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DEVELOPMENT OF AN OFFICE HOLOPRINTER V

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Abstract

The development of the Office Holoprinter makes progresses and people become interested. Discussing the possibilities one of the major concerns is the image quality. How does the quality of an one-step holograms compare with that of a traditional hologram? Can holograms made with different recording techniques be compared and if so by which means. This paper will discuss several parameters to compare different holograms and how to determine the quality. It is not the intention of this paper to come up with means to determine the quality of one-step holograms.

1. Introduction

For many years we produce reflection and transmission holograms recorded in the traditional way. Comparing different holograms made during our existence is always being described as not possible because the quality depends mainly on the recorded object. Every object has its own characteristics like stability, reflection properties and size. The size of the object makes holographers change the geometry of the recording setup introducing possible lens like aberrations. The luminance, graininess, noise, hotspots, and bandwidth depends on the illumination of the object, the object beam, processing techniques and the quality of the recording medium. Most of these aspects we don't have under control because they also depend on the skills of the holographer, chemistry, temperature, moisture, etc. This makes it hard to make two identical holograms.

In the last few years the two-step recording technique is more and more used also because of its freedom of choice of object, full color possibilities and animation. With this technique a better quality definition is possible as the object recorded is always the same ground glass. The images projected on the ground glass, by means of slide film or LCD, is under control. Remains the transferring the master hologram the traditional way.

Now with the development of the one-step process there is no H1 master hologram and transferring involved therefore it is possible to describe its quality. With the one-step process it is possible to make many identical holograms because all the parameters involved are under control, not by a holographer or user but depend on the quality of the printer.

The only thing left to destroy even a great hologram is the way of illumination. For comparison we always can use the same illumination techniques, the same light bulb at the same distance. In the two-step case wrong illumination creates double images in the background [Halle]. In the one-step process it is possible to change the shape of reference beam for every printed column to ensure image quality.

We start with a general comparison between the different recording techniques and quality aspects for the user. From many aspects involved in de production of holograms we pick the most significant for our study. Every recording technique is analyzed on that aspect resulting in a conclusion.

2. Quality aspects for the user

One-step holograms produced by the Office Holoprinter will have many applications. What we know up to now is that the holograms need to be printed rather fast in as large as possible size, full colour, high quality, high resolution, large viewing angle and fully automatic. To compare other recording techniques these parameters should be of consideration. Table 1,2 gives an overview of the three recording methods and the main parameters involved.

	Object	Mastering	Transfer	Quality
One-step	computer graphics	computer	printer	printer
Two-step	slides photography	two-step printer technician skills	transfer techniques	chemistry, geometry projection screen
Traditional	scaled model	holographers skill	transfer techniques	chemistry object, skills

Table 1.

	Size norm	Viewing Angle	Resolution	Automatic	Production time
One-step	DIN A4	90o	LCDpixel print column	printer	15 min.
Two-step	DIN A4	50o	screen, speckle	technician	1 day
Traditional	DIN A4	50o	object, speckle	holographer	1 day

Table 2.

In the scope of this paper we will not discuss the quality dependence on the skills of the holographer, chemistry and recording medium. Therefore we will not discuss: spectral bandwidth, noise, scattering, etc. The discussion will focus on the main physical difference: the object. In the following discussion we will record one holopixel (smallest 3 dimensional holographic object point or image point) at a certain depth from the image plane. In the traditional case the holopixel is a small part of the object with the two-step method a point on the diffuse projection screen and in the one-step case a holopixel.

Explaining holography to ordinairy people we always compare a hologram with a window. Standing in front of the window one can see every thing out side. The hologram records all of that in every small part of the hologram.

When a small part , in the order of millimeters, is exament it is hard to tell if the recorded information is realy 3D. It is not possible to look trough such a small aperature with two eyes simultaniusly. Projecting the information, illuminating it with a reference beam, does not results in a focused 3D image. So one could say that the hologram recorded many 2D images from different locations with in its window. Redusing the amount of viewpoints can give an observer still a good 3D image. This reduction is automaticaly done in the traditional case because an illuminated object point creates speckles on the window surface. In the two-step case the reduction is done because only 100 up to 200 views are recorded. But in the proces it selve speckles are created again. In both cases the size and distribution of the speckle is difficult to control. In the one-step case the designer determins the size and distribution by shoosing an appropiate system of lenses and designer diffusers.

The main difference between the three techniques is therfore the recorded object thus we will discribe the holographic quality on that bases. In reality not the object is recorded but it's reflection, using coherent laserlight to illuminate the object results always in spekle. Speckle is the source that detiermins the quality and will be analised in the folowing section.

