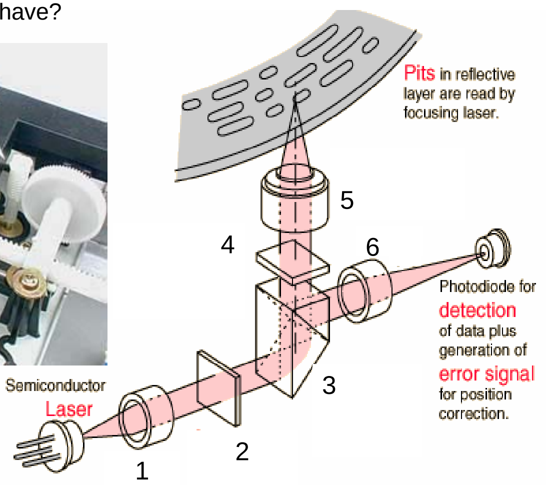
Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

Exercise: Layout of CD-player

- How does a CD-player work?
  - What are components 1 to 6?
  - What function do they have?

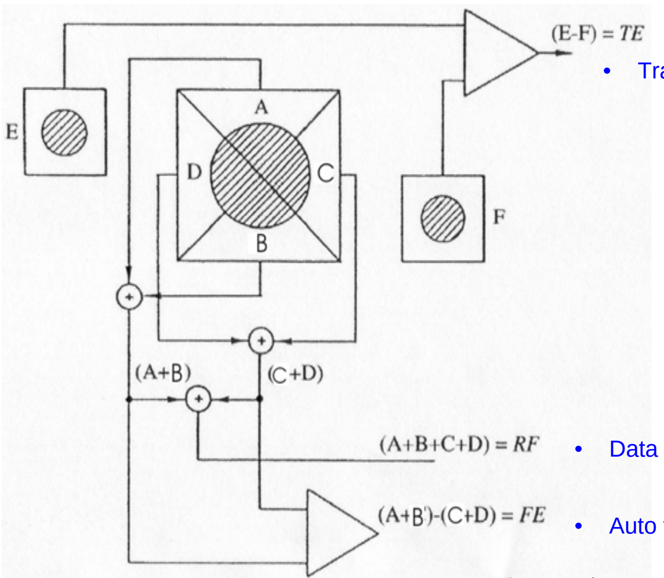


www.howstuffworks.com



Source: hyperphysics.phy-astr.gsu.edu/hbase/audio/cdplay.html

Circuit diagram for photodiode

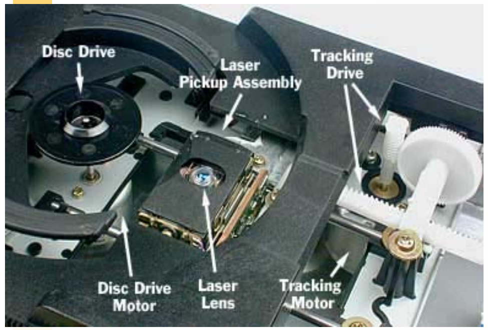


- Tracking
- Data signal
- Auto focus

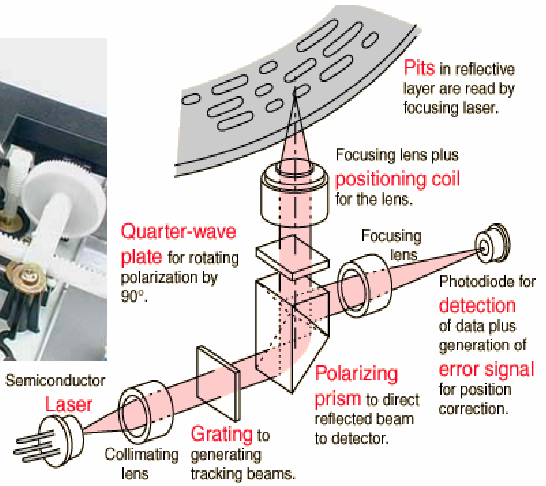
Source: Imlau

Layout of CD-player

- Optical beam path consists of laser diode, grating, polarizing prism, λ/4-waveplate, various lenses and photodetector.

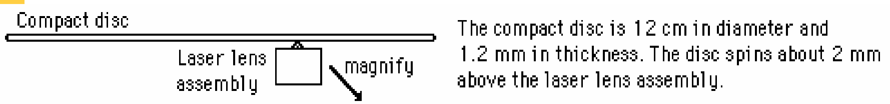


www.howstuffworks.com

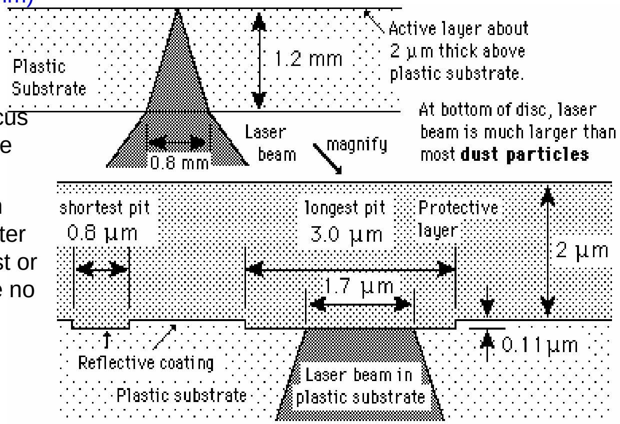


Source: hyperphysics.phy-astr.gsu.edu/hbase/audio/cdplay.html

Reading data I



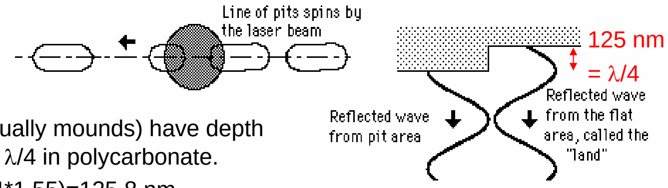
- Data read by laser (780 nm) through polycarbonate-substrate.
  - Laser diameter at focus is 1.7 µm on reflective coating.
  - Beam enters through substrate with diameter of 0.8 mm. Thus, dust or small scratches have no influence.



