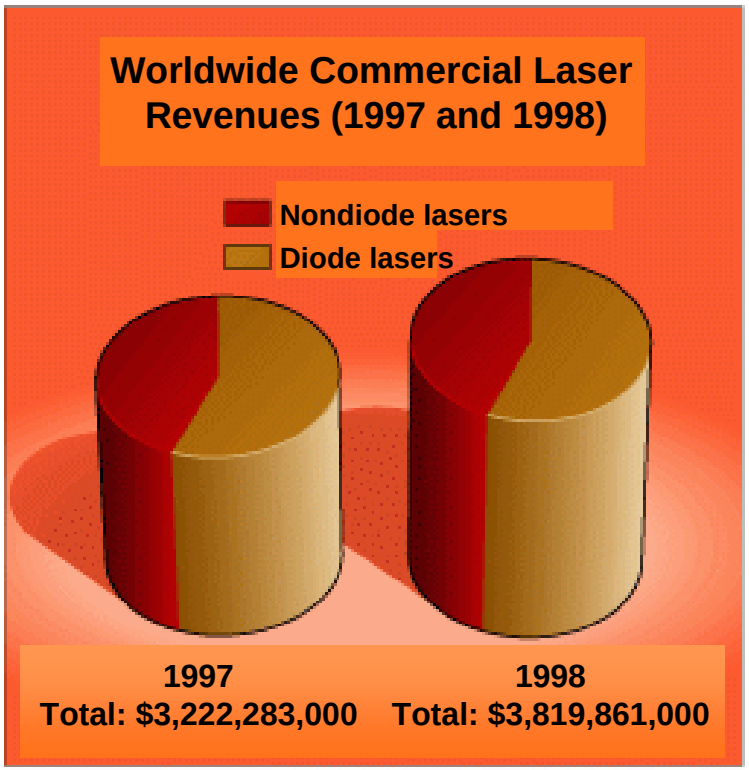
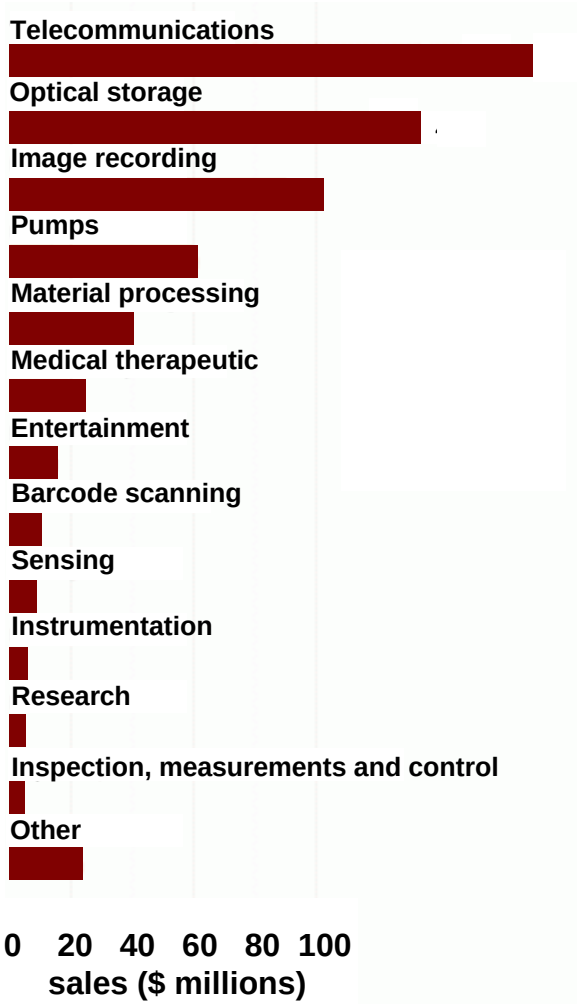
Review of Diode Laser Market

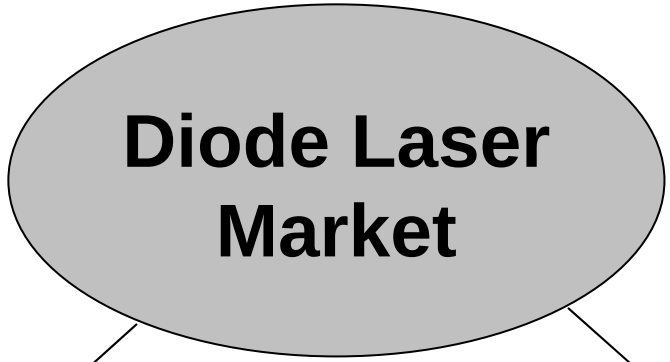


- Diode lasers represent **57%** of the worldwide laser market
- The diode-laser portion of the market showed **13%** growth

Worldwide Diode Laser Sales



- Telecommunications
- Optical Storage
- Image Recording
- Pumps
- Material Processing
- Medical Therapeutic
- Entertainment
- Barcode Scanning
- Sensing
- Instrumentation
- Research
- Inspection, measurements & control



Short-wavelength regime
(λ = 635 - 980 nm)

Fabrication by epitaxial growth on ***GaAs*** substrates

Non telecommunication

Long-wavelength regime
(λ = 980 -1550 nm)

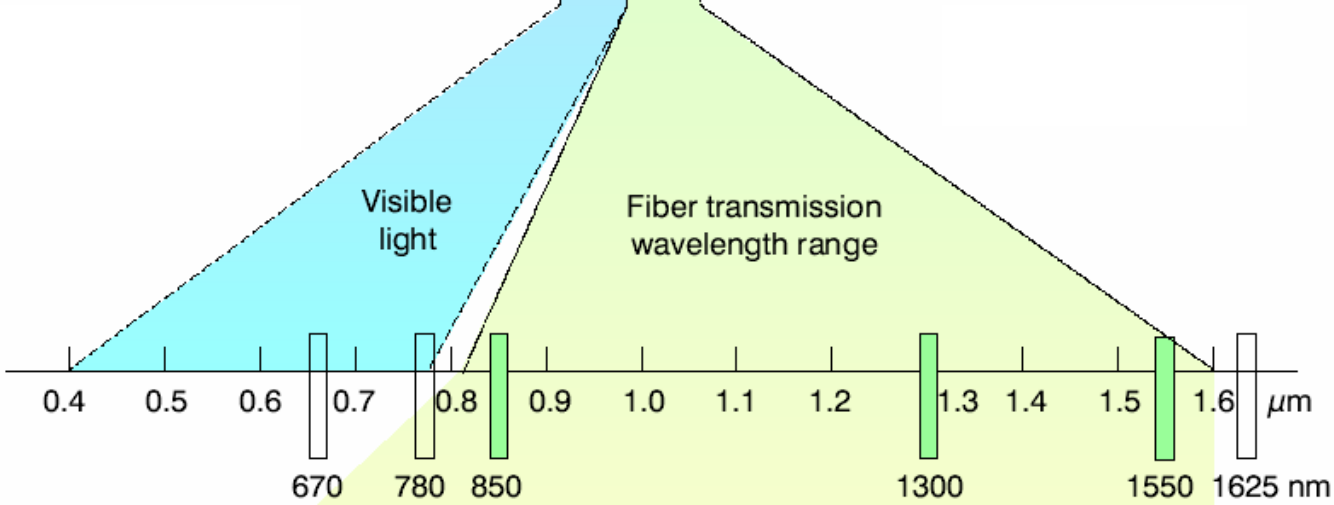
Fabrication by epitaxial growth on ***InP*** substrates

