6. Conclusions and guidelines

The aim of this book is to provide a comprehensive overview of bidirectional transmission in optical networks. It offers fundamental insight as well as its practical application/implementation. Many technical aspects of bidirectional transmission were treated in the different chapters: network aspects (ch.2), physical aspects (ch.3), transmission aspects (ch.4), and polarisation handling (ch.5). Both direct-detection systems and coherent (multi-channel) systems were considered. Many experiments have been performed to support the theoretical insight.

The conclusion of this book is that bidirectional transmission over a single fibre or network can be an attractive option to create a system with bidirectional communication. Bidirectional transmission offers savings in network costs and equipment costs by combining optical functions (special transceivers, bidirectional optical amplifiers). Especially in bidirectional (coherent) multichannel systems the polarisation handling complexity can be largely reduced. On the other hand, bidirectional transmission introduces complications for the system design: limitations of the duplexer (loss, wavelength dependence, costs), crosstalk from reflections, Rayleigh backscattering (alone or in combination with four-wave mixing), Brillouin scattering and crosstalk in optical amplifiers.

Therefore, when transmission systems are developed that comprise two-way communication, bidirectional transmission over a single optical fibre should at least be considered. This book provides the necessary information for evaluating and designing bidirectional single-fibre systems, and it determines the technical limitations mentioned before.

This last chapter summarises the main conclusions of the different sections (section 6.1) and discusses the practical consequences of the results of this book (section 6.2).
6. Conclusions and guidelines

6.1 Conclusions

This subsection summarises systematically all results and conclusions of the preceding sections of this book. An interpretation of the conclusions for practical bidirectional-system design is given by section 6.2.

Section 2.1 considered the network topology. It was found that the optimum topology at transmission level depends on the type of service provided. The best topology for a distributive (coherent) multichannel network (e.g. the distribution of video channels) is a star-tree topology, since in this way the available power is distributed most efficiently. The size of the star network is determined by the number of channels. Optical amplifiers are a very viable way to extend the number of subscribers and/or the geographical coverage. In contrast, it was found that for a coherent multichannel network in the case of bidirectional services (e.g. videophony) a tree-tree topology may be a better network topology, because of the relation between the number of channels and the number of subscribers. Optical amplifiers were found to be less interesting in this application.

Section 2.2 discussed the frequency management of coherent multichannel systems. Frequency management is relatively simple in a distributive system, which has all transmitters located at the same site. However, when transmitters are distributed over two or more locations, as in bidirectional/multipoint networks, some frequency stabilisation of the remote transmitters is required. Two schemes were found to have a good feasibility, as they require the least extra hardware: the “reference frequency comb” scheme, which locks all transmitters to a centrally issued distributed frequency comb, and the “tandem locking” scheme, in which the remote transmitter is frequency-locked to an incoming channel. Both schemes have been demonstrated in experiments.

Section 3.1 regarded the reciprocity of optical fibre and components. Reciprocity means that the attenuation and the time-delay of a signal are the same in both directions. Most optical components known today are reciprocal: couplers, Y-branches, optical fibres, retarders, optical networks, modulators, (unsaturated) semiconductor optical amplifiers and (unsaturated) doped-fibre optical amplifiers. Some exceptions are Brillouin optical amplifiers, acousto-optic frequency shifters and Faraday rotators. Because of their non-reciprocity, Faraday rotators are used in optical isolators and circulators.

Section 3.2 regarded the reciprocity of the polarisation behaviour. It is known that the polarisation orthogonality of copropagating waves is only preserved in linear reciprocal systems, when there is no polarisation dependent loss. However, polarisation orthogonality of counterpropagating waves is preserved in any linear