Patricia Daukantas

65 Years of "Born and Wolf"

Generations of physical scientists have made *Principles of Optics* their standard reference in the field—but the book's authors faced challenges before its first publication.

Above: Max Born reading in his office (undated photo). Right: Emil Wolf in 1959, the year of the publication of the first edition of *Principles of Optics*.

AIP Emilio Segrè Visual Archives, Segrè Collection / Courtesy of Bruno Wolf

Emil Wolf (upper left) and Max Born (center), in 1953 at Max Born's retirement.
E. Wolf, "Recollections of Max Born," Opt. News **9**, 10 (1983).

Habent sua fata libelli. The Nobel laureate Max Born once quoted the venerable Latin maxim—"Books have their destinies"—when telling an audience of young researchers about a book he and a coauthor had just finished. Little did he know that the new volume would grow into an oft-cited classic—or that it would have an origin story as compelling as its contents.

The book, of course, is *Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light* by Born, who received the Nobel Prize in physics in 1954, and Emil Wolf, an Optica Honorary Member who served as the society's president in 1978. The two scientists were separated by 40 years in age, but they shared a deep appreciation of mathematical rigor and first principles. Both had emigrated from Nazi-occupied Europe and rebuilt their lives in English-speaking countries after World War II: Born at the University of Edinburgh, UK, and Wolf at the University of Rochester, USA.

Born and Wolf embarked on their joint authorship after Born struggled to wrest ownership of his previous optics text from the US government, which wrongly classified him as an "enemy alien." Along the way, the pair had to fight against the mendacity of a less-than-honorable publisher. Once they conquered their challenges, though, Born and Wolf were rewarded with a volume that has seen seven editions and numerous reprints since its debut in 1959—and is often called by the names of its authors. A book that predated the invention of the laser has held its niche in optical physics.

Born and *Optik*

In the future, people may wonder why Born was the lead author of an optics book, since his Nobel Prize singled him out for fundamental research in quantum mechanics and his students made discoveries in nuclear physics. He was certainly a prolific polymath.

A native of Breslau, German Empire (now Wrocław, Poland), the young Born moved among several

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German universities until he landed at the University of Göttingen, where such famous mathematicians as David Hilbert and Hermann Minkowski mentored the young student. Born earned his Ph.D. in mathematics under Carl Runge, then pivoted toward physics for his habilitation work.

As a professor at Göttingen, Born collaborated with many of the pioneers of 20th-century physics, including Werner Heisenberg, with whom he formulated the matrix mechanics representation of quantum mechanics. Despite his famous misgivings about quantum physics, Albert Einstein nominated both Born and Heisenberg, along with Born's former student Pascual Jordan, for the Nobel Prize, but only Heisenberg received it in 1932.

Born was a noted mentor whose Göttingen doctoral students included J. Robert Oppenheimer, father of the atomic bomb, and Maria Goeppert-Mayer, the second woman to win a physics Nobel. A prolific writer, he also penned books on topics slightly out of his field, such as relativity—and optics. "Like every physicist, like every professor, I felt the need to record in lasting form one of the many carefully prepared lectures that I had given in my life and regularly repeated in an improved form," Born told an audience of young researchers in June 1959.

In 1931, Born and two students began working on a 700-page tome, *Optik*, which Springer published in Germany in January 1933—just as Adolf Hitler came to power. Born, of Jewish ancestry, was suspended from his university post by May 1933 and lost his German citizenship two years later. Fleeing the country with his copy of *Optik*, he reached out to former students and contacts and eventually landed at the University of Edinburgh, UK.

After World War II ended, Born walked by a bookshop window and saw a copy of *Optik*—with a different cover. The Edinburgh professor was astonished to learn that the US Office of Alien Property Custodian, which had confiscated reams of intellectual property deemed to belong to wartime enemies, had republished his book, which "was found to be useful for many different optical and also radar problems," Born said.

Born wrote to the US officials to protest their action—especially since he had become a British subject the day before World War II began. The government wrote back that the matter would be settled "in due time," Born told the 1959 audience. A few years later, he read in a British newspaper that the Finnish composer Jean Sibelius had been similarly deprived of US royalties for his music. Again, Born complained and received the same "in due time" response.