Telecommunication

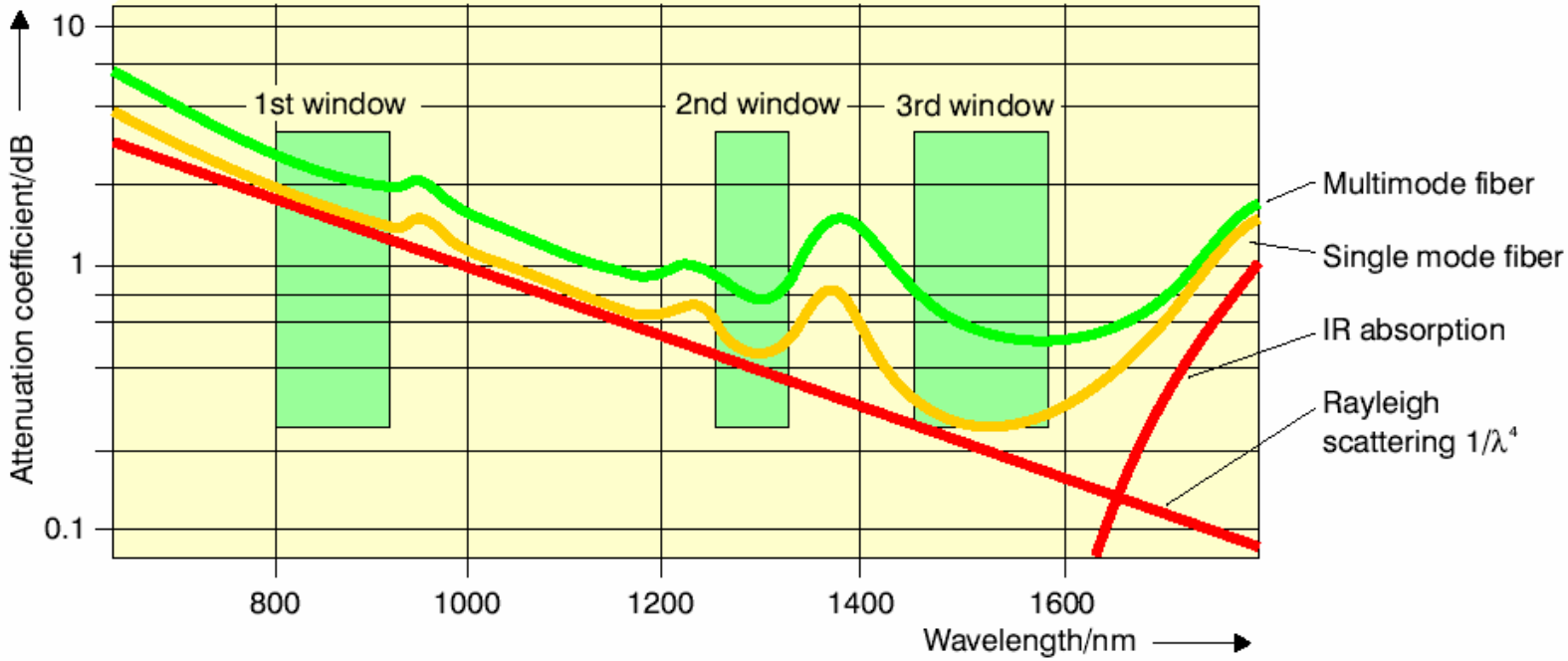
Optical Fiber Communications

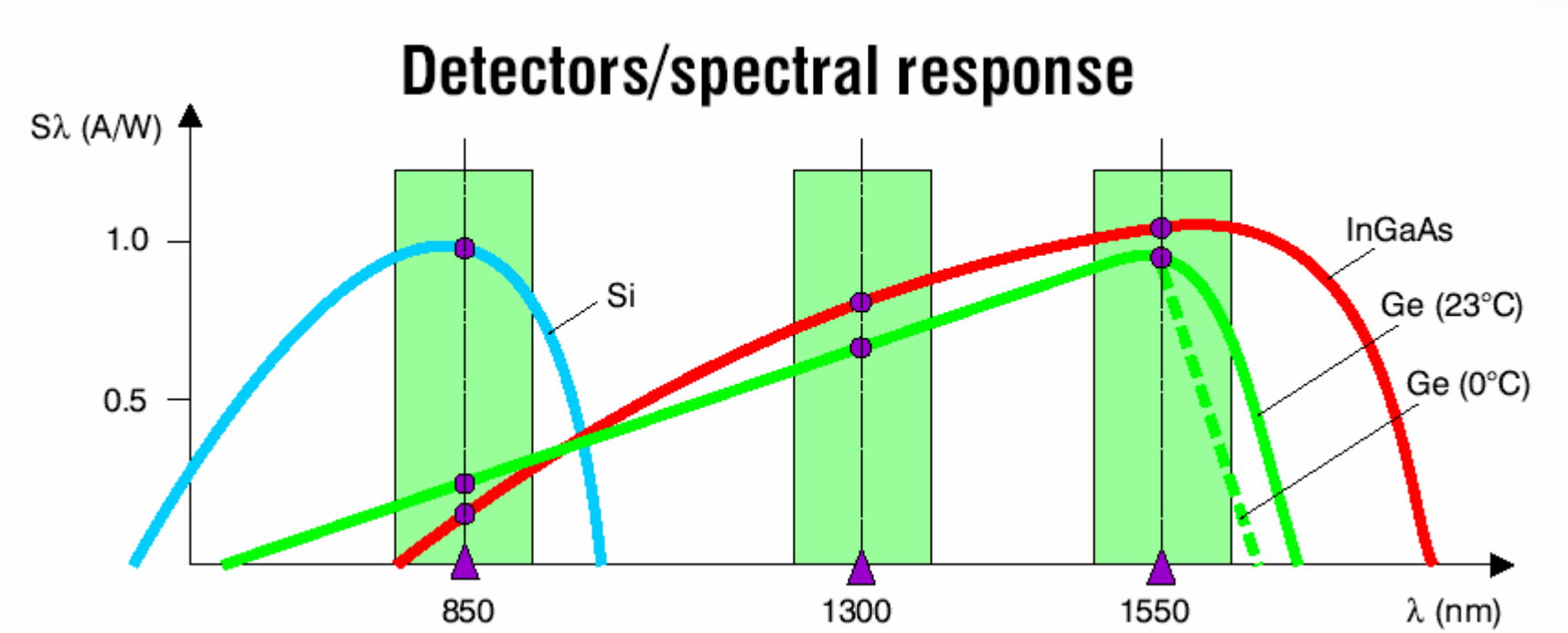
64% of the total diode laser market

- Signal Transmission: *λ=1.3 μm, 1.5 μm*
- Erbium Doped Fiber Amplifier (EDFA)
  Pumping: *λ=980 , 1480 nm*
- Dense Wavelength-Division Multiplexing (DWDM):
  Distributed Feedback (DFB) Lasers



