Laser Diode

- Light emitters are a key element in any fiber optic system.
- This component converts the electrical signal into a corresponding light signal that can be injected into the fiber.
- The light emitter is an important element because it is often the most costly element in the system, and its characteristics often strongly influence the final performance limits of a given link.

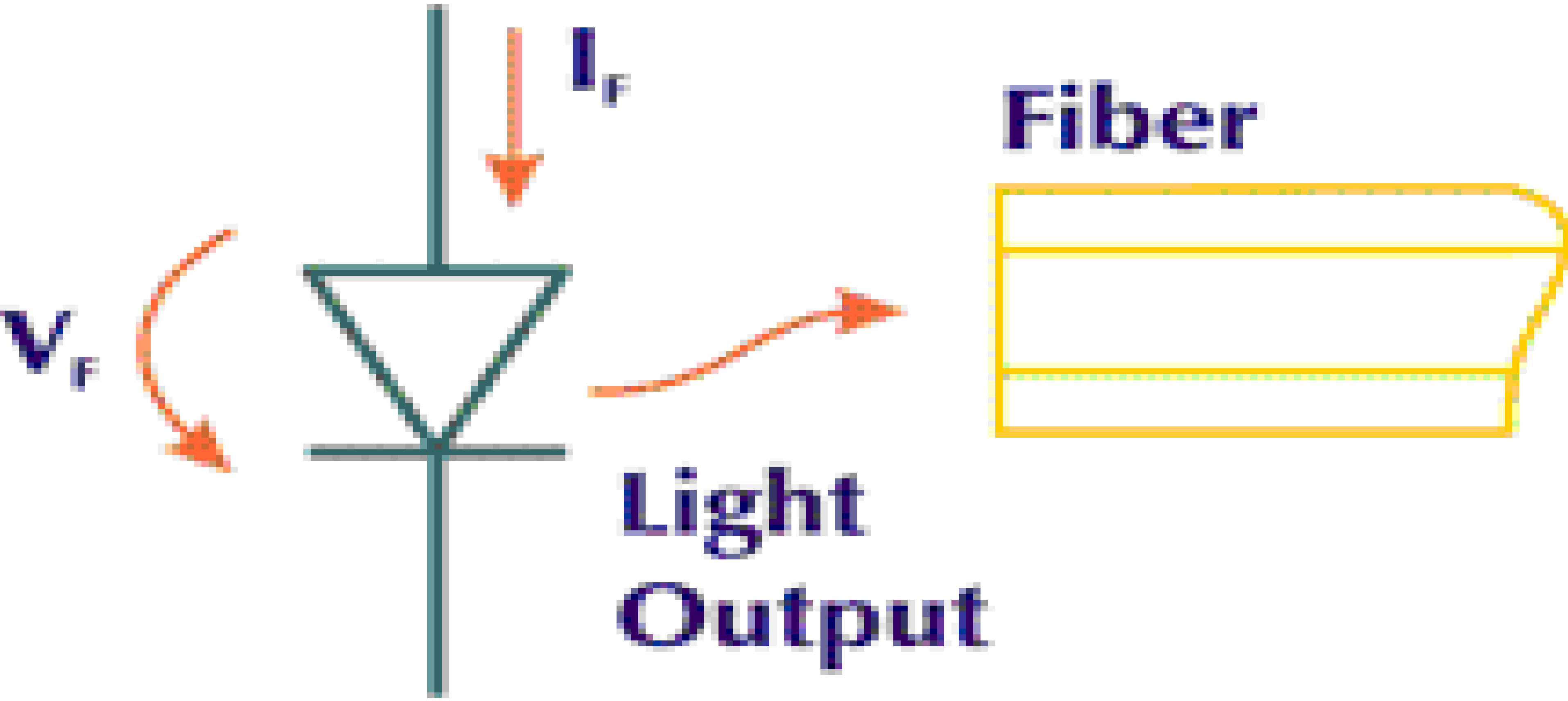

Figure 1 - **Laser Diodes Convert an Electrical Signal to Light**

Laser Diode

- **Laser diodes** are complex semiconductors that convert an electrical current into light.
- The conversion process is fairly efficient in that it generates little heat compared to incandescent lights.
- Five inherent properties make lasers attractive for use in fiber optics.
  1. They are small.
  2. They possess high radiance (i.e., They emit lots of light in a small area).
  3. The emitting area is small, comparable to the dimensions of optical fibers.
  4. They have a very long life, offering high reliability.

