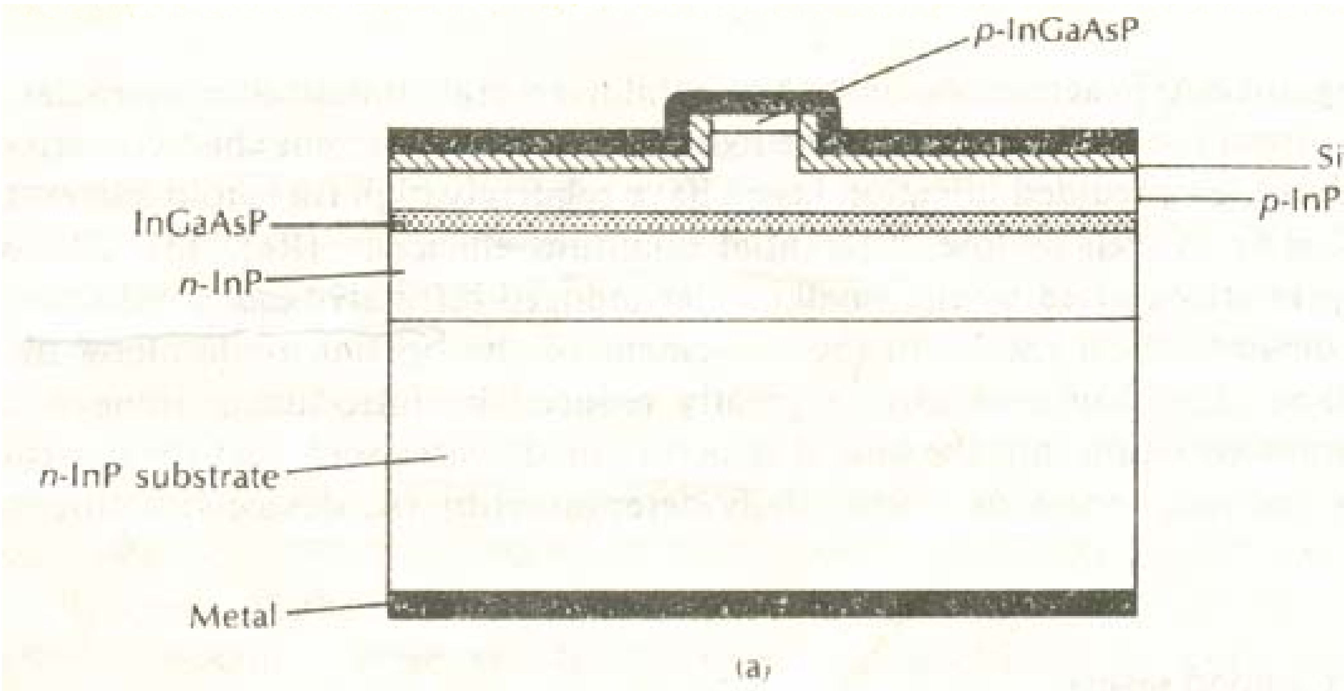
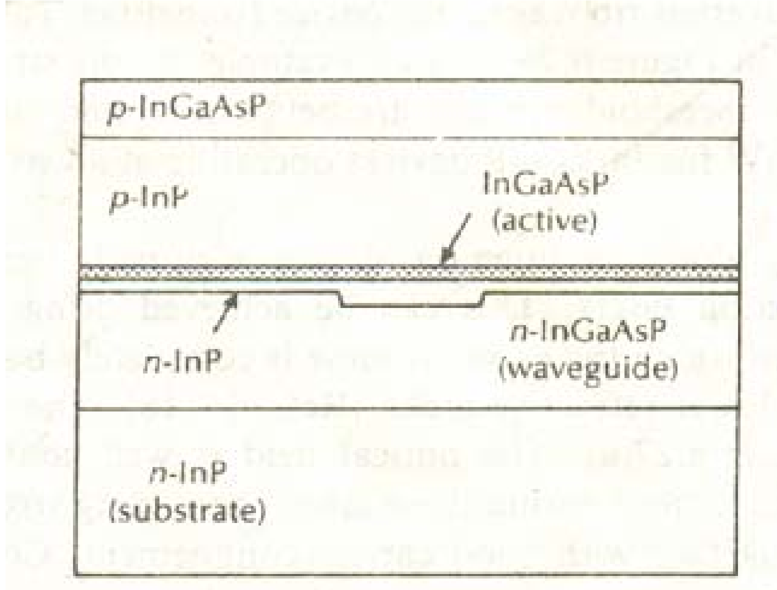
INDEX GUIDED LASERS:



A: Ridge acts as narrow current confining stripe.
I th = 40 to 60 mA (Typical)

-Can operate with single lateral mode

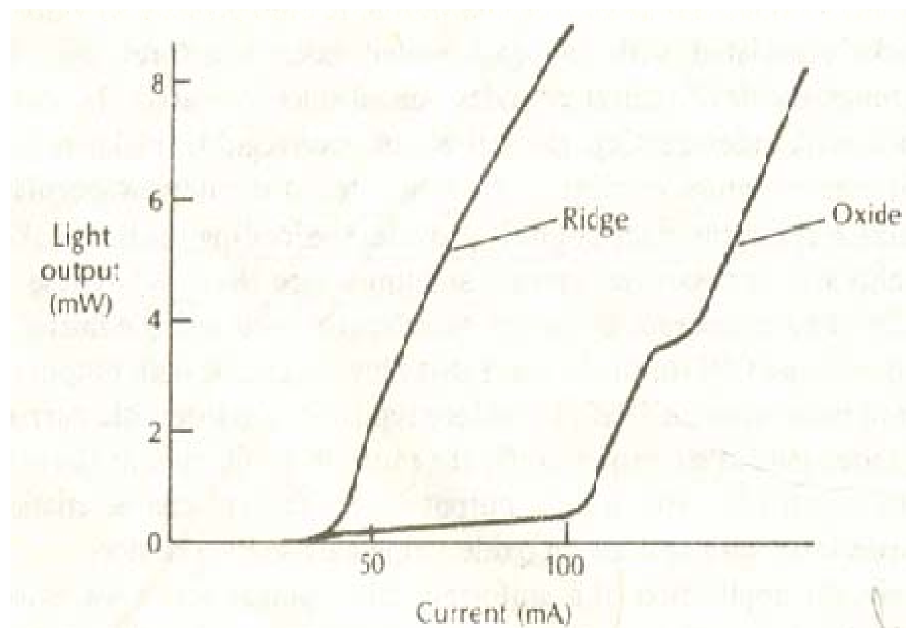
POWER O/P=25 mW (at Ith=18 mA at room temp.)



