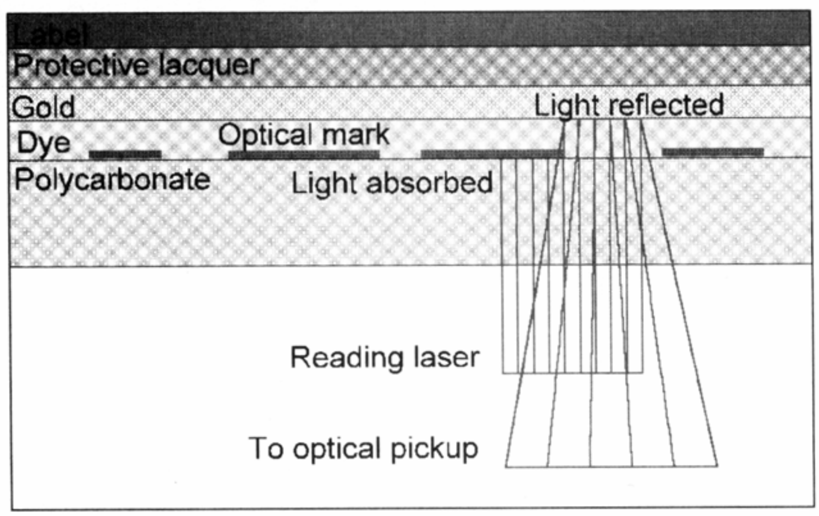
CD-R Organic Dye Disks

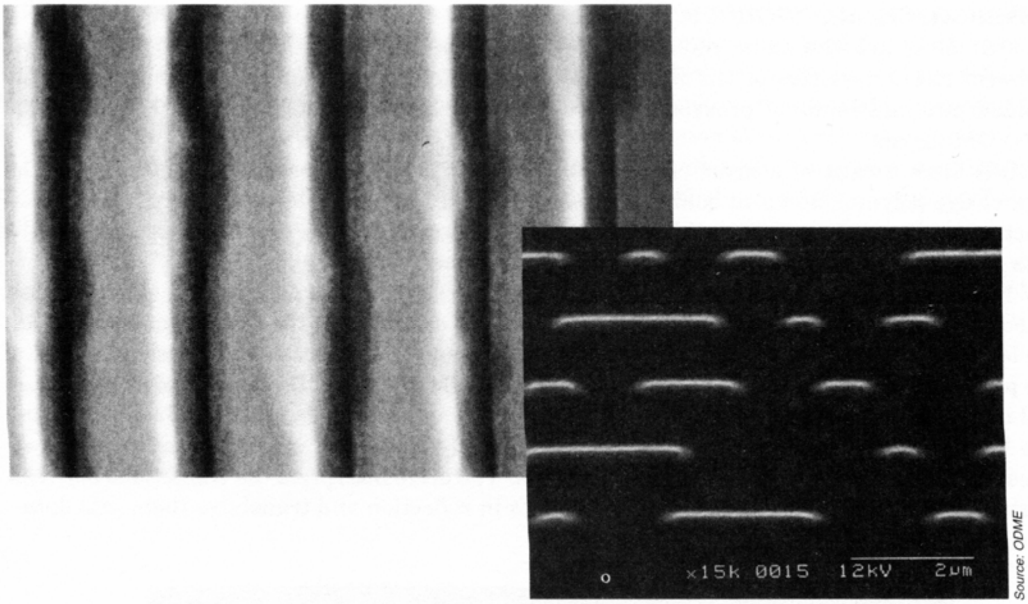
- CD-R (12 cm) uses organic die molecules
- Gold, silver or aluminum coating provides reflection
- Dye layer blue, green (better), gold (best) in unwritten state
- Laser writer 4-11 mW 790 nm (CD-R), 630-650 nm (DVD)
- Laser heats dye to 250 C (when 11 mW)
- Depending on dye either destroys dye or may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



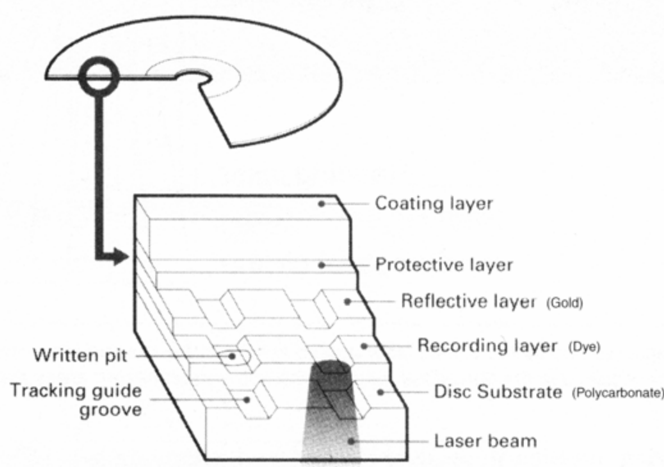
The optical marks created by the writing laser absorb light from the reading laser, while unmarked areas reflect the light back. Again, it is the transitions between marked and unmarked areas that represent binary ones.

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.

CD/DVD RW Phase change

- CD/DVD RW's use a phase change operation
- Uses silver, indium, antinomy, tellurium alloy
- Alloy is a eutectic (lower melting point than metals themselves)
- Using 8-14 mW lasers
- Alloy layer starts out crystallize: reflecting
- Write with 14 mW: heat to 600-700 C: melts & rapidly cool
- Amorphous state lower reflectivity
- To erase use 8 mW: heats ~200 C (below melting point)
- Now re-crystallizes & becomes highly reflecting
- Because phase change can be done large number of times

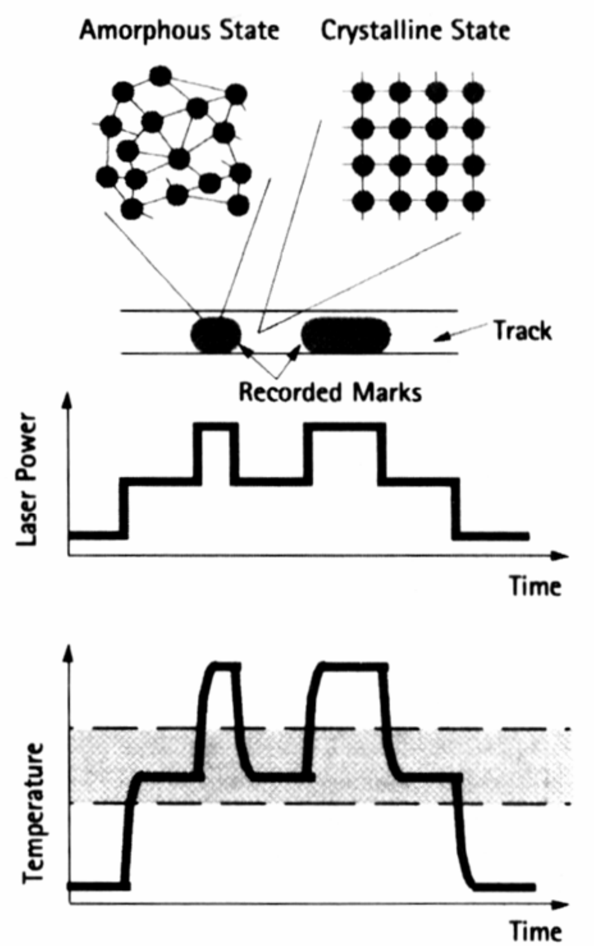
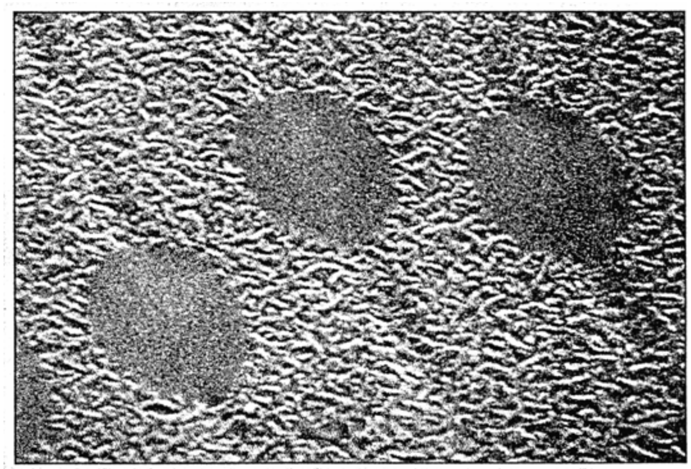


Figure 2-2



Putting Erasable Data into Crystals

Under an electron microscope, the blank crystalline areas of a disk of selenium and tellurium compounds are brightly reflective. But in those areas where a short, intense laser pulse has melted the disk, the orderly pattern of molecules in a crystal is disrupted, creating a so-called amorphous phase, in which molecules are randomly oriented and less reflective—dark ovals representing data *(right)*. But these spots can also be returned to their bright crystalline state by reheating them and cooling them more gently—for instance, with an oval laser beam that is hot at its leading edge and cool at its trailing edge. Such disks are cheaper and generate a stronger signal than do magneto-optic disks. However, early versions have lacked the ability to undergo as many write-erase cycles as magneto-optic disks, a limit to their usefulness.

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)

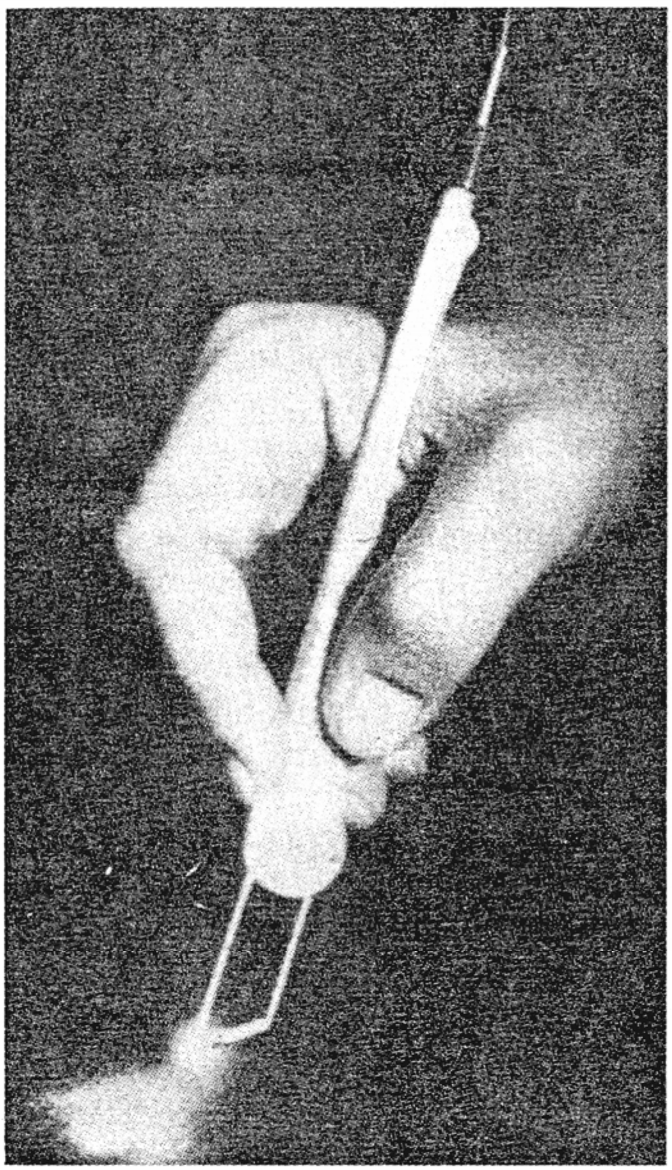


Figure 10-13 A laser scalpel with sapphire blade for excision of devitalized wounds. (Courtesy David C. Auth)