Laser Diode

- 5. They can be modulated (turned off and on) at high speeds.
- **Table 1**offers a quick comparison of some of the characteristics for lasers and LEDs. These characteristics are discussed in greater detail throughout this article and the article on light-emitting diodes.

Table 1 - Comparison of LEDs and Lasers

Characteristics	LED	Lasers
Output Power	Linearly proportional to drive current	Proportional to current above the threshold
Current	Drive Current: 50 to 100 mA Peak	Threshold Current: 5 to 40 mA
Coupled Power	Moderate	High
Speed	Slower	Faster
Output Pattern	Higher	Lower
Bandwidth	Moderate	High
Wavelengths Available	0.66 to 1.65 µm	0.78 to 1.65 µm
Spectral Width	Wider (40-190 nm FWHM)	Narrower (0.00001 nm to 10 nm FWHM)
Fiber Type	Multimode Only	SM, MM
Ease of Use	Easier	Harder
Lifetime	Longer	Long
Cost	Low ($5-$300)	High ($100-$10,000)

Laser Diode

- Laser diodes are typically constructed of GaAlAs (gallium aluminum arsenide) for short-wavelength devices. Long-wavelength devices generally incorporate InGaAsP (indium gallium arsenide phosphide).

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Laser Diode Performance Characteristics

- Several key characteristics lasers determine their usefulness in a given application. These are:

  Peak Wavelength: This is the wavelength at which the source emits the most power. It should be matched to the wavelengths that are transmitted with the least attenuation through optical fiber. The most common peak wavelengths are 1310, 1550, and 1625 nm.

  Spectral Width: Ideally, all the light emitted from a laser would be at the peak wavelength, but in practice the light is emitted in a range of wavelengths centered at the peak wavelength. This range is called the spectral width of the source.

Laser Diode Performance Characteristics

- ***Emission Pattern*: The pattern of emitted light affects the amount of light that can be coupled into the optical fiber. The size of the emitting region should be similar to the diameter of the fiber core.**

  ***Power*: The best results are usually achieved by coupling as much of a source's power into the fiber as possible. The key requirement is that the output power of the source be strong enough to provide sufficient power to the detector at the receiving end, considering fiber attenuation, coupling losses and other system constraints. In general, lasers are more powerful than LEDs.**

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Laser
Emission Pattern

Laser Diode Performance Characteristics

- ***Speed*: A source should turn on and off fast enough to meet the bandwidth limits of the system.**
- The speed is given according to a source's rise or fall time, the time required to go from 10% to 90% of peak power. Lasers have faster rise and fall times than LEDs.
- **L**inearity is another important characteristic to light sources for some applications.
- Linearity represents the degree to which the optical output is directly proportional to the electrical current input.
- Most light sources give little or no attention to linearity, making them usable only for digital applications.

Laser Diode Performance Characteristics

- Analog applications require close attention to linearity. Nonlinearity in lasers causes harmonic distortion in the analog signal that is transmitted over an analog fiber optic link.
- **L**asers are temperature sensitive; the lasing threshold will change with the temperature.
- Figure 3 shows the typical behavior of a laser diode.
- As operating temperature changes, several effects can occur.
- First, the threshold current changes. The threshold current is always lower at lower temperatures and vice versa.
- The second change that can be important is the slope efficiency.
- The slope efficiency is the number of milliwatts or microwatts of light output per milliampere of increased drive current above threshold.

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Laser Diode Performance Characteristics

- Most lasers show a drop in slope efficiency as temperature increases.
- Thus, lasers require a method of stabilizing the threshold to achieve maximum performance. Often, a photodiode is used to monitor the light output on the rear facet of the laser.
- The current from the photodiode changes with variations in light output and provides feedback to adjust the laser drive current.

