ELEC 466 Project Two

I certify that this submission is my original work and meets the Faculty's Expectations of Originality

Submitted to

Dr John XiupuZhang
Professor's name

Date: ____Nov24th__, 2021_

By

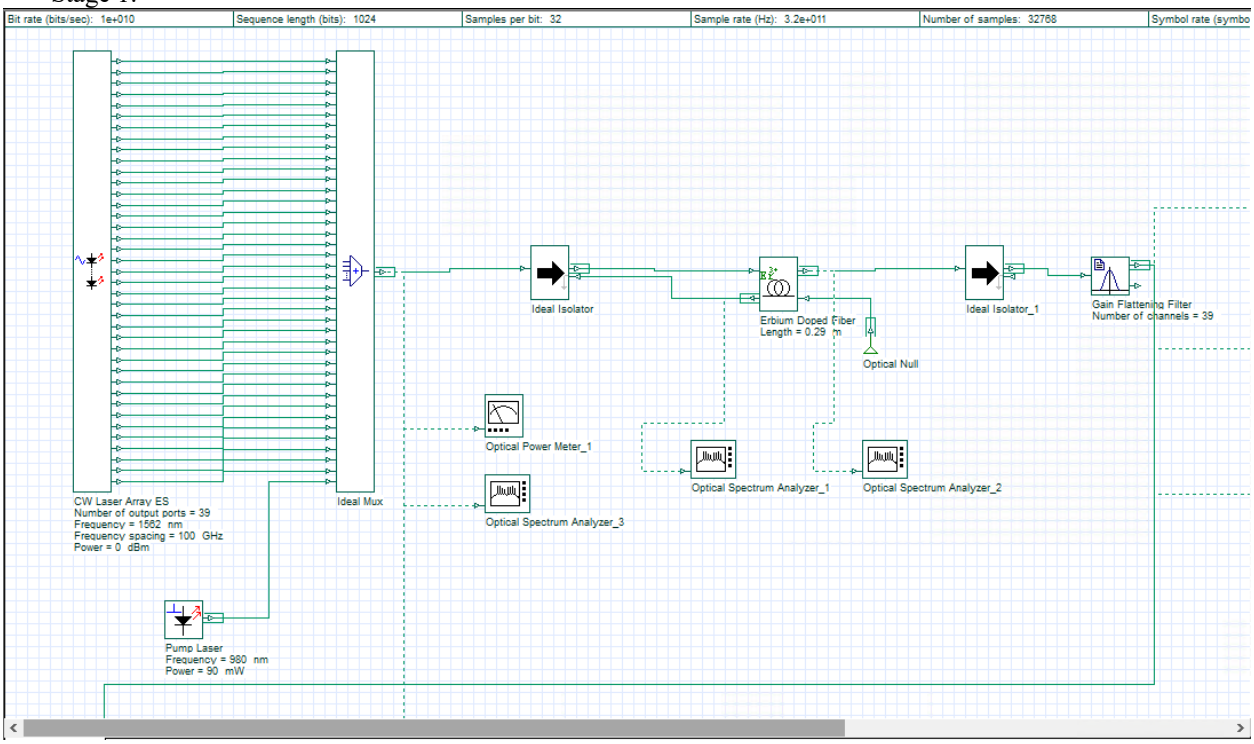
Yifan Huang	40068609
Name	student ID

Optical EDFA amplifier design simulation

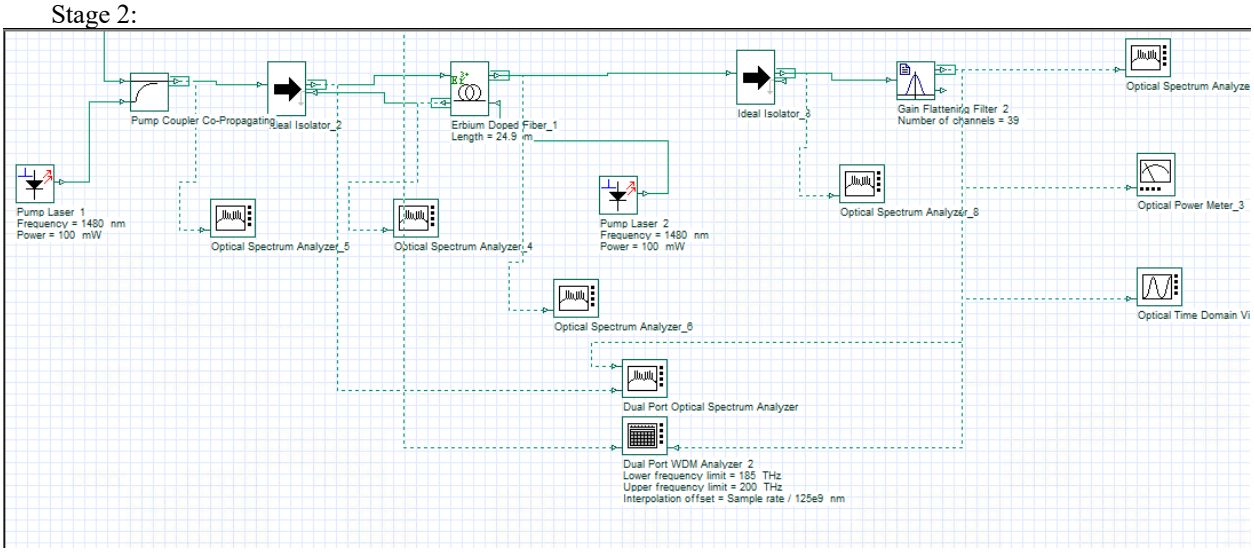
1. Design Layout

