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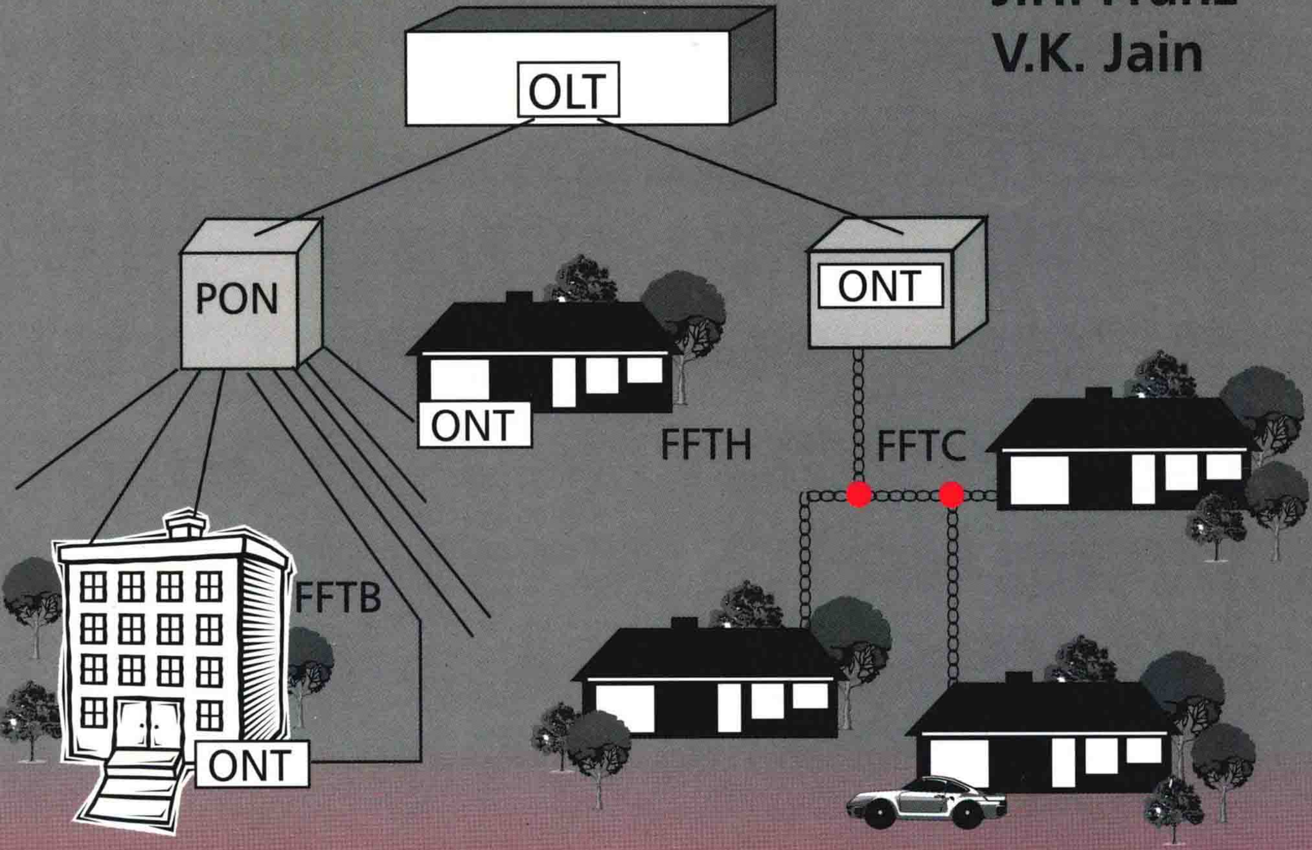

OPTICAL COMMUNICATIONS

COMPONENTS AND SYSTEMS

Alpha Science

Optical Communications

Components and Systems

Analysis • Design • Optimization • Application

(with 326 Figures)

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Optical Communications

Components and Systems

Physical Constants and Conversion Formulas

Physical Constants

Constant	Physical meaning	Quantity
c_0	Velocity of light	$2.998\cdot10^{8}$ m/s
e	Electron charge	$1.601\cdot10^{-19}$ As
h	Planck's constant	$6.624\cdot10^{-34}$ Ws^2
k_B	Boltzmann's constant	$1.379\cdot10^{-23}$ Ws/K
ϵ_0	Permittivity constant	$8.854\cdot10^{-12}$ As/(Vm)
μ_0	Permeability constant	$1.256\cdot10^{-6}$ Vs/(Am)