B: This structure provides variation in current confinement layer thickness (refractive index variation)

I th =70 to 90 mA

P output=20mW(at Ith at room temp) at 1.3 µm wavelength



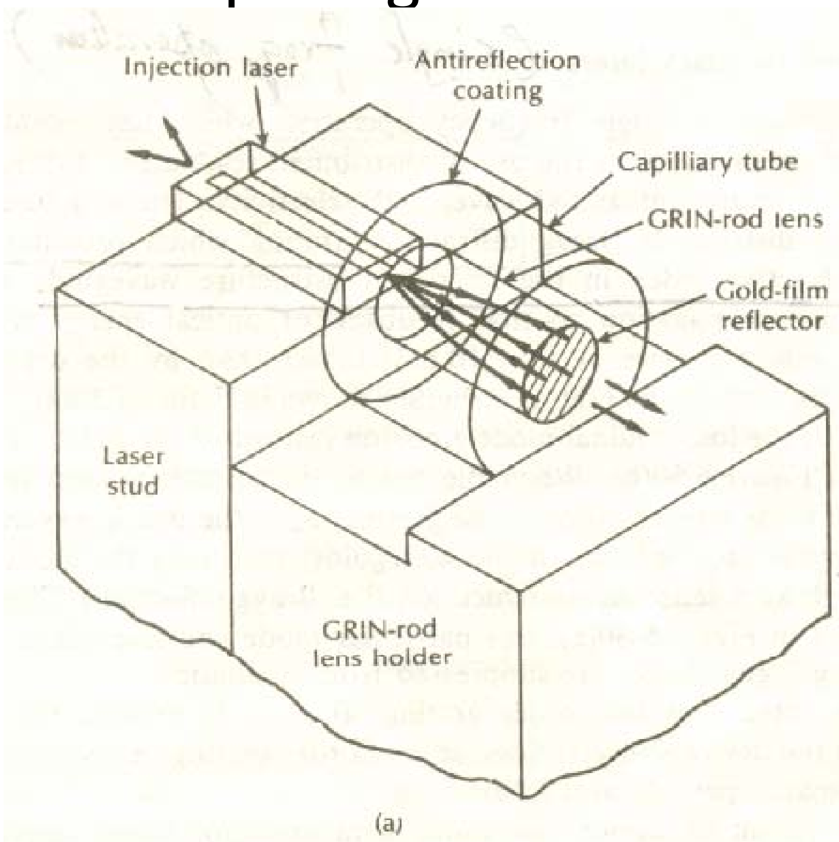
COUPLED CAVITY LASER

Single mode operation is achieved by shortening the length of the cavity so that only a single longitudinal mode falls within the gain bandwidth of the device.

Shortening the length from 250 to 25 µm will have the effect of increasing the mode spacing from 1 to 10 nm.

FIG : **grin rod lens is used to enhance coupling to an external mirror**

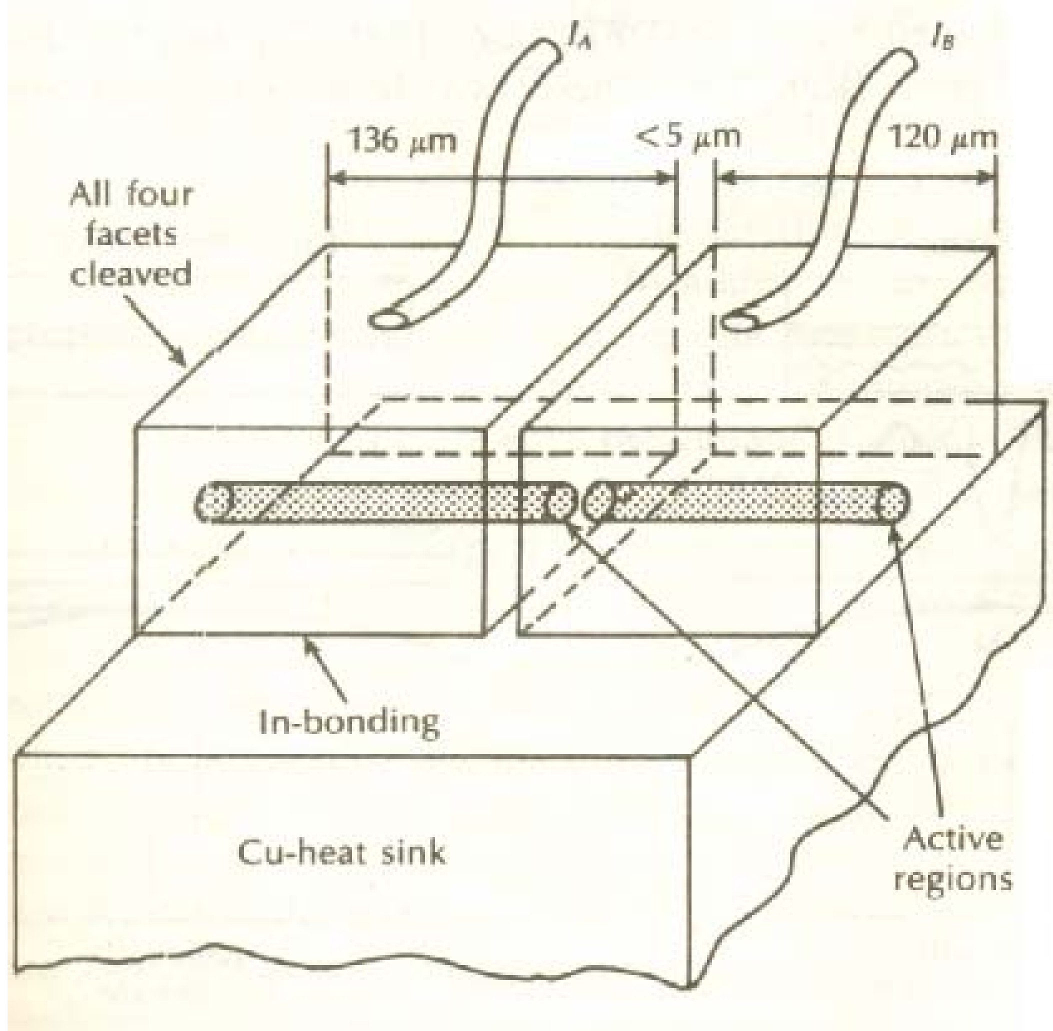
SHORT EXT. CAVITY LASER USING GRIN ROD LENS



COUPLED CAVITY LASER

- Conventional cleaved mirror structures are difficult to fabricate with cavity lengths below 50 μm.
- Configurations employing resonators have been utilized.
- Such resonators form a short cavity length of 10 to 20 μm thereby providing single mode operation.
- Both the cavities shown in the three mirror resonator (previous slide) are in resonance

FIG B: two active laser sections are separated by a λ gap. It yields **cleaved coupled cavity (C^3) laser**.



