MULTI-DIMENSIONAL IMAGING

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For Bethany, Ariana, Darius, and Vida

In memory of our friend and colleague, Dr Fumio Okano

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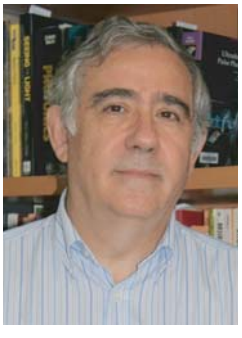
About the Editors

Bahram Javidi is the Board of Trustees Distinguished Professor at University of Connecticut. He has been recognized by nine best paper awards, and major awards from professional societies, including fellowships of IEEE, OSA, EOS, and SPIE. In 2008, he received the Fellow Award from the John Simon Guggenheim Foundation. He has written over 870 publications, which have been cited 11 000 times according to the ISI Web of Knowledge (*h index = 55*). He has received the 2008 IEEE Donald G. Fink Prize Paper Award, the 2010 George Washington University's Distinguished Alumni Scholar Award, the 2008 SPIE Technology Achievement Award, and the 2005 SPIE Dennis Gabor Award in Diffractive Wave Technologies. In 2007, the Alexander von Humboldt Foundation awarded him the Humboldt Prize for Outstanding Scientists. He was the recipient of the (IEEE) Photonics Distinguished Lecturer Award in 2003–2005. He was awarded the Best Journal Paper Award from the *IEEE Transactions on Vehicular Technology* in 2002 and 2005. In 2003 he was selected, as one of the nation's top 160 engineers between the ages of 30–45 by the National Academy of Engineering (NAE), to be an invited speaker at The Frontiers of Engineering Conference. He is an alumnus of the Frontiers of Engineering of The NAE since 2003. He was a National Science Foundation Presidential Young Investigator and received The Engineering Foundation and the IEEE Faculty Initiation Awards. He is on the Editorial Board of the *Proceedings of the IEEE* journal (ranked number one in electrical engineering), and is on the Advisory Board of the *IEEE Photonics* journal. He was on the founding editorial board of the *IEEE Journal of Display*. In 2008, he was elected by the members to be on The Board of Directors of the SPIE. He received his BSc from George Washington University, and his PhD from the Pennsylvania State University.

Enrique Tajahuerce was born in Soria, Spain, in 1964. He received his PhD in Physics from the University of Valencia (UV), Spain, in 1998. Dr Tajahuerce was a researcher at the Technological Institute of Optics, Colour and Imaging (AIDO) in Paterna, Spain, from 1989–1992. Since 1992 he has been member of the Physics Department in the Universitat Jaume I (UJI), in Castelló, Spain, where he is an Associate Professor. He is currently Secretary of the Physics Department and Deputy Director of the Institute of New Imaging Technologies (INIT).

Dr Tajahuerce's research interests lie in the areas of diffractive optics, digital holography, ultrafast optics, computational imaging, and microscopy. He has co-authored more than 90 scientific publications, and over 140 communications in conference meetings (35 of them by invitation). He is member of the SPIE, OSA, EOS, and the Spanish Optical Society (SEDO). In 2008, Dr Tajahuerce received the IEEE Donald G. Fink Prize Paper Award.



Pedro Andrés was born in Valencia, Spain, in 1954. He earned a PhD in physics/optics from the University of Valencia (UV) in 1983. His thesis received the 1984 Special Distinction awarded by the UV. Dr Andrés has been full a Professor of Optics since 1994 at the UV. He acted as the UV's Head of the Department of Optics from 1998–2006. He was also the Director of both the PhD and the Masters Program in the Faculty of Physics (UV) from 2008–2010.

His current research interests include static and dynamic diffractive optical elements, advanced imaging systems, microstructured fibers, temporal imaging, and ultrafast optics. He has co-authored more than 130 peer-reviewed papers. Two of these articles have received more than 200 citations each. He also supervised 13 PhD works (four of them received a Special Distinction awarded by the University of Valencia).

