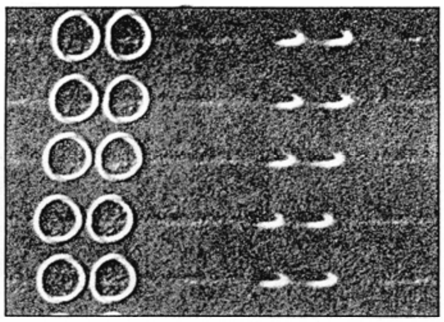
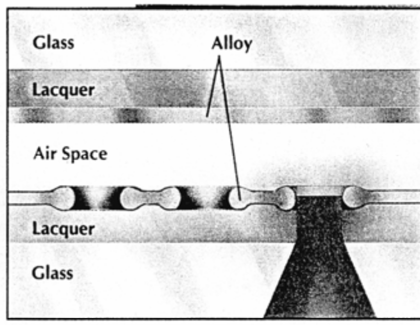
# Computer CD-R & WORM Disks

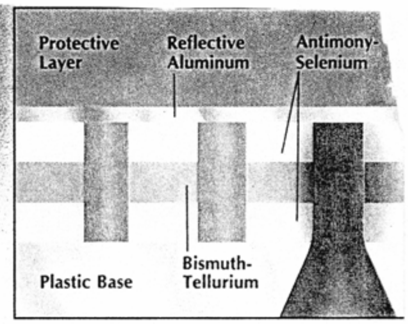
- First read/write system 12" to 14" disks •
- Write Once, Read Many (WORM)
- Operates by making physical changes in special disk
- Hole making: melts tellurium selenium alloy
  holes less reflective
- Fusion method: melts antimony-selenium into
  Bismuth-tellurium, changes to transparent hole



**Recordable disk.** An electron micrograph of a WORM disk reveals manufactured grooves that facilitate tracking, prerecorded pits *(above, left)* for synchronization and identification, and the holes of recorded data created by the heat of the high-power laser beam.



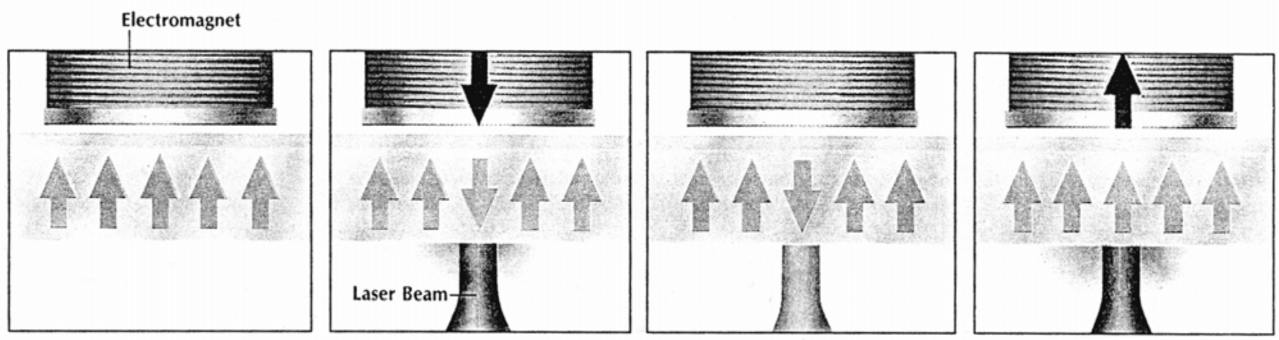

**A hole-making approach.** To record information on a tellurium-selenium alloy disk, a laser shines through the protective layers of glass to melt holes in the alloy; the air space accommodates the molten materials. When read, the holes are less reflective than their surroundings.




**A fusion method.** In another type of WORM disk, heat from a laser, shining through a plastic base, fuses two layers of antimony-selenium alloy with one of bismuth-tellurium alloy. A metallic plug fo that, during reading, is more transparent to laser l than is the surrounding unfused area.

# Magneto-optical Read Write disks

- Uses a more powerful laser
- Starts with magnetic film in one direction
- Laser melts magnetic film, with magnet opposite field
- When freezes field changed
- Change magnet field and can reverse
- Read by Kerr effect: polarization angle changed by magnetic direction




**The unrecorded disk.** Before recording, particles *(orange arrows)* on a magneto-optic disk are all magnetized in the same direction *(up, here)*, at right angles to the surface of the disk.

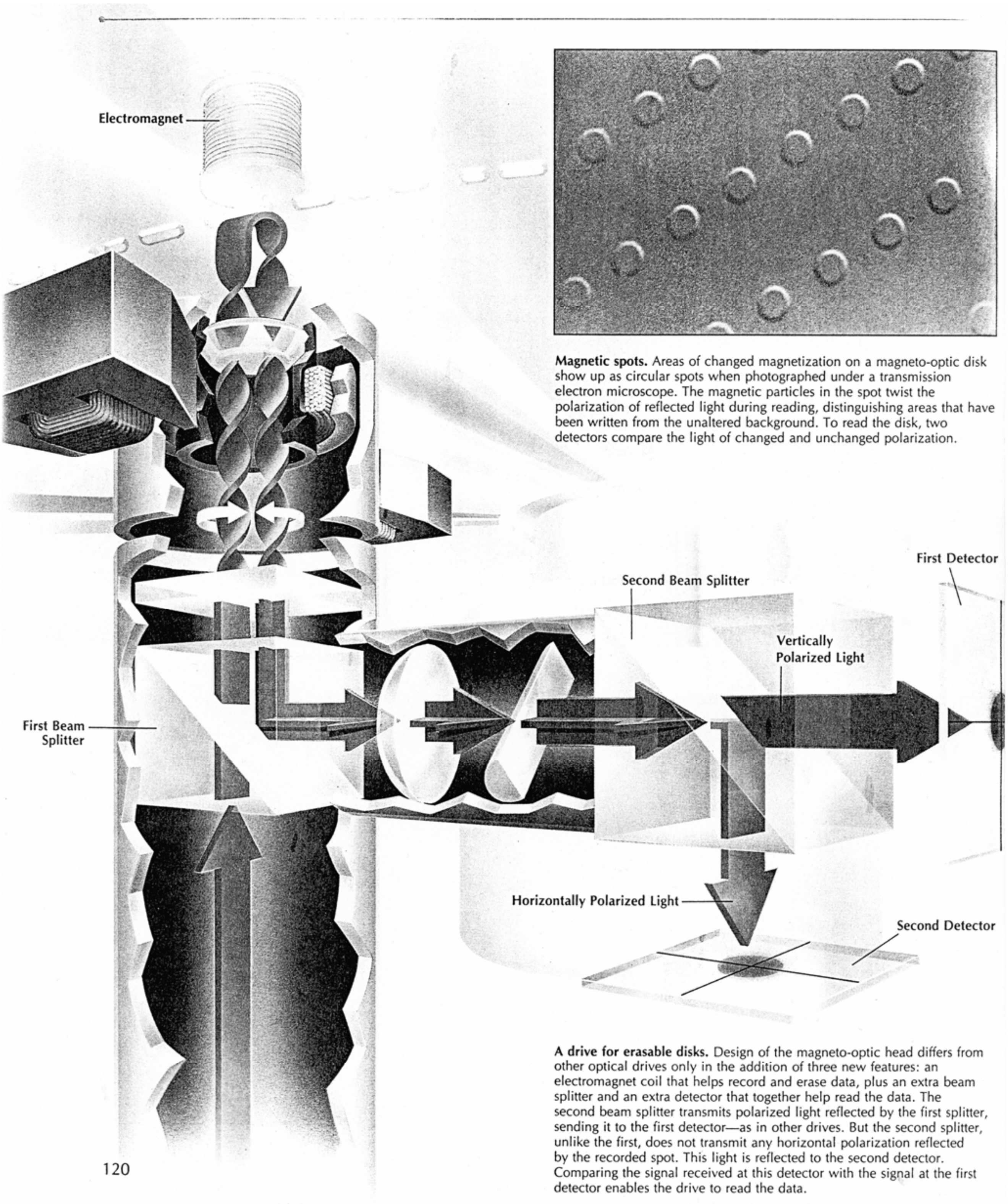
**Recording.** To write on the disk, a coil is switched on, with its magnetic field *(purple arrow)* oriented opposite to the direction of magnetic particles on the unrecorded disk. Where the recording beam heats the disk, the magnetization of the particles is reversed by the external magnetic field.