Parameter:
First Stage:
Input Power: -20dBm
Channel Num: 39, Frequency range: 1530nm – 1562nm, gap: 100GHz
Pump Power: 90mW at 980nm
Gain Flat Filter: 39 channels
EDF length: 0.29m
Second stage:
Forward Pump power:100mW at 1480nm
Backward pump power:100mW at 1480nm
Gain Flat Filter: 39 channels
EDF length: 24.9m

Layout:
Stage 1:



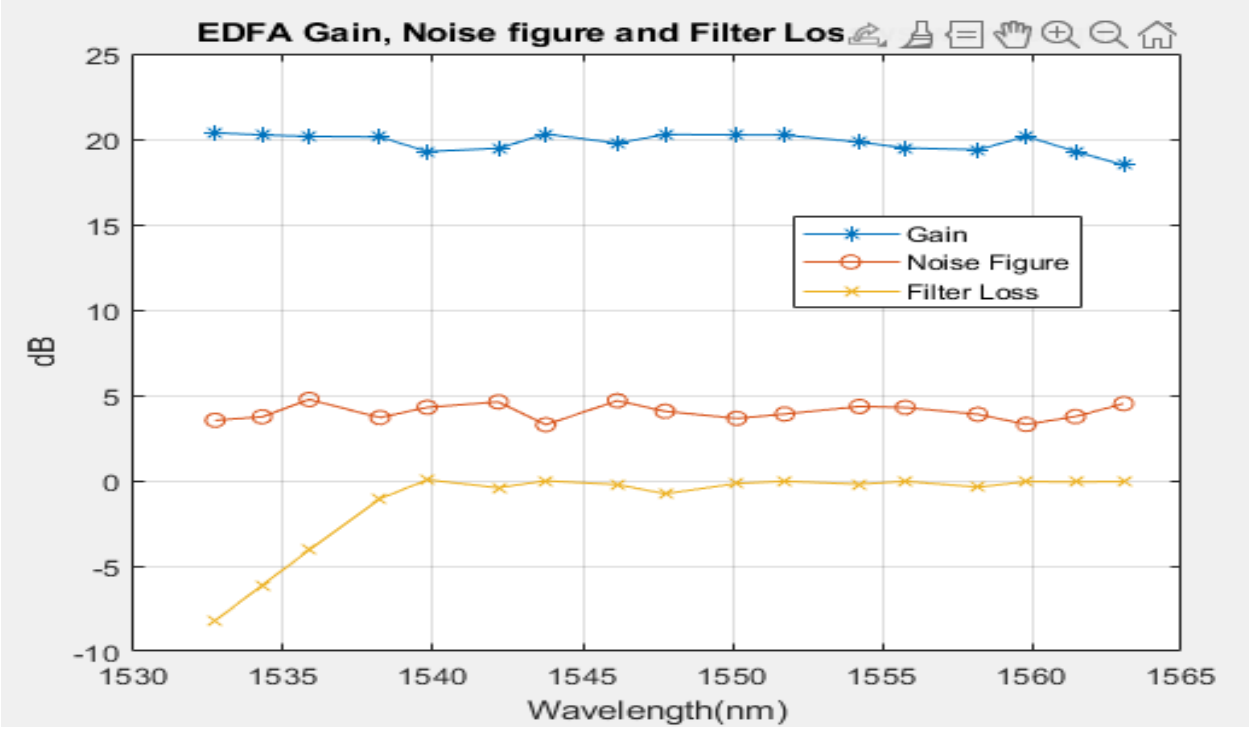
Stage 2:



