Photonic Systems Laboratory

Photonic Systems and Technologies – Lab 6
Erbium-doped fiber amplifiers

1. Topics covered

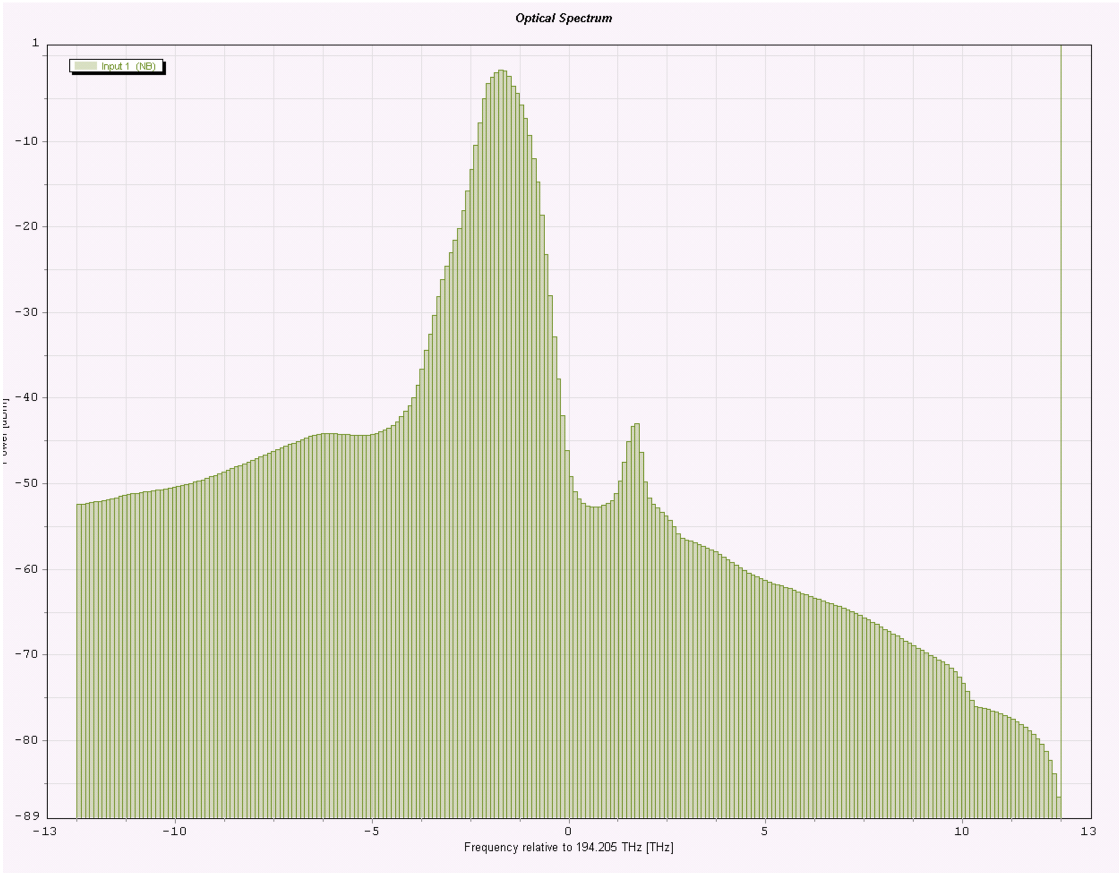
- Light amplification in distributed erbium-doped fiber amplifiers, forward and backward pumping, optimization of doped fiber length and pump power, notion of optical signal-to-noise ratio and noise figure.

2. Laboratory simulations

Erbium-doped fiber (EDF) parameters, i.e. length, doping concentration, pump power, pump and signal wavelength etc., can be accessed in General/Physical parameters, and are changed manually or using sweeps in every simulation.

All schematics represent an EDF section (*DopedFiber_vtms1*), which is co-, counter- or bidirectionally pumped using 980 or 1480 nm laser diode.

a. Open the setup OA1_1. In the setup there is no input signal in 1550 nm band. Only forward and backward ASE is analysed. To model ASE, VPI exploits the concept of "noise bins" (NB) - multiple broadband signals of a fixed spectral width and uniform power distribution.



Question 1: Run the model with default settings. Check and describe the results, obtained in "Inversion" tab. Compare forward and backward ASE spectra.

Questions 2. Run *Sweep_FiberLength* and consider only forward ASE. Describe the evolution of ASE spectra for various EDF length.

