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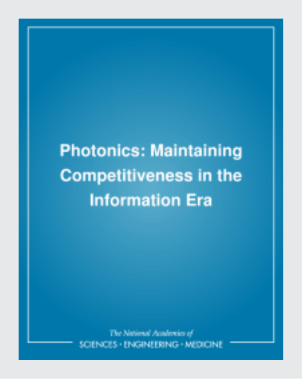

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DETAILS

112 pages | 6 x 9 | PAPERBACK
ISBN 978-0-309-03940-6 | DOI 10.17226/1145

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Panel on Photonics Science and Technology Assessment
Solid State Sciences Committee
Board on Physics and Astronomy
Commission on Physical Sciences, Mathematics, and Resources
National Research Council

NATIONAL ACADEMY PRESS
Washington, D.C. 1988

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dimensions of current research on these devices. While these device limitations are being actively addressed, much systems research is also needed to achieve large-scale application of optical switching devices in systems as a replacement for electrical-to-optical conversion accompanied by electronic switching.

Optical Amplifiers

Optical amplifiers are potentially important building blocks of all optical communication systems. In present optical communication systems the amplification function is accomplished by converting the optical signal to electronic form (detection), amplifying the electronic signal with an electronic amplifier, and then reconverting the amplified electronic signal to optical form. There are two main types of optical amplifiers: (1) fiber-based amplifiers, and (2) semiconductor laser-based amplifiers. The main uses of optical amplifiers are in (1) pre-amplifier applications where amplification of low-level signals is performed and there is no intentional loss between the output of the amplifier and the receiver and (2) in-line applications where relatively large optical signals are amplified and loss is expected between the output of the amplifier and the receiver. The former are likely to be important in high-bit-rate (>2 Gbits/s) systems if good APDs do not exist. In-line amplifiers are believed to be useful in both long haul (to compensate for fiber losses), in the local loop (to compensate for split-off and coupling losses), and in optical switching to compensate for losses in the switches.

Over the last few years, there has been considerable worldwide activity in developing amplifiers with large available gain, low insertion loss, low noise, large bandwidth, and saturation output power. To date, no practical semiconductor laser amplifier has been developed. The main potential advantages are the ease of manufacturing, high gain, and the tunability of the bandpass used for noise filtering and channel selection. However, semiconductor laser amplifiers have polarization-dependent gain that needs to be controlled through development of better optical isolators.

Fiber amplifiers, especially Raman amplifiers, suffer from the high pump power required for amplification. Research needs to be performed on special fibers with low loss and high Raman cross-section as well as special dopants for optically pumped fiber amplifiers. This is a promising field that needs increased attention.

Integration And Packaging

The interfacing of optical components with electronic ones is a key element for all future information transmission systems where one envisages the merger

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of optical signal processing with purely electronic media such as high-speed computers. One can imagine that in the interest of low cost and circuit simplicity, the terminal sources and receivers in the optical link may take on electronic processing involved with the communication link. One can fabricate, for example, a heterojunction bipolar transistor driver and a laser on a single chip or a pin photodiode and a field-effect transistor on the same chip. More complex integrated devices involving arrays of lasers, detectors, amplifiers, transistors, and modulators can be imagined. One of the main motivations for optoelectronic integration besides cost is performance. As speed increases, the interconnection of integrated circuits and subsystems becomes more critical and cannot be easily implemented with technologies available today. Compound semiconductor-based transistors are intrinsically faster than Si ones, and the monolithic approach provides significant additional improvements through reduction of undesirable parasitics associated with packaging discrete devices.

A key stumbling block in the exploitation of optoelectronic integrated devices has been the materials and processing technology. With high levels of integration, large-area compound semiconductor substrates of exceptional quality (low defect and dislocation density) and a vapor-phase crystal growth technique for growing uniform, epitaxial layers on the surface are required. Recent progress with hybrid MOCVD and MBE techniques suggests that this may be close at hand. However, because of the many conflicting processing requirements for optical and electronic devices, the ability to grow patterned structures in situ in a multichamber MBE machine will ultimately be extremely important if one is to exploit the full benefits of optoelectronic integrated devices. Major emphasis should be placed on developing further the materials and processing technology based on hybrid MBE/chemical-vapor deposition multiwafer, multichamber machines.

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