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ELECTRO- OPTICS HANDBOOK

**RONALD WAYNANT
MARWOOD EDIGER**

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ELECTRO-OPTICS HANDBOOK

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ACRONYMS

2DEG	two dimensional electron gas	CBE	chemical beam epitaxy
2PA	two photon absorption	CCD	charge coupled device
III-V	Group III, group V of periodic table	CDRH	Center for Devices and Radiological Health (of FDA)
3HG	third harmonic generation	Ch	choroid
AEL	accessible emission limit	CID	charge-injection device
AM	amplitude modulation	CIE	Commission International de l'Eclairage
ANSI	American National Standards Institute	COD	catastrophic optical damage
AO	acousto-optic	CPM	colliding-pulse mode-locked
APD	avalanche photodiode	cw	continuous wave
APDs	avalanche photodiodes	D*	detectivity
APM	additive pulse mode locking	DBR	distributed Bragg reflector
AR	anti reflection	DCG	dichromated gelatin
ASE	amplified spontaneous emission	DFB	distributed feedback
BEFWM	Brillouin enhanced four wave mixing	DFDL	distributed feedback dye lasers
BH	buried heterostructure	DIN	Deutsche Institut für Normung
BLIP	background-limited infrared performance	DM	depth of modulation
C/S	coupler/splitter	DODCI	diethyloxadicarbon-cyanine iodide
CAD	computer-aided design	DOES	double heterostructure optoelectronic switches
CAIBE	chemically assisted ion-beam etching	DoF	depth of focus
CARS	coherent anti-stokes Raman spectroscopy	DUT	device under test
		EA	electron affinity
		EB	electron beam

EBCCD	electron bombarded charge coupled device	GRO	Gamma Ray Observatory
EBS	electron bombardment silicon	GSMBE	gas source molecular beam epitaxy
ECL	emitter-coupled logic	GVD	group velocity dispersion
EKE	electronic Kerr effect	GVDC	group velocity dispersion compensation
EL	exposure limits	HAZ	heat-affected zone
EMI/ESD	electromagnetic impulse/electrostatic discharge	HbO	oxyhemoglobin (blood)
EO	electro-optic	HBT	heterojunction bipolar transistors
ESA	excited state absorption	HEAO	High Energy Astronomy Observatory
FAFAD	fast axial flow with axial discharge	HEMTs	high-electron-mobility transistors
FDA	Food and Drug Administration	HID	high intensity discharge
FEL	free electron laser	HOE	holographic optical element
FELs	free electron lasers	HpD	hematoporphyrin derivative
FET	field-effect transistors	HR	high reflection
FFT	fast Fourier transform	HR	high resistivity
FGC	focusing grating coupler	HUD	head-up display
FHD	flame hydrosis deposition	IC	integrated circuit
FID	free-induction decay	ICI	International Commission on Illumination
FM	frequency modulation	IDT	interdigital transducer
FOV	field of view	IEC	International Electrotechnical Commission
FTFTD	fast transverse flow with transverse discharge	ILD	injection laser diodes
FTP	Fourier transform plane	IO	image orthicon
FWHM	full width half-maximum	IODPU	integrated optic disk pickup
G-R	generation-recombination	IOSA	integrated optic spectrum analyzer
GRIN-SCH	graded index waveguide separate confinement heterostructure	IPC	imaging proportional counter

ir	infrared	MO	magneto-optic
JFETs	junction FETs	MOCVD	metal organic chemical vapor deposition
KTP	KTiOPO ₄ , potassium tellurium phosphate	MOPA	master oscillator power amplifier
LANs	local area networks	MOS	metal-oxide-semiconductor
LAVA	laser assisted vascular anastomosis	MOVPE	metal organic vapor phase epitaxy
LDV	laser Doppler velocimeter	MPE	maximum permissible exposure
LED	light emitting diode	MPI	multiphoton ionization
lidar	light detection and ranging	MQW	multiple quantum well
LIF	laser induced fluorescence	MSM	metal semiconductor metal
LIS	laser isotope separation	MTBF	mean time between failure
LiTaO ₃	lithium tantalate	MTF	modulation transfer function
LLTV	low light level television	NA	numerical aperture
LLNL	Lawrence Livermore National Laboratory	NALM	nonlinear amplifying loop mirror
LM	light microscopy	NEP	noise-equivalent power
LPE	liquid phase epitaxy	NHZ	nominal hazard zone
LSI	large scale integration	NIST	National Institute of Standards and Technology
LSO	laser safety officer	nm	nanometers = 10 ⁻⁹ meters
LTE	local thermal equilibrium	NO	nitric oxide
LURE	Laboratoire pour l'Utilisation du Rayonnement Electromagnetique	NO	non-linear optic
μm	micrometers (microns) = 10 ⁻⁶ meters	NOHA	nominal ocular hazard area
MAMA	multianode micro-channel array	NRL	Naval Research Laboratory
MBE	molecular beam epitaxy	OD	optical density
MCP	microchannel plate	OEIC	optoelectronic integrated circuits
MES	metal semiconductor	OIC	optical integrated circuit
ml	mode-locked	OKE	orientational Kerr effect
MMIC	monolithic microwave integrated circuit		