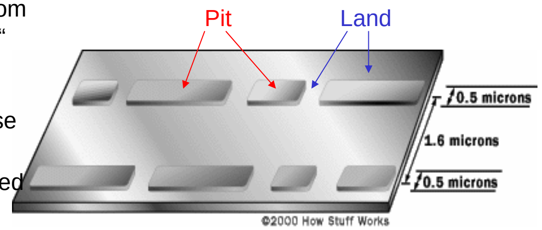
Source: hyperphysics.phy-astr.gsu.edu/hbase/audio/cdplay3.html

Reading data II

- As all areas of CD are metal coated, reflectivity does not change with position.
- Signal due to constructive or destructive interference.



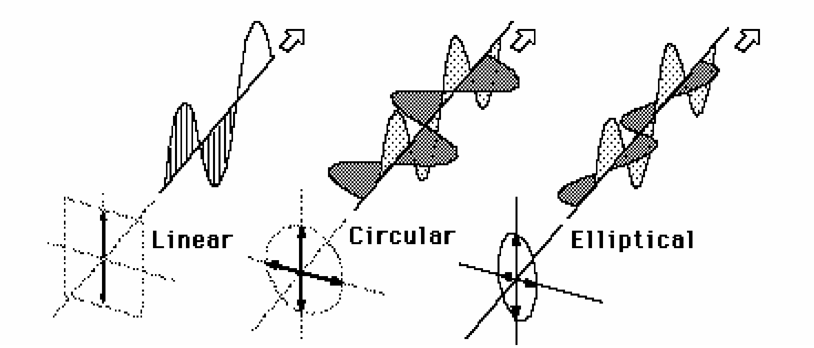
- „Pits“ (actually mounds) have depth of exactly $\lambda/4$ in polycarbonate.
- 780 nm/(4*1.55)=125.8 nm.
- Half the beam reflected from „Land“ other half from „Pit“ causes destructive interference in vertical direction due to 180° phase shift.
- If beam completely reflected from „Land“, constructive interference results.



Source: www.howstuffworks.com; hyperphysics.phy-astr.gsu.edu/hbase/audio/cdplay3.html

Reminder: Polarization

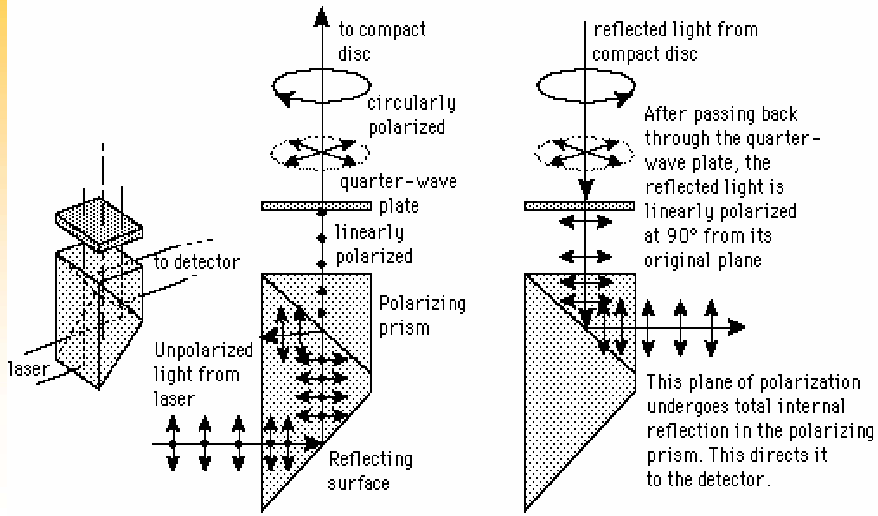
- Linearly polarized light is plane wave with fixed orientation of electric field
- Circularly polarized light may be described by two plane waves with equal amplitudes and 90° phase difference.



Source: hyperphysics.phy-astr.gsu.edu/hbase/phyopt/polclas.html

Polarizing beam splitter

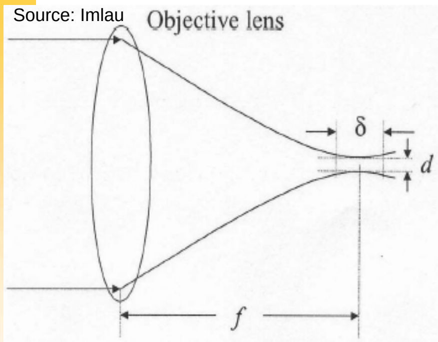
- Reflected light passes to photodetector and not back to laser diode due to polarizing beam splitter and $\lambda/4$-Wellenplatte.



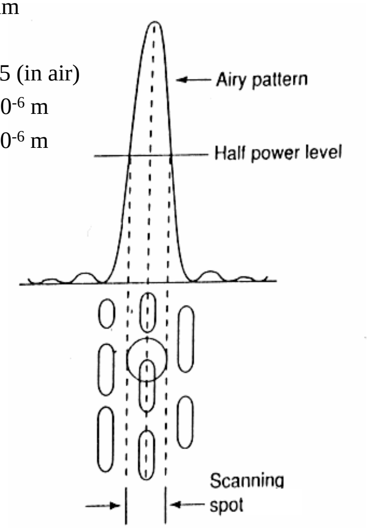
Source: hyperphysics.phy-astr.gsu.edu/hbase/phyopt/polclas.html

Focusing of laser beam I

Source: Imlau



λ = 780 nm
n = 1.5
NA = 0.45 (in air)
$d = 1.3 \cdot 10^{-6}$ m
$\delta = 7.7 \cdot 10^{-6}$ m