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

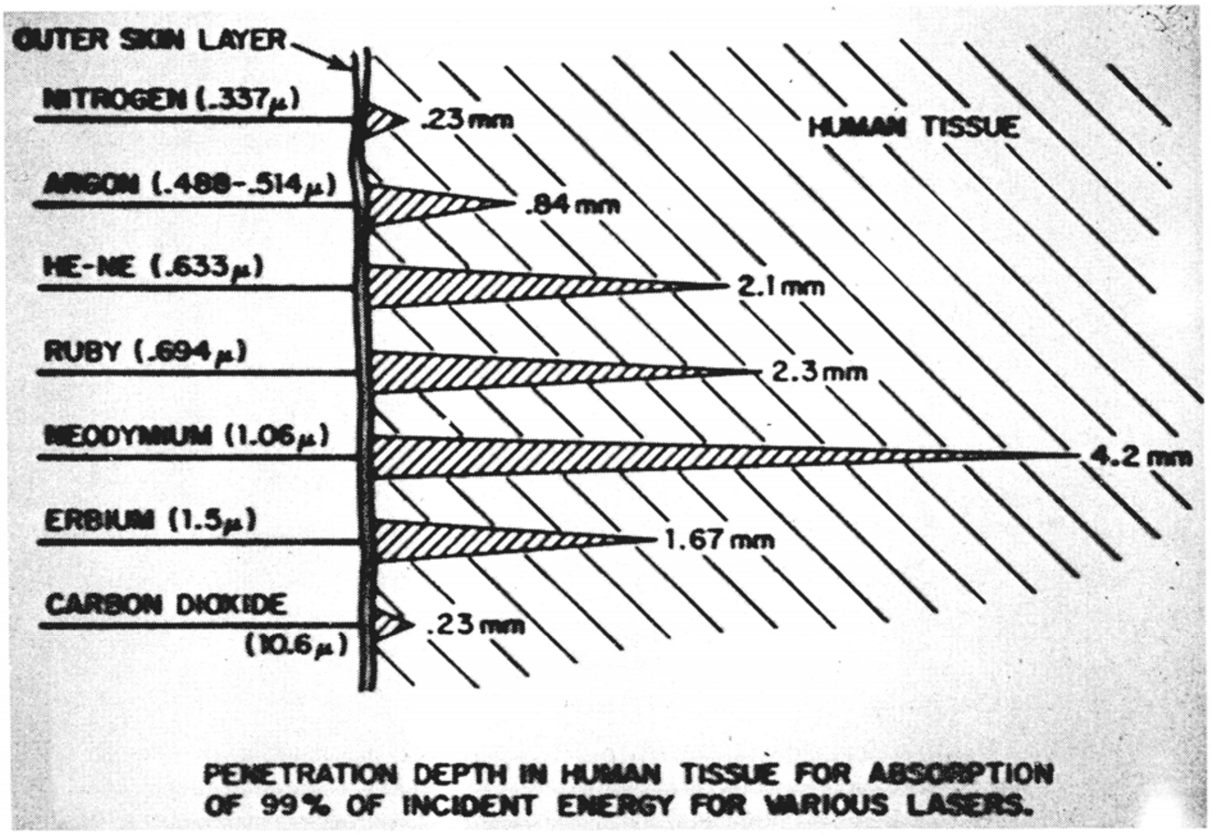


Figure 7.1 Comparative depth of penetration of laser energy in human tissue for various lasers. (Courtesy of R. James Rockwell.)

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

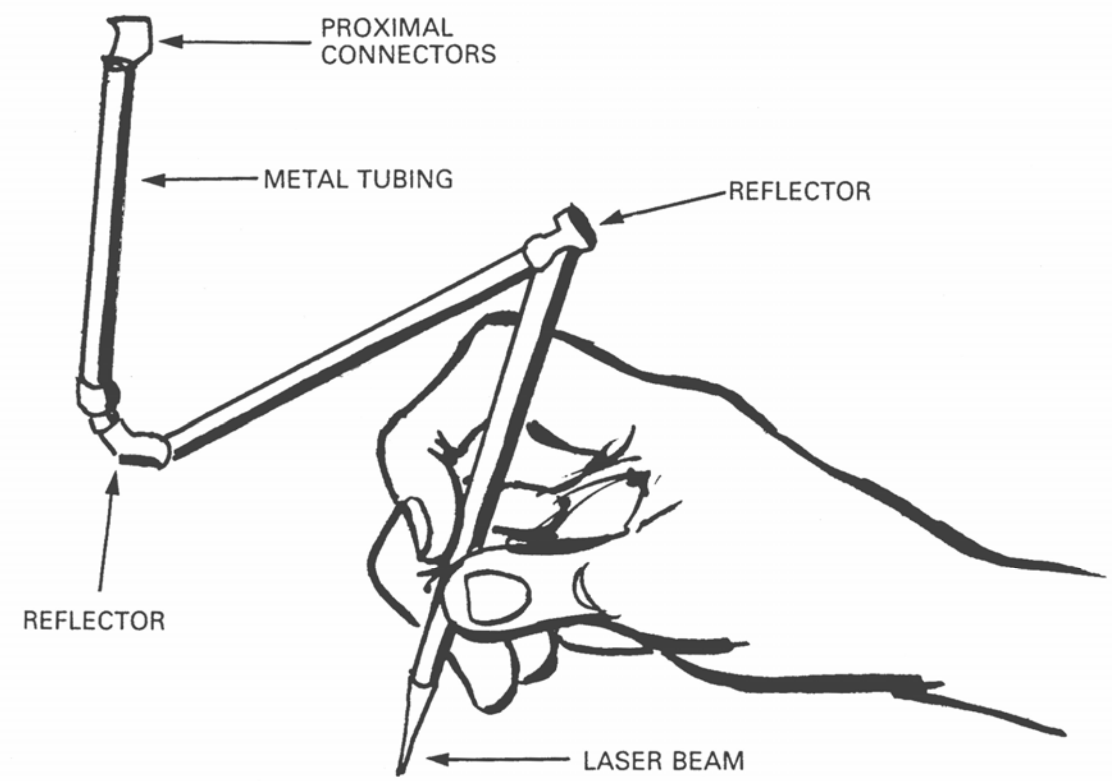


Figure 10-11 An experimental CO_2 articulated waveguide currently in use. (After Bell Laboratories.)

CO_2 Laser Surgery Head

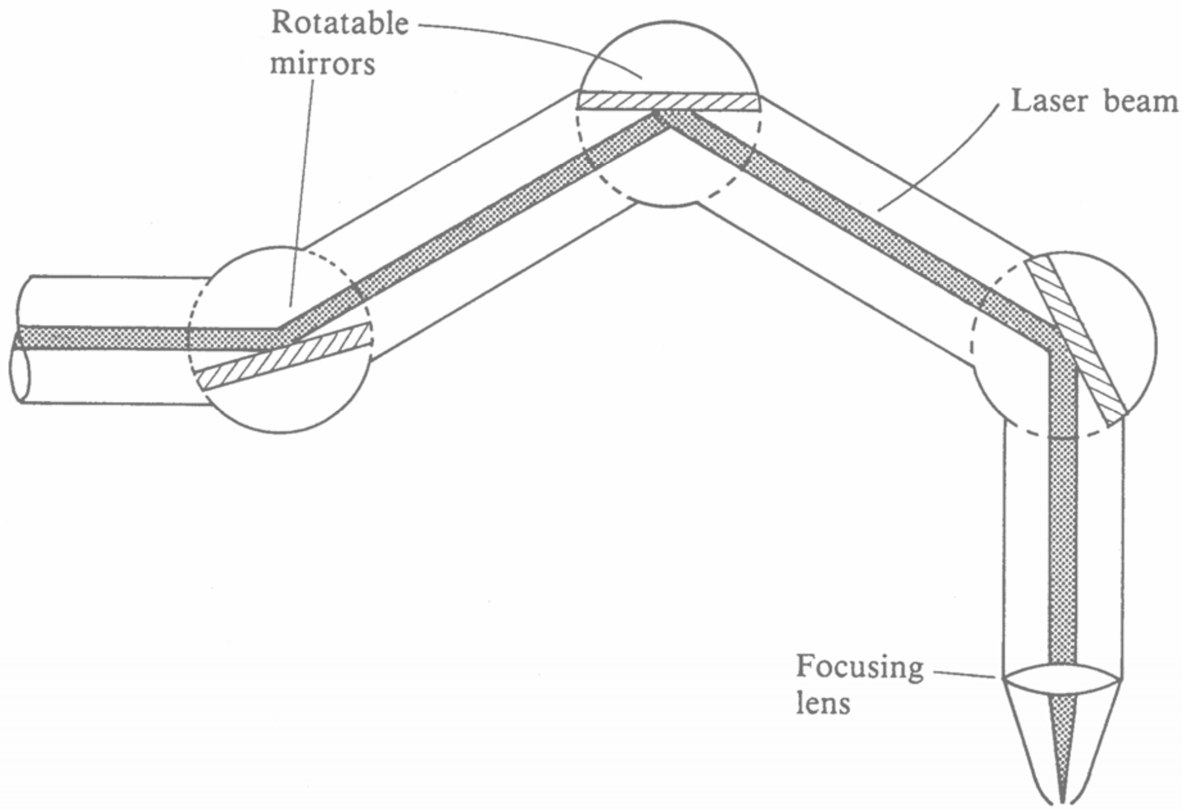


Fig. 5.21 Schematic diagram of articulated arm beam delivery system for use with CO_2 lasers in surgery.

