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# Analysis of Optical Amplifiers with Different Parameters

**Anish Verma, Neha Gupta**

***Abstract:*** ***In any fibre optic communication systems the transmission distance is limited by the fibre losses. The recent approach to overcome the loss limitation is the use of optical amplifiers which ensures the accomplishment of fibre optic communication systems for long distances efficiently. Different categories of optical amplifiers found for widespread use such as Erbium Doped Fibre Amplifier (EDFA)], Ytterbium Doped Fibre Amplifier (YDFA). We consider about EDFA and YDFA which are made by doping the fibre core with rare-earth elements of Erbium and Ytterbium respectively. The gain of EDFA is 10dB, 15dB, 20dB and 25dB with fiber length at 5m, 7.5m, 10m and 12.5 m respectively and the gain of YDFA is 15dB, 20dB, 30dB and 30dB with fiber length at 0.5m, 0.75m, 1.0m and 1.25 m respectively. Amplifier performance improves with increase with fiber length.***

***Index Terms: Fiber Length, Gain, Output Power, EDFA and YDFA.***

## I. INTRODUCTION

An optical fiber amplifier is a fiber optic device used to amplify optical signals directly without conversion into electrical signals. Optical fiber transmission has revolutionized networking and communication systems. Multiple communication devices, like optical transmitters and receivers, are used in optical fiber transmission systems.

An optical fiber amplifier is used in transmitting data in fiber optic communication systems. Amplifiers are inserted at specific places to boost optical signals in a system where the signals are weak. This boost allows the signals to be successfully transmitted through the remaining cable length. In large networks, a long series of optical fiber amplifiers are placed in a sequence along the entire network link.

The first optical fiber amplifier, called an erbium-doped fiber amplifier (EDFA), was invented in the late 1980s. An optical fiber amplifier consists of a low single mode fiber made of silica glass. A coupling pump light generates length gain at both fiber ends or in between locations.

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Optical fiber amplifiers are categorized based upon different physical mechanisms, as follows:

- Doped fiber amplifiers (DFA): Use a doped optical fiber medium for boosting signals in a similar manner to fiber lasers. The signal requiring amplification, along with a pump laser, is multiplexed in a doped fiber medium and intersects with doping ions. Amplified spontaneous emission is the major reason behind the DFA noise. An ideal noise level for DFA is around 3 decibels. Practically, the noise figure is calculated at around 6 to 8 decibels.
- Semiconductor optical amplifiers: Use semiconductors to produce the gain medium in the laser. The analogous structure is made of laser diodes. The recent design of semiconductor optical amplifiers has added antireflective coatings and window regions to minimize the end face reflection.
- Raman amplifiers: Employ Raman amplification techniques to boost optical signals. The two types of Raman amplifiers are distributed, where the transmission fiber is used by multiplexing the pump wavelength along with the signal wavelength as the gain medium, and lumped, where short length and dedicated fibers are used for amplification. Nonlinear fiber is used to increase the intersection between the pump wavelength and the signal to reduce the fiber to the required length.

Optical parametric amplifiers: Permit the amplification of weak signal impulses to a nonlinear optic medium. They use non-collinear interaction geometry for broader bandwidth amplifications.

## II. TYPES OF OPTICAL FIBER AMPLIFIERS

On the bases of doping optical fiber amplifiers are two types:

- EDFA
- YDFA

### A. Erbium Doped Fiber Amplifiers (EDFA)

In optical communication network, signals travel through fibers for very large distances without significant attenuation. However, when distances become hundreds of kilometers, it becomes necessary to amplify the signal during transit. Optical fiber amplifiers provide in-line amplification of optical signals by effecting stimulated emission of photons by rare earth ions implanted in the core of the optical fiber. Erbium is the preferred rare earth for this purpose though amplifiers using Praseodymium are also in use.


