HOLOGRAPHY News®
INTERNATIONAL NEWSLETTER OF THE HOLOGRAPHY INDUSTRY
www.holography-news.com
ISSN 0895-9080
Volume 27 - No 5 - May 2013

Book Review

Ultra-Realistic Imaging

Subtitled *Advanced Techniques in Analogue and Digital Colour Holography*, this heavyweight (literally and metaphorically!) book co-authored by Hans Bjelkhagen and David Brotherton-Ratcliffe provides definitive coverage of its subtitle topic. It comprises over 600 pages of lavishly illustrated history and instruction on the creation of 'ultra-realistic' holograms.

Both authors are recognised as practising experts in this field (and Bjelkhagen is an advisor to *Holography News®*). As long-time practitioners, they bring a wealth of knowledge, history and practical experience to this comprehensive survey of the field. Even though they are both involved in their own research and commercial projects, they are willing to share their extensive knowledge to equip others with the techniques needed to produce ultra-realistic images, which they define as 'any imaging technique that is able to record and reconstruct the visible electromagnetic light field scattered from a real-world object or scene with a resolution better than or equal to that of the unaided human eye.' They then go on to acknowledge that their primary concern in the book is volume phase holography, which means that other actual or potential ultra-realistic imaging techniques are ignored or only referenced in passing. Perhaps this is a missed opportunity to set out the different characteristics of various imaging methods.

High Virtual Volume Holograms

That definition encapsulates not only the subject of the book but the authors' scientifically precise style ('visible electromagnetic light field etc' instead of 'the light'). Sections of the book are well-written surveys of what has happened in holography and what is now available to make ultra-realistic holograms feasible; these sections are accessible to a lay reader. Other sections, those setting out the physics, chemistry and techniques of what the authors term *high virtual volume* (HVV) holograms, are necessarily and unashamedly technical and scientific, with substantial use of mathematical formulae.

The book covers the developments and characteristics of the necessary tools and components for these kinds of hologram, from lasers through the optics to the exposure media. Understandably, there are sections which relate the authors' own relevant project experience, such as Bjelkhagen's involvement in the *Silver Cross* project to develop the ultimate exposure material for colour reflection holograms (see HN Vol 19 No 11). There is also a fascinating appendix detailing the history of Geola, the Lithuanian company founded by Brotherton-Ratcliffe that is a leader in digital display holograms, which shows the part that vision, determination and serendipity play in creating a successful operation.

Ultra-Realistic Imaging (ISBN 978-1-4398-2799-4) is published by the CRC Press, price £108/$169.95, high, but not excessive for the production quality and content of this definitive guide to this type of hologram.

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Ultra-Realistic Imaging: Advanced Techniques in Analogue and Digital Colour Holography

Hans Bjelkhagen and David Brotherton-Ratcliffe
CRC Press, 2013; $169.95 (hardcover).

This volume is both a textbook and a reference devoted to real-time color volume phase holography. It touches on a variety of subjects, including the physical theory of the holographic grating, digital holographic printing and pulsed lasers for holography. It is written in a very accessible style, with clear exposition of all the main results. Also worthy of note is the collection of over 500 photographs, diagrams and schematics relating to the recording and production of ultra-realistic holographic images. This book is intended for anyone wishing to get acquainted with imaging techniques with a resolution better than or equal to that of the unaided human eye and their relevance to holographic microscopy and endoscopy and bubble chamber holography.

Review by Christian Brosseau, OSA Fellow, Université de Bretagne Occidentale in Brest, France.

The opinions expressed in the book review section are those of the reviewer and do not necessarily reflect those of OPN or OSA.