Conversion Formulas

1 μm $=10^{-6}$ m $=10^{-4}$ cm
1 Å $=10^{-4}$ μm $=10^{-10}$ m
1 Np = 8.686 dB
Frequency f in Hz $\approx 3\cdot10^{14}$/wavelength λ in μm
Bandwidth Δf (at centre wavelength λ) $\approx (c/\lambda^2)\cdot$ bandwidth $\Delta\lambda$

PREFACE

For several years now, optical fiber communication systems are being extensively used all over the world for telecommunication, video and data transmission purposes. Optical communications offer advantages of ultrahigh speed and highly reliable information transmission. Further, light intensity modulation and direct detection transmission links are cost effective as well. Optical communication links have now been preferred over the other high bit rate point-to-point communication links. In communication engineering, optical fiber and free-space communications have become more and more important. Besides microelectronic and software, optical communications represent a key technology of modern telecommunication systems.

Since the middle of the nineties, optical fiber technology has progressed from fiber links to optical networks. Besides transparency, these networks offer flexible optical routing based on optical crossconnects and wavelength division multiplexing. Such networks provide digital broadband accesses to end users by means of fiber-to-the-building and fiber-to-the-home.The optical fiber systems represent a key component of information superhighways which are required for high-quality, interactive multimedia services.

With advanced techniques such as coherent detection, optical communications can reach a new horizon, characterized by a number of new applications. Coherent optical communication systems offer significant advantages based on improved receiver selectivity and increased sensitivity. The second advantage is partially reduced in comparison to direct detection system with an optical preamplifier, but the first advantage still remains. It is quite important in coherent multichannel communication systems which offer the possibility of exploiting fully the large optical bandwidth available with the fibers.

This book has been written with the aim of providing basic material required for advanced study in theory and applications of optical fiber and space communication systems with and without optical amplifiers. The background required to study the book is only that of typical engineering students. Specifically, it is presumed that the reader has been introduced to the principles of electromagnetic theory and communication engineering. It would be helpful if the reader has some exposure to spectral analysis and statistics. Some relevant topics are briefly reviewed in this book also to maintain continuity.

The book is recommended to those, who have interest in optical communications. It can be used for an introductory level course as well as for a senior level course to engineering students. The practising engineers and physicists will also find it useful to update their knowledge in the field. In addition, this book will also be useful as a working reference in the selection and design of optical fiber and free-space communication systems.

We are pleased to thank our colleagues, students and friends who made many valuable suggestions and skilful services in the preparation of the manuscript. Last but not least, we would like to thank our wives and children for their patience during the time we devoted to write this book.

The authors wish all readers a successful study.

J. H. Franz
V. K. Jain

CONTENTS

1 INTRODUCTION

To begin with, this Chapter presents a short review of the history of optical communications which started more than 2000 years ago (Section 1.1). Thereafter, an introduction to modern optical communications, its background and some discussion on related technical and nontechnical aspects are presented in Section 1.2. Finally, Section 1.3 gives an overview of contents and organization of the book.

1.1 HISTORY

When someone talks about optical communications, people normally think of lasers, optical fibers and high bit rate data transmission. This basically represents the modern, high-tech part of optical communications. On the other hand, there is a part of optical communications which was used more than 2000 years ago. It has been verified that around 800 BC, *fire signals* were used to transmit information out of a limited number of selected messages known to the operators. Fire signals are optical signals, since their spectrum is located in the optical frequency domain just as the spectrum of a laser or a light emitting diode (LED). Information transmission with fire signals represents an optical free-space communication system as described in Chapter fifteen. Two hundreds years later, message of final conquest of Trojan was transmitted by fire signals via eight intermediate relay stations to Argos which is about 500 km away. This historical relay link is known as the *torchpost of Agamemnon*.