(b)

CLEAVED COUPLED CAVITY LASER (contd)

This four mirror resonator device provides single mode operation with side mode suppression achieved thr' control of magnitude & phases of two Inj. Currents as well as temp.

Single freq. emission can be tuned over a range of some 26 nm by varying the current thr' one section.

NON- SEMICONDUCTOR LASER

The Nd: YAG laser

Nd: YAG structure-(YTTRIUM-ALUMINIUM-GARNET) = $Y_3 Al_5O_{12}$

DOPED WITH NEODYMIUM(Nd^{3}+),

(RARE EARTH METAL ION)

Max doping level=1.5 %

PROPERTIES :

1) Suitable source for single mode systems (near 1.064 & 1.32 μm wavelength)
2) Narrow line width (<0.01 nm). So less dispersion
3) Long life time
4) Reduced size (dimension)

DRAW BACKS :

1) external Opt. modulator is necessary
2) Technology not developed fully as in semiconductors
3) High Cost due to pumping & modulation

END PUMPED Nd : YAG LASER

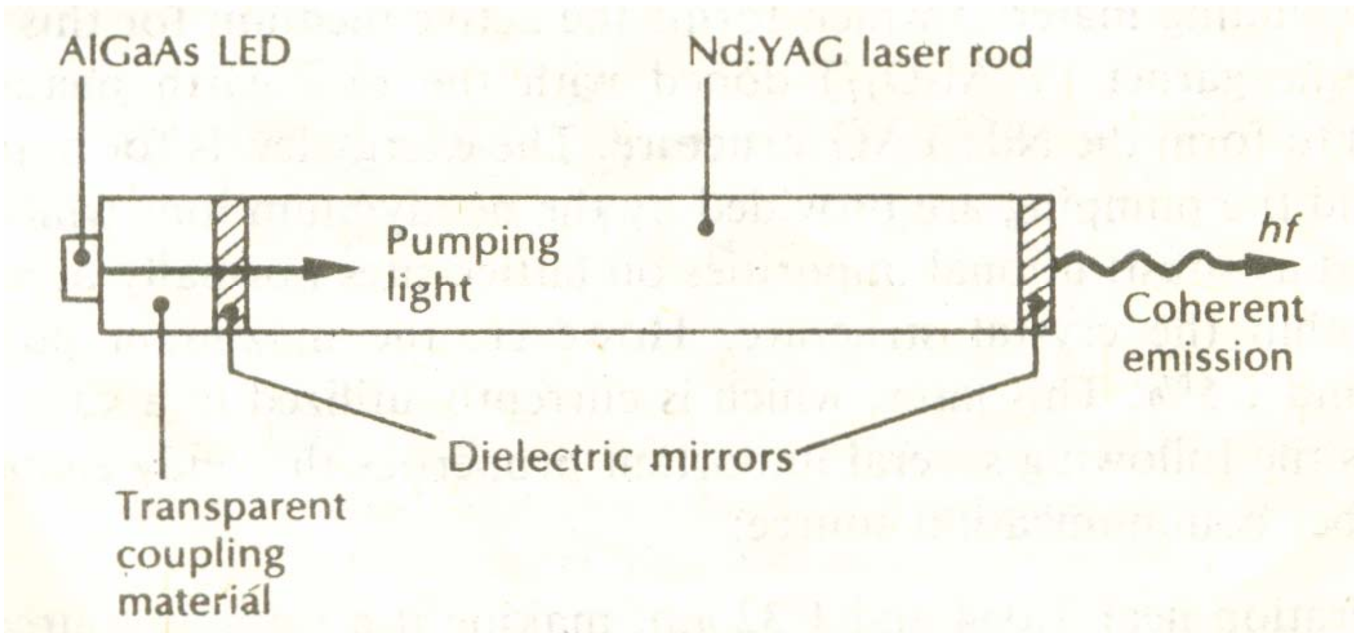


Diagram of an end pumped Nd:YAG laser.

END PUMPED Nd : YAG LASER(contd)

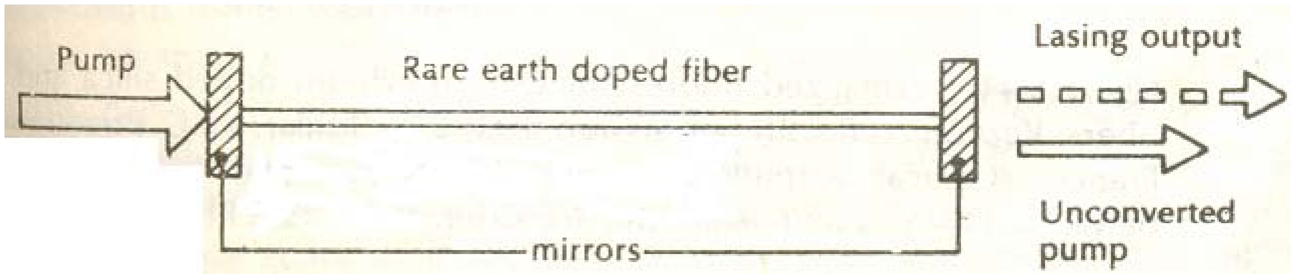
One mirror is fully reflecting , other is 10% transmitting.

Nd: YAG laser is a four level system.

-Strongest pumping bands at wavelengths of o.75 & 0.81 μm, giving major useful lasing transitions at 1.064 & 1.32 μm.

-Single mode operation possible when L is about 1 cm

GLASS – FIBER LASER :-



Opt fiber core doped with rare earth ions forms the laser cavity. (Fabry-Perot cavity).

