Holographic Video Based on Acoustooptical Interaction

Vladimir Petrov

Dept. of Physics, Saratov State University, Saratov, Russia, PetrovVV@info.sgu.ru

Abstract

The method of holographic building of moving bulk scene that based on the acoustooptical interaction principles is discussed. Some results of numerical simulation of bulk image process reconstruction are given.

1. Introduction

The research direction, devoted to development of 3-D information systems, became very attractive for both university scientific groups, and big production company research laboratories. In some countries new State-level R&D programs are opened with sufficient financing. Hundreds of publications are devoted to this topic and their number growths exponentially (see, for example, [1-15]). The reason of this interest is the bright example of marketing circle and the time when bulk television, computer, mobile phone and other information displays will be considered as one of mass production lots will come soon. But this is still a future. The appreciable number of approaches to 3-D display creation are developed now by different scientific groups in all over the World. These approaches are based on various physical principles and some examples of them can be named:

- Multi-view stereoscopic 3-D imaging;
- Computer-aided 3-D imaging;
- Computer generated holograms for 3-D displays;
- Optical scanning holography;
- Acousto-optically based 3-D holographic imaging;
- LCD based 3-D imaging;
- 3-D Microscopy;
- Rotating screen based 3-D scenes reconstruction;
- Multi-plane volumetric 3-D displays, and others.

But to the present time just very few approaches reached the manufacturing level. The examples of ready-for-sell level 3-D information displays are known, which on the multi-view principle are based. Essential shortcomings of that principle, the main of which is the mixing of two images on zone boundary, insist on the continuation of deep research aimed to find closed to reality methods of bulk scene reconstruction. The holographic principle is considered as one of most prospective for realization of that idea, as it allows to bring to the observer all necessary information about bulk scene (or all parameters of plenoptic function that was offered in [16] for characterization of 3D object optical information). Promising results were reported recently in this direction [1-15]. At the same time there are set of problems, that one can meet on the way of creation of 3D holographic moving scene reconstruction system. The general problem is to find some way for creation of switch-on and switch-off hologram to realize the principle of realistic bulk moving scene. That problem dictates to finding different invention ways for creation of electronically controlled hologram. The evaluation of one of such principles is the very aim of present paper. The general idea of considering method consists in formation of optical hologram by means of acoustical field in such a way that generated acoustical field possessed by space distribution of refractive index that exactly corresponds to transmission function of original hologram. Bulk holographic image is reconstructed due to acoustooptical effect by illumination of sound field with reference optical beam under the Bragg angle.

The first suggestion of similar method was offered in [11] for hologram forming by surface acoustic waves and was further developed in [4,12-15] for thick hologram that are formed by bulk acoustic waves and the Bragg regime of acousto-optical interaction is used.

2. General Approach

Fig.1. shows the scheme of acoustooptical holographic way of moving image reconstruction. Thick transparent plate that represents the AO interaction medium serves for electronic forming of optical hologram. Multielement electro-acoustical transducer that represents the line of thread-shape elements excites the acoustical field. Each element is feed by the separate signal with certain frequency that is directed from digital or analog control system. The length b of element defines the thickness of hologram and as a sequence stipulates the high diffraction efficiency and spectral and space selectivity. The size b is comparable with sound wave length. That allows exciting by each element very divergent sound beam forming in far zone the complicated sound field, space distribution of refractive index of which corresponds to hologram of object, fixed at moment of time t_0. The hologram formed by such a way can be considered as thick hologram (or so-called Denisyuck hologram [17]). Such thick hologram realizes the Bragg regime of light diffraction and it possessed by the features of unique diffraction order, spectral and spatial selectivity (these features can not be realized with thin hologram formed by surface acoustic waves, considered in [11]). Formed by such a way hologram is electrically controlled that allows switching it on or of and as a sequence to reconstruct moving bulk holographic scene.