2. Result

a. Gain vs Wavelength
b. Noise Figure vs Wavelength
c. Gain filter Loss vs Wavelength

Plot:



Explanation:

a. Gain is relatively flat in the range between the range of 1540nm – 1560nm with around -1/+1dB fluctuation. Although the initial gain was tilted below wavelength of 1540nm, and the GFF output showed the gain was flattened below 1540nm. This is because using Gain flat filter at the output of EDFA. However, the gain was not flat above 1560nm, it shows GFF has little impact on output gain control above 1560nm, other tools like GVD could be used. In the region of C band, the Gain is 20 dB

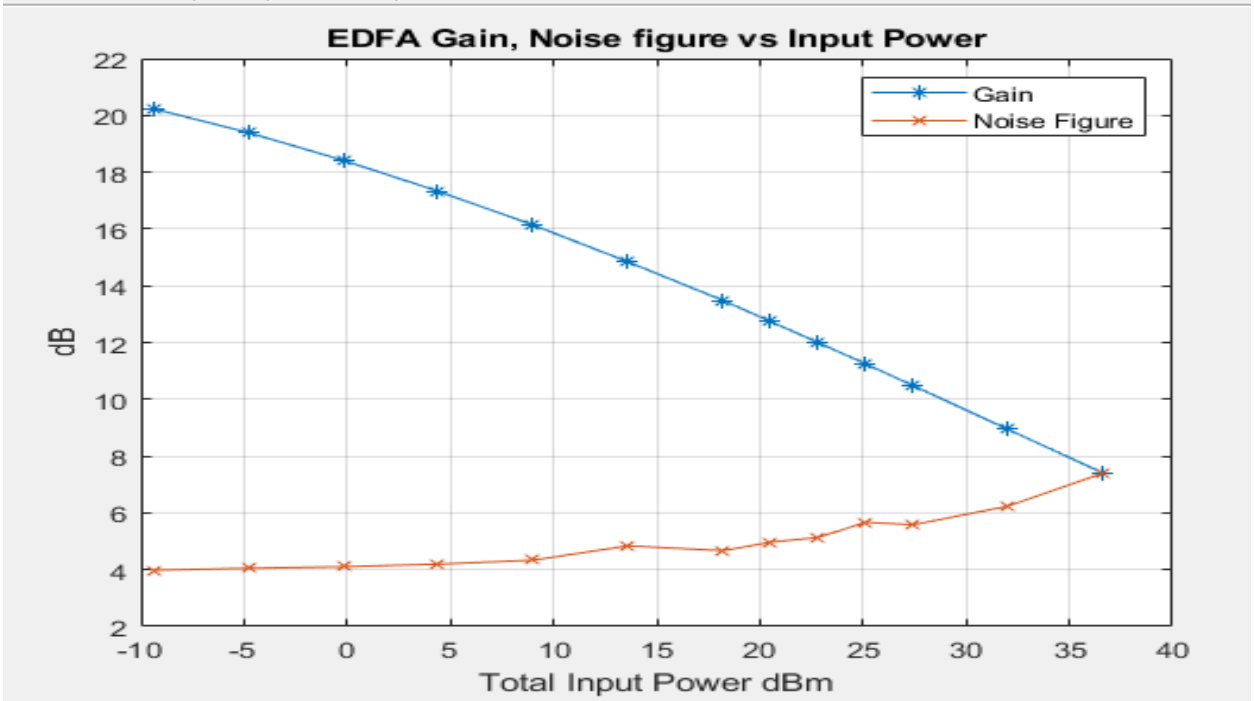
in average for input channel power -20dBm and 0dBm channel output power. The EDFA gain was relatively flat even if with no using Gain Flat Filter, this is because Carrier lift time accumulating in metastable state will last very long in order of ms, any fluctuation of photo frequency will have little impact on the Gain. So the gain will remain stable in this region.