Rare earth elements Lanthanum (La), atomic no.57

Lutetium- atomic no 71

Major dopants: Neodymium(Nd 3+) Erbium (Er 3+)

La provides a 4 level scheme o/p at 0.90, 1.06 & 1.32 μm

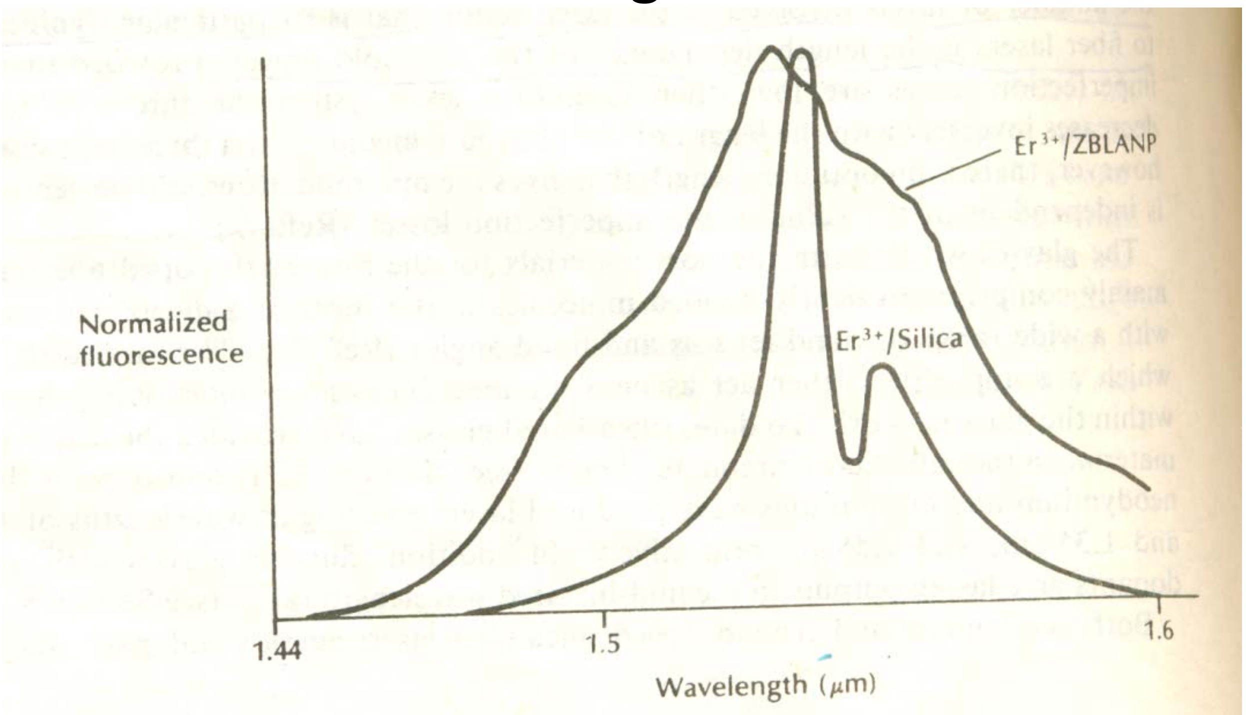
Lutetium provides a 3 level scheme, o/p at(0.80,0.98 & 1.55 μm)

Threshold power depends on length of cavity

Host material :Glass, silica based glass, fluoride glass.

Codopants : phosphorus pentoxide (P_2O_5)
germania (GeO_2, $GeCl_4$)Alumina (Al_2O_5)

Dopant level: 400 parts per million (Low) to avoid crystallisation within the glass structure



Significant spectral broadening of curve occurs due to host glass materials (in contrast to Nd : YAG laser)

ZBLANP(fluorozirconate) fiber has lead fluoride added to glass to raise the relative ref. index

GLASS – FIBER LASER(contd)

LIMITATIONS

- Launching of light from mirror end can cause damage to the mirror coating
- Reduction in launch efficiency
- Gain spectrum extends over 50 nm wavelength but output is between 10 -15 nm
- This linewidth is too narrow for broadband operation but too wide for single freq output

RELIABILITY (LASERS)

Degradation (in behavior)

1)catastrophic 2)gradual

catastrophic degradation could be due to mech. damage of the mirror faces; leading to partial or complete laser failure.

The operation may be limited to low opt. power levels.

Gradual Degradation could be due to

a) Defect formation in the active region
b) Degradation of current confining junctions

a) & b) lead to higher threshold currents thereby lowering the ext. quantum efficiency.

a) Could be due to

i) High density of recombining holes. Non radiative electron – hole recombinations cause point defects (**due to possible strain, thermal gradients) at the active region**, called **Dark Spot Defects(DSD)**

ii) **Mobile impurites in the active region(O_2, Cu, Beryllium or Zinc atoms)**, can cause high local absorption of photons causing dark lines in the o/p spectrum, called **Dark Line defects (DLD)**

b) This is due to increase in leakage current which increases the device threshold and reduces the ext. quantum η.