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EDFAs are used top rovide amplification in long distance optical communication with fiber loss less than0.2dB/km by providing amplification in the long wavelength window near 1550 nm. The principle of rare earth doped fiber amplifier is the same as that of lasers excepting that such amplifiers do not require a cavity whereas a cavity is required for laser oscillation. Advantages of EDFA are as follows:

- It provides in-line amplification of signal without requiring electronics i.e., the signal doesnot need to be converted to electrical signal before amplification. The amplification is entirely optical.
- It provides high power transfer efficiency from pump to signal power.
- The amplification is independent of data rate.
- The gain is relatively flat so that they can be cascaded for long distance use.
- On the debit side, the devices are large, there is gain saturation and there is also presence of amplified spontaneous emission (ASE).

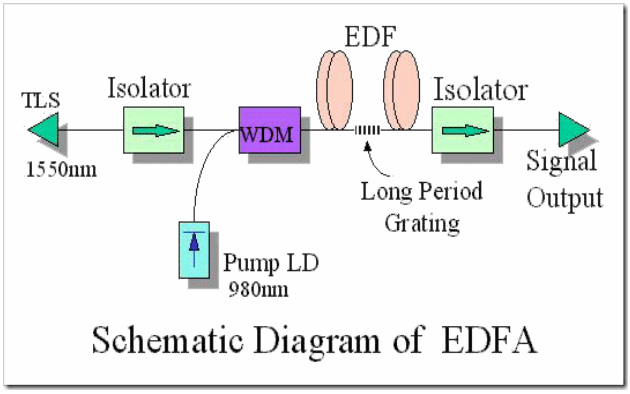


**Figure 1: Schematic Diagram of EDFA**

### B. Ytterbium-Doped Fiber Amplifier

The Ytterbium-Doped Fiber Amplifiers (YDFA) series utilize Ytterbium (Yb) doped fiber technologies to achieve optical amplification in 1064 nm wavelength range. The all-fiber-based products are extremely reliable and require no routine maintenance. Commercially proven 915 nm pump laser sources ensure long-term reliability. These units are well-suited for Bio-medical, SHG, fiber sensors, LIDAR pulse amplification and free space communications. The YDFA is available in three different operating range options:

- ➤ Standard range: 1055 nm to 1080 nm
- ➤ Long range: 1055 nm to 1090 nm
- ➤ Short range: 1035 to 1070 nm

## III. EXPERIMENTAL WORK

### A. EDFA:

System parameter for experiment

1480nm with signal wavelength of 1550nm. Pump power 1000mw and single power 0.03mw is applied. Doped fiber length of 10m and doped fiber core diameter 5.5um.

**Table 1: Parameter for EDFA**

| | |
|---|---|
| Pump wavelength(nm) | 1480 |
| Signal wavelength(nm) | 1550 |
| Pump power(mw) | 1000 |
| Signal power(mw) | 0.03 |
| Doped fiber length(m) | 10 |
| Doped fiber core diameter(um) | 5.5 |

Parameter for EDFA given in table 1, pump wavelength is

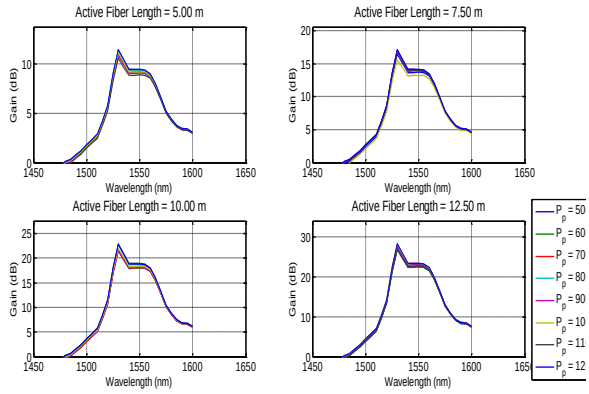


**Figure 2: Wavelength vs Gain**

Figure 2 gives the gain of EDFA 10dB, 15dB, 20dB and 25dB with fiber length at 5m, 7.5m, 10m and 12.5 m respectively.