Attenuation coefficient α of silica fibers

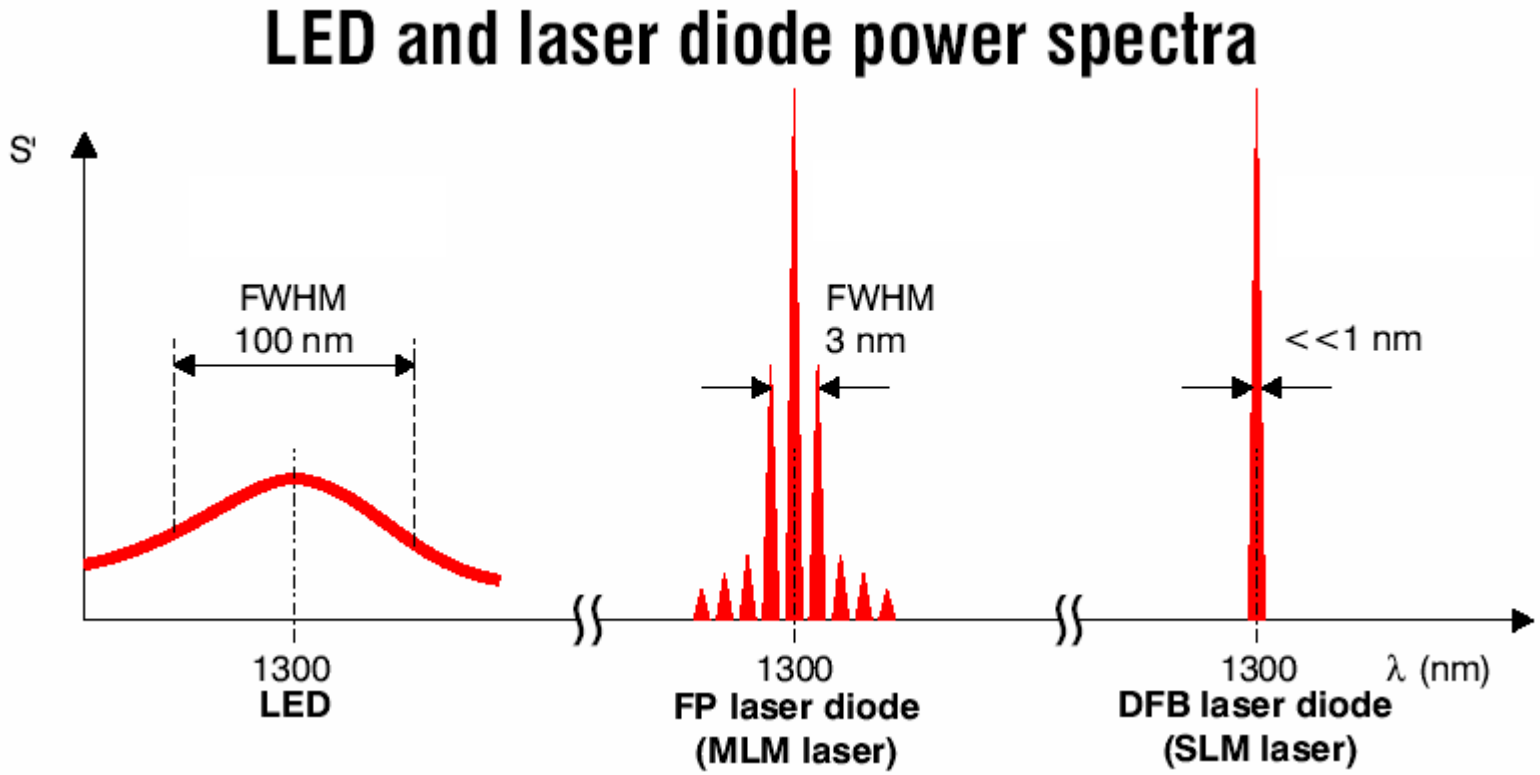




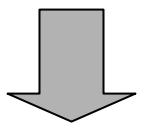
Si: best choice for visible light range (400-1000 nm)

Ge: covers all three optical windows (750-1600 nm)

InGaAs: ideal for $\lambda > 1000$ nm (particularly in 3rd optical window)