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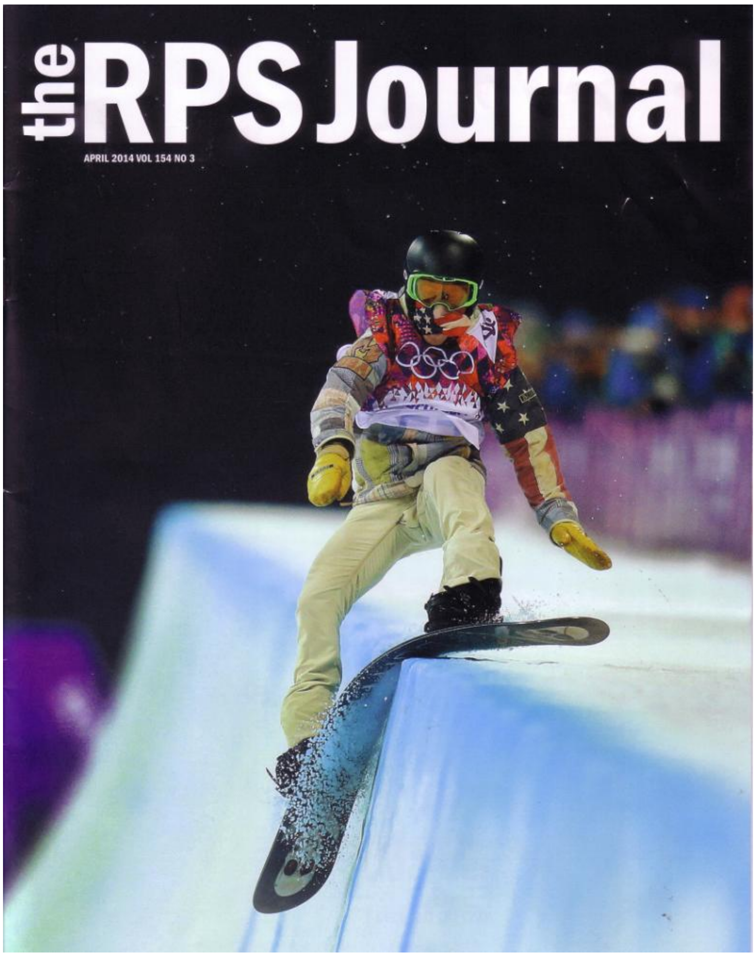

ULTRA-REALISTIC IMAGING
Hans I Bjelkhagen & David Brotherton-Ratcliffe
CRC Press, 184×260mm, HB, 638 pp.
ISBN 978-1-4398-2799-4. £108

Produced to the highest quality, with excellent illustrations throughout – almost always printed on the same page as the relevant text – this book will no doubt become the standard reference work on the subject. Its co-author, Hans Bjelkhagen, is Chair of The Society's 3D Imaging & Holography Group, and Professor Emeritus of Interferential Imaging Sciences at Glyndŵr University Centre for Modern Optics, North Wales, and has contributed to many advances in holography and interferometry.

Its other co-author, David Brotherton-Ratcliffe, is the founder and Scientific Director of Lithuanian holographic equipment company Geola, and an expert on light and image recording, holding patents on dot-matrix digital 3D printing.

The book starts with a history of display holography, from its invention in 1947 to the present. The main text begins with a description of Lippmann photography. A special interest of Bjelkhagen's, the technique uses the interference of light wavefronts to produce its colour. The principle can be traced back as far as Goethe (1810), but in practice it had to wait until 1892, when Gabriel Lippmann, having developed a rigorous theory of the principle, used his own ultrafine-grain photographic emulsion to produce a permanent image in natural colours. Recent research uses holographic silver halide material, or photopolymer.

The following two chapters discuss lasers suitable for colour holography, detailing the design and construction of both continuous-wave and pulse lasers (a speciality of Geola's), with diagrams showing their construction. They list the demands of silver halide recording materials, explaining the necessity for very high resolving power and the minimisation of reciprocity failure (exposure times may be anything from a few nanoseconds to several minutes). There are details of the preparation of both silver halide and dichromated gelatine emulsions. Photopolymer materials are dealt with more briefly, as most of these are unavailable to the public at present. Photoresists aren't mentioned.

The next section gets down to the basics of analogue colour holography. After a brief look at earlier attempts, which were hampered by inadequate emulsions and a limited choice of laser wavelengths, the authors deal with the theory of colour reproduction in terms of tristimulus values, showing how subjective colour errors are necessarily introduced by the use of single wavelengths rather than the broader-band sources employed in photography.

Tests made using MacBeth ColorChecker targets show that the optimum wavelength combination with three lasers gives a subjective colour reproduction error not exceeding 2% over the visible spectrum, and that the use of four laser wavelengths can reduce all errors to within 1%. The authors also discuss in detail the practical setups and processing techniques for Denisyuk colour holography.

We are now introduced to the principles of digital holography. Strictly speaking, this term should refer to holograms made entirely by digital means. However, it is now generally taken to mean any hologram in which digitisation plays a substantial part, such as a holographic stereogram made from digitally produced 2D images.

This section therefore begins with the development of the holographic stereogram, from DeBitetto's original conception to its present state. The authors discuss a number of commercial printers that produce either horizontal-parallax-only or full-parallax images, including details of distortion correction where the subject or the recording equipment is rotated between separate exposures, as in Lloyd Cross' cylindrical holograms.

