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Practical Holography VII: Imaging and Materials

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Contents:

Generation of intermediate parallax images for holographic stereograms, pp.2-8 Author(s): Susumu Takahashi, Toppan Printing Co., Ltd., Sugito-machi, Kita-katsushika, Saitama-ken, Japan; Takeo Honda, Tokyo Institute of Technology, Yokohama, Japan; Masahiro Yamaguchi, Tokyo Institute of Technology, Midori-ku, Yokohama, Japan; Fujio Iwata, Toppan Printing Co., Ltd., Sugito-Machi, Kita-Katsushika, Saitama-ken, Japan. Abstract: We propose a new image processing approach to construct intermediate parallax-images from parallax-images at coarsely sampled viewpoints for Holographic Stereograms. Compared with the usual method that requires a large number of parallax-images, this approach reduces recording labor. In our approach, the intermediate parallax-images are made by projections of 3-D surface data, which are computed from several given parallax-images. It uses a new technique to reconstruct 3-D surface data of object scenes. The 3-D surface data is reconstructed from original parallax-images and camera positions. Almost all conventional techniques of stereo-matching need preprocess of feature extraction, and match only one stereo-pair at once. This technique simultaneously treats all given parallax images to find the depth map. In addition, feature extraction is not required in the matching process. Therefore it is possible to apply to almost all kind of scenes for holographic stereograms.!10

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Development of an office holoprinter III, pp.9-14 Author(s): E.van Nuland, Dutch Holographic Lab. B.V., Eindhoven, Netherlands; Walter C. Spierings, Dutch Holographic Lab. B.V., Eindhoven, Netherlands. Abstract: We will report on the status of the development of the OFFICE HOLOPRINTER$+TM$/. We are investigating a new active matrix color LCD spatial light modulator driven by our Silicon Graphics workstation with TRACES$+TM$/ software. Discussed will be the results and experiments. Also different kinds of HOE's in combination with the LCD screen together with a variety of one-step recording possibilities will be discussed. The final part of the paper will include DHL's concept for the holoprinter as a whole and which parts are being improved to arrive at a professional multi-purpose office holoprinter. This includes tests of software and approaches to make 3D images.!15

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Compact prototype one-step Ultragram printer, pp.15-24 Author(s): Michael A. Klug, MIT Media Lab., Cambridge, MA, USA; Michael W. Halle, MIT Media Lab., Cambridge, MA, USA; Mark E. Lucente, MIT Media Lab., Cambridge, MA, USA; Wendy J. Plesniak, MIT Media Lab., Boston, MA, USA. Abstract: We describe a prototype reduced-size holographic stereogram printer capable of producing scalable, Ultragram-format hardcopy output. An analysis of the resolution requirements for high quality stereogram output with respect to the printing method and printer components is presented. A holographic optical element is combined with a pseudorandom band-limited diffuser to focus the spatially modulated object beam and provide Fourier-plane broadening, thus improving image quality. We analyze issues of image preparation time and integration of image rendering and exposure control to optimize system resource requirements.!12

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Phase-added stereogram: calculation of hologram using computer graphics technique, pp.25-31 Author(s): Masahiro Yamaguchi, Tokyo Institute of Technology, Midori-ku, Yokohama, Japan; Hideshi Hoshino, Tokyo Institute of Technology, Midori-ku, Yokohama, Japan; Toshio Honda, Tokyo Institute of Technology, Yokohama, Japan; Nagaaki Ohyama, Tokyo Institute of Technology, Midori-ky, Yokohama, Japan. Abstract: The wavefront reconstruction of hologram and holographic stereogram are analyzed to compare their imaging properties, and 'phase added stereogram' (PAS) is proposed as a technique for the calculation of computer generated hologram (CGH). Applying PAS, computer graphics techniques, for example, surface shading and hidden surface removal are easily applied in CGH generation process. The amount of computation is reduced compared with actual hologram calculation, and the quality of reconstructed image is superior to that of holographic stereogram. The theoretical expression of PAS is presented, and experimental results are also demonstrated.!5

