

Surface Emitting Semiconductor Lasers and Arrays

Edited by Gary A. Evans
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Semiconductor laser diodes come in different shapes and sizes. Traditionally, devices with lasing emission in the plane of the substrate—edge emitters—have been used in long-distance telephone fiber-optic transmission systems, laser printers and audio compact-disk players. These edge-emitting devices can be of the Fabry-Pérot type, with lasing in multiple longitudinal modes, or emission can be made single mode by coupling to an integrated, distributed feedback grating. An alternative to edge emission is vertical emission with lasing light emerging perpendicular to the surface of the semiconductor substrate.

This book deals with engineers' efforts over the last 15 to 20 years to improve the performance and increase the number of potential applications of surface-emitting laser diodes. As such, the book makes a useful reference for those with an advanced interest in designing, fabricating and testing such devices.

In reading the book, I was amazed by the extraordinary efforts that have been devoted over the years to the development of surface emitting lasers. The use of edge-emitting Fabry-Pérot laser diodes arranged in two-dimensional arrays with integrated turning mirrors, lenses, sophisticated heat-sinking strategies, and output power measured in tens of watts particularly caught my attention. These devices might be used for specialized applications such as optically pumping Nd:YAG solid-state lasers. The use of gratings as an alternative to turning mirrors is also extensively covered in the book. Another well discussed subject is evanescent optical coupling between closely spaced arrays of laser diodes.

Most interesting from a historical perspective is the discussion of the pioneering work of Kenichi Iga and his colleagues at the Tokyo Institute of Technology on vertical cavity surface-emitting laser diodes. Here we have an example of a Japanese team aggressively pursuing scientific research in a subject of general technological interest. It is a historical fact that only after Iga and his colleagues demonstrated encouraging results did

researchers in the US make significant contributions. For example, workers at AT&T Bell Laboratories and Bellcore realized that very-high-finesse dielectric mirrors could be fabricated using state-of-the-art molecular beam epitaxial crystal growth techniques and that optically active quantum well gain regions could be accurately placed at an optical antiresonance between the upper and lower mirrors. The combination of the Japanese and US efforts produced the modern vertical surface-emitting laser diode. While many practical issues still need to be addressed, such as the high series resistance for current flowing through the mirror stacks and (according to Iga) the absence of polarization control in lasing light output, initial results are encouraging enough that some companies (Hewlett-Packard is one) are considering developing vertical cavity surface-emitting laser arrays for use in high-speed parallel optical data links.

It would be encouraging if the research and development of surface-emitting lasers resulted in new products. For example, surface-emitting lasers could replace the enormously successful edge-emitting Fabry-Pérot laser diode manufactured almost exclusively by the Japanese for use in their compact disk players. This so-called CD laser is a device produced in quantities of several million per month and is probably the most successful example of volume manufacture and commercialization of a laser-diode-based consumer product.

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The Broken Dice and Other Mathematical Tales of Chance

Ivar Ekeland (Translated
by Carol Volk)

U. Chicago P., Chicago, 1993.
183 pp. \$19.95 hc ISBN
0-226-19991-6

If the two centuries of Newtonian scientific hegemony can be called the Era of Determinism, the 20th century seems destined to go down as the beginning of the Era of Chance. Chance first entered physics via the practical necessity of treating the macroscopic effects of atoms by statistical methods and soon became imbedded within the heart of quantum theory. Over the past two decades, chance has invaded the classical do-

main through studies of chaos; in *Broken Dice*, Ivar Ekeland deals with it from the point of view of a highly literate mathematician.

All thoughtful human beings realize that much of what matters in their lives is at the mercy of fate, and they have personal strategies for dealing with this predicament. These strategies often have more to do with psychological comfort than with rational calculation: Most people will accept a high level of familiar risk rather than take their chances with the unknown. Any rational assessment, for example, would lead one to fear the drive to the airport more than the flight that follows, but that is not how our minds deal with risk. What Ekeland is trying to do in his book is form a bridge between the scientific and personal dimensions of chance, with the latter exemplified by fables chosen mainly from Scandinavian folklore.

The book draws its title from a fabled toss of the dice by King Olaf Haraldsson of Norway to decide the ownership of an island. The King of Sweden having already thrown two sixes, Olaf's situation seemed hopeless. But on his toss, one die came up a six, while the other split in two, displaying a six and a one. The fable takes this highly improbable event as a clear sign of the divine favor that ultimately led to sainthood for the revered 11th-century monarch.

As a mathematician, Ekeland is particularly intrigued by the emergence of chance within his orderly discipline. Addressing the problems of the pseudorandom-number generators employed in computing, he uses very simple algorithms to illustrate how easily these generators lapse into periodicity or bias. Even though every number in the sequence is predetermined from the start, the best of them can pass an impressive battery of tests for randomness. This introduces a central theme of the book: how apparent randomness can arise from determinism, and *vice versa*.

In one particularly dramatic example, Ekeland cites Thucydides's account of the lifting of the siege of Syracuse as the result of an Athenian commander's hesitation when faced with the spectacle of a lunar eclipse. This battle was a major factor contributing to the ultimate defeat of Athens in the Peloponnesian War. It is this eclipse, seemingly random to the ancient Greeks, that enables us to date the event precisely to 27 August 413 BC.