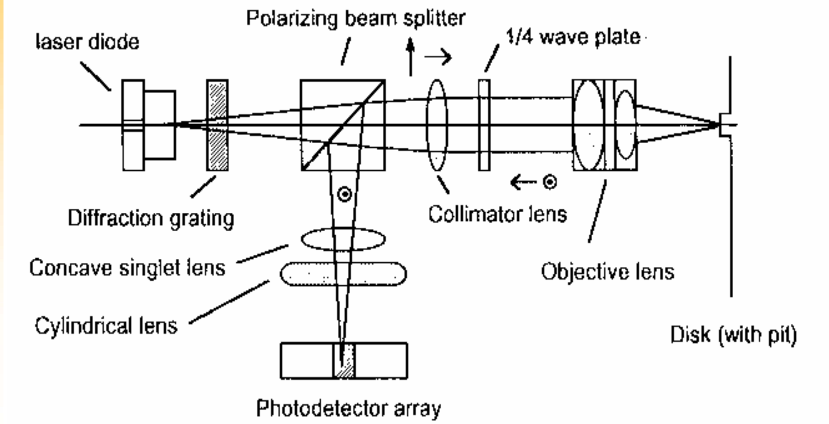


- Objective lens focuses laser beam onto active layer.
- Due to circular aperture beam exhibits Airy-pattern.
- Beam is diffraction limited.

Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

Focusing of laser beam II

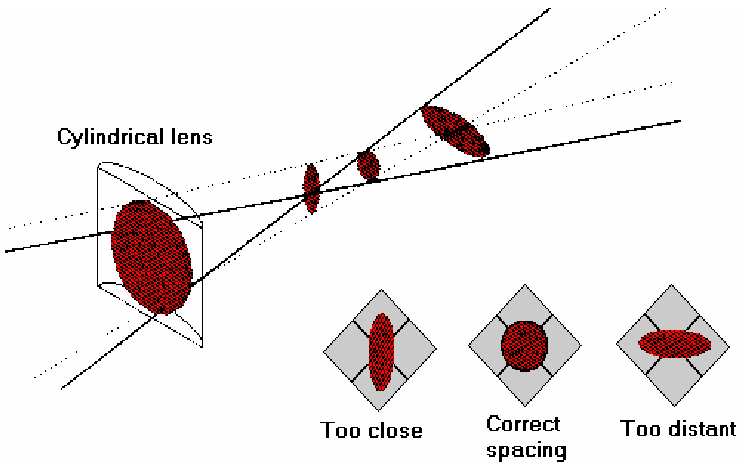
- As planarity of CD is ca. 50 µm and „Wobble“ is ca. 100 µm continuous refocusing is necessary to prevent crosstalk.
- Focusing achieved with astigmatic lens (Combination of spherical objective lens and cylindrical lens in front of detector) and quadrant detector.



Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

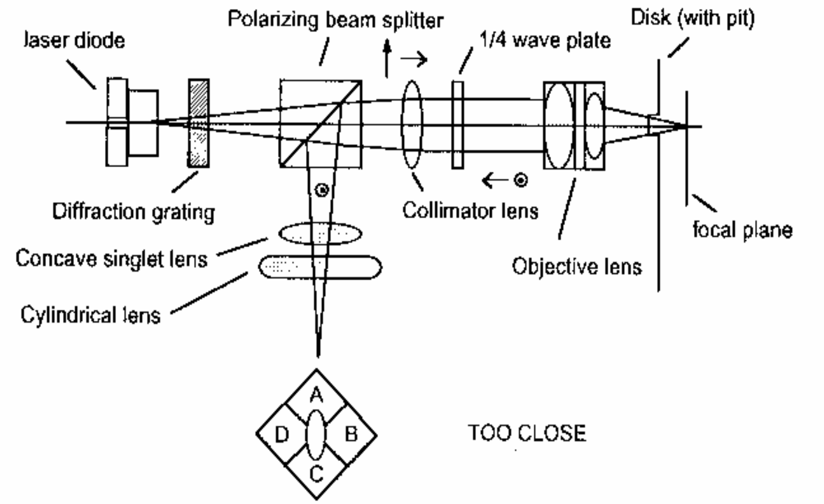
Astigmatic lens combination

- Astigmatic lens combination causes only at correct spacing round shape.
- Quadrant detector used to analyze beam shape



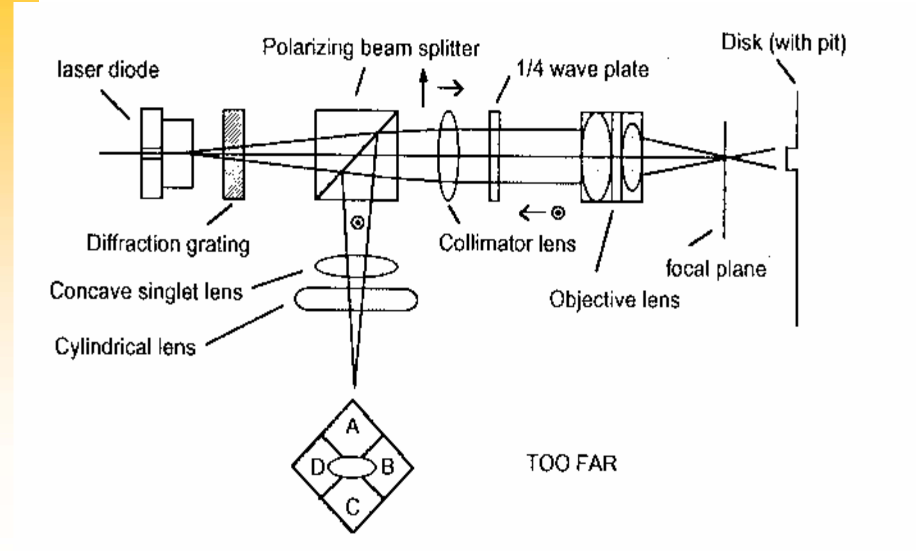
Source: www.physics.udel.edu/%7Ewatson/scen103/cd-astig.html