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Robot for recording analog multifacet holograms, pp.34-40 Author(s): Max Monti, Swiss Federal Institute of Technology, Lausanne, Switzerland. Abstract: Multifacet holographic optical elements (MFHOE) have interesting applications in different field, such as optical computing, optical connections, structured light for vision system, scanning techniques, security, display, and non-standard problems. In some applications, where very small facets are not necessarily needed, the MFHOE can be obtained by direct holographic recording. This technique, simpler and cheaper than CGH, allows the realization of large-area MFHOE. The minimal facet size is however limited to about 1 mm$+2$/. A machine for the automatic recording of large analog MFHOE has been built. Holograms as large as 200 $MUL 300 mm can be recorded. The size of the facets ranges from 1 $MUL 1 mm to 20 $MUL 20 mm. The main components of this robot are two moving arms carrying two phase-stabilized PM-fibers, a moving plate-holder and a fixed mask, which can be a simple window or a complex pattern. This machine is specially designed for the fabrication of a very large light collector, which is the key component of a 4m-wide laser scanning system. This paper presents the principal characteristics of the robot and some examples of holograms that can be realized with this machine.!7

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Plate optics prepared for making two-step Lippmann holograms, pp.41-49 Author(s): Masane Suzuki, Nagoya College of Creative Arts, Omiya City, Saitama, Japan; Motonori Kanaya, Fuji Photo Optical Co., Ltd., Omiya City, Saitama, Japan; Masayuki Nakata, Fuji Photo Optical Co., Ltd., Oomiya City, Saitama Pref., Japan; Nobuyoshi Kataoka, Chuo Precision Industrial Co., Ltd., Chiyoda-ku, Japan; Yutaka Munakata, Chuo Precision Industrial Co., Ltd., Chiyoda-ku, Japan. Abstract: In most laser optical systems, beams are commonly transmitted via optical elements which are put on a table. The drawback of this is that a complicated optical system cannot be formed easily because optical elements on tables are likely to interfere with their own optical paths. It is difficult to arrange an optical system without restriction. We tried to transmit laser beams in a grooved table and got good results with a Fresnel hologram recording system. But we couldn't study the downsizing potential as the merit of plate optics thoroughly because this system was sized 20 inches square. In the field of optoelectronics downsizing of devices will be demanded. We then made a 10 inches square sized plate optics and formed a two step Lippmann hologram recording system which is more advanced then the Fresnel type.!2

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Construction of a 100-metric-ton holographic table, pp.50-54 Author(s): Leopold Pflug, Swiss Federal Institute of Technology, Lausanne, Switzerland; Mauro Pedretti, Instituto Maccanica dei Materiali S. A., Lugano, Switzerland. Abstract: A 100-ton (metric) holographic table has ben built as a testing facility for the mechanical and civil engineering industry. The table is made of a rectangular concrete slab of 5 by 20 m and it is presented in both directions in order to achieve maximum stiffness and stability. Due to the large size and the loading capacity of this table, full scale examination of large specimens or heavy concrete elements can be performed by means of optical methods including holographic interferometry, speckle interferometry or high sensitivity moire. Rheological behavior, i.e. creep and shrinkage, induces redistribution of internal stresses. Scale effects blurry the actual phenomena if observed on a reduced size model. In order to manage a desirable 'Design by testing' such a facility allowing full scale testing certainly offers a very efficient tool.!6

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Capacity considerations for multiplexed holographic optical data storage, pp.56-65 Author(s): Abraham Aharoni, Stanford Univ., Stanford, CA, USA; Matthew C. Bashaw, Stanford Univ., Menlo Park, CA, USA; Lambertus B. Hesselink, Stanford Univ., Stanford, CA, USA. Abstract: The capacity of volume holographic data storage depends on the multiplexing efficiency of input holographic data arrays or pages. We compare this page-packing capacity of two common approaches: angle, and wavelength multiplexing. For maximal page packing the angular separation between the reference and signal beam incidence in the angle and wavelength multiplexing methods should be 90$DGR and 180$DGR@, respectively. We find that in these optimal arrangements both methods can multiplex a similar number of paraxial data-page signals, which is comparable to conceptual storage capacity limits derived from

considerations of resolution in three-dimensions. In practice, the high number of multiplexed data pages predicted here will be compromised by material-related noise sources.!17