<u>Use of substrates & treating of mirror faces reduces these defects.</u>

Mean life time (injection laser)≈ 10^6 hours (100 yrs) at op.temp of 50^0c

LASER CHARACTERISTICS

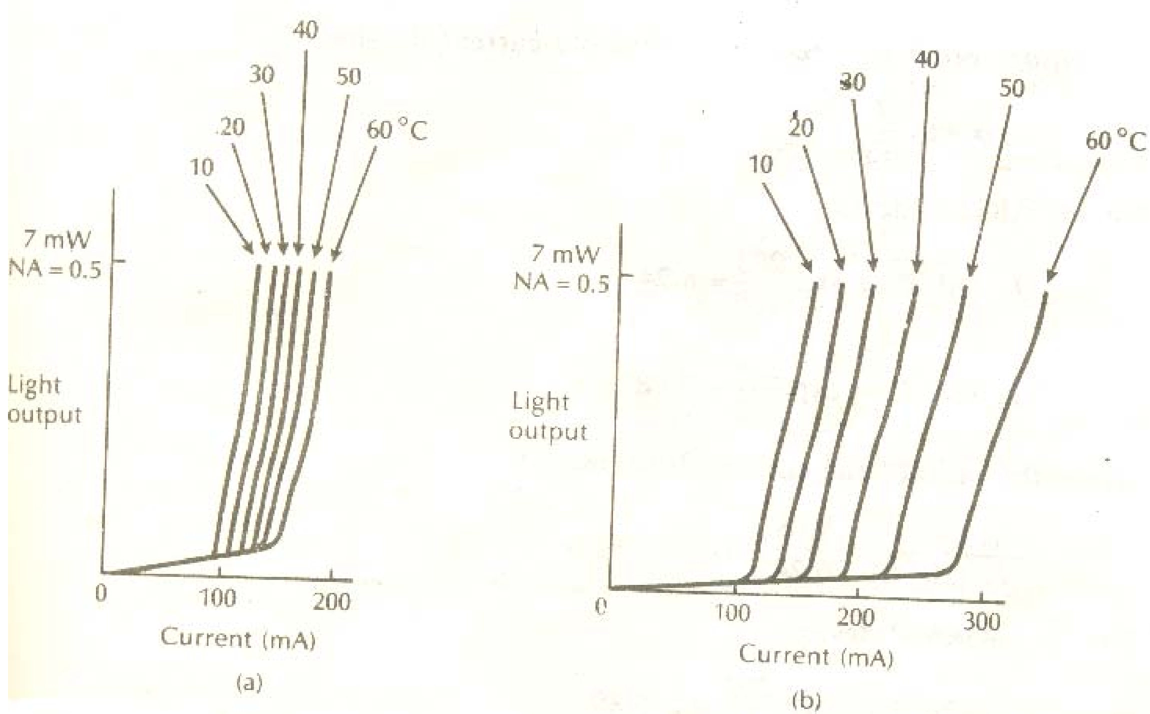
Threshold current temp. dependance

Jth α e^{T/T_0} where T – Device abs. temp

T_0 - Threshold temp coefft. (depending upon quality of material/structure of device)=120 to 190 K for (a) and 40 to75 K for (b)

Stripe width

= 20 µm



Variation in threshold current with temperature for gain-guided injection lasers: a) AIGaAs device; (b) InGaAsP device.

LASER CHARACTERISTICS (CONTD)

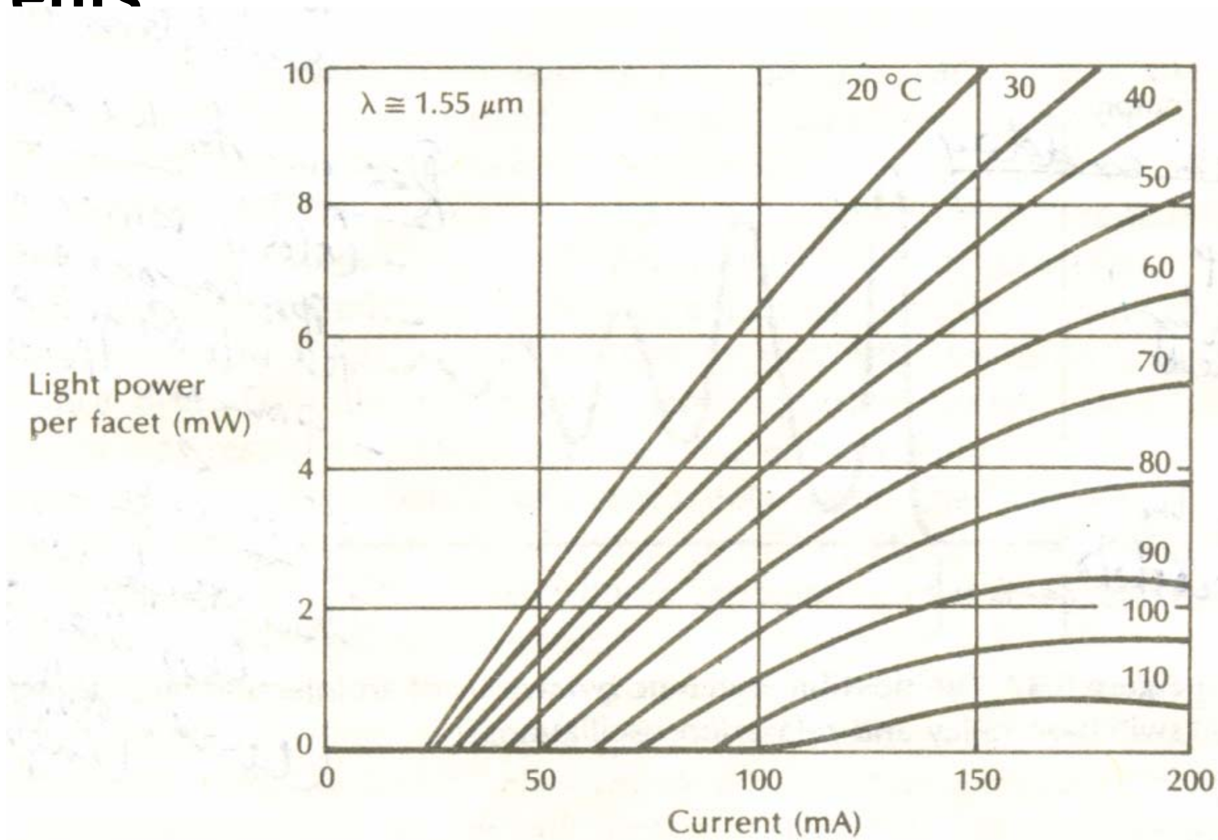
- There is stronger temp. dependence in InGaAsP devices due to increasing energy spread of electrons & holes.
- Intrinsic physical properties of InGaAsP material system (carrier leakage effects, band absorption etc) may cause its higher temp sensitivity.

Note : Higher the value of To, less will be the temp dependence.

Light o/p vs current for a plannar BH In GaAsP laser

(At λ=1.55µm)- Index guided laser

Substantial attention should be paid to **Thermal dissipation to provide efficient heat sinking arrangements to achieve low operating currents**