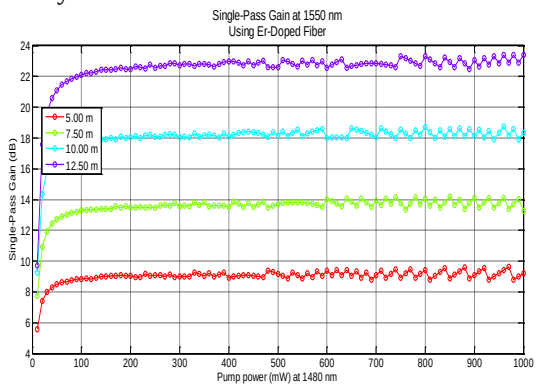


**Figure 3: Pump Power vs Signal Power**

Figure 3 gives the single pass gain with pump power at different fiber length of 5m, 7.5m, 10m and 12m with 8dB, 13dB, 18dB and 22dB respectively.

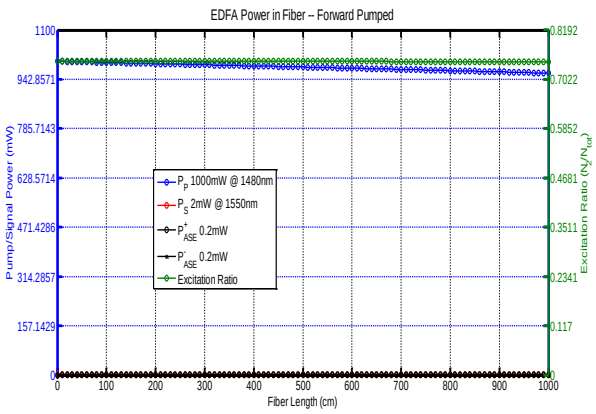


**Figure 4: Fiber Length vs Pump Power**


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Pump power 1000mW at 1480nm shown in figure 4.

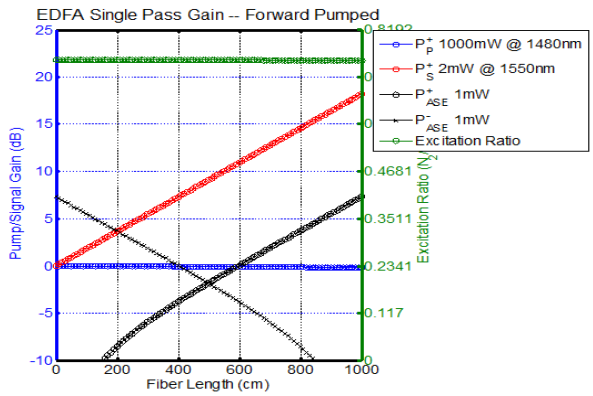


**Figure 5: Fiber Length vs Signal Power**

Signal pass gain with forward pumping is shown in figure 5, pump signal gain dB.

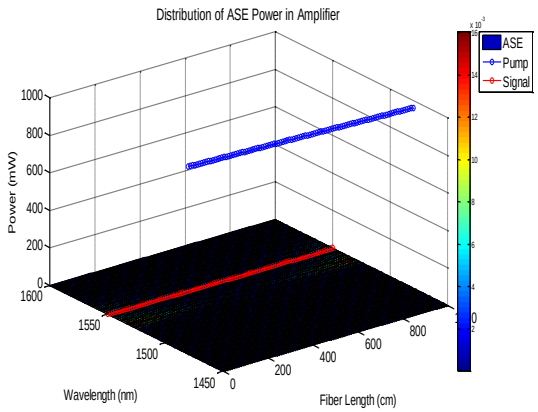


**Figure 6: Distribution of ASE Power in Amplifier**

Distribution of ASE power in amplifier is shown in figure 6 with very good with amplification.

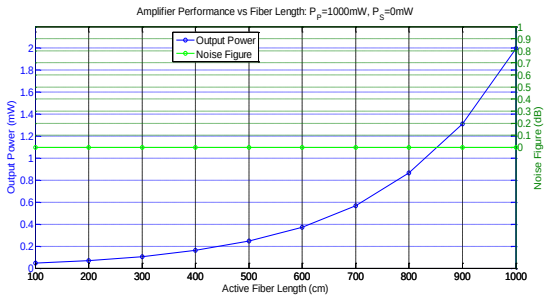


**Figure 7 : Amplifier Performance vs Fiber Length**

Amplifier performance improves with increase with fiber length.

