Problem 10 solution

1. There is an optical pre-amplifier in an optical receiver before the photodiode. The input optical power to the optical amplifier is $P_{in} = -20\text{dBm}$, and the optical amplifier has a 6dB noise figure. Other parameters are, operation temperature $T = 300\text{k}$, load resistance $R_L = 50\Omega$, photodiode responsivity $\mathcal{R} = 0.9\text{A/W}$, and the operation wavelength $\lambda = 1550\text{nm}$.

(a) If the gain of the optical amplifier is $G = 30\text{dB}$, please find the noise power spectral densities of thermal noise, shot noise and signal-ASE beat noise at PD output.

(b) What is the required optical gain of the amplifier so that signal-ASE beat noise is $10\text{dB}$ higher than the thermal noise after photo-detection?

2. For a semiconductor optical amplifier (SOA) with $25\text{dB}$ peak optical gain, if both end surface have the same power reflectivity $R$, what is the maximum $R$ allowed so that the maximum gain ripple is less than $1\text{dB}$ near the peak gain wavelength?

3. At $\lambda = 1548\text{nm}$ wavelength, the emission and absorption cross-sections of an erbium-doped fiber (EDF) are $\sigma_e = 1\times10^{-24}\text{m}^2$ and $\sigma_a = 0.7\times10^{-24}\text{m}^2$, respectively. Erbium doping density of this EDF is $N_T = 7.5\times10^{24}\text{m}^{-3}$, and the confinement factor is $\Gamma = 0.1$.

(a) Please find the emission and absorption rate in dB/m for this EDF.

(b) If the length of the EDF is $L = 2\text{m}$, and the pump power is strong enough so that the carrier inversion is complete (that is: $N_2 = N_T$, $N_1 = 0$), what is the small-signal optical gain at $1548\text{nm}$ wavelength?

4. An EDFA originally has an optical gain of $G = 25\text{dB}$ and a noise figure $F = 5\text{dB}$ at a certain wavelength. Neglect gain saturation effect.

Now there is an addition $3\text{dB}$ loss associated with the EDFA. This forms an "extended EDFA" as illustrated below.

(a) If the $3\text{dB}$ loss at the input side of the original EDFA, what is the noise figure of the extended EDFA? (Hint: use noise figure definition)

(b) if that $3\text{dB}$ loss is at the output side of the EDFA, then what is the noise figure of the extended EDFA? Please explain.