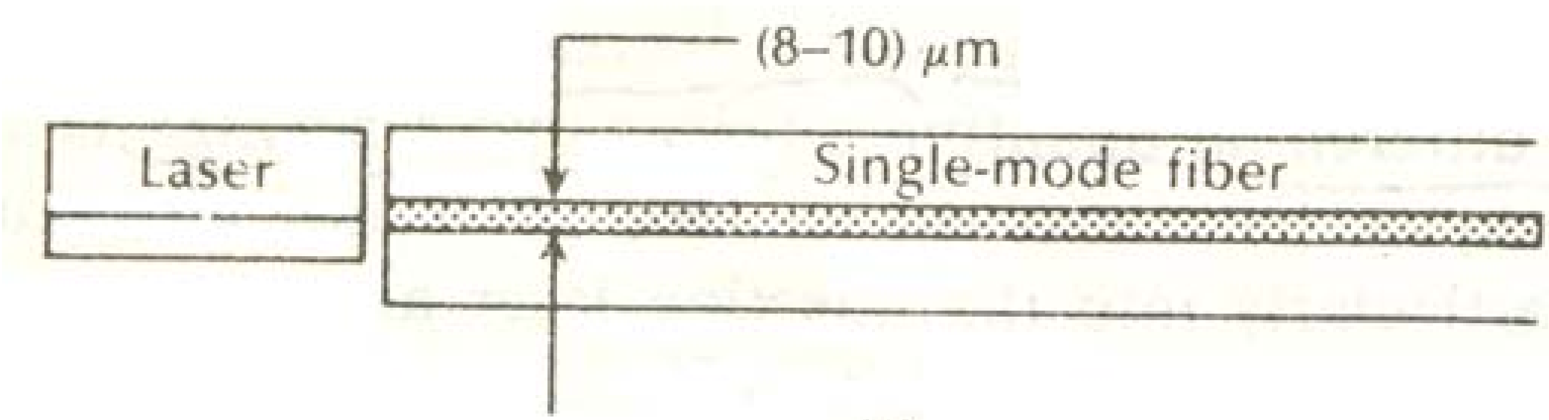
Light output versus current characteristics at various temperatures for a lnGaAsP double channel planar BH laser emitting at a wavelength of 1.55 µm.

INJECTION LASER TO FIBER COUPLING

Light needs to be efficiently coupled between laser & optical fiber (Lasers have diverging o/p fields)

Single mode fibers have narrow acceptance angles, small core dia. & low NA

COUPLING TECHNIQUES - (a) BUTT COUPLING

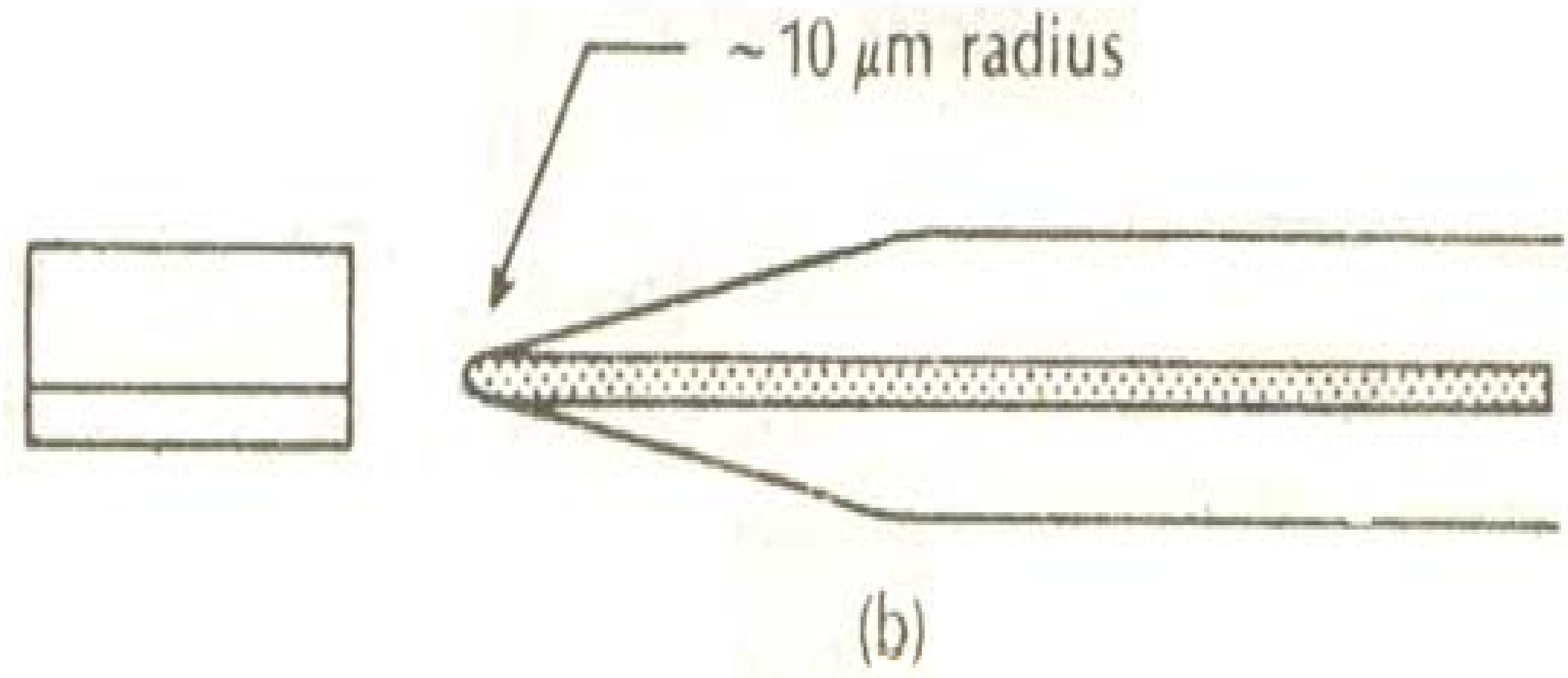


(a)

Disadvantage : Back reflection from fiber, produce noise at output resulting in degradation in performance

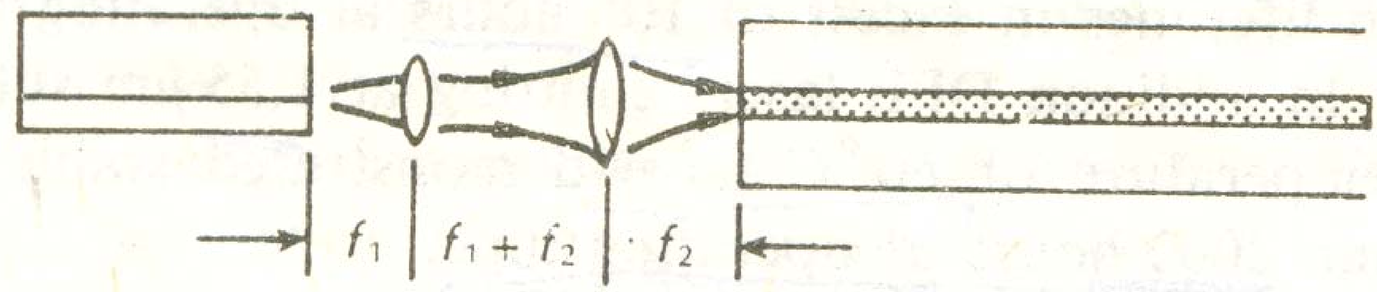
b) TAPERED HEMISPHERICAL COUPLING

o/p field from laser is matched to o/p field of fiber.



