Fundamentals of Optical Fiber Communications

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Contents

Preface

Since the early 1970s, the authors of this book have given courses in optical glassfiber communications at the Department of Electrical Engineering of the Eindhoven University of Technology, as a part of their general teaching activities in telecommunications. Over the years they have selected topics that, on the one hand, give a good overview of the main principles of optical fiber communications and, on the other hand, are well suited to being taught in the classroom. This book is a compilation of the class notes originally established by the authors and updated by continuing use. It assumes some basic knowledge of the principles of electromagnetic fields, optics, semiconductor physics, Fourier analysis and noise calculations. Chapters 1, 2, 6, 7, 8, Sections 12.1–12.3 and 13.1–13.3 and Chapter 15 contain material for an undergraduate course, while the rest of the book can be taught in a graduate course. In addition, the text is well suited as a reference for scientists and engineers in research and development laboratories.

Chapter 1 starts with a comparison of optical communication systems with other communication systems of different kinds. Attention is paid to the fabrication processes that are used to produce glassfibers, to the different causes of attenuation and to a method to measure this attenuation. The most important properties of the light sources and the detectors, the elements necessary to form a simple communication link with an optical waveguide as the transmission medium, are reviewed and a general model of a link is established. The first part of the book, Chapters 2–7, deals with the propagation of light through optical waveguides. Chapter 2 starts with the treatment of slab waveguides, on the one hand as an introduction to the solution techniques used in subsequent chapters and on the other hand because these waveguides play an important role in integrated optics. The waveguides are analyzed with the help of Maxwell's equations, the characteristic equation with its discrete solutions is derived and the mode concept is introduced. In Chapter 3 this is repeated for the round step index waveguide. The E, H and hybrid modes are derived and attention is paid to LP modes. The expressions for the phase characteristics that follow from the solutions are further developed in Chapter 4, which treats the dispersion of the waveguides and the influence of the fiber on the bandwidth. A separate chapter, Chapter 5, is devoted to single-mode fibers. The principles derived in the earlier chapters are applied for this special case. Chapter 6 treats graded index fibers. In the previous chapters the wave optics model was used. In this chapter the waveguides are analyzed with the geometric optics model, using the eikonal equation as the starting point. At the end of the chapter the results are compared with the results obtained by the WKB method. In Chapter 7 two different models are used to derive the dispersion in graded index fibers. Chapter 8 deals with the semiconductor light sources and detectors that are used in optical fiber communication systems. Little attention is paid to the physical background, the emphasis being on the external characteristics. This approach is further elaborated in Chapter 9 for the modulation aspects of the sources. Once the optical fiber waveguiding and the light sources and detectors are introduced, a description of an entire link can be given; this is done in Chapter 10. A great deal of the total link loss is due to coupling losses; Chapter 11 gives an extensive treatment of these coupling losses, both in multimode and single-mode fiber links. The receivers in an optical transmission system require special attention. Noise phenomena are quite different compared to the classical communication model, where the noise is assumed to be additive, stationary and Gaussian. The shot noise, or Poisson noise, does not show these elegant properties. That is why analog receivers (Chapter 12) require a different approach compared to digital receivers (Chapter 13). Apart from the aforementioned shot noise, multimode optical fiber systems can suffer from system noise (Chapter 14), which arises from non-ideal matching of system components. In general, realization of an optical fiber link or network requires more components than standard optical fiber, light source(s) and detector(s). Such components may be: wavelength division multiplexers, optical isolators, polarization-maintaining fibers, etc. These components and other system aspects are treated in Chapter 15. Finally, Chapter 16 has been devoted to coherent optical fiber communication, a subject to which much attention is now being paid in laboratories and which may lead to very promising applications in the future.

A number of subjects closely related to optical fiber communications, but not specific to it, are dealt with in the appendices. These include: Bessel functions, transmission via bandpass systems, Gaussian beams and Poisson processes.

At the end of most of the chapters some exercises are provided, giving the reader the opportunity to check his or her knowledge by means of practical problems.

A task as extensive as writing a book always requires support. We thank Dr Peter Attwood for correcting the English text, and Gerard Baten for producing a number of the figures. One of the authors (W. v. E.) thanks his wife Kitty for typing his part of the manuscript.