CHAPTER 1

INTRODUCTION

1.1 Introduction to Communication System

Communication can be defined as the transmission of data, voice, signals and any information from one place to another place over a distance at near visible light at high frequencies such at near visible light or near infrared region. Communication can be achieved by using an electromagnetic wave as a carrier to carry information. This carrier of information is then transmitted to any receiver where the original signal is separated from the carrier electromagnetic waves [1]. The practical communication system comprises of three main elements such transmitter, transmission medium and receiver [3,6]. At the transmitter, the message is generated and put into a form suitable for transfer over the communication channel. The information travels from the transmitter to the receiver over this channel via transmission medium. At the receiver, the message is extracted from the information channel and put into its final form. The information is converted into an electrical signal and then superimposed on top of the optical carrier.

The different types of telecommunications has different origins, but most of them are converging towards networks that deliver many different services. Convergence will never be complete due to some services differing widely from others. Convergence is strongest in the global backbone network. It is designed to carry digitized signals for worldwide usage. In a communications satellite, video signals can be relayed to the television broadcasters, cable television companies and subscribers to direct broadcaster services. Paging services and mobile data transmission can also be provided by satellites [3].

Optical communication was developed very quickly after the first low-loss fibers were invented in the 1970s [5]. Optical communication systems differ from microwave systems only in the range of the carrier wave that is used to carry the information. The optical carrier frequencies are around ~200THz while the carrier frequencies for a microwave system are around ~1GHz. It increases in the information capacity of optical communication systems by factor up to 10,000 due to such high carrier frequencies use for lightwave systems. The research for fiber optic communication system had started at around 1975s[2,3].

The optical fiber communication systems can be classified into two categories; long haul and short haul systems which is depending on whether it transmits data over relatively long or short distances [3]. Fiber optic telecommunication systems in general greatly benefit long haul communication systems which require high-capacity trunk lines. Each successive generation of lightwave systems is capable of operating at higher bit rates and over longer distances. For long haul systems, repeaters are required to amplify optical signals every 50 – 100km. However, more than an order-of-magnitude increased in both the repeater spacing and the bit rate compared with those of coaxial systems has made the use of lightwave systems very attractive for long haul applications [3]. Optical amplifiers are normally used for modern optical systems to optically amplify the signal especially for the purpose of transmissions over hundreds of kilometers.

1.2 Advantages of Fiber

We are now ready to discuss the advantages of fiber optics. But first, a caveat; Fiber systems are not 100% perfect. They have technical and economic limitations. The following discussion of the desirable properties of fiber can be useful for evaluation purposes.

The basic material of fiber is silicon dioxide. Comparison between fiber and metallic cables would be compared. Some fiber cables are cheaper than its wire equivalents. The savings would be done when the comparison is made on the basis of cost per unit of information transfer [5]. Fibers have greater information-carrying capacities than metallic channels. For longer paths, fiber cables are cheaper to transport and easier to install than metal cables because, fibers are smaller and lighter [5,6]. Optical fibers are generally chosen for systems requiring higher bandwidth or spanning longer distances. Another benefits of fiber is that the even when run alongside each other for long distances, fiber cables experience effectively no crosstalk [7].

The main benefits of fibers are its exceptionally low losses, allowing long distances between amplifiers or repeaters; and its inherently high data-carrying capacity, such that thousands of electrical links would be required to replace a single high bandwidth fiber cable. The losses of transmission are very low- of only a few tenths of a dB/km are available for use around the 1.3μm and 1.55μm wavelength region. Very long communication links can be constructed because of the availability of low-loss fibers [5,6,7].

One of the biggest advantages of fiber is their ability to carry large amounts of information in either digital or analog form. A copper wire can carry a signal up to 1 MHz over a short distance. A coaxial cable can propagate a signal up to 100MHz. Radio frequencies are in the range of 500 KHz to 100 MHz. Microwaves, including satellite channels, operate up to 100 GHz. Fiber optic communication systems use light as the signal carrier; light frequency is between 100 to 1000THz, therefore, one can expect much more capacity from optical signal [9]. For another example, a single fiber of the type developed for telephone service can propagate data at the T3 rate, 44.7Mb/s. This fiber transmits 672 voice channels. Although the pulse spreading limits the maximum rate, fiber capabilities meet the requirements of most data-handling systems and exceed the capabilities of conducting cables. In analog format, modulation rates of hundreds of megahertz or more can propagate along fibers.