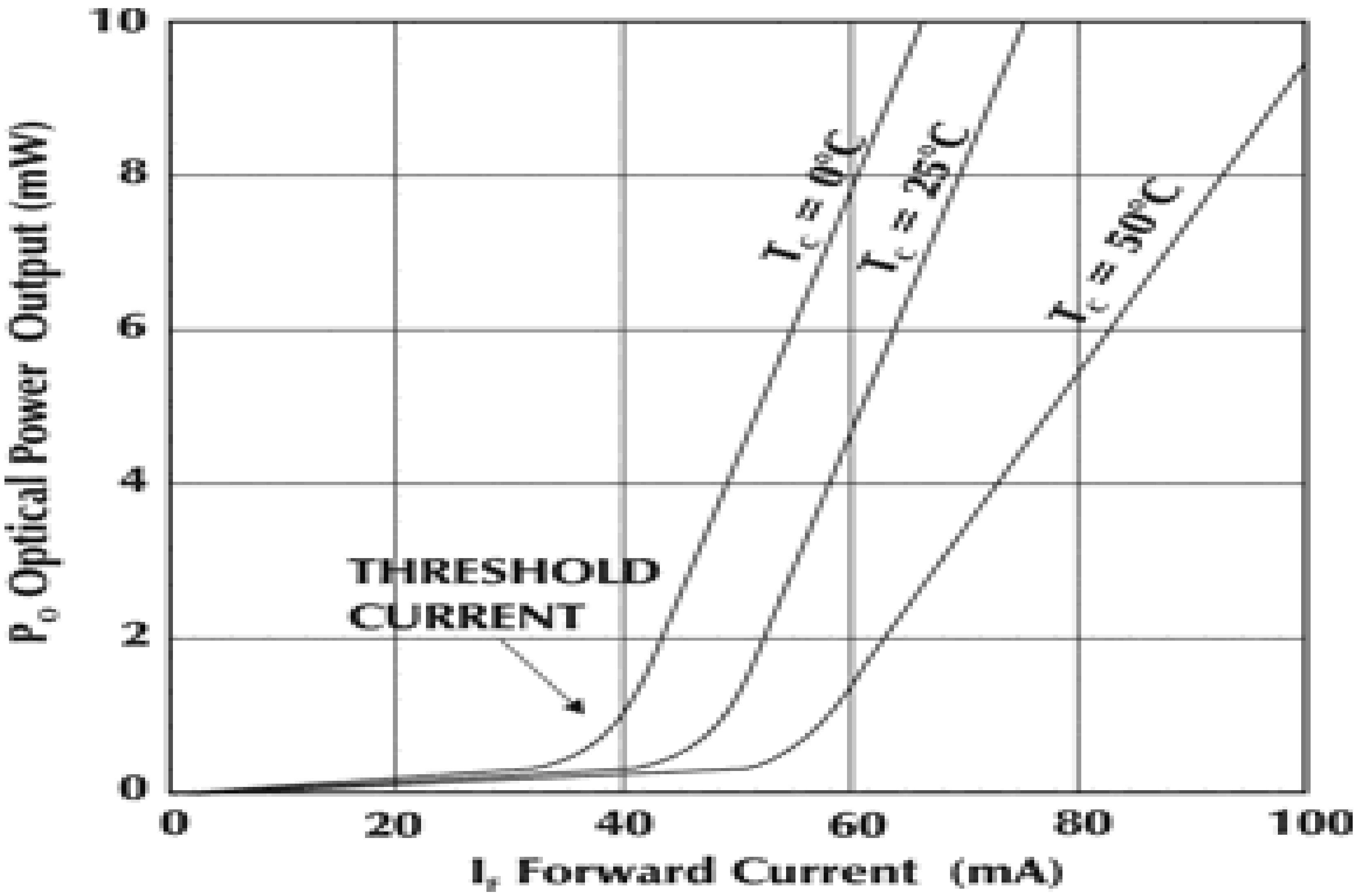

Figure 4 **- Emitters Characteristics**

a) LED

b) Laser

Laser Diode Performance Characteristics

- Figure 4a shows the behavior of an LED, and Figure 4b shows the behavior of a laser diode.
- The plots show the relative amount of light output versus electrical drive current.
- The LED outputs light that is approximately linear with the drive current.
- Nearly all LED's exhibit a "droop" in the curve as shown in Figure 4b.
- This nonlinearity in the LED limits its usefulness in analog applications.
- The droop can be caused by a number of factors in the LED semiconductor physics but is often largely due to self-heating of the LED chip.

