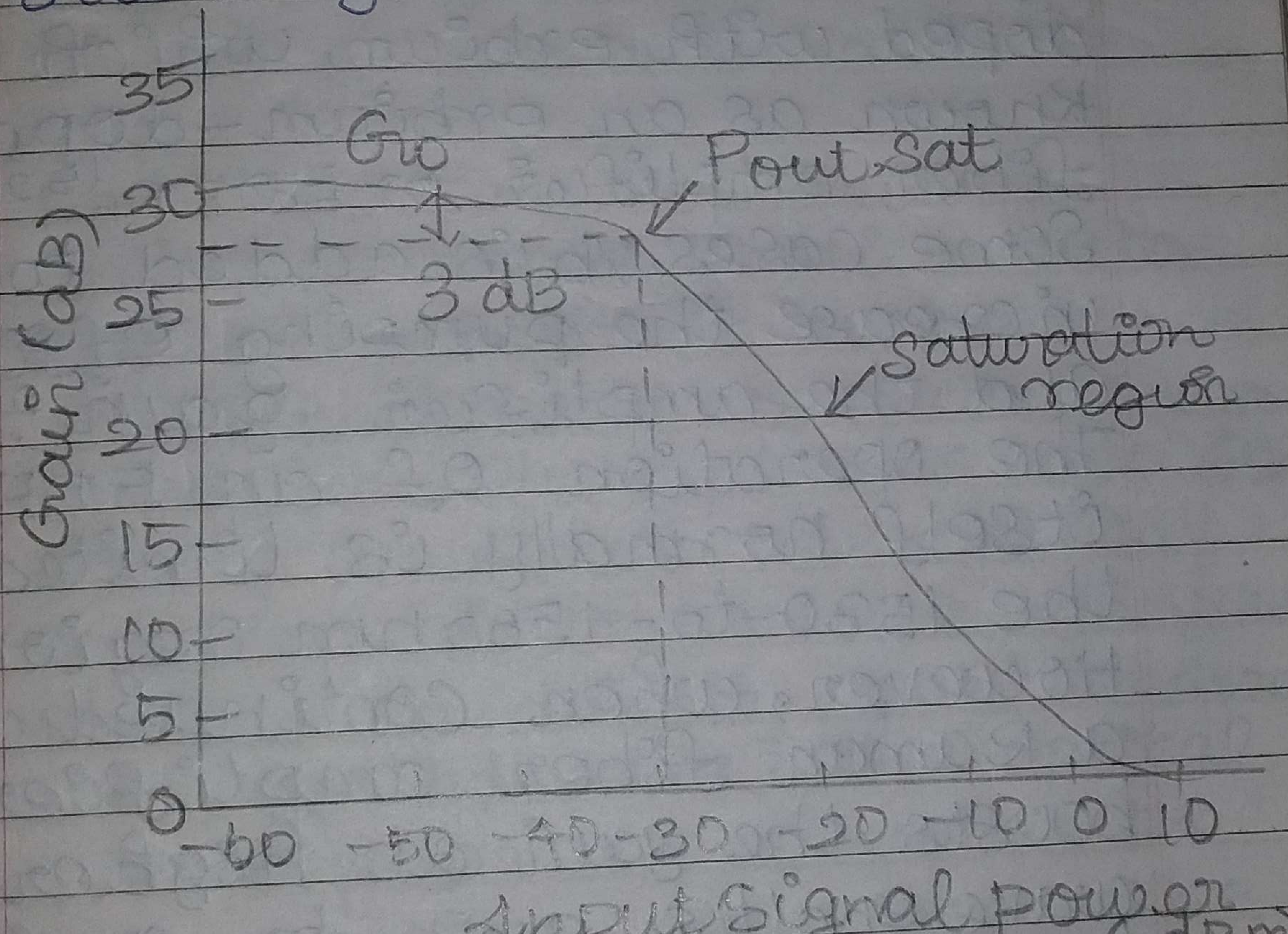
coefficient K is given by.

$$K = \frac{\pi \delta n \eta}{\lambda_{Bragg}} \quad ---(7)$$

Erbium-Doped Fiber Amplifiers:

The active medium in an optical fiber amplifier consists a normally 10 to 30-m length of optical fiber, that has been lightly doped. (eg (1000 parts per million weight) with a rare earth element, such as erbium (Er), ytterbium (Yb), neodymium (N or praseodymium (Pr). The host fiber material can be either standard silica, a flouride-based glass, or a multicomponent glass.

