Tribute to Emil Wolf

Science and Engineering Legacy of Physical Optics


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PREFACE

In his classic text: "*Principles of Optics*," written with Nobel laureate Max Born, Emil Wolf laid the foundations of contemporary physical optics. By frequency of citation, that book is one of the three most popular physics books. In the first edition, published in 1959, Emil Wolf described the almost unknown concept of *spatial coherence* before lasers were introduced. He was also the first to document in a book a new concept: Gabor's *holography*. The basic idea of publishing a modern book on physical optics came from Max Born, but the fact that the closely related concepts of spatial coherence and holography appeared so early in textbook form had a formidable impact on science and physical optics engineering. At present we can identify at least 250 companies and corporate divisions in the English-language zone alone (U.S.A., Great Britain, Australia, and Canada), the origins of which are easily traced to modern physical optics in general, and to the book *Principles of Optics* in particular. Moreover, several multibillion dollar industries can also be traced to this legacy, including liquid crystal and LED displays and screens, screens for direct-projection and rear-projection TV, and many other advanced illumination systems, sensors, and nonimaging optical devices.

This SPIE Press book pays tribute to Emil Wolf (see Fig. 1) for his pioneering contributions to the science and engineering of physical optics. His close friend, collaborator, and well-known authority on diffractive optics, Professor Brian Thompson, refers to Alexander Pope's "An Essay on Man" in characterizing Emil Wolf's contributions. With the ever growing impact of Prof. Wolf's fundamental ideas on the nature of light, Pope's famous epitaph for Newton comes to mind:

Nature and Nature's laws lay hid in Night:
God said, *Let NEWTON be*! And all was Light.

Even though his position that spatial coherence is critical to physical optics was to some degree opposed by Max Born, it has, over the years, become a very pow-

Figure 1 Emil Wolf and his wife Marlies at the SPIE Annual Meeting, August 2003, San Diego, California.

erful concept in many areas of physical optics, some of which are presented herein. These include diffraction optics, statistical optics, polarization of light, electromagnetic theory of optical coherence, microscopic theory of spatial coherence, physical radiometry (radiance), physical optics modeling of millimeter wave antennas, coherent optical microscopy, color vision, and Wolf's wavelength shift. Professor Jan Peřina reviews optics in the Czech Republic (then Czechloslovakia, where Prof. Wolf was born). Others address coherence-based light scattering, new aspects of the Sommerfeld half-plane problem as well as Young's experiment, comparison between Doppler and Wolf's shifts, phase and information, wave-optical engineering, and holography and the inverse and scattering problems. Also discussed here are controversial topics in contemporary optics, total-internal-reflection tomography, coherence-mode analysis, nano-optics, special problems in coherence, and Newton-Goethe controversy.

All the chapters of this book are presented by major experts in the field (see Fig. 2), many of them closely connected to Emil Wolf's University of Rochester School of Optics. The ideas they express are their own, subject only to peer review. The papers are part science and part memoir, but all are suffused with love and admiration of Emil Wolf, and for his contributions to science and engineering.

Figure 2(a) Some attendees at SPIE AM 100 Conference, Tribute to Emil Wolf, Engineering Legacy of Physical Optics.

Figure 2(b) Silhouettes of attendees from Fig. 2(a): (1) Frank Wyrowski, Friedrick-Schiller, Univ. of Jena, Germany; (2) Gajendra Savant, Physical Optics Corp., Torrance, CA; (3) Sharon Peet, Physical Optics Corp.; (4) John Foley, Mississippi State Univ.; (5) Ari Friberg, Royal Inst. of Technology, Sweden; (6) Aristide Dogariu, CREOL, Univ. of Florida; (7) Chrysostomos L. Nikias, Univ. of Southern Calif.; (8) Nitin Savant, Physical Optics Corp.; (9) Tomasz Jannson, Physical Optics Corp.; (10) Joseph Kunc, Univ. of Southern Calif.; (11) Kristina M. Johnson, Duke Univ.; (12) Kurt Oughstun, Univ. of Vermont; (13) Marlies Wolf, Emil's wife; (14) James Bilbro, SPIE 2004 President, and NASA Marshall Space Center; (15) David Fischer, NASA Glenn Research Ctr.; (16) Emil Wolf, Univ. of Rochester; (17) Riccardo Borghi, Univ. di Roma Tre, Italy; (18) Christian Brosseau, Univ. de Bretagne Occidentale, France; (19) Taco Visser, Free Univ. Netherlands; (20) Petr Smid, Palacky Univ., The Czech Republic; (21) Anya van der Meulen-Visser, Taco's wife; (22) Pavel Horwath, Palacky Univ., The Czech Republic; (23) Mikael Ciftan, Army Res. Center; (24) G.S. Agarwal, Physical Research Lab., India; (25) Mark Bennahmias, Physical Optics Corp.; (26) Zu-Han Gu, Surface Optics, San Diego, CA.