b. Noise Figure is below 5 dB in average, and it is very closed to the shape symmetrical with the Gain. When Gain has a little increase, NF in same region will tend to decrease a little, and vise versa. Mathematically, NF = SNRin/SNRout, so ignoring ASE noise, when input signal keeps constant, output signal increasing will result in NF decreasing.

c. Gain Filter loss has a negative loss below 0dB. The loss was getting larger below 1540nm. This is because the initial Gain with no GFF has gain tilted below 1540nm, and gain was suppressed between 1540nm to 1560nm. GFF need generate the reciprocal loss corresponding to the initial Gain form to flatten the gain.

d. Total Input Power vs Gain at 1550nm
e. Total Input Power vs Noise Figure at 1550nm

Plot:



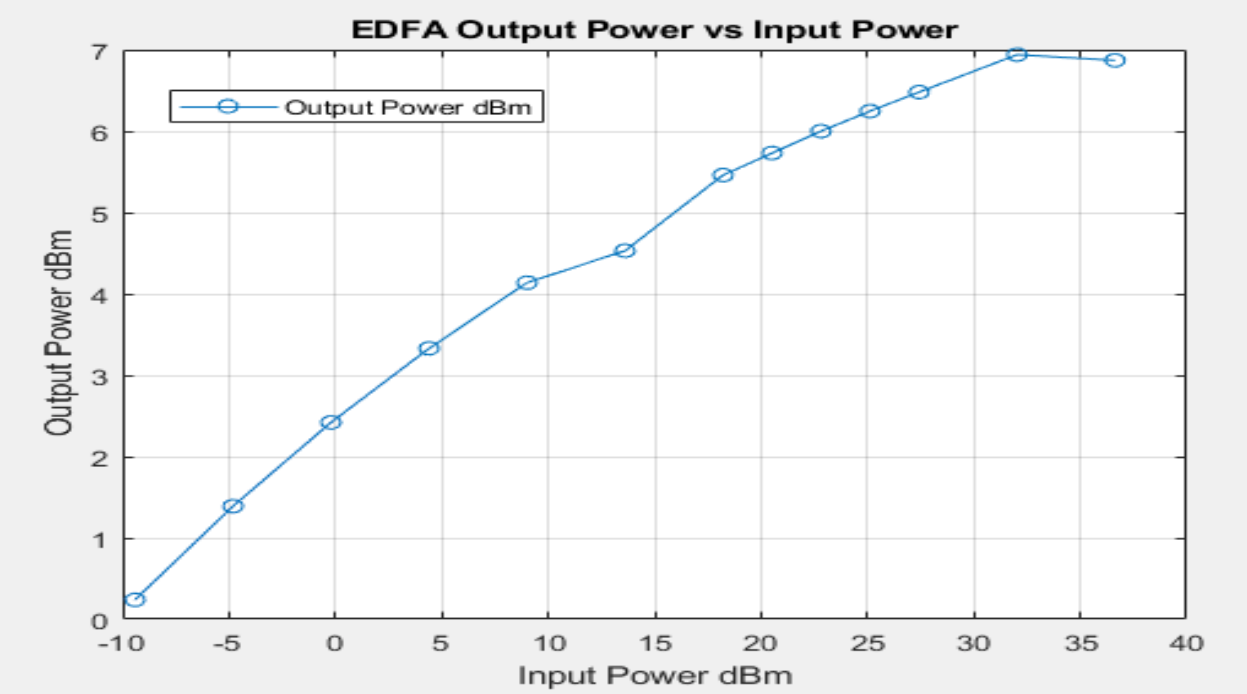
Explanation:

a. Gain significantly drops for about 10 dBwhen total input signal power increased from -10dBm to 35dBm. This is because EDFA was operating in saturation region. The output signal power does not increase linearly with input power, G=Pout|dB – Pin|dB, when Pin|dB increasing slope overrates Pout|dB, G|dB will decrease.

b. Noise Figure increases at the same time as the Gain decreases. This is because increasing input signal power will generate more ASE noise at the input port. However, noise figure increasing rate does not have the reciprocal slope like Gain. As we found the noise figure has a flat slope when input signal power increases.
This is because of the contribution of two stages design. Stage one used 90mW forward pump at 980nm, and EDF length is minimized to 0.29m. This makes the gain in first stage very small , but the advantage also could be the ASE noise is minimized. Stage two used 100mW co-pump at 1480nm and

EDF length is maximized to be 24.9m. Co-pump could make the pump power stable in C band, which results in larger output signal power and larger Gain. But ASE noise could also be increase in stage two. Nevertheless, what we saw from the plot noise increasing slop being supressed. Mathematically explanation could be as follows:
Total NF = NF1 + NF2/Gain1, NF1 was minimized, even though NF2 is large, due to impact of Gain1 the value of NF2/Gain1 is only a fraction od NF2. Therefore, total NF is small.

f. Total Input Power vs Output power at 1550nm
Plot:



Explanation:

Output signal power increases while input signal increases. But the increasing rate is not linear. Pout increasing is supressed and bending down while Pin increases. This also could be explained by that EDFA was actually working in the saturation region. Pout was relatively saturated to certain range, even though Pin kept increasing. Therefore, we can found Pin increased by about 40dB, while Pout only increased by 7dB, and Pout started to drop after Pin reached 35dBm.