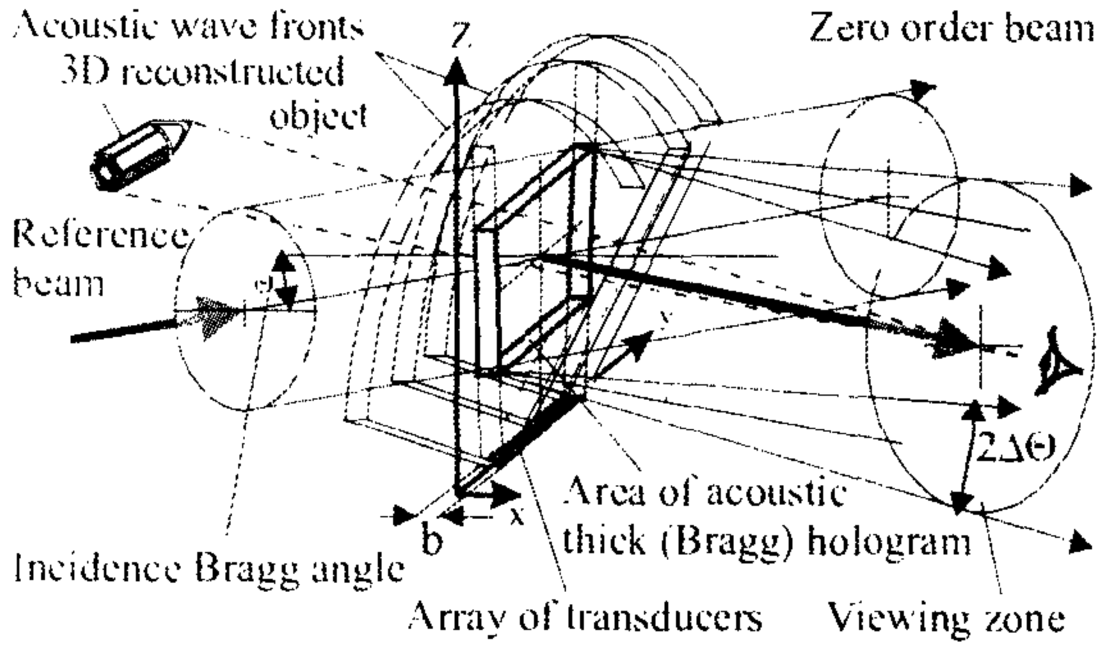

Fig. 1. Architecture of acoustooptical 3D image Reconstruction holographic set-up

It is obviously that for development of such a hologram it is necessary to find for acoustooptical interaction the medium with low sound attenuation and high figure of merit. This is important because of necessity to excite the sound field at very high frequencies so that to reach as small sound wave lengths as optical waves have. In this case the spatial resolution can be comparable with usual optically created hologram. Besides the bandwidth of acoustooptical interaction must be very large to allow the excitation of a large range of spatial frequencies at the hologram to translate maximum data and not to loose some information about reconstructed image. Today already known the experimental works in realization of very wide band (up to 3 GHz) and very high frequencies (up to 10GHz) acoustooptical interaction [18]. At such high frequencies the sound wave lengths are already comparable with optical the wavelengths. Of course up to now the sound attenuation is still very high in know materials.

3. Mathematical Modeling Algorithm

Not deepening here to the process of mathematical modeling of object 3-D image registration and reconstruction process [11,15,19-20] due to restricted paper space, we just stop briefly at the steps of this process.

3.1 Reconstruction process simulation

- It is assumed that spatial distribution of elasto-optical medium refractive index variation, created by sound waves at the fixed moment of time, exactly repeats the space distribution of optical hologram transmission function variation. This assumption means the equivalence of each spectrum components of these optical and acoustical fields.
- Simulated set of electrical signals can be used for 3D holographic image reconstruction.
- By Fourier transform of the expression for these signals time-space distribution the spectrum components of electrical signal's can be found.
- With the developed correspondence algorithm between acoustical and optical holograms produces the sound field transformation.
- By back Fourier transform the sound field two-dimensional distribution can be written.
- The reconstructed optical 3D image can be formed by using the equation for mathematical hologram when the hologram is illuminated by the same reference optical field as during the registration process.

4. Some Results of Numerical Simulation

3-D object hologram can be represented by superposition (with phase shifting) of single-plane hologram [19]. On Fig.2 the image of two groups of plane objects (cross and square) is presented, that recorded at different distances D1 and D2 from hologram plane and reconstructed at the distance D2. It is seen that lower group of objects is in sharpness (D2) when the upper one (recorded at D1) is blurred.

