# Optical Amplifiers: An Overview

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**Abstract:** As the demand of carrying large information in optical fiber communication network increased, there came the need of some special devices in the network to accomplish this task. An Optical amplifier is a key enabling technology for optical communication networks. It is a device that amplifies an optical signal directly, without the need to first convert it to an electrical signal. Together with wavelength-division multiplexing (WDM) technology, which allows the transmission of multiple channels over the same fiber, optical amplifiers have made it possible to transmit many terabits of data over distances from a few hundredsof kilometers to transoceanic distances, providing the data capacity required for current and future communication networks.
The purpose of this paper is to provide an overview of optical amplifiers. Different hybid combinations like EDFA-SOA, EDFA-RAMAN, EDFA-SOA,RAMAN will improve the performance of the DWDM network.

***Keywords:*** *WDM, DWDM, EDFA, SOA, RAMAN*

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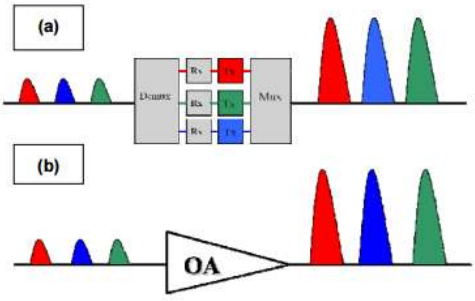
## I. INTRODUCTION

A basic optical communication link comprises a transmitter and receiver, with an optical fiber cable connecting them.Although signals propagating in optical fiber suffer far less attenuation than in other mediums , there is still a limit on the distance signal can travel before becoming to noisy to be detected.
Before the commercialization of optical amplifiers, it was necessary to electronically regenerate the optical signals every 80-100 km in order to achieve transmission over long distances. This meant retiming, reshaping and regeneration of the signals by the optoelectronic repeaters. But the system capacity was limited by speed of electronic circuits. This called for the use of optical amplifiers which amplifies the signal without actually converting them to electrical domain. Optical amplifiers works completely in the optical domain.
At the same time optical amplifiers can work with WDM/DWDM links. It can amplify all WDM channels together, and is generally transparent to the number of channels, their bit-rate, protocol, and modulation format. Thus, a single optical amplifier can replace all the multiple components required for an electronic regeneration station.




Figure(1) (a)Block diagram for an electronic regeneration station in which channels are separated, detected amplified separately electronically and then recombined (b) an optical amplifier where all channels are optically and transparently amplified together[3]

### 1.1 Applications of Optical amplifiers

There are three ways in which optical amplifiers can be used to enhance the performance of optical data links. A booster amplifier is used to increase the optical output of an optical transmitter just before the signal enters fiber. The optical signal is attenuated as it travels in the optical fiber. An inline amplifier is used to restore (regenerate) the optical signal to its original power level. An optical pre-amplifier is used at the end of the optical fiber link in order to increase the sensitivity of an optical receiver.

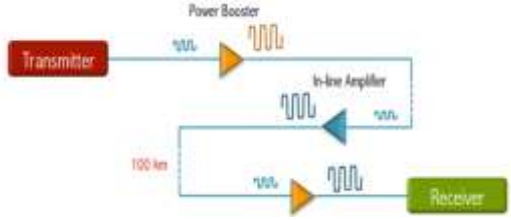



Figure 2: An optical amplifier as a power booster, In-line amplifier and pre amplifier[2]

By using optical amplifiers the system speed can be increased at the same time more reliable, low cost DWDM link can be set transmitter and receiver ends.

## II. AMPLIFICATION PRINCIPLE

All optical amplifiers increase the power level of incident light through a stimulated emission or an optical power transfer process. Stimulated emission takes place when the population at the higher energy state is higher than lower energy state. When such is the case light gets amplified as it travels down the medium. Amplified light have same characteristics as the incident photon.Three fundamental types of optical amplifiers include Semiconductor optical amplifier, Doped fiber amplifier and Raman amplifier.

## III. SEMICONDUCTOR OPTICAL AMPLIFIER (SOA)

SOAs are amplifiers which use a semiconductor to provide the gain medium. It is basically a InGaAsP laser without optical feedback which provides lasing.
In SOA the mechanism for creating population inversion that is needed for stimulated emission to occur is same as is used in Laser diodes. An external injection current is passed through the device that excites the electrons in the active region.When photons (light) travels through the active region it can cause these excited electrons to loose some of their energy in the form of more photonsthat match the wavelength of initial ones.

