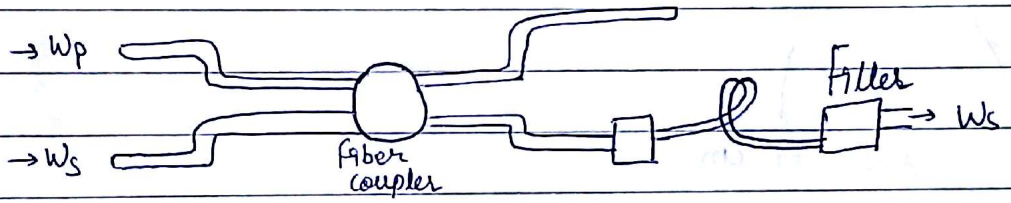
* Raman Amplifiers

- Fiber based amplifier which uses stimulated raman scattering in silica fiber when intense pump beam propagates thru it.
- Diff b/w SRS & SE: In SRS, the incident pump photon looses its energy to create another photon of reduced energy & low frequency.

Basic component are:- 1) Pump laser 2) wavelength selective coupler 3) Fiber.



W_p → Pump frequency
W_s → signal frequency

- Energy is transferred from pump beam to signal beam via SRS.
- Pump signal in RA are 500/cm higher in freq. than the signal to be amplified.
- Pump signal can propagate in both forward/backward direction.

- **Raman Gain**

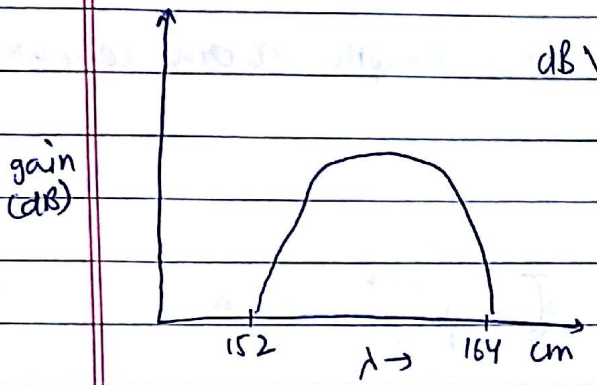
$$G_R = \exp\left[\frac{g_R P_p L_{eff}}{A_{eff} K}\right]$$

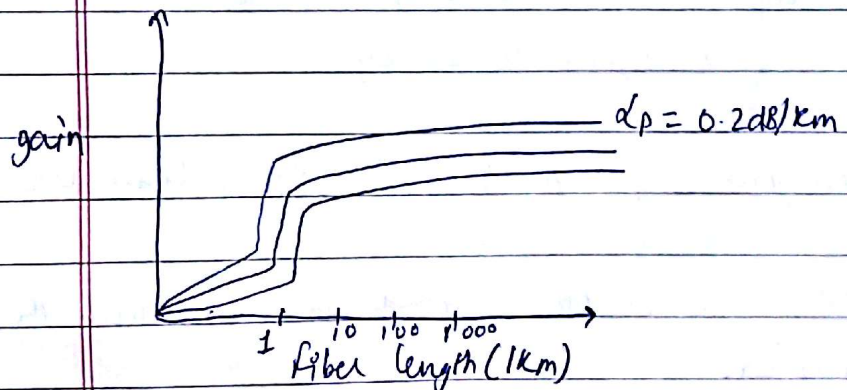
g_R → Ramain gain coefficient
L_{eff} → Length
P_p → Pumping power
A_{eff} → Area of fiber core
K → Numerical factor

- Higher G_R, less Losses

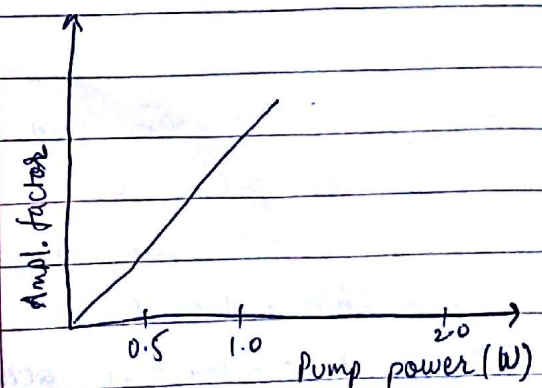
Advantages

1) Self phase matching b/w pump & signal
2) High speed Response
3) Low coupling Loss
4) High gain
5) More stability & insensitivity to the reflection.





gain Vs fiber length.



SBS

$P_B = 4.4 \times 10^{-3} \times d^2 \times \lambda^2 \times \alpha_{dB} \nu$ watts.

$d \rightarrow$ core diameter (μm)
$\lambda \rightarrow$ wavelength (μm)
$\alpha_{dB} \rightarrow$ attenuation in dB/km
$\nu \rightarrow$ source B.W (GHz).

- Modulation of light through thermal molecular vibration in fiber.
- Incident photon in this scattering process produces a ~~photon~~ phonon of acoustic freq.
- The incident photon produces an optical freq. shift which is max. in backward direction & zero in forward.

Mechanism

- Power level of incident light is increased through stimulated emission. Mechanism is same for laser diode to produce population Inversion.

- O/P is not a coherent light.
- External source is Pump.
  Pump raises e^- to excited state for PI
  Incoming photon triggers excited e^- & bring them to a lower state thereby producing an amplified signal.