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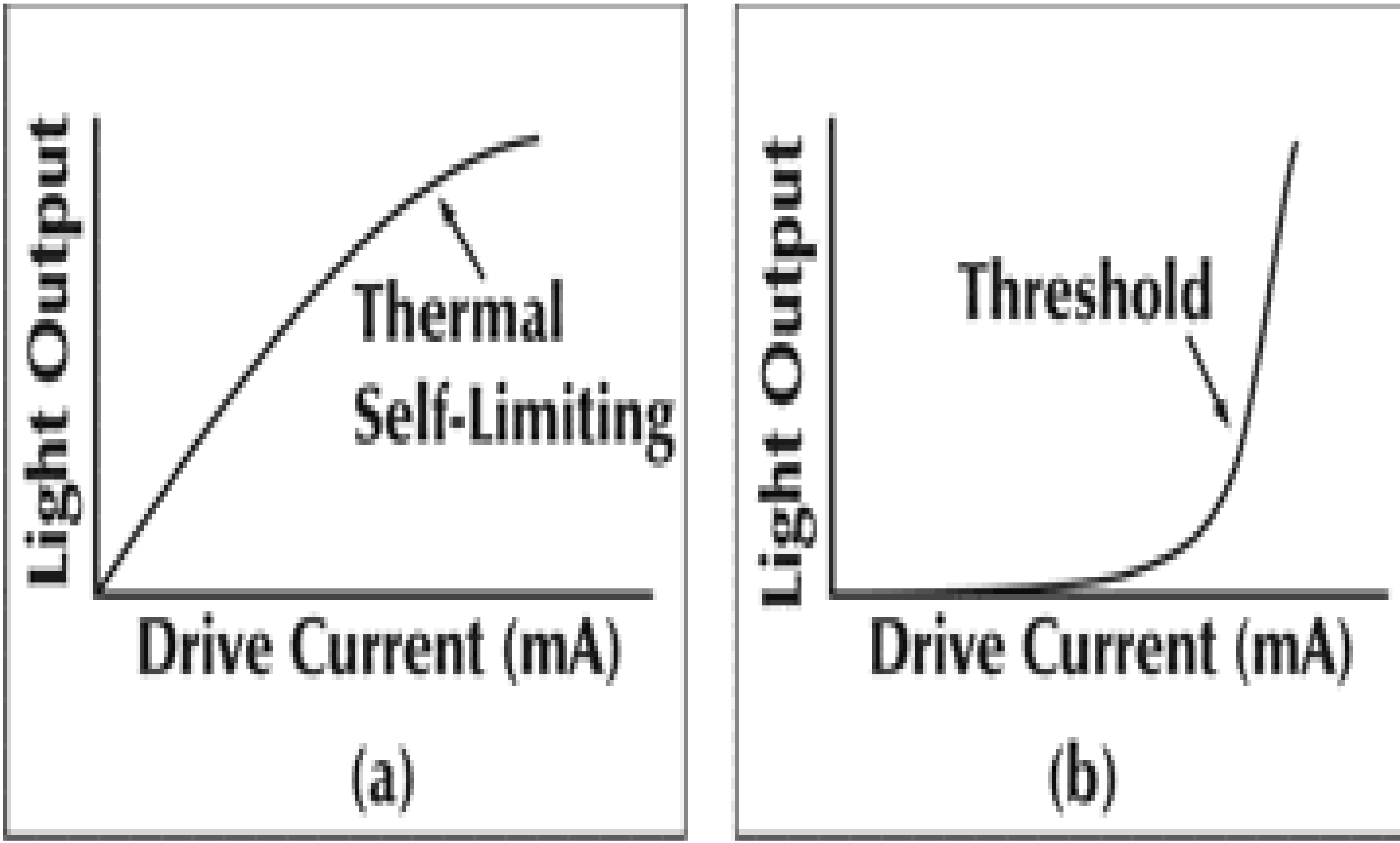
Laser Diode Performance Characteristics

- All LED's drop in efficiency as their operating temperature increases.
- Thus, as the LED is driven to higher currents, the LED chip gets hotter causing a drop in conversion efficiency and the droop apparent in Figure 4a.
- LED's are typically operated at currents to about 100 mA peak.
- Only specialized devices operate at higher current levels.