**Reading.** With the external magnet switched off, a low-power beam reflects off the spot of reversed magnetization. Its reversed magnetization twists polarization of the beam relative to polarization of reflections from unrecorded areas, generating a signal to be read by the paired detectors.

**Erasing.** The original magnetic direction can be restored to the recorded spot by reheating with the electromagnet turned on so that its field *(purple arrow)* now matches the upward orientation of an unrecorded area, causing the magnetization of the particles at the spot to reverse.

# Magneto-Optical setup

- Must have polarized light in optical path




**Magnetic spots.** Areas of changed magnetization on a magneto-optic disk show up as circular spots when photographed under a transmission electron microscope. The magnetic particles in the spot twist the polarization of reflected light during reading, distinguishing areas that have been written from the unaltered background. To read the disk, two detectors compare the light of changed and unchanged polarization.

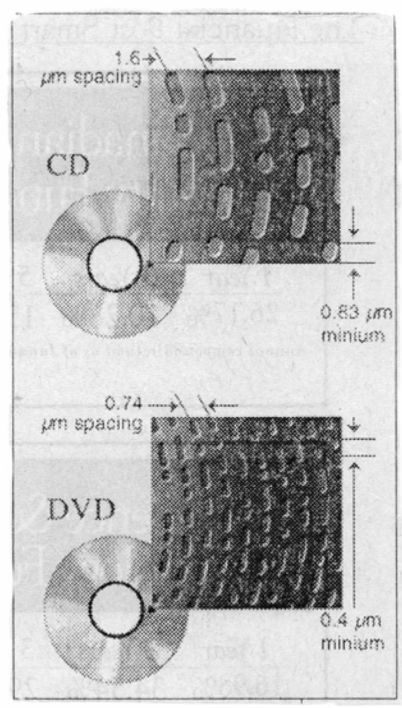
**A drive for erasable disks.** Design of the magneto-optic head differs from other optical drives only in the addition of three new features: an electromagnet coil that helps record and erase data, plus an extra beam splitter and an extra detector that together help read the data. The second beam splitter transmits polarized light reflected by the first splitter, sending it to the first detector—as in other drives. But the second splitter, unlike the first, does not transmit any horizontal polarization reflected by the recorded spot. This light is reflected to the second detector. Comparing the signal received at this detector with the signal at the first detector enables the drive to read the data.

# Digital Video Disk

- Designed for full video playback/recording
- Uses Red laser (650 nm) not IR (830 nm)
- Pit size 48%, date density 2.12x
- Total memory 4.8x to 3.28 GBytes: Transfer rate 9x CD
- DVD-R recordable, DVD-RAM printed
- Two sided, 2 levels/side top level partially reflecting
- Increase to 8.5 GB (2 sided), 17 GB (2 levels, 2 sided)
- Aimed at fully video playback of 2 hour movies
- Uses MPEG2 compression for video: movie aspect ratio
- Audio uses Dolby AC-3 for 6 track sound!
- Standard allows 50 GB with blue lasers!