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Novel photopolymer system and its application to color hologram, pp.66-74 Author(s): Masami Kawabata, Nippon Paint Co., Ltd., Osaka, Japan; Akihiko Sato, Nippon Paint Co., Ltd., Osaka, Japan; Iwao Sumiyoshi, Nippon Paint Co., Ltd., Osaka, Japan; Toshihiro Kubota, Kyoto Institute of Technology, Sakyo-ku, Kyoto, Japan. Abstract: We present a new type of photopolymer system for recording reflection holograms. The photopolymer system using radical and cationic photopolymerization controlled by the wavelength of light gives us enhanced diffraction efficiencies and a balanced recording sensitivity (20 approximately 60 mJ/cm$+2$/) in the blue to red region of the spectrum. In color hologram recordings, diffraction efficiencies of around 60% are obtained when using a photopolymer film composed of different spectral-sensitive photopolymer layers.!13

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Holograms in the edge-illumination geometry--new materials development, pp.75-81 Author(s): Nicholas J. Phillips, Loughborough Univ. of Technology, Loughborough, Leicestershire, United Kingdom; Ce Wang, Loughborough Univ. of Technology, Loughborough, Leicestershire, United Kingdom; Zane A. Coleman, Loughborough Univ. of Technology, Loughborough, Leicestershire, United Kingdom. Abstract: Some rigorous statements are made about the recording of holograms in the true edge- illuminated geometry. An essential asymmetry is outlined between the role of the substrate refractive index and that of the recording medium. Laboratory observations indicate that unique possibilities exist for recording in this regime using the photopolymers of Du Pont. Unlike any other regime of holography, numerous optical criteria have to be met simultaneously. We believe that self-induced index matching between the recording polymer layer and the substrate on which it is mounted is the key to a workable recording system.!3

Contents

Using thick DCG, 30-100 micron, pp.82-90 Author(s): Richard D. Rallison, Ralcon Development Lab., Paradise, UT, USA; Scott R. Schicker, Ralcon Development Lab., Paradise, UT, USA. Abstract: Thick holographic films are useful for making multiple recordings in the same volume and for reducing the amount of light diffracted into unwanted orders by a single recorded grating. Dichromated gelatin (DCG) is a material that may be used in thick layers and processed in a way that leads to behavior as a thick hologram. We investigated ways to coat and process layers up to 100 microns thick on glass. We found that the control of the modulation and integrity of the original exposed structure was a formidable task. The angular bandwidth was often smaller than the angular error and the angular error was sometimes a random variable over the surface and volume. Uniformly hardened films were made and exposed to uniform plane waves but the resulting recordings often lacked uniformity in every property but thickness. The lower range of thicknesses was far easier to work with and process than the higher range.!3

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Determination of average refractive index of spin-coated DCG films for HOE fabrication, pp.91-100 Author(s): T.J. Kim, Univ. of Arizona, Tucson, AZ, USA; Eugene W. Campbell, Univ. of Arizona, Tucson, AZ, USA; Raymond K. Kostuk, Univ. of Arizona, Tucson, AZ, USA. Abstract: The refractive index of holographic emulsions is an important parameter needed for designing holographic optical elements (HOEs). In this paper theoretical calculations of the accuracy required for the refractive index and thickness of emulsions needed to meet predetermined Bragg angle conditions are presented. A modified interferometric method is used to find average refractive index of the unexposed and the developed dichromated gelatin holographic films. Slanted transmission HOEs are designed considering the index and thickness variations, and used to verify the index measurement results. The Brewster angle method is used to measure surface index of the unexposed and the developed films. The differences between average index and surface index are discussed. Theoretical calculation of the effects of index variation on diffraction efficiency, and experimental results for index modulation variation caused by process changes are also presented.!12