CD too close



Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

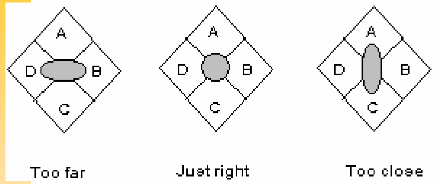
CD too far

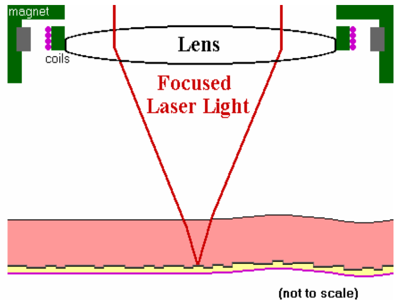


Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

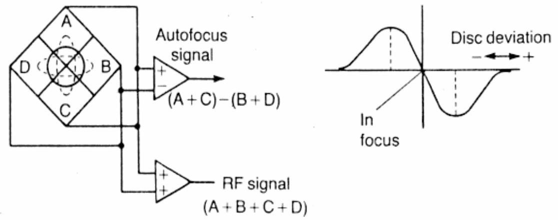
Autofocus

Source: www.physics.udel.edu/wwwusers/watson/scen103/less-cd.html





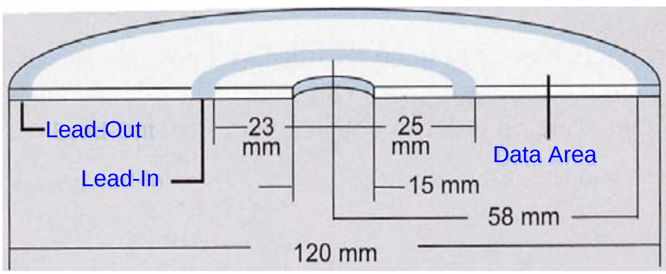
- Quadrant detector allows for simultaneous reading of data and generation of autofocus signal.
- Objective lens adjusted fast and precise with moving coil.



Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

Rotation of CD

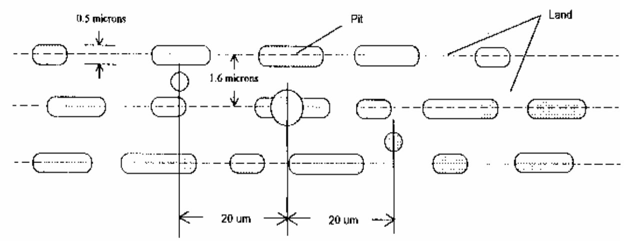
- Data on CD read with constant linear velocity of 1.3 m/s.
- Due to constant linear velocity, angular velocity needs to be reduced from 500 RPM on the inside to 200 RPM on the outside.

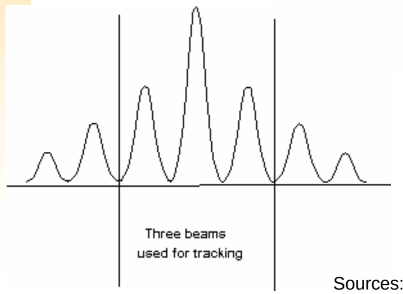


Source: Waser: „Nanoelectronics and Information Technology“

Tracking I

- During reading of CD optical head needs to be kept on spiral track.
  - Accomplished with „Three-beam-tracking“.
- Grating generates side beams around main beam.

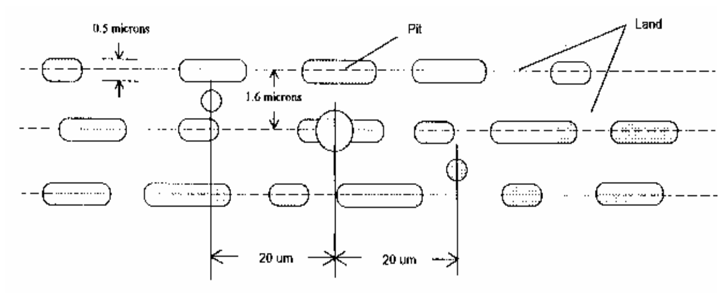


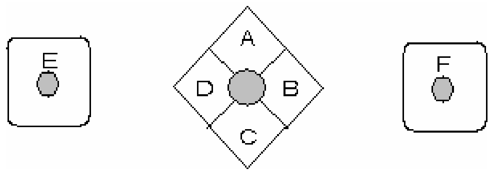


Sources: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm; hyperphysics.phy-astr.gsu.edu/hbase/phyopt/phopic/gratinghene2.jpg

Tracking II

- Side beams fall between data tracks and are measured with two extra detectors.

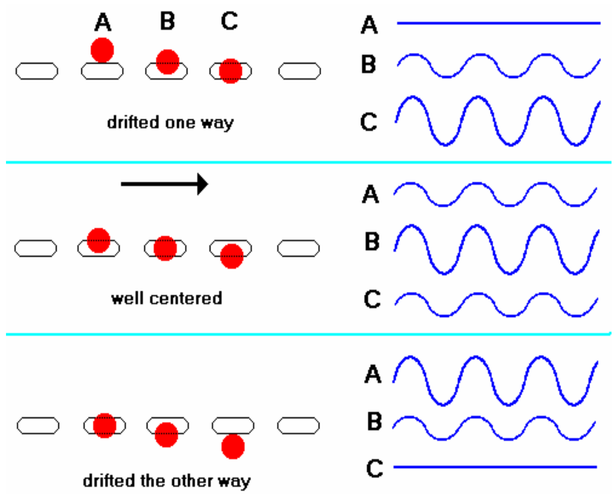




Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

Tracking III

- If signal intensity of side beams is equal, tracking is adjusted correctly.
- Tracking done with servo drives.



Source: www.physics.udel.edu/%7Ewatson/scen103/cd-tracking.html

How may the data density be increased?

- Data density given by:

$$D_{2D} = \frac{\# bits}{Area}$$

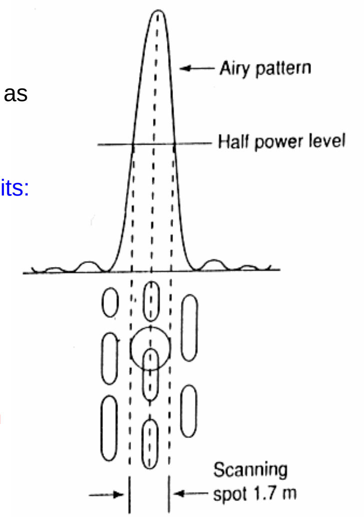
  – Thus, bits should be chosen as small as possible for high data density.

