Multiple-wavelength Transmitter for WDM Optical Network

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Abstract: Optical network based on wavelength-division-multiplexing (WDM) technology will be a most active research topic in the 21st century. This paper describes a WDM multiple-wavelength transmitter and several key corresponding devices for optical network, including ASE spectrum-sliced multiple-wavelength optical source, optical add/drop multiplexer (OADM), semiconductor optical amplifier (SOA), as well as the spectrum noise suppression scheme. The new research results are reported. The applications of these developed devices are also introduced.

1. INTRODUCTION

As now well known, optical fiber has a very broad optical bandwidth (10-20THz). The transmission capacity of optical communication systems is presently limited to about 2.5Gbits/sec in single-channel by the optical source modulation bandwidth and dispersive and nonlinear propagation effects. Wavelength division multiplexing (WDM) could increase optical system capacity by simultaneously transmitting data on several optical carrier signals at different wavelengths in a single fiber. The total system capacity is increased by a factor equal to the number of different wavelength channels.

WDM-based optical network systems generally include a separate optical modulation source for each optical channel or individual transmission wavelength. For example, an array of laser diodes may be used--with each laser diode being tuned to a different wavelength and modulated individually. The laser wavelengths are combined as, for example, by an optical coupler and are then launched into one end of an optical fiber. At the other end of the fiber, the wavelength channels are separated from one another and directed to corresponding receivers.

While a WDM system would be considered cost-effective if a large number of channels (32-64 or even 128) were made available, present multi-channel laser diodes are very difficult to fabricate with acceptable yield even with as few as 8 channels. Therefore to develop an economical and stable multiple-wavelength modulated optical sources for WDM optical network is the key faced by the researchers.

In this paper we present a new design of the multiple-wavelength transmitter for the WDM optical network system. This optical source is based on ASE spectrum slicing of a semiconductor optical amplifier, combined with a recently developed optical add/drop multiplexer and a HF spectrum noise suppression scheme. The performances for the related devices will be discussed and analyzed.

2. WDM MULTIPLE-WAVELENGTH TRANSMITTER ARCHETECTURE

The proposed WDM multiple-wavelength transmitter architecture is shown schematically in Fig.1. The output of amplified-spontaneous-emission (ASE) from first semiconductor optical amplifier (SOA) is followed by a spectrum-sliced device using an eight-channel optical add/drop multiplexer (OADM). The channel spacing of the OADM is 200GHz. The light from SOA is spliced to different wavelength signals by OADM at its drop-ports. These signals are modulated using different modulators corresponding to the separate channels. The modulated signals are coupled from the add-ports of OADM into the transmission line, forming a plural WDM signal. This plural WDM signal is then amplified by an EDFA to promote the signal power lever, and by a second SOA, to suppress the high-frequency spectral noise.

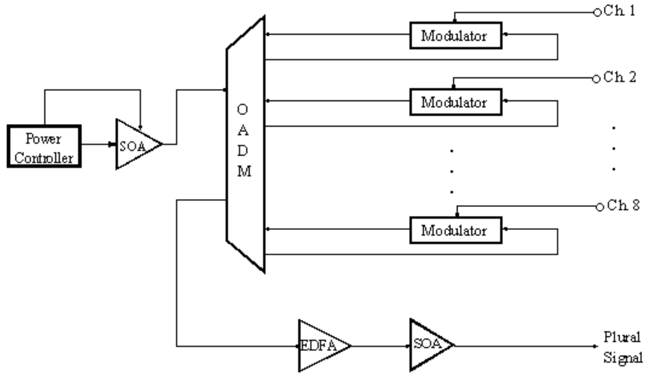


Fig.1 WDM multiple-wavelength modulated transmitter architecture

3. OPTICAL ADD/DROP MULTIPLEXER

The proposed optical add/drop multiplexer (OADM) comprises dual-fiber contact pin, coupling GRIN lens and dielectric film interference filter, as shown in Fig.2. The light from SOA is dropped at the drop ports and eight-channel wavelength signals are extracted. After these signals are modulated by the modulators of separate channels, the modulated signals are added to the line output by the same OADM again at the add ports. The basic theory for this novel device is based on so called "symmetry coupling" of a GRIN lens. That means, while the line input light of the same wavelength with the channel filter will transmit the filter and exit from the drop port, the modulated light entered from the add port, will also transmit the filter but exit from the line out of the OADM.

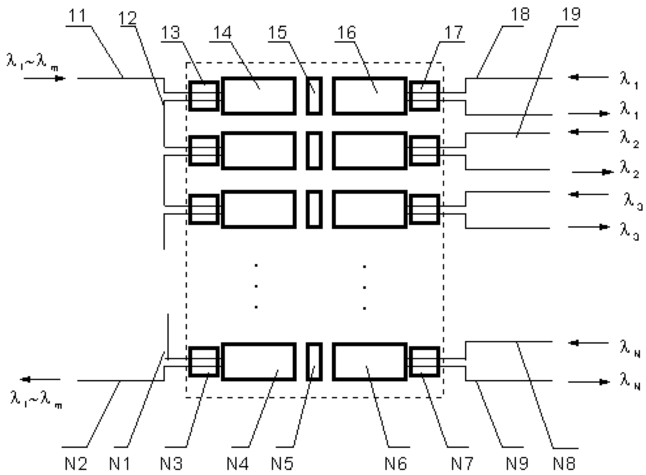


Fig.2 Configuration of the proposed optical add/drop multiplexer

11,12 ~ N1,N2: input fibers; 13 ~ N3: dual-fiber contact pin; 14 ~ N4: coupling GRIN lenses
15 ~ N5: DWDM filters; 16 ~ N6: coupling GRIN lenses; 17 ~N7: dual-fiber contact pin
18,19 ~N8,N9: output fibers

