DEPARTMENTS

BOOK REVIEWS

Fundamentals of Photonics

Bahaa E. A. Saleh and Malvin Carl Teich, 984 pages, illus., index, references, and appendixes. ISBN 0-471-83965-5. John Wiley and Sons, Inc, 605 Third Avenue, New York, NY 10158-0012 (1991) $69.95 hardbound.

Reviewed by Eugene Hecht, Adelphi University, Physics Department, Garden City, NY 11530.

The first thing one is moved to say about *Fundamentals of Photonics* by Saleh and Teich is that this is a big book. Happily, it is also a good book, well worth owning and reading. Actually, the work is several texts in one, which is why it's so massive and why assimilating it is a daunting proposition. The word "fundamentals" in the title might suggest, just as the word "advanced" might suggest, that the discourse was aimed at a specific level. Nonetheless, this book assumes a high degree of sophistication and is certainly not written for the uninitiated or casual reader looking for an introduction to the field. The authors tell us that the book comprises four parts: Optics and Fiber Optics (Chaps. 1 to 10), Quantum Electronics (Chaps. 11 to 14), Optoelectronics (Chaps. 15 to 17), and Electro-Optics and Lightwave Technology (Chaps. 18 to 22)—clearly a full and admirable agenda.

Indeed, just drawing the distinction between electro-optics, optoelectronics, quantum electronics, quantum optics, and lightwave technology is a feat in itself, whether entirely desirable or not. Practitioners writing in the contemporary literature have already fragmented the discipline into a hodgepodge of linguistic subdivisions. Nowadays, this fragmentation seems to be a natural sociotechnological process even though these divisions tend to obscure the fact that the entire subject is simply the interaction of radiant energy and matter. And it is here, in the tension between pragmatism and philosophical rigor, that this book and I have our small parting.

Fundamentals of Photonics is modern in its conception, up-to-date in its content, and very nicely illustrated. The authors have given much thought to the figures, and several of the original representations are quite engaging. The book has a decidedly practical posture; it gets on with business in a cut-and-dried, fast-paced way—sometimes perhaps too fast. Thus, it starts on page 1 with ray optics and is already dealing with Fermat's principle by page 4. There we read "light rays travel along the path of least time," but to quibble, light rays are themselves mathematical paths; in what sense do light rays travel? Light travels, rays just show us the route. So I went back to reread Saleh and Teich's definition of ray. Only then did I realize that although they talk about the behavior of a ray, they never define it. The reader could easily conclude that a ray is a narrow beam of light—it is not. Rays are not physical entities; they carry no energy. Thus, very early on in this tome one gets the disconcerting sense that the authors have a lack of appreciation for the precise use of the language of physics.

What's wrong with this sentence (p. 9): "All paraxial rays originating from each point on the axis of a spherical mirror are reflected and focused onto a single corresponding point on the axis."? Hint: (1) What about all the axial points from F to the vertex? Those rays diverge. (2) What about rays pointing away from the mirror? Those rays never get to the axis. The authors are not always as careful as one would hope for in a textbook where a special obligation exists to be rigorous. Overlooking these minor flaws, the chapter, which goes on to do a nice job on GRIN media and the eikonal, is well done.

The very first paragraph of Chap. 2 gets off to a strange start. The single most important, most widely used, and universally standardized constant in all of physics is c, the speed of light in vacuum. Why then would these authors choose to use c_0 instead? And if that weren't enough, why would they call the speed of light in a medium, of all things, c rather than v or anything else? This may be the only modern text, and I hope it is, where whenever you see c you must remember it isn't really c. One can learn to live with this little idiosyncrasy, but it ill serves the student who is attempting to find interdisciplinary harmony in the body of physical science. Of course, the subscript zero goes nicely with ε and μ, and this innovation might well have been appreciated a century ago, but not now.

That same unfortunate paragraph goes on to say that "the range of optical wavelengths contains three bands—ultraviolet (10 to 390 nm), visible (390 to 760 nm), and infrared (760 nm to 1 mm)." Are Saleh and Teich really trying to tell the innocent reader that no such thing as microwave optics exists, or that radio and x-ray telescopes are not optical devices? It would seem so, and I guess they have the right to their opinion. Yet on page 520 we find that "Improved x-ray optical components are in the offing... ." Well, that leaves the careful reader totally confused about the meaning of the word optics, which in a book about optics is a tad disconcerting. I think it would be nice to recognize that contemporary optics embraces the entire electromagnetic spectrum. One might even be tempted to extend the definition to include all particles. After all, the electron microscope has been around for decades, and we now have atomic interferometers.