- Resolution determines minimum size of bits:

$$y_{\min} = 1.22 \frac{\lambda}{2n \sin \alpha}$$

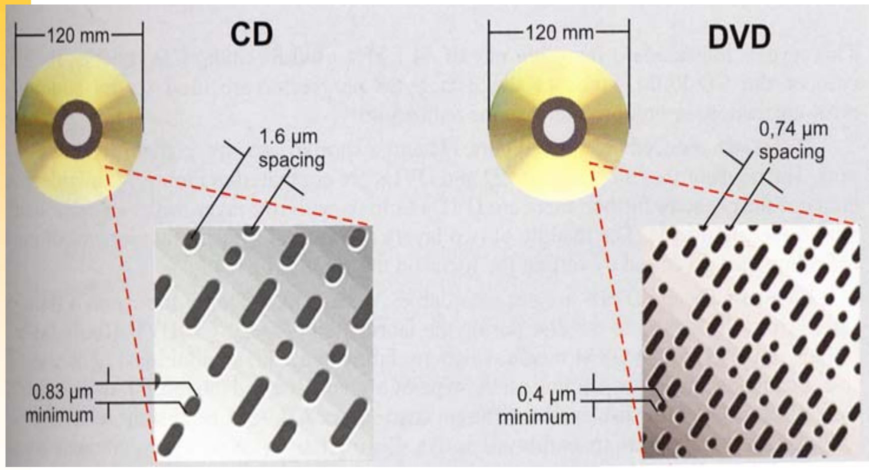
  – n*sin(α)=NA is numerical aperture of objective (n=1, as objective in air).

- To achieve high data density, wavelength should be small and NA large!



Source: www.ee.washington.edu/conselec/CE/kuhn/cdaudio/95x6.htm

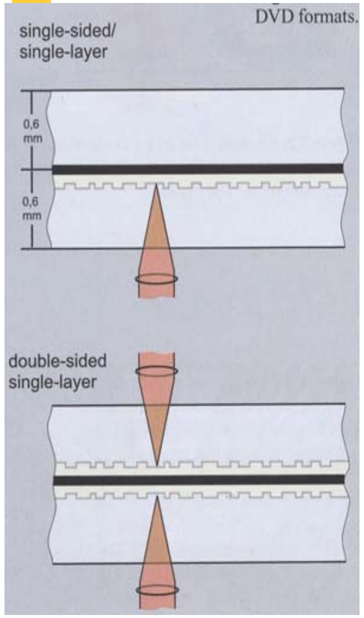
Comparison CD and DVD

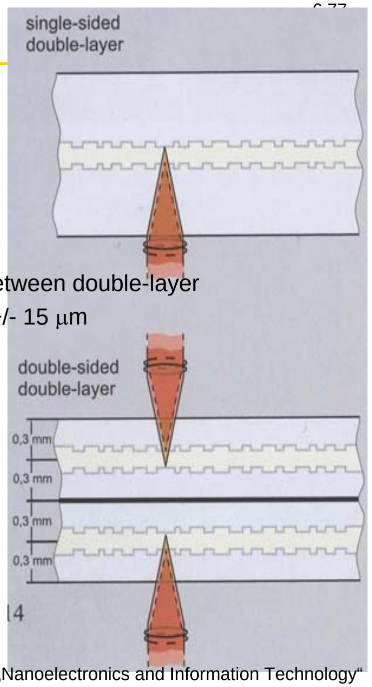


- For DVD smaller wavelength and larger NA is used. Also number of layers is increased to increase data density.

Source: Waser: „Nanoelectronics and Information Technology“

DVD Formats





Distance between double-layer layers: 55 +/- 15 µm

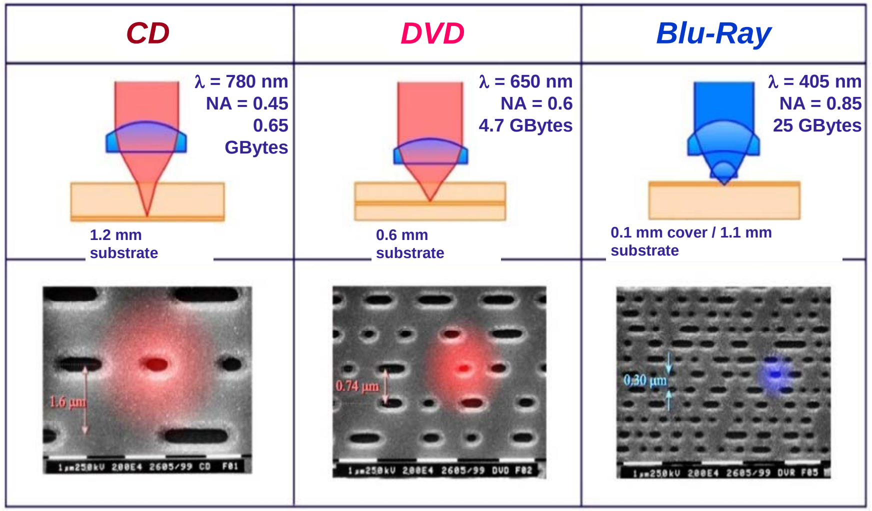
Source: Waser: „Nanoelectronics and Information Technology“

Comparison CD and DVD

	CD	DVD
Diameter	120 mm	120 mm
Thickness	1.2 mm	2 x 0.6 mm or 4 x 0.3 mm joint layers
Track distance	1.6 µm	0.74 µm
Width of pits	0.83 µm	0.40 µm
Laser wavelength	780 nm	650/635 nm
Data layers / sides Capacity	1/1 ≙ 680 MB	1/1 ≙ 4.7 GB 2/1 ≙ 8.5 GB 1/2 ≙ 9.4 GB 2/2 ≙ 17 GB
NA	0.45	0.6

Source: Waser: „Nanoelectronics and Information Technology“

Comparison CD - DVD - Blu-Ray

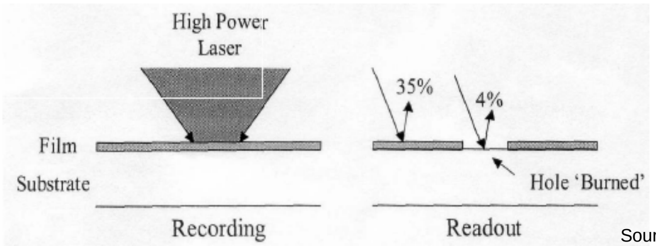


Writable CDs and DVDs

- The following categories are distinguished:
  - Prewritten CDs and DVDs are read-only
  - WORM (write once read many): may be written once and read many times, e.g., CD-R
  - R/W (read/write): maybe written and read many times
- Most important criterion for writable CDs and DVDs is that they may be read in conventional CD- and DVD-players
  - As in conventional read-only CDs and DVDs the reflection properties need to be changed.