This book is based on the authors' presentations at SPIE Conference AM100: Tribute to Emil Wolf: Engineering Legacy of Physical Optics, T.P. Jannson, Chair, at the SPIE Annual Meeting in August 2003 in San Diego, California. Most chapters in this book are extended versions of those conference presentations.

Tomasz P. Jannson
James C. Wyant
James W. Bilbro
September, 2004

ACKNOWLEDGMENT

This book is mostly a product of the SPIE Conference: Tribute to Emil Wolf, August 2003, San Diego, California. The idea for this conference came from James W. Bilbro, NASA Marshall Space Flight Center, and 2004 SPIE President; Dennis H. Goldstein, SPIE Fellow, Air Force Research Lab.; James C. Wyant, Director, Optical Science Center/University of Arizona; and H. John Caulfield, SPIE Fellow, Fisk University, and the organizer of the two previous SPIE Conferences—also tributes to pioneers in optics (Adolf W. Lohmann; Yuri N. Denisyuk and Emmett N. Leith).

However, for whole logistics, as well as all organizational issues, we are all in debt to the SPIE and the Conference Organization Committee members who provided, through their parent organizations, a significant financial contribution to support both the conference and this book. The committee members include James W. Bilbro, H. John Caulfield, Mikael Ciftan, Program Manager Army Research Office; Dennis Goldstein, Kristina Johnson, Dean, Pratt School of Engineering, Duke Univ.; Joseph Kunc, Professor, Univ. of Southern California; Joseph Mait, SPIE Fellow, Army Research Lab.; Chrysostomos L. Nikias, Dean, School of Engineering, Univ. of Southern California; John M. Pellegrino, Director, Army Research Lab.; Lev Sadovnik, CEO, WaveBand Corp.; Todd D. Steiner, Program Manager, Air Force Research Lab.; and James C. Wyant.

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September 2004

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August 2004

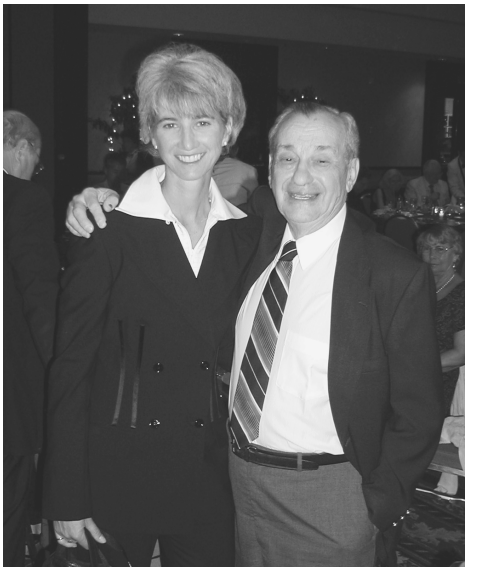
Dear Emil,

It was an honor and a pleasure to be part of the Society of Photo-Instrumentation Engineers Annual Meeting Tribute to Emil Wolf: Engineering Legacy of Physical Optics, recognizing your seminal contributions to this field. Your energy, enthusiasm, and passion for optics and life have inspired generations of students, including myself and fellow graduate students at Stanford, University of Colorado, and now Duke University.

I recall the first time we met. It was in Cuernavaca, Mexico where many of the luminaries in the field gathered in February of 1981 to enjoy lively discussions on all aspects of physical optics, as well as the good weather. There were only a handful of students at the meeting, and we were a bit intimidated by the stellar participants. Always a teacher, coach and mentor, you and Marlies took us under your wings and spent most of the week with us. That serendipitous meeting started a lifelong friendship that means the world to me.

Our tradition of swimming at 7:00 a.m. before optics meetings started in the freezing waters in Mexico. We continued to swim in Tucson at the 1982 OSA meeting, where you and Marlies met my mother, establishing another friendship

Marlies Wolf, Kristina Johnson, and Emil Wolf at SPIE's Annual Meeting 2003. (Courtesy of Valerian Tatarskii, copyright 2003.)



Kristina Johnson and Emil Wolf, 2003.

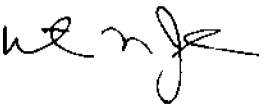
that lasted until her death in 1999. We swam in New Orleans (1983), Rochester (with Bailey's Irish Cream, 1985), and in San Diego (2003).

You showed me how to build community within the academy. When I became an assistant professor of electrical engineering at the University of Colorado, you invited me to give a talk at Rochester on May 2, 1990. You and Marlies hosted a dinner party for me and other participants of the Cuernavaca meeting, including Profs. Nicholas George and Brian Thompson. We had a fabulous evening of interesting conversation, good food, and great friends. And, of course, we swam.

Emil, you taught me about mutual coherence theory, the "Wolf Shift," and how to be a leader in the field. And, like my advisor, Joseph Goodman at Stanford, you taught me that great men of optics are simply great men.

I look forward to your visit to Duke University this fall and to your lecture in our Fitzpatrick Center distinguished speaker series. We will again enjoy eating and thinking. Bring your swimsuit.

With my love, respect, and admiration,



Kristina M. Johnson
Professor and Dean