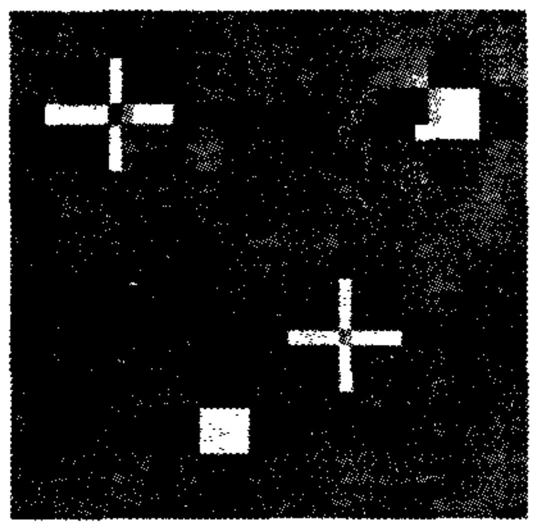

Fig.2. Two plane objects image reconstructed at different distance

Fig. 3 illustrates the simulation of hologram recording and image reconstruction of point light source. When calculating this recording and reconstruction process the acoustical attenuation was taken into account.

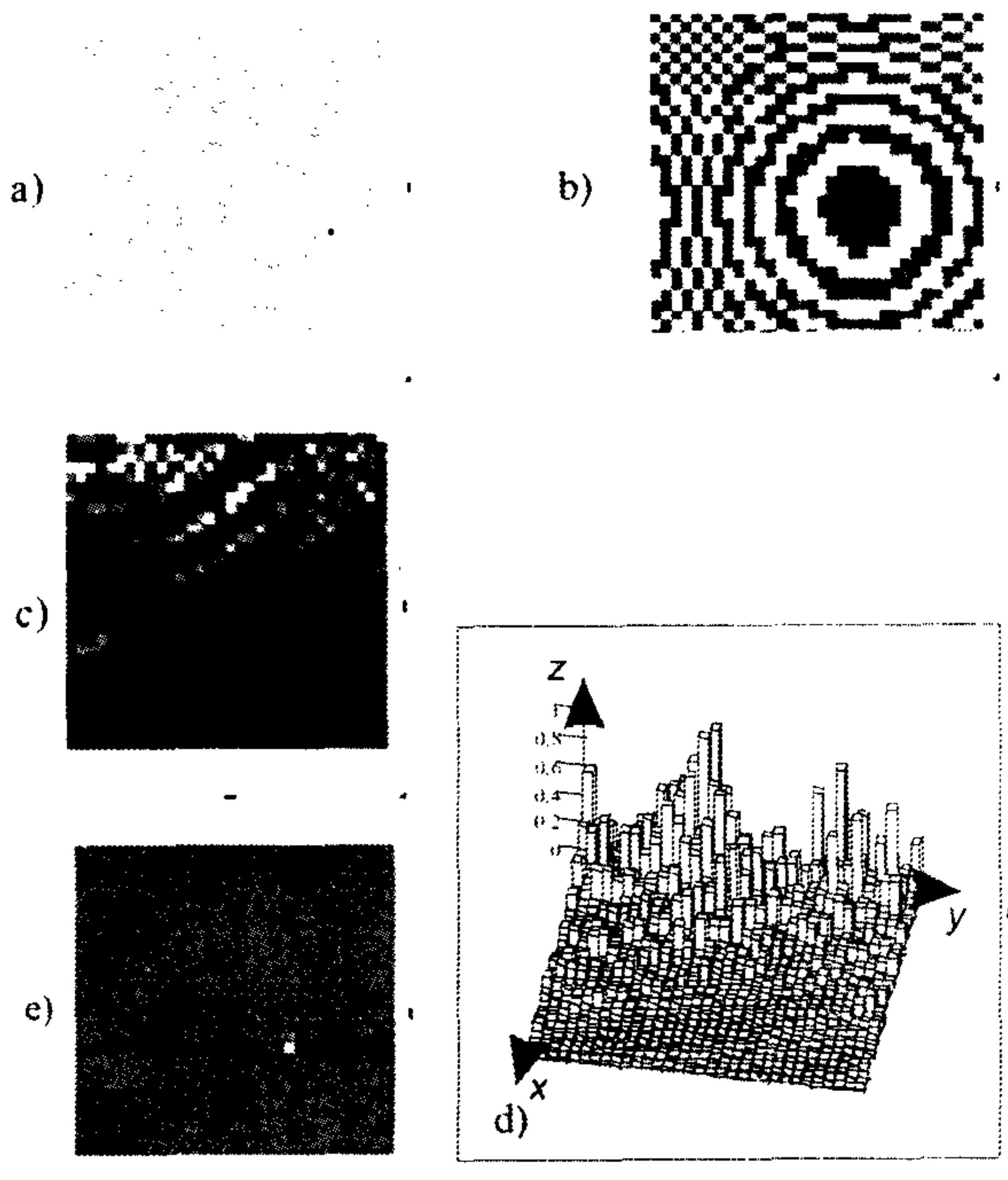

Fig. 3. a, b – point source optical and acoustically created holograms; c,d – space-time (y-x axis) distribution of electrical field excites the sound hologram; e – reconstructed image of point source.

Fig. 4 presents: 1– one plane of 3D object image; 2–static optical hologram of this image; 3–dynamic acoustically created hologram transparency function; 4 – object image reconstructed from optical ,5 - object image reconstructed from sound hologram with time factor 1.2 at illumination pulse period; 6- that image, reconstructed from acoustically created hologram at exactly synchronized time.

For modeling of 3D object we used single 2D image - one plane of 3D object (opaque function) as it is known that hologram of 3D object can be mathematically build from holograms of unique object planes given with certain phase shift.