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Dichromated gelatin--some heretical comments, pp.101-114 Author(s): Nicholas J. Phillips, Loughborough Univ. of Technology, Loughborough, Leicestershire, United Kingdom; Richard D. Rallison, Ralcon Corp., Paradise, UT, USA; Christopher A. Barnett, Loughborough Univ. of Technology, Loughborough, Leicestershire, United Kingdom; Scott R. Schicker, Ralcon Corp., Paradise, UT, USA; Zane A. Coleman, Loughborough Univ. of Technology, Loughborough, Leicestershire, United Kingdom. Abstract: This paper looks at some ideas old and new that relate to the formation of images in dichromated gelatin. The traditional view that the dichromated system hardens gelatin thus preventing solubilization of the material must be balanced against other observations such as that of the reduction of the bulk index of the gelatin layer and the appearance of gelatin in the processing solutions. We revisit the problem and take a look at some new chemical ideas that relate to the behavior of gelatin during bleaching of silver halides. A new method for the processing of silver halide-sensitized gelatin (S.H.S.G.) is proposed which endows the silver halide emulsion with more than three orders of magnitude of speed when compared with D.C.G. per se.!10

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New initiation system for photopolymer holographic recording material, pp.115-119 Author(s): Cunlin Zhang, Beijing Institute of Technology, Beijing, China; Meiwen Yu, Beijing Institute of Technology, Beijing, China; Yongyuan Yang, Institute of Photographic Chemistry, Beijing, China; Jun Li, Institute of Photographic Chemistry, Beijing, China; Erjian Wang, Institute of Photographic

Chemistry, Beijing, China. Abstract: Some p-N,N-dimethylamine and diethylamine substituted benzal ketone derivatives (ABK) are used as a new class of sensitizer for laser light induced radical photopolymerization of N-vinyl carbazole (NVC) and methacrylic acid benzal ester (MABE) by combination with diphenyliodonium salt (DPIO). The relative efficiency of various ABK for polymerization of NVC and MABE to record holograms is in the order DEBP$GRT@DABA$GRT@ABA. An argon ion laser (488 nm) is used for exposure .Trichromatic filters were made with the material.!8

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Computer-generated microlenses with high efficiency, pp.122-133 Author(s): Edgar Pawlowski, Heinrich-Hertz-Institut fuer Nachrichtentechnik Berli n GmbH, Berlin, Federal Republic of Germany; Margit Ferstl, Heinrich-Hertz-Institut fuer Nachrichtentechnik Berli n GmbH, Berlin, Federal Republic of Germany; Berndt Kuhlow, Heinrich-Hertz-Institut fuer Nachrichtentechnik Berli n GmbH, Berlin, Federal Republic of Germany. Abstract: Blazed Fresnel zone microlens arrays were fabricated by Ion-Beam-Sputter deposition technique on different substrate materials. The lenses have circular and square apertures with the smallest width of 0.2 mm and different focal lengths for the wavelength of 1.52 $mu@m and for the wavelength of 0.63 $mu@m. The kinoform profile in each zone of the Fresnel zone lenses was approximated by a sixteen level profile. Such stepped profiles were realized with several masks, written with electron-beam and with photolithographic technology. The effects of fabrication errors, such as level heights, alignment and linewidths errors, on the diffraction efficiency were discussed. The microlenses were coated with an antireflection coating. The reflection of these lenses was analyzed on the basis of an angular spectrum approach. A minimum reflectivity as low as 2 $MUL 10$+$MIN@4$/ was realized using in situ controlled multilayers of TiO-2/ and SiO-2/. Our measurements reveal, that the spot- sizes of the fabricated microlenses are close to the diffraction limited values, and the highest measured diffraction efficiency for the sixteen level structure is 96%.!18

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Machine for continuous hologram production, pp.134-144 Author(s): Mark L. Armstrong, DuPont Imaging Systems, Wilmington, DE, USA; Douglas F. Tipton, DuPont Imaging Systems, Wilmington, DE, USA. Abstract: The Du Pont OmniDex$+TM$/ Replicator uses a unique cylindrical scanning geometry for continuous production of holographic images. The replicator is designed to contact copy reflection holograms into the OmniDex$+TM$/ family of holographic imaging films. The continuously moving web is coupled to a master hologram which is mounted on a cylinder and scanned to record the copy. The typical production rate is 5 square feet per minute. Examples presented and discussed.!3

