Graded Exercise

Part 1:

An Erbium doped fiber amplifier built from a co-doped silicate L22 fiber could be used to amplify a 940 nm signal, where the spontaneous life time is 0.001 ms, or in the C-band, where the spontaneous lifetime is 14.5 ms. You can either pump at 800 nm or 980 nm, where the absorption cross sections are $4 \cdot 10^{-22}$ cm^2 and $10 \cdot 10^{-22}$ cm^2, respectively. The fiber has a radius of 4 μm.

(a) What pump wavelength would you use to amplify 940 nm? What minimum pump power would it require? Is such amplifier practical? What is the limiting factor?

Should use 800 nm only.

$$P_{\min} = \frac{a_p h\nu}{\sigma_a \tau_{sp}} = \frac{\left(\pi\left(4\cdot 10^{-6}\right)^2\right)\left(6.626\cdot 10^{-34}\frac{\left(3\cdot 10^8\right)}{\left(800\cdot 10^{-9}\right)}\right)}{\left(4\cdot 10^{-26}\right)\left(0.001\cdot 10^{-3}\right)} = 312.24\text{ W}$$

The power is too high, therefore not practical. This is due to the very short lifetime which makes pumping to population inversion difficult.

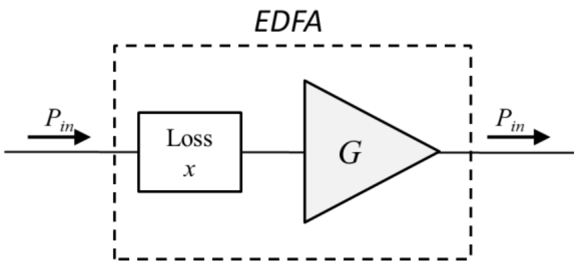
(b) What pump wavelength would you use to amplify in the C-band? What would be the minimum pump power required in this case?

Could use either 800 nm or 980 nm. However it is better to use 980 nm because of the large cross section and the lower photon energy.

$$P_{\min} = \frac{a_p h\nu}{\sigma_a \tau_{sp}} = \frac{\left(\pi\left(4\cdot 10^{-6}\right)^2\right)\left(6.626\cdot 10^{-34}\frac{\left(3\cdot 10^8\right)}{\left(980\cdot 10^{-9}\right)}\right)}{\left(10\cdot 10^{-26}\right)\left(14.5\cdot 10^{-3}\right)} = 7\text{ mW}$$

Part 2:

A 25 dB gain C-band EDFA is used as a preamplifier but due to a bad design, it suffers from an optical loss at the input port as shown below. The power entering the EDFA is therefore xP_{in}.



Without the loss section (that is when x = 1) the EDFA has a noise figure of $NF = 2n_{sp} = 5$ dB. When installed the loss is actually of 3 dB (x = 0.5). We want to calculate the noise figure of the lossy amplifier (the relation $NF = 2n_{sp}$ does not hold anymore).

(a) Does the loss impact the input signal to noise ratio $(SNR)_{in}$? Assuming that shot noise dominate at the input, find the expression for $(SNR)_{in}$.

No it does not impact because the power is taken at the input of the composite EDFA, that is before the loss block. Let P_{in} be the input power to the composite EDFA, that is before the loss block.

$$SNR_{in} = \frac{(RP_{in})^2}{\sigma_s^2} = \frac{RP_{in}}{2q\Delta f}$$

(b) Assuming that signal-ASE beat noise dominates after the EDFA, find the expression for $(SNR)_{out}$.

The EDFA amplifies the light that has gone through the loss block, that is xP_{in} . The SNR at the output is therefore

$$SNR_{out} = \frac{\left[RG(xP_{in})\right]^2}{\sigma_{sig-spn}^2} = \frac{GxP_{in}}{4S_{ASE}\Delta f} = \frac{GxP_{in}}{4n_{sp}h\nu(G-1)\Delta f}$$

(c) Find the expression for the new NF. Estimate its value in the limit $G \gg 1$ and η = 100%.

The noise figure is therefore:

$$NF \equiv \frac{(SNR)_{in}}{(SNR)_{out}} = \frac{RP_{in}}{2q\Delta f}\frac{4n_{sp}h\nu(G-1)\Delta f}{GxP_{in}} = \frac{2\eta n_{sp}(G-1)}{Gx}$$

In the limit $G \gg 1$ and η = 100%, we get: $NF \equiv \frac{2n_{sp}}{x} = \frac{NF_{EDFA}}{x}$.

We have a new noise figure of 5 dB + 3 dB = 8 dB in the case of x = 0.5.