Questions 3: Using the results of the level inversion for different EDF length, and considering EDF as a three level (band) laser system, find a qualitative explanation, why forward and backward ASE spectra are different, and why ASE central emission line is shifted while increasing the EDF length.

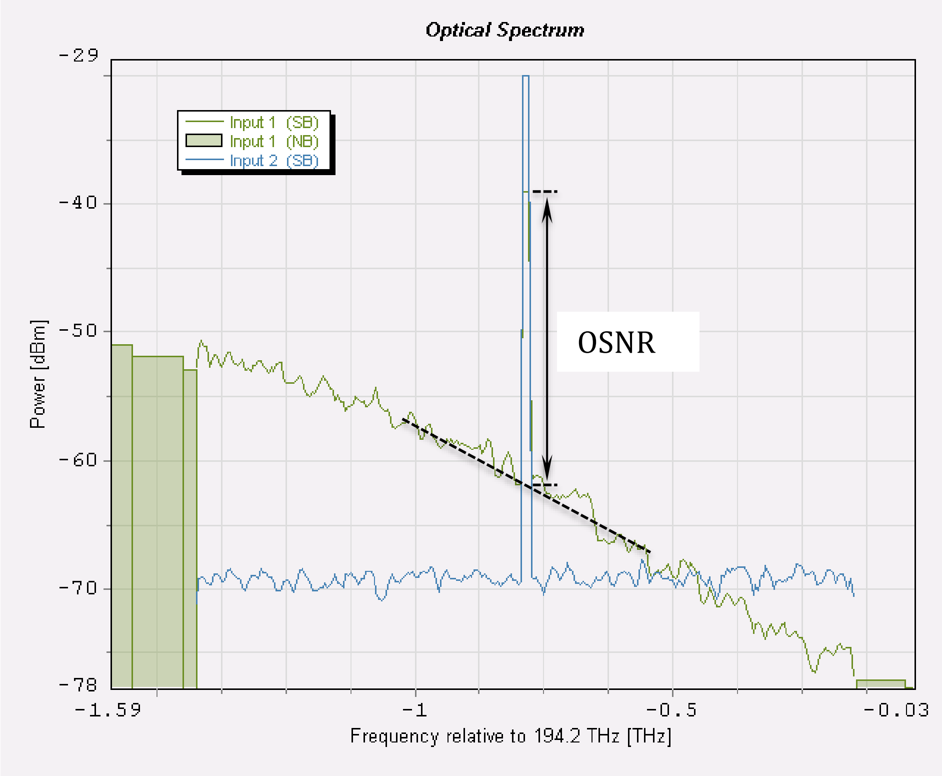
b. Open the setup OA2_1. Now we include a seed signal (*LaserCW_vtms2*), which wavelength can be swept. The pump and signal waves are combined using ideal multiplexer (*WDM_MUX_N_1_Ideal_vtms1*). Signal transmission is evaluated and is plotted vs. its wavelength.

Question 4: Run *Sweep_LaserWavelength*, which changes both a seed wavelength and a pump power. Explain obtained transmission spectra.

c. Open the schematics OA3_1. In general, it reproduces the previous setup, with the exception that optical signal-to-noise ratio (OSNR) is set now for the seed signal using a noise generator *SetOSNR_vtmg1*.

OSNR is determined as a ratio between signal power and noise background.

Noise figure (NF) of the amplifier is a ratio between $OSNR_{in}$ and $OSNR_{out}$.



Question 5: Run *Sweep_iterations* (the same simulation will be performed 11 times, and results are averaged out), and determine OSNR, gain and NF of the amplifier.

d. Open the model OA4_1. In this schematics we investigate the influence of the pump power on the gain for different length EDF sections.

Question 6: Run the build-in sweep to change pump power at 4 different fiber length values. Describe the results. Why the gain does not increase anymore for high values of pump power?

e. The model OA5_1 replicates the previous one. However, this time the pump power is fixed, and the EDF length is swept.

Question 7: Run the build-in sweep to determine an optimal fiber length, which provide the highest signal gain. Why the gain coefficient drops after a certain distance, and even becomes negative (hint: linked to the Q3)?

f. Open the model OA6_1. It represents the EDFA, which is co-, counter- or bi-directionally pumped, and is used as an amplifier for a multiwavelength signal. The pump is split using directional coupler (*X_Coupler_vtms1*), so the total pump power is kept constant. The tester *TestSetAmplifier_vtms1* is used to analyze gain and NF at every channel.

Question 8: Sweep coupling ratio to test different pump direction schemes. Describe the results.