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
  hence see the operation
- 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

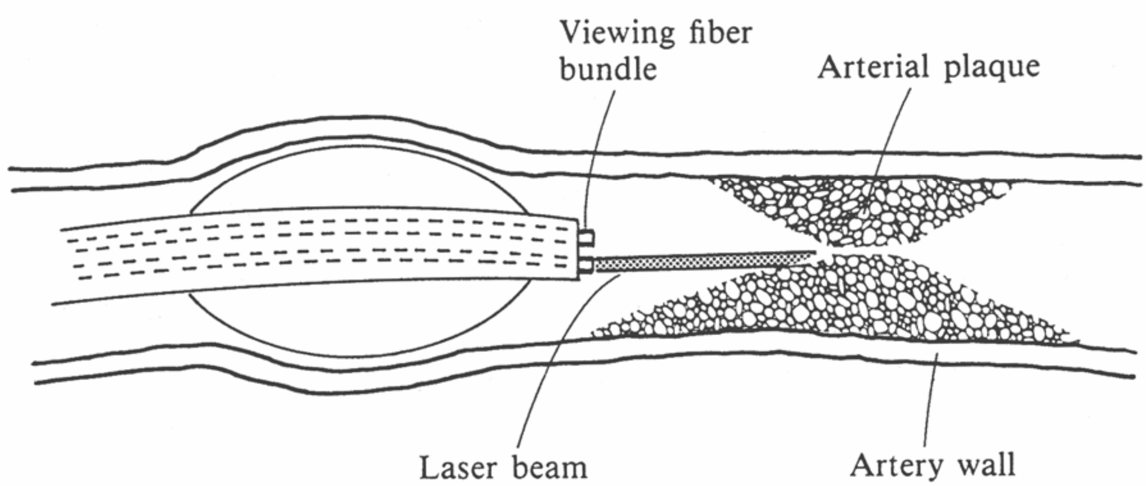


Fig. 5.22 Removal of arterial plaque using laser radiation carried down an optical fiber inserted into the artery. A viewing fiber bundle is also incorporated.

Laser Operations using Fiber Optics

Laser Operations using Fiber Optics

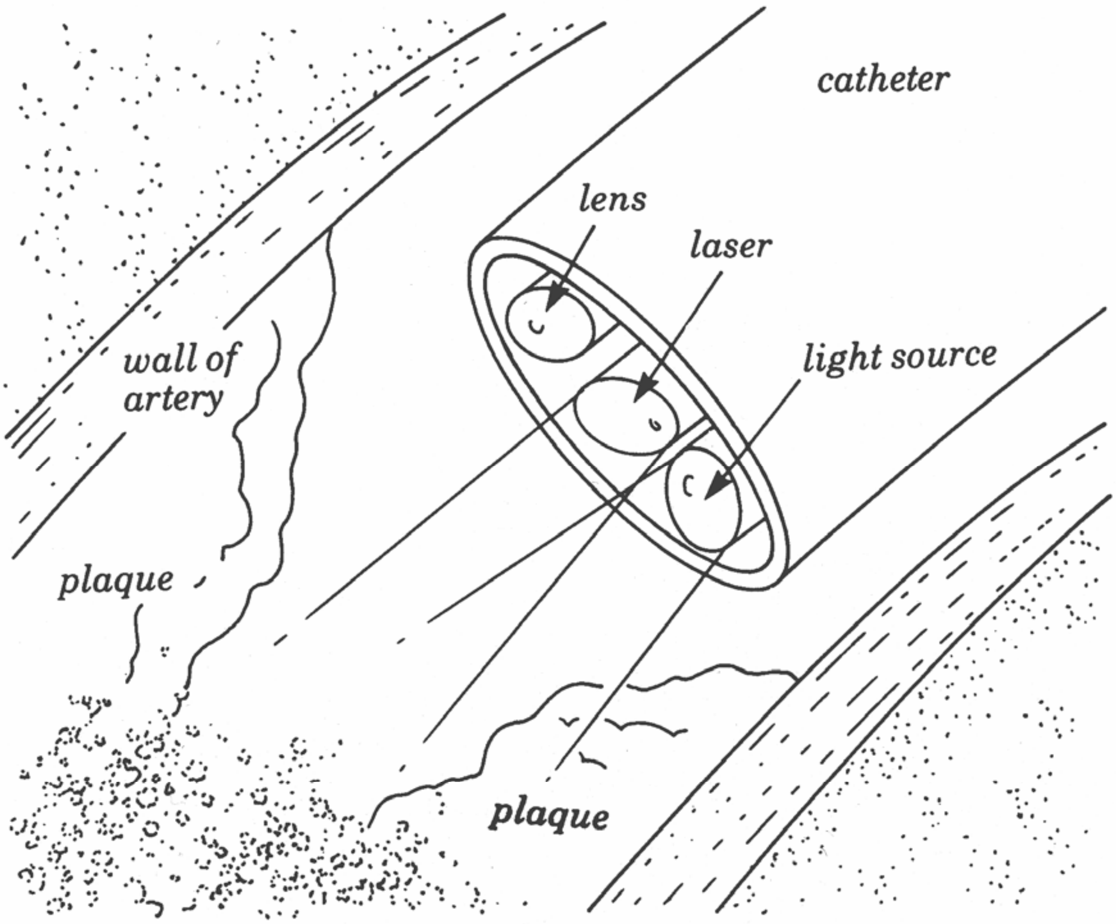


Figure 7.3 Illustrative sketch showing method of vaporizing plaque inside plugged artery using optical fiber to transmit controlled laser energy within catheter.

Other Laser Surgery

Laser Tonsillectomy

- Use CO_2 with mirror bouncing system
- Operation takes 15 minutes, no pain
- Cauterizes blood vessels & Lymphatic vessels
  no blood in throat
- Patient eat & drink just after operation
  unlike regular surgery

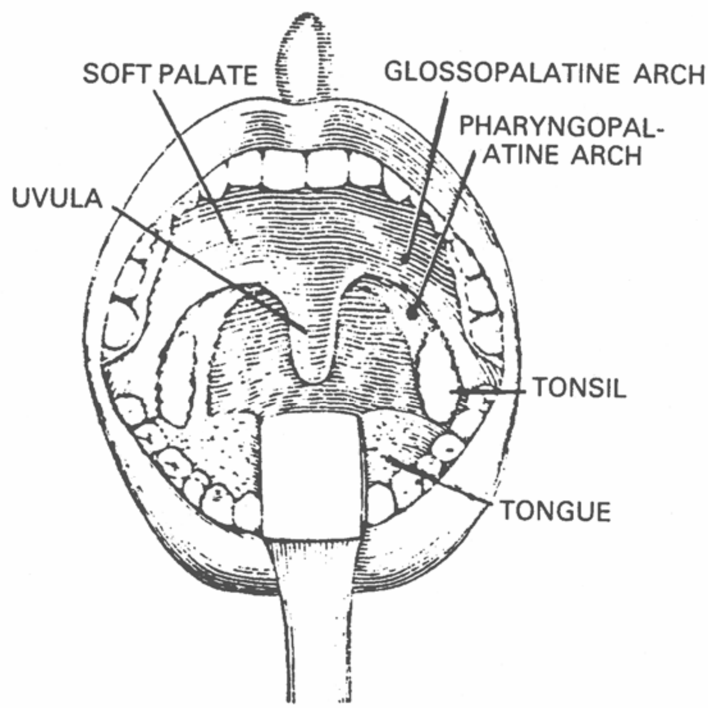


Figure 10-5 Front view of the tonsils, with open mouth.

Gastrointesinal Surgery

- Uses fiber to bring in Argon Beam
  Same system my combine CO_2 gas to remove blood
- Cauterizes blood vessels
- Beam used to stop bleeding internally
- Esophagus, Stomach & Intestines

Endoscopic (Fiber Optic) Laser

Fallopian Tube Surgery

- Blockages in Fallopian tubes
  common cause of infertility in Women
- Use Endoscopic Laser
  fiber optic direction of CO_2 beam
- Burns away blockages, in 1-2 pulses

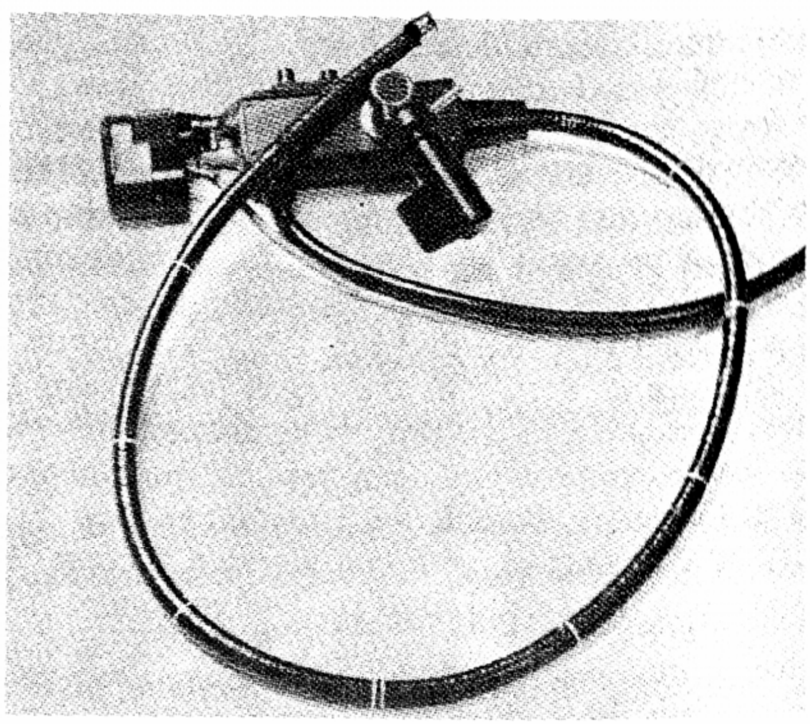


Figure 10-7 Endoscopic laser coagulator Model 770 used for the treatment of internal bleeding (Courtesy of Spectra-Physics, Inc.).

Laser Welding of Nerves

- Leaser "Welds" Nerve bundles (actually scars)
- Makes very smooth connection
- Should allow better nerve connections

