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100 years of Emil Wolf: introduction

GREG GBUR,¹  GIRISH AGARWAL,² MIGUEL ALONSO,³  P. SCOTT CARNEY,⁴ ARI T. FRIBERG,⁵
PETER KNIGHT,⁶ JANNICK P. ROLLAND,⁷  AND TOMOHIRO SHIRAI⁸ 

¹UNC Charlotte, North Carolina, USA

²Texas A&M University, College Station, Texas, USA

³Institut Fresnel and Centrale Marseille, France, and University of Rochester, Rochester, New York, USA

⁴Optica, Washington, DC, USA

⁵University of Eastern Finland, Finland

⁶Imperial College, UK

⁷University of Rochester, Rochester, New York, USA

⁸National Institute of Advanced Industrial Science and Technology, Japan

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The groundbreaking research and ideas introduced by Emil Wolf continue to inspire researchers and motivate ongoing research in the wave properties of light. This special issue commemorates the legacy of Emil Wolf with research in physical optics, with specific focus on those areas where Wolf was active, such as optical coherence theory, inverse problems, singular optics, imaging, and polarization, and the intersection of these fields of study. Here we discuss the life of Emil Wolf and his influence on optical science and the optics community. © 2022 Optica Publishing Group

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This year marks the centenary of the birth of Emil Wolf (1922–2018), an exemplary optical physicist who not only did groundbreaking and foundational theoretical research, but also had a huge role in the education of optical scientists and was an influential member of Optica (formerly the Optical Society). This special issue of JOSAA, “100 Years of Emil Wolf,” brings together the works of friends, collaborators and research colleagues to commemorate the lasting influence that Wolf has had on both the people and the science of optics.

Wolf's early years were shaped by the turbulent times he found himself in. Born in Prague to Jewish parents, Emil and his brother Karel left Czechoslovakia in 1939 ahead of the invading Nazi forces. Emil worked for a time for the Czech government in exile in Paris, but again escaped the advancing German army and found himself penniless in Britain in 1940. He won scholarships to continue his education and earned his bachelor's degree in 1945 at the University of Bristol. He continued his studies under E.H. Linfoot at Bristol and completed his PhD in 1948, with his first paper, “On the determination of aspheric profiles,” submitted in 1947.

At around the same time, Linfoot moved to the Cambridge University Observatory, and Wolf went to work with him for the next two years. This gave Wolf the opportunity to attend local meetings of the optics community at Imperial College, where he became friends with Denis Gabor, the inventor of holography. Around 1950, Max Born was looking to revise and expand his earlier German text *Optik* and wanted to hire a younger scientist to help with the effort. Gabor recommended Wolf, and Wolf moved to the University of Edinburgh in 1951 to work with

Born. Thus began the collaboration that culminated in 1959 with the publication of the first edition of *Principles of Optics* (commonly called “Born and Wolf”), which is today the most cited textbook in physics and is in its seventh edition.

Wolf moved to the University in Manchester in 1954, where he did some of his best-known work, establishing the foundations of optical coherence theory. Before Wolf, a number of researchers, such as Verdet, van Cittert, and Zernike, had established important but isolated results describing the behavior of fluctuating light fields. Wolf made two key arguments that guided the development of coherence theory. The first of these was an emphasis on observable properties of light waves, in particular the two-point correlation functions that can be measured in interference experiments, rather than optical wave fields that oscillate too fast to be observed directly. The second key argument was the discovery that the correlation functions themselves satisfy wave equations, essentially demonstrating that the statistical properties of light follow predictable rules that can be employed for both physical understanding and practical applications. These equations, called the Wolf equations today, are beautiful in their simplicity and easy to derive; however, their existence was not so obvious to all. When Wolf first explained his results to Born, Born replied, “Wolf, you have always been such a sensible fellow, but now you have gone completely crazy!” To his credit, Born quickly realized the importance and correctness of Wolf's results.

In 1959, Wolf accepted a position at the University of Rochester, becoming one of the researchers who would establish the Institute of Optics as a leading center for optical science.

