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Golden anniversary of Fourier optics: guest editorial

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In 1968, Professor Joseph W. Goodman published the first edition of *Introduction to Fourier Optics*, which also laid the foundation of this field. For half a century, the book has been the definitive teaching and reference text, well known in particular for its clear and insightful writing. At OSA's Imaging and Applied Optics Congress 2018, a special event was organized to commemorate the fiftieth anniversary of the book, with a series of talks covering the teaching and scientific development of Fourier optics.

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1. ORIGINS AND EVOLUTION

The 1960s was a time of exciting developments in the field of optics. Laser was newly invented and had just become commercially available. The fundamental principle of holography had been established, and significant improvement in its imaging scheme had led to widespread interest in this technology. Joseph Goodman, with a background in radar countermeasures, became fascinated by holography and optical information processing, and started research in this area at Stanford University. In 1965, he taught a full course on Fourier optics at Stanford for the first time. As there was no suitable textbook, he decided to write his own notes for the students, covering materials including two-dimensional signals and systems, scalar diffraction theory, Fresnel and Fraunhofer diffraction, basic lens theory with Fourier analysis, coherent and incoherent illumination, spatial filtering, optical information processing, and holography. These eventually became the first edition of *Introduction to Fourier Optics*, published in 1968 by McGraw-Hill [1].

More than 5,000 copies of the book were sold during the first two years of publication. It also received very positive reviews, praising in particular its appeal to electrical engineers with its profuse use of the language and tools familiar to those in that field [2]. For another quarter century, sales of the book continued steadily at around 1,000 copies per year. A sabbatical in 1994 finally allowed Goodman time to work on a second edition, expanding significantly the discourse on optical information processing and holography, and adding a new chapter on wavefront modulation, with materials on liquid crystals and diffractive optical elements. All in all, the book grew from 287 pages in the first edition to 441 larger pages in the second edition, published in 1996 [3].

Goodman retired from Stanford University in 2000, after an illustrious career as an eminent researcher, a beloved and well-respected teacher, and an accomplished academic leader. He was the primary dissertation advisor for 49 Ph.D. students at Stanford, many of whom continued to be active in the field of optics. In preparing for the third edition, he saw the need to add a new chapter on Fourier optics in optical communications, reflecting the significant development in that area since the late 1990s, and an appendix on the grating equation. This edition grew to 491 pages, and was published by a start-up publishing company named Roberts & Company, in 2005 [4].

In the following years, Goodman worked on other book projects, including a new book, *Speckle Phenomena in Optics*, published in 2007 [5], and a second edition of *Statistical Optics*, published in 2015 [6]. Coming back to *Introduction to Fourier Optics*, he expanded the book once again with a new chapter on computational diffraction and propagation and another new chapter on point-spread function and transfer function engineering, as well as many other additions and improvements. He also chose to remove some content on optical processing that was deemed no longer relevant. The 546-page fourth edition came out in 2017, forty-nine years since the first edition, and was published by W.H. Freeman (an imprint of Macmillan, which acquired Roberts & Company) [7].

Introduction to Fourier Optics has reached well beyond the English-speaking world with its many translations. Authorized or known translations of different editions appeared in Chinese, Korean, Japanese, Russian, Spanish, French, and Persian (Farsi), among others.

2. CELEBRATION

Much of the above history was told by Goodman to a packed audience at OSA's Imaging and Applied Optics Congress on June 26, 2018 in Orlando, Florida, in a talk entitled "Origins and Evolution of Introduction to Fourier Optics."

The idea of celebrating the fiftieth year publication of *Introduction to Fourier Optics* was proposed by Chris Dainty the year before, and subsequently the *Computational Optical Sensing and Imaging* topical meeting took on the responsibility, and I became the organizer of this special event.

Eight distinguished speakers were invited to present on topics spanning coverage from the use of *Introduction to Fourier Optics* in teaching to the evolvement of the field. After the first talk by Goodman, the second talk was entitled "What's the Problem? Insight and Inspiration Derived from Solving the Exercises in J. Goodman's Classic Book 'Introduction to Fourier Optics.'" The talk was prepared by James Leger from the University of Minnesota Twin Cities, where he focused in particular on what he considered the best attributes of the book—the interplay between the derivations in each chapter and the subsequent homework problems. He illustrated through a variety of examples, and concluded that the key to true learning was the involvement of the students in the homework problems. (Unfortunately, due to unforeseeable circumstances, Leger could not attend the meeting, and a detailed script carefully prepared by him was read on his behalf.)

The third talk, "The Transition of Fourier Optics Towards Computational Imaging and Digital Holography," was given by Demetri Psaltis from École Polytechnique Fédérale de Lausanne. He praised in particular the robustness of the book, how it started with imaging, analog computing and holography, continued its relevance to newer topics such as fiber optics and 3D displays, and stayed strong as a key text for more recent advances in computational imaging. This was followed by the talk "Linear-Algebra Optics" presented by Bahaa Saleh from the University of Central Florida. *Introduction to Fourier Optics* was essential in making linear systems theory a powerful tool for the analysis and understanding of optical wave propagation, according to Saleh. He likened this to Paul Dirac's *The Principles of Quantum Mechanics* [8], which established matrix algebra as the fundamental mathematical tool for quantum mechanics, and in this talk, he further expounded on how linear algebra should become the unifying foundation for both classical and quantum optics.

The fifth to eighth presentations came after a break to divide the celebration into two sessions at the Congress. This second session consisted of talks by former students of Goodman, arranged according to their graduation year. The first one was given by William Rhodes from Florida Atlantic University, on the topic "Teaching Fourier Optics: What I Do Differently After 50 Years." Rhodes received his Ph.D. in 1971, and had first-hand experience in using *Introduction to Fourier Optics* for teaching since the early days of its first edition. In the talk, he shared his journey with educating countless students on this topic throughout his career. The second presentation was given by James Fienup from the University of Rochester, entitled "ABCD Matrix Analysis for Fourier-Optics Imaging." ABCD propagation, also called ray-transfer matrix, started to appear in Appendix B of the second edition of the book, and was further expanded in the main text in the fourth edition. In this talk, Fienup elaborated on the Fourier optics analysis of a general ABCD paraxial optical imaging system, and also related to several homework problems from the book [9].

Masud Mansuripur from the University of Arizona presented the third talk in this session, "Fourier Optics in the Classroom." He developed an optical system software simulation that had been used in both industrial research and classroom teaching of Fourier optics, and he showed a number of simulations that helped him demonstrate the beauty of the subject to his students [10]. Raymond Kostuk, also from the University of Arizona, then spoke on "A Review of the Wonderful Discussion of Holography by Professor Goodman in His Book: The Introduction to Fourier Optics." He recalled with the audience how the book clearly laid out the basic principles of holography before moving on to different setups and systems, and proceeded to discuss his recent work on developing holographic instruments in early stage cancer detection.

The OSA Image Sensing and Pattern Recognition Technical Group hosted a reception afterwards for attendees to mingle and continue the conversations.

Acknowledgment. I became the last Ph.D. student of Goodman in 1996, the same year the second edition of *Introduction to Fourier Optics* was published. I am truly grateful for the incredible privilege to learn first-hand from the master. I am also thankful to all the wonderful speakers at this special event, and many others who have helped in its organization, including in particular Gisele Bennett, Abbie Watnik, and Rajesh Menon.

Prof. Goodman was recently named the 2018 Honorary Member of OSA, "for fundamental contributions in the fields of Fourier Optics and Optical Information Processing through his research, teaching and classic textbooks." Hearty congratulations on this well-deserved honor!

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