OODR	optical-optical double resonance	RIBE	reactive-ion-beam etching
OPD	optical path difference	RIE	reactive ion etching
OPO	optical parametric oscillator	RIKES CARS	Raman-Induced Kerr-effect spectroscopy
OSSE	Oriented Scintillation Spectrometer Experiment	RIMS	resonance ionization mass spectroscopy
PAC	photoactive compounds	RPM	resonant passive mode-locking
PC	photoconductive	SAFAD	slow axial flow with axial discharge
PDT	photodynamic therapy	SAW	surface acoustic waves
PE	pigment epithelium	SBN	strontium barium ni-trate
PES	photoelectron spectroscopy	SBS	stimulated Brillouin scattering
PFL	pulse forming line	SEBIR	secondary electron bombardment-in-duced response
PGC	phase-generated carrier	SEC	secondary electron conduction
PLL	phase-locked-loop	SEED	self-electro-optic ef-fect devices
PM	polarization main-taining	SELFOC	self-focusing
PMMA	polymethyl methac-rylade	SEVA	slowly varying enve-lope approximation
PMT	photomultiplier tube	SHG	second harmonic generation
PPCM	passive phase conju-gate mirror	SI	semi-insulating
PVF	polyvinyl fluoride	SIT	silicon intensified tube
PWS	port wine stains	SLB	super lattice buffer
PZT	lead zirconate	SLD	superluminescent diodes
PZT	piezoelectric trans-ducer	SLM	single longitudinal mode
QE	quantum-effect	SMF	spectral matching factor
QW	quantum-well	SNR _D	signal to noise ratio of a display
RC	resistance-capaci-tance	SNR _{DT}	signal to noise ratio of a display at threshold
RE	rare earth		
REC	rare earth cobalt		
REMPT	resonantly enhanced multiphoton ioniza-tion		
RGH	rare gas halide		

SNR _{VO}	signal to noise ratio of video (for white noise)	TO	thermo-optic
		TPF	two-photon fluorescence
SPM	self-phase modulation	TVL	threshold limit values
SQW	single-quantum-well	TVL/PH	television lines/picture height
SRS	stimulated Raman scattering	uv	ultraviolet
TCDD	tetra chlorodibenzo- <i>p</i> dioxin	VCO	voltage-controlled oscillator
TCE	trichloroethane	VCSEL	vertical cavity surface emitting lasers
TEA	transversely excited atmospheric	VLSI	very large scale integration
TEA	triethylamine		
TEM	transmission electron microscopy	VLSIs	very large scale integrated circuits
TGFBS	twin-grating focusing beam splitter	VSTEP	vertical to surface transmission electro-phonic
TGS	triglycerine sulfide		
TGSe	triglycerine selenate	vuv	vacuum ultraviolet
THG	third harmonic generation	WDM	wavelength division multiplexing
TIR	total internal reflection	XPM	cross phase modulation
TMAE	tetraKis-(dimethylamino) ethylene	YAG	yttrium aluminum garnet
TMAH	trimethylaluminum hydride	YLF	LiYF ₄ , lithium yttrium fluoride

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CHAPTER 1

INTRODUCTION TO ELECTRO-OPTICS

Ronald W. Waynant and Marwood N. Ediger

1.1 INTRODUCTION

The field of electro-optics has become increasingly more important in the last 20 years as its prodigies and applications have found their way into most facets of science, industry, and domestic use. This near-revolution, which essentially started with the advent of the laser, has been the result of extensive parallel and often symbiotic development of sources, materials, and microelectronics. The combination of these technologies has enabled a great variety of compact devices with ever greater intelligence and performance. If source development was instrumental in initiating the field, materials and detectors were the binding elements. Vast improvements in optical materials have made fiber optics feasible and the availability of high-quality, affordable fibers has, in turn, made optical circuits and a variety of optical sensors possible. Refinement and development of new materials have resulted in an astonishing variety of devices to modulate, polarize, frequency-shift, and otherwise control coherent radiation. In turn, detectors have achieved greater performance and smaller size and cost.