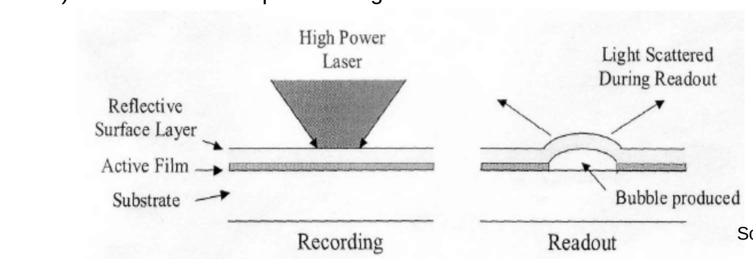
Methods for writable CDs/DVDs I

a) Burning of holes in thin metal layer (e.g., Tellurium due to low melting point)



Source: Imlau

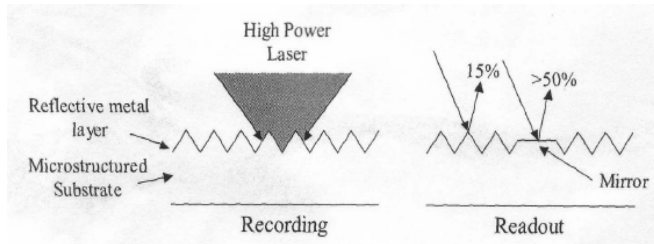
b) Blister formation upon heating



Source: Imlau

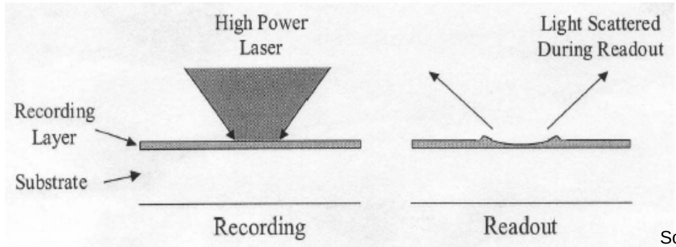
Methods for writable CDs/DVDs II

c) Thermo-plastic methods



Source: Imlau

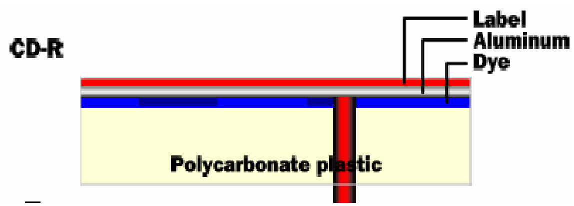
d) Change of texture



Source: Imlau

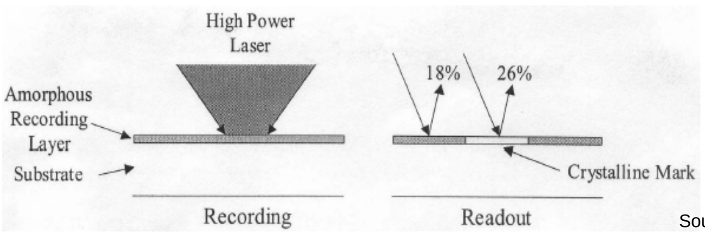
Methods for writable CDs/DVDs III

e) Chemical change of dye layer -> used in CD-R



computer.howstuffworks.com/cd-burner.htm/

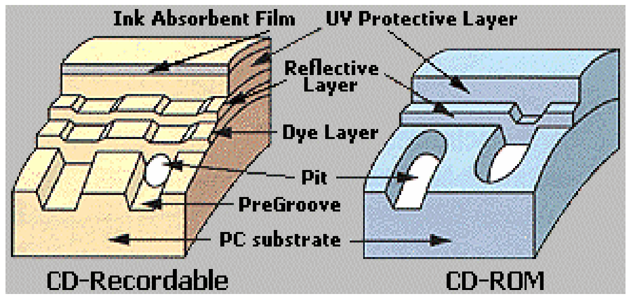
e) Phase change from crystalline to amorphous -> used for DVD-R/W



Source: Imlau

CD-R: Tracking and Timing

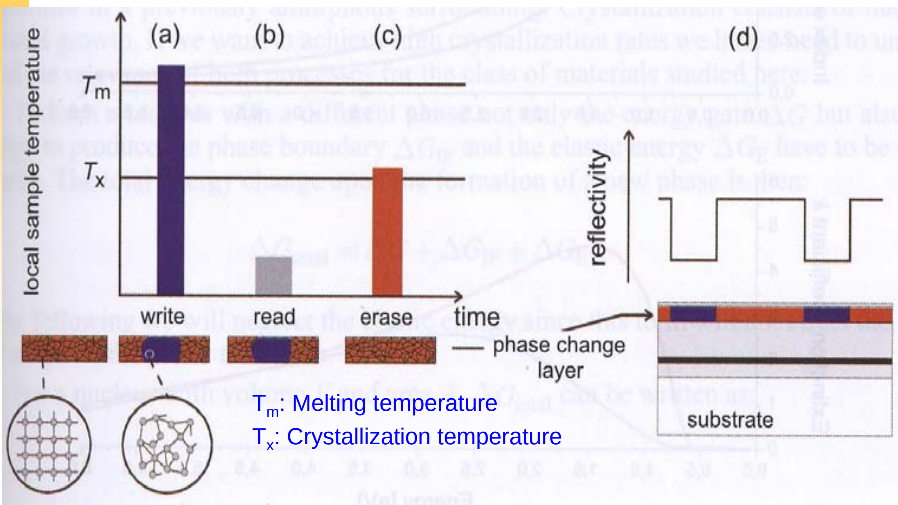
- Pre-groove allows for tracking.
- Additionally pre-groove has „Wobble" superimposed, a 22.05 kHz sinusoidal deviation from track center with 30 nm amplitude. This allows for adjustment of writing speed.



www.chipchapin.com/CDMedia/cdr2.php3

DVD-R/W

- Rewritable DVDs based on reversible phase change of medium by heating with laser beam.