Light Output
Thermal
Self-Limiting
Drive Current (mA)
(a)
Light Output
Threshold
Drive Current (mA)
(b)

LASER TYPES

- **T**here are two basic types of laser diode structures: Fabry-Perot (FP) and distributed feedback (DFB). Of the two types of lasers, Fabry-Perot lasers are the most economical, but they are generally noisy, slower devices.
- DFB lasers are quieter devices (e.g., high signal-to-noise), have narrower spectral widths, and are usually faster devices.
- **D**FB lasers offer the highest performance levels and also the highest cost of the two types.
- They are nearly monochromatic (i.e. they emit a very pure single color of light.) while FP lasers emit light at a number of discrete wavelengths.

LASER TYPES

- DFB lasers tend to be used for the highest speed digital applications and for most analog applications because of their faster speed, lower noise, and superior linearity.
- Fabry-Perot lasers further break down into buried hetero (BH) and multi-quantum well (MQW) types.
- BH and related styles ruled for many years, but now MQW types are becoming very widespread. MQW lasers offer significant advantages over all former types of Fabry-Perot lasers.
- They offer lower threshold current, higher slope efficiency, lower noise, better linearity, and much greater stability over temperature.

LASER TYPES

- As a bonus, the performance margins of MQW lasers are so great, laser manufacturers get better yields, so laser cost is reduced.
- One disadvantage of MQW lasers is their tendency to be more susceptible to backreflections. See article “Laser Backreflection – The Bane of Good Performance" for more information.

