Coherent-Mode Representations in Optics

Andrey S. Ostrovsky

SPIE
PRESS
Bellingham, Washington USA

Library of Congress Cataloging-in-Publication Data

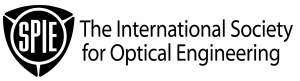
Ostrovsky, Andrey S.
Coherent-mode representations in optics / Andrey S. Ostrovsky.
p. cm. -- (SPIE monograph ; pm 164)
Includes bibliographical references and index.
ISBN 0-8194-6350-7
1. Coherence (Optics). 2. Physical optics. I. Title. II. Series.

QC476.C6O77 2006
535'.2--dc22 2006011409

Published by

SPIE—The International Society for Optical Engineering
P.O. Box 10
Bellingham, Washington 98227-0010 USA
Phone: +1 360 676 3290
Fax: +1 360 647 1445
Email: spie@spie.org
Web: http://spie.org

Printed in the United States of America.



To the memory of my mother, Alla Burjinskaya Ostrovskaya,
and my father, Sergey Ostrovsky.

Contents

Preface

Everyone knows the fundamental role that the Fourier transform plays in optics, representing a monochromatic light field as a linear superposition of plane waves propagating in different directions. Perhaps, the coherent-mode representation of the optical field broached for the first time by H. Gamo in his *Matrix Treatment of Partial Coherence* (Progress in Optics III, E. Wolf, ed., North-Holland, Amsterdam, 1964), which was later developed by E. Wolf in his "New theory of partial coherence in the space-frequency domain" (*J. Opt. Soc. Am. A*, Vol. 72, No. 3, 1982, and Vol. 3, No. 1, 1986), plays a not less important role in contemporary optics. From a physical point of view, the coherent-mode representation describes an optical field of any state of coherence as a linear superposition of uncorrelated, completely coherent modes, a fact that gives new insight into the physics of generation, propagation, and transformation of optical radiation. From a mathematical standpoint, it expresses the cross-spectral density function of an optical field as a sum of terms that are separable in space, a fact that allows significant simplification of the analysis of statistical optical processes and systems. However, to my mind, the coherent-mode representation of optical fields, despite its power and attractiveness, has not yet found its due place in optical science and practice. This is affirmed, in particular, by a relatively small number of publications where the coherent-mode representation is treated. Even in a monumental treatise like *Optical Coherence and Quantum Optics* by L. Mandel and E. Wolf, less than two dozen pages are dedicated to this subject.

The present book represents a modest attempt to make up, to a certain extent, for a deficiency in possible applications of the coherent-mode representations in several areas of optics. This book is mainly based on the original results obtained by the author and his postgraduate students but, to ensure a thorough coverage of the total scope of the subject, it also contains some results of other authors, which are properly referenced. I tried to present this book in a brief recapitulative form, handy for both professionals and postgraduate students in physical optics. I hope that the book will be interesting for the reader and will stimulate the subsequent development of the coherent-mode representations in optics and their practical applications.

There are many people to whom I owe a special word of thanks for their help with the creation of this book. First of all, I consider it my pleasant duty to mention here the scientists whose publications had a decisive influence on the results presented in the book. Listed in alphabetical order, they are: G. S. Agarwal, W. Carter, J. Durnin, J. Duvernoy, J. T. Foley, A. T. Friberg, H. Gamo,

J. W. Goodman, F. Gory, G. Guattari, L. Mandel, E. W. Marchand, N. Mucunda, R. Martínez-Herrero, P. Mejías, M. Nieto-Vesperinas, C. Padovani, B. E. A. Saleh, R. Simon, K. Sundar, J. Turunen, J. van der Gracht, V. Vasara, A. Walther, and E. Wolf. I would also like to mention with gratitude my former postgraduate students, M. V. Rodríguez Solís, O. Ramos Romero, and J. C. Ramírez San-Juan, who are the coauthors of several of my papers used in this book. I am much indebted to Yulia Ostrovskaya and Philip J. Stabler for the excellent language redaction of the manuscript.

The main part of the writing was done at the Physics and Mathematics Department of the Autonomous University of Puebla, Mexico. I am grateful to M.Sc. E. Doger Guerrero, former rector of the university, M.Sc. E. Agüera Ibáñez, current rector, Dr. P. H. Hernández Tejeda, vice-rector, and Dr. C. Ramírez Romero, head of the department, for providing the excellent facilities for my work. Part of the text was prepared during my sabbatical leave at the National Institute of Astronomy, Optics, and Electronics, Mexico. I acknowledge my indebtedness to Dr. J. S. Guichard Romero, Director of the Institute, Dr. J. F. Soto Eguibar, Deputy Director, and G. Martínez Niconoff, former coordinator of the Optical Division, for their hospitality and fruitful collaboration. The work on the book was partially supported by the National Council for Science and Technology (CONACYT) of Mexico under the projects 3644-E, 25841-E, and 36875-E; this is much appreciated.

I acknowledge with thanks the excellent cooperation I received from the staff of SPIE Press at all stages of the production of this book. In particular, I wish to express my appreciation to Timothy Lamkins, Acquisitions Editor, and Sharon Streams, Press Manager, for their exceptional attention to my work.

Finally, I thank my wife, Marina, without whose patience, encouragement, and support this book would not have been possible.

Andrey S. Ostrovsky

Autonomous University of Puebla
Puebla, Mexico
May 2006