Currently, Professor Andrés is an expert on the Board (Branch Science) for the Evaluation of Faculty Members of Spanish Universities, President of the Iberian-American Network for Optics, Fellow of the OSA, elected member of the Board of Directors of the European Optical Society (EOS), Past-President of the Imaging Committee of the Spanish Optical Society (SEDOPTICA), and Academic Mentor of the EOS Comunidad Valenciana Student Club.

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Preface

Imaging sciences and engineering are rapidly evolving in many ways by encompassing more sensing modalities, display media, digital domains, and consumer products. This field of research and development is frenetically active in multiple scientific, innovative disciplines including those of materials, sensors, displays, algorithms, and applications. Today, the term "optical image" refers not only to the concept of image formation and its multiple analysis, reconstruction, and visualization techniques, but also to computer vision, terahertz frequencies and electromagnetic imaging, medical imaging, algorithms for processing of images, and three-dimensional image sensing, among many others.

In the last two decades, research into advanced imaging systems has made great progress. There are many new procedures in microscopy that overcome the classical resolution limit. The field has benefited from the astonishing results of computational imaging techniques. The advances in imaging through turbid and scattering media allow the achievement of images with good resolution, either from deep layers of tissue in living beings, or the cosmos through telescopes on Earth's surface. Optics in the life sciences incorporates new methods for non-invasive imaging of *in vivo* biological material and the tools to translate that knowledge and procedures for the study, diagnosis, and treatment of diseases. Sources of entangled photons in quantum imaging can provide high-quality images at a very low level of illumination. To all this, we must add many other rapidly evolving areas such as modern adaptive optics, imaging in nuclear medicine, optical tweezers that are opening new avenues for the study of single cells, the role of spatial light modulators in advanced imaging, and so on.

Recently, there have been rapid advances in imaging systems because of the introduction of various multi-dimensional imaging techniques, including digital holography, integral imaging, multiview, light field, multispectral imaging, polarimetric imaging, temporal multiplexing; development of new algorithms, such as those used for compressive sensing or computational imaging; and the application of new light sources, such as ultrashort lasers, laser diodes, super-continuum sources, and so on. In parallel to the development of new imaging techniques, there has been a great advance in image resolution by increasing the number of pixels of different detector arrays and reducing pixel size. It has been recognized that, in many situations, it is also very important to measure not only the spatial intensity distribution of the object, but also other useful dimensions of an image, such as spectral, polarization, optical phase, or three-dimensional structure, leading to the development of multi-dimensional imaging. As a result, there have been substantial multidisciplinary activities in the development of polarimetric cameras, multispectral sensors, holographic

techniques, three-dimensional visualization devices, and so on, integrated with special purpose algorithms to produce multi-dimensional imaging systems for a variety of applications, including medical, defense and security, robotics, education, entertainment, environment, and manufacturing.

Given the great interest in multi-dimensional imaging research, development, and education, this book, entitled *Multi-dimensional Imaging* aims to present an overview of the recent advances in the field by some of the leading researchers and educators. The book intends to educate and provide the readers with an introduction to some of the important areas in this multi-disciplinary domain. This broad overview is useful for students, engineers, and scientists who are interested in learning about the latest advances in this important field.

This book addresses a selection of important subjects in multi-dimensional imaging describing fundamentals, approaches, techniques, new developments, applications, and a relevant bibliography. It consists of 17 chapters and is divided into four parts that deal with multi-dimensional digital holographic techniques, multi-dimensional biomedical imaging and microscopy, multi-dimensional imaging and display, and spectral and polarimetric imaging. The chapters are written by some of the most prominent researchers and educators in the field.

We wish to thank the authors for their outstanding contributions, and the Wiley editors and staff for their support and assistance.

This book is dedicated to the memory of our departed friend, Dr Fumio Okano.

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Be with those who help your being.
Rumi