Hemispherical lens (10 µm radius) formed on the end of tapered opt. fiber.

CONFOCAL LENS SYSTEM



(c)

Use of lens provides relaxation in alignment tolerance

Efficiency=40 % (with spherical/ grin rod lens)

=49 – 55 % (Grin rod lens with one convex surface and with a silicon plano -convex lens)

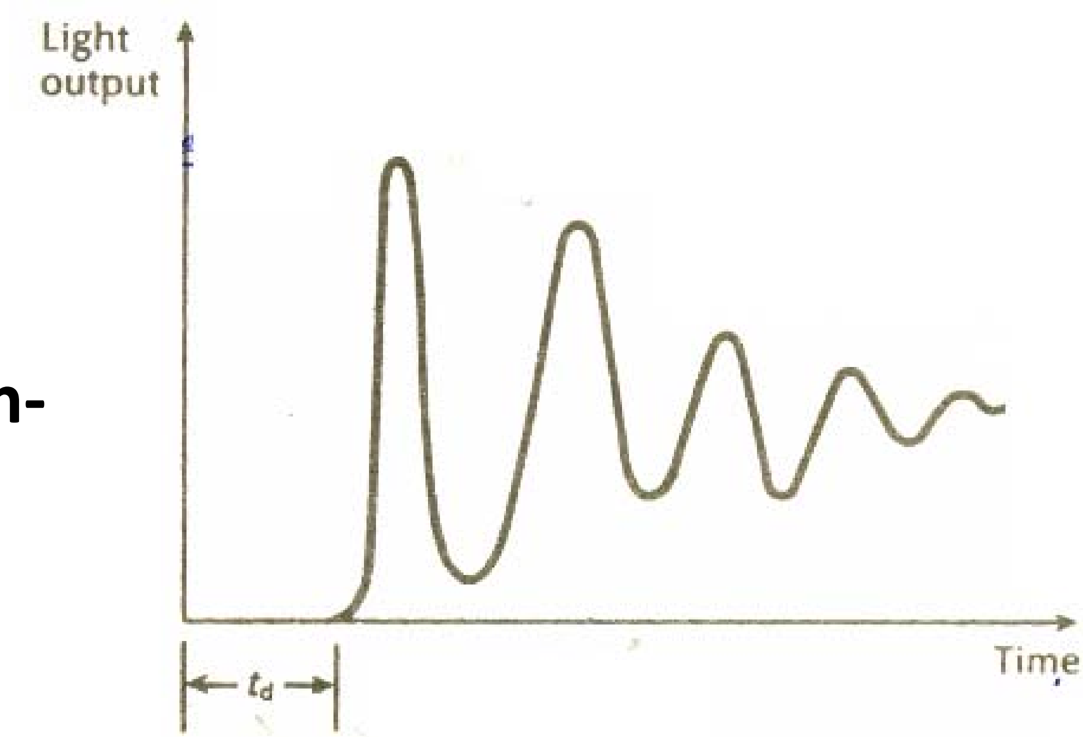
=70 % (silicon lens with a confocal system)

DYNAMIC RESPONSE (INJ. LASER)

This behavior is critical, esp. at high bit rate (wideband)

The application of current results in switch-on delay, followed by HF (≈ 10 GHz or so) damped oscillations known as **relaxation oscillations (RO) .**This is a transient phenomena.

The possible dynamic behavior of an injection laser showing the switch-on delay and relaxation oscillations.



DYNAMIC RESPONSE(contd)

The inj. Laser o/p comprises several pulses as the electron density is repetitively built up and quickly reduced, causing RO's

$t_d \approx 0.5$ ns, RO = twice the t_d approx

At data rates above 100 M bits/sec, a serious deterioration in the pulse shape is produced

-these transient phenomena occur while electron and photon population come into equilibrium

DYNAMIC RESPONSE (contd)

Hence reducing t_d and damping RO is highly desirable.

- The **switch on delay,** which is caused by initial build up of photon density is related to minority carrier lifetime & current thr' the device

This delay is reduced by biasing the laser near threshold (pre-biasing)

- **RO damping is obtained in DH / BH structures with stripe widths less than 3 µm (carrier diff. length).This also helps in giving fast response**

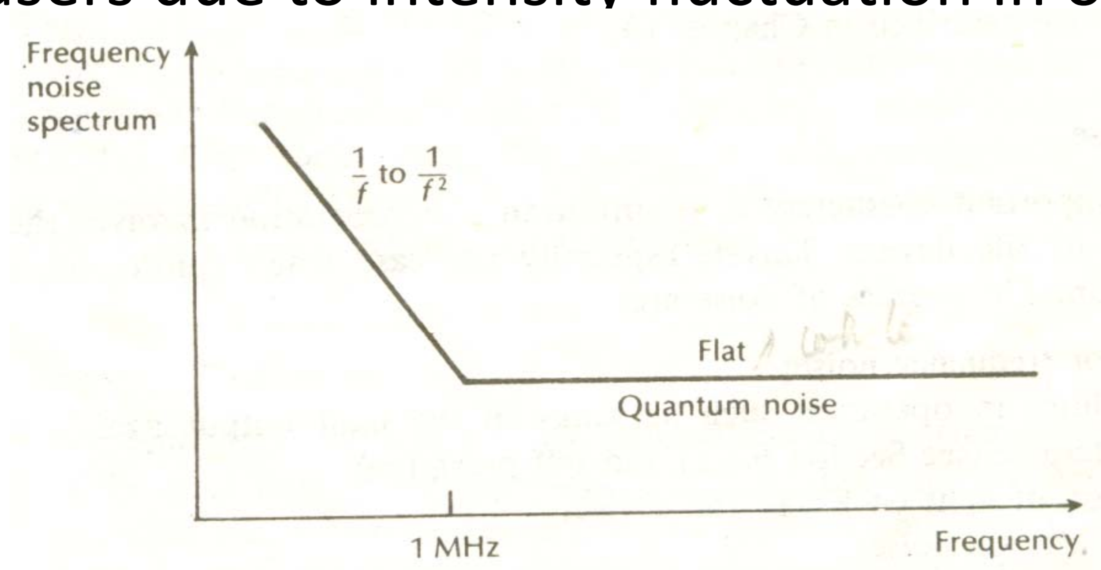
NOISE - ILD (esp. when considering analog transmission)