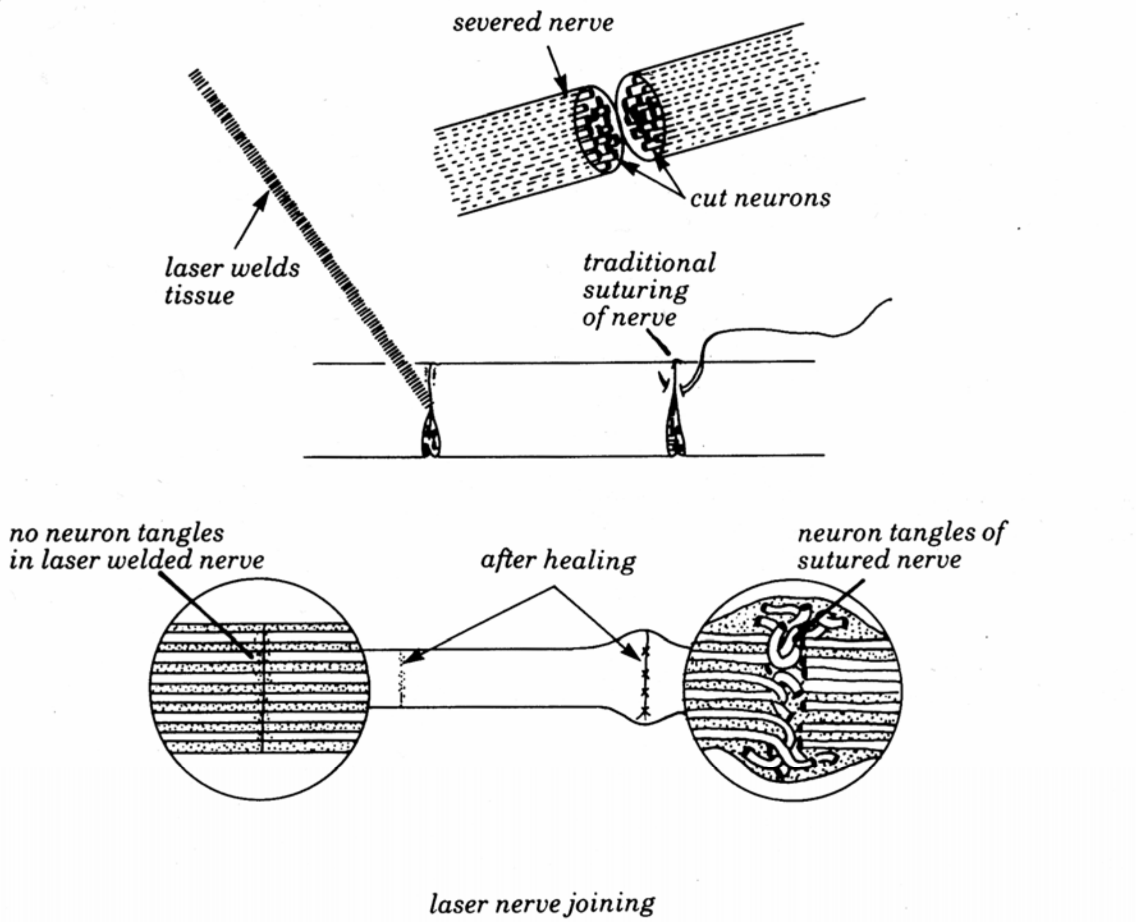


Figure 7.2 Illustrative sketch showing dramatic difference in "welding" nerve tissue with laser energy vs. traditional suturing method.

Laser Dermatology (Skin Operations)

- Use the ability of the Laser to penetrate the skin
- Most common Argon laser removing skin discolourations
- eg Portwine marks: blood coloured birth defects
- Argon laser bleaches out blood spots
  Almost removes such spots
- Laser tattoo removals:
  light penetrates skin, bleaches tattoo dye

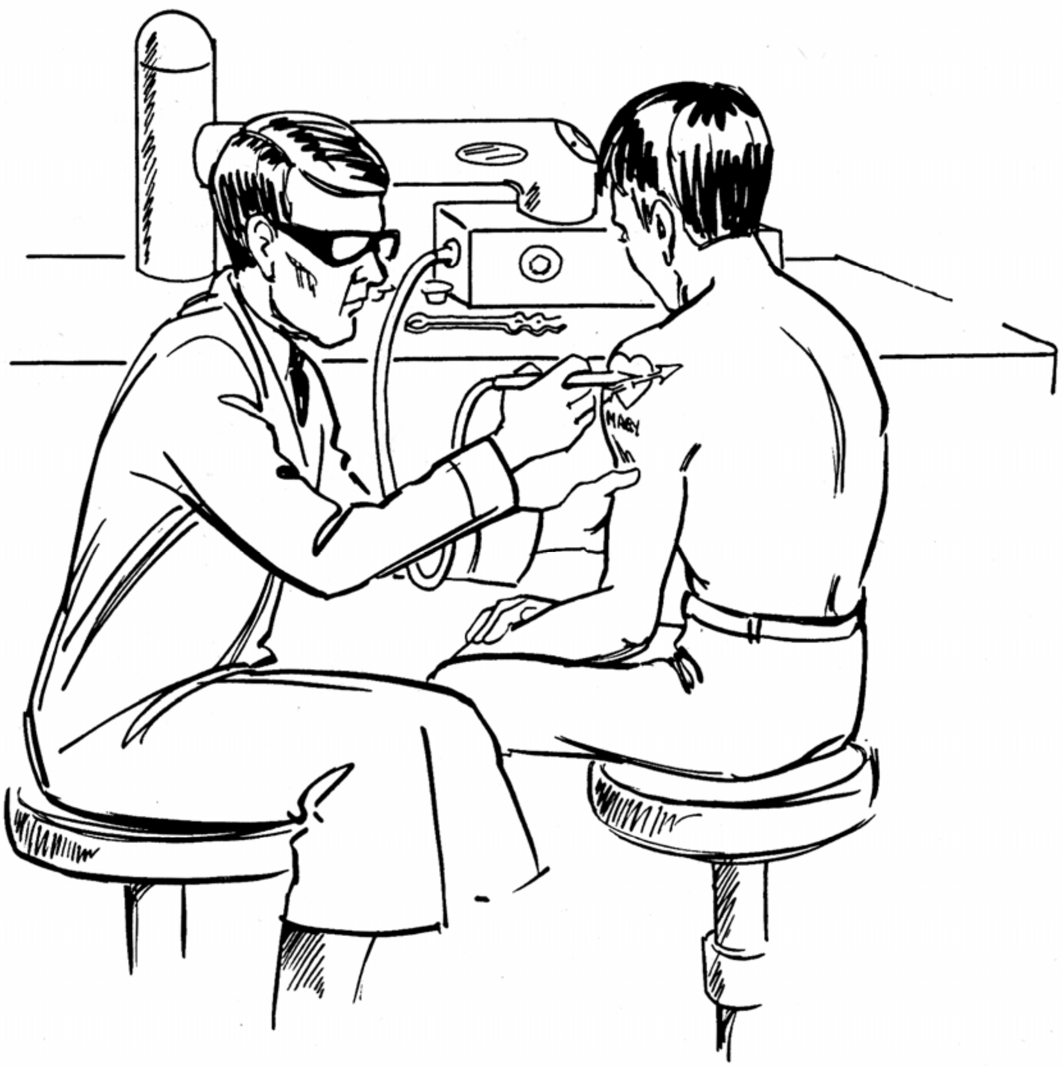


Figure 10-2 Simplified illustration of the removal of tattoos with a laser beam.

Photoradiation Therapy

Herpes

- Uses laser light to cause direct or indirect treatment
- eg Herpes virus creates lesions in skin and moist tissue
- Little in conventional treatment
- CO_2 used to destroy diseased cells & virus
- Beam directed on lesions using a microscope
  destroys tissue without bleeding

Cancer Photoradition

- Patient injected with dye (eg HpD)
- Dye absorbed preferentially by Cancer tissue
  normal tissue excretes dye
- Exposed to 630 nm HpD has photochemical reaction
  produces a poison directly only in cancer tissue
- 630 nm obtained from Argon pumped Dye laser

Laser Acupuncture

- He-Ne laser, penetrates 3-10 mm
- Laser irradiated for 60 sec at 2 mW
  controversial process

Ophthalmology (eye operations) & Dentistry

- Most common attaching detached retinas
- Uses Argon laser beam (Sometimes Ruby laser)
- Beam strongly absorbed by blood
- Creates a burn scar which reattaches retina
- Laser cornea shaping with Eximers (already discussed)
- Eximer also for Dentistry removal of diseased soft tissue

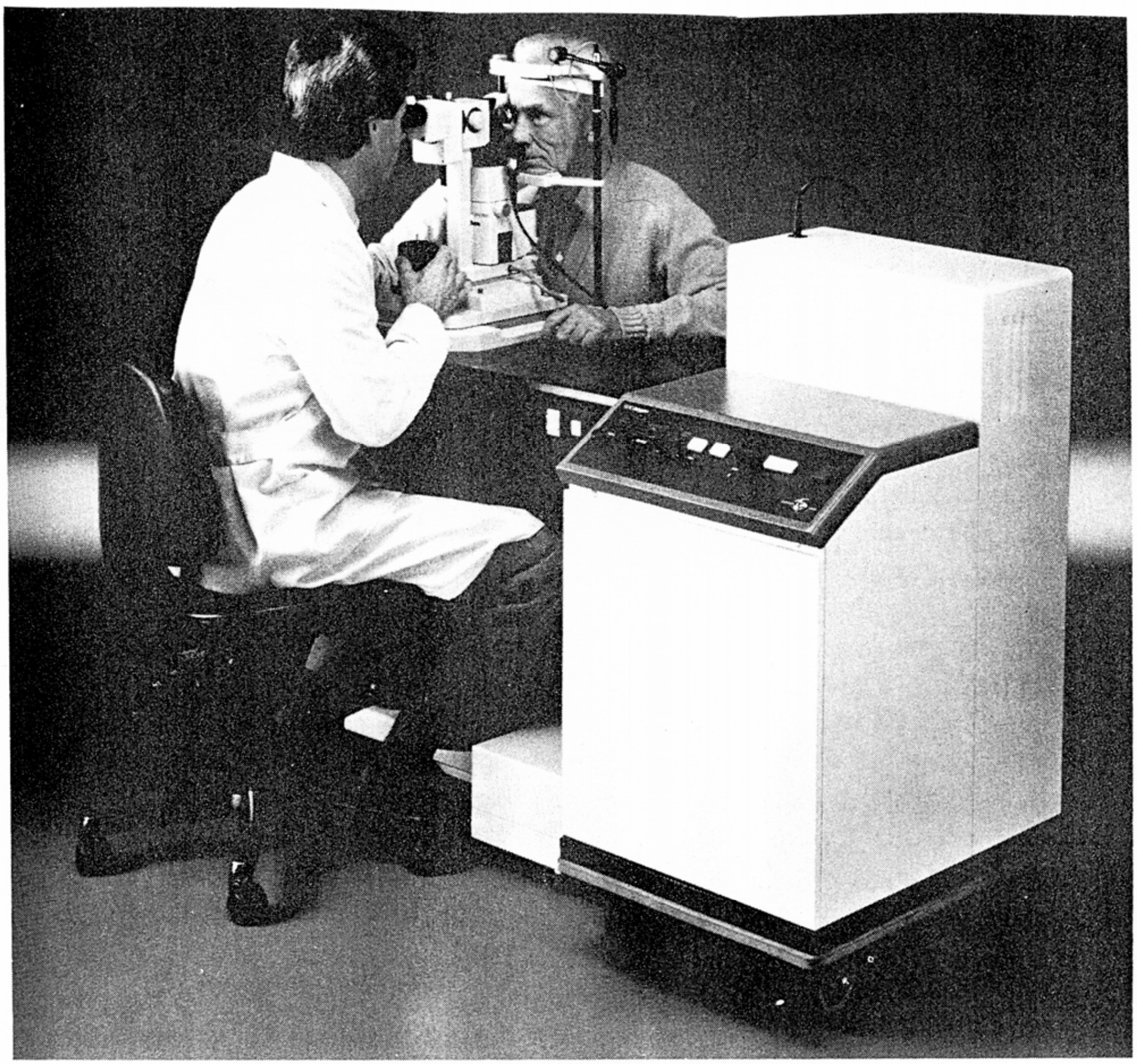


Figure 7.5 Clinical YAG (or argon) laser assembly used in ophthalmology.