What's wrong with this sentence (p. 65): "An interferometer is an optical instrument that splits a wave into two waves using a beamsplitter. . . ."? Hint: Does Michelson's stellar interferometer have a beamsplitter? No. Does an entire class of interferometers exist that does not use beamsplitters? Yes! The authors also should consider the Pohl interferometer, which is arguably yet another class of interferometric devices that does not use beamsplitters. And if one is to believe the authors, no such thing as a radiofrequency interferometer exists, since that device is by definition not optical (10 nm to 1 mm).

Overall Chap. 4 is a fine discussion of Fourier optics, although it too has a few minor flaws. Figure 4.1-3 shows "a thin element whose amplitude transmittance is a harmonic function." A plane wave impinges on it and a single plane wave is transmitted, emerging at some upward angle. But if the grating is symmetrical, how does the wave know to emerge upward? And what would happen if we quietly rotated the sinusoidal grating 180 deg; would the beam still come out upward? Hint: Fig. 4.5-2, which is 30 pages away, shows the same setup but this time properly depicting three transmitted waves, one up, one down, and one undeflected. What's wrong with this sentence (p. 143): "A hologram is a transparency containing a coded record of the optical wave."? Hint: How about all those millions of stamped-out metallized plastic replica holograms; are they transparencies?

Again a chapter starts off with a bang, this time it is Chap. 5, Electromagnetic Optics. The chapter begins with a figure that defines light as the band of the electromagnetic spectrum that extends from the infrared to the ultraviolet (1 mm to 10 nm). Now, certainly the word light is used loosely by some to mean the entire spectrum, especially when talking about the speed of light. And certainly the popular press often refers to infrared light and ultraviolet light when they more properly should speak of IR and UV "radiation" or "radiant energy." But is this the professional consensus usage? I think not. It has been the common understanding for millennia, certainly since that ringing phrase "And God said, Let there be light," that light is the anti-thesis of darkness. Light is what we see. As W. D. Wright has stated "Only radiations within the visible spectrum should properly be described as light radiations. . . ."[1] If Saleh and Teich would like to propose a different definition, they owe it to their readers to point out that their understanding is not universally accepted in the scientific community.

The paragraph that calls extreme IR, "light," is followed by one that is also troublesome (p. 158). There we are told that "Electromagnetic radiation propagates in the form of two mutually coupled *vector* waves, an electric-field wave and a magnetic-field wave." Are students to take this sentence literally? The implication that two distinct, though coupled, physical waves exist is a bit misleading. There can be a static electric field and there can be a static magnetic field, but there is only an electromagnetic wave. (Actually, there is only a stream of photons, and when considered in that context, the sentence is meaningless.) When an electric field varies in time, the electric field is always inextricably accompanied by a magnetic field and vice versa; one cannot exist without the other. They are not separable; they do not dance through space like two children holding hands. They are two concurrent manifestations of a single indivisible electromagnetic entity. I suspect what Saleh and Teich meant to say was that the mathematical descriptions of the **E** and **H** fields each satisfy the wave equation, and each has the familiar mathematical form of a wave.

The next several chapters are interesting and well done, although more thorough copy editing would have helped to smooth out the rough edges. For example (p. 287), "The core of a graded-index fiber has a variable refractive index. . . ." I suppose they do not really mean "variable" as able to be varied. In any event, I will spare the reader my further small complaints and jump to Chap. 11, Photon Optics. Keeping in mind Einstein's lament "Every physicist thinks that he knows what a photon is, I spent my life (trying) to find out what a photon is and I still don't know it," we turn with no little trepidation to page 386. There, the authors state "Light consists of particles called photons." Does that mean just UV, visible, and IR, which is what this book defines to be light, or are there x-ray photons too? Already one begins to get a sense of how careless definitions can profoundly distract from an otherwise impressive work.

