Woodhead Publishing Series in Electronic and Optical Materials

Subsea optics and imaging

Edited by John Watson and Oliver Zielinski

WP Woodhead Publishing

Woodhead Publishing Series in Electronic and Optical Materials: Number 46

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WOODHEAD PUBLISHING

Oxford Cambridge Philadelphia New Delhi

Published by Woodhead Publishing Limited,
80 High Street, Sawston, Cambridge CB22 3HJ, UK
www.woodheadpublishing.com
www.woodheadpublishingonline.com

Woodhead Publishing, 1518 Walnut Street, Suite 1100, Philadelphia,
PA 19102-3406, USA

Woodhead Publishing India Private Limited, 303 Vardaan House, 7/28 Ansari Road,
Daryaganj, New Delhi – 110002, India
www.woodheadpublishingindia.com

First published 2013, Woodhead Publishing Limited

British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library.

Library of Congress Control Number: 2013945055

ISBN 978-0-85709-341-7 (print)
ISBN 978-0-85709-352-3 (online)
ISSN 2050-1501 Woodhead Publishing Series in Electronic and Optical Materials (print)
ISSN 2050-151X Woodhead Publishing Series in Electronic and Optical Materials (online)

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Typeset by Newgen Knowledge Works Pvt Ltd, India
Printed by Lightning Source

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Preface

From coastline to deep-water and from lakes to rivers, many challenges face us in our drive to understand, utilise and preserve our aquatic environment. New techniques and instruments are continually being developed to enable us to probe and monitor its character and behaviour, and to help us optimise the oceans, seas and lakes of the world as sustainable resources of energy, minerals and food for the future. Of increasing importance amongst these techniques is the use of optical methodology, instrumentation and photonics devices for imaging, vision and sensing; this technology is playing an increasingly crucial role in our understanding and exploitation of this unique habitat.

Although the use of optics in studying our 'subsea' habitat has a long and distinguished pedigree stretching back to ancient Greek and Roman times, it was surely the invention of the laser in 1960 and the parallel developments of electronic detectors and high-performance computers that projected optics to the forefront as one of the cornerstones of underwater investigation. Since then, the progress and development of optical science and technology in general has been rapid, dramatic and profound. There is now hardly an aspect of modern life where optics and the laser have not had an impact; this is as true underwater as it is on land and in space.

This explosion of optics activity has led to new sensors being developed and new applications being tackled, across such diverse areas as holographic imaging, subsea laser welding, fibre-optic sensors, laser scanning systems, spectroscopic instrumentation, laser ranging and 3D imaging. Imaging has become a crucial tool for subsea operations and offers a new perspective for operational assessment of aquatic organisms. Hyperspectral sensing has improved the understanding of light and its interaction with biogeochemical water constituents, contributing to the global response to climate change and hazard mitigation. All these advances, many of which are described in this volume, have been supported by rapid developments in semi-conductor-, nano- and other enabling technologies, and promise even more sophisticated optical instruments for the next decade.

Subsea optics and imaging serves as an introductory textbook for students and workers in the field and, at the same time, offers a review of recent trends and technologies. Contributions have been written by renowned experts in the field and review progress in selected areas to provide a transition from fundamental background principles towards in-depth knowledge of specific technologies. We should note that the term 'subsea' is often used in reference to underwater technologies, equipment and methods, whether or not these are in the sea or in fresh-water. Throughout this book we will refer to 'subsea optics' as an interdisciplinary field of natural and engineering sciences focused on the utilisation of light below the water surface, in the context of environmental and industrial objectives.

The book is divided into three parts. The first part provides a general introduction to the concepts of subsea optics and imaging and puts them into a historical context. Two introductory chapters on subsea optics (Chapter 1) and subsea imaging technologies (Chapter 2) are provided by the editors themselves, and a third outlines the history of ocean optics and colour (Chapter 3).

Part II comprises those chapters with a biogeochemical and/or environmental theme. It starts with an overview of underwater light fields and the measurement of optical properties to understanding the nature of propagation of light in water (Chapter 4) followed by an overview of coloured dissolved organic matter – CDOM – (Chapter 5) and assessment of nutrients in the water column (Chapter 6). This section concludes with discussions of the properties of subsea bioluminescence (Chapter 7), an assessment of harmful algal blooms and their impact (Chapter 8) and finally an outline of optical techniques for studying the impact of turbulence and mixing in the marine environment of suspended sediments, turbulence and mixing (Chapter 9).

Part III encompasses all those chapters with an optical systems and imaging theme. Imaging and visualisation using conventional photography and video (Chapters 10 and 11) or advanced techniques such as digital holography (Chapter 12), laser line-scanning (Chapter 13), or range-gated imaging (Chapter 15) are key tools in our study of the oceans and their impact on our environment. They can offer new perspectives for monitoring aquatic life, mapping the seafloor, or mensuration of natural and man-made structures. In the wider context, high-resolution monitoring and rapid assessment of the environment rely on the application of optical sensors, often in parallel with acoustical and other physical/electronic probes. Such sensors can be integrated onto autonomously or remotely controlled observation platforms or global observation networks (Chapter 19). More recently, linked networks of observation platforms allow data from dozens of sensors to be combined; the whole field of data acquisition and visualisation, and subsea optical communications, is crucial to our developments. From conventional two-dimensional to three-dimensional imaging, subsea imaging and sensing have a vital role to play. Techniques such as Raman spectroscopy

(Chapter 16) to hyperspectral sensing (Chapter 20) have improved our understanding of light and its interaction with biogeochemical water constituents. Laser Doppler anemometry (LDA) and particle image velocimetry (PIV) (Chapter 14), optical fibre sensing (Chapter 17) and LIDAR (Chapter 18) are examples of how important newer optical technology is in widening our understanding of the sea. Finally, a chapter on fluorescence methodologies (Chapter 21) brings the volume to a close.

There are many important benefits to be derived from the application of optical technology and from studying the interaction of light in the marine environment. These include increased effectiveness of subsea operations, a clearer understanding of the role of the oceans in the global carbon cycle, the introduction of new technical approaches to the measurement of particles and dissolved substances in seawater, and higher resolution monitoring of the emission and dispersal of pollutants. Subsea optics, therefore, can make an important contribution to international security, facilitate the protection and sustainable management of the resources of the oceans, and contribute to the urgent requirement for monitoring the response of marine systems to climate change. We hope that the chapters included in this volume will have demonstrated the power and importance of optics in the subsea environment inspiring and fostering research and application of subsea optics, imaging and vision.