Laser Confinement Fusion

- Use powerful laser to compress and heat hydrogen
- Hydrogen stored in very small pellets
- Outside of pellet boiled off by laser beam
  Terawatt power
- Ablation causes pellet to compress & heat
- reach temperature/pressure of sun
- Get Fusion reaction

$$H^3 + H^2 \rightarrow He^4 + n + 14MeV$$

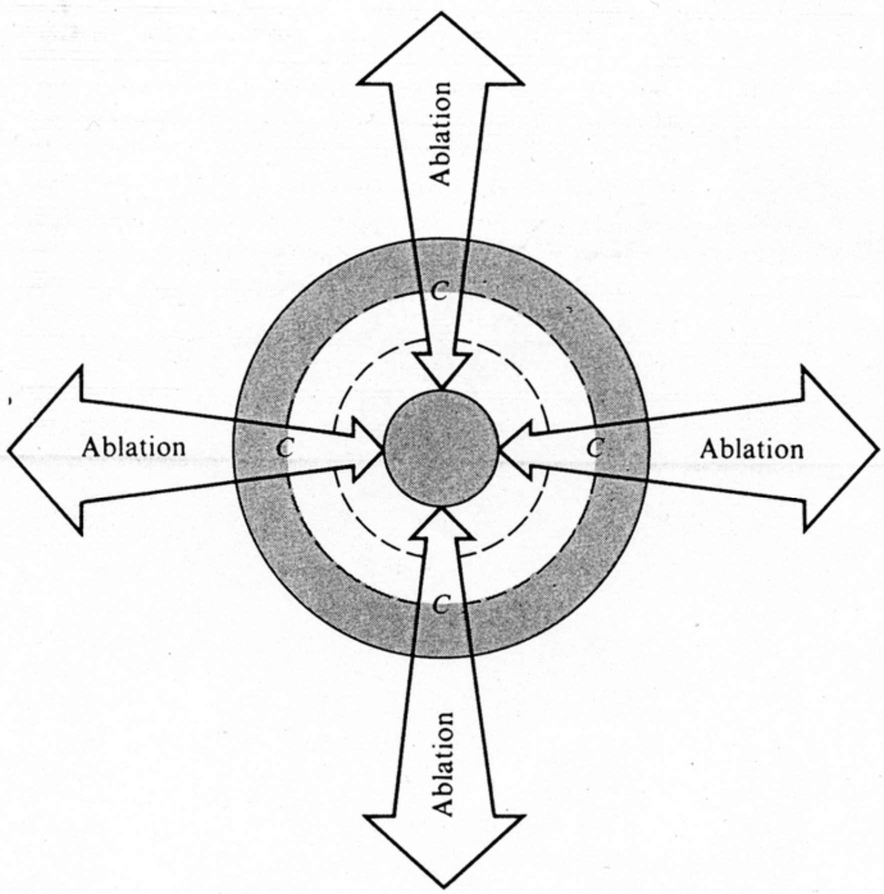


Fig. 9.10 Heating the deuterium-tritium ice pellet causes ablation of the outer surface. The reaction to this outward expansion of material is a compressional wave force (denoted as *C*) inward.

Argus Laser Fusion Facility

- Lawrence Livermore Labs: 2 Terawatt

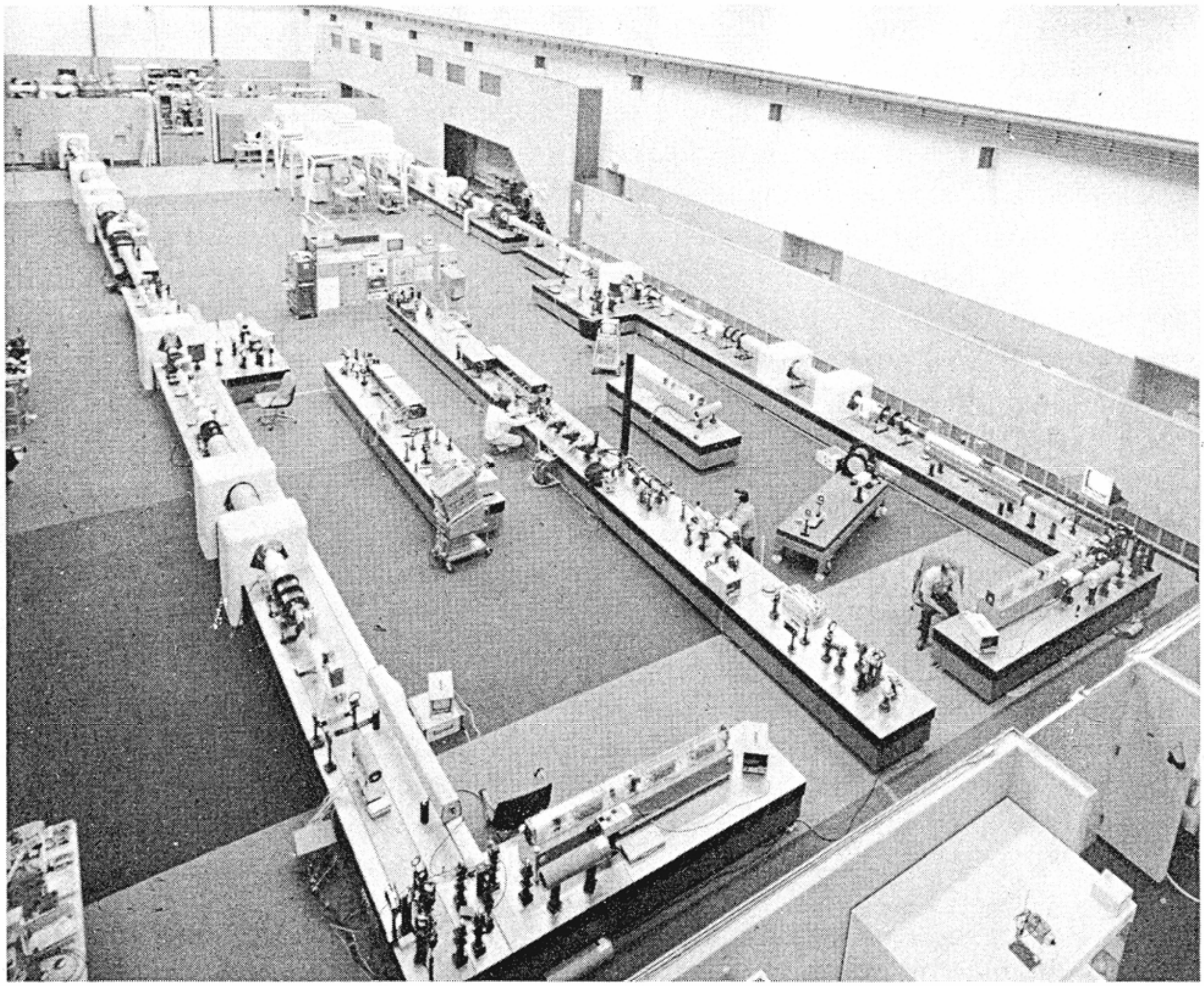


Fig. 9.11 Two-terawatt Argus laser system. A master oscillator (the L-shaped box on the center table) generates a 10-megawatt subnanosecond laser pulse. The pulse moves toward the lower right and is split in two. One pulse moves to the left; the other to the right. At the corners, they are reflected along parallel paths through a series of amplifiers toward the target chamber barely visible behind the wall at the upper left. (Courtesy of Lawrence Livermore Radiation Laboratory, University of California.)

Shiva Laser Fusion Facility

- 20 Arm Nd:Yag system
- Lawrence Livermore Labs: 2 Terawatt

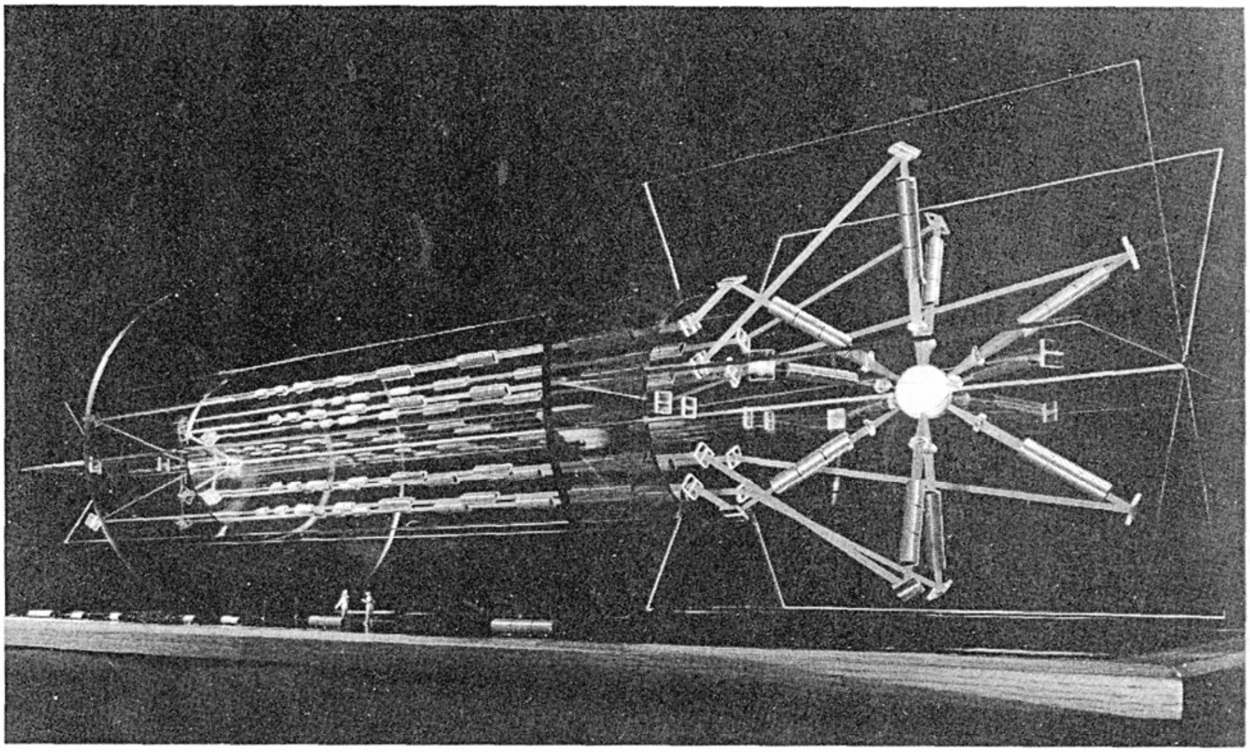


Fig. 9.12 Model of a 12-arm Shiva laser facility. The master oscillator is centrally located in the background of the figure. Each line corresponds to an Nd:glass amplifier chain. In the foreground is the combustion chamber with incoming beams arranged symmetrically about the center. The actual system contains 20 amplifier arms. (Courtesy of Lawrence Livermore Radiation Laboratory, University of California.)