This handbook attempts to cover a broad spectral bandwidth—from x-rays to far infrared. A primary motivation in extending the short-wavelength limit of the source spectrum, and the handbook's coverage of it, is the demand for higher resolving powers in materials and device fabrication applications as well as medical and biological imaging. Figure 1.1 depicts the size of objects of interest in the biological, materials science, and electronics worlds, and the wavelength necessary to resolve them as prescribed by the Rayleigh criterion. The infrared boundaries of the spectrum are also continually being strained by sources, materials, and detectors in the development of a variety of applications such as imaging, optical diagnostics, and spectroscopy.

Each chapter of this handbook falls into one of four categories: sources, materials, and their properties (e.g., nonlinear optics), detectors, and applications. In the remainder of this chapter we present some simple overlying principles of each category and a topical map to aid the reader in finding the desired information.

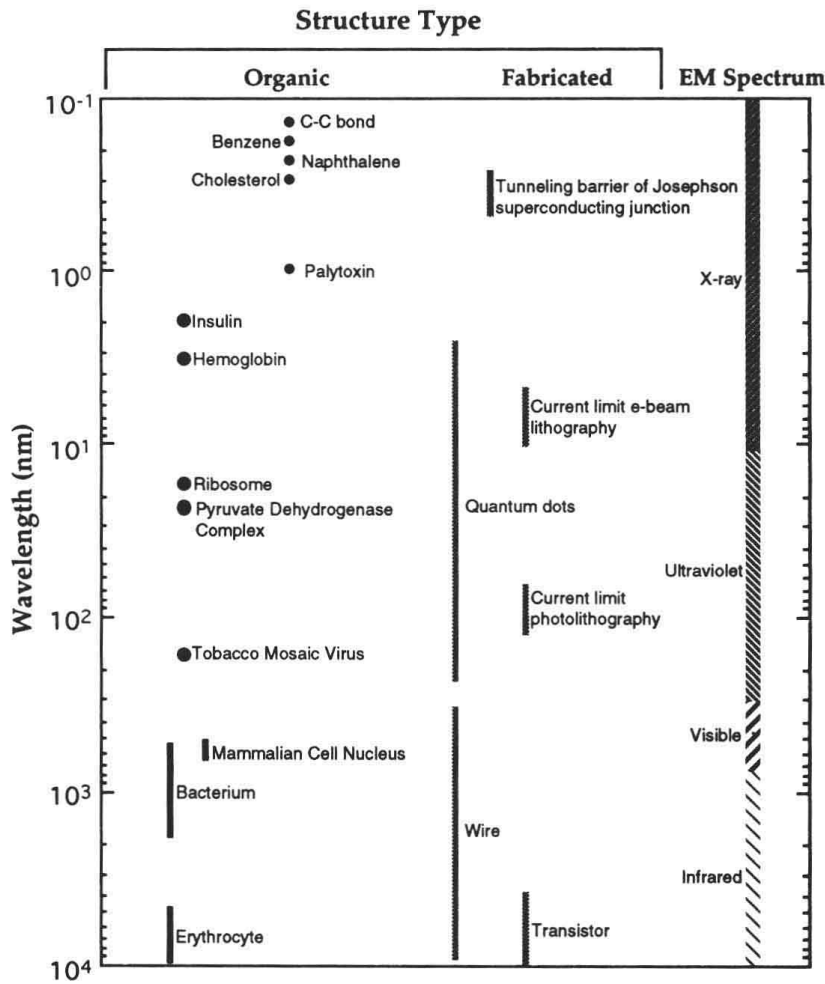


FIGURE 1.1 Relation of object size and resolving wavelength.

1.2 TYPES OF LIGHT SOURCES

Chapter 2 takes a detailed look at incoherent sources, and Chaps. 3 through 8 are devoted to the numerous laser sources grouped in part by media and in part by wavelength. Ultrashort pulse lasers and techniques are covered in Chap. 9.

Although the activity in the field of electro-optics has often been mirrored by events in laser development, incoherent sources still have an important role. Lasers are much newer and more space is devoted to them in the chapters to follow; however, the inescapable fact is that lamps currently have a much greater effect on our everyday lives than do lasers. With hundreds of millions of plasma discharge lamps and billions of incandescent light bulbs in constant use on a worldwide basis, power expenditure on lighting alone approaches the Terawatt level. Even the 22 percent or lower efficiency of most lamps still exceeds that of most lasers.

Arc lamps are characterized by high currents (several amperes) and high pressures (atmospheres) with ballast resistors used to prevent complete runaway. The lamps can be exceedingly bright. Examples include high-pressure (3 to 10 atmo-