

Digital Holography and Holographic Displays

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Holography is now more than 60 years old since the time when Dennis Gabor published his first paper in 1948, introducing the new coherent imaging technique. Holography had to wait for its first practical applications a little over 10 years until the laser was invented and laser light could be used for recording the first holograms. This happened almost simultaneously in both the USA and the former USSR. Since that time, interest in holography has been growing at an increasing rate, and has given rise to numerous applications of holographic techniques in science, industry, medicine, and art. During the first decades mainly analog holograms were recorded, using continuous-wave and pulsed lasers. Display holograms, holographic optical elements (HOE), holographic interferometry, and holographic nondestructive testing (HNDT) used different types of recording materials, often combined with wet processing. It was a time-consuming technique and required special expertise to obtain good results. When computers became faster and their storage capacity increased, very simple computer-generated holograms (CGHs) were introduced to show the potential of generating holograms and HOEs without having to record a real object. Very soon computer programs were introduced for the evaluation of interference fringes in metrology and nondestructive testing.

Since the beginning of the new millennium, there has been a dramatic progress in computer technology in regard to computer storage capacity, speed, and graphics, which has made applications of CGHs and holographic displays an important part of current holographic techniques. HNNT and speckle interferometry are now only performed with the help of computers, images being recorded on electronic holographic recording devices. For example, CGHs are also used as null elements in optical testing.

Today computers and electronic recording devices are used in different ways. The possibility of recording very high spatial frequencies employing electronic devices is, however, still very limited. For ultrahigh-resolution holographic recording, spatial frequencies of up to 10,000 line pairs/mm are required. For example, to display a full-parallax hologram in real time on a 40-in. wide screen with 30-deg horizontal and 10-deg vertical field of view, a bandwidth of 10^{15} Hz is required. The ultimate goal is to computer generate the interference fringe structure which is necessary to generate a holographic image for display. For a large-sized hologram, it is not possible to generate the necessary data fast enough to get a refreshment rate of 25 to 30 Hz. If we compare this with the

analogue technique, using a pulsed laser to record a very large hologram of a complex object or scene, the interference structure is created and stored in a high-resolution photographic material in 20 ns, provided the pulsed laser energy is sufficient.

Holographic microscopy using in-line holography combined with charge-coupled device (CCD) recording devices is common practice today. Some CCDs have sufficient spatial frequency resolution and can be used for holographic particle studies in real time, using fast Fourier transform programs. CGHs are also used to generate small holographic optical variable devices for important security document applications.

Today a combination of techniques is used in order to obtain various types of CGHs. A technique for recording large, color display holograms is to print them pixel by pixel on a high-resolution holographic material. Each pixel hologram, or hogel, is computer generated and displayed on a LCD or liquid crystal on silicon (LCOS) device. Using this technique to obtain a large one-square-meter color display hologram, the printing of the entire hologram can take many hours, depending of the RGB laser's pulse repetition rate. Using this type of hologram printing technique, both completely computer-generated three-dimensional (3D) images can be recorded, as well as a combination of a large number of photographically recorded images, such as those captured by a digital camera moving along a horizontal rail, for example. The two-dimensional images are then transformed and used to create the printed hologram.

For holographic displays, HOEs can be used as a stereo projection screen generating autostereoscopic moving 3D images. There is a lot of research going on in these fields, aiming to create 3D images in real time for potential 3D television techniques. In the future, when computers become even faster, and when nanotechnology-based electronic display devices have sufficient spatial frequency resolution to display full parallax real-time color holograms directly, electronic ultrarealistic 3D images could become a reality.

This special section contains state-of-the-art papers on the applications mentioned above. The papers are ordered according to the date of acceptance.

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Hans I. Bjelkhagen, professor emeritus at Glyndŵr University, United Kingdom, was awarded his PhD degree in 1978 by the Royal Institute of Technology in Stockholm, Sweden. During his employment there he developed methods for recording interferometric holograms, and performed holographic nondestructive testing for the Swedish car and airplane industry. In 1983, he joined European Organization for Nuclear Research (CERN) in Geneva, Switzerland,

where he was involved in the development of bubble chamber holography, after which he continued neutrino physics experiments in the 15-ft bubble chamber at Fermilab in Batavia, Illinois. Between 1985 and 1991 he was employed at Northwestern University, Evanston, Illinois, working on medical endoscopic applications in holography. Over the past 15 years, he has become widely known for his work in color holography, holographic recording materials, and Lippmann photography. In December 1997 he joined the Centre for Modern Optics (CMO) at De Montfort University, Leicester, England, where he continued his research on 3D imaging, color holography, color HOEs, and holographic recording materials. He has published over 100 papers in refereed journals and conference proceedings and holds 9 international patents. His most important academic contribution to date is his book *Silver-Halide Recording Materials for Holography and Their Processing* (Springer Verlag, 1993). The book is considered to be a standard textbook on the subject, and is now used by many universities teaching holography, as well as most international companies producing display holograms. He is a member of the OSA, a fellow of SPIE, and chairman of SPIE's Photonics West Practical Holography Conference and the SPIE Holography Technical Group. He is an accredited senior imaging scientist and Fellow of the Royal Photographic Society (RPS). In 2011 he received the RPS Saxby Award for his work in holography.