Principles of Nano-Optics FREE

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Physics Today **60** (7), 62 (2007);
https://doi.org/10.1063/1.2761806

Principles of Nano-Optics

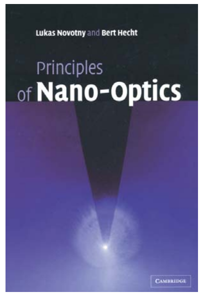
Lukas Novotny and Bert Hecht
Cambridge U. Press, New York, 2006. $75.00 (539 pp.). ISBN 978-0-521-83224-3

To a great extent, the principles of nano-optics are the same as those of near-field optics. The major part of Lukas Novotny and Bert Hecht's *Principles of Nano-Optics* provides the reader with a comprehensive overview of important theoretical concepts and experimental techniques in near-field optics. Novotny is a professor in the departments of optics and of biomedical engineering and physics at the University of Rochester in New York, and Hecht is an associate professor in the institute of physics and astronomy at the University of Würzburg in Germany. Both have made substantial contributions to the development of near-field optics.

The study of nano-optics focuses on understanding light–matter interactions on a length scale either comparable to or smaller than the classical diffraction limit of light. *Principles of Nano-Optics* is intended as a textbook for graduate students who have a solid background in classical, nonrelativistic electrodynamics and optics. A text on this level is highly needed. The book contains problem sets at the end of each chapter and is so comprehensive that lecturers have sufficient material for introductory and advanced graduate courses. It is also well-written, and I have found only a few mistakes.

From the first half of the book one can build a good tutorial for students in physics and in engineering. The chapters cover the fundamentals of macroscopic electromagnetic theory, the propagation and focusing of optical fields, limits to spatial resolution in optics, nanoscale optical microscopy, near-field probes, and probe–sample distance control. In the second half, the chapters on photonic crystals, optical microcavities, and surface plasmons also allow the material to be incorporated into an introductory course.

Green functions and evanescent waves play a central role in theoretical descriptions of light–matter interactions on the nanoscale, and the authors' introduction of those tools is excellent. For optical microscopy, spatial resolution is a key issue, and a solid analysis of the physics behind the resolution problem beyond the classical diffraction limit is indispensable in a textbook on nano-optics. Novotny and Hecht's classical analysis may serve as a good starting point for quantum physical studies of the problem. The authors discuss the focusing of optical fields, a method based on the fields' angular spectrum representation. A superb introduction to the angular spectrum representation and its usefulness in optics can be found in Leonard Mandel and Emil Wolf's *Optical Coherence and Quantum Optics* (Cambridge U. Press, 1995). But the presentation in Novotny and Hecht's book is particularly nice because it is in the context of near-field optical microscopy, in which the spatial frequencies associated with evanescent fields are important.



A substantial number of experimental configurations are used in modern near-field optics, and many of them are carefully described. The authors also offer a summary of far-field microscopy; the overview helps students obtain a clear understanding of the Rayleigh criterion and why near-field approaches are needed to overcome the classical diffraction limit in optical microscopy. Various techniques can be used to squeeze light into subwavelength regions and to detect light from nanoscale regions. Optical probes that can achieve the squeezing and detection of light are key components in near-field microscopy, and the book offers an excellent overview of the variety of probes.

Solid-state nano-optics, in which light–matter interactions are studied on a length scale far shorter than the classical diffraction limit, generally requires a quantum description, as do mesoscopic systems with linear extensions shorter than the wavelength of light. The book takes the reader on a journey to the quantum world of nano-optics, but it certainly does not present the quantum aspects in a systematic way. Although mistakes are minimal, they are not absent. For example, in chapter 2, the authors wrongly state that the dyadic Green function can be transformed from the frequency domain to the time domain: Only the transverse part of the Green function exists in the time domain. In chapter 8, they claim that only the far-field term of a dipole contributes to the energy transport, but energy conservation requires the inclusion of both near- and mid-field terms. Still, despite such errors, the text may serve as a nice stimulant for graduate students interested in the fundamental physical aspects of near-field electrodynamics.

I like the way the authors have introduced readers to the microscopic world—namely, through the microscopic classical description. In the description, matter is assumed to consist of charged point particles whose mutual electrodynamic interactions are described in terms of the microscopic Maxwell–Lorentz equations. This approach enables one to successfully link the classical physical theory, the semiclassical quantum theory of the material response, and the field-quantized formulation. Within the framework of the point-particle theory, Novotny and Hecht discuss the multipole description of light–matter interaction, the radiating electric dipole, radiation reaction, spontaneous decay, local density of states, dipole–dipole interactions, energy transfer between point particles—atoms and molecules, for example—in near-field contact, and dipole emission near planar interfaces.

For experimentalists, a good chapter on quantum emitters, such as quantum dots and fluorescent molecules, is included. To help readers understand the exotic physics behind quantum emission in spacetime, the authors make use of the electric-dipole oscillator model, rate equations, and classical correlation function analysis. Novotny and Hecht also discuss forces in confined fields and fluctuation-induced interactions, which are somewhat outside the main themes of the book.

Overall, I enjoyed the authors' presentation of the subjects in *Principles of Nano-Optics*, and I think the material will help students obtain a broader perspective of the nano-optical world.

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Dark Cosmos

In Search of Our Universe's Missing Mass and Energy

Dan Hooper
Smithsonian Books/HarperCollins, New York, 2006. $24.95 paper (240 pp.). ISBN 978-0-06-113032-8

Unless you've been hiding in a cave, you've probably heard about the recent revolution in our understanding of the universe. During the past five decades cosmology has gone from a fringe science, with lots of speculation and woefully insufficient data, to a firmly established field with its own standard model, buttressed by precise measurements and a wealth of data. The dark side of this shift is that we've discovered our ignorance of the basic con-