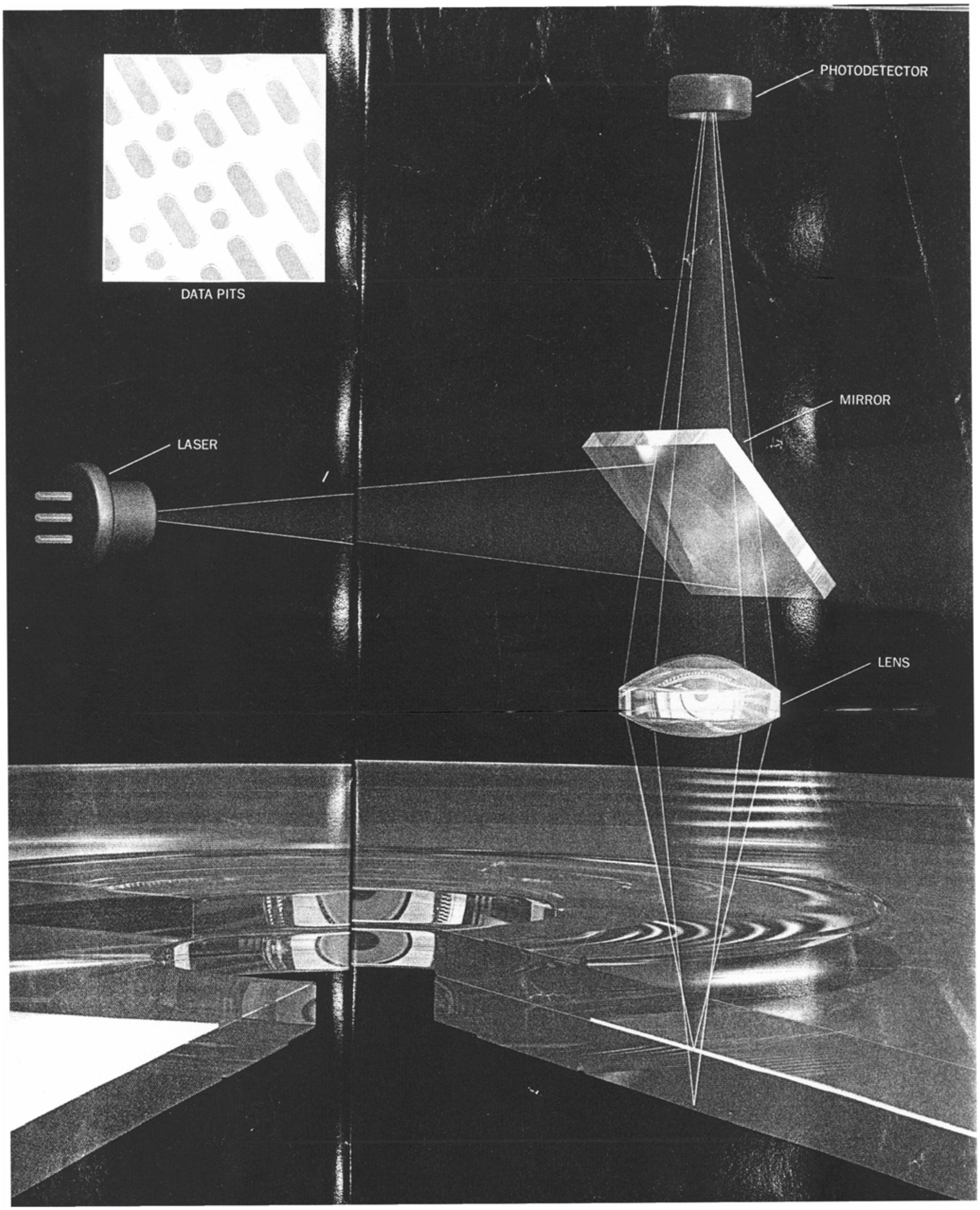
How the DVD and CD Compare

| Feature | New Format | Old Format |
|---|---|---|
| Disc diameter | 120 millimeters | 120 millimeters |
| Disc structure | Two substrates, each 0.6 millimeter thick | One substrate, 1.2 millimeters thick |
| Minimum pit length | 0.4 micron | 0.83 micron |
| Laser wavelength | 635 to 650 nanometers | 780 nanometers |
| Capacity | Two layers, one on each side, 9.4 gigabytes total<br>Two layers, both on one side, 8.5 gigabytes total<br>Four layers, two on each side, 17 gigabytes total | One layer on one side, 0.68 gigabyte total |
| Numerical aperture | 0.60 | 0.45 |
| Track density | 34,000 tracks per inch | 16,000 tracks per inch |
| Bit density | 96,000 bits per inch | 43,000 bits per inch |
| Data rate | 11 megabits per second | 1.2 to 4.8 megabits per second |
| Data density | 3.28 gigabits per square inch | 0.68 gigabits per square inch |



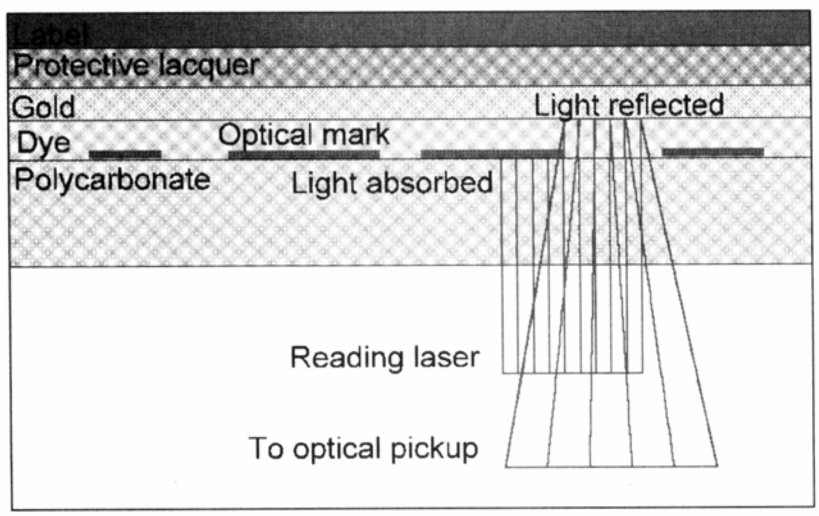
# Digital Video Disk

- 2 level have two different focus points



# CD-R Organic Dye Disks

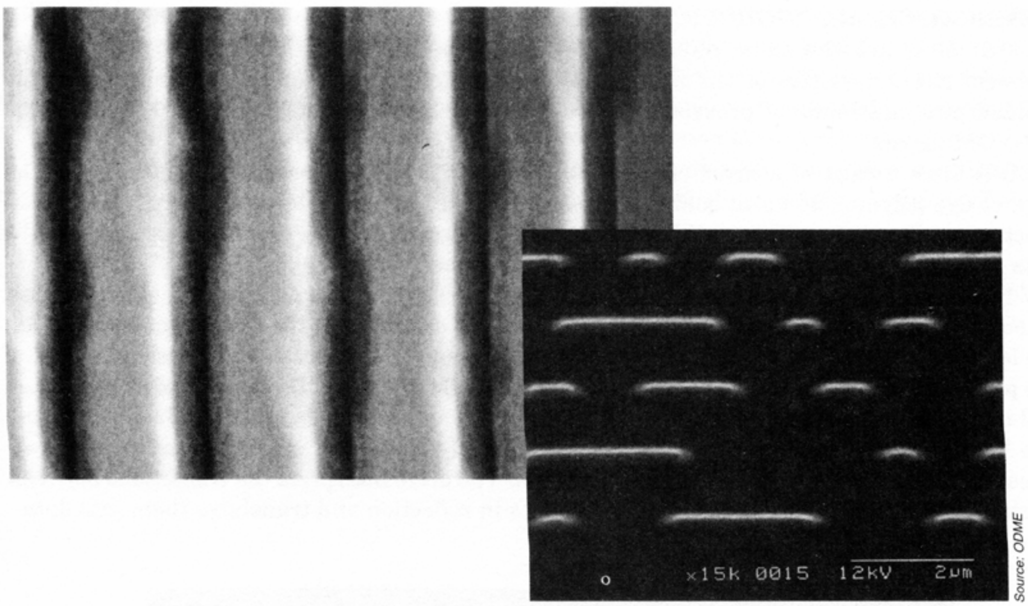
- CD-R (12 cm) uses organic die molecules
- Gold, silver or aluminum coating provides reflection
- Dye layer blue, green (better), gold (best) in unwritten state
- Laser writer 4-11 mW 790 nm (CD-R), 630-650 nm (DVD)
- Laser heats dye to 250 C (when 11 mW)
- Depending on dye either destroys dye or may disintegrate material
- Problem: ratio of dark/light spots 50%-30% regular
- Hence may not play in some CD players