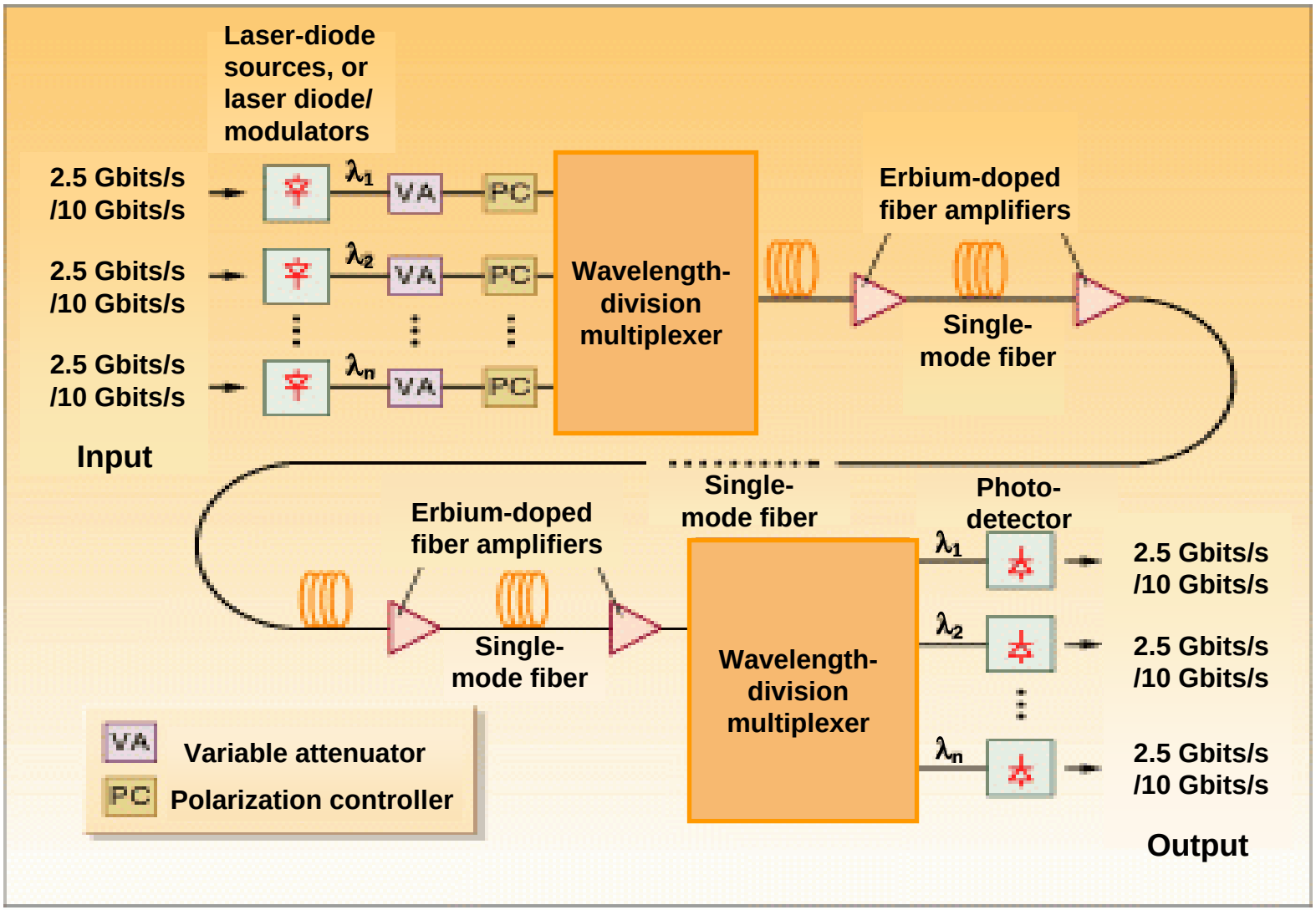


Narrow spectral bandwidth of the source diode

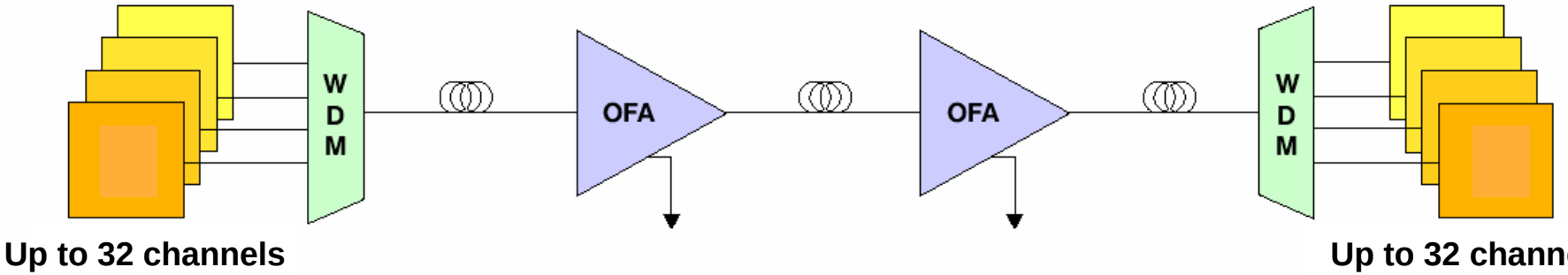


High frequency bandwidth / bit rate of the system

Dense Wavelength-Division Multiplexing (DWDM) System

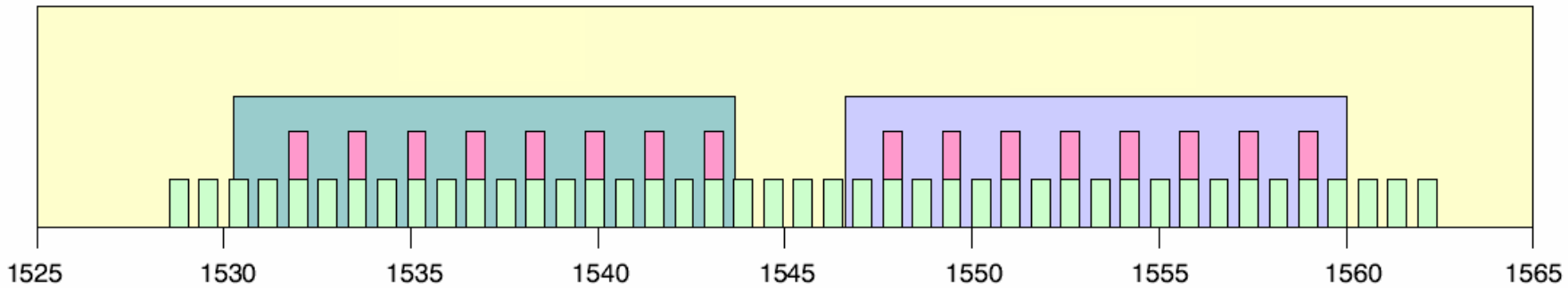


Channel Spacing in Dense WDM System



Up to 32 channels

Up to 32 channels

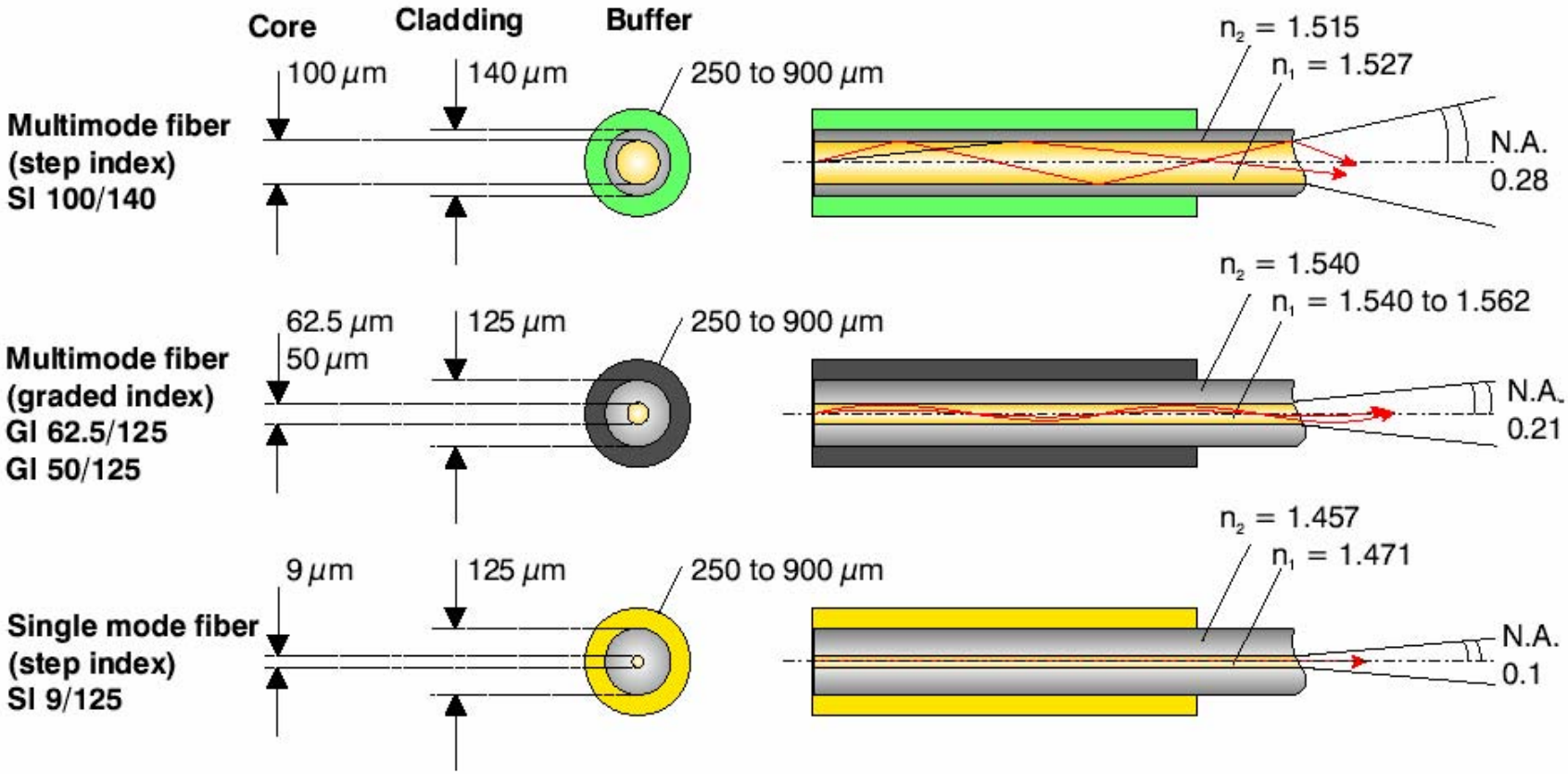


Wavelength/nm

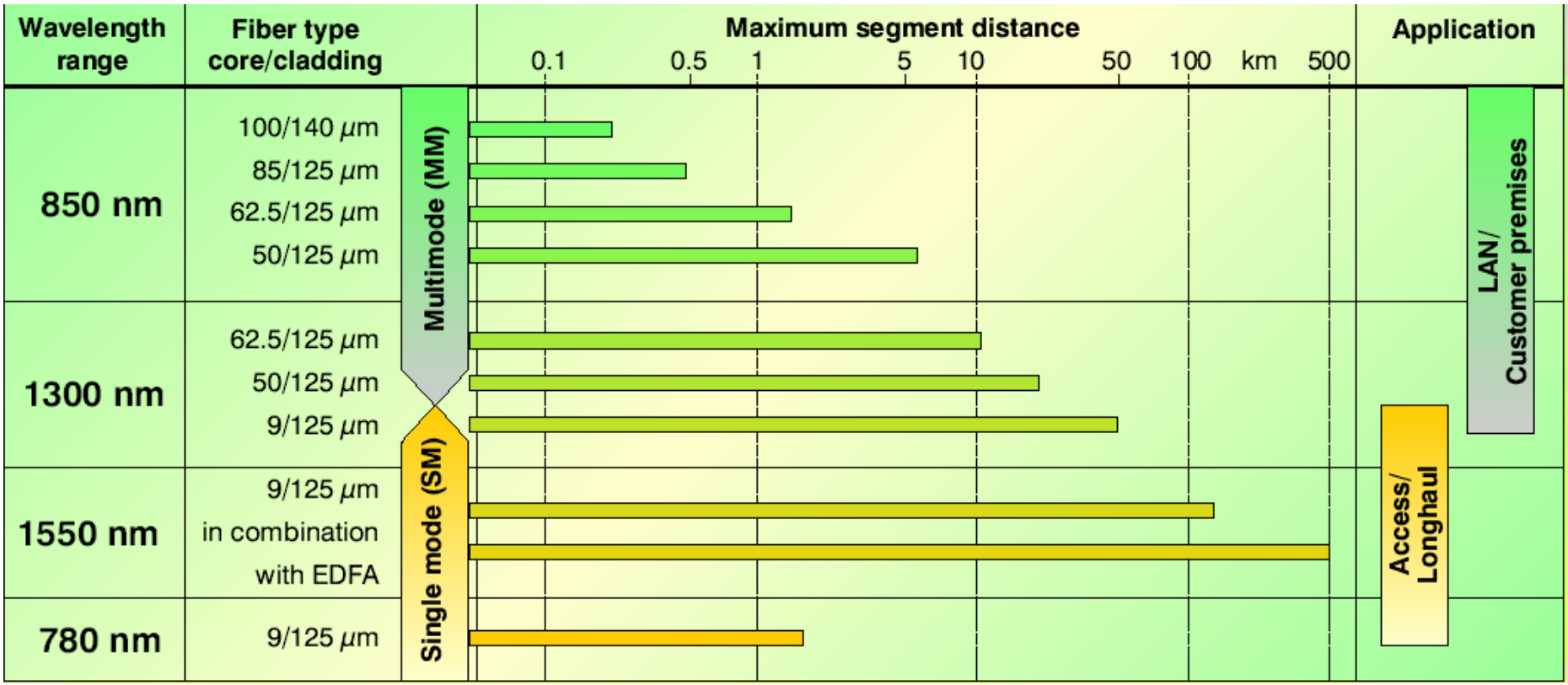
$\lambda_{REF} = 1552.52\ nm$

$\Delta\lambda_{channel} = 0.8\ nm$

Different Fiber Types



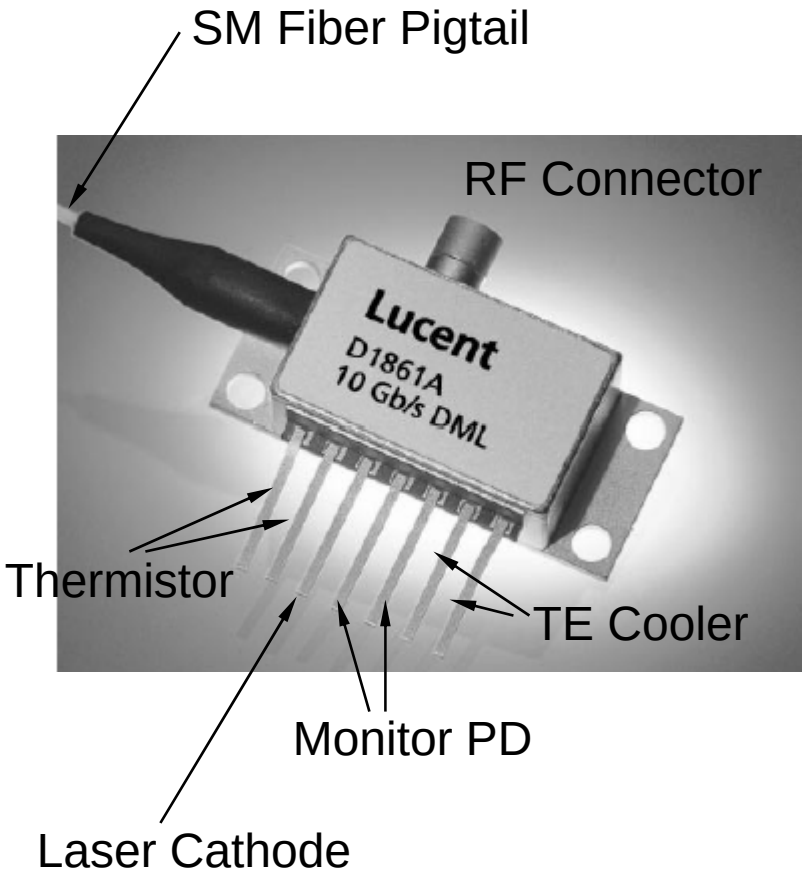
Application Areas for Fiber Optics Technology



850/1300 nm MM ⟶ Bit rate: 10 Mbit/s

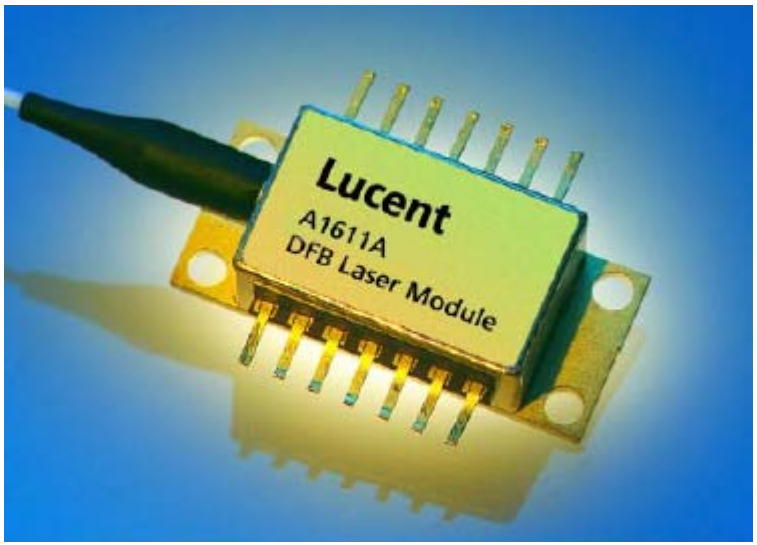