The operating regions of these devices depend on the host material and the doping elements. Fluorozirconate glass doped with Pr or Nd are used for operation in the 1300-nm window, since neither of these ions can amplify 1300 n-m signals when embedded in silica glass.[12-14]



Typical dependence of the single pass-gain on optical input power for a small signal gain of G0 = 3 dB (a gain of 1000).

* repeat.

[Since, neither of those ions can amplify 1300nm signals when embedded in silica glass[12-14]. The most popular material for long-haul telecommunication applications is a silica fiber doped with erbium, which is known as an erbium-doped fiber amplifier or EDFA.[15-20] In some cases, Yb is added to increase the pumping efficiency and the amplifier gain[21]. The operation of an EDFA by itself normally is limited to the 1530-to-1560 nm region. However, when continued with a Raman fiber amplifier that boosts the gain at higher wavelengths, a 3-dB gain bandwidth of 75 nm has been achieved over the 1531-to-1616-nm region.[22] For simplicity of discussion in this section, we will use the designation "1550-nm signals" to refer to any particular optical channel in this spectral band.

Amplification Mechanism:

Whereas semiconductor optical amplifiers use external current injection to excite electrons to higher energy levels, optical fiber amplifiers use optical pumping. In this process, one uses photons to directly raise electrons into excited states. The optical pumping process requires the use of three energy levels. The top energy level to which the electron is elevated must lie energetically above the desired lasing level. After reaching its excited state, the electron mus[t] release some of its energy and drop to the desired lasing level. From this level, a signal photon can then trigger it into stimula[ted] emission, whereby it releases its remaining energy in the form of a new photon with a wavelength identical to that of the signal photon. Since the pump photon must have a higher energy than the signal photon, the pump wavelength is shorter than the signal wavelength.

The metastable band is separated from the bottom of the 4/15/2 ground state level by an energy gap ranging from about 0.814 eV at the bottom of the metastable band (1527- to 0.841 eV at the ~~top~~ (1477-nm photon

The energy band for the pump level exists at a 1.27-eV separation (corresponding to a 980-nm wavelength) from the ground state. The pump band is fairly narrow, so that the pump wavelength must be exact to within a few nanometers. The gap b/w the top of the $^4I_{15/2}$ level and the bottom of the metastable band is around 0.775 eV (1600 nm).