3. The source: Speckle

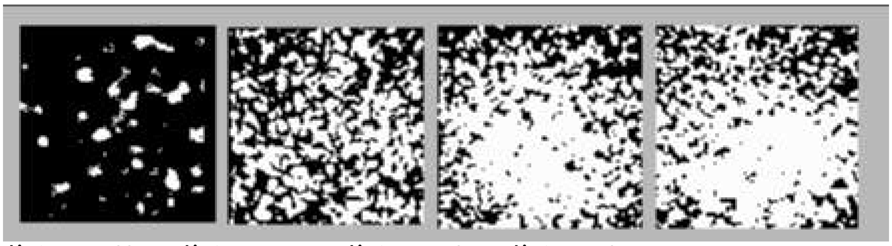
The speckle fenomena is explaind extensively in many books and [Uozumi][Ohtsubo]. Within this paper we will only concern our selfs with the macroscopic effects not how speckle is created.

The speckle theory leads to the folowing equation:

Speckle size = Materialproperties x Distance/ Illuminating size

To illustrate the above equation we carried out some basic experiments. We illuminated a ground glass screen with different spot sizes and captured the resulting speckle patern on a screen located 30 cm in front of it.

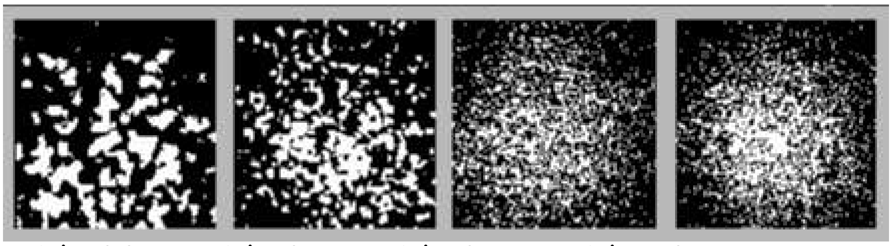
The results are shown in Figure 1.



distance 100 cm distance 75 cm distance 50 cm distance 25 cm

Figure 1. Speckle size dependence on the distance. Source: ground glass, illuminating spot size 0.5 mm. Each picture is 75 mm wide.

Changing the distance between the illuminated part of ground glass and the projection screen results in a different speckle pattern, see Figure 2.



spotsize 0.25 mm spotsize 0.5 mm spotsize 0.75 mm spotsize 1.0 mm

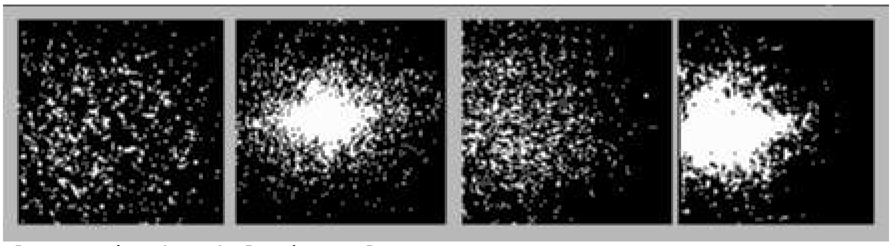
Figure 2. Speckle size dependence on the illuminating spot size. Source: ground glass, at 30 cm Each picture is 75 mm width .

It is obvious that, to creat small speckles, we need to illuminate a large area and stay close to the difractive screen. In the next 3 cases we will discusse the influence of speckle.

There are several methods to reduce the size of the speckle, such as: Low-Pass filtering, Partial Coherent Illumination, Redundency and Time Averaging [Gerritsen][Kato][Lowenthal]. This paper is not intended to discribe means to reduce the speckle size but choosing the wright method makes holograms much better. The best methods are kept securate off course.

3.1 Traditional case

In the traditional recording technique an expanded beam of laser light illuminated the object. The master hologram surface records the reflected light of the object together with the reference beam. The result of the reflected light from one holopixel (smallest part of the object recorded) on the holographic surface will be build up out of speckles.



plaster painted wood plastic steel

Figure 3. Speckle pattern formed by one holopixel. from different materials a).. Illumination spotsize 0.5 mm screen distance 50 cm. Each picture is 75 mm wide.

As shown in figure 3. different materials give different speckle patterns. Not only the size of the speckle but also the distribution (size and intensity) are different. A material is therefore characterized by a

complex statistical, gausian, formula. Some materials, like plaster, give uniform small size speckles across a large area others, like steel, result in a so called hot spot.

When we record only a small part of the object, see figure 4, the traditional way the H1 master hologram records the resulting speckle pattern. This means that not every part of the hologram recorded the holopixel, only on those locations where there are speckles with enough intensity. A steel like holopixel is therefore recorded on a very small part of the hologram. In the transfer stage all the speckles project the holopixel, forming back its 3D location. An observer looking at the transferred H2 hologram will see the holopixel trough every speckle. When the size and distribution of the speckle is large, then the amount of view point of the holopixel is limited.

