Editorial

Andreas Erdmann* and Guohai Situ

Special issue on ptychography

https://doi.org/10.1515/aot-2017-0067

An image is worth a thousand words – how about hundreds or thousands of images? Recent developments in computational imaging and image detection have revolutionized the way we compile images and extract information from them. Ptychography and Fourier ptychography are special computational imaging techniques that use many diffraction data and images to retrieve both amplitude and phase information on objects. The knowledge of amplitude and phase enables the synthesis of high resolution images from pure diffraction data (lensless imaging) or from many low resolution images.

The word ptychography was derived from the Greek words ptyché (πτυχή = fold) and gráphein (γράφειν = to write). Ptychography computes the phase from multiple diffraction patterns, which are obtained from a transversal scan of the sample with a focused coherent beam while adjacent probe spots overlap significantly in the sample plane. In Fourier ptychography the sample is illuminated from different directions, corresponding to the transversal scan of the sample's Fourier spectrum. Both techniques employ iterative algorithms to de-convolve (or unfold) the phase information from redundant datasets of overlapping spatial areas or spatial frequency areas, respectively.

Originally invented by Walter Hoppe in 1969, ptychography has been developed to be a powerful technique for phase retrieval over the past 50 years. It has found applications in various fields of science and engineering, ranging from crystallography to industrial and biological inspection, with the wavelength of illumination beam ranging from electron and X-ray to optics.

The papers for this special issue of *Advanced Optical Technologies* have been compiled to provide an insight into ptychography and Fourier ptychography and to demonstrate selected recent developments in this field. The tutorial article of Sander Konijnenberg from the Technical University of Delft provides an introduction to the theory of ptychographic phase retrieval methods. It will help scientists, technicians and students without prior experience in the field of phase retrieval or ptychography to understand the basic theory and approaches behind ptychography techniques and provides an overview in the more specialized literature.

Two review articles give overviews on special applications of ptychographic techniques. The article of Patrick Helfenstein and his co-authors from PSI summarizes recent developments in the application of lensless imaging with extreme ultraviolet (EUV) light for the characterization of masks and wafers for semiconductor lithography. Liheng Bian and his co-authors from Tsinghua University review recent development in Fourier ptychography microscopy.

The four research articles of this special issue cover different aspects of ptychographic systems and their applications. Ptychography in the interesting spectral range of EUV requires light sources with sufficient brightness and coherence. The article of Jan Bussmann and his collaborators report on the application of compact plasma-based EUV light sources for lens-less imaging applications. The article of Xinrui Cao and Stefan Sinzinger from the Technical University of Ilmenau employs numerical simulations and experiments to investigate the impact of imperfections of the illumination system on the reconstruction results of ptychography microscopy. Lars Loetgering and his co-authors describe how data-compression strategies can be employed to cope with the large amount of data in ptychographic techniques. The application of ptychographic retrieval algorithms for the measurement of large optical elements in high power laser facility is demonstrated in a research article of Xue Dong from Shanghai Institute of Optics and Fine Mechanics and his collaborators.

Many thanks to the authors and reviewers who contributed to this special issue of *Advanced Optical Technologies*. We hope that it will help readers to get some insights into this emerging sub-topic of computational imaging and perhaps trigger further research in this field.

***Corresponding author: Andreas Erdmann,** Fraunhofer Institute for Integrated Systems and Device Technology IISB, Erlangen, Germany, e-mail: andreas.erdmann@iisb.fraunhofer.de
Guohai Situ: Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Jiading-qu, Shanghai, China

Andreas Erdmann
Fraunhofer Institute for Integrated Systems and Device Technology IISB, Erlangen, Germany
andreas.erdmann@iisb.fraunhofer.de

Andreas Erdmann is head of the Fraunhofer IISB lithography and optics group and teaches as 'Privatdozent' at the University of Erlangen. Dr. Erdmann is also mentor of the Erlangen School of Advanced Optical Technologies (SAOT), which is one of the Excellence Initiatives of the German Research Foundation (DFG). Dr. Erdmann's fields of research include simulation of optical lithography, computational imaging, computational electrodynamics, microelectronic process technology and modern optics. He is a renowned expert in optical and EUV lithography with almost 20 years of experience and more than 170 scientific publications in this field. He chaired SPIE conferences on 'Optical Microlithography' and 'Optical Design' and is organizer of the International Fraunhofer Lithography Simulation Workshop. He contributed to the development of several advanced lithography simulators including the Development and research LiTHOgraphy simulator Dr. LiTHO. Dr. Erdmann is a Fellow of the SPIE.

Guohai Situ
Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, Jiading-qu, Shanghai, China

Guohai Situ is a Professor with the Shanghai Institute of Optics and Fine Mechanics, Chinese Academy of Sciences, holding a '1000 Youth Talents' professorship. Before he joined this institute in late 2012, he spent about 6 years working in University College Dublin in Ireland, Universität Stuttgart in Germany and Princeton University in the United States, after he obtained his PhD degree from the Chinese Academy of Sciences in 2006. Dr. Situ's research interests span a wide field of computational optical imaging, ranging from developing novel techniques and algorithms for phase retrieval, to actively engineering the phase for computational optical imaging and optical signal processing. He has published 44 papers in leading journals including Nature Photonics. His papers have been cited over 2200 times according to Google Scholar. Dr. Situ is in the editorial boards of Scientific Reports, Advanced Optical Technologies and Applied Optics.