INVESTIGATION OF SPM AND XPM IN SOA-NOLM AND ITS APPLICATION IN WAVELENGTH CONVERSION

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LIST OF ABBREVIATIONS

APD	Avalanche photodiode
ASE	Amplified spontaneous emission
CW	Continuous wave
CWDM	Coarse wavelength division multiplexing
DIP	Dual in line packaging
EMI	Electromagnetic interference
EMP	Electromagnetic pulse
ER	Extinction ratio
FDM	Frequency division multiplexing
FWM	Four wave mixing
LD	Laser diodes
LED	Light emitting diodes
MI	Michelson interferometer
MQW	Multiple quantum well
MZI	Mach-zehnder interferometer
NOLM	Nonlinear optical loop mirror
NRZ	Non return to zero
OPC	Optical phase conjugate
OTDM	Optical time division multiplexing

QP	Q-penalty
ROADM	Reconfigurable add/drop multiplexing
SBS	Stimulated Brillouin scattering
SC	Super continuum
SNR	Signal to noise ratio
SOA	Semiconductor optical amplifier
SOA-NOLM	Semiconductor optical amplifier nonlinear optical loop mirror
SPM	Self phase modulation
SRS	Stimulated Raman scattering
TE	Transverse electric
TDM	Time division multiplexing
TM	Transverse magnetic
TOAD	Terahertz optical asymmetric de-multiplexer
TWA	Traveling wave amplifier
WC	Wavelength conversion
WDM	Wavelength division multiplexing
XGM	Cross gain modulation
XPM	Cross phase modulation

LIST OF SYMBOLS

A	Ampere
dB	Decibels
Gbs-1	Giga bit per second
GHz	Gigahertz
m	Meter
µm	Micrometer
nm	Nanometer
ps	Picosecond
THz	Terahertz

PENYIASATAN SPM DAN XPM DI DALAM SOA NOLM DAN APLIKASINYA DI GELOMBANG PENUKARAN

ABSTRAK

Tesis ini memberi tumpuan kepada penyiasatan modulasi fasa diri (SPM) dan modulasi merentas fasa (XPM) dalam semikonduktor penguat optik cermin gegelung optik tak linear (SOA-NOLM) dan aplikasi dalam penukaran gelombang. Seni bina baru untuk merealisasikan kesan linear menggunakan SOA dibentangkan. Objektif kajian ini dibahagikan kepada dua bahagian utama: pertama, penyiasatan SPM dan XPM di dalam SOA berasaskan NOLM dan kedua, aplikasi dalam penukaran gelombang. Dalam persediaan ini, pam kawalan adalah gelombang 1540 nm dan panjang gelombang isyarat 1555 nm. Persediaan simulasi berdasarkan interferometer Sagnac. Tahap keuntungan diperolehi dengan menetapkan suntikan semasa SOA kepada 0.2 A. Tiga kadar pengulangan isyarat yang berbeza digunakan di dalam simulasi; 2.5 Gbs^{-1}, 5 Gbs^{-1} dan 10 Gbs^{-1}. Pada kuasa input yang rendah, isyarat menghadapi perubahan fasa yang sangat kecil, tanpa mengira tetapan keuntungan daripada SOA. Walau bagaimanapun, seperti kuasa meningkat keluk fasa mula bercanggah. Ini tersirat bahawa untuk mencapai anjakan fasa besar pada kuasa yang rendah isyarat input, tahap keuntungan pada SOA mesti ditetapkan kepada nilai yang lebih tinggi. Dalam kajian ini, keputusan yang diperolehi adalah parameter operasi optimum seperti semasa suntikan berubah-ubah bagi SPM dan XPM kesan dalam persekitaran OptSim. Sistem ini boleh digunakan untuk kajian akan datang dalam peranti fotonik lain dan juga permohonan dalam pemprosesan isyarat optik, pensuisan optik dan penukaran panjang gelombang. Kajian

ini juga memberikan peningkatan dan teknik untuk membangunkan peranti fotonik lain pengetahuan.

INVESTIGATION OF SPM AND XPM IN SOA NOLM AND ITS APPLICATION IN WAVELENGTH CONVERSION

ABSTRACT

This thesis focuses on investigation of self phase modulation (SPM) and cross phase modulation (XPM) in semiconductor optical amplifier nonlinear optical loop mirror (SOA-NOLM) and its application in wavelength conversion. An improved architecture for realization the nonlinear effect using SOA is presented. The objective of this research is divided into two major parts: first, the investigation of SPM and XPM in SOA based NOLM and second, its application in wavelength conversion. In this setup, the control pump wavelength is 1540 nm and the signal wavelength is 1555 nm. The simulation setup is based on Sagnac interferometer. The gain level is obtained by setting the injection current of the SOA to 0.2 A. Three different signal repetition rates are used in the simulation; 2.5 Gbs^{-1}, 5 Gbs^{-1} and 10 Gbs^{-1}. At low input power, it is noticed that the signal encountered very small phase change, irrespective of the gain setting of the SOA. However, as the power increased the phase curve began to diverge. This implied that in order to achieve a large phase shift at low input signal power, the gain level at the SOA must be set to a higher value. In this research, the results obtained are the optimum operation parameters such as the variable injection current for the SPM and XPM effects in OptSim environment. This system can be used for future research in other photonic devices and also application in optical signal processing, optical switching and wavelength conversion. The research also gives knowledge enhancement and techniques to develop other photonic devices.

CHAPTER 1

INTRODUCTION

1.1 Optical Fiber Communication Technology

An optical communication system is similar to other communication system which consists of an information source (input), a transmitter, an information channel, a receiver and a destination (output) as shown in Figure 1.1 below (Agrawal, 1997).