1300 /1500 nm SM ⟶ Bit rate: 10 Gbit/s

1.3 μm Direct Modulated Laser Module for 10 Gbit/s Digital Transmission



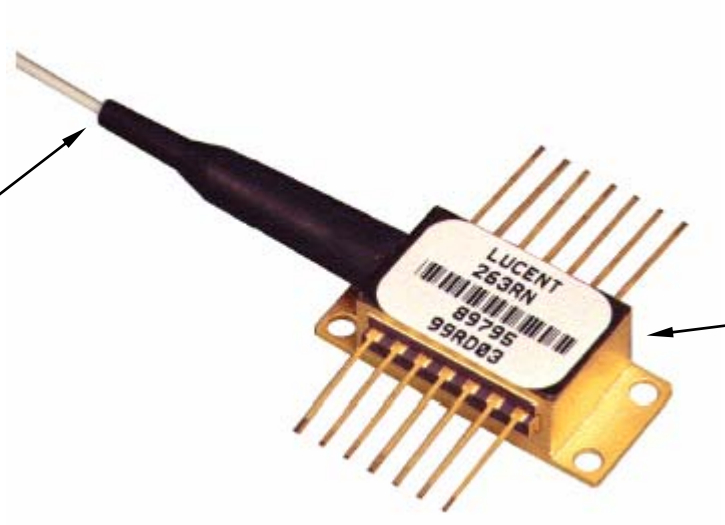
- Output Power: 4mW
- External efficiency: 0.15 W/A
- Threshold Current: 30 mA
- WL Tuning Coefficient: 0.085 nm/^{0}C
- Side-mode Suppression Ratio: 35 dB

1.3 μm DFB Laser Module for Broadcast CATV Applications



- *High Linearity*
- *112* Channel Loading
- Output Power: *13 mW*
- Side Mode Suppression Ratio: *30 dB*

0.98μm CW Optical Pump Source for 1.5 μm EDFA



Single Mode Fiber Pigtail

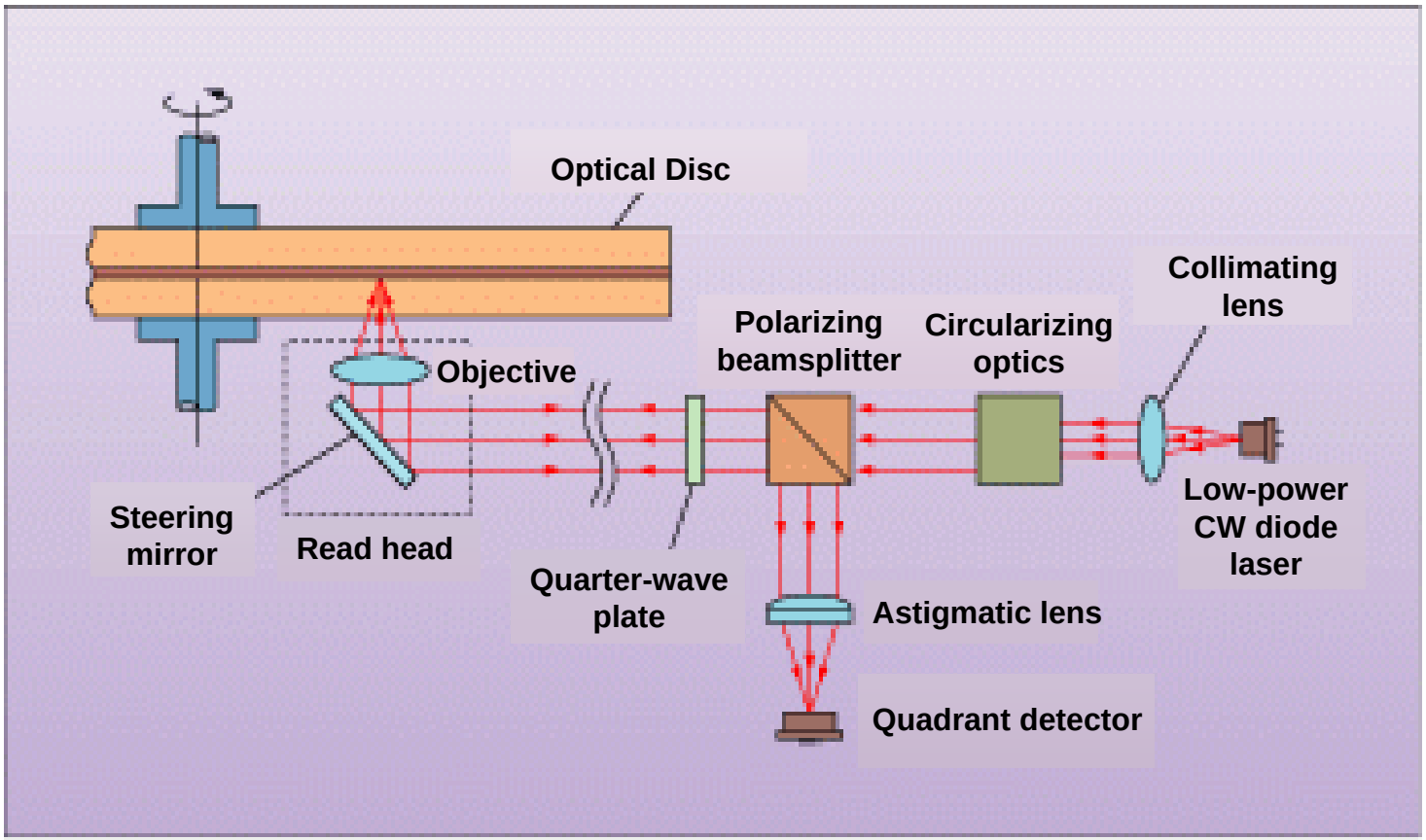
Compact 14-pin Butterfly Package

- InGaAs/GaAlAs Quantum-Well Chip Design
- Output Power up to *180 mW CW*
- Internally Controlled Thermal Stability

