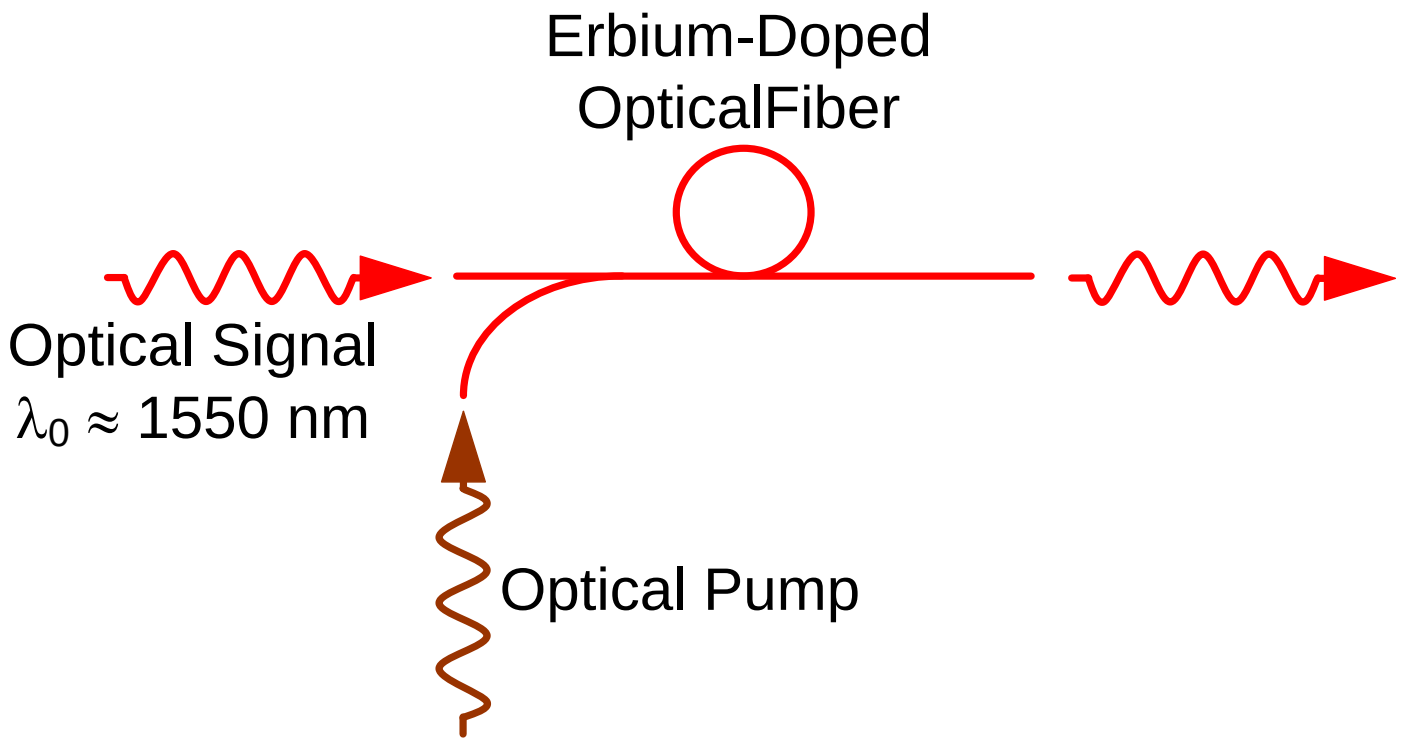