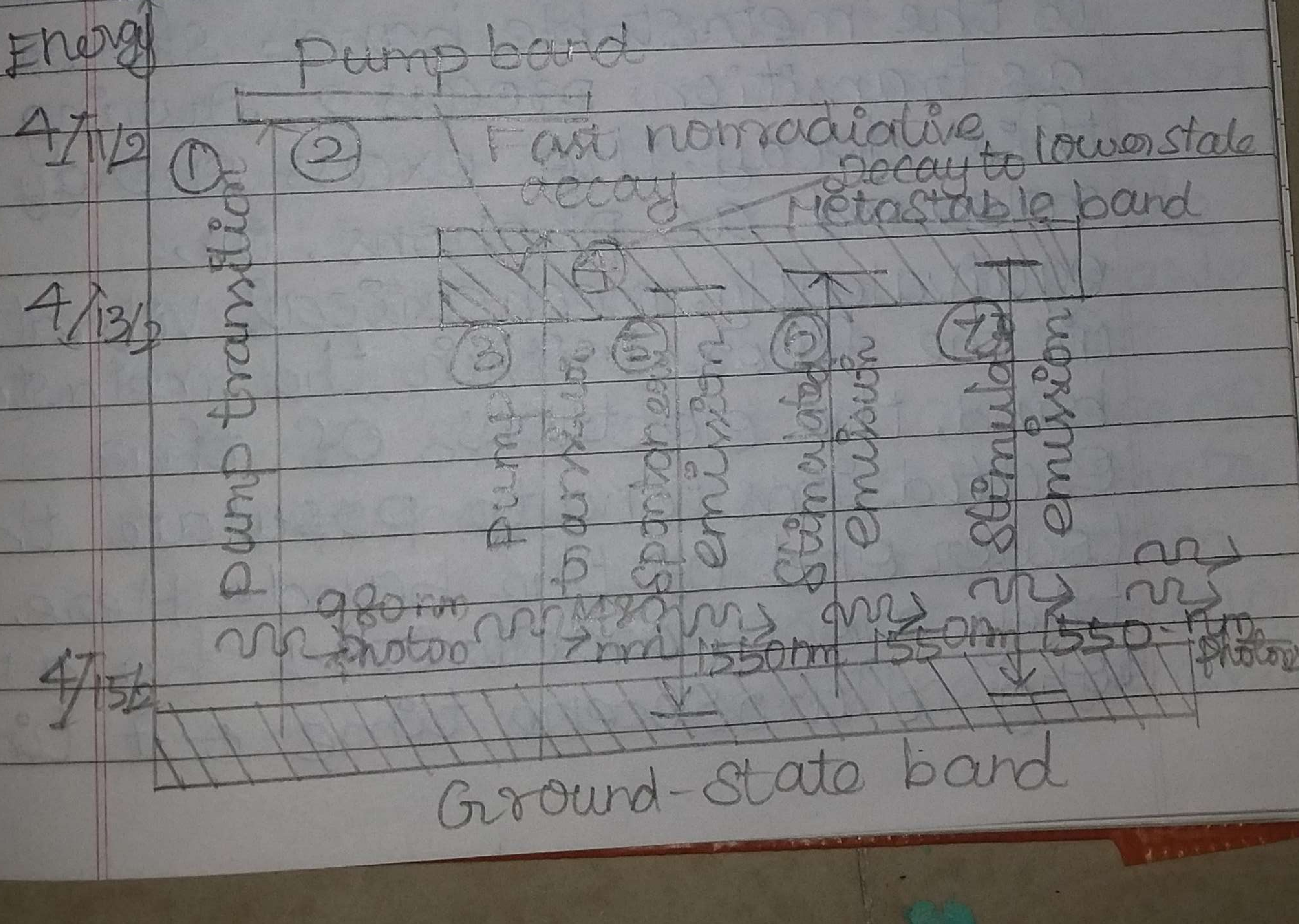


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Fig:- Simplified energy level diagrams and various transition processes of Er^{3+} ions in silica.

In normal operation, a pump laser emitting 980-nm photons is used to excite ions from the ground state to the pump level as shown by transition process 1 in Figure. These excited ions decay (relax) very quickly (in about 1 μs) from the pump band to the metastable band, shown as transition process 2, During this decay, the excess energy is released as phohons, or, equivalently, mechanical vibration in the fiber. Within the metastable band, the electrons of the excited ions tend to populate the lower end of the band. Here they are characterized by a very long fluroSecene time out time of about 10 ms.

Another possible pump wavelength is 1480 nm. The energy of these pump photons is very similar to the signal-photon energy, but slightly higher. The absorption of a 1480-nm pump photon excites an electron from the ground state directly to the lightly populated top of the metastable level, as indicated by transition process 3. These electrons then tend to move down to the more populated lower end of the metastable level (transition 4). Some of the ions sitting at the metastable level can decay back to the ground state in the absence of an externally stimulating photon flux, as shown by transition process 5. This decay phenomenon is known as spontaneous emission

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and adds to the amplifier noise.
Two more types of transitions occur when a flux of signal photons that have energies corresponding to the band-gap energy b/w the ground state and the metastable level passes through the device. First, a small portion of the external photons will be absorbed by ions in the ground state, which raises these ions to the metastable level, as shown by transition process 6. Second, in the stimulated emission process (transition process 7) a signal photon triggers an excited ion to drop to the ground state, thereby emitting a new photon. Of the same energy, wavevector, and polarization as the incoming signal photon

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The width of the metastable and ground-state levels allow high levels of stimulated emissions to occur in the 1530-to-1560-nm range. Beyond 1560 nm, the gain decreases steadily until it reaches 0 dB (unity gain) at around 1616 nm.

EDFA Architecture:-

An optical fiber amplifier consists of a doped fiber, one or more pump lasers, a passive wavelength coupler, optical isolators, and tap couplers, as shown in Figure. The dichroic (two-wavelength) coupler handles either 980/1550-nm or 1480/1550 nm wavelength combinations to couple both the pump and signal optical powers efficiently into the fiber amplifier. The

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tap couplers are wavelength intensitive with typical splitting ratios ranging from 99:1 to 95:5. They are generally used on both sides of the amplifier to compare the incoming signal with the amplified output. The optical isolators prevent the amplified signal from reflecting back into the device, where it could increase the amplifier noise and decrease its efficiency.