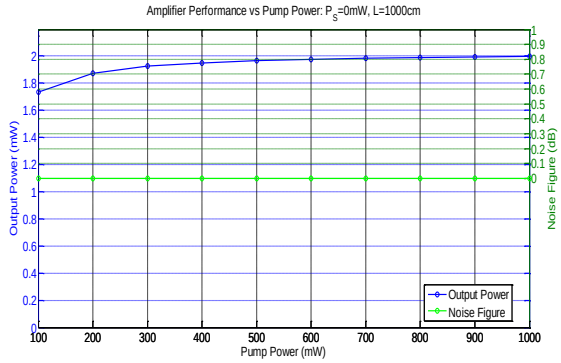


**Figure 8: Amplifier Performance vs Pump Power**

Figure 8 shows amplifier performance as output power with pump power.

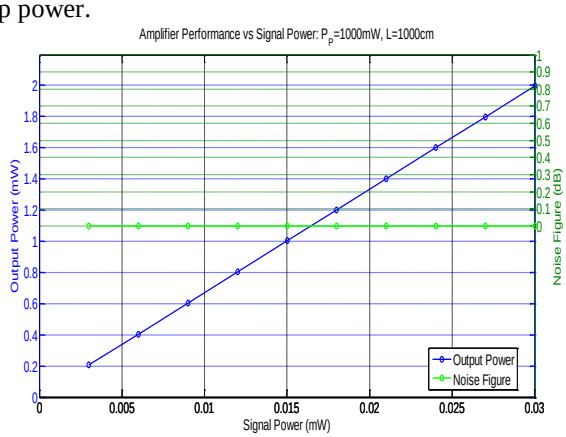


**Figure 9: Signal Power vs Output Power**

Amplification of signal power is shown in figure 9.

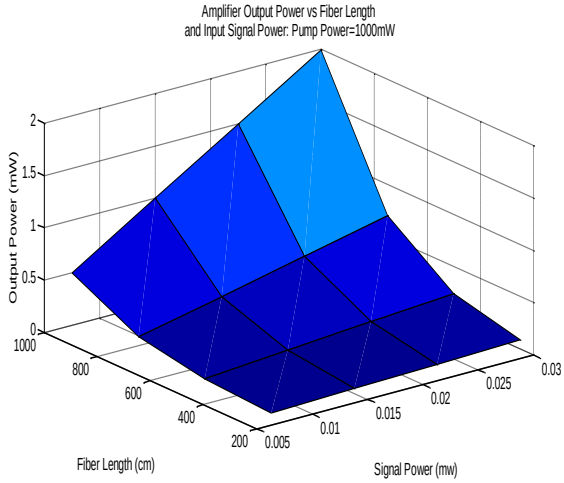


**Figure 10: Amplifier Output Power vs Fiber Length and Input Signal Power**

Amplifier output power, fiber length and input signal poweris shown in figure 10.

## B. YDFA:

System parameter for experiment


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**Table 2: YDFA Parameter**

| | |
|---|---|
| Pump wavelength(nm) | 975 |
| Signal wavelength(nm) | 1064 |
| Pump power(mw) | 1000 |
| Signal power(mw) | 5 |
| Doped fiber length(m) | 10 |
| Doped fiber core diameter(um) | 6 |

Parameter for YDFA given in table 2, pump wavelength is 975nm with signal wavelength of 1064nm. Pump power 1000mw and single power 5mw is applied. Doped fiber length of 10m and doped fiber core diameter 6um.

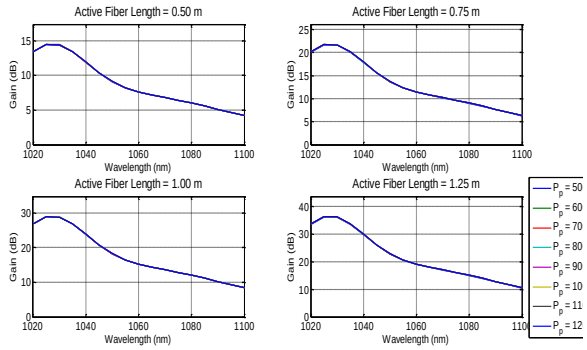


**Figure 11: Wavelength vs Gain Graph**

Figure 11 gives the gain of FDFA15dB, 20dB, 30dB and 30dB with fiber length at 0.5m, 0.75m, 1.0m and 1.25 m respectively.