The authors also say "A photon has zero rest mass and carries electromagnetic energy and momentum. . . . The photon travels at the speed of light in vacuum (c_0); its speed is retarded in matter." Now I have problems! I always thought from special relativity that a zero-mass particle could only exist at $c = 2.99792458\times10^8$ m/s. (Forgive me, I can't bring myself to use c_0.) Photons cannot travel in matter with a "retarded" speed. Also, photons always travel in a vacuum anyway—the vacuum between the atoms of the material medium. Sorry guys, photons only exist at *c*! Saleh and Teich say that "photons travel at the speed of light in vacuum," which is tautological, but that aside, what happens if we put a few atoms in an otherwise perfect vacuum? Do all the photons traversing the space slow down? How do they know any atoms are in there? Do slow photons have the same kinetic energy as fast ones of the same frequency? Do they lose energy when they enter glass and somehow get it back when they emerge? If they are "retarded" does their frequency change in a medium? Red bathing suits always look red under the water, do they not?

On page 386, Saleh and Teich give us some rare historical color. Unfortunately, to even imply that Planck was responsible for the conception of photons is to do mischief to history. Planck abhorred the notion of the photon. Radiant energy was first quantized by Einstein (1905), and Planck at least once apologized for his young friend's foolish idea. In fact, as the chief critic of the photon hypothesis Planck was still opposing it as late as 1913.

Oh dear, on page 388 we find an example dealing with "a microwave photon." What could that be, since they just finished telling us that light consists of photons and specifically excluded microwaves from being light? Are we to assume that the remainder of the electromagnetic spectrum is also photonic? I hope so. The rest of Chap. 11 is a mixed blessing: there are monochromatic and polychromatic photons (and I always thought each photon had a single frequency defined by E/h), and there is a fresh new notation for the uncertainty principle written with lowercase sigmas. (Why use the old fashioned $\Delta x\Delta p$ of the past seven decades?) I had hoped to find out how a single photon, which carries intrinsic angular momentum, could be linearly polarized, but they did not deal with that small point. There are lots of interesting topics covered and lots of provocative statements made. For example (p. 391), "Because momentum is conserved, its association with a photon means that the emitting atom experiences a recoil of magnitude hv/c." Evidently, here (and nowhere else) that means that the photon momentum is E/v, (their *c* is everybody else's *v*), but I thought a photon's momentum was always E/c (not their *c*, but everybody else's *c*). This is a case where if they are wrong, they are right.

The introductory paragraphs of each chapter seem to be afterthoughts added on by some editor who did not quite get the point. The introductions almost always contain grand sweeping this-is-the-way-it-is statements that are not quite correct. The one-line all-there-is genre is extremely difficult, if not impossible. What's wrong with this sentence (p. 424): "A photon may interact with an atom if its energy matches the difference between two energy levels." Hint: A photon may also *interact* with an atom if its energy is either less than or more than the difference between two energy levels. A photon can even rip electrons out of the atom altogether. What the authors meant to deal with was resonant absorption as opposed to, say, elastic scattering, or "upconversion." They did not actually mean "interact." In fact, when light (i.e., visible radiant energy) passes through clear glass it interacts (and hence there is an index of refraction), but light is not anywhere near a resonance. Incidentally, the difference between the $n = 5$ and $n = 6$ levels of the hydrogen atom is 0.16 eV. A 0.16-eV photon whose "energy matches the difference between two energy levels" is not very likely to be absorbed unless the atom is already in the highly excited $n = 5$ state, and we can apply the same argument to $n = 500$ and $n = 501$. Somehow I am sure they did not mean to be taken quite this literally.

I think the *c* in Example 12.2-1, which gives the "intensity spectral density" in "free space," should be c_0, but I'm so confused I couldn't swear to it—maybe they mean the real *c* now and wrote c by mistake. Incidentally, Fig. 19.2-6 needs help: the #3 wave does not exist before the #1 and #2 waves overlap to create it. There is a typographical error on the last line of page 920—it is not supposed to be $\cos(\pi t)^2$. In fact, I did not know you could make transcendental functions with arguments that have physical units, so Table A.1-1 is a revelation to me. The units in the power series expansion of $\exp(-\pi t)^2$ must be a sight to behold; I wonder how they add up the terms. Well that is enough, I hesitate to further try the patience of my readers, who may grow weary with a complete accounting of all the little blemishes.