- SBS can transfer energy from higher freq. channel to a lower when channel spacing = Brouillin shift.

$$\nu_B = \frac{\Omega_B}{2\pi} = 2\bar{n}\frac{V_A}{\nu_P}$$

$\bar{n} \rightarrow$ mode index

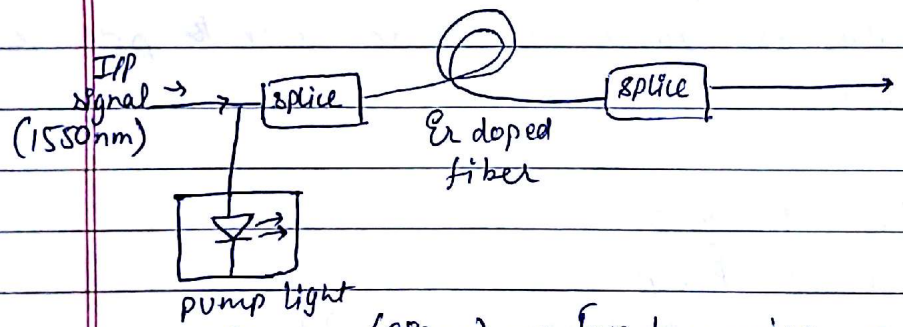
- Provides high gain at modest optical pump power of around 1mW.
- Narrow band process
- Does not induce interchannel crosstalk when channels propagates in forward direction.
- Does not limit channel power.

Advantages

- Used for channel selection within WDM system by allowing amplification of 1 channel w/o boosting others.

* EDFA

Working Principle



(980nm) → for low noise power
1480nm → not efficient coz low degree of PI

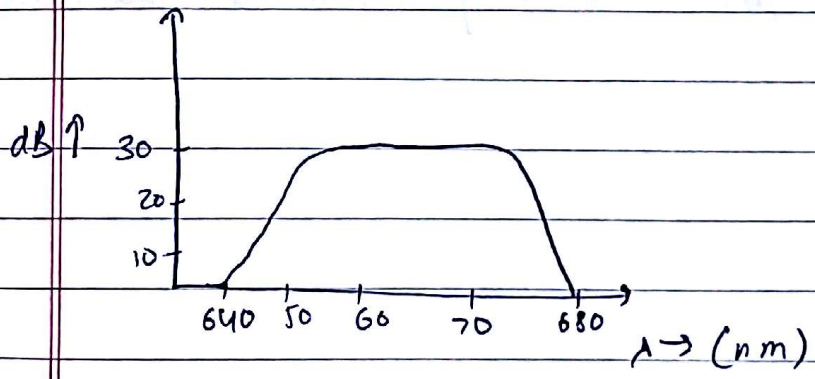
- Minimal interchannel crosstalk interference
- High power → 200mW
- Insensitive to bit rate modulation format, power & d.
- Low - distortion, naise, insertion loss
- high - pumping, sensitivity
- Long distance optical communication as fiber loss is less than 2dB/km

Advantages

- Provides inline Amplification w/o requiring the signal to be converted to electrical i.e Amplification is entirely optical.
- High power transfer efficiency (Pump to laser)
- Amplification is independent of data Rate.
- Gain is flat so that they can be cascaded for long distance use.

$$\text{Gain} = 10 \log_{10} \frac{P_{out}}{P_{in}}$$

Gain of EDFA depends on pump power & pump 'λ'.
Gain ↑ as temp ↓



- Gain Flattening - Required for cascading EDFA.
  Relative flat gain > 20 dB for WDM app.

- Gain Saturation - The max. o/p power beyond which no amplification occurs is known as gain saturation.

* Noise Figure
- Measure of quality of Amplification.

$$N.F = \frac{SNR(I/P)}{SNR(O/P)}$$

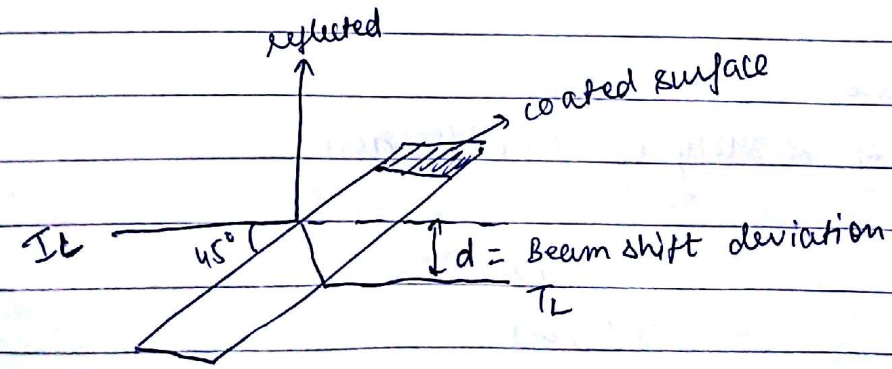
* Beam Splitter
- Splits beam of incident light
- Using planar waveguide technology

1) Plate beam splitter
- Consists of thin flat glass plate quoted with thin film layer of metallic or dielectric coating.
- Introduces a shift deviation into light beam due to thickness of plate.
- For normal deviation ∠Incidence = 45°.

- Divides optical beam based on Power / λ.
- Reflected & T^x optical path length are different.
- Designed for highest power handling & coating types determine the strength.

Advantages
- Inexpensive
- Light weight
- Easy to manufacture

Disadv
- Beam shift of T^x Light.
- Reflected & T^x optical paths are different
- R^x & T^x optical paths are different



2) Cube Beam Splitter

- Consists of two triangular glass prism joined together at base by using polyster epoxy.
- Used to split incident light into separate polarised components S-polarised & p-polarised
- Divides optical beam on power/polarization.
- S-polarized light is ⊥ to incident light & P-polarized light is // to incident light

Advantages

- No beam shift
- R^x & T^x optical paths are equal
- Easy integration
- Stable & compact.

Disadv.

- Heavy solid glass constant.
- Difficult to manufacture in larger sizes
- Expensive.