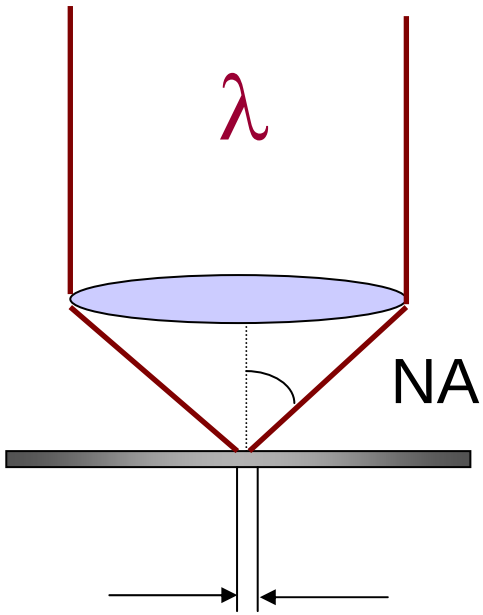
Optical Memory

- The second largest applications after telecommunications
- Encompasses several diode lasers categories:
  - CD-ROM: λ=780 nm, P=5 mW
  - CD-R: λ=780 nm, P=30 mW
  - DVD-ROM: λ=635-650 nm, P=5 mW
  - DVD-R: λ=635-650 nm, P=30-40 mW

Process of Reading an Optical CD



Storage Capacity of Optical Discs



D=1.22λ/(NA)