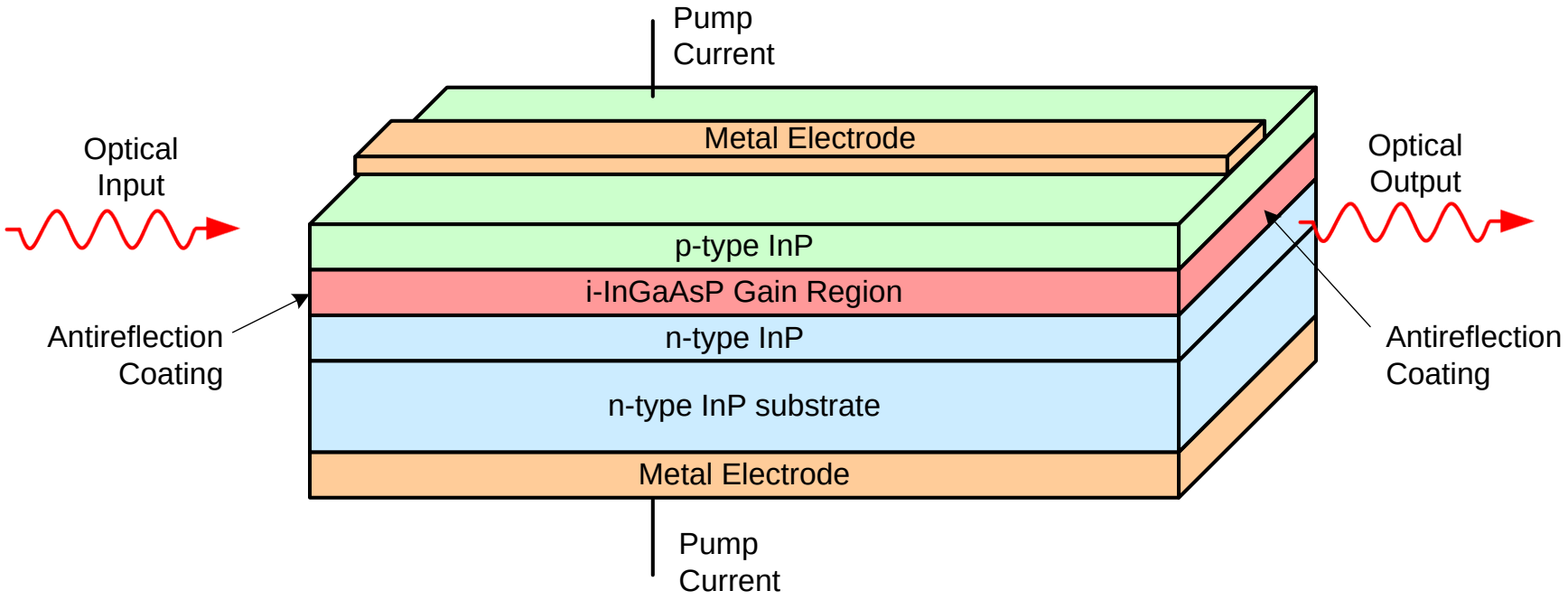
Types of Optical Amplifiers