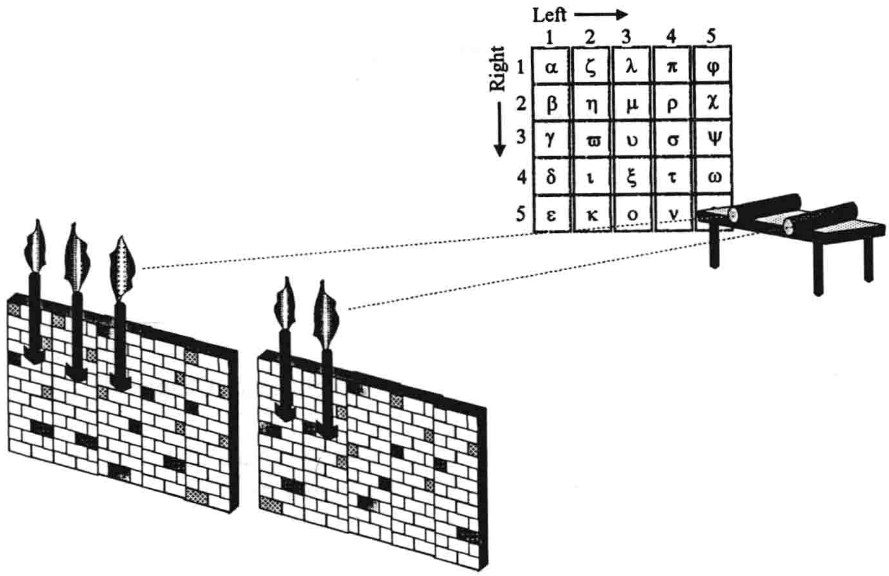

Fig. 1.1: Coding-based optical communication system and coding table of Polybios (200 BC)

In the ancient time, many other optical relay links were realized. However, they all show one main disadvantage. Instead of possibility to transmit every kind of information, only a limited number of selected messages were available which were a result of a previous agreement of the users. Around 200 BC, the Greek *Polybios* developed a torch-based transmission system which was able to transmit single letters instead of fixed messages. The basic idea of this system was to use a *coding table* as shown in Fig. 1.1. Depending on the number of torches behind the left and right wall, each letter out of 24 letters could be coded, transmitted, received and finally decoded. If, for example, two torches were behind the right wall and three torches behind the left one, the Greek letter μ was sent. With trained and educated operators, about eight letters were sent in one minute using this *coding-based optical communication system*. By taking into account an information capacity of five bits per letter, it results in a bit rate of 0.67 bit/s in contrast to some Gbit/s at present.

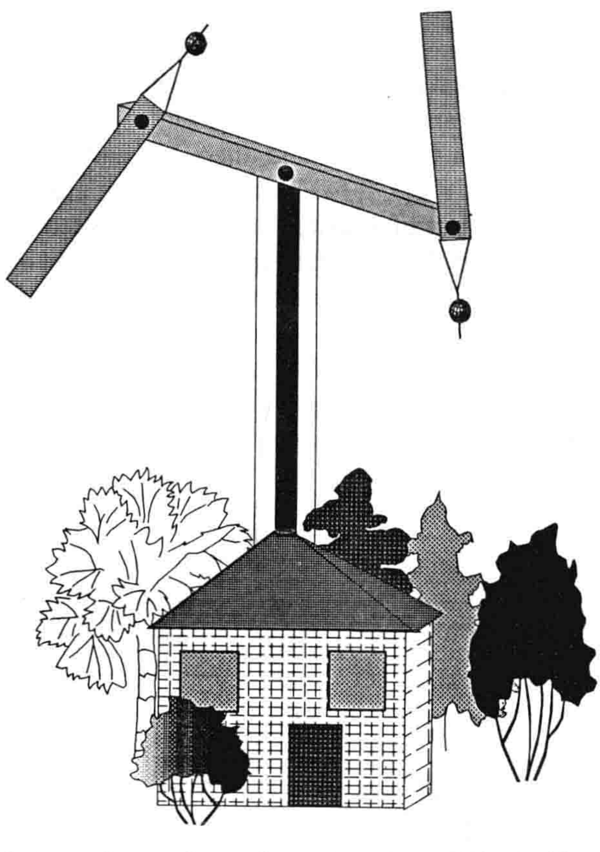

Fig. 1.2: Optical semaphore telegraph station of Claude Chappe (1800)

While optical communication was frequently used during the ancient time, there is no knowledge about an intense use of optical communication between Antiquity and the Middle Ages. A rebirth of optical communications took place in 1600, when first telescope was fabricated. A first breakthrough of optical communication was given in the year 1791. *Claude Chappe* successfully experimented an optical message transmission system based on semaphores shown in Fig. 1.2.