Principles of Optics was published that same year. The book, which at first was intended to be a simple extension and translation of Born's original text, had expanded into a discussion of some of the most current topics in the field of optics, including the earliest text discussions of coherence theory and holography. These inclusions turned out to be timely; with the invention of the laser, there was intense interest in both.

Wolf's important contributions to optical science continued for the rest of his career and touched upon many aspects of physical optics. In the 1960s, he collaborated with his Rochester colleague Leonard Mandel on problems in quantum coherence theory; their friendship and collaboration was lifelong, and it culminated in their co-authored text *Optical Coherence and Quantum Optics*, published in 1995. In 1969, Wolf introduced a method to solve the inverse scattering problem using holography, in the paper "Three-dimensional structure determination of semitransparent objects from holographic data," a technique that would later be called *diffraction tomography*. In the 1970s, Wolf investigated the foundations of radiometry and connected it to coherence theory. In this same era, he began investigations into electromagnetic sources that produce no radiation, now called "nonradiating sources," that are a precursor to modern invisibility theory.

In the 1980s, Wolf implemented a space-frequency formulation of coherence theory to demonstrate that the spectrum of light waves can be modified by coherence effects, starting a broad area of study known as correlation-induced spectral changes. In 1987, he drew worldwide attention for showing that it is possible for coherence effects to mimic Doppler line shifts. This work showed the value and power of performing coherence in the space-frequency domain, and this is now the standard approach for researchers in coherence theory.

Even in the early 2000s, approaching 80 years old, Wolf continued to perform compelling and influential research. He was one of the first researchers to apply coherence theory to the field of singular optics, looking at how optical vortices manifest in fields with partial spatial coherence. It was also in this era that he introduced his final great work: a complete electromagnetic description of coherence theory, unifying scalar theories of partial coherence with electromagnetic theories of partial polarization. In 2007, he wrote an introductory book on coherence theory that incorporated these new developments, *Introduction to the Theory of Coherence and Polarization of Light*.

In total, Emil Wolf published over 400 papers and mentored some 30 PhD students over the course of his 70-year career. He is also remembered for editing 60 volumes of the long-running

and still going series *Progress in Optics*, which collects reviews of trending topics in optical science and engineering by top researchers. A special volume of *Progress in Optics* was published in 2020 in honor of Wolf's contributions.

Wolf also showed an incredible dedication to the greater optics community. He became an active member of Optica (then the Optical Society of America) when he moved to the United States, and served as the President of the Society in 1978. He won the Ives Medal of the Society in 1977 and became an honorary member in 1987, earning the society's two highest honors. He also won the Born Award for outstanding contributions in physical optics in 1987, and the Esther Hoffman Beller Medal in 2002 for his great work in education of optical science and engineering. He was a regular fixture at the Society annual meeting, and always had time to talk to students and encourage them in their work. When the Emil Wolf Outstanding Student Paper Competition was established in 2008, the timing matched the 50th consecutive year that Wolf had presented a paper at the OSA Annual Meeting. Wolf also co-founded the Rochester Conference on Coherence and Quantum Optics (CQO) in 1960, which has met every six years since, except for one cycle shortened to five years, to bring together researchers to discuss and direct the latest research in the fields.

Those who knew Emil remember him as unfailingly kind and supportive. He was passionate about his research, and could get into heated arguments about science, but always stressed that the participants would remain friends afterwards. He had a great sense of humor, and was always happy to share amusing stories about his life and those scientists that he had known.

It is in the memory of Wolf's outstanding contributions to optics and his ongoing influence that this special issue is dedicated. In this issue you will find a wide variety of articles touching upon different aspects of physical optics, including coherence, quantum optics, structured light, singular optics, propagation through random media, and more. A review is included discussing different techniques for measuring the spatial coherence of light, as recent years have seen a number of innovative and efficient approaches introduced. The topics covered range from articles on extremely fundamental optics, such as a study of caustic colors in Newton's prism, to extremely practical optics, such as a study of beams that maintain some structural stability in atmospheric turbulence.

We believe that the variety of topics presented, and the quality of the papers included, serve as a fitting tribute to Emil Wolf, a truly singular and great figure in optics.