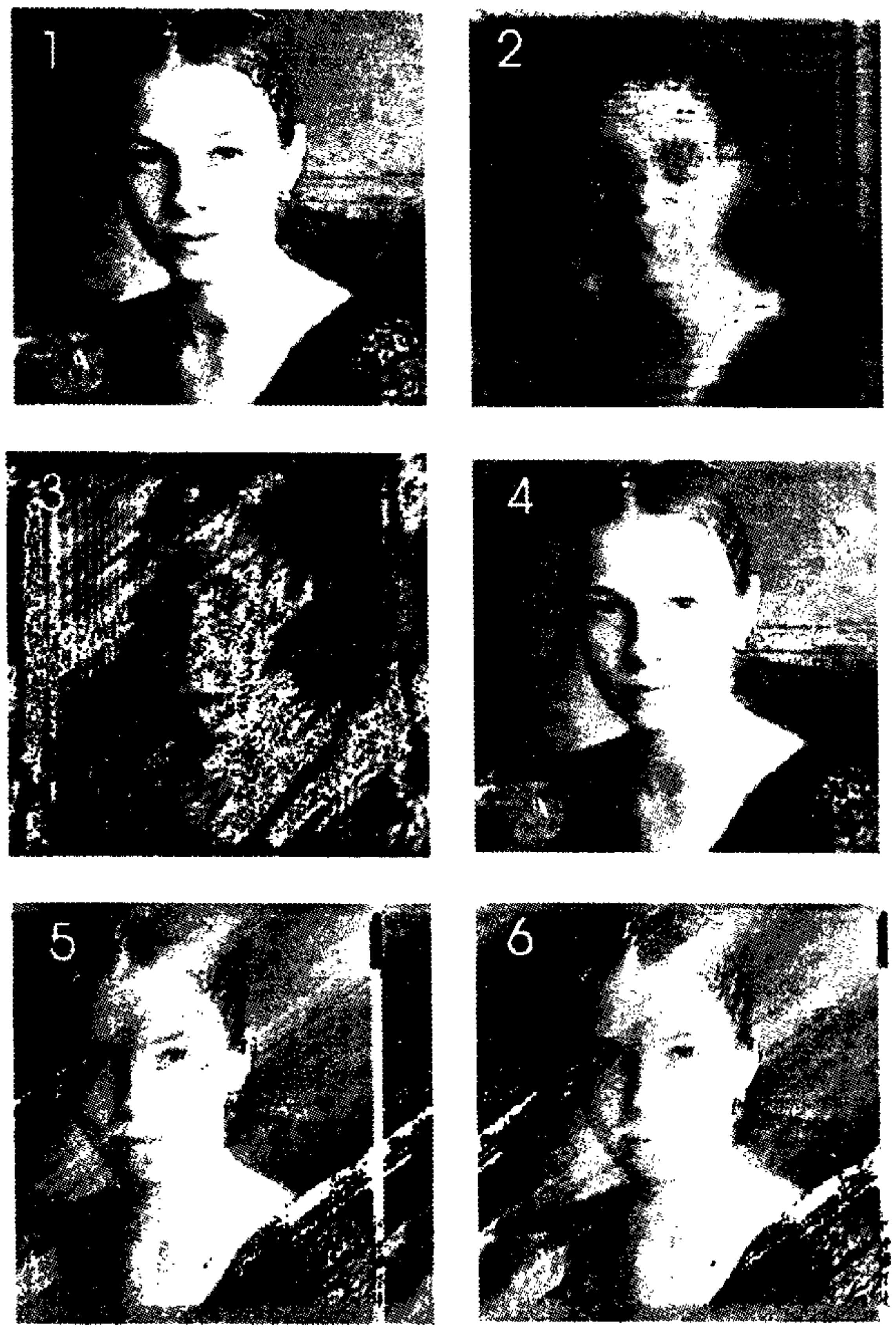

Fig.4. Some steps of simulation process

The appearance of additional noise when recreating the image from acoustically build hologram might be probably stipulated by regular mistake accumulation when numerical modeling in the restricted special frequency range.

The effect of downing of the reconstructed image intensity along the sound wave propagation coordinate is taken into consideration and