- Erbium Doped Fiber Amplifiers (EDFA's)
  - Best performance
  - Wide spread use
- Raman Amplifiers
  - Used in conjunction with EDFA's
- Semiconductor Optical Amplifiers
  - Small package
  - Potential use for low-cost applications
  - Potential use for optical switching

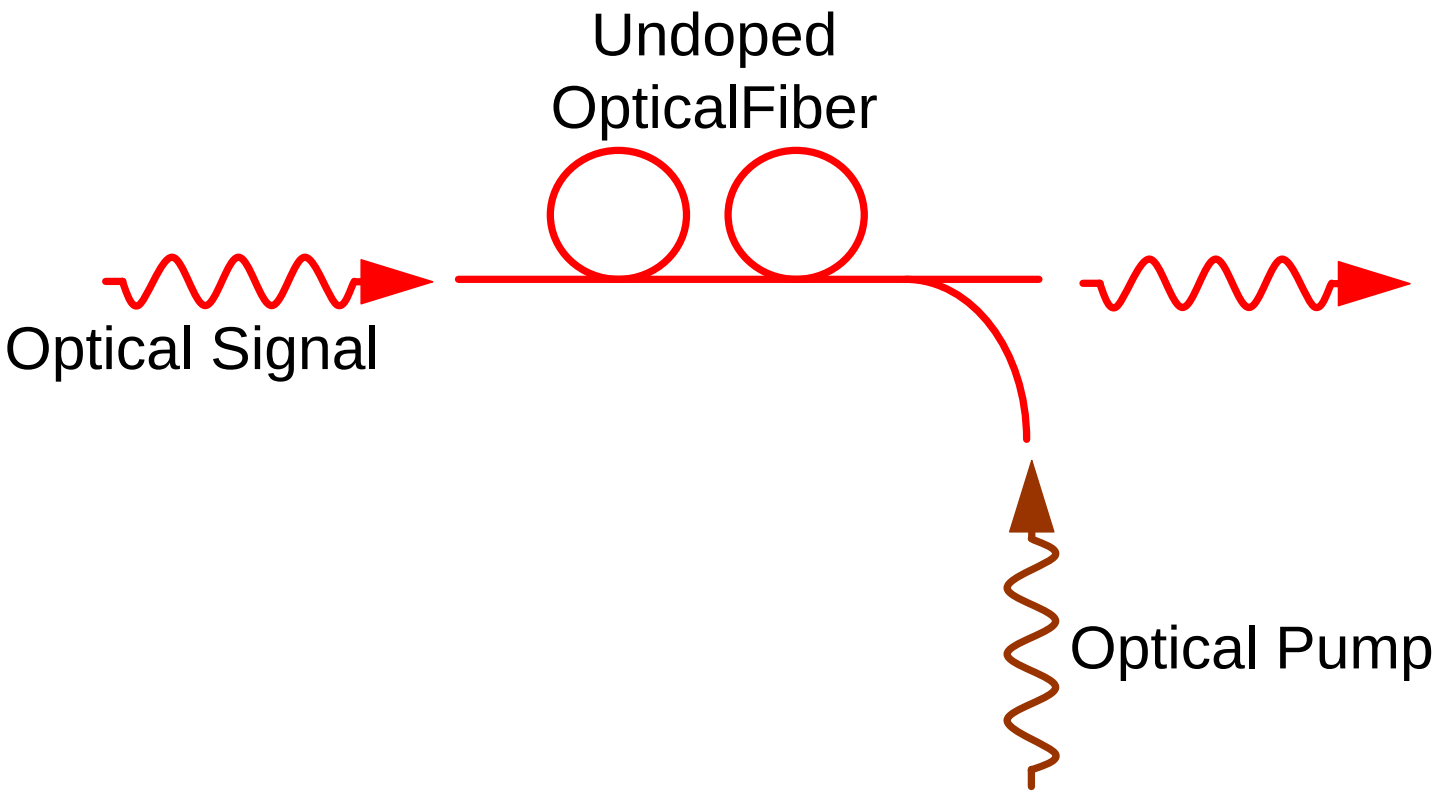
Erbium-Doped Fiber Amplifiers



Semiconductor Optical Amplifiers



Fiber Raman Amplifier



Typical EDFA Characteristics

Wavelength	1.55 μm
Bandwidth	30-40 nm
Gain	30-45 dB
Pump Power	20-100 mW
Pump Wavelength	980 nm, 1480 nm
3 dB Saturation Power	5-10 dBm
Polarization Sensitivity	No
WDM Crosstalk	No
Noise Figure	4-6 dB

$$\text{Noise Figure} = \frac{\text{Signal-to-Noise Ratio}_{in}}{\text{Signal-to-Noise Ratio}_{out}}$$