Since the title of this work is *Fundamentals of Photonics* let's jump to Chap. 19 and more insights on photons. The section called "Wave mixing as a photon interaction process" is a trifle unorthodox. Here we are told on several occasions that "a photon of frequency ω_3 combines with a photon of frequency ω_4 to produce a photon of frequency ω_1. . . ." Saleh and Teich have photons combining and "splitting" as if they were flying wads of clay and not fundamental particles. What does it mean to state that a photon splits? I grant you there are precedents for this sort of casual usage, but the fact that Yariv[2] puts quote marks around the word splitting does not make matters much better. If a photon is an elementary particle, it would seem that two of them could not possibly coalesce to produce a third; certainly one of them could not possibly split. Figure 19.2-8 has photons doing all those neat tricks in an ersatz-Feynman diagram, and much is made on page 750 of conservation of "energy and momentum." But Saleh and Teich only talk about linear momentum. Alas, photons possess intrinsic angular momentum. Whatever happened to conservation of angular momentum? When a photon "splits" what in heaven's name happens to its angular momentum? Are we supposed to take all of this seriously? And if not, why do it? Processes like wave-mixing and second-harmonic generation never happen without the presence of matter: quanta are absorbed by the medium and new quanta are emitted.

The professional who has been around and can read between the lines will find this work a fine resource. It provides a single reference to much of modern optics and can be very helpful. On the other hand, the meticulous scholar who cherishes precision of language, clarity of exposition, and conceptual rigor might be a little disappointed. Whether to use the work as a classroom text, I leave to my colleagues who will have the obligation of picking up after it. This could have been a great book—it is not.

The Laser Guidebook: Second Edition

Jeff Hecht, 498 pages, illus., subject index, references, and one appendix. ISBN 0-07-027737-0. McGraw-Hill Inc., 1221 Avenue of the Americas, New York, NY 10020 (1991) $44.95 hardbound.

Reviewed by Fred Abbott, Consultant in Optics & Quality Programs, 2899 Agoura Road, Suite 327, Westlake Village, CA 91361.

In the preface to this book the author states, "I wrote this book because it is something which I long wanted to have on my bookshelf. Several excellent textbooks describe the physics of lasers. Handbooks tabulate laser lines reported in the scientific literature. But I have never found any book devoted to functional characteristics of commercial lasers—information vital to those of us who work with lasers." This reviewer echoes those comments and has, until relatively recently, been frustrated both as a laser user and a teacher with the lack of a suitable text that explains the ever increasing complexity of laser technology in a logical and understandable form. This need was fulfilled, at least for this reviewer, when he located a book entitled, *Understanding Lasers,* by Jeff Hecht in a consumer electronics store for a cost of about $4. Undoubtedly, *Understanding Lasers* is the best instructional book on this topic that this reviewer has ever seen, and I frequently refer both students and clients to this economically priced book. I was excited when asked to review this text, and based on my previous interactions with Hecht's work, I probably expected too much of the present volume.

The present book is definitely an encyclopedia of knowledge of commercial laser technology, but it has, in this reviewer's opinion, some glaring omissions whose correction would make the volume more attractive. As an example, the book does not contain a single reference to Gaussian beams. With the present emphasis on instruments designed for laser beam characterization and measurement, this topic has become widely discussed and, unfortunately, poorly understood. Hecht is an excellent writer and is able to reduce complex topics to simple and easily understood terms. His inclusion of this topic would surely have added to the value of the reader's knowledge. In the portion of the book that deals with Laser Theory and Principles (Chap. 3), laser modes and cavities are mentioned but only in general terms. In that chapter, an illustration of laser modes is shown, and this material was taken from the Melles Griot Optics Guide 4. [Surely, a more original reference than this exists. See, for example, Kogelnik and Li, *Appl. Opt.* 5, 1550 (1966).]

Chapter 1 of the book is an introduction that provides a considerable amount of material on a variety of topics (market size, laser safety, and applications, for example). Chapter 2 enunciates the history of the laser in a brief but informative way. Included in this history is a blow-by-blow description of the conflict that lasted for many years with regard to the original inventor of certain types of lasers. Although the author gives the credit to Maiman for his development and demonstration of the first working model of a laser, he stops short of describing the laser in diagram form, and the usual photograph of Maiman holding the laser is not present. Although the chapter is short (10 pages), the review is comprehensive, and more recent developments are included.

