A Digital Design Methodology for Optical Computing

Miles Murdocka. xi + 161 pp., illus., subject index, bibliography. ISBN 0-262-13251-6. MIT Press, 55 Hayward St., Cambridge, MA 02142 (1990) $30.00 hardbound.

Reviewed by Alastair D. McAulay, Wright State University, Department of Computer Science and Engineering, Dayton, OH 45435.

This book is based on the author's Ph.D. thesis and describes a methodology for designing optical combinational logic circuits. The design uses 2-D spatial light modulators (SLMs), acting as parallel AND or OR gates, connected with regular, free-space, two-input, two-output interconnections, using masks to select interconnections. Such combinational circuits should permit demonstration of special-purpose logic and optical computing. However, the author's goals appear to be to show that this optical combinational logic approach is superior to others and is sufficient for constructing computing machines that are efficient and competitive with electronic machines.

Chapter 1 discusses the photon versus electron advantage for interconnects. It suggests that free-space, regular interconnects are superior to guided waves (as in fibers and integrated optics) and to irregular free-space interconnects because free-space regular interconnects are easier to implement and permit pipelining.

Chapter 2 describes briefly three devices: SEED, optical logic etalon, and interference filter. In addition, a brief review of interconnection networks is provided. The remainder of the book concentrates on two-input, two-output, regular interconnection networks. A further constraint allows only crossover or straight through and shift, where the shift between one SLM and the next is the same for every element in the SLM.

Chapter 3 mentions a few approaches to optical computing. There is a six-page description of symbolic substitution. Six other approaches are described too briefly, in approximately 200 words each: QWES, neural networks, optical VLSI interconnects, bit serial computer, and acousto-optic cell computers. The basic concept for the book, free-space regular interconnects, is described in approximately 300 words.

Chapter 4, over a third of the book, provides the design methodology. The first step reduces combination logic to a parallel set of AND gates, followed by a parallel set of OR gates, as in electronic logic design using programmable logic arrays. The next step for optical design replaces the multiple input gates by a sequence of two-input, two-output gates. This results in a series of 2-D SLMs for ANDing followed by a series of 2-D SLMs for ORing and specified interconnections between SLMs. An unimaginative trial and error algorithm is presented in which input and output locations are selected and interconnections between them are traced along allowable paths. If there are conflicts, the positions of the outputs are moved and the process is repeated. A similar algorithm is proposed when the connections are constrained to straight through and shift. Interconnections between SLMs are implemented with a beamsplitter, surrounded on four sides with the input, a periodic prism for crossover connections, a mirror, and the output. A mask is used at the output to select interconnections. The procedure is illustrated by applications to the design of a serial adder and a random access memory. A micro-optic implementation proposes stacking of arrays of lenslets, prisms, and SLMs. A figure on looping is inadequately described.

Chapter 5 describes three applications: a sorter circuit, an optical design for the DARPA-sponsored experimental Connection Machine, and a content addressable memory (CAM). Reasons are presented why a proposed optical sorting circuit might be better than a VLSI design. A preliminary optical design for the Connection Machine architecture is discussed, including an ALU, router, and hypercube interconnections. I agree with the author that "the resulting design is not immediately practical." Parallel search and tree gathering are performed optically in the CAM, while the remainder of the machine is electronic. A preliminary optical design for a CAM word module is described.

The book does not provide sufficient evidence that the proposed optical combinational logic using free-space, regular interconnects and masks is superior to combinations of other approaches. Analysis and optical experiments comparing this approach with others is required to show superiority. The fixed masks restrict design flexibility. Reconfigurability is generally needed for reasons such as fault tolerance. It would have been useful to see a discussion of how the masks are to be implemented and how the use of reconfigurable masks would affect performance. Further, it seems unlikely that a single optical combinational logic circuit approach is sufficient for constructing all elements of a complete computer that is efficient and competitive with electronic machines. The author tries to use this one approach for everything.

In summary, the book is reasonably clear and makes a good presentation of the free-space, regular interconnection approach to optical combinational logic circuit design. It should be of interest to logic designers in computer engineering. The claims of superiority to other approaches and the ability to use this concept to construct optical computers that are competitive with electronic ones remain to be proven. A minor comment: in such a short book, it does not seem necessary to repeat figures such as the architectural concept (pp. 41, 142), the micro-optic design (pp. 28, 64), and the optical interconnection diagram (pp. 24, 77, 101). It is also disconcerting to find blank spaces in the middle of chapters; 21 pages have over 8 lines blank and four pages have a half page or more blank.
BOOKS RECEIVED


Linear Controller Design: Limits of Performance, by Stephen P. Boyd and Craig H. Barratt; edited by Thomas Kailath. xi + 416 pp., illus., subject index, notes and references following each chapter. ISBN 0-13-538687-X. Prentice-Hall, Inc., Englewood Cliffs, NJ 07632 (1991). Covers design specifications, analytical tools, and numerical methods, using a less formal mathematical approach than some other books. Main focus is on describing how the controller design problem can be solved for a restricted set of systems and design specifications by combining recent theoretical results with numerical convex optimization techniques.


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Semiconductor Diode Lasers, Peter S. Zory, Univ. of Florida, Mon., 8:00 am-5:30 pm.

High Power Coherent Semiconductor Laser Arrays, James R. Leger, Massachusetts Inst. of Technology, Tues., 6:00-10:00 pm.

Applications of Laser Diodes, Chandrasekhar Roychoudhuri, United Technologies Research Ctr., Tues., 1:30-5:30 pm.

Principles of Polarized Light, Robert A. Fisher, RA Fisher Associates, Sun., 8:00 am-5:30 pm.

Laser Diagnostics

Diode Laser Testing, Thomas K. Plant, Oregon State Univ., Tues., 8:00 am-noon.