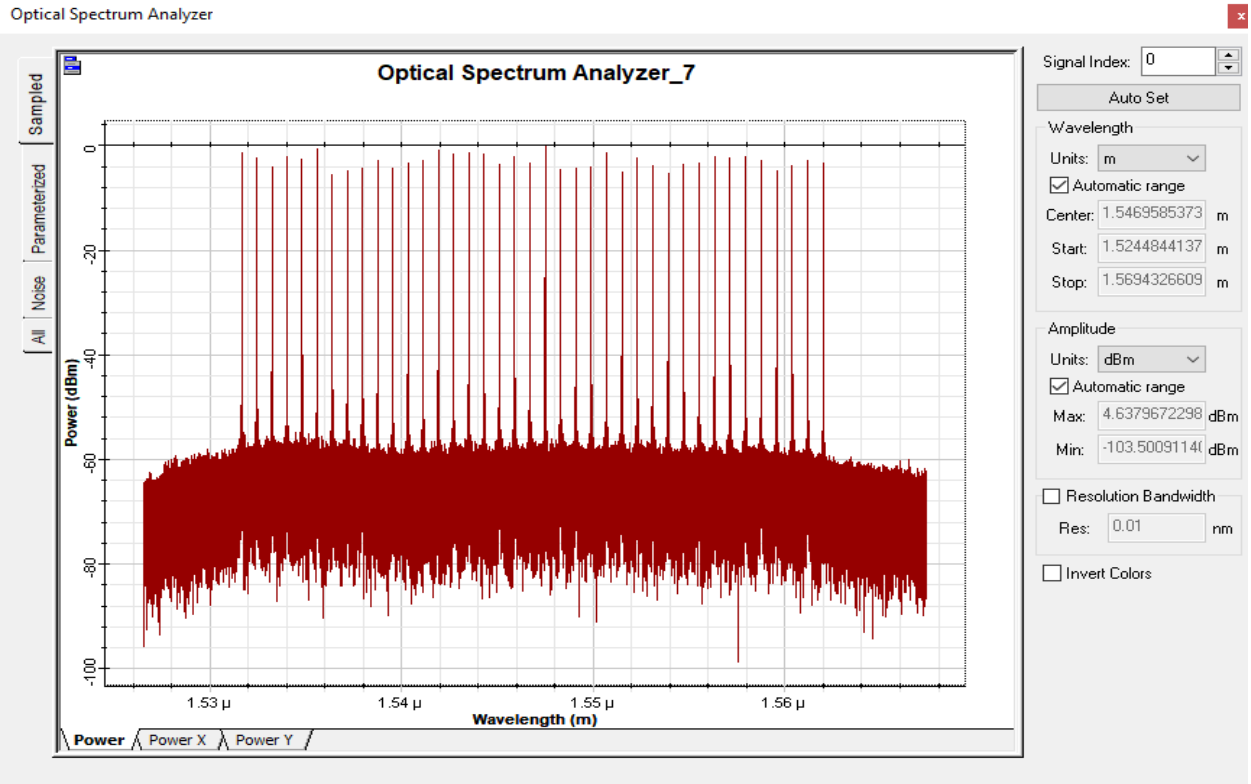
Conclusion :

I implemented a 2 stage EDFA. The first stage is to minimize the noise while keep gain relatively lower. The second stage is to increase the gain, the flip side is that ASE noise also being generated. To minimized the noise, EDF length should be selected smaller and pump should be working at 980nm. To maximize the gain, the EFD length should be selected longer and both forward and backward pump should be used, so as to increase the output gain the output power. Because the first stage has lower NF, the system would have lower noise output. Gain flat filter was implemented to tune the gain, GFF loss is at reciprocal shape of gain, in in order to cancel the gain fluctuation peak and dent.