Laser Fusion Reactor

- Pellets dropped into reactor
- Laser ignites small explosion
- Liquid Lithium shield adsorbs neutrons and energy
- Regular "steam" generator to get power

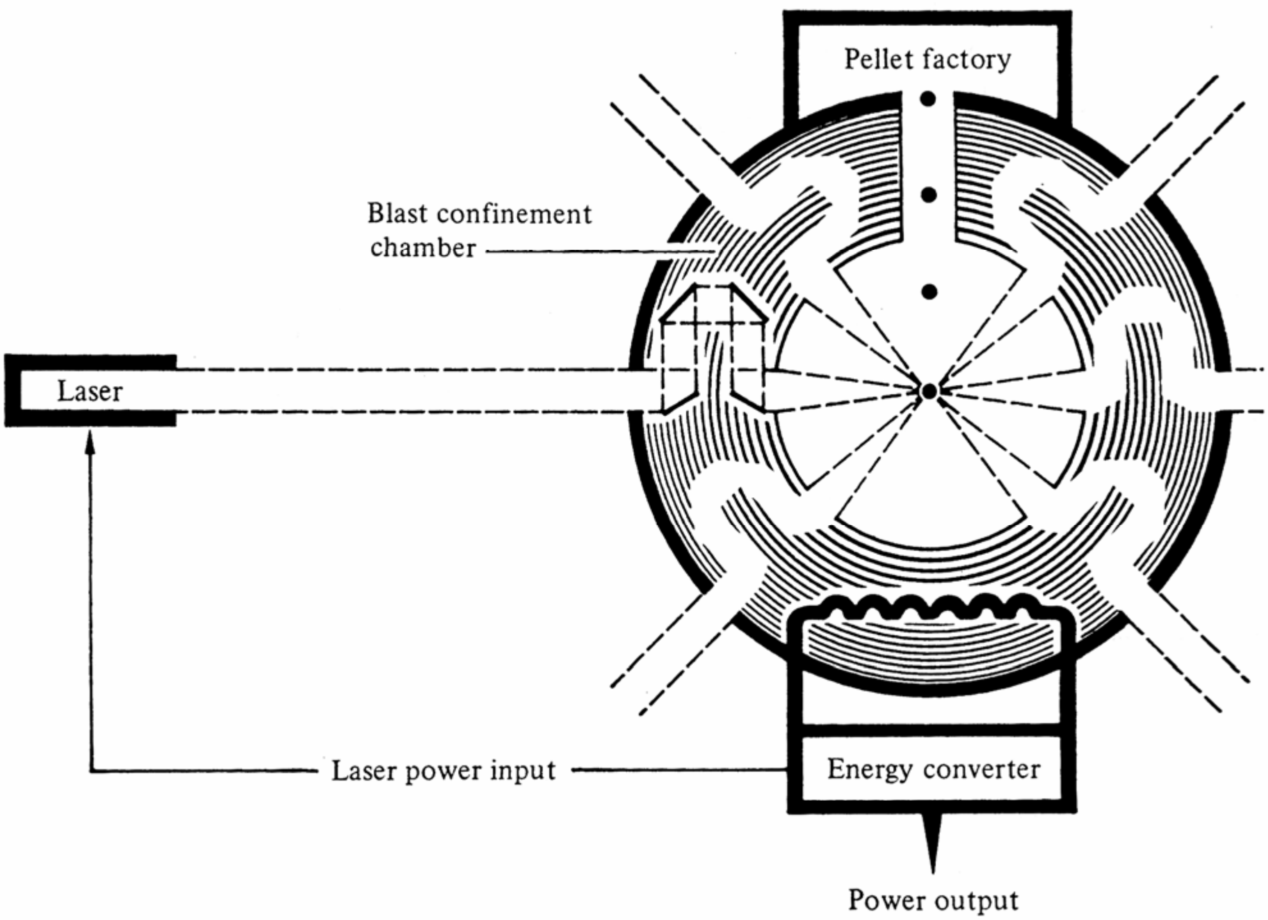
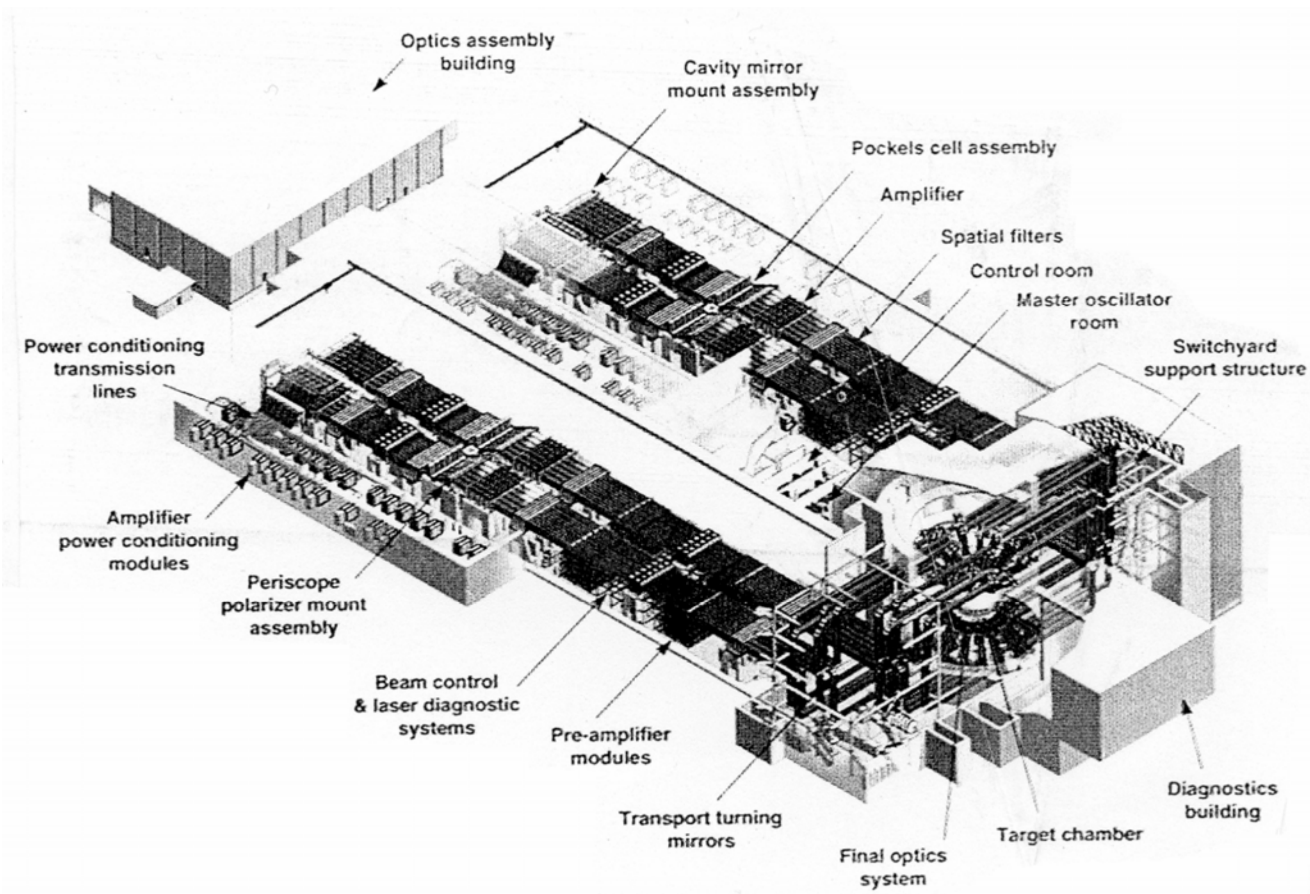


Fig. 9.13 Schematic drawing of a laser fusion power plant. The contorted beam path is designed to admit the laser beam, yet block x-ray and neutron emission from the reaction. (Courtesy of Lawrence Livermore Radiation Laboratory, University of California.)

National Ignition Facility

- National Ignition Facility (NIF) newest design
- 1.8 megaJoul, frequency tripled Nd:glass laser
- 10 ps pulse, 10^{19} W/cm^2
- 192 beam lines combined
- Test concepts with Peta Wat laser
- 1.25x10^{15}W, 0.55 ps pulse, 1021 W/cm^2
- Located at Lawrence Livermore Labs



Laser Flight

- Use orbital laser satellites to send down beams
  orbital solar power satellites
- Light focused and tracts aircraft
- Flight takes off normally - regular engines
- Works in upper atmosphere

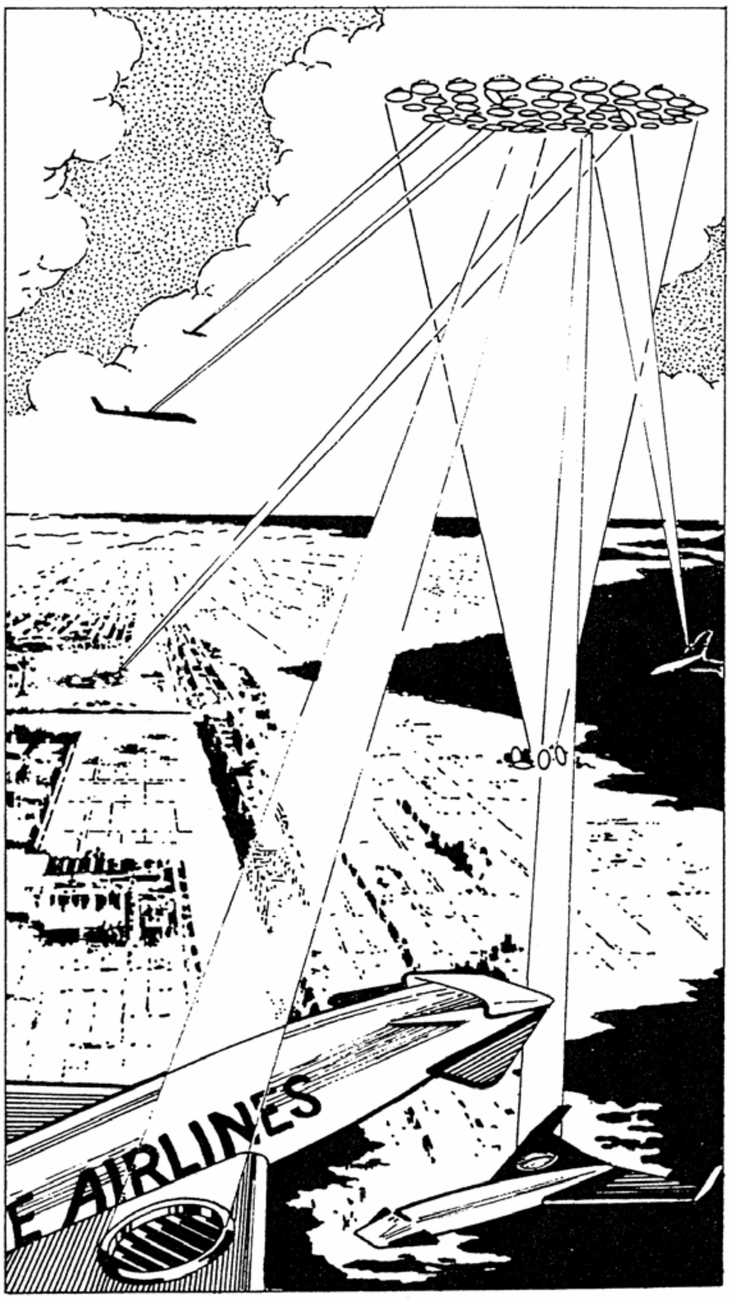


Figure 2–6. Concept for laser-powered aircraft (after Beckey & Mayer, Aerospace Corp., 1976); redrawn by artist R. Rue.