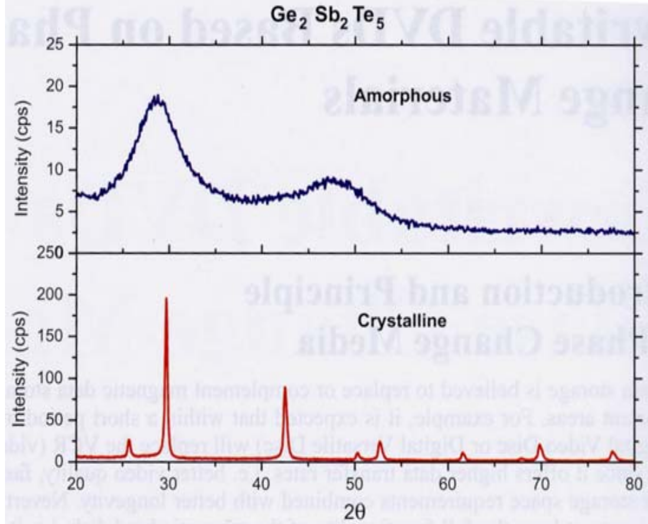
T_m: Melting temperature

T_x: Crystallization temperature

Waser: „Nanoelectronics and Information Technology“

Phase Change Media I

- X-ray diffraction shows different structure of amorphous and crystalline layer of $Ge_2Sb_2Te_5$.



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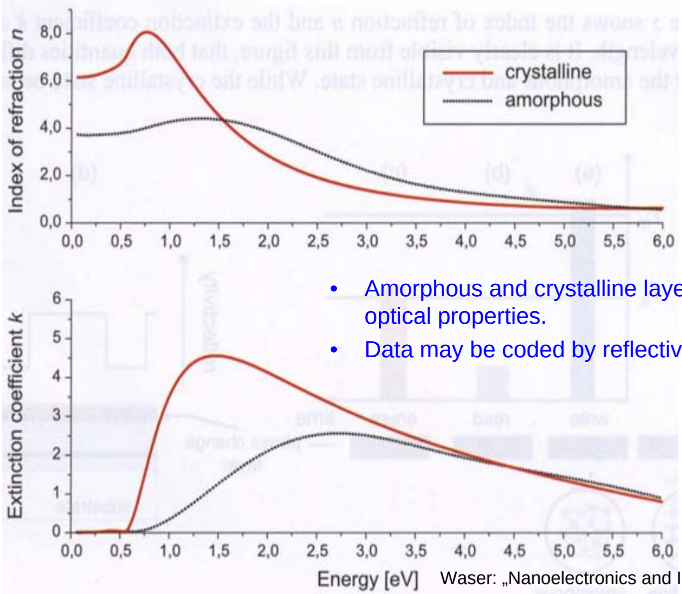
Phase Change Media II



- Amorphous and crystalline layer have different optical properties.
- Data may be coded by reflectivity.

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DVD-R/W: Layer sequence

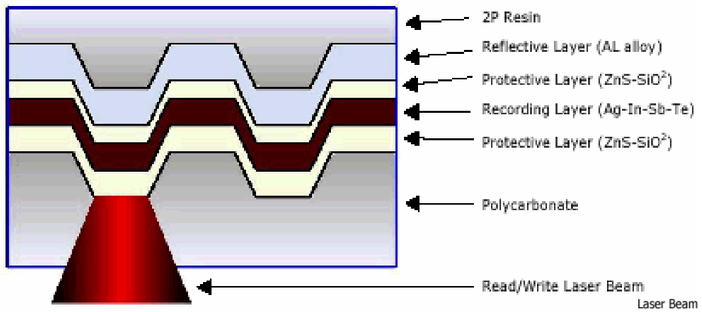
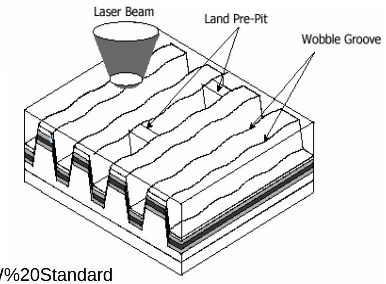


Figure One: DVD-RW Disc Construction

- Dielectric layers on both sides of active layer ensure maximum energy absorbance and protect active layer.
- Tracking and timing again by use of pre-groove with „wobble“.



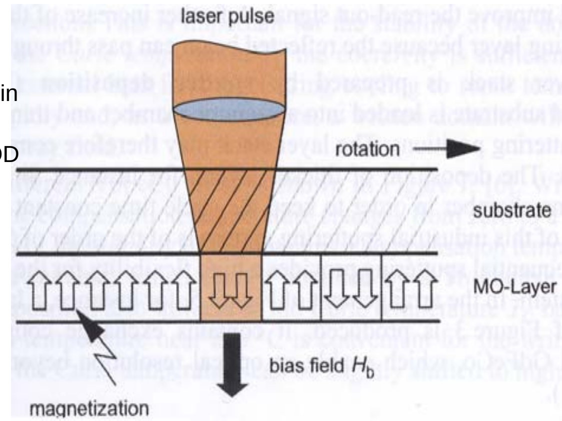
www.digitaldrives.com/Sections/TechReferences/Sources/DVD-RW%20Standard

Figure Five: Wobble Groove and Land Pre-Pit Addressing

Course outline

Magneto-Optical Discs (MOD), MiniDisc (MD)