This is followed by a discussion of the theory and design of algorithms for horizontal-parallax (rainbow) images. This discussion is then extended to include full-parallax images. Some neat mathematical footwork may be needed to assimilate this section, though the accompanying diagrams help to clarify matters, especially with regard to distortion correction.

The text continues with the origination of material to form the subject matter for a digital display hologram. In most cases, the 2D images will have been originated by a mechanically controlled high resolution digital camera (usually called a holocam system). The camera is mounted on a rail and operated using a stepping motor. For a final hologram with limited parallax, a fixed wide angle lens may suffice. A larger field of view may demand a shift lens, and for the largest field, it will be necessary to rotate the camera between exposures, so that its optic axis always points toward the centre of the subject matter.

Although several of these techniques may be combined to reduce keystoning and other distortions, a correction program is still advisable, and this section shows how to derive the appropriate equations, with illustrations of the results. The geometry of the Cross hologram is also analysed. In these stereographic techniques, the final image is a rainbow hologram. However, a limited amount of vertical parallax can be introduced, by making several passes with the camera axis shifted vertically between them. This is the method discussed here.

The remainder of this chapter is devoted to the writing of algorithms for computer-generated subject material. It concentrates on a specific type applicable to the design program 3DStudioMax Version 8. The example given is for a typical 20×30cm (landscape) hologram, with horizontal parallax only, and a scale of 1:10. It begins by showing the creation of an animation sequence as it would be seen by a camera with linear movement. Finally, the method of programming using MAXScript for a full-parallax three-colour reflection hologram is described. An example of this program appears in Appendix 5.

"This book deserves a place on the shelves of every optics department"

The next section (chapters 11-12) presents a theoretical basis for high-fidelity display holograms. In order to follow this section, you need to be fairly familiar with the language of complex numbers and vector calculus, although, unless you are going to be involved in serious research, you may not need a thorough grasp of this rather difficult material. Chapter 11 deals with the Bragg condition, distortion correction, diffraction efficiency, polarisation and image blurring, in both analogue and digital holograms, in monochrome and colour.

Chapter 12 presents an alternative approach to the more familiar coupled-wave theory of Kogelnik. This gives a closer prediction of the practical outcome where complicated gratings simultaneously recording several wavelengths are created within the emulsion (it can also be employed to study the formation of Lippmann gratings).

Chapter 13 returns to practical aspects of displaying holographic images. The importance of positioning, illumination bandwidth and spatial coherence is discussed, and a number of suitable geometries for display illustrated. The pros and cons of earlier light sources, such as lasers and mercury vapour and filament lamps, are listed, and there is a thorough examination of the construction and illuminative qualities of LED sources for both monochrome and colour displays. The edge-lighting principle is also considered in some detail.

The final section deals with the scientific, commercial and pictorial possibilities of ultra-realistic imaging, and looks forward to possible future applications of various techniques, such as bubble chamber imaging, endoscopy and microscopy. It discusses the future for the holography of museum artefacts, and possible roles for holography in urban planning and architecture. And now that RGB pulse lasers are a reality, holographic portraiture may well achieve the popularity enjoyed by present-day photographic portraiture.

The book is rounded off by a list of abbreviations (mislabelled 'acronyms') used in the text, and a further list containing the molecular formulae of all the materials and chemicals mentioned. There are eight appendices, dealing respectively with historical origins, the history of the Geola Company, laser frequency stabilisation, aberration correction, the MAXScript Holocam program, the design of RGB illumination sources, interpolation in direct-write digital imaging, and the rigorous coupled-wave theory mentioned earlier.

Finally, there is an update on recent research – a necessary addition to any textbook or manual that may have spent several years in gestation. There is a competent index, though this could possibly be improved by a separate index of proper names. It would also have been good had the book included also a list of the symbols used in vector calculus, group theory, electromagnetism and Fourier optics, as these appear without explanation in the mathematical part of the text.

Even in a book as excellent as this, there are bound to be a few errors. Most of these are simple typos: Kaveh Bazargan is renamed 'Kevin' (p 24); and in Figure 1.17, Margaret Benyon's painted embellishments to her holographic portraiture are unfortunately described as 'gauche' instead of 'gouache'. Such minor blemishes are probably due to an overenthusiastic spellchecker. A more serious error occurs in Figure 11.9, where the wavefront patterns for forming transmission and reflection interference planes have somehow become switched.

Curiously, the text contains no mention of holographic interferometry, and says very little about the applications of holography to teaching and forensic imaging. Nevertheless, this publication represents an outstanding contribution to holographic literature. In spite of its price, it deserves a permanent place on the shelves of every optics department. **Graham Saxby HonFRPS**