Laser Powered Turbofan

- Laser light focused into heat exchanger
- Acts as black body cavity
- heat exchanger heats air
- Air expands as in regular turbofan
- Engine runs without fuel and pollution

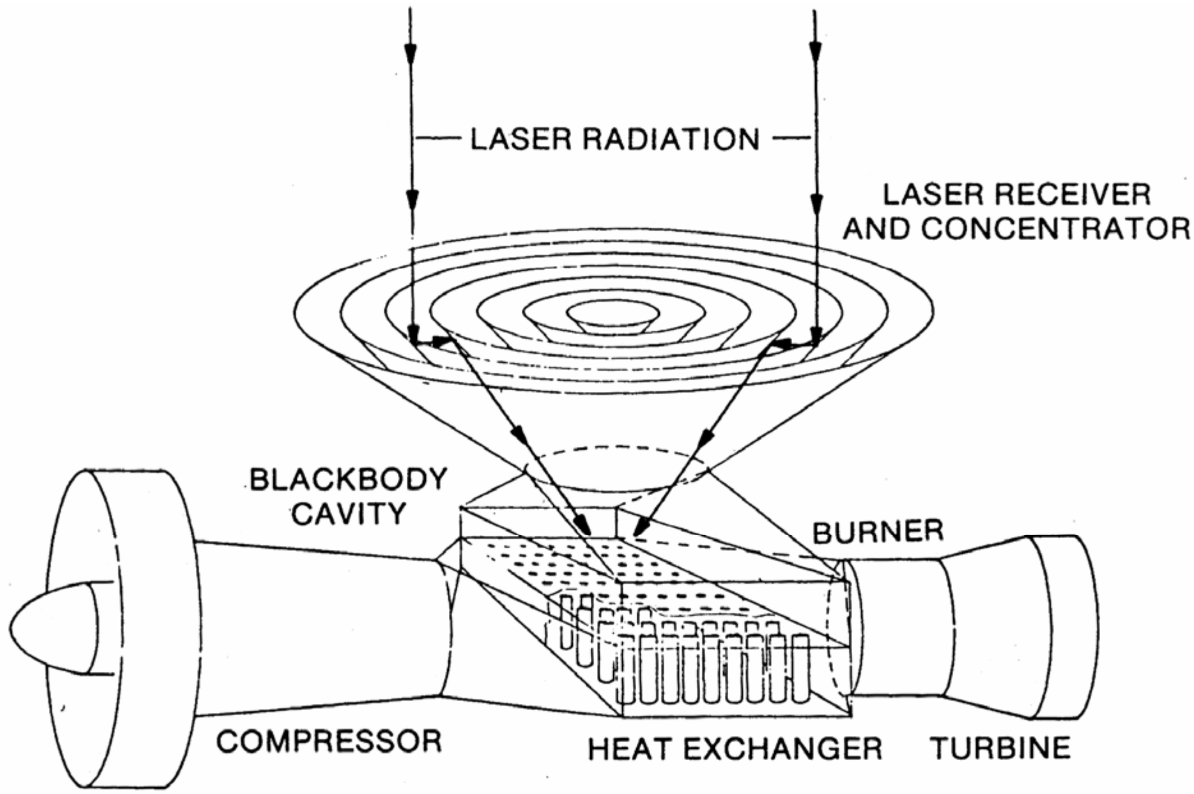


Figure 2–7. Laser-powered turbofan concept (Hertzberg and Sun, Univ. of Washington, 1978)

Laser Driven Rocket Engines

- Laser light focused into rocket chamber
- Absorbed by "fuel" eg ice/water
- Fuel boils off and expands in chamber
- Can be heated much higher than regular material
- Very simple construction

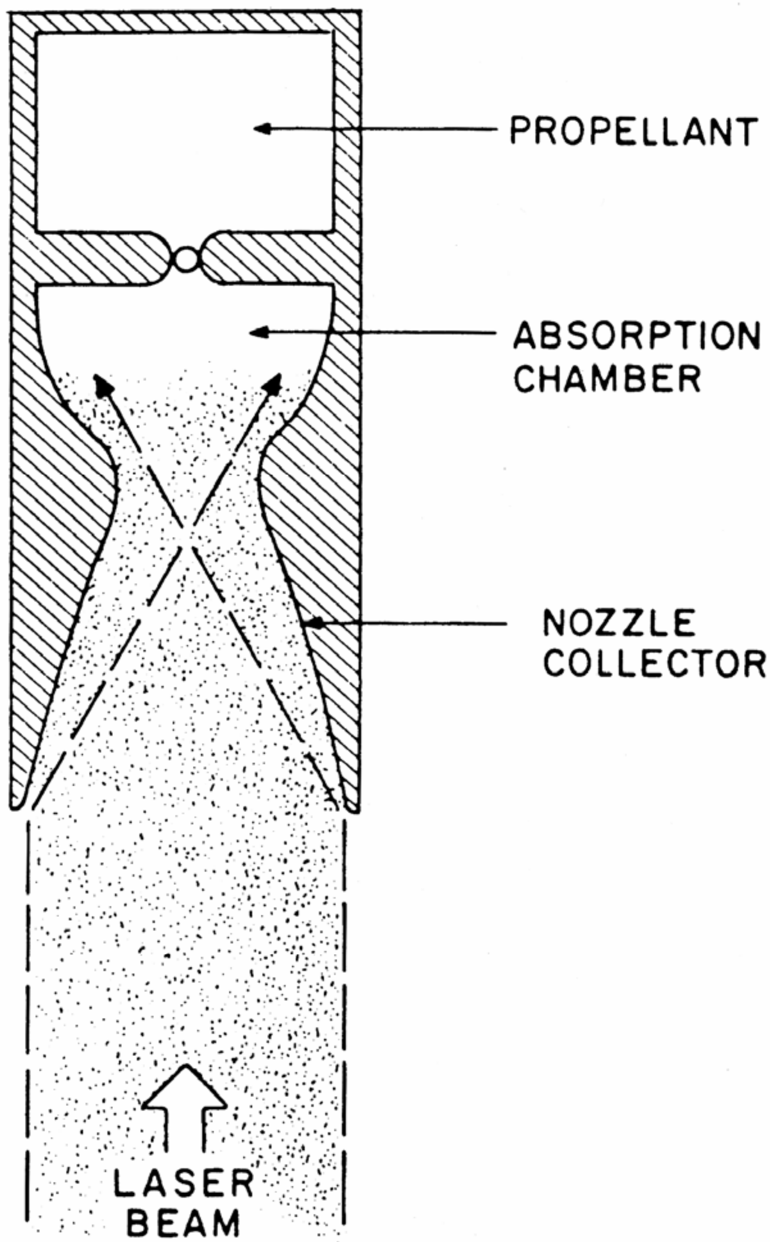
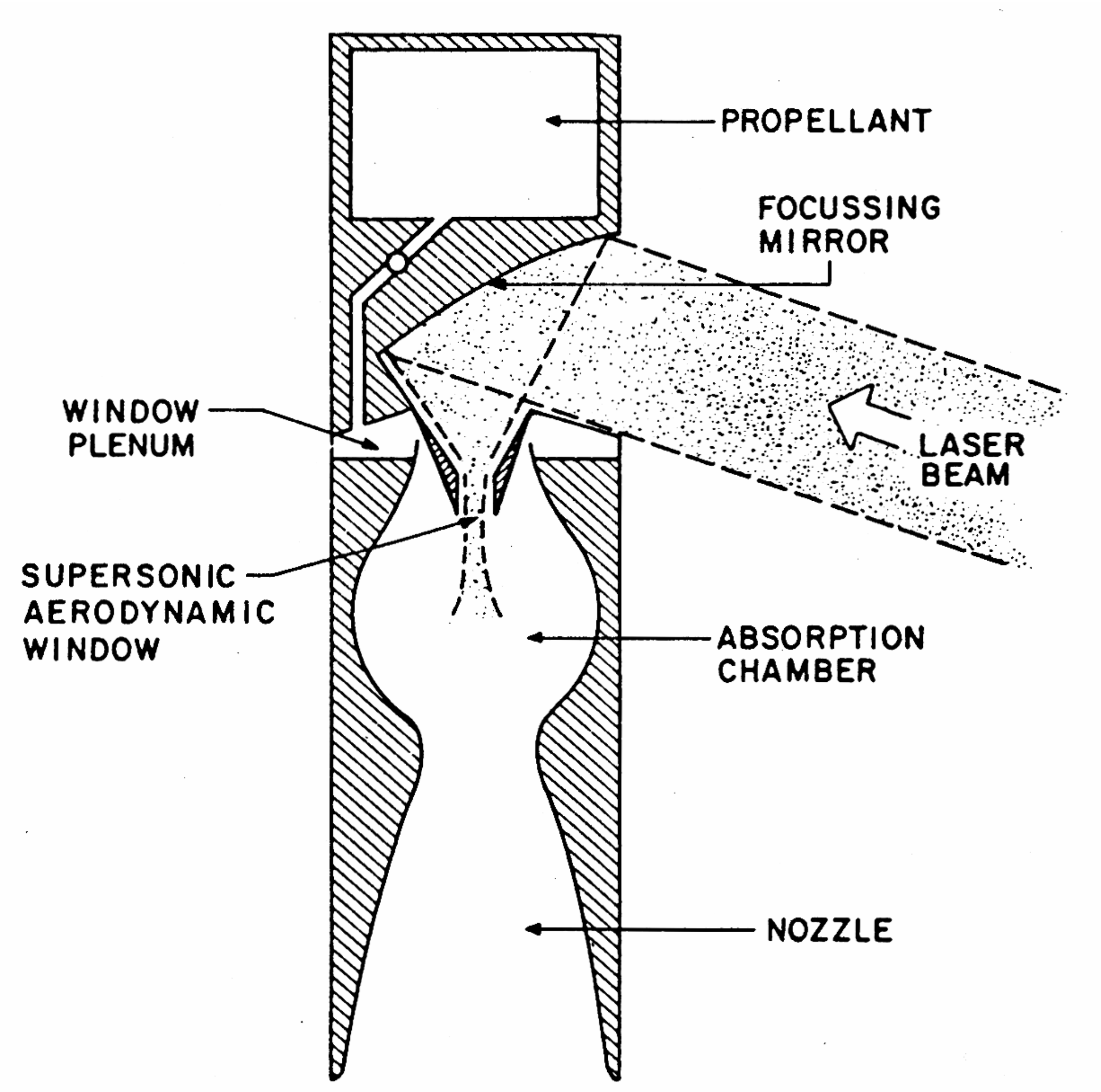