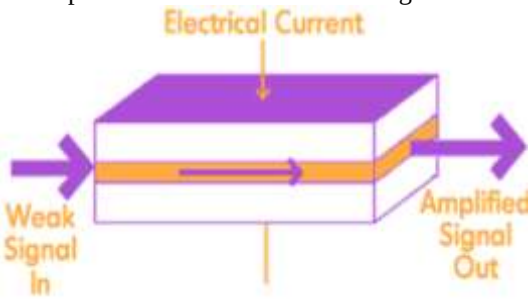



Figure 3: Semiconductor optical Amplifier[2]

SOA can be made to work in O band (around 1310nm) as well as in the C band. They consume less electrical power. Theyhave fewer components and are more compact. They haver rapid gain response which is of the order of 1 to 100ps.

## IV. DOPED FIBER AMPLIFIER (DFA)

In this type of optical amplifiers the fiber material itself is doped with a rare earth material like Erbium. Erbium doped fiber amplifier (EDFA) are widely used in C band (1530nm to 1565nm) for optical communication networks.

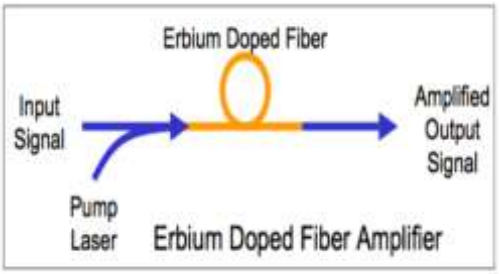



Figure 4: Erbium Doped Fiber Amplifier[2]

Erbium is a rare element with phosphorescent properties. Fiber is doped with erbium material. Photons at 1480 or 980 nm when imposed on the doped fiber it will activate electrons into a metastable state. The electrons from the metastable state will fall back to the lower state emitting the the light in the 1550nm range.

## V. RAMAN AMPLIFIER

A Raman optical amplifier is based on nonlinear effect called Stimulated Raman Scattering (SRS), which occurs in fibers at high power.

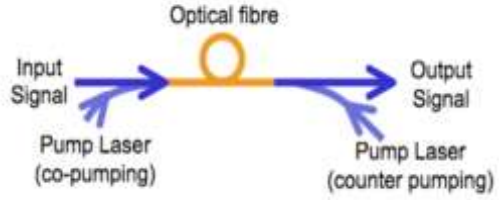



Figure 6: Raman Amplifier[2]

These type of amplifiers are topologically simple to design. No special doping is required for these amplifiers. It uses intrinsic optical non-linearity of the fiber material. In this case amplification takes place throughout the length of the optical fiber. Hence are called as Distributed Amplifiers.

### 5.1 SRS Non-linearity

Stimulated Raman Scattering is an interaction between lightwaves and the vibrationalmodes of silica. If photon with energy hv1 is incident on a molecule having vibrational frequency vm, the molecule can absorb some energy from photon.In this interaction, the photon is scattered, thereby attaining a lower frequency v2 and a corresponding lower energy hv2.

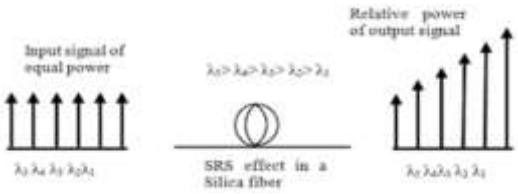



Figure 7: SRS effect in a Silica fiber[4]

SRS transfers optical power from shorter wavelength to longer wavelength.

**Advantages:**

- Variable wavelength amplification possible.
- Compatible with installed SM fiber
- Can be used to extend EDFAs
- Can result in lower average power over a span, good for lower crosstalk
- Very broadband operation is possible

**Disadvantages:**

- High pump power requirements.
- Sophisticated gain control needed.
- Noise is also an issue.

## VI. HYBRID OPTICAL AMPLIFIERS

Optical fibers has many non-linear effects like SPM, XPM, gain saturation and FWM etc in the optical amplifiers which restrict them to be used for various applications in optical communication system. So, therecomes the need to propose the hybrid optical amplifiers (HOAs) to increase the gain bandwidth of WDM system with least gain variation over the

effective bandwidth, reduce the losses due to non-linearities, avoid the constraint of high costgain flattening filters & multi pumps for large gain flatness.[1]
Hybrid amplifiers means the combination of two or more different types of optical amplifiers connected together. RAMAN-EDFA, RAMAN-SOA, EDFA-RAMAN-EDFA such type of combinations will surely improve the performance of optical communication link.

## VII. CONCLUSION

To have higher transmission rates, along with WDM/DWDM network links optical amplifiers gives the best results. The optical amplifiers in hybrid configuration provide the better gain bandwidth product with minimum gain variation among the channels, as compared to regenerators.

## REFERENCES

**[1]** 'Performance evaluation of different hybrid optical amplifiers for DWDM system'India Conference (INDICON), 2016 IEEE Annual
[2] 'Optical Amplifiers' by Venkat Venkatramanan, Institute for optical sciences, University of Toronto
[3] 'Introduction to optical amplifiers' Finiser White paper June 2010
[4] 'Optical Fiber Communication' by Gerd Keiser