- Data stored in small ferromagnetic domains that may be written and erased
  - Ferromagnetic domains are volume elements of homogeneous orientation and magnetization.
- Generation of domains by combination of light and magnetic field. Light heats material locally.
  - Principle of MOD investigated in 70th
  - Announced with CD in 1982
  - First commercial MOD in 1988



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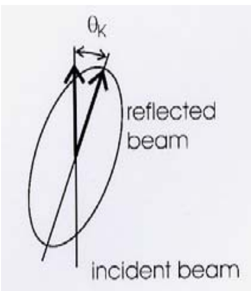
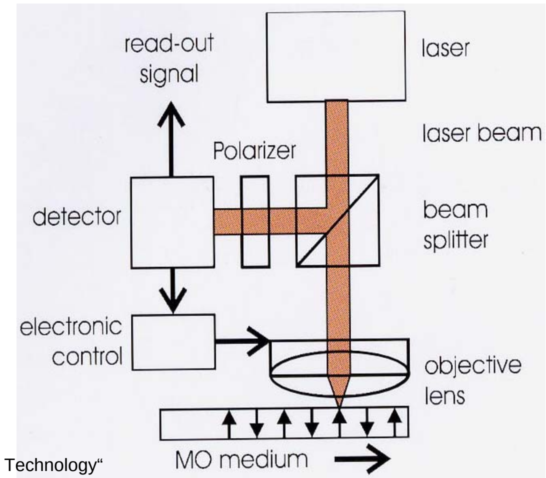
MOD: Reading

- Magneto-optical Kerr-effect (MOKE) causes slight rotation of polarization state of reflected compared to incident light (ca. 0.5°).
  - Sign depends on orientation of ferromagnetic domain
- Polarizer converts polarization modulation to amplitude modulation.





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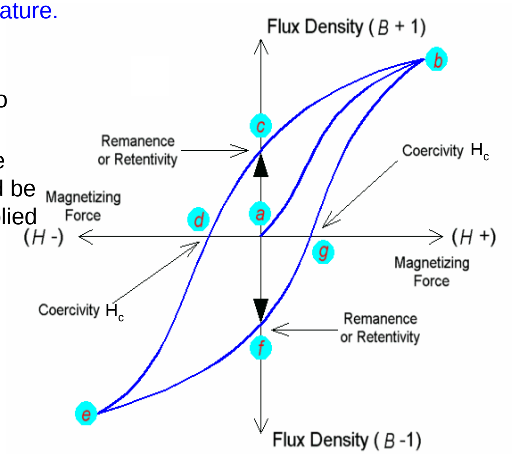
MOD: Writing

- For applied magnetic field larger than coercivity H_c change in domain orientation achieved
- In MODs materials are used whose H_c depends strongly on temperature.
  - At room temperature and heating be weak read laser beam, H_c should be large to keep data state.
  - Upon heating with intensive write laser beam, H_c should be small to write data with applied magnetic field



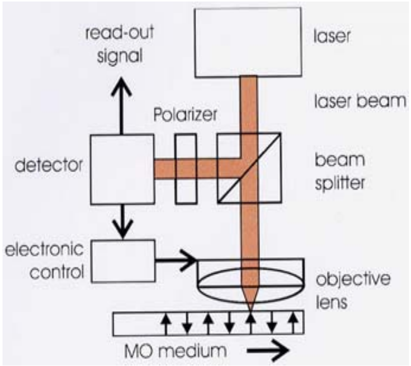
www.twysted-pair.com/hyster1.htm

MOD: Materials

- Only a magnetization orthogonal to layers may be read with typical reading configurations.
  – Most materials have orientation of domains parallel to layer (shape anisotropy FA)

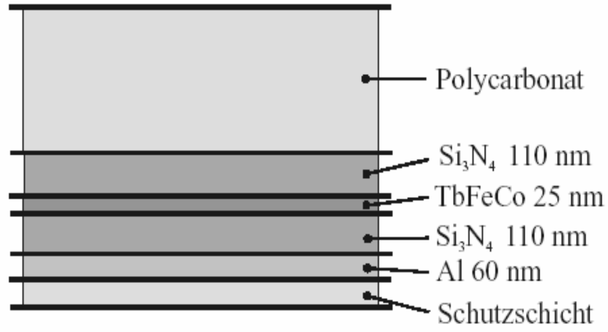
$$FA \approx \frac{1}{2}\mu_0 M_S^{\;2}$$

- Only materials with larger orthogonal anisotropy Ku than shape anisotropy FA may be used: Ku>FA.
  – This is the case e.g. for Co. Co has small magnetization though.
  – Better is combination of several materials, e.g., TbFeCo.



Layer sequence of MOD

- Al-layer reflects light. Light passes TbFeCo-layer twice.
- Si_3N_4-layer prevents water absorption in the TbFeCo-layer and serves as antireflective layer.



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Comparison MO-disc and DVD-RAM

- 3,5" MO-Disk
  – At maximum 2,3 GB,
  – 16 EUR
  – Operating system recognizes MOD as hard drive
  – Higher physical data security
    • MOD insensitive to light
    • MOD insensitive to temperature up to ca. 100 °C

- DVD-RAM
  – 4,7 GB
  – 2,40 EUR
  – Faster data transfer
  – DVD-RAM-burner cheaper
  – DVD-RAM sometimes linked as DVD-burner

Source: http://de.wikipedia.org

Compilation of questions

- Name three methods for optical distance measurements! Explain one in detail!
- For which distances may time-of-flight measurements be used?
- What is an autocollimator?
- How does an optical mouse work?
- When does speckle occur?
- How does a photocopier work?
- How does a laser printer work?
- Sketch and explain the laser scanner unit of a laser printer!
- What are differences between mass storage and „random-access“-storage?
- Sketch a CD-player and explain the individual components!
- How is the data coded on a CD?
- How is the laser beam kept on track during CD-reading?
- How may the data density be increased?
- Name three methods for realizing writable CDs!
- How is the data stored in an MOD?
- What are the parts of an MOD-player?
- Name an advantage of an MOD compared to a DVD-RAM!