The first edition of *Principles*

Born also received a visit from a scientific attaché at the US embassy in London. The US Navy was planning to publish a book on optics and had already rounded up an author team, Born was told, but if his book matched the Navy's intentions, the service would give up its plans, which the scientist deemed "very honorable."

Between the US government's hold on his old book and the developments in optics since 1933—as well as his advancing age and retirement plans—Born realized he needed a completely new book on the field. First he sought advice from Dennis Gabor, a future Optica Honorary Member who was in the midst of publishing a series of papers on his invention of holography, which would garner him a Nobel Prize. Born, Gabor and Harold H. Hopkins, a colleague of Gabor's at Imperial College, London, who had just published a book on the wave theory of aberrations, initially agreed to author the book. Gabor invited a young scientist friend of his, Wolf, whom he had met at meetings of the Optical Group of the British Physical Society, to contribute a section on diffraction theory of aberrations.

Like Born, Wolf had been forced into exile from his native Czechoslovakia when the Nazis invaded. He wound up at the University of Bristol, UK, where he studied mathematics and physics up to his Ph.D. in 1948, then followed his doctoral adviser, Edward H. Linfoot, to Cambridge University.

Soon afterward, Hopkins bowed out of the project, so Gabor, with Born's approval, wrote to Wolf and Linfoot with an invitation to collaborate on the

Robert Maxwell in the United Kingdom in 1969.
Barrette / Daily Express / Hulton Archive / Getty Images

optics book. Wolf fretted that his work with Linfoot would impede his efforts on the book. In late 1950, Gabor arranged a dinner meeting for himself, Born and Wolf in London. Born agreed quickly to hire Wolf to work with him in Edinburgh, which Wolf later learned was due to Born's great trust in the judgment of his friends.

Incidentally, one of Born's previous Ph.D. students and assistants, Manhattan Project veteran Klaus Fuchs, had recently been convicted of passing British military secrets to the Soviet Union. Smarting from the bad publicity, Born wrote to the university's principal (or top official), the Nobel laureate Edward Appleton, for permission to hire "a Wolf after a Fox" (the meaning of the German *Fuchs*).

In January 1951, Wolf joined Born in the small basement offices of Edinburgh's department of advanced mathematics. Born's role was in planning and providing advice for the new book, while Wolf and Gabor were supposed to write it. Soon, Gabor found himself too busy to contribute more than one section, so the team became Born and Wolf. The latter wrote the bulk of the manuscript, though Born insisted on contributing an appendix on the calculus of variations, inspired by presentations by David Hilbert in Born's youth.

The goal was to complete the book in time for Born's planned retirement in 18 months, but that deadline fell by the wayside. "In spite of my relative youth I could not compete with the speed with which Born wrote, even at his advanced age, and it soon became clear to me that he was not too pleased with my slow progress," Wolf wrote in *Optics News* decades later. It took eight years for them to finish the book, and by then, Born and his wife had retired to the resort town of Bad Pyrmont, Germany.

The duo encouraged other physicists to contribute chapters and appendices, and several did so, including Gabor, biophysicist Alec Stokes and Avadh Bhatia. Other scientists made promises but did not deliver on them. One prospective chapter author disappeared for more than a year, "and my father was beside himself because he was getting all kinds of pressure to get the book done," says Bruno Wolf, Emil Wolf's son. The man had been in prison for a year, and when he was let out, he wrote a letter to Born and Wolf asking for partial payment for the work he never performed.

By 1957, Born was again asking Wolf about his progress on the book, and Wolf replied by letter that he was still working on the chapter on partial coherence. As the younger scientist later recalled, Born quickly retorted, "Who apart from you is interested in partial coherence? Leave the chapter out and send the rest of the manuscript to the printers." A few years later, though, Born and Wolf were both pleased that the advent of the laser sparked readers' interest in the book's in-depth treatment of partial coherence. Unfortunately, factors that had nothing to do with physics would camouflage the level of reader appreciation for some time.