The pump light is usually injected from the same direction as the signal flow. This is known as codirectional pumping. It is also possible to inject the pump power in the opposite direction to the signal flow, which is known as counter-directional pumping. One can employ either a single pump

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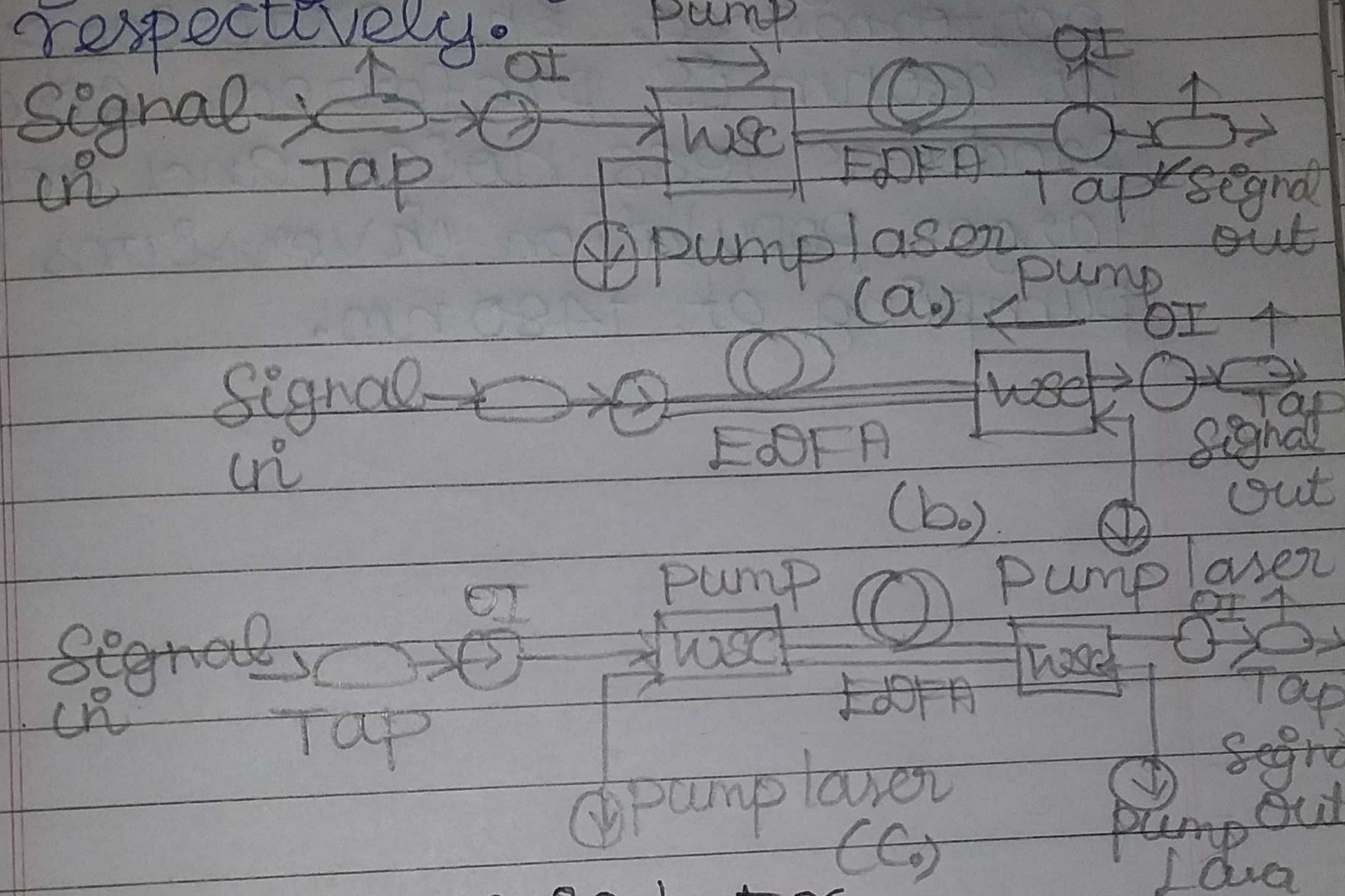
Source or use dual-pump schemes with the resultant gains typically being +17 dB and +35 dB respectively.



OI: optical isolator
WSC: wavelength selective coupler
There possible configurations of as EDFA: (a) codirectional pumping, (b) counterdirectional pumping, (c) dual pumping.

Counterdirectional pumping allows higher gains, but codirectional pumping gives better-noise performance. In addition, pumping at 980nm is preferred. Since it produces less noise and achieves larger population inversions than pumping at 1480 nm.