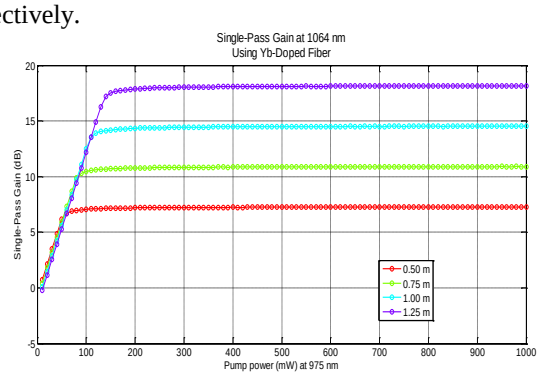


**Figure 12: Power Pump vs Single Pass Gain**

Figure 12 gives the gain of EDFA6dB, 10dB, 12dB and 18dB with fiber length at 0.5m, 0.75m, 1.0m and 1.25 m respectively.

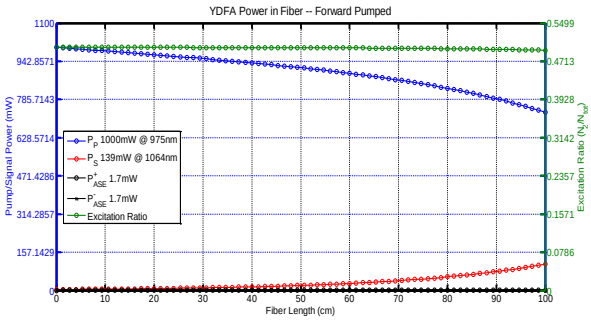


**Figure 13: Fiber Length vs Power Pump**

Figure 13 gives the single pass gain with pump power at different fiber length of 5m, 7.5m, 10m and 12m with 15dB, 20B, 30dB and 30dB respectively.

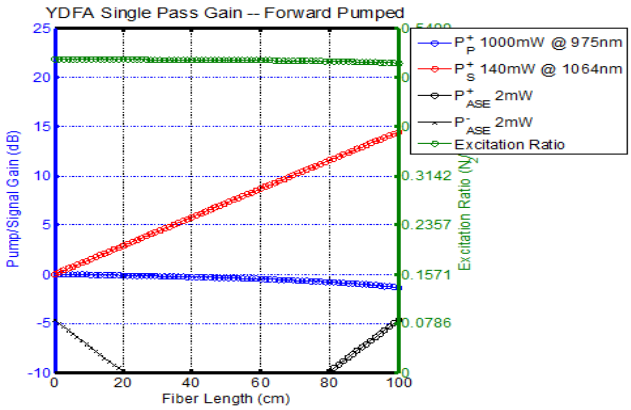


**Figure 14: Fiber Length vs Signal Gain**

Signal pass gain with forward pumping is shown in figure 14, pump signal gain dB.

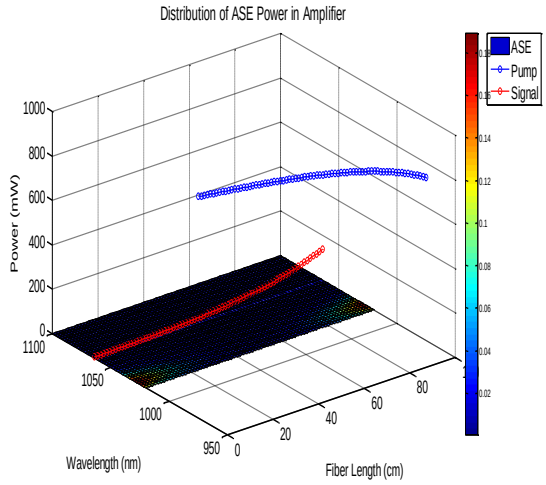


**Figure 15: Distribution of ASE Power in Amplifier**

Distribution of ASE power in amplifier is shown in figure 15 with very good with amplification

