Field Guide to

Digital Micro-Optics

Bernard C. Kress

SPIE Field Guides
Volume FG33

John E. Greivenkamp, Series Editor

SPIE PRESS
Bellingham, Washington USA

Library of Congress Cataloging-in-Publication Data

Kress, Bernard C., author.
Digital micro-optics / Bernard C. Kress.
pages cm. – (The field guide series; FG33)
Includes bibliographical references and index.
ISBN 978-1-62841-183-6
1. Optoelectronic devices–Design and construction. 2. Optical MEMS. 3. Integrated optics. 4. Digital electronics. 5. Diffraction gratings. I. Title.
TK8360.O68K74 2014
621.36–dc23

2014016927

Published by
SPIE
P.O. Box 10
Bellingham, Washington 98227-0010 USA
Phone: 360.676.3290
Fax: 360.647.1445
Email: Books@spie.org
www.spie.org

Printed in the United States of America.
First printing.

SPIE.

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Field Guide to Digital Micro-Optics

The term "digital micro-optics" was introduced in the early 1990s to refer to a specific variety of micro-optics. It is now widely accepted by industry and academia. Digital micro-optics can be related to their counterparts in the electronics realm—"digital electronics," or "integrated electronics" (ICs)—in various ways, from design to modeling, from prototyping to mass fabrication, and eventually system integration. Historically, the term "digital" in digital electronics refers to three aspects:

- their digital functionality (binary logic),
- the way they are designed via a digital computer, and
- the way they are fabricated (through sets of digital or binary masks).

In digital micro-optics, the term primarily refers to how such optics are designed and fabricated, similar to digital electronics, through specific electronic-design-automation (EDA) software packages and sets of digital masks. Traditional macro-optics, such as telescopes, microscopes, and other imaging optics, have been designed without complex design software tools. Digital optics, especially wafer-scale micro-optics, cannot be designed without specific software and tools. Digital layouts for wafer-level fabrication of micro-optics are also often generated by algorithms similar to the ones used in conventional EDA tools (Cadence, Synopsys, Mentor-Graphics, etc.). Because there is often no analytical solution to the micro-optics design problem, complex iterative optimization algorithms may be required to find an adequate solution.

Unlike digital electronics, digital micro-optics can implement either digital or analog functionality, or a combination thereof. A typical digital function may be a fan-out beam splitter, and an analog function may be an imaging task. A hybrid may result in a complex multifocus imaging lens, a function impossible to implement in traditional analog macro-optics.

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Glossary

AMOLED	Active-matrix organic light-emitting diode
ARS	Antireflection surface
CD	Critical dimension
CGH	Computer-generated hologram
CIF	Caltech Intermediate Format
DBS	Direct binary search
DEAP	Dielectric electroactive polymer
DFT	Discrete Fourier transform
DOE	Diffractive optical element
DOF	Depth of focus
DTM	Diamond turning machine
DWDM	Dense wavelength division multiplexing
EAP	Electroactive polymer
EDA	Electronic design automation
EDOF	Extended depth of focus
EMT	Effective medium theory
FDTD	Finite-difference time domain
FFT	Fast Fourier transform
FLCOS	Ferroelectric liquid crystal on silicon
FZP	Fresnel zone plate
GDSII	Graphic Data System II
GRIN	Gradient index
HEBS	High-energy beam sensitive
HMD	Head-mounted display
HOE	Holographic optical element
H-PDLC	Holographic-polymer dispersed liquid crystal
IC	Integrated circuit
IFTA	Iterative Fourier transform algorithm
IL	Insertion loss
ITO	Indium tin oxide
LAF	Light-absorbing film
LC	Liquid crystal
LCOS	Liquid crystal on silicon
LGA	Local grating approximation
M-DOE	Moiré diffractive optical element
MEMS	Micro-electro-mechanical system
MLA	Microlens array
MOEMS	Micro-opto-electro-mechanical system
NA	Numerical aperture

Glossary

OLED	Organic light-emitting diode
OPC	Optical proximity correction
OPD	Optical path difference
OPU	Optical pick-up unit
PBS	Polarization beamsplitter
PC	Photonic crystal
PDLC	Polymer dispersed liquid crystal
PDM	Pulse-density modulation
PLC	Planar lightwave circuit
PSF	Point spread function
PSM	Phase-shift mask
PT	Parity time
PWM	Pulsewidth modulation
RCWA	Rigorous coupled-wave analysis
RET	Resolution enhancement technique
RIE	Reactive ion etching
SA	Simulated annealing
SBWP	Space–bandwidth product
SPDT	Single-point diamond turning
TIR	Total internal reflection
VHDL	Very-high-speed-integrated-circuit hardware description language
VLSI	Very-large-scale integration