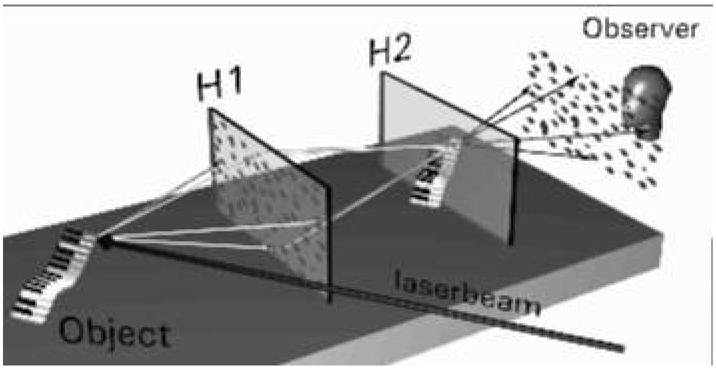


Figure 4. Traditional recording setup.

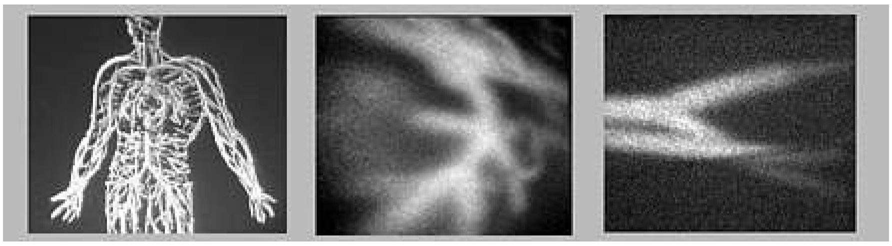


Figure 5. Traditional H2 hologram projection of the image, A projection of the image, B1) Illuminating spot size 1 mm, projection screen distance 50 cm, picture width 30 cm, B2) Illuminating spot size 0.2 mm, projection screen distance 50 cm, picture width 30 cm.

To reveal the information of an H2 hologram we illuminated it with a laser beam, the hologram, projects a speckle pattern as shown in figure 5. Using a 0.2 mm spot size gives a very large speckle pattern (2 mm).

Because the speckles are correlated the holopixel is radiates its material properties. Looking at holographic images you get the impression of the material, much better then in photography. Reducing the speckle size in one way or the other decorelates the speckle pattern and therefore the look and feel of the material properties.

3.2 Two-step case

In this case the size of the smallest projected point depends on the photographic resolution, projection system and ground glass screen. The diffusity of the screen is here the most important factor. It needs to diffuse the point across the whole H1 surface, uniform, and keep a sharp image. Illuminating a ground glass screen with a small point, this point can start to glow making it's size larger and give rise to very small speckles. A different screen that does not glow keeps a sharp image but gives large speckles.

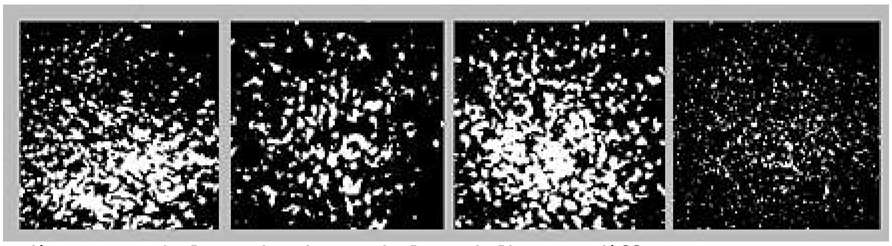

ordinary ground glass Edmund ground glass chalk paper diffuse screen

Figure 6. Speckle pattern from different projection screens. Spot size 0.5 mm distance 50 cm, each picture is 75 mm wide.

The mastering is done in a step and repeat process (see figure 7), for every slit a new picture is projected. Holopixels that are far behind or in front of the image plane move faster across the screen. Therefore there is no correlation between the speckle pattern of one holopixel. When an observer looks at the transfer hologram he not only sees the holopixel trough every speckle in the H1 plane but also trough a limited amount of slits. Recording only a small number of viewpoints makes the holopixel jump [Halle] [Yoshikawa]. The decorelation eliminates the look and feel for material properties.

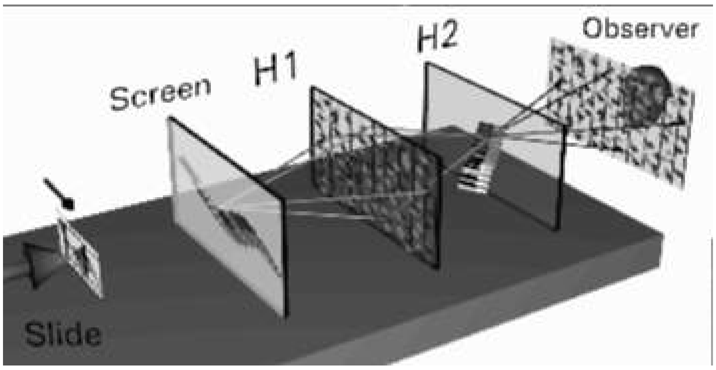


Figure 7. Two-step recording setup.