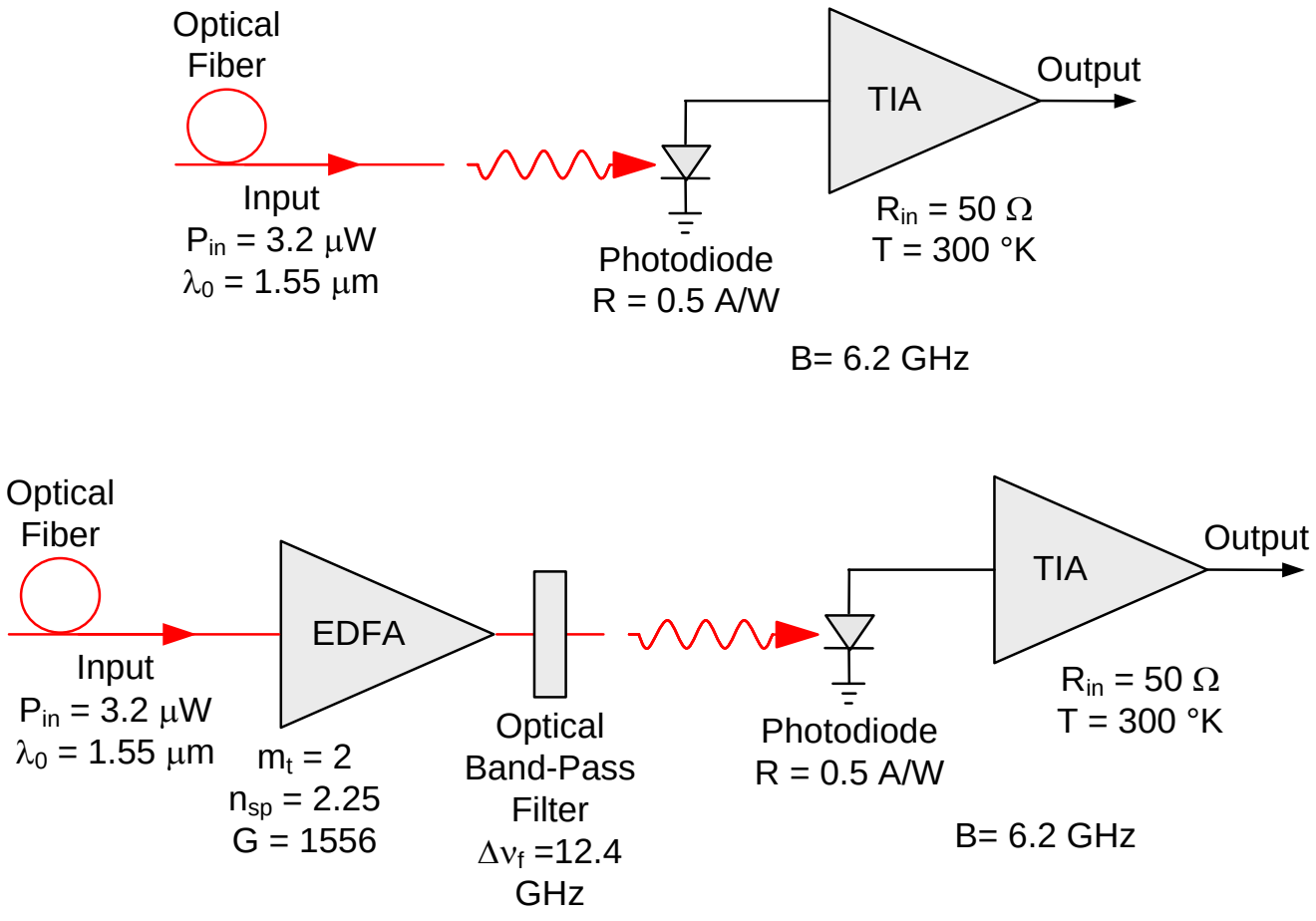
0 dBm = 1 mW

Optical Communication Bands

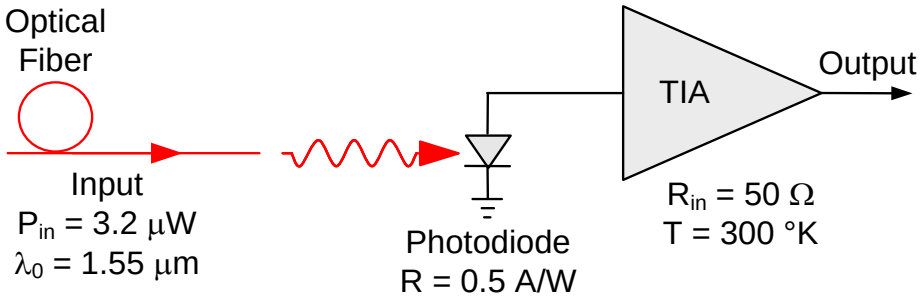
Band	Descriptor	Range (nm)
O band	Original	1260 to 1360
E band	Extended	1360 to 1460
S band	Short wavelength	1460 to 1530
C band	Conventional	1530 to 1565
L band	Long wavelength	1565 to 1625
U band	Ultralong wavelength	1625 to 1675

Source http://www.linktionary.com/f/fiber-optic.html

EDFA as a Pre-Amplifier



Noise Sources Without EDFA



$$\left\langle i_{shot}^2 \right\rangle = 2eI_sB$$

$$= 2\left(1.6\times10^{-19}\right)\left(3.2\times10^{-6}\times0.5\right)6.2\times10^{9}A^2$$