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Diffractive printing methods using volume holograms, pp.145-154 Author(s): William J. Gambogi, Jr., Du Pont Imaging Systems, Wilmington, DE, USA; T.J. Trout, Du Pont Imaging Systems, Wilmington, DE, USA. Abstract: A unique, proprietary, holographic printing technology has been demonstrated using DuPont OmniDex$+TM$/ Holographic Recording Films which can incorporate multicolor, image individualization and anticounterfeiting functions into volume holograms. Starting with a monocolor volume hologram, we describe a process using simple existing photopatterning technologies to introduce imagewise selective colors into the monochrome hologram. In this process a latent image is recorded in our OmniDex$+TM$/ Color Tuning Film. This latent image is transferred to a prerecorded hologram by lamination and developed by heating. Bright, multicolor holographic images were achieved with high resolution. The process flexibility and applications of this technology to graphic arts holography and security printing will be discussed.!12

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Holographic polarization measurements, pp.155-160 Author(s): Sergei A. Aleksandrov, Belarussian Research Institute, Minsk, Belarus; Leonid V. Tanin, Institute of Physics, Minsk, Belarus. Abstract: The present paper deals with the problems of increasing the accuracy of holographic measurements and information. To solve these problems, we suggest the use of polarization methods. The proposed approach permits performing measurements of angles instead of distances in investigating all objects, including the diffusely reflecting ones. This solves the problem of the phase difference sign the problem of increasing the accuracy of measurement. With the aid of this approach we can determine the values and directions of displacements of the points of objects, study complicated reliefs of surfaces with the determination of convexities and concavities investigate the phase media, etc.!2

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Neural-net concept for fabricating HOE in photoresist, pp.161-174 Author(s): Rong-Seng Chang, National Central Univ., Chung-Li, Taipei, Taiwan; Yeu-Jent Hu, National Central Univ., Chung-Li, Taipei, Taiwan; Chern-Sheng Lin, National Central Univ., Chung-Li, Taipei, Taiwan. Abstract: Abstract not available.!15

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Field-addressed electrohologram, pp.176-187 Author(s): William P. Parker, Diffraction, Ltd., Waitsfield, VT, USA. Abstract: For some applications it is not necessary to change the image content of a hologram but instead simply to turn it on and off (without modifying the illumination). We describe a device that operates in a switching manner utilizing transmission holographic recordings of any size by applying an electric field to holo-lithographically generated transparent electrode structures underlying a suitable modulating material. This technique is applicable to all existing formats for transmission holograms and may find use in heads up displays (HUD's), for animation and multiplexing of holograms and in data playback where the information has been holographically stored.!2

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Advances in holographic video, pp.188-196 Author(s): Pierre St.-Hilaire, MIT Media Lab., Cambridge, MA, USA; Stephen A. Benton, MIT Media Lab., Cambridge, MA, USA; Mark E. Lucente, MIT Media Lab., Cambridge, MA, USA; John D. Sutter, MIT Media Lab., Cambridge, MA, USA; Wendy J. Plesniak, MIT Media Lab., Boston, MA, USA. Abstract: We discuss recent developments in the MIT electronic holography display. These include the use of multiple galvanometric scanners as the horizontal scanning element, two 18-channel acousto-optic modulators (AOM's) working in tandem, and a bank of custom-designed high-bandwidth framebuffers. We also describe some recent progress on computational issues.!6

Contents

Improved experimental holographic movie to estimate picture quality for holographic television, pp.197-205 Author(s): Kazuhito Higuchi, Nippon Telegraph and Telephone Corp., Yokosuka shi, Kanagawa, Japan; Jun Ishikawa, Tama Art Univ., Setagaya-ku, Tokyo, Japan; Shigeo Hiyama, Tama Art Univ., Setagaya-ku, Tokyo, Japan. Abstract: Holographic movies can be seen as a tool to estimate the picture quality of moving holographic images as a step towards holographic television. As a step towards the development of truly practical holographic movies, we have built an improved experimental holographic movie system and produced short duration holographic 3D films. In the improved system, various objects were positioned within a scene and illuminated with He-Ne lasers (632.8 nm). Conventional film-making techniques were adopted during the holographic recordings to create a more attractive sequence. These techniques included stop-motion, tracking, up-shots, overlaps, and pans. A series of Fresnel type frame holograms was recorded on perforated 35 mm holographic film. An interesting technical point is that the frame holograms were 12 mm high by 122 mm wide at maximum, and consisted of two diamond- shaped elemental holograms, one for the left eye and one for the right. Frame holograms were recorded diagonally at an angle of 10 degrees of the film to reduce the film driving length. After developing, the films were driven intermittently with a shutter, and the films were illuminated by the same type of laser as that used in the recording. The films were viewed through a pair of diamond-shaped windows, and the display speed could be varied from 8 to 16 frames per second.!4