Optic fibers, glass or plastic are insulators. No electric current flows through them, either owing to the transmitted signal or owing to external radiation striking the fiber. The fiber is well protected from interference and coupling with other communications channels, be it electrical or optical in nature. Corrosion caused by water or chemicals is less severe for glass than for the copper it replaces. However, water must not be allowed to penetrate the glass. For submerged applications, fibers are encapsulated within cables, which protect them from water [6].

In this dissertation, we use a short length of photonics crystal fiber (PCF) as gain medium in fiber laser system. Photonics crystal fibers (PCFs) are a class of micro-structured fiber which possesses a solid core surrounded by a cladding region. That is defined by a fine array of air holes that extend along the full fiber length. Due to the high index difference between silica core and air hole cladding, these PCFs allow much stronger mode confinement, and thereby much higher nonlinearities than that of a conventional single mode fiber (SMF).

1.3 Wavelength Division Multiplexing (WDM) System

The main purpose using an optical fiber link is for the optimization of data transmission capabilities and to allow for future expansions that are economical and do not incur major operating disruptions. Two methods use to increase data transmission rates are the multiplexing techniques through Time Division multiplexing (TDM) and Dense Wavelength Multiplexing (DWDM) [4]. By using a TDM system, the overall link capacity can be increased by increasing the data rate of a single wavelength transmitted through a single fiber. For example, if an optical fiber link designed to operate with a maximum capacity of 1.25 Gb/s is to be upgraded to 2.5Gb/s, all the terminal equipment must be replaced by new equipment that is capable of handling the new required transmission rates of 2.5 Gb/s [20].

The quest for finding methods to increase the optical fiber system capacity is WDM. Through WDM, multiple optical carriers of different wavelengths utilize the same optical fiber. With a WDM system, a dramatic increase of the system capacity can be achieved. WDM is fast becoming the technology of choice in achieving smooth, manageable capacity expansion. WDM is a technology which multiplexes to multiple optical carrier signals and transmit simultaneously on a single fiber. A demultiplexer at the receiver end split signals with different wavelengths and directs them to the appropriate receivers [4,5,20].

Figure 1.1 illustrate a block diagram of a simplified conventional optical fiber system that is composed of a single wavelength, while figure 1.2 illustrate an optical fiber system that is composed of five optical wavelengths, which are processed through a WDM mode of operation. The system of figure 1.1 is capable of transmitting data rates of up to 1.25 GB/s on a single optical fiber. If the system is designed for long distance transmission, it will require several repeaters that convert optical signals to electrical, amplify the signal and then convert them to optical signals for retransmission to the next repeater. These repeaters are essential if the system is to maintain a satisfactory SNR (Signal to Noise Ratio) or BER (Bit Error Rate). The system in figure 1.2 is capable of transmitting data rates of up to 5 Gb/s at the same distance through a single fiber, using only one in-line EDFA.