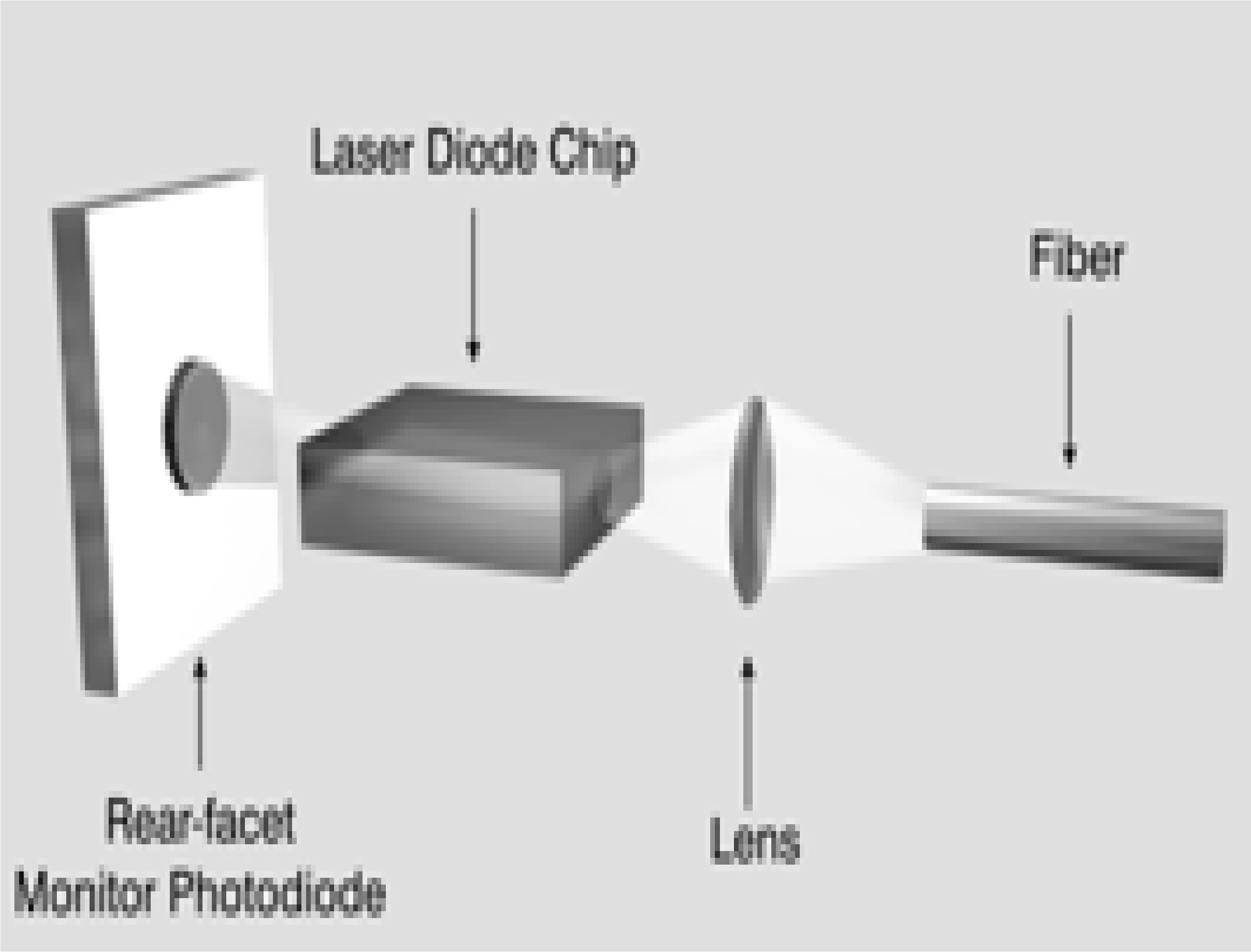


***Figure 5* - Laser Construction**

LASER TYPES

- **VCSELs** are a new laser structure that emits laser light vertically from its surface and has vertical laser cavity.
- Figure 6 illustrates the structure of a VCSEL.