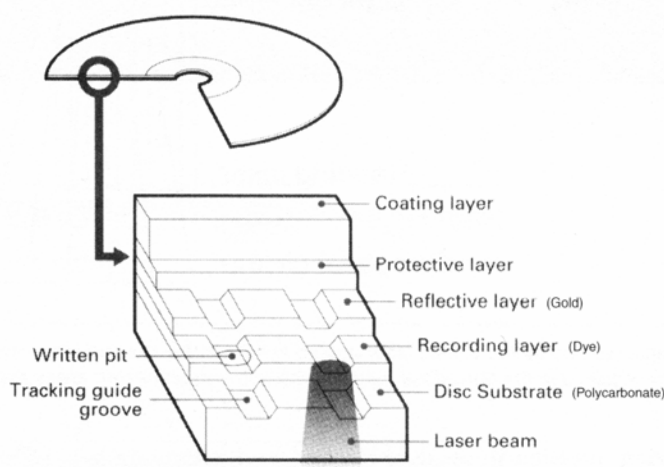

*The optical marks created by the writing laser absorb light from the reading laser, while unmarked areas reflect the light back. Again, it is the transitions between marked and unmarked areas that represent binary ones.*

## CD-R/DVD-R/DVD+R Operation

- Different dyes use different processes: give different reflectivities
- Cheaper dyes burn to dark, have less reflection ratios
- Others melt or chemically degrade & heats recording layer
- Has less volume – cover layer melts in & creates pit
- Much harder to see the pits in CD-R under microscope
- Hence much less reflection
- Higher speed (52x) uses higher power lasers & rotation rate



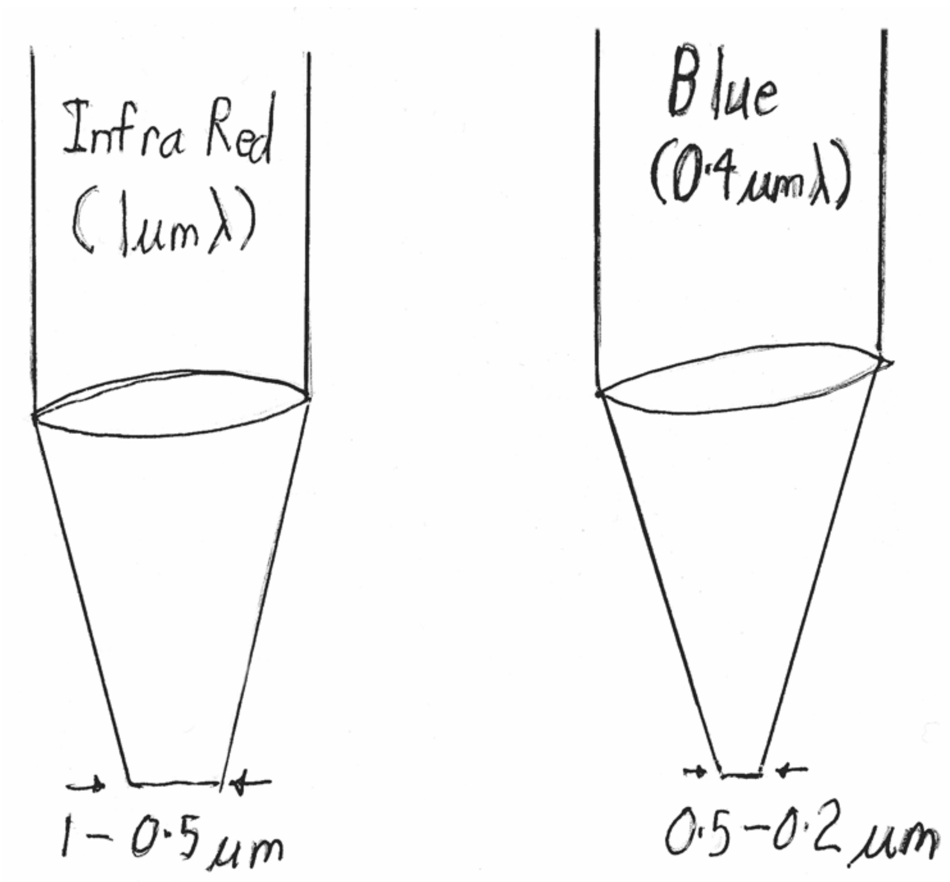

*These enlarged photos of marks in CD-R dye polymer and molded pits in a pressed CD demonstrate that even if optical marks are not physically apparent, a laser can "see" the differences in reflectivity.*




*A CD-R disc uses a thin layer of pure gold, instead of aluminum, as a reflector, and adds a layer of organic dye polymer as a recording layer.*