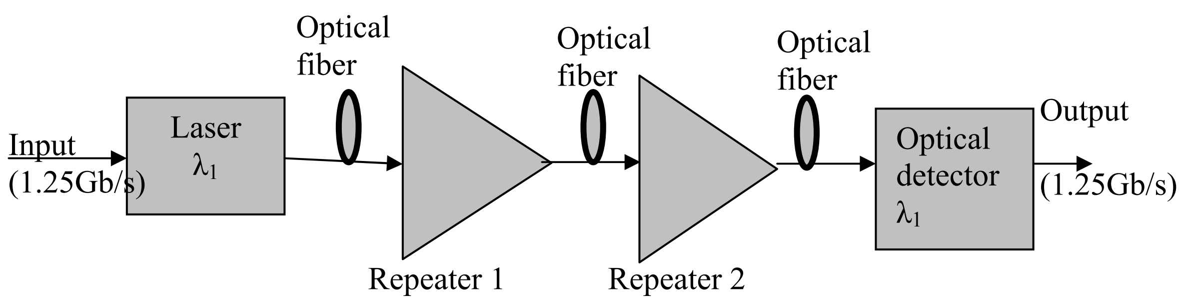

Figure 1.1: A conventional single wavelength optical fiber system

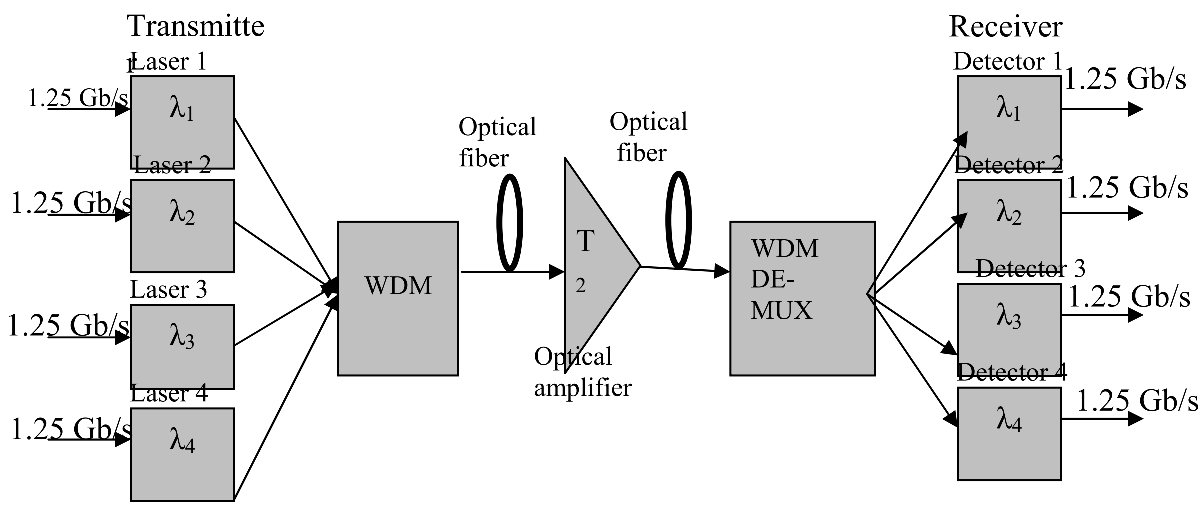

Figure 1.2: A 4-Channel WDM optical fiber system

In the earlier days, the cost of WDM systems was very expensive and complicated to use. However, vast improvements within the WDM system technology has made it cheaper to deploy. WDM systems are divided into different types, conventional or coarse and dense WDM. Coarse WDM (CWDM) systems provide up to 16 channels in the 3rd transmission window(C-band) of silica fibers around 1550 nm. Dense WDM (DWDM) uses the same transmission window but with a denser channel spacing [20]. WDM, DWDM and CWDM are all based on the same concept of using multiple wavelengths of light on a single fiber, but differ in spacing of the wavelengths, number of channels, and the ability to amplify the multiplexed signals in the optical space. For CWDMs, wideband optical amplification is not available, limiting the optical spans to several tens of kilometers [20]

1.4 Multiwavelength Fiber Laser

Multiwavelength fiber laser sources attract considerable interest due to their applications in optical communication, instruments testing, optical signal processing and in sensor applications. Multiwavelength sources provide a cheap and efficient alternative to the deployment of multiple laser diodes at different wavelengths. Above all else it is also compact, consume less energy and generate less heat than multiple laser diode systems [17]. Simultaneous multiwavelength oscillations based on erbium-doped fiber (EDF) lasers have been demonstrated using different methods. For example, multiwavelength Raman fiber ring lasers incorporating a Fabry-Perot etalon, a sagnac loop filter, phase shift fiber Bragg grating, and cascaded long period fiber grating (LPFG). Tunable multiwavelength laser structures have recently been reported, which are based on the employment of multiple distributed feedback (DFB) lasers [15], erbium doped fiber laser [15], and multiwavelength Raman laser [16]. Recently, multiwavelength Raman fiber lasers have been investigated for the simple operation at room temperature because of its inhomogeneous broadening characteristic. Raman lasers have the advantage of multiwavelength emission over extremely large bandwidths. Besides their large bandwidths, the advantages of fiber Raman amplifiers over EDFAs and other optical amplifiers include the possibility of operating in any wavelength region and superior noise performance of distributed amplification [14]. So, multiple wavelengths Raman lasers are very useful for application in WDM systems. In addition, uniform fiber gratings have low dispersion inside the reflective bandwidth. This is important for application in WDM systems with uniform grating pitch. From [10], multiple Raman fiber lasers based on Sample Bragg Grating (SBGs) were proposed and demonstrated. The simple and flexible SBG proved to be effective in generating multiwavelength sources. A multiwavelength EDFL also was demonstrated by using a HiBi (High Birefringence) fiber loop mirror to adjust the operating wavelength channel spacing [12,13]. From [11], they have demonstrated a novel multiwavelength lasing scheme of a SBS/Er fiber laser with a Brillouin enhanced four-wave mixing process in a Sagnac loop mirror. The laser operates at 34 multiple Stokes lines mainly caused by cascaded SBS processes as well as at an anti-Stokes of 0.08nm [11].

