# Amplifiers for the Masses: EDFA, EDWA, and SOA Amplets for Metro and Access Applications

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**Introduction**

The demand for quality bandwidth is increasing with the rise of internet dependence. From daily purchases to social networking to operating businesses, high internet-traffic metropolitan areas need communication with metropolitan areas in different states and even different countries. To maintain the integrity of information sent from one location to another, optical amplifiers, such as erbium-doped fiber amplifiers (EDFA), erbium doped waveguide amplifiers (EDWA), and semiconductor optical amplifiers (SOA), are utilized to extend transmission range. Soon after the early application of EDFA, coarse-wavelength division multiplexing (CWDM) was used to boost amplifiers, increasing bandwidth capacity per fiber. This gave rise to the potential of transmitting multiple wavelengths per fiber by cascading optical amplifiers (OA) via dense wavelength division multiplexing (DWDM) and EDFA technology.

DWDM success is cost driven. Metropolitan networks require more configuration due to higher traffic volume; therefore OAs are designed to be low-cost and high performance. As OAs become smaller, they require more resources to maintain low temperatures in nodes, customer sites, and underground vaults. Additionally, OAs must be easy to use since configurations are often made by different technicians.

|  | EDFA amplet | EDWA | SOA | Units |
|---|---|---|---|---|
| Output power | > 15 | > 12 | > 13 | dBm |
| Gain | > 24 | > 20 | > 25 | dB |
| Noise Figure | < 6 | < 6 | < 8 | dB |
| Max Gain Flatness Deviation | < 0.75 | < 0.75 | < 0.1 | dB / nm |
| PDG | < 0.3 | < 0.5 | < 0.5 | dB p-p |
| Size | 45x70x12 | 70x18x12 | 30x12.5x12.5 | mm |
| Power Consumption | < 1 | < 1 | < 5 | W |
|  | Fully isolated with input and output detectors. | Fully isolated with input and output detectors. | Fully isolated packages available. |  |

Figure 1:  Performance of three different optical amplifiers:  EDFA, EDWA, and SOA

**Applications**

EDWA array allows for pump sharing and VOA utilization for DWDM.  DWDM with a high volume of add/drop nodes and low channel count would typically use EDWA.  It is cost effective since there are up to 16 amplifiers per node.

SOAs amplifying WDM channels operate as linear systems.  Changes in the WDM channels as a result of network reconfiguration or burst data does not affect the gain of the optical amplifiers; in other networks using erbium amplifiers, network and data volume changes easily affect gain.  SOA systems with varying number of channels support either 8 or 16 10-Gb/s DWDM channels.

SOAs are also advantageous in amplification of coarse WDM (CWDM).  In CWDM, a coarse wavelength grid of 20nm spaced channels with 13nm passbands use filters and uncooled lasers to transmit information.  CWDM can add more bandwidth capacity per fiber and OADM flexibility to complex networks

**Structure**

In erbium based devices, light from a pump source excites erbium ions to an excited state, emitting light that is optically amplified.  EDFA amplifiers are heavily doped with erbium ions, providing gain when light is pumped into the system.  EDWA are planar waveguides doped with erbium ions and are excited similar to EDFAs.  In semiconductor devices, such as SOAs, a waveguide structure of p-doped

and n-doped layers enclose an active layer. An electronic pump fills the active layer with electrons and holes from the doped layers.
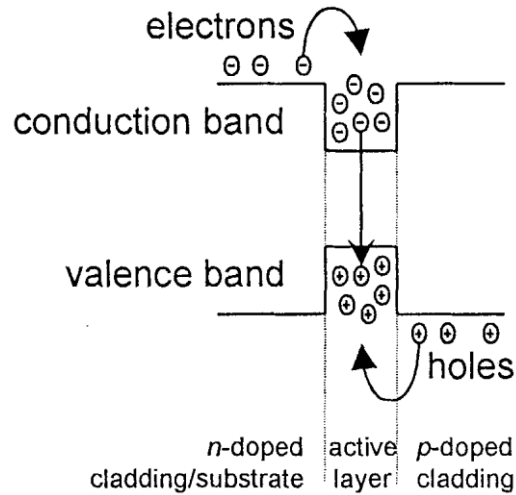
Figure 2: Active layer of a semiconductor amplifier

**Design**

EDFAs consist of a pump laser, pump WDM coupler, erbium doped fiber (EDF) spool, input and output isolators, and input and output detectors. Shorter EDF lengths and tighter bend radii gave rise to smaller components and packaging. The pump laser operates over a large temperature range and drive current, improving noise performance and reducing power consumption.

EDWAs integrate several functions and components onto a mass produced integrated circuit. EDWAs are created via metal ion exchange (IE) and plasma-enhanced chemical vapor deposition (PECVD). In PECVD, the erbium ions are deposited passively onto the substrate via vapor deposition. In IE, metal ions are embedded into the glass substrate, raising the index of refraction of the waveguide. EDWAs are less efficient than EDFAs due to higher erbium concentration in the waveguide on the substrate. Greater erbium ion concentration causes more pumping power to quench to the system. Additionally, there is greater loss in waveguides than fibers.

SOA is created via metallorganic chemical vapor deposition (MOCVD); in this process, metallorganic compounds are heated and react with the substrate surface, resulting in the crystalline active layer between the n-doped and p-doped layers. An energy source pumps current into the active layer; however, they should not be saturated to avoid cross-gain modulation. Cross-gain modulation limits the total output power, determining span length and channel count.
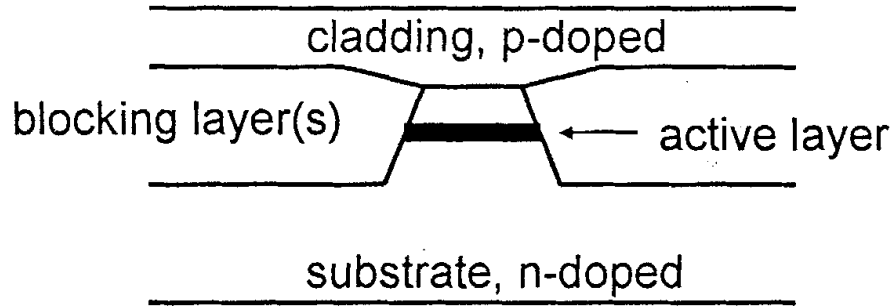
Figure 3: SOA device structure

**Summary**

Three different cost efficient and high performance OAs were introduced to maintain signal integrity and to support the growing need for more bandwidth. The amplifiers are cost efficient, physically small, and easily configured. EDFAs, EDWAs, and SOAs have different properties and designs, making them suitable for different applications and distance ranges.

Reference

Zimmerman, Donald R. and Spiekman, L.  **Amplifiers for the Masses:  EDFA, EDWA, SOA Amplets for Metro and Access Applications**.  Journal of Lightwave Technology, Vol 22 No. 1; January 2004