Shady accounting

Once Born and Wolf finished the manuscript, they sought a publishing house. They found Paul Rosbaud, a German metallurgist who had worked at Springer Verlag for many years. A man of integrity, he had helped several Jewish people out of Nazi Germany and passed military intelligence to the Allies. Rosbaud had joined up with a publisher named Robert Maxwell to start Pergamon Press, and the pair had already attracted several other distinguished British scientist-authors. Additionally, Maxwell was a fellow Czech exile. Thus, Rosbaud and Maxwell persuaded Born and Wolf to publish with Pergamon.

Years later, Rosbaud told Wolf that Maxwell kept three sets of financial records: one for the authors, one for the tax authorities and one for himself.

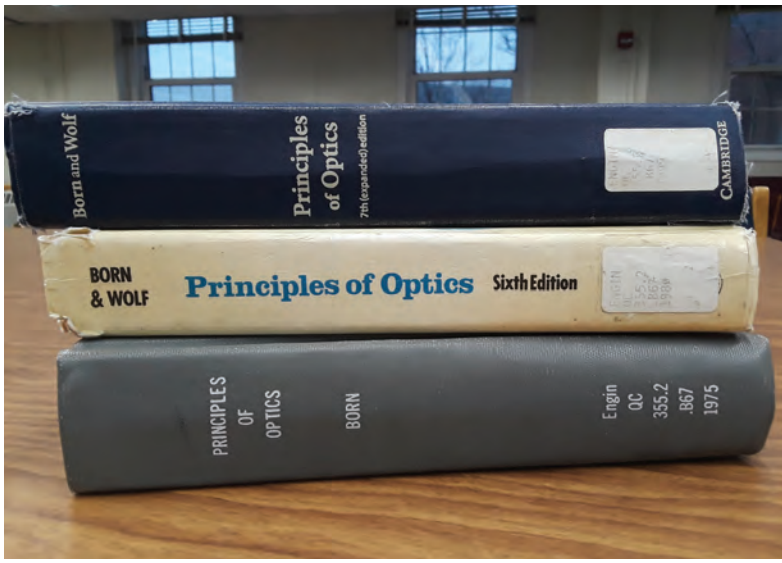
Bruno Wolf, now a software engineer in Rochester, NY, USA, recalls, "My father told me, early on as he was working on the book, he met with Maxwell a few times to discuss how the book was going. And [on] at least one or two of those occasions, believe it or not, he told me Maxwell opened a drawer in his desk, pulled out some cash and gave it to my father because he knew my father was struggling."

But Maxwell had shady motives. In 1956, he told Born and Wolf that he'd struck a deal with McGraw Hill for US distribution of the book, but the authors would have to accept reduced royalties for the first 2,500 copies sold to McGraw Hill or another US publisher. Maxwell had promised the book to McGraw Hill for 1956, but Rosbaud stepped in and said the book wouldn't be ready for another 12 to 15 months. However, Maxwell eventually sold the book in the United States through Pergamon Press, which he claimed to be a US company and thus paid smaller royalties to its authors.

Not long thereafter, Rosbaud left Pergamon because he'd figured out Maxwell's level of dishonesty. Years later, he told Wolf that Maxwell kept three sets of financial records: one for the authors, one for the tax authorities and one for himself.

Wolf once wrote to Gustav Born, Max Born's son, about Maxwell's fraud. "The opening [sales] figures for one year did not agree with the closing figures for the previous year," he told his coauthor's son. "Hundreds of copies were not accounted for, and we also discovered that Pergamon Press reprinted some editions several times without telling us and without accounting for them."

Bruno Wolf says that Maxwell's company kept saying *Principles of Optics* wasn't selling well when, in fact, it was. Through a contact at the publisher, his father found out that the sales figures were much higher than he was being told. Wolf eventually took the company to court, and it took several years before he finally won the case. Bruno Wolf says his father's main motivation was to make sure his older colleague got his due, because Born was counting on this money to finance his retirement.



Library copies of the fifth, sixth and seventh editions of *Principles of Optics*.