SOURCES OF NOISE :-

a. **Phase/freq. noise.(Intrinsic property of lasers)**
b. **Instabilities in operation (kinks)**
c. **Reflection of light back into device**
d. **Mode partition noise**

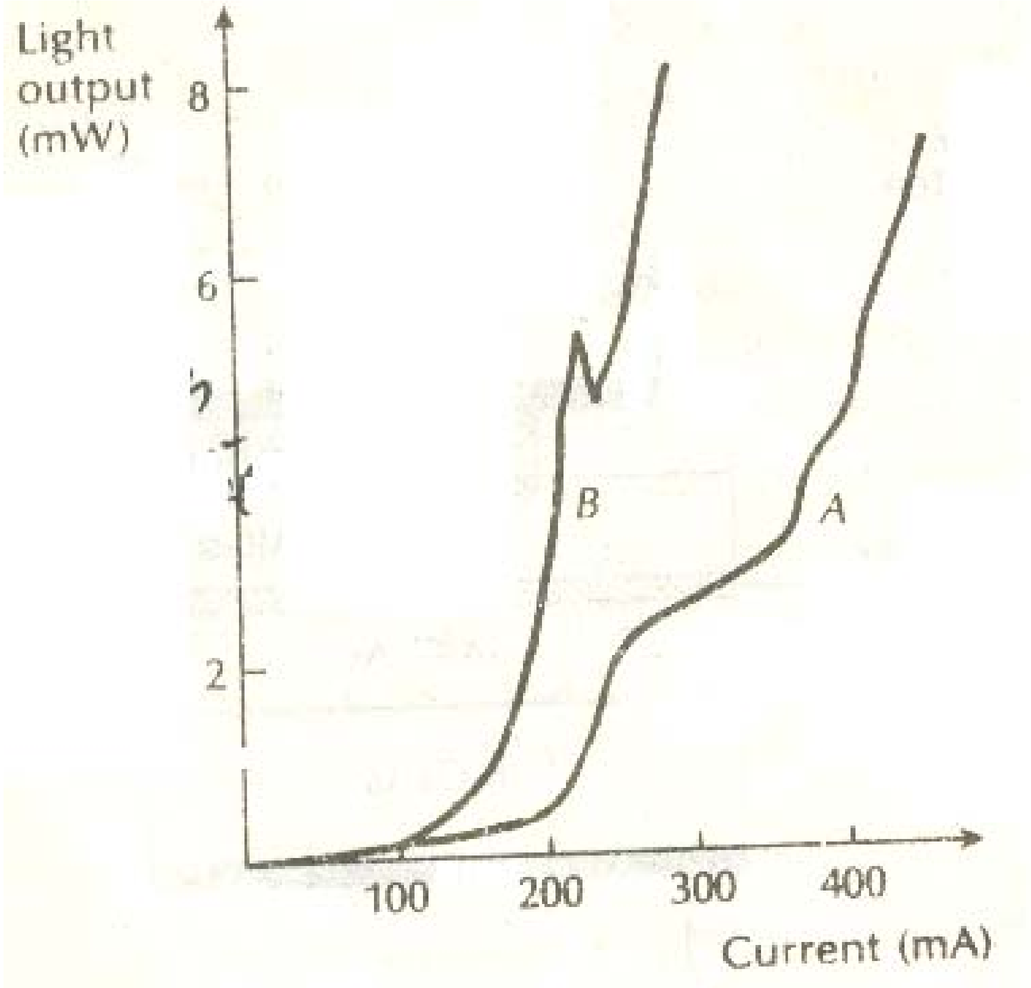
a) PHASE NOISE :- Inevitable aspect of laser emission

Exists in all types of lasers due to intensity fluctuation in opt. emission.



Spectral characteristic showing injection laser phase noise.

b) KINKS :-



The light output against current characteristics for an injection laser with nonlinearities or a kink in the stimulated emission region

Single mode lasers have demonstrated greater noise immunity. (by as much as 30db when $I > I_{th}$)

c) Affects the intensity & freq. stability of SC laser.

d) **MODE PARTITION NOISE**

This occurs in multimode semiconductor lasers (modes not well stabilised) .Temp changes also affect the output.

Note 1 :- At freq above 1 MHz, noise spectrum is flat or white and is known as Quatum noise.

Note 1 :- **Quantum noise is a principle cause of line width broadening,** within semiconductor lasers.

Note 2 :- Below 100 MHz –Quant. Noise ↓ between 200 MHz & 1GHz –Quant. Noise ↑

COMPARISON – LED VS LASER

		LED	LASER
1.	Power/J	Low	High
2.	Coherence	Poor/low	High
3.	Mode of operation	multimode source (with multimode fiber)	Single mode source (with single mode fiber)
4.	Amplification	No	Yes
5.	Light emission process	Spontaneous	Stimulated

COMPARISON – LED VS LASER

		LED	LASER
6.	Line width	30 to 40 nm	1 nm or so
7.	Light focusing capability	Poor	Good

8. **Performance** – Laser has improved performance over LED due to use of stripe geometry/BH/DH , better carrier confinement and faster response

COMPARISON – LED VS LASER

		LED	LASER
9.	Mean life time	$>10^6$-10^7 hrs(100-1000 yrs) AlGaAs $>10^9$ hrs for surface emitting LED (InGaAsP)	10^6hrs (100yrs- at 1.55µm λ (temp 50^0c)
10.	Coupling η	upto 15% (with lens)	upto 65%
11.	Int. Quantum η	50%	60 to 80 %

COMPARISON – LED VS LASER

		LED	LASER
12.	Modulation bandwidth	Low	High
13.	Cost	Low	High
14.	Construction	Simple fabrication (no mirrors, no cavity, no stripe geometry)	Relatively complex fabrication
15.	Reliability	not subject to catastrophic degradation and are much less sensitive to gradual degradation	subject to catastrophic degradation and are more sensitive to gradual degradation

COMPARISON – LED VS LASER

		LED	LASER
16.	Temp Dependence	Less	More (Raising temp increases Threshold current)
17.	Drive circuitry –	simple	Complex
18	Linearity	Yes	No

Note : Advantages of LED over LASER (SI NO 13 to 18) combined with high radiance development and possible use of high BW devices have ensured that LED remains an extensively used source for OFC.

Assignment

- Discuss different kind of LASERS with their advantages and disadvantages.

- What are non semi conductor lasers? Give their properties & disadvantages.

- Discuss Laser characteristics in detail.

- Give detailed comparison list between LASERS and LEDS.