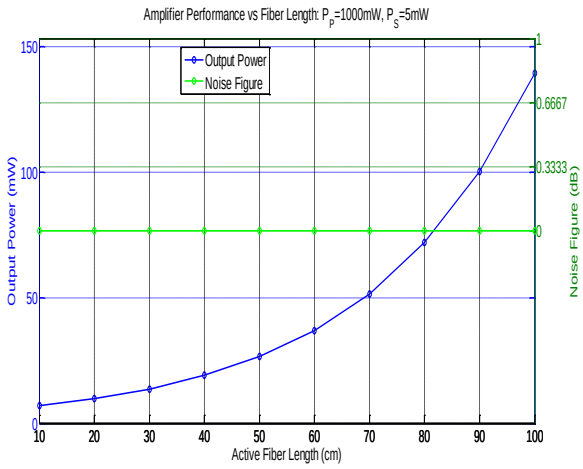


**Figure 16: Active Fiber Length vs Output Power**

Amplifier performance improves with increase with fiber length.



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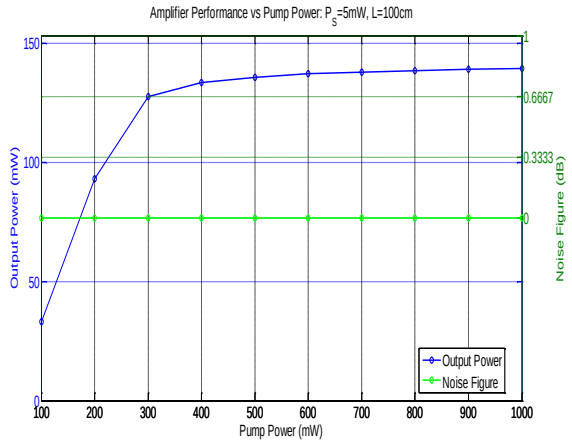


**Figure 17: Pump Power vs Output Power**

Figure 17 shows amplifier performance as output power with pump power.

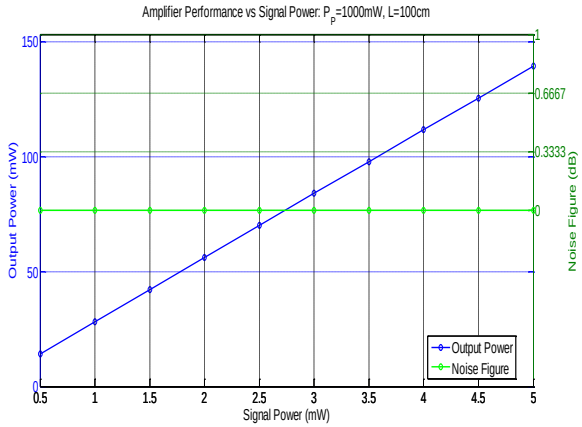


**Figure 18: Signal Power vs Output Power**

Amplification of signal power is shown in figure 18.

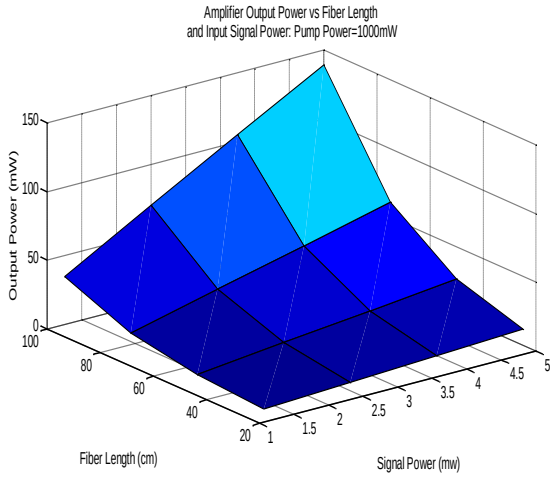


**Figure 19: Amplifier Output Power vs Fiber Length and Input Signal**

Amplifier output power, fiber length and input signal power is shown in figure 19.

## IV. CONCLUSION

The system has been designed to analyze the gain and pump power dependence of the optical amplifiers EDFA and YDFA for various fiber length. Both the amplifiers have increased power spectrum with increase in pump power and have maxima at amplification region.

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