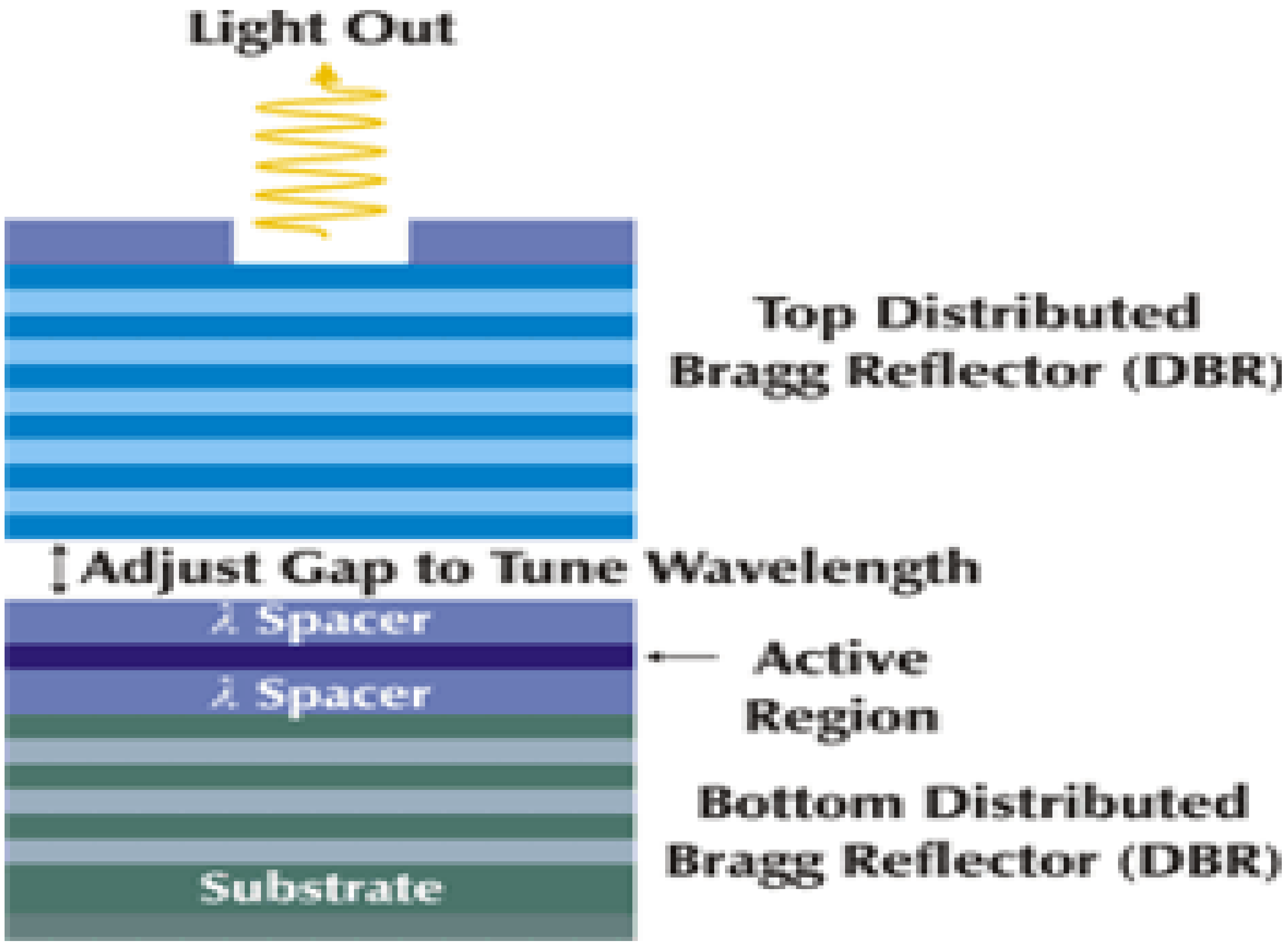


***Figure 6* - Basic VCSEL Structure**

LASER TYPES

- The VCSEL's principles of operation closely resembles those of conventional edge-emitting semiconductor lasers.
- The heart of the VCSEL is an electrically pumped gain region, also called the active region, emits light.
- Layers of varying semiconductor materials above and below the gain region create mirrors.
- Each mirror reflects a narrow range of wavelengths back into the cavity causing light emission at a single wavelength.

- VCSELs are typically multi-quantum well (MQW) devices with lasing occurring in layers only 20-30 atoms thick.
- Bragg-reflectors with as many as 120 mirror layers form the laser reflectors.

LASER TYPES

- There are many advantages to VCSELs.
- Their small size and high efficiency mirrors produce a low threshold current, below 1 mA.
- The transfer function allows stability over a wide temperature range, a feature that is unique to this type of laser diode.
- These features make the VCSEL ideal for applications that require an array of devices.

Bragg Lasers

- FP Resonator produce Laser light that lacks required spectral quality.
- Employing Bragg grating as reflectors help achieve narrow spectrum
- DFB Lasers are monolithic Devices with in internal structure based on waveguide technology and internal grating,typically at the interface InP substrate and InGaAsP layers to provide optical feedback fixed wavelength that is determined by the Greater pith,hence DBR-DFB
- DFB structure may be combined with multiple Quantum- well structure to improve the along width of reduced lasers(a few hundred kHz)

Bragg Lasers

- DFB tunned laser arrays is also be integrated to produced the rang of desired wavelength.
- In this case independent filter rather than a cavity waveguide grating determined the wavelength of the each laser.
- 20 channel selectable sources with 50 GHz separation and 0 dB output power and modulated at 2.5 Gb/s have produced device with long term liability and low chirps.

DFB Advantages

- Lasers can be integrated on a small device.
- Have a short cavity and are modulated at high speed independently.
- Temperature variability is the same for all lasers in the device.

DFB Disadvantages

- Difficult to obtain precise channel spacing due to variability of individual filters.
- Frequency shift of lasers does not track each other and they drift into each other.
- Difficult to integrate many channels due to intrinsic losses
- Required a fine period grating
- Increased electrical cross talk due to close proximity of integrated amplifiers.
- Directly modulated DFBs exhibit positive frequency Chirp ;the spectral leading edge of a pulse is blue-shifted (wavelength shortens) and the trailing edge is red-shifted (wavelength is elongated)

Table 3. Tunable-laser comparisons

Laser	Advantages	Disadvantages	Market applications
Distributed feedback (DFB)	Wavelength stability; established fabrication process	Low output power*; limited tuning range	Narrowly tunable applications
Distributed Bragg reflector (DBR)	Fast switching speed**; established fab process	Broad line width; wavelength instability	Access; switching; optical add/drop multiplexing (OADM)
Sampled-grating DBR	Broad tuning range; fast switching speed**	Low output power; broad line width; non-continuous tuning	Access; metro; switching; OADM
Vertical-cavity surface-emitting laser (VCSEL)	Narrow line width (for O/P)***; low power consumption; mode stability; circular beam emitted; test at wafer level	Low output power (for E/P)***; traditionally confined to short wavelengths (850/1,300 nm)	Metro; access
Micro-external-cavity lasers	High power; narrow line width; low relative intensity noise; continuous tuning; broad tuning range	Switching speed - shock/vibration sensitivity	Long haul; ultra long haul; metro; OADM; switching

* Although there are fixed-wavelength DFB lasers with >20-mW output power, the tunable DFBs have limited power.

** When thermal stabilization is not required. Thermal stabilization typically leads to >25 msec tuning time.

*** The O/P (optically pumped) VCSEL demonstrates narrow line width but higher output power. The E/P (electrically pumped) VCSEL has a large line width (~150 MHz) and low output power.

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