Diffraction-limited
Focused Spot

CD

λ=780 nm, NA=0.45

~ 0.7 bit/μm²

DVD

λ=650 nm, NA=0.6

~ 4.5 bits/μm²

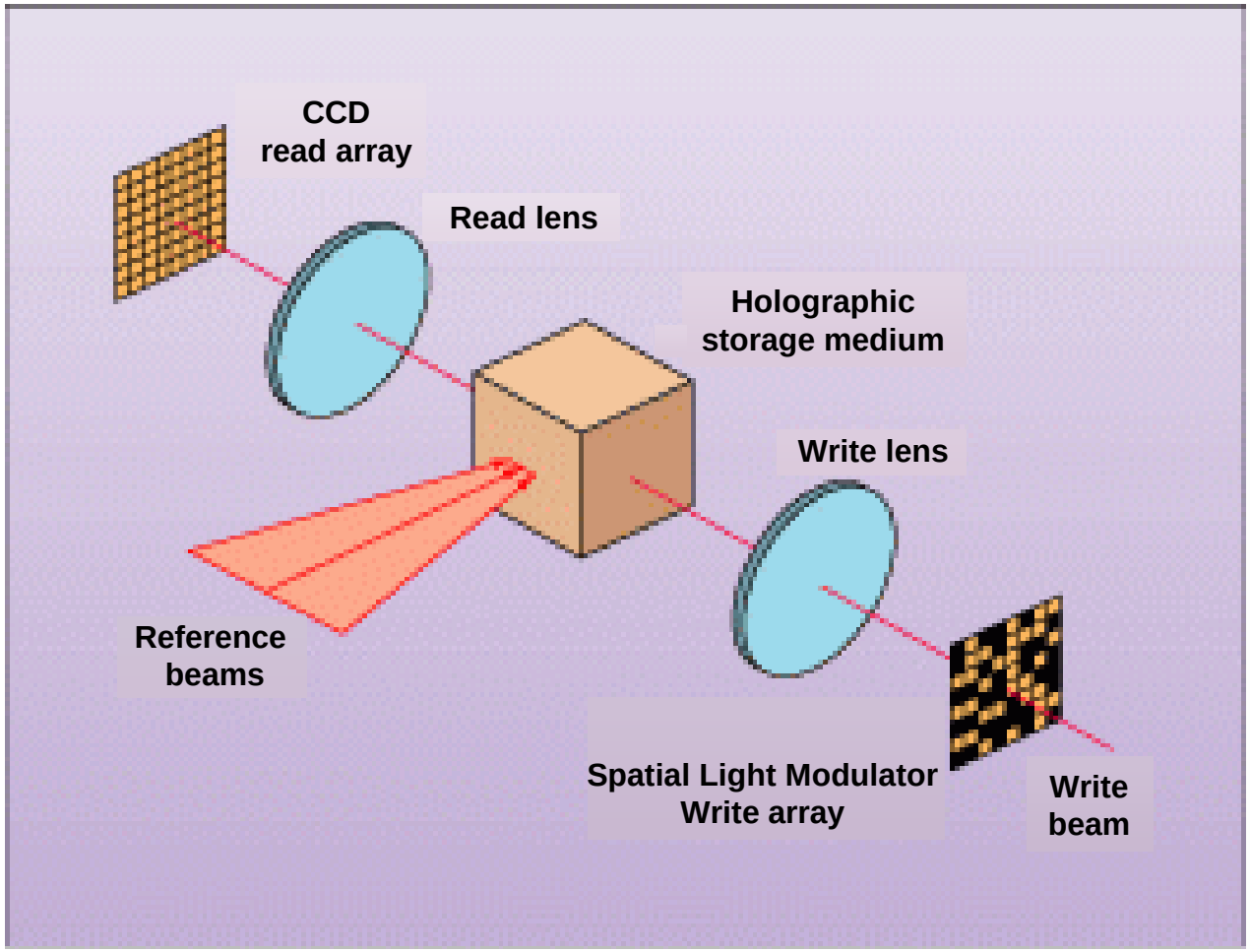
DVR

λ=405 nm , NA=0.85

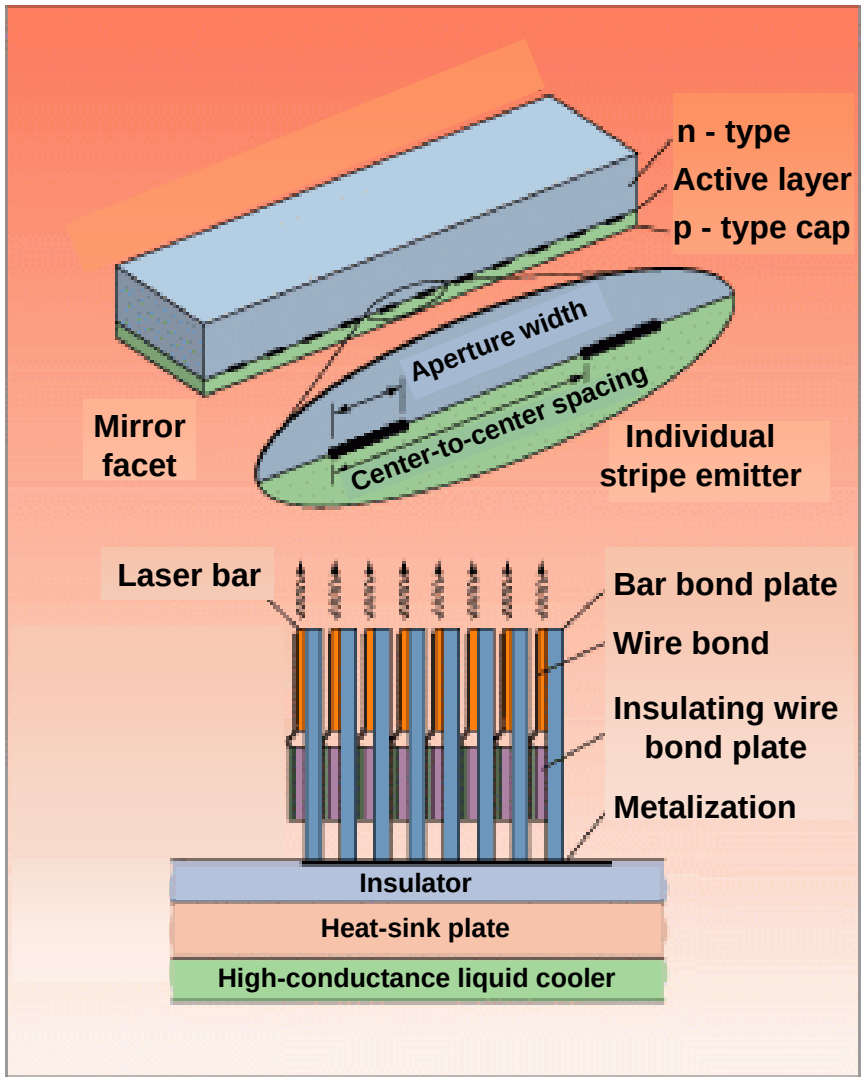
> 20 bits/μm²

Holographic Data Storage

Storage Density: ~ 400 bits/μm^2



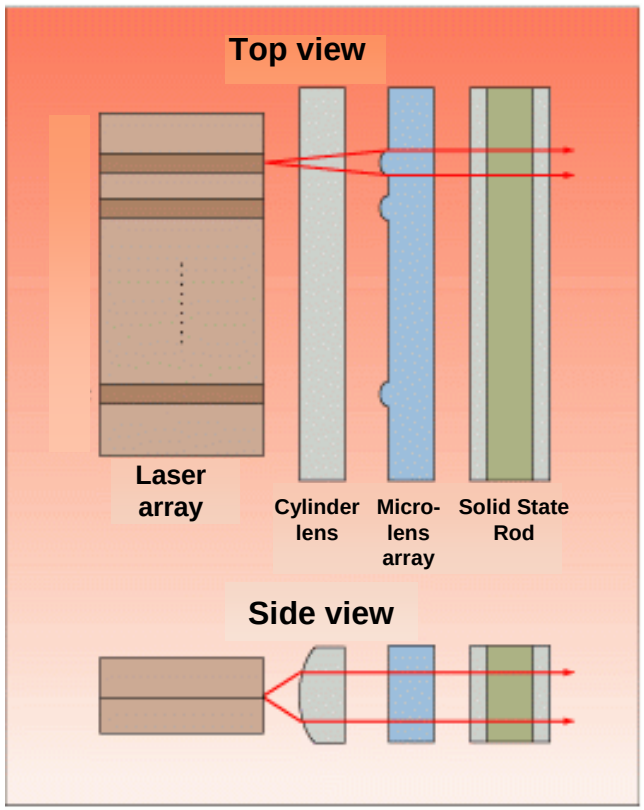
Diode Laser Arrays



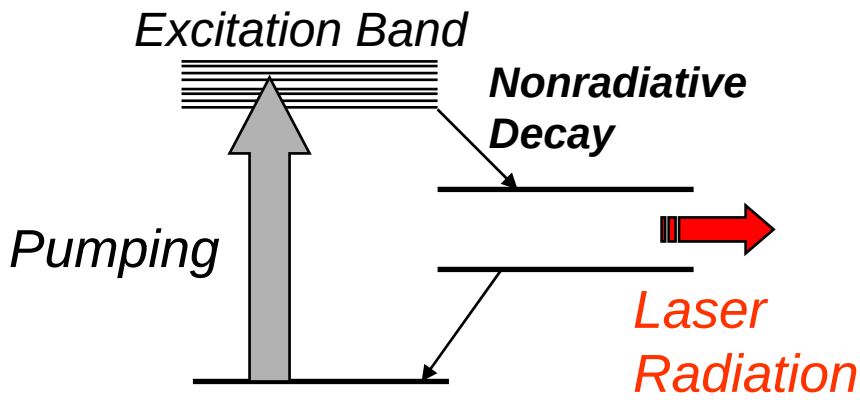
In edge-emitter arrays, individual stripe lasers are components of monolithic bar arrays

To form a two-dimensional array, bars are stacked together on a common heat sink

Solid State Lasers Pumping



Typical Side-Pumped Solid State Laser



Flash Lamp: Wide Spectrum

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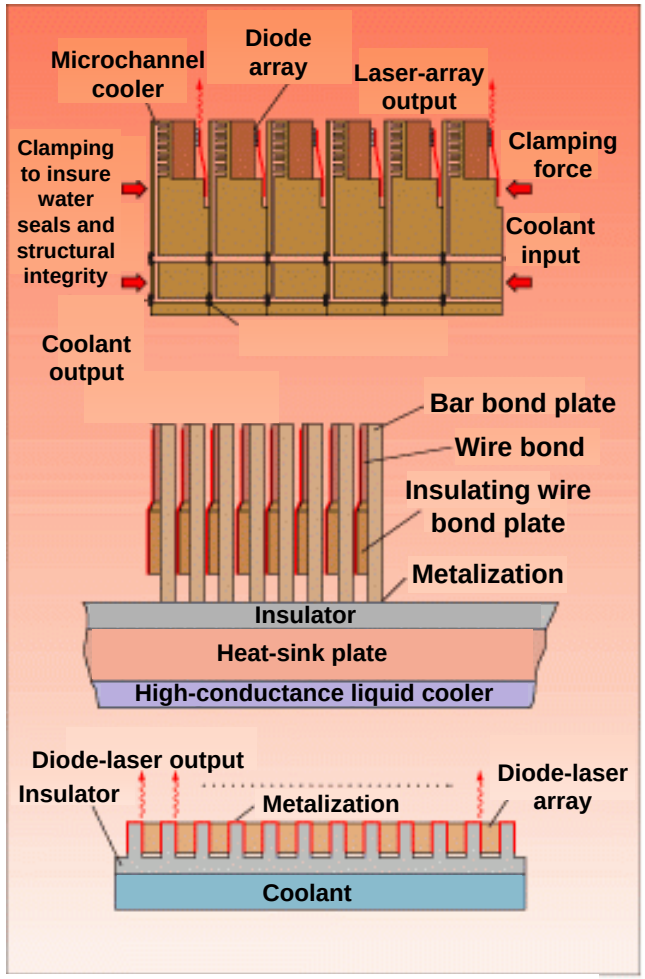
Low Pumping Efficiency

Diode lasers pump energy directly in the excitation band

Laser Array Cooling Techniques

Output Power is dependant on array thermal design

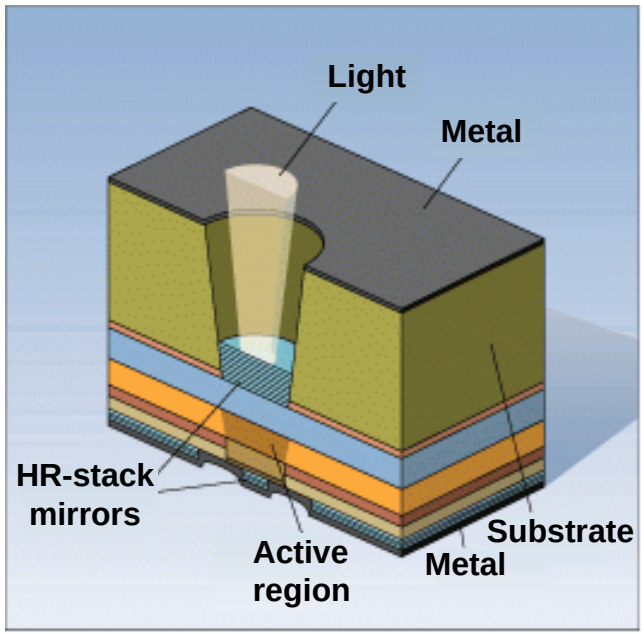


Microchannel Cooling of Each Bar

Common Heat Sink for Separate Bars

Bars Directly Mounted on a Common Heat Sink

Vertical-cavity surface-emitting lasers (VCSELs)