4. SEMICONDUCTOR OPTICAL AMPLIFIER

The polarization-insensitive SOAs have been successfully developed. The active chips of the SOA adopt a tensile strained and compressive strained multi-layer quantum well structure. Tensile strain (T) makes a light hole band moves up to the top of the valence band The transition of electron to light hole mainly generates TM polarization-state photons and few TE polarization-state photons. Thus tensile strained quantum well enhances TM mode gain by suppression of TE mode gain. Compressive strain (C) makes a heavy hole band moves to the top of the valence band. But the transition of electron to heavy hole only generates TE polarization-state photons. Thus compressive strained quantum well only provides TE mode gain. If the active-layer contains two types of strained quantum well at the same time, such type of active-layer can provide TE and TM modes gain meanwhile. Hence we can adjust TE mode gain to be approximately equal to TM mode gain by properly designing the composition of the grown material, well width, the amount of strain and layer number to reduce the polarization sensitivity.

We chose the mix QW structure of 4T3C to fabricate the SOA wafer. The subsequent technique of device introduced the Double Channel Planar Buried Heterostructure (DCPBH) extension chip. The chip was 600 μm in length and 2 μm in width after cleavage, and AR film was coated on the two cleaved ends to reduce the residual reflectivity to 5×10^{-4} , which forms the travelling-wave amplification. Thus the SOA chip was produced.

The output spectrum of the SOA is very close to the spontaneous emission spectrum of SLED, and the gain bandwidth of SOA may be approximately equal to the spontaneous radiation spectrum bandwidth of SOA, and is measured to be 46nm. The curve of TE and TM modes gain versus driving current is shown in Fig.3. The gain difference between TE and TM mode (i.e. P) is less than 0.5dB below the saturation current, and the maximum unsaturated gain achieved is 22.5dB. Due to the influence of residual reflectivity of cleaved ends, the saturation output current is only 150mA, which doesn't achieve the theoretical expected value. The performance of SOA could be continuously greatly improved by reducing the residual reflectivity.

Such SOA is of perfect performance in the proposed multiple-wavelength transmitter.

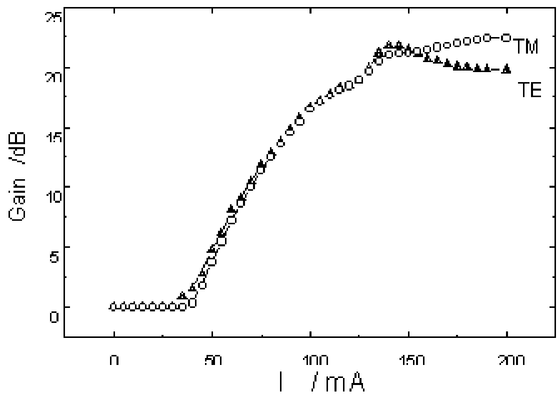


Fig.3 Gain spectrum of SOA for TE and TM modes

5. OPTICAL SPECTRUM NOISE SUPPRESSION SCHEME

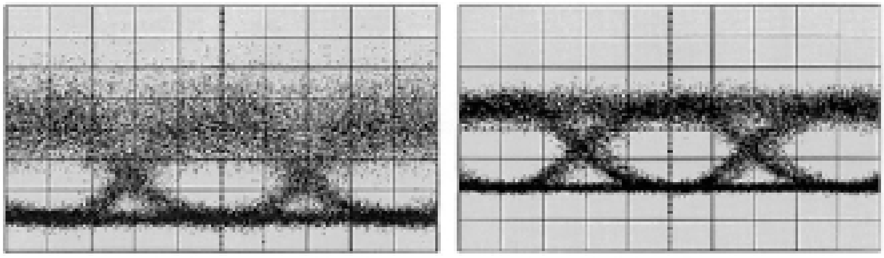
Spectrum-sliced multiple-wavelength light source requires no cavity structure and can be used well in a WDM network communication system. The spectrum-sliced light, however, has a large intensity noise inherently that increases the optical channel bandwidth proportional to the bit rate. The signal-to-noise ratio (SNR) due to optical beating is given by the optical bandwidth to the electrical bandwidth and consists of a dc part arising from the beat between the same optical frequency components and a ac part due to the beat between the different frequency components. While the dc ASE power is used as carrier, the time-varying ac part is the noise. The SNR of ASE light at the receiver is given by [1, 2]

$$SNR = \frac{mB_o}{B_e}$$

where m is the number of polarization modes, Bo is the optical bandwidth, and Be is the electrical bandwidth. Thus the excess noise caused by the beating of the various Fourier components within the broad ASE spectrum becomes dominant over the electronical noise when the optical bandwidth per channel is significantly reduced, e.g. to 100GHz or less as in a DWDM system.

Here in our experiment we use the gain-saturation characteristics of SOA to suppress the intensity noise and increase the intensity-noise-limited signal-to-noise ratio (SNR) very effectively. The switching time of the conventional SOA is less than 1ns. Thus, the channel bit rate may be as high as a few gigabits per second.

Fig.4 shows the measurement results for the transmission performance. The eye diagrams without SOA intensity-noise suppress and with SOA intensity-noise are shown in (a) and (b), respectively. It is apparent that a great improvement has been achieved using this optical spectrum noise suppression scheme.



(a) (b)

Fig.4 Eye diagrams with and without SOA for spectrum noise suppress

6. CONCLUSION

The spectrum-sliced ASE of SOA could be used as light source for DWDM system rather than separate wavelength-selected DFB laser and has been applied in some experimental communication systems [3-5]. In this paper a new configuration is presented and the corresponding devices are developed. The experimental results show that an excellent transmission performance could be reached through optimizing the system structure parameters.

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