avoided by applying of special algorithm in the process of numerical simulation.

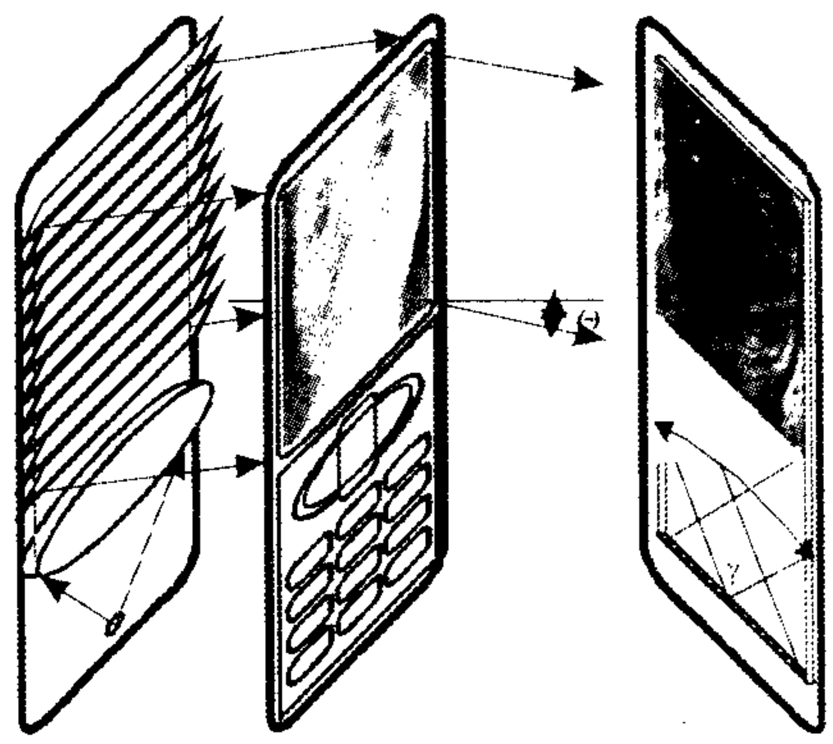

Fig.5. Mobile phone application sample of 3D display based on acoustically created optical hologram

Picture at Fig. 5 shows the example of mobile phone application of AO created dynamic hologram. The illumination scheme for creation of reference light beam is given from the method that offered in the work [21].