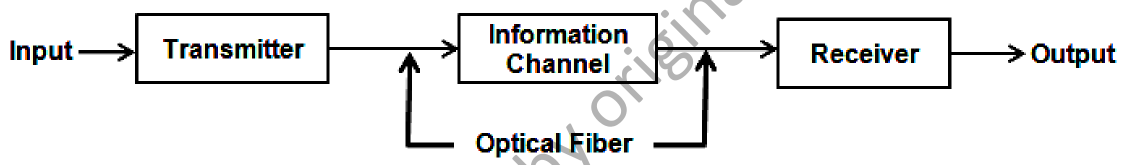

Figure 1.1: Block diagram of optical fiber communication.

Optical communication system can be classified into two broad categories which are guided and unguided. As the system name implies, in the case of guided lightwave systems, the optical beam emitted by the transmitter remains spatially confined. This is achieved by using optical fibers. Since all guided optical communication system currently use optical fibers, the commonly used term for them is fiber optic communication systems. The term lightwave system is also sometimes used for fiber optic communication systems, although it should generally include both guided and unguided systems. In the case of unguided optical communication systems, the optical beam emitted by the transmitter spreads in space, similar to the spreading of microwaves. However, unguided optical systems are less suitable for broadcasting application than microwave systems because optical beams spread mainly in the forward direction.

The application of optical fiber communications is in general possible in any area that requires transfer of information from one place to another. However, fiber optic communication systems have been developed mostly for telecommunication applications. The telecommunication applications can be broadly classified into two categories, long haul and short haul, depending on whether the optical signal is transmitted over relatively long or short distances compared with typical intercity distances (~ 100 km). Long haul telecommunication systems require high capacity trunk lines and benefit most by the use of fiber optic lightwave systems. Indeed the technology behind optical fiber communication is often driven by long haul systems. Each successive generation of lightwave systems is capable of operating at higher bit rates and over longer distance. Furthermore, transmission distances of thousands of kilometers can be realized by using optical amplifiers. Short haul telecommunication applications cover intercity and local loop traffic. Such systems typically operate at low bit rates over distances of less than 10 km.

The block diagram of Figure 1.1 applies to a fiber optic communication systems. The only difference being that the communication channels is an optical fiber cable. The two other components are the optical transmitter and the optical receiver. It is designed to meet the needs of such a specific communication channel.

The role of an optical transmitter is to convert the electrical signal into optical form and to launch the resulting optical signal into the optical fiber. It consists of an optical source, a modulator and a channel coupler. Semiconductor lasers or light emitting diodes (LED) are used as optical sources because of their compatibility with the optical fiber communication channel. The optical signal is generated by modulating the optical carrier wave. The coupler is typically a micro lens that focuses the optical signal onto the entrance plane of an optical fiber with the maximum possible efficiency.

The role of information channel is to transport the optical signal from transmitter to receiver without distorting it. Optical fiber is mostly be used in lightwave system as the information channel because fibers can transmit light with a relatively small amount of power loss. The important design issue is fiber loss as it determines directly the repeater spacing of a long haul lightwave system. Fiber dispersion is another important design issue which leads to broadening of individual optical pulses inside the fiber.

The role of optical receiver is convert the optical signal received at the output end of the optical fiber back into the original electrical signal. The coupler focuses the received optical signal onto the photodetector. Semiconductor photodiodes are used as photodetectors because of their compatibility with the whole system. The design of the demodulator depends on the modulation format used by the lightwave system.

1.2 Advantages and Disadvantages of Fiber Optic Systems

Fiber optics communication systems hold some distinct advantages over other systems. These include large bandwidth, small lightweight size, electromagnetic interference immunity, lower data loss, lack of inter-channel electromagnetic interference (EMI) crosstalk, less sparks, lower cost, compatible with solid state sources and no emission licenses (Downing, 2005).

The bandwidth of a medium depends directly on the frequency of the carrier. The bandwidth means the width of the frequency band that be used. Thus, for instance, if using the band from 1000 to 1010 Hz, the bandwidth is 10 Hz. The information transmitted per time is proportional to the bandwidth and it also depends on signal-to-noise ratio. Shannon's theorem says that the maximum data rate in bits per second cannot exceed the bandwidth times a small numerical factor times the logarithm of the signal to noise ratio. Modern communication systems come very close to meeting the Shannon limit. The maximum frequency of a signal sets a limit on the data rate, since the bandwidth cannot be greater than the maximum frequency. Optical carriers are superior compared to microwave carriers due to their higher frequencies. Optical fibers offer the possibility of several thousands of GHz and THz of bandwidth as fiber cables are made of silica glass or plastic, which is much lighter than copper or aluminum. They are cheaper and easier to be transported. Fiber diameter is much smaller compared to others. Hence, less space for storage, small volume and low density, optical fiber cables enjoy considerable weight advantages over typical coaxial ones (Powers, 1999).

Since optical fibers are non-conducting, they will neither generate nor receive electromagnetic interferences. This feature allows its usage in high electric fields region as example power electronics, radar feed horns/antennas, nuclear explosions and other sources of intense electromagnetic fields. One of the best applications for fiber optics is sending control signals into power stations which it could be obliterated by switching transients. Fiber optics are also used in telemetry links for bringing information out of a system such as electromagnetic pulse (EMP) or military aircraft lightning strike tests. They are also used to telemeter information out of underground atomic bomb test caverns.

A form of EMI occurs when two conducting lines are close enough to allow the signal from one to leak into the other (Powers, 1999). Traditional solutions included further separation of the cables or increased shielding by increasing the size, weight and cost of the coaxial cables. However, the optical fields from an optical fiber are negligible in eliminating optical pickup between adjacent cables. In special purposes