# What Limits the Data on a CD/DVD?

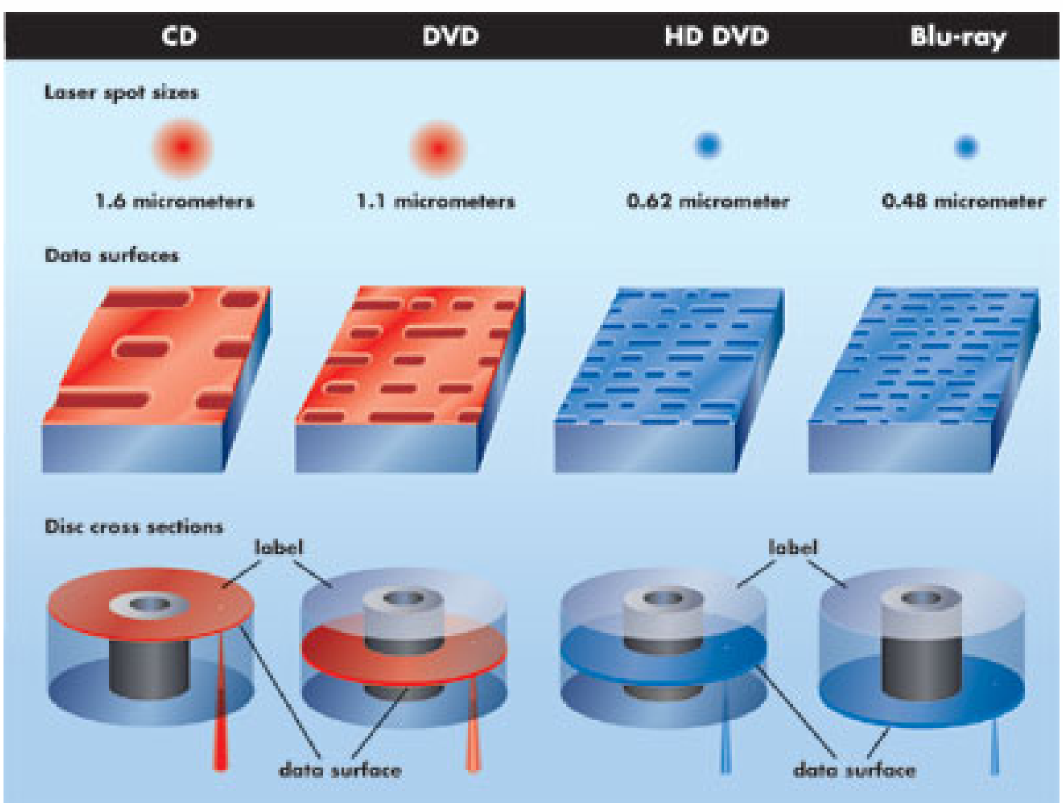
- Each pit is one “bit” (0 or 1) of data
- How fast the CD turns (1.4 m/sec for single speed)
- Rotation speed limit: about 52x (72.8 m/sec)
- Beyond that disk destroyed by rotation stress
- Infrared GaAs light 830 nm & 790 nm currently
- Final DVD target Blue lasers ~405 nm to get 0.2 μm pits
- Problem is lifetime of Blue laser approaching 1000 hrs



# HD-DVD vs Blue Ray DVD Wars

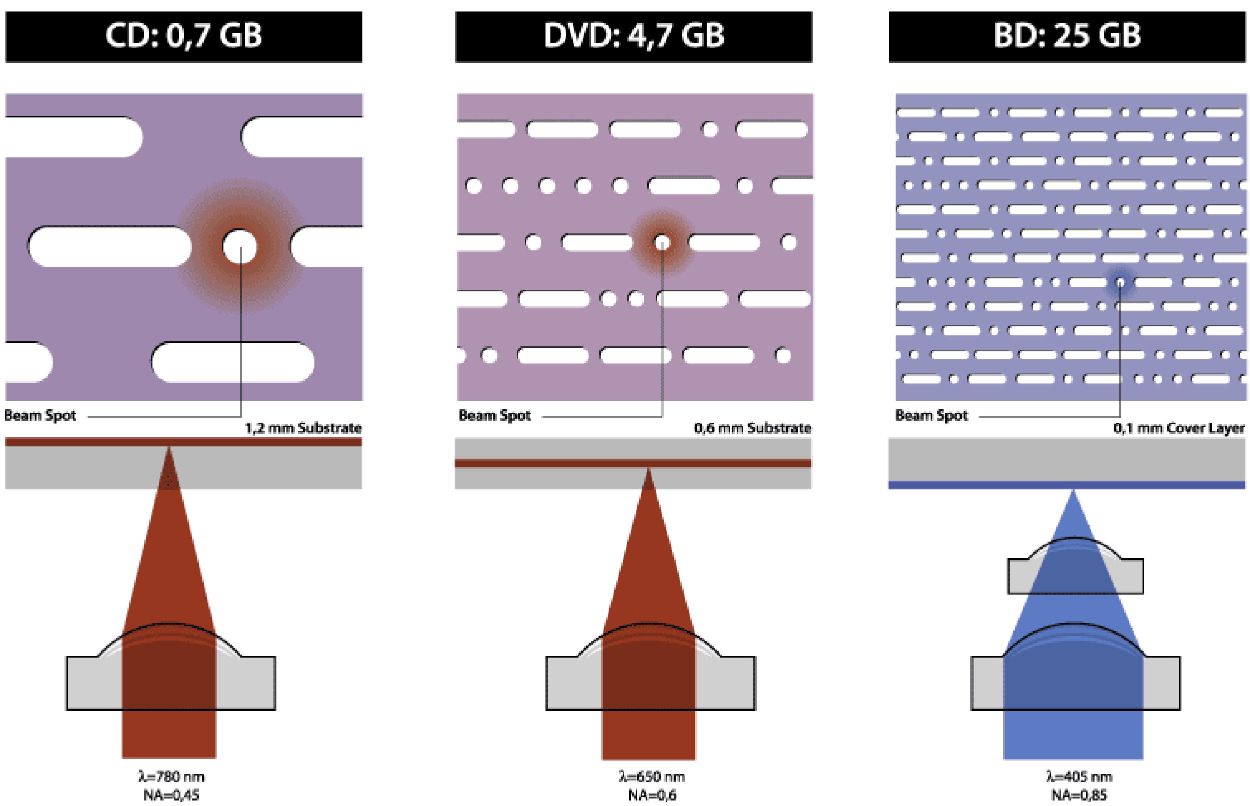
- Next generation DVD format has two competitors
- HD-DVD: Toshiba, NEC, Microsoft, entertainment industry
- Blue Ray (BD): Sony, Hatachi, Panisonic, Apple etc (PC makers)
- All use 405 nm blue (really violet) laser diodes
- Blue Ray higher capacity (25 GB) vs HD (15 GB)
- Reason: Blue ray spot smaller (0.48 μm) vs HD (0.62 μm)
- Hence shorter pits/track: Blue ray 0.16 μm, HD 0.205 μm
- Track spacing: Blue ray 0.32 μm, HD 0.40 μm
- Problem is that Blue ray is much nearer the surface (0.1 mm)