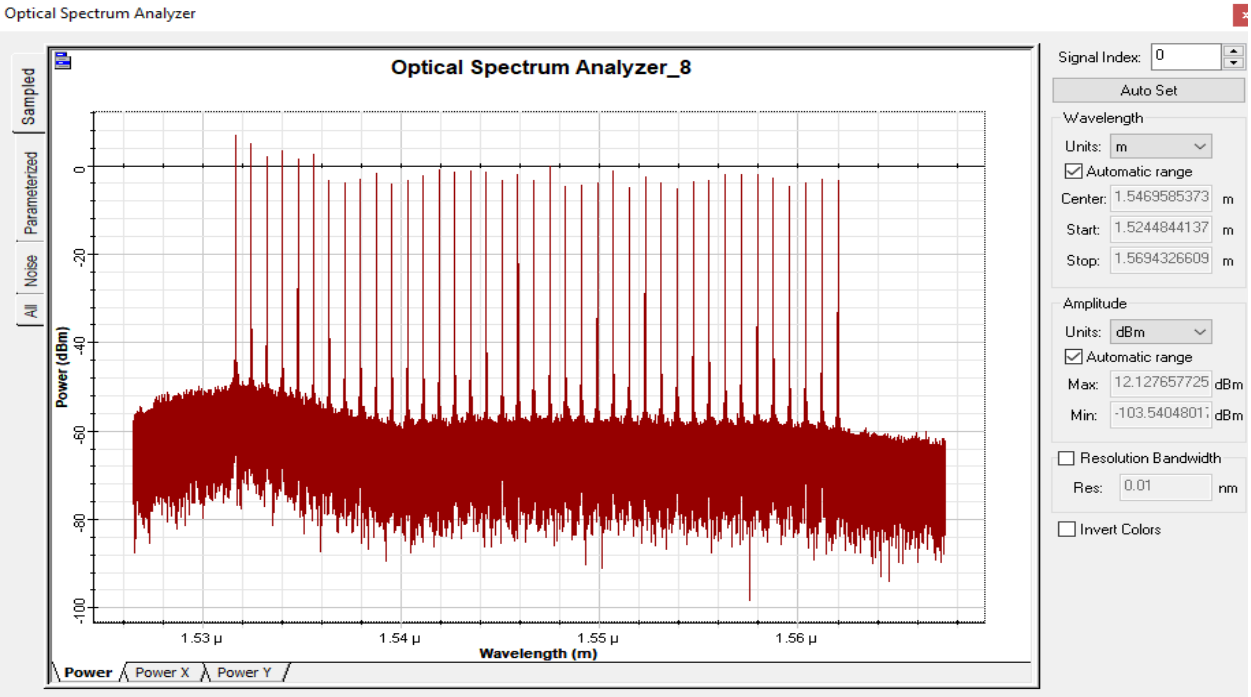
Appendix:

Print :

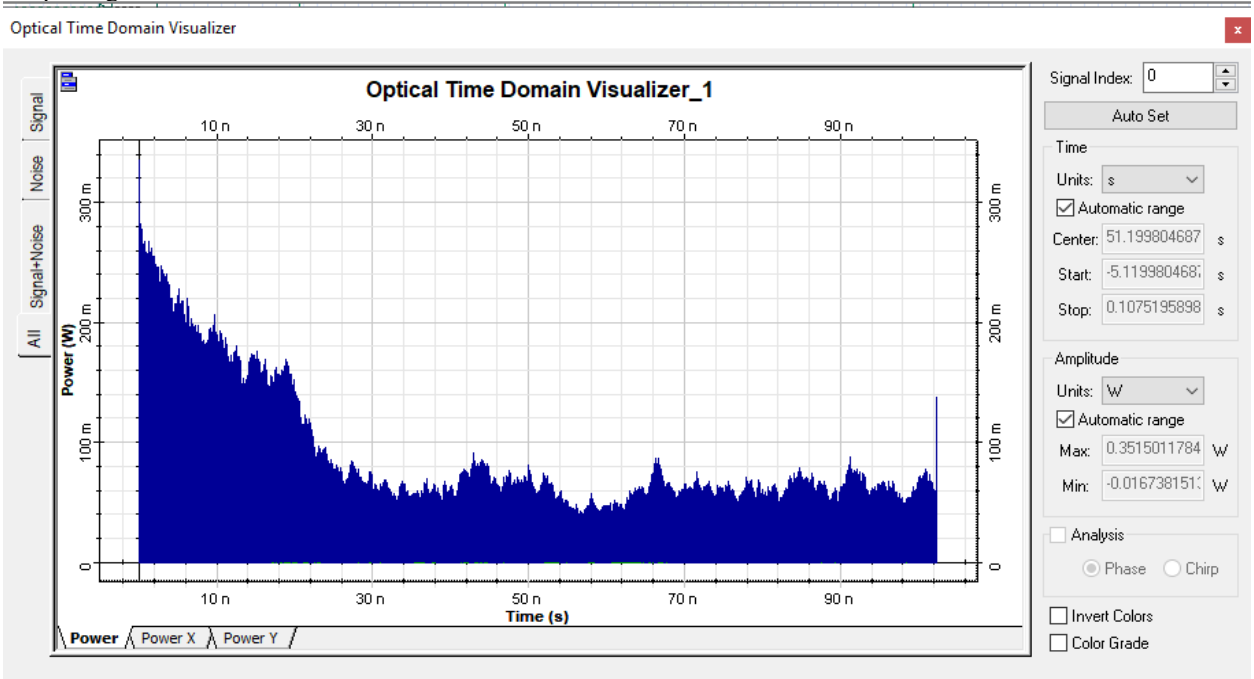
Power Spectrum with GFF :



