Preface to the Second Edition

Life always bursts the boundaries of formulas

Antoine de Saint Exupéry

As we sat down to consider writing a new edition of *Digital Holography*, we, the original authors (U. Schnars and W. Jüptner), asked ourselves if the field had advanced sufficiently with enough new and novel developments to merit a second edition. The answer was an overwhelming YES and came from seeing the profound developments and scale of applications to which digital holography, and in the wider context 3D imaging technologies in general, are now being routinely applied. In the intervening years, the evolution of digital holography has been, both, extensive and dramatic.

Some of the areas in which we have seen considerable advances and application include computational wave field sensing and digital holographic microscopy, with a huge number of papers being published in these and related fields. To reflect these advances adequately in our book and to broaden its scope, we invited Claas Falldorf (BIAS) and John Watson (University of Aberdeen) to join us as co-authors. Claas works actively in wave field sensing using computational methods such as phase retrieval or computational shear interferometry. John is an international expert in digital holographic microscopy and, particularly, to underwater holography of aquatic organisms and particles; and also 3DTV and related fields. Both are ideal partners to support the approach and philosophy of the new edition.

Accordingly, this second edition has been significantly revised and enlarged. We have extended the chapter on Digital Holographic Microscopy to incorporate new sections on particle sizing, particle image velocimetry and underwater holography. A new chapter now deals comprehensively and extensively with computational wave field sensing. These techniques represent a fascinating alternative to standard interferometry and Digital Holography. They enable wave field sensing without the requirement of a particular reference wave, thus allowing the use of low brilliance light sources and even liquid-crystal displays (LCD) for interferometric applications. We believe that, in the coming years, computational wave field sensing will prove to be an excellent complement to Digital Holography to determine the full complex amplitude of wave fields.

All the authors wish to thank colleagues past and present (too numerous to mention) with whom they have worked over the years. As with the first edition, several pictures and figures in this book originate from common publications with other colleagues and we thank them for permission to describe their work and to use their pictures. All of our co-workers are gratefully acknowledged.

Bremen, May 2014
Aberdeen

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Preface to the First Edition

Sag' ich zum Augenblicke verweile doch, Du bist so schön

J.W.v. Goethe, "Faust"

An old dream of mankind and a sign of culture is the conservation of moments by taking an image of the world around. Pictures accompany the development of mankind. However, a picture is the two-dimensional projection of the three-dimensional world. The perspective—recognized in Europe in the Middle Ages—was a first approach to overcome the difficulties of imaging close to reality. It took up to the twentieth century to develop a real three-dimensional imaging: Gabor invented holography in 1948. Yet still one thing was missing: the phase of the object wave could be reconstructed optically but not be measured directly. The last huge step to the complete access of the object wave was Digital Holography. By Digital Holography the intensity and the phase of electromagnetic wave fields can be measured, stored, transmitted, applied to simulations and manipulated in the computer: An exciting new tool for the handling of light.

We started our work in the field of Digital Holography in 1990. Our motivation mainly came from Holographic Interferometry, a method used with success for precise measurement of deformation and shape of opaque bodies or refractive index variations within transparent media. A major drawback of classical HI using photographic plates was the costly process of film development. Even thermoplastic films used as recording medium did not solve the hologram development problem successfully. On the other hand the Electronic Speckle Pattern Interferometry (ESPI) and its derivate digital shearography reached a degree mature for applications in industry. Yet, with these speckle techniques the recorded images are only correlated and not reconstructed as for HI. Characteristic features of holography like the possibility to refocus on other object planes in the reconstruction process are not possible with speckle metrology.

Our idea was to transfer all methods of classical HI using photographic plates to Digital Holography. Surprisingly, we discovered that Digital Holography offers more possibilities than classical HI: The wavefronts can be manipulated in the numerical reconstruction process, enabling operations not possible in optical holography. Especially the interference phase can be calculated directly from the holograms, without evaluation of an interference pattern.

The efficiency of Digital Holography depends strongly on the resolution of the electronic target used to record the holograms. When we made our first experiments in the 1990s of the last century, Charged Coupled Devices began to replace analogue sensors in cameras. The resolution of commercially available cameras was quite low, about some hundred pixels per line, and the output signal of cameras already equipped with CCDs was still analogue. In those days, digital sampling of camera images and running of routines for numerical hologram reconstruction was only possible on special digital image processing hardware and not, as today, on ordinary PCs. The reconstruction of a hologram digitized with 512 × 512 pixels took about half an hour in 1991 on a Digital Image Processing unit developed at BIAS especially for optical metrology purposes. Nevertheless we made our first experiments with these types of cameras. Today, numerical reconstruction of holograms with 1 million pixel is possible nearly in real time on state-of-the-art PCs.

Then, fully digital CCD cameras with 1 million pixels and smaller pixels than those of the previous camera generation emerged on the market. These cameras showed better performance and first applications in optical metrology became possible. Today, digital CCD cameras with 4 million pixels are standard.

The tremendous development in opto-electronics and in data processing pushed Digital Holography to new perspectives: It is applied with success in optical deformation and strain analysis, shape measurement, microscopy and for investigations of flows in liquids and gases. In this book we make the trial to describe the principles of this method and to report on the various applications. We took pains to prepare the manuscript carefully and to avoid mistakes. However, we are not perfect. Comments, suggestions for improvements or corrections are therefore welcome and will be considered in potential further editions.

Some pictures in this book originate from common publications with other co-authors. All of our co-workers, especially W. Osten, Th. Kreis, D. Holstein, S. Seebacher, H.-J. Hartmann and V. Kebbel are gratefully acknowledged.

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