| OPTICAL-DISC FORMAT SPECIFICATIONS | | | | |
|---|---|---|---|---|
| Prerecorded formats | CD | DVD | HD-DVD | BLU-RAY DISC |
| Maximum data rate, in megabits per second (Mbps) | 1.4 Mbps | 11 Mbps | 36 Mbps | 36 Mbps |
| Data capacity (single-side, single-layer), in gigabytes (GB) | 0.74 GB | 4.7 GB | 15 GB | 25 GB |
| Laser wavelength, in nanometers (nm) | 780 nm | 650 nm | 405 nm | 405 nm |
| Diameter of laser spot on data layer, in micrometers (μm) | 1.6 μm | 1.1 μm | 0.62 μm | 0.48 μm |
| Track pitch | 1.6 μm | 0.74 μm | 0.4 μm | 0.32 μm |
| Minimum pit length | 0.83 μm | 0.40 μm | 0.204 μm | 0.15 μm |
| Overall disc thickness | 1.2 mm | 1.2 mm | 1.2 mm | 1.2 mm |
| Distance from disc surface to data surface | 1.1 mm | 0.6 mm | 0.6 mm | 0.1 mm |

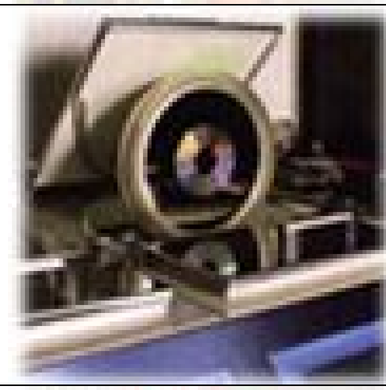


# HD-DVD vs Blue Ray DVD: Why the Difference

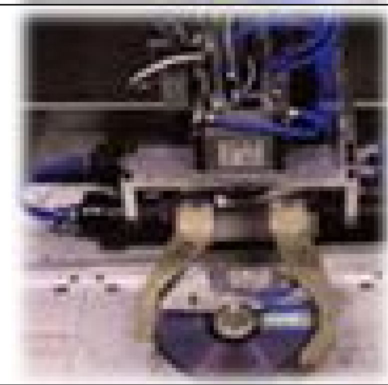
- Problem is Blue ray uses Higher NA lens 0.85 vs HD 0.65
- Much shorter focus: Blue ray 0.1 mm vs HD 0.6 mm
- Allows for smaller spot, higher density
- But production equipment different:
- Blue ray 1.1 mm substrate (new technology)
- HD uses standard DVD 0.6 mm substrates
- HD simple modification to existing DVD lines & faster production
- Will be to market first
- Blue ray can have 8 layers, up to 200 GB, HD 4 layers, 60 GB
- Initial format 2 hours of High Definition TV, 4 hours later/layer
- Limit is really the codecs (digital decoding)
- Harder to make Blue Ray read current DVD's



# CD/DVD Manufacturing: Creating Masters

| | |
|---|---|
| **Premastering**<br>• Converting the video/sound into data<br>• Conversion to mpeg/compressed files |  |
| **Mastering**<br>• Glass master coated with photoresist<br>• UV laser beam Recording writes data pattern<br>• Develop resist to create pits<br>• Sputter silver coating |  |
| **Electroplating**<br>• Electroplate nickel layer on glass master<br>• 0.3 mm nickel forms mould for disk<br>• Separate pressing mould from glass master<br>• Called a stamper |  |

# CD/DVD Disk Manufacturing

| | |
|---|---|
| **Pressing**<br>• Liquefied polycarbonate injected into mould<br>• Cools to create base layer with pit pattern |  |
| **Metallization**<br>• Sputter deposit aluminum layer<br>• Creates reflective layer with pits |  |
| **Varnishing**<br>• Varnish lacquer layer spun on<br>• Forms hard layer for scratch protection<br>• Acts as vapour barrier to water<br>• Prevents Aluminum distruction |  |
| **Labelling**<br>• Silk screen printing the label |  |

- Multilayer/Double sided disks
- Repeat stamp/metallize/varnish for each level

**HD-DVD Blue Ray DVD Wars**

- HD backed by Toshiba/Microsoft/Hitachi
- Studios Paramount Pictures/Universal
- Blue Ray: Sony/Philips
- Studios Sony, MGM, Walt Disney,Universal, Warner Bros.
- Sony learned from Beta/VHS tape: get many on board
- HD advantage – could modify DVD production equipment
- But Blue ray costs came down to same level <$1/disk
- Hence Disk cost to consumer the same
- Also Blue ray can do next generation HD
- Make money when switch formats
- End case when major retails saw 2:1 blue to HD sales
- Walmart/Best Buy switched in Feb. 2008

## Lasers in Medicine

- Medical applications one of fastest growing laser fields
- $US400 million (2004), 7.5% of laser sales
- Growing at ~10%/year, but more slowly than overall laser market
- Three main Areas:
- Surgery, as a cutting tool
- Ophthalmology (eye operations)
- Dermatology (Skin Operations)