Power Spectrum with no GFF :



Output Signal Power vs Time:



Matlab code:

File_01:

```
%this snipper is to plot the optical EDFA gain and noise figure vs wavelength
clear;
clc;
close
c = 3e+8;
%wavelength and frequency
FreqTHZ = [191.93,192.128,192.33,192.53,192.83,193.02,193.33,193.53,193.83,
194.03,194.33,194.53,194.83,195.03,195.33,195.53,195.73];
lenda =c ./ (FreqTHZ .* (1e+12));% in meter
lendaNM = lenda .* (1e+9);% in nm
%EDFA gain with Gain Filter in dB
GainDB_Filter =
[18.476,19.279,20.157,19.376,19.48,19.824,20.235,20.245,20.272,19.76,20.3,19.
46,19.27,20.124,20.158,20.243,20.368];
GainDB_NoFilter =
[18.533,19.36,20.218,19.76,19.524,20.034,20.276,20.41,21.046,19.9923,20.315,1
9.88,19.2225,21.19,24.23,26.37,28.57];
%Gain filter loss
LossDB_Filter = GainDB_Filter - GainDB_NoFilter;
%EDFA noise figure in dB
NFDB =
[4.506,3.75,3.29,3.88,4.28,4.34,3.898,3.64,4.058,4.68,3.27,4.61,4.29,3.69,4.7
48,3.734,3.532];
plot(lendaNM, GainDB_Filter,'-*');
hold on
plot(lendaNM, NFDB,'-o');
plot(lendaNM, LossDB_Filter, '-x');
xlabel('Wavelength(nm)');
ylabel('dB');
legend('Gain', 'Noise Figure', 'Filter Loss');
```

```
title('EDFA Gain, Noise figure and Filter Loss vs wavelength');
grid on
hold off
```

File_02:

```
%this snipper is to plot the optical EDFA gain, noise figure and output vs
input
clear;
clc;
close
InputDB = [-20,-18,-16,-14,-12,-10,-8,-7,-6,-5,-4,-2,0];
Total_InputDB =10.*log(10.^(InputDB./10) .*39);
%EDFA gain with Gain Filter in dB
GainDB=[20.24,19.396,18.42,17.33,16.139,14.84,13.48,12.74,11.999,11.25,10.48,
8.94,7.4];
%EDFA noise figure in dB
NFDB =
[3.98,4.05,4.105,4.195,4.335,4.84,4.67,4.97,5.135,5.67,5.58,6.2397,7.398];
plot(Total_InputDB, GainDB,'-*');
hold on
plot(Total_InputDB, NFDB, '-x');
xlabel('Input Power dBm');
ylabel('dB');
legend('Gain', 'Noise Figure');
title('EDFA Gain, Noise figure vs Input Power');
grid on
hold off
```

File_03:

```
%this snipper is to plot the output vs input
clear;
clc;
close
InputDB = [-20,-18,-16,-14,-12,-10,-8,-7,-6,-5,-4,-2,0];
Total_InputDB =10.*log(10.^(InputDB./10) .*39);

OutputDB =
[0.239,1.39,2.42,3.33,4.137,4.53,5.46,5.73,6.0,6.246,6.48,6.94,6.87];
plot(Total_InputDB, OutputDB,'-o');
xlabel('Input Power dBm');
ylabel('dB');
legend('Output Power dBm');
title('EDFA Output Power vs Input Power');
grid on
```