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After Maxwell's death in 1991, Gustav Born, a noted pharmacologist who died in 2018, wrote a scathing summary of his father's and Wolf's treatment for a British magazine. He attributed Maxwell's deviousness to the huge postwar growth in scientific activity and to most scientists' combination of "absolute professional integrity with comparatively little interest in money."

Debut and initial reviews

Principles of Optics came out in December 1959, three months after the first International Conference on Quantum Electronics kicked off the race to build the first laser and the same month that Richard Feynman gave an influential talk on the field that would eventually be dubbed nanotechnology. Pergamon Press priced the book at US$17.50 (US$186.12 in today's currency).

Scientific journals warmly reviewed the new 803-page book. In *American Scientist*, Richard H. Milburn of Tufts University, USA, wrote, "In the process of modernization the structure of the parent *Optik* has been altered severely, yet so carefully that one finds

little of the awkwardness frequently characterizing new editions of out-dated [sic] texts and treatises." Milburn praised the addition of the chapters on geometrical optics, which the 1930s volume had omitted.

John Strong, then of Johns Hopkins University, USA, predicted in *Science* that the new volume would "become a great book." Strong, who served as the 1959 president of OSA (now Optica) and would later become an Honorary Member, praised the authors' coverage of partially coherent light and image-forming instruments but lamented the absence of several topics related to spectroscopy and polarimetry.

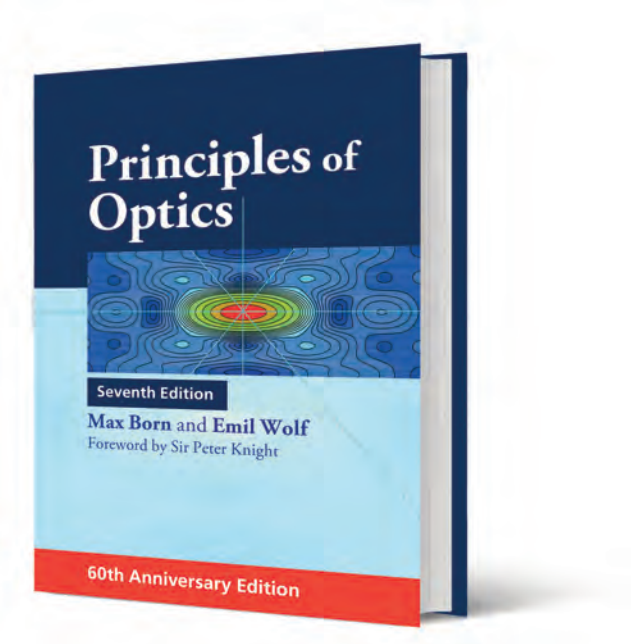
Revision and expansion

The second edition of Born and Wolf appeared in 1964; it had five more pages than the original, with the same cover price. Bruno Wolf says that he's sure his father wanted to keep the book current, and his father's graduate students would proofread the manuscripts and find mistakes for him to fix.

Pergamon Press published six editions of *Principles of Optics* between 1959 and 1980. In 1970, Max Born died in Göttingen at the age of 87. Bruno Wolf says he never met Max Born, since the two families lived on opposite sides of the Atlantic Ocean. But the son recalls hearing Walter Cronkite on the CBS Evening News say that Born had died, and how strongly the news affected his father.

In 1991, Maxwell sold the publishing house to cover debts elsewhere in his empire. According to Simon Capelin, who retired in 2019 from a 40-year career in physics publishing at Cambridge University Press, UK, the Dutch company Elsevier took over the entire Pergamon physics list and kept the Born and Wolf book in print for several years. "They completely neglected it and didn't even send copies to optics meetings, something that made Emil mad," Capelin says.

When Elsevier hinted that it was seeking to sell the physics list, Wolf was determined to transfer the *Principles of Optics* rights to a university-based publisher and selected Cambridge University Press in 1997. At first, Cambridge reissued the sixth edition, which had been the last Pergamon edition. But Wolf signed a contract to revise and update the book, even though he was by then in his 70s. Cambridge completely reset the text, which allowed additions on light scattering from inhomogeneous media, diffraction theory and computerized axial tomography.