Chapter 3 is on Laser Theory and Principles, and Chap. 4 briefly covers the topic of Enhancements. These subjects could probably be covered in the same chapter because a good portion of the theory of laser operations is used in the Enhancement section.

The subject of Chap. 5 is External Optics and Their Functions. A laser on its own is of little value without the addition of some type of optical system. There are many books that cover optical design, and Hecht references several of them. (One book was written before the development of the laser! Although the author claims that this book is available from the Department of Defense, this reviewer believes that the text was withdrawn in 1986 and is no longer available.) Very few of the referenced books accurately describe the problems associated with developing optical systems for use with a laser source, and this is an area of great concern for this reviewer. The chapter on Optics in this book covers a miscellaneous group of optical topics but never shows an actual system. The chapter contains a number of inaccuracies and misleading facts and does not add to the book's value. In this reviewer's opinion, the book would not suffer from the omission of Chap. 5.

For most readers of this book, useful material begins at Chap. 6, where the topic is the Classification of Major Laser Types. This is a short chapter (7 pages) and merely serves as a preface to the ensuing chapters on various types of lasers. Chapters 7 through 29 contain descriptions of various types of lasers, with each chapter following a similar format: active medium, structure, beam characteristics, operating requirements, reliability, commercial devices, and applications. In addition each chapter is followed by an extensive bibliography. (For some reason the reader is only referred to *Appl. Opt.* once. Perhaps the author does not read this journal. If he did, then he surely would have referenced the pioneering issue of *Appl. Opt.* entitled Optical Masers, which was published as a supplement in 1962. This issue contains many excellent papers and a photograph of the first helium-neon laser, which is much more

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1. W. D. Wright, *The Measurement of Colour*, p. 1, Van Nostrand Reinhold Co., New York (1971).
2. A. Yariv, *Quantum Electronics*, p. 380, Wiley, New York (1967).

clear than the very same photograph shown on page 17 of *The Laser Guidebook*).

The subjects of the various chapters cover all types of lasers: helium-neon; noble gas ion; helium-cadmium; carbon dioxide; chemical, copper, and gold vapor; excimer; nitrogen; and dye, to name a few. Every type of laser has been included and, if any injustice has been done, it would be to the argon ion laser. This laser certainly justifies a chapter of its own and should not have been included as a mere subset of noble gas ion lasers. The information is these various chapters is comprehensive and well written, and Hecht must be complimented on the tremendous job he has done in drawing all of this information into a single reference. The sections of each chapter, which cover applications of the respective lasers, are extensive in listing applications but are short on details. Future editions of this important work could, perhaps, concentrate on expanding those sections. (Or perhaps those sections could be the subject of an additional book.)

The book concludes with an Appendix that contains a listing of the various types of lasers listed by output wavelength. This is a valuable reference table for workers in the field.

Despite initial disappointment in the book, this reviewer would like to compliment the author. No other comparable book exists, and *The Laser Guidebook* is a valuable reference, even for those who are only remotely connected with the field. The book is complete and up-to-date with respect to available commercial lasers, which is a difficult task to accomplish in this rapidly expanding field.

The Laser Guidebook by Jeff Hecht will occupy a prominent place on the already overcrowded bookcase of this reviewer, and I will recommend it highly to both colleagues and attendees of my seminars on optics.

BOOKS RECEIVED

Advances in Information Storage Systems, edited by Bharat Bhushan. 421 pp., illus., index, references. ISBN 0-7918-0021-0. American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017 (1991) $85 softbound. This inaugural volume covers 22 articles from leading engineers and research scientists, reflecting the latest scientific thinking in the field, covering a wide range of topics including surface finishing, friction, lubrication, heat transfer, belt tracking, and vibration and wear.

Probability, Statistical Optics, and Data Testing: A Problem Solving Approach, B. R. Frieden. 443 pp., illus., index, references, appendix. ISBN 3-540-53310-9 (Berlin) and 0-387-53310-9 (New York). Second edition of Vol. 10 in the Springer Series in Information Sciences. Springer Verlag, Inc., 44 Hartz Way, Secaucus, NJ 07096-2491 (1991) $59 softbound. Includes the axiomatic approach, continuous random variables, Fourier methods in probability, functions of random variables, Bernoulli trails and limiting cases, the Monte Carlo calculation, stochastic processes, estimating a probability law, the chi-square test of significance least-squares curve fitting-regression analysis, principal components analysis, and controversy between Bayesians and classicists.

