Erbium-Doped Fibre Amplifiers: Principles and Applications
Emmanuel Desurvire, Wiley, New York, N.Y., 1994, $89.95.

After its invention by researchers at Southampton University in 1987, the erbium-doped fiber amplifier (EDFA) has undergone some of the most intensive investigations worldwide and seen probably the most rapid development in the history of optical communications. EDFAs are among the most important and influential breakthroughs in the field of optical fiber communications. They have replaced the cumbersome electronic repeaters and have offered full transparency over 40 nm across the third optical communication window enabling, among other unique functions, single-channel, high bitrate transmission over transoceanic distances, the possibility of wavelength-division-multiplexing (WDM) operation, as well as soliton generation and propagation. The author and his former AT&T colleagues are among the most important contributors in the EDFA field and have contributed enormously both in the theoretical and experimental investigation and demonstration of the capabilities of EDFAs. Desurvire is one of the most qualified researchers to cover the subject and his book is comprehensive.

The book is wisely organized in three major sections that can be considered independently to some degree. The sections supplement each other and provide a clear understanding of the features of and the unique solutions provided by EDFAs. The first section is entirely theoretical and deals with fundamental issues related with EDFAs. It introduces the main concepts needed for the modeling of the erbium atomic transition. The analysis is quite detailed and the significance of the various parameters, such as field distributions and overlap integrals, under different operating conditions, is clearly stressed. In addition to the general model, which can be handled only numerically, analytical models are included that can be particularly useful in low gain or low saturation applications. The density matrix, alternative formulation (unclear) is briefly outlined and applied to the thorough study of complex atomic susceptibility, complex refractive index and inhomogeneous broadening of Stark-split, two- and three-level systems. This section, and the corresponding appendices, contain a number of useful generalizations of existing models that are published for the first time.

Also in the first section the author presents the fundamental quantum properties of noise in single- and multiple-stage optical amplification of classical light. The analysis not only discusses in great depth the nature and clarifies the origin and inevitability of noise in optical amplification, but also provides useful engineering formulae for the measurement of noise introduced by the amplification process. In addition, the effect of single- and multiple-stage amplification on the photon statistics is considered in detail and assists in understanding some of the issues involved in photodetection. The subject of nonlinear photon statistics is briefly touched on and opened to further investigation. Moreover, an excellent account of the enhancement is given. Finally, the impact of optical amplification on the detection of digital and analog signals is addressed. I particularly found the treatment of noise and photon statistics quite detailed and illuminating.

The second section constitutes the book's core and focuses tightly on the device aspects of the EDFA. This part is primarily experimental and covers almost all the practical issues related with EDFAs. However, when specific characteristics of the erbium transition are discussed, the necessary theoretical modifications and additions, supplementary to the general formulations given in the first section, are provided. First, the most important effects and parameters related to the main Er^{3+} transition at 1.55 μm, such as homogeneous/inhomogeneous broadening and spectral and polarization hole burning, are thoroughly explained and characterized. Parasitic effects such as pump and signal excited state absorption, energy transfer and co-operative up-conversion, concentration quenching, and ion clustering are discussed in detail. However, the extremely useful Er-Yb power transfer case has been slightly under-presented. Following is an in-depth presentation of the gain and noise characteristics of the EDFA. Great emphasis is placed on the role of the pump, signal and ASE power on the performance of the amplifier and their significance in the EDFA optimization. An excellent and detailed account of the self- and signal-induced saturation on amplifier noise figure is given. In addition to the steady-state operation, the transient gain dynamics of the EDFA and its implications on cross-talk in WDM applications is covered satisfactorily. On the important issue of pulse amplification requirements, the book considers briefly only the special but very exciting case of solitons. Other types of amplifiers are just mentioned mainly for the sake of completeness.

In the third section, the author concentrates on the most important system issues involving EDFAs and the extra requirements imposed on them. The first part of this section is an extension of the basic amplifier geometry and reviews composite EDFA configurations with specialized response and properties, such as automatic gain and power control, flat gain, and channel equalization. The use of EDFAs in optically controlled switches and gates as well as recirculation fiber delay lines and their applications in pulse shaping and optical signal processing is covered. Finally, the vast and growing field of fiber lasers is briefly reviewed with the stress on configurations that use erbium-doped fiber as the amplifying medium.

The last part of the third section is primarily concerned with some of the up-to-date linear and nonlinear communication systems and local area networks and the enormous impact that EDFAs have had on the practical and successful implementation of these systems. The significance of EDFAs in optically pre-amplified receivers is emphasized. The most significant digital (linear) and soliton (nonlinear) system experiments performed to date are also reviewed. Limitations imposed on linear systems by fiber nonlinearities and dispersion are briefly mentioned.

The ground that is covered in the third part (concerning applications) is quite diverse and could have well been the subject of several separate volumes.

Therefore, its inclusion in this book is inevitably of a review type. However, the way and the extent to which these applications are benefited and/or enhanced by the use of erbium-doped fibers of EDFAs is clearly pointed out.

The book gives one of the most comprehensive and detailed accounts of the physics and fundamental principles of EDFAs. Although not lacking in applications, the book emphasizes the basic principles of EDFAs. It goes into great depth analyzing and clarifying all the complicated concepts involved and facilitates an in-depth understanding of EDFA characteristics. Surely the book will be of great help to all scientists and engineers working in the field and are struggling with the properties and the understanding of EDFAs. The unified and in-depth presentation of the subject will benefit, in particular, researchers and post-graduate students dealing with problems involving optical amplification in general. Certain parts of the book, especially the modeling section and the entire second section, could well be used to supplement undergraduate courses. I thoroughly recommend it to everybody interested in EDFAs.

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