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Information reduction by limited resolution for electroholographic display, pp.206-211 Author(s): Hiroshi Yoshikawa, Nihon Univ., Funabashi-shi, Chiba, Japan; Kenko Sasaki, Nihon Univ., Funabashi-shi, Chiba, Japan. Abstract: Because the information content of a hologram is extraordinarily large, information reduction is essential to the realization of a practical electro-holographic display system. We have investigated a sub-sampling method to reduce the information content of an electro- holographic display. This sub-sampling, however, also causes a blurring of the displayed 3D images. We discuss both the theory of the relation between the information reduction rate and the image blur and our experimental results.!7

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Electronic display system using LCD, laser diode, and holography camera, pp.212-218 Author(s): Hidetoshi Katsuma, Tama Art Univ., Hachioji-shi, Tokyo, Japan; Koki Sato, Shonan Institute of Technology, Fujisawa-shi, Kanagawa-ken, Japan. Abstract: We have presented the experiments about the cinehologrаphy constructed with the many element holograms which were made with cw laser and holographic-TV using LD LCD and holography camera. The interference fringes with holography camera were recorded on the CCD of TV-camera. The fringe signals were transferred into electronic ones. And transformed into the LCD, the fringes were constructed on the one. At this time, with the help of LD, the panel of LCD were illuminated and so hologram was reconstructed in the LCD at real time.!6

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IC vision--a VLSI-based holographic display system, pp.219-229 Author(s): Jeffrey H. Kulick, Univ. of Alabama in Huntsville, Huntsville, AL, USA; Stephen T. Kowel, Univ. of Alabama in Huntsville, Huntsville, AL, USA; T.Leslie, Univ. of Alabama in Huntsville, Huntsville, AL, USA; R.Ciliax, U. S. Army Missile Command, Huntsville, AL, USA. Abstract: This paper describes the design of a full-color, full-parallax, true holographic display system which will be fabricated as the top layer of an optically flat massively parallel computer. The individual processors of the parallel computer are themselves connected via free-space optical interconnects. The holographic display, which is called the Hoxel Display, utilizes electrostatic fields created by the parallel computer to modulate a thin layer of liquid crystal material, which forms the diffractive display. The computation performed by the embedded processors are used to drive very fine electrodes on the surface of the chip which modulate the liquid crystal. The entire system is fabricated using standard Very Large Scale Integrated (VLSI) circuit technology. There are two major innovations in this work. First, the display will be a low power, low cost, rugged, flat panel holographic display. Second, integrating the processor with the display into a single substrate removes the need for electrical interconnections between the processor and display unit. Each processor/display element contains a photodetector and data extractor circuit, and all information enters the system optically, thus obviating the need for any connections other than power and ground.!8

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Folding time into space: novel approaches to integral holography, pp.230-235 Author(s): Doris K. Vila, Gesellschaft fuer Mathematik und Datenverarbeitung, New York, NY, USA. Abstract: This paper describes a novel computer technique for holography developed by the author called Speedograms. Using an existing 2-D animation program, this technique creates depth by moving different graphic elements at varying speeds over the screen. This method has the advantage of popular software and is the basis for development of an

automated 2-D/3-D printer for photoresist. This paper also describes innovative applications of integral holography, including the skyline of Cologne. In addition, natural phenomena have also been recorded using multiple photographs from a stationary photo camera with the subjects moving horizontally. This way the continuous flow of water in the Rhine was recorded and a steady wind served as the track for a naturalistic hologram in clouds. The use of LCD video projection onto the holographic surface is shown with both recorded and real-time imagery. Future developments will expand on the projection system, with holograms, computer graphics, and real-time video combining in an approach to interactive multimedia holography.!4

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