$$= 3.174\times10^{-15}A^2$$

$$\left\langle i_{ther}^2 \right\rangle = \frac{4kTB}{R_{in}}$$

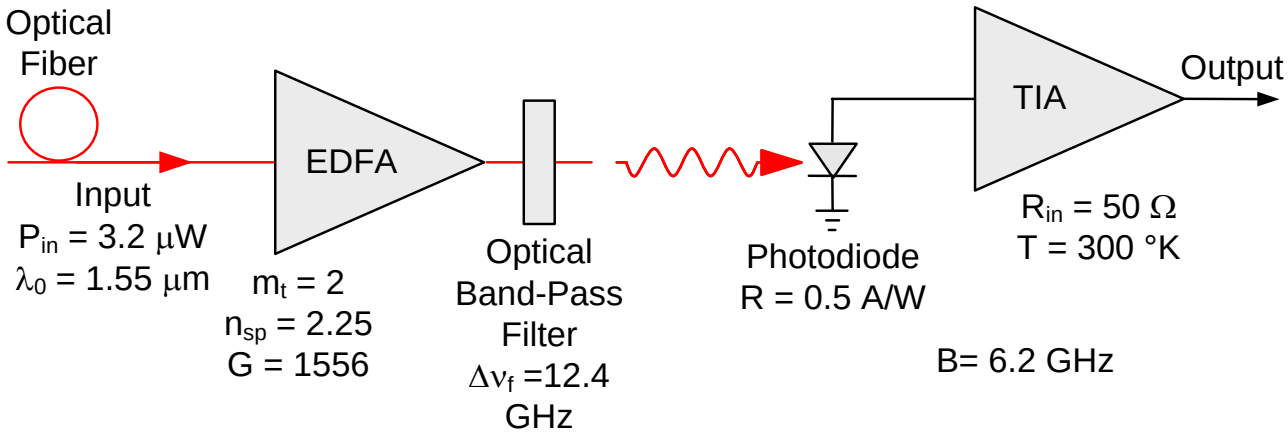
$$= \frac{4\left(1.38\times10^{-23}\right)(300)\left(6.2\times10^{9}\right)}{50} = 2.053\times10^{-12}A^2$$

Signal-to-Noise Ratio (SNR) - No EDFA

$$SNR = \frac{\left(P_s R\right)^2}{\frac{4kTB}{R_{in}}} = \frac{\left(3.2\mu W \times 0.5 A/W\right)^2}{\frac{4\left(1.38\times10^{-23}\right)(300)\left(6.2\times10^{9}\right)}{50}}$$

$$= \frac{2.56\times10^{-12}A^2}{2.053\times10^{-12}A^2} = 1.25$$

Amplified Spontaneous Emission (ASE) in the EDFA



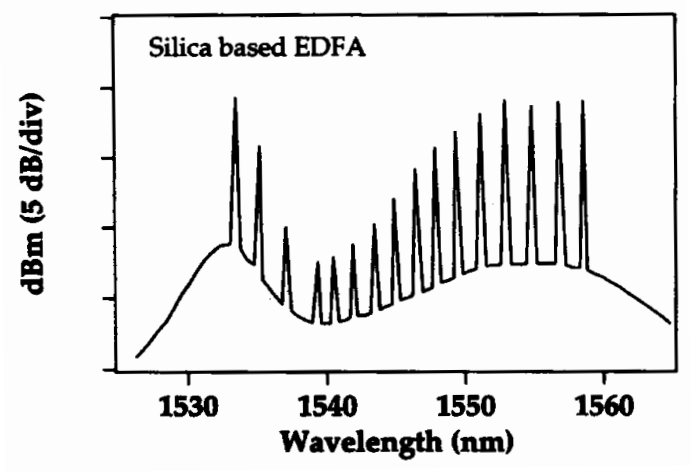
$$P_{ASE} = m_t n_{sp} h\nu \Delta\nu_f$$

$$= (2)(2.25)\left(6.63\times10^{-34}\right)\left(1.94\times10^{14}\right)\left(1.24\times10^{10}\right)$$

$$= 7.18x10^{-9}W$$

$$I_{ASE} = RP_{ASE} = (0.5)\left(7.18\times10^{-9}\right) = 3.59\times10^{-9}A$$

"Beat" Noise from the EDFA



$$\left\langle i^2_{sig-spon} \right\rangle = 4GI_sGI_{ASE}\frac{B}{\Delta\nu_f}$$

$$= 4(1556)\left(3.2\times10^{-6}\times0.5\right)(1556)\left(3.59\times10^{-9}\right)\frac{6.2\times10^{9}}{1.24\times10^{10}}$$

$$= 2.78\times10^{-8}A^2$$

SNR with EDFA Pre-Amplifier

$$SNR = \frac{\left(GP_s R\right)^2}{\left\langle i^2_{sig-spon} \right\rangle}$$

$$= \frac{\left(1556 \times 3.2\mu W \times 0.5 A/W\right)^2}{2.78 \times 10^{-8} A^2} = 223$$

- 180 times better SNR with EDFA pre-amplifier