5. Conclusion

Computer simulation of acoustooptical method of 3D objects holographic reconstruction is briefly discussed. Conducted modeling allows concluding that, in spite of some existing technological problems, the offered approach could be prospective for building of computer controlled systems for holographic 3D information reconstruction in many domains of application like for example micro display systems.

6. References

1. T. Yatagai, "Stereoscopic approach to 3-D display using computer-generated holograms," Appl. Opt. 15, pp. 2722-2729, 1976.
2. V.G.Komar, O.B.Serov, *Art holography and holographic cinematography*, Moscow "Isskustvo" - Publishing house,1987.
3. S. A. Benton, "Holographic displays: 1975-1980," Opt. Eng. 19, pp. 686-696, 1980.
4. V.V.Petrov. *Holographic Video. Acoustooptical approach*, Saratov, "GosUNZ" -Publishing-house, 2002, 77 pages.
5. Y. Li, D. Abookasis, and J. Rosen, "Computer-generated holograms of three-dimensional realistic objects recorded without wave interference," Appl. Opt. 40, pp. 2864-2870, 2001.

6. Voronov A.V., Golovkov A.A, Kuznetsov S.V., Titov V.U. The way of shaping of the three-dimensional scenes and device for its realization. Patent N 2103752, Russian Federation, priority 27.07.95. Registration 27.01.98.
7. Color video projection apparatus using acousto-optical deflector. Pat. 4833528 USA. IKI H 04 N9/10 / Kobavashi Koji; Kowa Co. LTD - N 253374; Publ. 23.05.89; Prioirity 9.04.86; N 61-80237 (Japan): NKI 358/53.
8. Taegeun Kim and Ting-Chung Poon, "Three-dimensional matching using phase-only holographic information and Wigner Distribution", J. Opt. Soc. Am. A, 17, pp.2520~2528 (2000).
9. Alampiev,V. et al. ["Technique for three dimensional electronic matrix with liquid crystal indicators"] (in Russian) Prib. i Sist. Upr .(USSR). No.9 p58-60 (1976).
10. Cole,H. et al. "A three dimensional display for radar returns" SID Symposium. May 22, p52-53 (1974).
11. L.Onural, G.Bozdagi, A.A talar, Optical Eng. V. 33. No 3, *New high-resolution display device for holographic three-dimensional video: principles and simulations*, 835 – 844 (1994).
12. V.Petrov, Acoustooptical approach for Moving Scene Holography. IMID'2003, Daegu, Korea, p.451-457, 2003
13. V.V.Petrov, *Set-up for electronic forming of three dimensional holographic image*, Patent of Russian Federation № 2117975, Priority 13.11.1996.
14. V.Petrov, Acoustooptical Club Proc. St.Petersburg, *Acoustooptical display for the creation of 3-D holographical image*, 95 (1997).
15. V.V.Petrov, D.A.Egorushkin, *Modeling of holographic television and computer displays*. Scientific paper's collection. Saratov, 1997, 85-87.
16. E.H.Adelson and J.R.Bergen, "The plenoptic function and the elements of early vision" Computational Models of Visual Processing, M.Landy and J.A.Morshon eds. (MIT press. Cambridge, Mass.,1991).
17. Yu.N.Denisyuk, DAN SSSR, v,144, *About the reflection of optical features of object in the wave radiation field that is scattered by this object*, 1275 (1962); Optics and spectroscopy , V,15., p. 522, 1963; V.18, p.152. (1965).
18. V.V.Petrov, M.A.Grigor'ev, and A.V.Tolstikov, Optics and Spectroscopy, Vol.89 No 3, *Experimental Study of Acoustooptical Interaction in Lithium Niobate in the Frequency Range from 7.5 to 10.5 GHz.*, 463-468 (2000).
19. L.Onural and P.D.Scott, Opt.Eng. 26(11), *Digital decoding of in-line holograms*, 1124 -1132 (1987).
20. L Yaroslavsky, Digital signal processing in optics and holography, M.: Radio i svyaz, 1987, 296 p.
21. A.Travis, Time-Multiplexed 3D Display IMID'2003, p.444-447, (2003).