Figure 4–1. Single-port engine

Laser Rocket Engines

- Alterative design: light enters side window
- Less problem with blocking by exhaust
- Estimate that would have Specific Impulse of 1000-2000 sec
- Specific Impulse how long on pound of fuel
  produces 1 pound of thrust
- Shuttle engines I_{sp} 430 sec



Laser Detonation Flight

- If laser light focused to enough intensity
- air breaks down, get a detonation
- Creates a shock wave
- Very powerful use of laser light

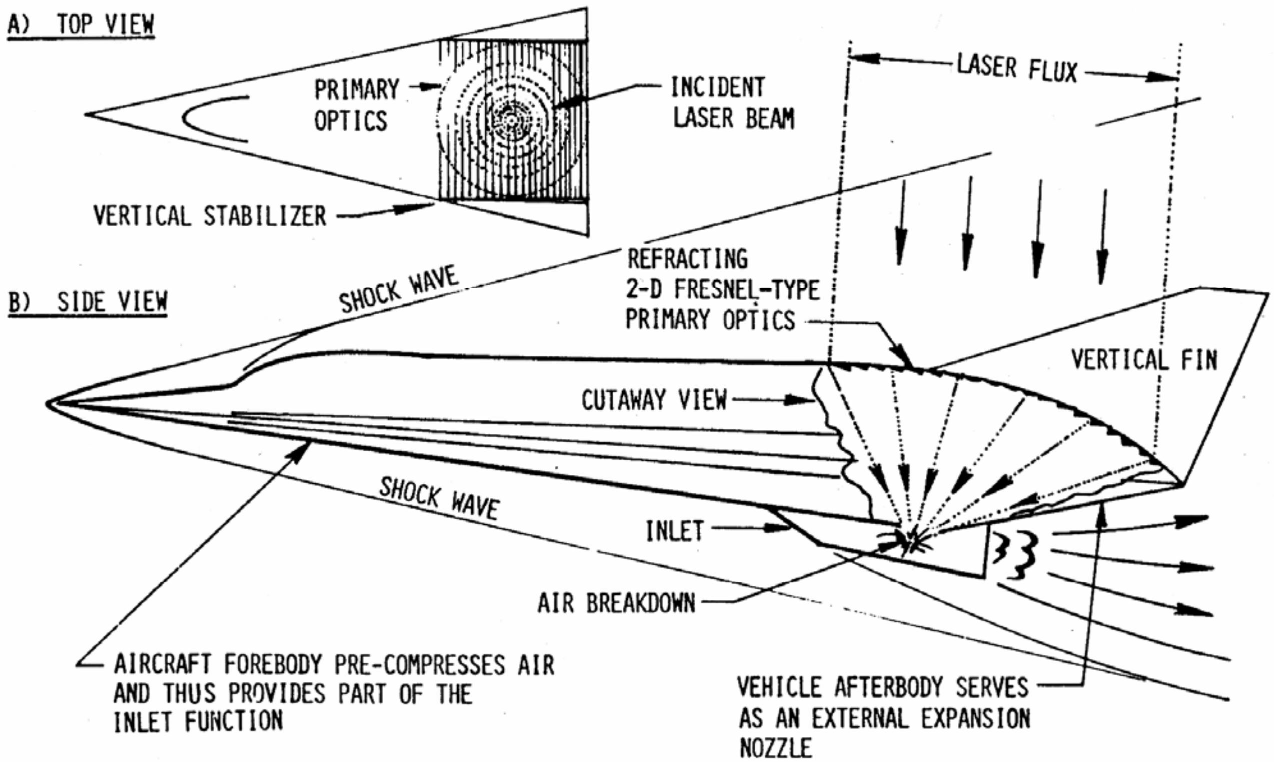


Figure 5–1. DELTA/IRH transport with transverse 2-D Fresnel lens (subsonic and VTOL capability)

Laser Detonation

- Also called External Radiation Heating (ERH)
- Aircraft shape forms engine
- LSD - Laser Shock wave Detonation moves along body

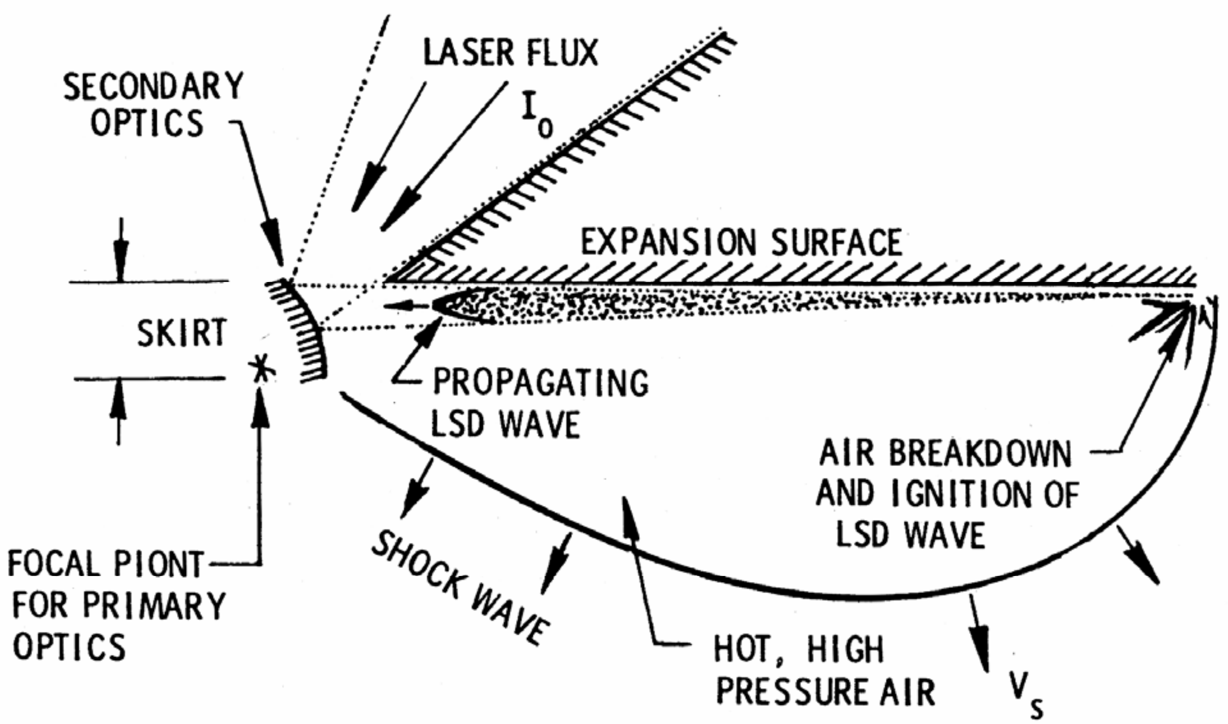


Figure 5–2. External radiation-heated (ERH) thruster concept

Laser Flying Saucer

- Can shape top surface as mirror to focus laser light
- Create Laser Detonation at bottom edges
- Lifts the body
- Change direction by tilting top
- Result a Flying Saucer

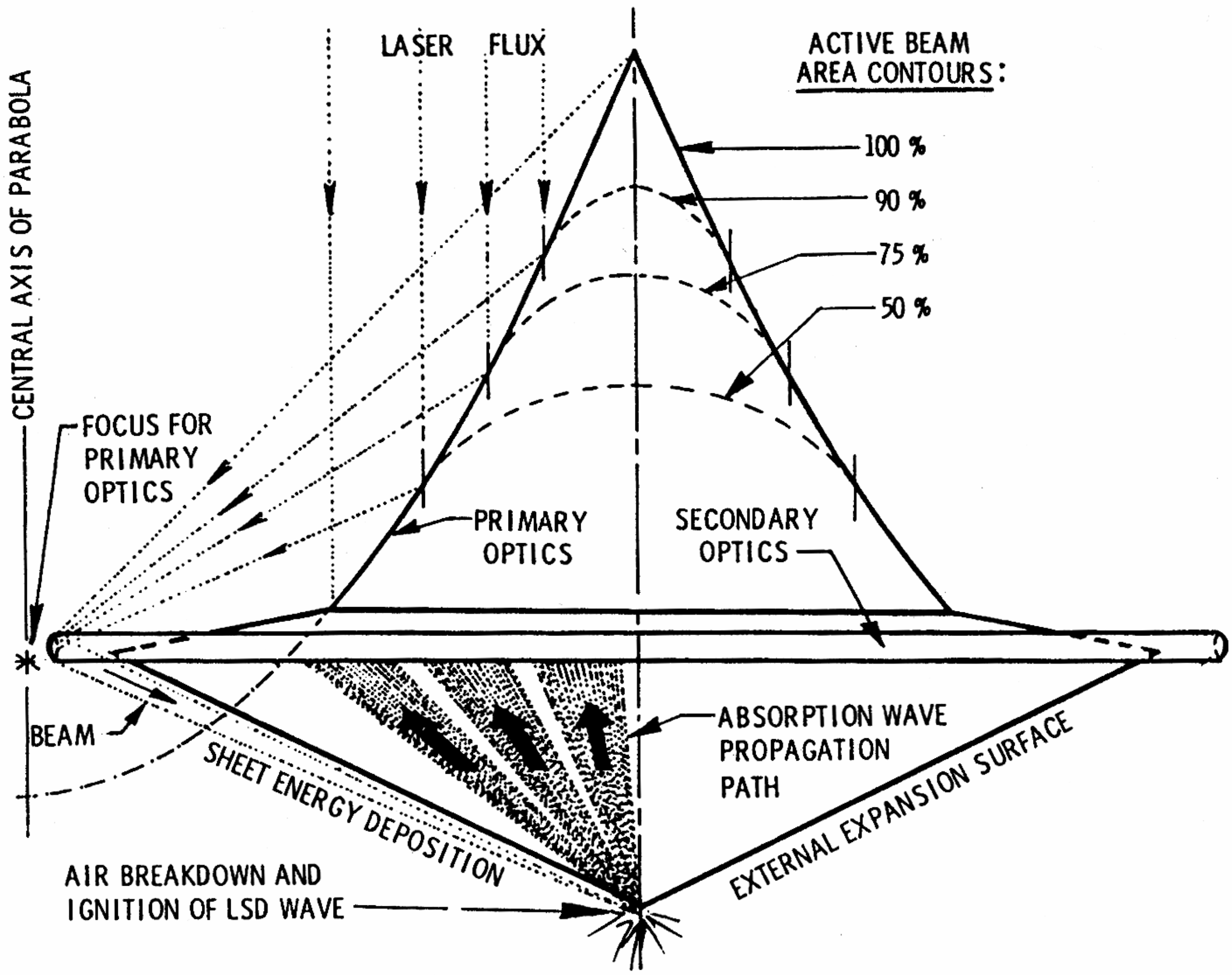


Figure 5–6. Small-wing radial IRH/ERH transport configuration in lateral translation flight (central focus)