CHAPTER 1

INTRODUCTION

1.1 Historical Perspective of the Progress in the Field of Fiber Optics

Even though the basic principle of total internal reflection, which is responsible for the guiding of light in optical fibers, is known from the nineteenth century and the uncladded glass fibers were fabricated in the 1920s, the field of fiber optics was really developed when the use of cladding layer glass fibers in the 1950s. The field then developed rapidly, mainly for the purpose of image transmission through a bundle of glass fibers. Initially the optical fibers exhibited very high attenuation with typical loss ~1000dB/km and were therefore not comparable with the coaxial cables they were to replace (i.e. 5 to 10dB/km)[1]. There were also serious problems involved in jointing the fiber cables in a satisfactory manner to achieve low loss and to enable the process to be performed satisfactory easily and repeatedly in the field. However, the situation changed in the 1970s when the loss of silica fibers was reduced to ~20dB/km. Further progress in the fabrication technology resulted in a loss of ~0.2dB/km near the 1.55μm wavelength, a loss level limited mainly by the fundamental process of Rayleigh scattering.

In parallel with the development of the fiber waveguide, the optics field was also stimulated in the 1960s with the invention of the laser[2,3]. This laser provided a powerful coherent light source, together with the possibility of modulation at high frequency. In addition to this, the low beam divergence of the laser also made enhanced free space optical transmission a practical possibility. The invention of the laser instigated a tremendous research effort into the study of optical components to achieve reliable information transfer using a lightwave carrier.

Attention was also focused on the other optical devices, which would constitute the optical fiber communication system. Semiconductor optical sources and detectors compatible in size with optical fibers were designed and fabricated to enable successful implementation of the optical fiber system. These active optoelectronic devices have moved forward with such speed that optical fiber communication technology would seem to have reached a stage of maturity.

1.2 Brief History of Optical Fiber Amplifiers

The basic concept of an optical fiber amplifier is simple: it amplifies an optical signal in a fiber by using the stimulated emission of optically excited rare-earth ions in the fiber core. The operation principle of optical fiber amplifiers is the same as lasers, except that amplifiers do not need a cavity whereas lasers need one for oscillation. The history of the rare-earth doped fiber amplifiers dates back to the early 1960s with the demonstration of optical gain in Neodymium-doped glass fiber at a wavelength of 1.06μm[4]. This first-generation fiber amplifier was developed by C.J. Koester, B. Ross, G.C. Holst and E.Snitzer[5,6]. In this experiment, a signal from an 1.06μm InAsP laser diode was amplified in Neodymium-doped glass fiber but the efficient amplification was not achieved. The research work was then followed by the demonstration of the single-crystal fibers using a CO_2 laser beam as a heat source in 1975[7,8].

Several kinds of optical amplifiers were studied and developed during 1980s. Semiconductor laser amplifiers were used initially, but the interest shifted toward fiber-based amplifiers because of the practical factors related to coupling loss, polarization sensitivity, and interchannel crosstalk. The real breakthrough in the optical fiber amplifier technology came in 1987 with the advent of the erbium-doped fiber amplifier(EDFA) operating in the 1.5μm wavelength region, which shows its potential applications in actual lightwave system. This can be called a second-generation fiber amplifier[9]. EDFAs are fundamentally linear, insensitive to polarisation and offer high gains.

For the past few years, optical amplifiers have been revolutionizing the performance and potential of telecommunications. The availability of optical amplifiers really represents a key point regarding the attenuation limit of optical networks. Optical amplification allows system designers to increase network performance, and in the meantime lower the number of repeaters and simplify the network. These optical amplifiers offer lower installation and maintenance costs and higher link reliability. Today, it can be said that optical amplification has overcome attenuation limits. Even though the dispersion constraints still limit the maximum transmission span for signals, as a matter of fact, the field of optical telecommunications is evolving toward a scenario of a network much less dependent on attenuation and dispersion limits, where optical amplification is playing and will play in the future an essential role.

1.3 Overview

Short amplifiers have received increased interest, especially for use in integrated optics. To make short high-gain Er^{3+}-doped fiber amplifiers

(EDFAs), it is necessary to use high Er^{3+}-concentration, which consequently cause the quenching process and hence degrade the amplifier's performance because the quenching process will reduce the pump efficiency and a full population inversion cannot be reached. Thus, to minimize quenching in the high Er^{3+}-concentration amplifier, Er^{3+}-doped fiber can be sensitized by Yb^{3+} ions. In view of this, Er^{3+}-Yb^{3+} codoped fiber amplifiers (EYDFA) have recently received considerable interest for their potential applications in optical communications systems. In this project, an EYDFA is extensively studied, especially a study of its amplification characteristics in order to understand its operation and limitations as these parameters are of importance for transmission systems. Therefore, the theoretical background study and experimental work of an EYDFA is reported in order to provide a comprehensive account of its characteristics.

The present chapter describes the brief history of fiber optics and optical fiber amplifiers. Chapter 2 outlines the rare-earth ions and amplification in fibers, the amplification characteristics of an optical amplifier as well as the mathematical model of an EYDFA. This chapter provides the theoretical background for understanding of an optical fiber amplifier. Experimental procedures, results and discussions are presented in Chapter 3 and 4. Finally, conclusions and suggestions for future work are discussed in Chapter 5.

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