Ekeland shows that in contests that require a blind guess at an opponent's strategy, such as the "rock-

scissors-paper" trial of the familiar children's game, a random choice will always prove the optimum strategy in the long run. He also illustrates the applicability of stochastic calculus, a descendant of Albert Einstein's treatment of Brownian motion, to such diverse topics as radar filters and investment strategy.

In a chapter on chaos, Ekeland introduces some laudably simple examples, while also briefly describing the Lorenz and Smale attractors. He traces the connection of chaos to fractals and shows how reasoning of this sort by Andrei Kolmogorov led to a successful treatment of turbulence. Henri Poincaré first drew attention to the chaotic nature of the classical three-body problem and opined that such nonintegrable cases represent the rule rather than the exception in nature. Ekeland thus credits Poincaré as the true father of chaos theory. Here we learn that our solar system, seemingly so stable over the span of recorded history, is almost certainly chaotic on a time scale of 10^8 years, making it a near-miracle that Earth has remained reasonably hospitable to life long enough for our species to evolve.

In only a few short passages does appreciation of Ekeland's treatment require more mathematical sophistication than that of an average college graduate. The translator has rendered the text into English so fluent that only an occasional sentence hints at its French origins. *Broken Dice* is recommended reading for anyone who wants a brief introduction to the science of chance.

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Civilizing Mission. Exact Sciences and French Overseas Expansion, 1830-1940

Lewis Pyenson

Johns Hopkins U. P.,
Baltimore, Md., 1993. 377 pp.
\$45.00 hc ISBN 0-8018-4421-5

Lewis Pyenson is the world's leading scholar and most prolific writer on the interaction of science and imperialism, a new growth area in the history of science. This book, on the role of the exact sciences (physics and astronomy are his virgin queens) in French overseas expansion, is the third volume by Pyenson on the exploitation of science in the economic,

political and cultural expansion of the great European powers.

This volume on the great French empire lays bare the role of science in the working of "mechanisms of political dominance" and the consequent subjection of science to a central authority. He has even the Society of Jesus, whose scientist-priests are the culture heroes of *Civilizing Mission*, finally subjected to the Parisian Leviathan. Pyenson sees here the pioneering role of the French model in the birth of the bureaucratic and military control of science. The importance of the book is thus as much in its general thesis as in the details of the antics and activities of French scientists in North Africa, Indochina, Brazil and many other parts of the world.

Civilizing Mission is part of Pyenson's broader body of work in comparative history, in the style of *Annales*: a vast study of the objective discourse of the exact sciences in many settings. Frequent comparisons of the French with other imperialists, especially the Germans, pop up in the book. These comparisons conform to all the old clichés about German original research and French second-rate stuff, mostly the collection of data. For example, in Chile, he writes, the French produced "geographical chronicles rather than theoretical or observational undertakings."

A simplistic interpretation of the notorious concept of French centralization dominates Pyenson's analysis of the activities of French scientists overseas. He sees the explanation of the mediocrity of French overseas scientists in their obsession with pleasing Parisian mandarins in order to be rewarded with good jobs and honors back in France, preferably in Paris. This explanatory model is not without its redeeming vices, but a little more nuance is certainly needed in its application. Pyenson even resurrects the defunct thesis of French scientific decline to provide a background for his statements on the superiority of German, English and American science—exact, of course.

On a more petty level, a reader or two may find some of the author's obsessions a little tiring, if not irritating. A striking example is his reference to the military as professional killers. Well, that's one way to put it. (The endpapers reproduce Henri Rousseau's painting *Le Rêve*; *La Guerre* might have been more appropriate.) Curiously the French military, according to Pyenson, was Christianized by the Jesuits. The author turns clinical in detecting the spread

of "the cancer of French presence" in North Africa. One could make many other minor criticisms of this idiosyncratic work, but it is more just to end on a note of envious admiration for an original, seriously researched and controversial work.

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AIP Handbook of Modern Sensors

Jacob Fraden

AIP, New York, 1993. 552 pp.
\$80.00 hc ISBN 1-56396-108-3

Should experimenters be attracted to a book on sensors? They certainly ought to be, considering the importance of sensors in determining the quality of the data we feed into our computers. The ability of computers to acquire, store, process, analyze and otherwise massage that data doesn't alter the "garbage in, garbage out" syndrome. It pays us to know how information is converted from physical, electrical, optical, mechanical, thermal and chemical measurands to the voltage or current signals that cross the computer's analog-digital threshold. We may then be better able to select an "optimum" sensor, while still recognizing the deficiencies that may make it incompatible with, for example, 16 bits of resolution.

In this *Handbook* Jacob Fraden addresses his subject in a logical way. Early on, he defines some terms the meanings of which are not always well understood in the science and engineering community. For example, what exactly distinguishes accuracy, repeatability, linearity and resolution from one another, and why is it important to consider hysteresis, saturation and dead band in the measuring process? (Those parameters may all be involved in the process of intelligent sensor selection.)

Rounding out the first section of the book is a long chapter—130 pages—titled "Physical Principles of Sensing." Here, Fraden catalogs the many kinds of effects on which sensor designs are based. It is a tribute to human inventiveness that such a large number and variety of physical effects have been exploited. Under the heading "Optical Components" is a brief discussion of fiber optics and waveguides. Entire books have been written about this "new kid on the block," see, for example, *Fiber Optic Sensors*, edited by Eric Udd (Wiley, 1991).

For the sake of completeness, the author includes a pertinent chapter