The reissued 60th-anniversary version of the seventh edition of *Principles of Optics* published by Cambridge University Press in 2019, a year after Wolf's death.
Cambridge University Press

The new round of typesetting in the mid-1990s also provided math-checking, proofreading and illustration opportunities for Wolf's graduate students at Rochester. For example, Wolf mentioned to a student over lunch that it had once taken him three months to produce a contour plot of the intensity of a focal region. After lunch, the student punched up some Mathematica code, reproduced the contour plot, printed it and brought it over to Wolf—all in 15 minutes. The plot graces the dust jacket of the 2019 60th-anniversary reprint of the seventh edition.

"I think Cambridge has been a wonderful steward of the book, and I'm just really grateful to Simon Capelin and to Cambridge for keeping it in print, keeping it in front of people, giving it prominence in their collection," says P. Scott Carney, Optica's chief science and technology officer. Carney, an Optica Fellow, earned his doctorate at Rochester under Wolf and later directed the school's Institute of Optics.

Optica Fellow Greg Gbur, another of the graduate research assistants who helped Wolf, says the long hours of redoing the book's index with new page numbers for the seventh edition was "menial work" that he nevertheless volunteered to do because working with Wolf was always entertaining. Students would gather at the Wolf home not just to proofread, but to have dinner together and enjoy wide-ranging conversations.

Although book citations are difficult to enumerate, the general consensus is that *Principles of Optics* is one of the most cited works in science.

"He was really, truly passionate about his work and, I think, considered it just as much fun as work," says Gbur, now a physics professor at the University of North Carolina at Charlotte, USA.

Though Emil Wolf did not discuss the details of his research and writing with his children when they were young—most schoolchildren, after all, haven't yet been introduced to calculus and matrix mechanics—he, as a single parent, would encourage Bruno and his younger sister to sleep late on weekend mornings so he would have some quiet time to work.

The legacy of "Born and Wolf"

"Emil was a truly wonderful man and a brilliant physicist, and I have so many good memories of my times with him," Capelin says. "It was his death in 2018 at the age of 95 that prompted me to propose the 60th-anniversary edition." That most recent version of *Principles of Optics* includes a forward by the newest Optica Honorary Member, Sir Peter Knight, Imperial College London, UK.

The current physics publisher at Cambridge University Press, Vince Higgs, says the prospect of a future new edition of *Principles of Optics* is highly unlikely. "We'd certainly be open to considering a revised edition, but it's a complicated situation with such a classic book when both authors are deceased," he says.

Born's son, Gustav, once summed up his father's attitude toward his work by quoting his father: "I wrote a successful textbook on optics and many years afterwards, another. This shows that in order to write a learned volume, one need not specialize in the subject but only grasp the essentials and do some hard work."

Although book citations are difficult to enumerate, the general consensus is that *Principles of Optics* is one of the most cited works in science. "It's difficult to find anything in modern science or engineering that doesn't involve optics," Carney says. Gbur, who writes both popular-science books and textbooks, adds that anyone who is studying theoretical optics can find explanations and further references in that volume.

Wolf (left) with then grad student Greg Gbur, who assisted Wolf with the indexing of the 1999 seventh expanded edition of *Principles of Optics*.

Courtesy of G. Gbur

Wolf once told an interviewer that the original publishing contract for *Principles of Optics* called for the printing of 8,000 copies, which prompted Born to say, "Wolf, that's crazy. Nobody's going to buy 8,000 copies of this book." By 2008, Wolf estimated that he and his coauthor had sold roughly 150,000 copies over the years.

"When it came out in 1959, it was absolutely on the cutting edge of the field and was timed perfectly for a lot of the things that were happening," Carney says. "It's still very much the source to go to today in classical optics."

Books indeed have their destinies, and it seems that the destiny of "Born and Wolf" is to provide a continuing link between the foundational principles of physical optics and the new generations of scientists harnessing those principles for their discoveries. OPN

Patricia Daukantas (patd@nasw.org) is a freelance science writer based in Lanham, MD, USA.

For references and resources, visit **optica-opn.org/link/0624-born-wolf**.

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