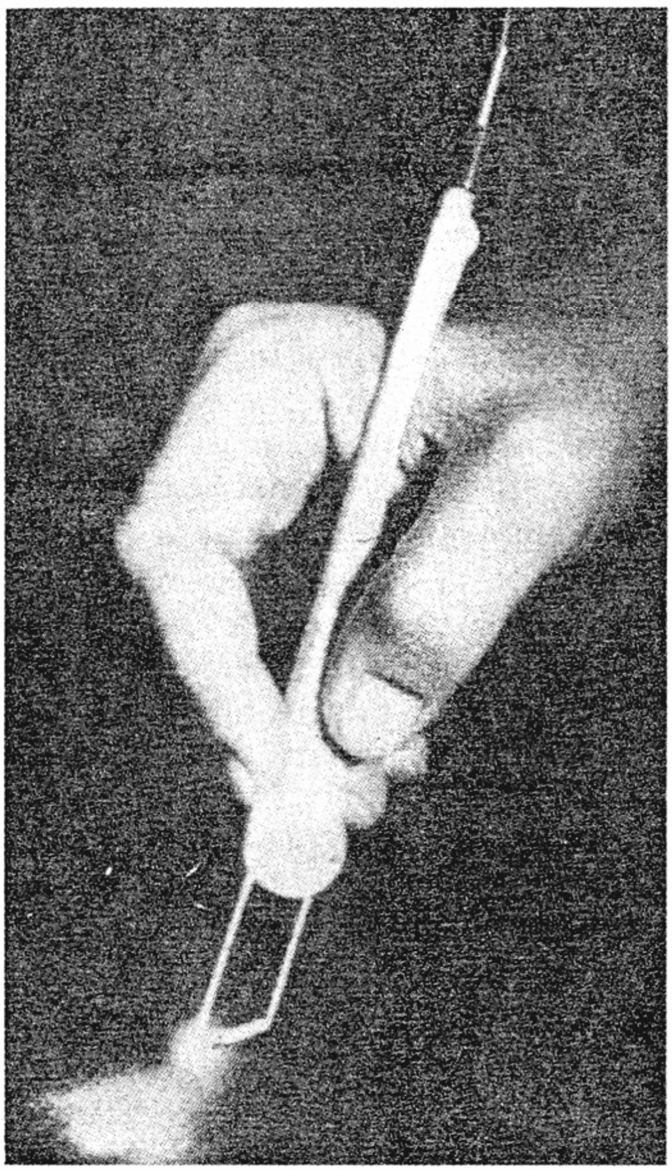


**Figure 10-13** A laser scalpel with sapphire blade for excision of devitalized wounds. (Courtesy David C. Auth)

# Lasers for Medicine

- $CO_2$ laser widely used for cutting
  10.6 μm heavily absorbed by water
  evaporation of water leads to destruction of tissue
- Nd:Yag penetrates deeper, but widely used
- Argon laser: skin blemishes, Ophthalmology
- Eximer: Cornea shaping & Herpes

**Table 10-1 Randomly selected surgical applications of lasers***

| Laser type | Spectral region, Å | Body tissue | Treatment |
|---|---|---|---|
| He-Ne | Visible, 6328 | Dermal | Photoradiation, wrinkle removal |
| Argon | Visible, 4500 | Otological, cholesterol clot, fallopian tube, gastrointestinal tract | Photocoagulation, skin blemishes, skin therapy, incision, ulcer |
| Argon | Ultraviolet, 3500 | Nasal mucous membranes, dermal tissue | Ultraviolet therapy, germicidal agent, retinopathy |
| Nd-YAG | Infrared, 10,640 | Stomach, liver, lungs, heart, kidneys, pancreas, brain, skin | Incision, control of hemophilia, cancer |
| $CO_2$ | Infrared, 106,000 | Stomach, liver, pancreas, skin, profuse bleeding, syphilitic tissue, herpes sores, melanoma, vocal cords, tonsils | Removal of tissue, sprained joint, cancerous tissue, fallopian tube |
| Erbium-YLF | Infrared, 12,280 | Eye tissue | Ophthalmology |
| Ruby | Visible, 6943 | Retinopathy, melanoma, skin blemishes | Eye disorders, cancerous tissue |
| Copper vapor | Visible, 5105 | Herpes sores | Excision |

# Beam Penetration in Skin

- Nd:Yag penetrates the most: 4.2 mm typical
- $CO_2$ relatively shallow: 0.23 mm

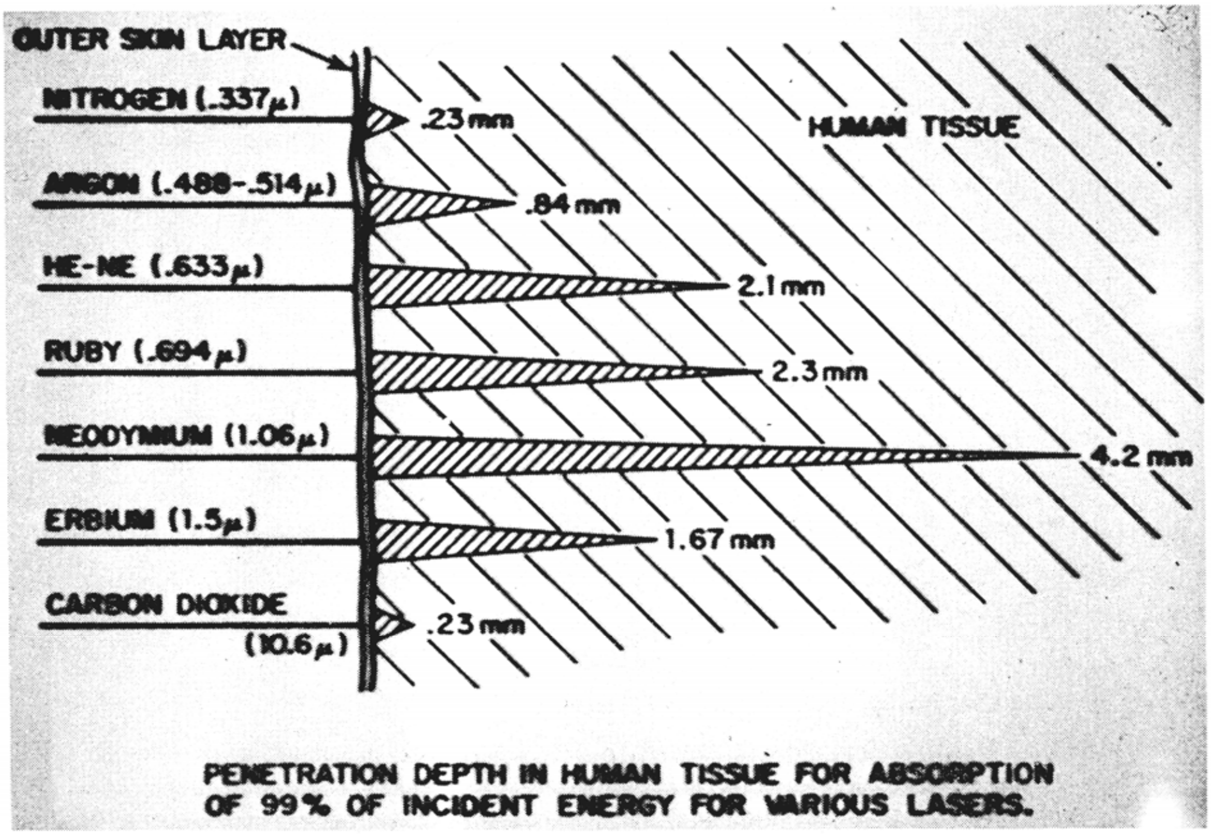



**Figure 7.1** Comparative depth of penetration of laser energy in human tissue for various lasers. (Courtesy of R. James Rockwell.)