Another method to construct multiwavelength fiber lasers is by using the Semiconductor Optical Amplifier (SOA) technique. Recently, Rong Zheng.etl has demonstrated a stable tunable wavelength comb by employing an SOA and an Opto-Very Large Scale Integration (VLSI) processor [22]. By uploading digital phase holograms onto the opto-VLSI processor, the amplified spontaneous emission of the SOA is arbitrarily sliced and injected back into the SOA to generate multiple lasing wavelengths with a channel spacing of 0.5nm[17].

1.5 Brillouin Fiber Laser (BFL)

Aside the other methods explained in the previous section, a multiwavelength comb can be generated using a stimulated Brillouin scattering effect (SBS) in the Brillouin /Erbium fiber laser (BEFL) [19,20]. This dissertation focuses on a BFL/BEFL as a source of multiwavelength fiber laser generation. The BFL can be configured so the SMF/PCF receives more Brillouin pump (BP) power in order to generate high back-propagating Stokes power and Brillouin gain in the cavity. BFLs have the property of narrow linewidth, arising from the narrow bandwidth and homogeneous gain. The general technique to produce a Brillouin Fiber Laser is to construct a critically-coupled resonator, which requires achieving threshold in a BFL for resonator pump power, because of the small magnitude of the Brillouin gain [18]. An erbium–doped fiber amplifier (EDFA) in a laser cavity of the BEFL compensates for the resonator loss that is critical in ordinary BFLs, while still originating lasing action from the nonlinear Brillouin gain.

Coherent laser sources with low intensity noise are essential requirements for a variety of applications, such as coherent optical communications, coherent LIDAR detection fiber gyros and sensors [7,8,21]. Fiber laser are known to be the best low noise coherent laser source, with spectral linewidths ranging from as wide as hundreds of kHz to as narrow as few kHz. These lasers have also the potential to produce near-quantum-limited intensity noise by combining the use of an amplitude squeezed pump diode and an electronic feedback loop. Nonlinear effects called the SBS were applied to that result from the interaction between the intense pump light and acoustic waves in a medium. This interaction gives rise to backward propagating frequency-shifted light [21].

1.6 Thesis Overview

The main objectives of this thesis are to design a multiwavelength source using SBS effect in a Photonic Crystal Fiber (PCF) for WDM systems application. The emphasis is on the design to produce a multiwavelength Brillouin bismuth-erbium fiber laser in a short length of PCF. A booster is designed to boost up the power of the generated SBS to assist in multiwavelength generation Bi-EDF used has high gain and low noise figures with a wide and flat gain over the amplification region. This thesis is divided into five chapters including this chapter as the introduction.

Chapter 2 is more directed towards a literature review about the theoretical background of WDM systems, basic characteristics of normal silica, erbium bismuth, energy levels and pumping schemes. Chapter 2 also reviews the characteristics of a PCF and its microstructure. The nonlinear characteristics in the material are discuss in this chapter. We also discuss about the principle of Brillouin scattering which plays an integral role in this dissertation.

Chapter 3 focuses on the characterization of the amplifier for the Bi-directional Bi-EDFA. Several characterizations were discussed in this chapter such as the insertion loss of the PCF and the influence of index matching gel to reduce the Fresnel reflection. In chapter 3, we also study the MWBEFL generation in a normal Single Mode Fiber (SMF).

Chapter 4 focuses on the discussion on research work on application of MWBEFL in a PCF. In this chapter, we study about the influence of Brillouin pump (BP) and laser diode (LD) in the generation of MWBEFL at different wavelengths. The threshold power to generate the first Stoke also is discussed here.

The improvement in the generation of MWBEFL of the PCF obtained by modification of a standard design BEFL, which has been explained in chapter 5. Chapter 5 describes the suitable of output position and study the performance of optical circulator compared to optical 3dB coupler which has been used as a bridge for incident light from BP to insert into the resonator.

Chapter 6 concludes all the results gained from this research work. Possible future suggestions are also be given.

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