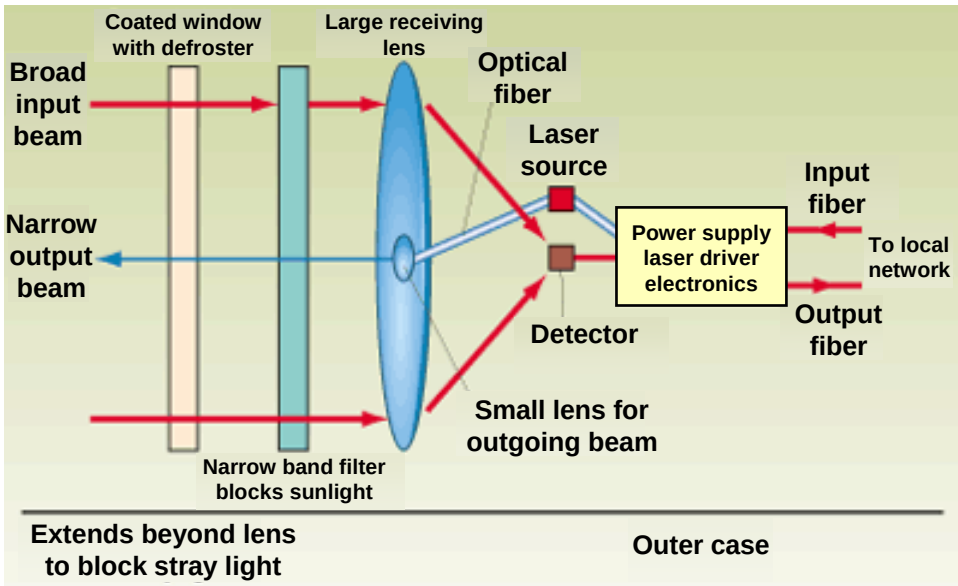
VCSEL consists of a vertical laser cavity defined by the active region surrounded by high-reflector (HR) stacks that comprise the mirrors

Light emission occurs through the top surface

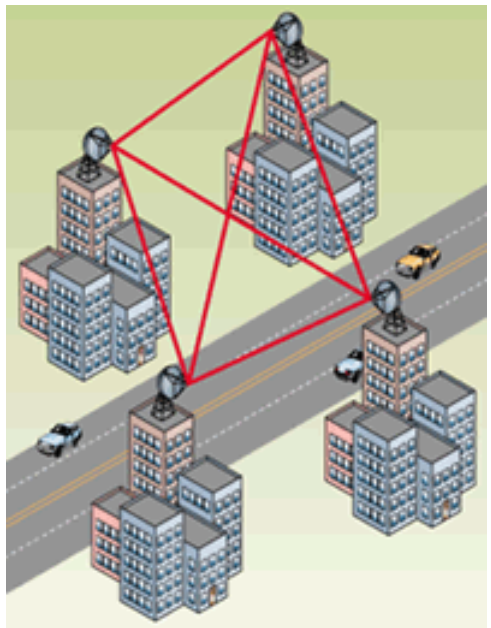
Each laser region is exceedingly small (a few μm across), and millions can be placed onto a single chip. Their compactness and low threshold current makes them suitable for *optical interconnects* and *optical computing*

Free-Space Optical Communications

Attractive Alternative to Optical Fibers



Components of a Single-Channel Atmospheric Transmitter/Receiver



Point-to-point Atmospheric Links Among Buildings

Free-Space Optical Communications

- Operation Wavelength:
  λ= 780, 850 nm (P < 1 mW)
  λ=1500 nm (P < 10 mW)

  } → Eye Safety, Low Cost

- Transmission Distance:
  100 m – 1 km

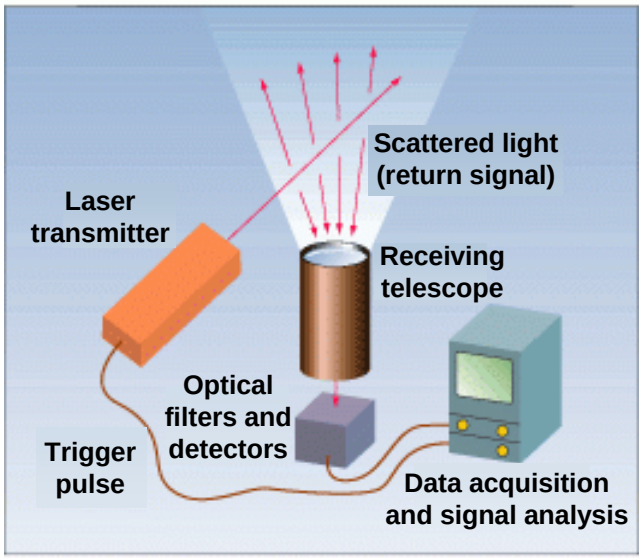
- Transmission Rate:
  155 Mbit/s; 622 Mbit/s

(Higher speed systems are in development)

- Major Potential Application:
  Cellular-phones connections bandwidth enhancement

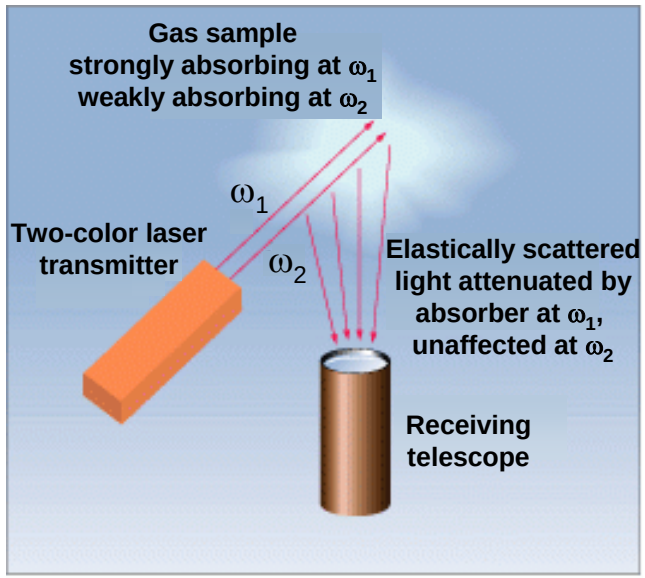
Light Detection And Ranging (LIDAR)

Basic LIDAR (Range Finder)



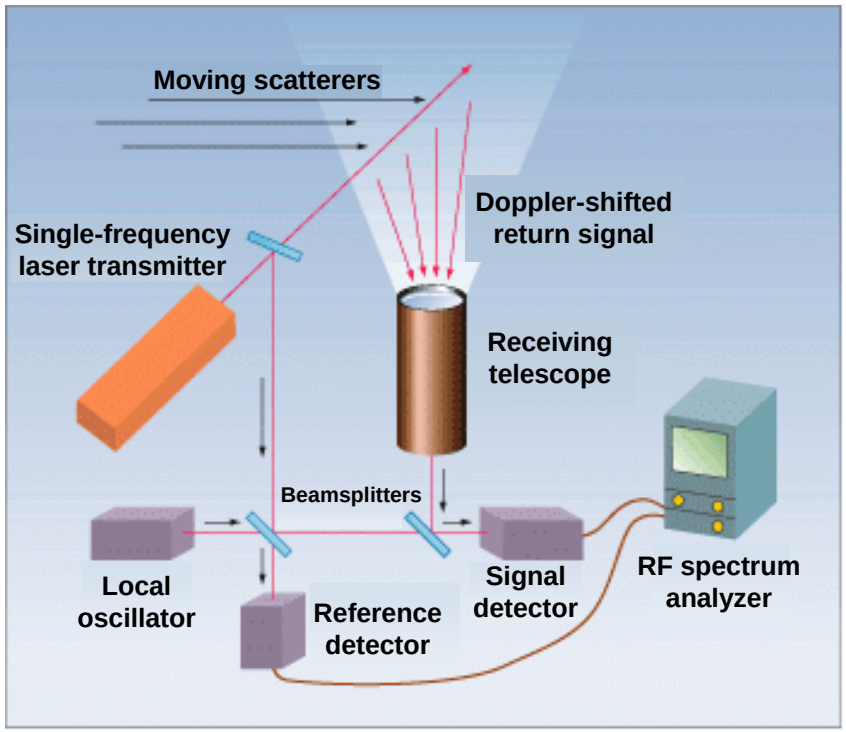
Used to measure the distance from a solid or hard target

Differential Absorption LIDAR(DIAL)



Used to measure chemical concentrations (ozone, water vapor, pollutants) in the atmosphere

Doppler LIDAR



Measurements of wind velocity

Doppler LIDAR systems on aircrafts detect dangerous air turbulence

A Doppler LIDAR system measures the velocity of moving targets by comparing the frequency of the return signal to that of the transmitter