# Laser Surgery

- Laser beam cuts and removes tissue
- Beam precisely positioned and automated
- Can reach inaccessible areas
  using beam directors ($CO_2$)
  & fiber optics (Nd:Yag)
- Limited damage to adjacent tissues
- Cauterizes nearby blood vessels
  reduces bleeding

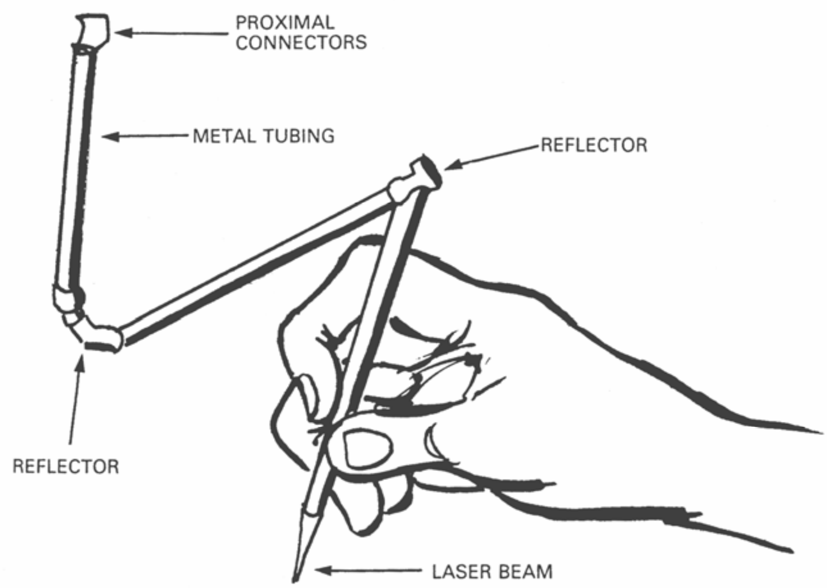



**Figure 10-11** An experimental $CO_2$ articulated waveguide currently in use. (After Bell Laboratories.)

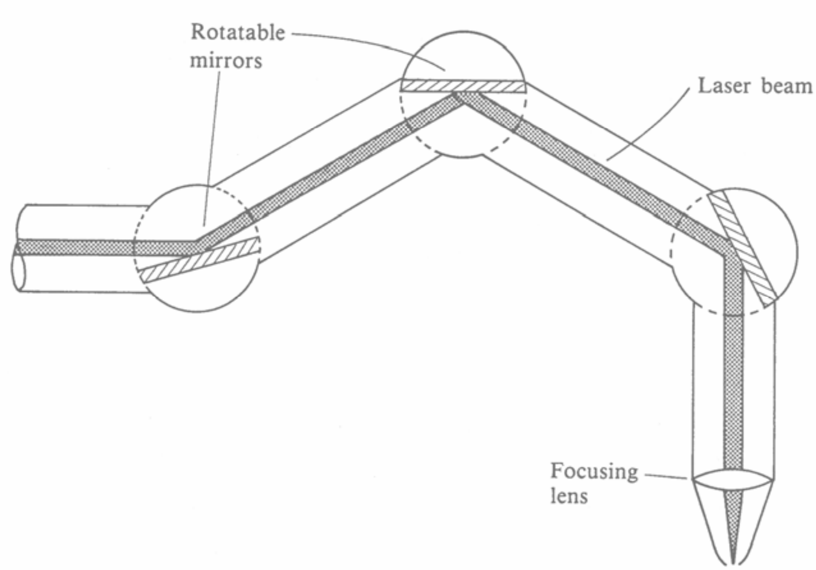



**Fig. 5.21** Schematic diagram of articulated arm beam delivery system for use with $CO_2$ lasers in surgery.

# Laser Operations using Fiber Optics

- Fiber optic cables contain light guides
- Very small, thus easy to insert into body
  removes need for major surgery in some cases
- Same fiber bundle can also transmit image of scene
- Eg Coronary Bypass & Stroke Prevention
  problem is build up of plague Artery
  reduces Artery size, causes stroke
- Fiber inserted into artery
- Plague absorbs Argon laser light
  removed from walls
  Plague has different absorption from Artery Walls

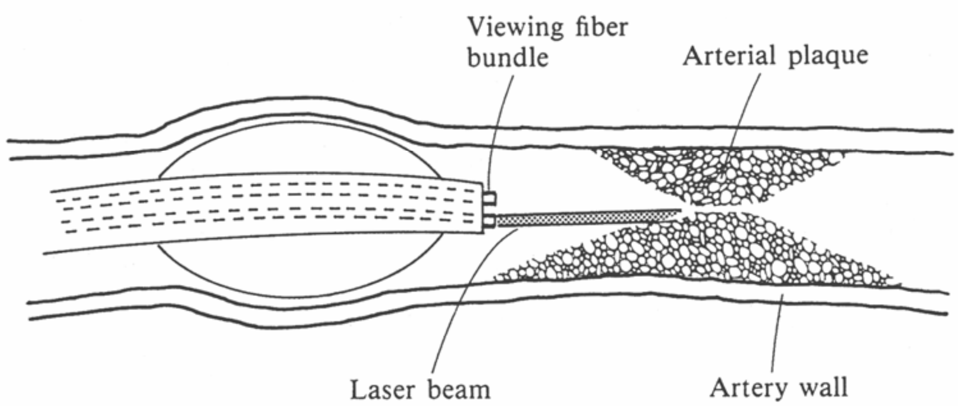



**Fig. 5.22** Removal of arterial plaque using laser radiation carried down an optical fiber inserted into the artery. A viewing fiber bundle is also incorporated.

**Laser Operations using Fiber Optics**

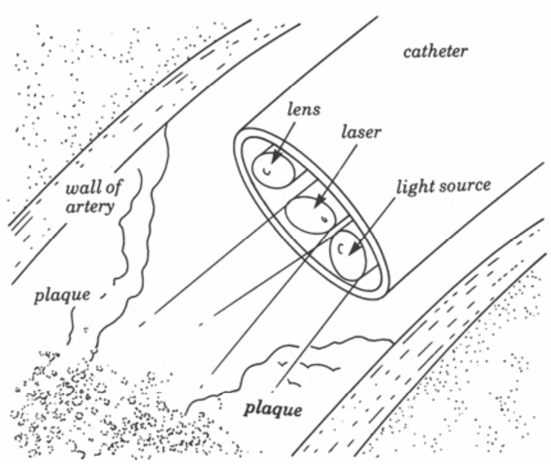



**Figure 7.3** Illustrative sketch showing method of vaporizing plaque inside plugged artery using optical fiber to transmit controlled laser energy within catheter.