

Semiconductor Optical Amplifiers and their Applications

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1. Introduction.

There has been rapid growth in the deployment and capacity of optical fibre communication networks over the past twenty-five years. This growth has been made possible by the development of new optoelectronic technologies that can be utilised to exploit the enormous bandwidth of optical fibre. Today, systems are operational which operate at bit rates in excess of 100 Gb/s. Optical technology is the dominant carrier of global information. It is also central to the realisation of future networks that will have the capabilities demanded by society. These capabilities include virtually unlimited bandwidth to carry communication services of almost any kind, and full transparency that allows terminal upgrades in capacity and flexible routing of channels. Many of the advances in optical networks have been made possible by the optical amplifier.

Optical amplifiers can be divided into two classes: optical fibre amplifiers (OFA) and semiconductor optical amplifiers (SOAs). The former has tended to dominate conventional system applications such as in-line amplification used to compensate for fibre losses. However, due to advances in optical semiconductor fabrication techniques and device design, the SOA is showing great promise for use in evolving optical communication networks. It can be utilised as a general gain element but also has many functional applications including an optical switching and wavelength conversion. These functions, where there is no conversion of optical signals into the electrical domain, are required in transparent optical networks.

This paper reviews SOA technology and the applications of SOAs in emerging optical communication networks.

2. SOA basics.

A schematic diagram of an SOA is shown in Fig. 1. The device is driven by an electrical current. The active region in the device imparts gain, via stimulated emission, to an input signal (Fig. 2). The output signal is accompanied by noise. This additive noise, amplified spontaneous emission (ASE), is produced by the amplification process. A comparison between OFAs and SOAs is given in Table 1.

SOAs are polarisation sensitive. This is due to a number of factors including the waveguide structure and the gain material. Polarisation sensitivity can be improved by the use of square-cross section waveguides and strained quantum-well material.

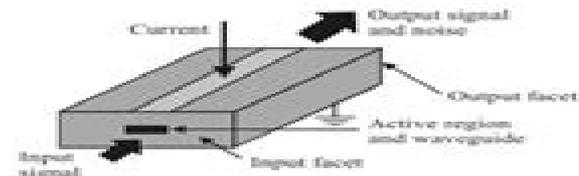


Fig. 1: Schematic diagram of an SOA.

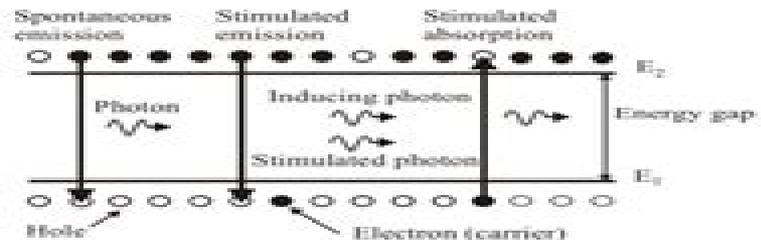


Fig. 2: Spontaneous and stimulated processes in a two level system.

Feature	OFA	SOA
Maximum internal gain (dB)	30 - 50	30
Insertion loss (dB)	0.1 - 2	6 - 10
Polarisation sensitive?	No	Weak (< 2 dB)
Pump source	Optical	Electrical
3 dB gain bandwidth (nm)	30	30 - 50
Nonlinear effects	Negligible	Yes
Saturation output power (dBm)	10 - 15	5 - 20
Noise figure (dB)	3 - 5	7 - 12 dBm
Integrated circuit compatible?	No	Yes
Functional device possibility?	No	Yes

Table 1: Comparison between OFAs and SOAs.

The gain of an SOA is influenced by the input signal power and internal noise generated by the amplification process. As the input signal power increases the gain decreases as shown in Fig. 3. This gain saturation can cause significant signal distortion. It can also limit the gain achievable when SOAs are used as multichannel amplifiers in wavelength division (WDM) multiplexed systems.

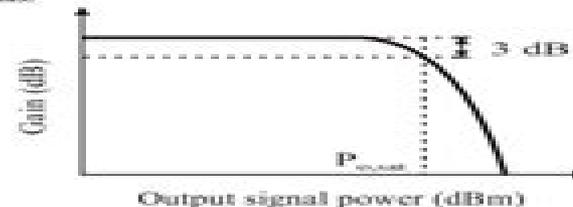


Fig. 3: Typical SOA gain versus output signal power.

SOAs are normally used to amplify modulated light signals. If the signal power is high then gain saturation will occur. This would not be a serious problem if the amplifier gain dynamics were a slow process.

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Table of Contents 1997 Tops Optical Amplifiers Their App

1. Understanding the eBook 1997 Tops Optical Amplifiers Their App
 - The Rise of Digital Reading 1997 Tops Optical Amplifiers Their App
 - Advantages of eBooks Over Traditional Books
2. Identifying 1997 Tops Optical Amplifiers Their App
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an 1997 Tops Optical Amplifiers Their App
 - User-Friendly Interface
4. Exploring eBook Recommendations from 1997 Tops Optical Amplifiers Their App
 - Personalized Recommendations
 - 1997 Tops Optical Amplifiers Their App User Reviews and Ratings
 - 1997 Tops Optical Amplifiers Their App and Bestseller Lists
5. Accessing 1997 Tops Optical Amplifiers Their App Free and Paid eBooks
 - 1997 Tops Optical Amplifiers Their App Public Domain eBooks

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- 1997 Tops Optical Amplifiers Their App Budget-Friendly Options
- 6. Navigating 1997 Tops Optical Amplifiers Their App eBook Formats
 - ePub, PDF, MOBI, and More
 - 1997 Tops Optical Amplifiers Their App Compatibility with Devices
 - 1997 Tops Optical Amplifiers Their App Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of 1997 Tops Optical Amplifiers Their App
 - Highlighting and Note-Taking 1997 Tops Optical Amplifiers Their App
 - Interactive Elements 1997 Tops Optical Amplifiers Their App
- 8. Staying Engaged with 1997 Tops Optical Amplifiers Their App
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers 1997 Tops Optical Amplifiers Their App
- 9. Balancing eBooks and Physical Books 1997 Tops Optical Amplifiers Their App
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection 1997 Tops Optical Amplifiers Their App
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine 1997 Tops Optical Amplifiers Their App
 - Setting Reading Goals 1997 Tops Optical Amplifiers Their App
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of 1997 Tops Optical Amplifiers Their App
 - Fact-Checking eBook Content of 1997 Tops Optical Amplifiers Their App
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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