The Laser in America 1950-1970, Joan Lisa Bromberg. 310 pp., illus., index. ISBN 0-262-023180-0. Massachusetts Institute of Technology, Cambridge, MA 02142 (1991) $30 hardbound. This book provides a historical perspective of the past 30 years of laser research. Covers masers, lasers, laser research, the laboratory and the marketplace, explanation of the laser, and the laser now and in the future.

Laser and Optoelectronic Engineering, Hrand M. Muncheryan. 371 pp., illus., index, five appendixes. ISBN 1-56032-062-1. Part of the Hemisphere Publishing Series in Electrical Engineering. Hemisphere Publishing Corporation, 1900 Frost Road, Suite 101, Bristol, PA 19007 (1991) $99.50 hardbound. Covers fundamental information, principles of laser radiation, holography and interferometry, laser metrology, laser beam communication, military laser systems, materials processing with laser beams, system characterizations of lasers, laser instrumentation in medical surgery, laser instrumentation in dentistry, laser fusion technology, mode locking and cavity dumping, and unique laser systems.

Light Induced Kinetic Effects on Atoms, Ions and Molecules, edited by Luigi Moi, Silvia Gozzini, Carlo Gabbanini, Ennio Arimondo, Franco Strumia. 312 pp., illus., index, references. ISBN 88-7741-560-6. Proceedings of the workshop held in Marciana Marina, Elba Island, Italy. ETS Editrice Pisa, Piazza Torricelli 4, Italy (1991). Includes papers on atom cooling techniques, limits, and applications; light-induced drift; and ion cooling.

Scattering and Diffraction in Physical Optics, Manuel Nieto-Vesperinas. 397 pp., illus., index, references. ISBN 0-471-61529-3. Part of the Wiley Series in Pure and Applied Optics. John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158-0012 (1991) $59.95 hardbound. Includes basic equations for electromagnetic fields, generalized extinction theorem and its role in scattering theory, radiated and scattered fields, mathematical properties of radiated and scattered fields, elements of the theory of diffraction, scattering from rough surfaces, propagation and scattering of phase-conjugate wavefields, inverse diffraction, inverse source and scattering problems in optics, and angular spectrum representation of wavefields.

Fiber Optics Handbook: For Engineers and Scientists, edited by Frederick C. Allard. Nine chapters, illus., index, references. ISBN 0-07-001013-7. Part of the Optical and Electro-Optical Engineering Series, McGraw-Hill Publishing Company, 1221 Avenue of the Americas, New York, NY 10020 (1990) $69.95 hardbound. Covers optical fibers; fiber optic cables; fiber optic splices, connectors and couplers; fiber optic test methods; optical sources for fibers; optical detectors for fibers; modulation; optical fiber sensors; and fiber optic systems design.

Principles of Adaptive Optics, Robert K. Tyson. 298 pp., illus., index, summary, bibliography. ISBN 0-12-705900-8. Academic Press, 1250 Sixth Ave, San Diego, CA 92101 (1991) $49.95 hardbound. Covers sources of aberrations, adaptive optics systems, wavefront sampling, wavefront sensing, wavefront correction, and reconstruction and controls.

Optical Signal Processing: Fundamentals, Pankaj K. Das. 483 pp., illus., index, references, bibliography, problems, appendixes. ISBN 0-387-51476-7. Springer-Verlag, Inc., 44 Hartz Way, Secaucus, NJ 07096-2491 (1991) $59 hardbound. Covers optics fundamentals, signal processing fundamentals, and introduction to SAW and CCD technology.

Reliability and Degradation of Semiconductor Lasers and LEDs, Mitsuo Fukuda. 343 pp., illus., index, references. ISBN 0-89006-465-2. Artech House, 685 Canton Street, Norwood, MA 02062 (1991) $88 hardbound. Covers basic semiconductor LEDs and lasers, reliability in LEDs and lasers, basic degradation mechanisms and enhancement factors, reliability and degradation of AlGaAs/GaAs light sources, reliability and degradation of InGaAsP/InP surface emitting type LEDs, reliability and degradation of InGaAsP/InP laser diodes, degradation of MBE-and MOVPE-grown lasers, degradation of bonds and heat sinks, and degradation modes and lifetime of semiconductor LEDs and lasers.