Speckle patterns resulting from the diffusing screen are often much less then that of reflective materials, but because the speckle is already decorelated one can use methods to reduce the speckle size.

To make high quality two-step holograms the printer should be very accurate to come close to the quality of traditional holograms. In the two-step set up the printer, slide film, projects the holopixels on the screen. The accuracy of the projection and movement of the slit/hologram influence the definition of the holopixel in 3D space.

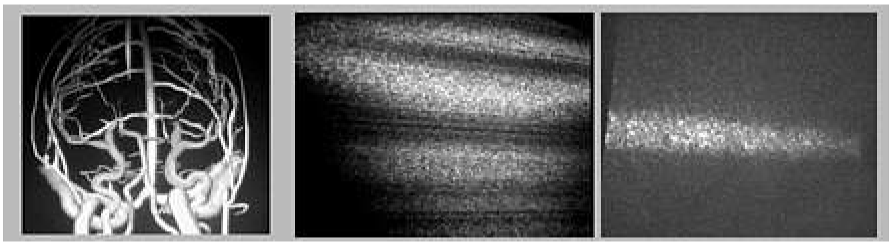


Figure 8. Two-step H2 hologram projection of the image, A projection of the image, B1) Illuminating spot size 1 mm, projection screen distance 50 cm, picture width 30 cm. B2) Illuminating spot size 0.2 mm, projection screen distance 50 cm, picture width 30 cm.

The projection of an H2 hologram, see figure 8, reveals a speckle pattern which are large in size (2 mm).

3.3 One-step case

The one-step hologram records not the reflection of an illuminated object point, a ray trace approach should be considerate. The computer calculates all the ray's that builds up an holopixel. An LCD screen is most often used to form these ray's. To limit the amount of ray's diffusers are used. For reflection type one step holograms a vertical diffuser is used in front of the image plane to give the hologram it's vertical viewing angle. Both diffusers are one dimensional and have to be made specially for there specific purpose [Yoshikawa][Wyrowski][Nuland][St. Hilaire]. Most commonly they are phase only diffusers that create almost no speckle.

Focusing the LCD image, without using any kind of diffuser, into a narrow slit results in a diffraction pattern at the fourier plane. This is due to the grid inside the LCD panel. In one direction the higher order diffraction can be blocked out at the holographic plane. The other direction can not be filtered at the that plane making it necessary to created two fourier planes. Using an ordinary diffuser, eliminating diffraction, limits the smallest possible size of holo column width. The width is then proportional to the diffusity of the diffuser used.

The one-step hologram is, see figure 9, dived in vertical slits, holo columns. Every holo column is subdivided in vertical pixels, the amount depends on the LCD screen used. Therefore the smallest holopixel has the dimension of holo column width and LCD pixel height, 0.12 mm x 12 mm.

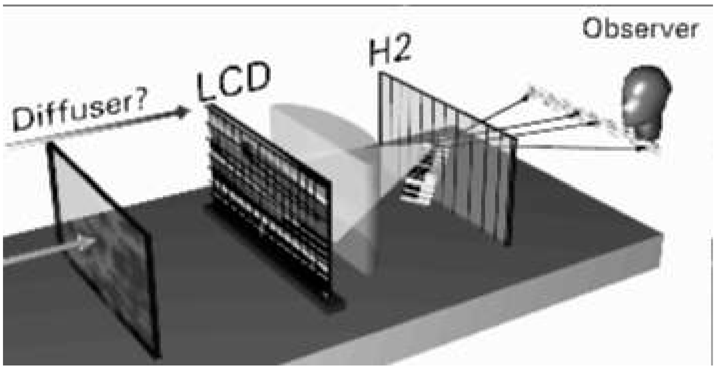


Figure 9. One-step recording setup.

To reveal the information contents of one holopixel it is illuminated with a very narrow laser beam that fits the dimension of one holopixel. Because we make, at this moment, transmission type Horizontal Parallax Only holograms the projected "speckle pattern" is in the form of a straight line, see figure 10. When no diffuser is used the hologram projects single pixels some distance between each other due to the LCD grid. Using some diffuser these blanks are filled in. It is hard to observe any speckle at all when the right diffusers are used.

Because there is almost no speckle involved in the one-step recording a higher definition of holopixels is possible, assuming enough input views are used. As said before, correlated speckles give a holopixel material properties, so introducing speckle could materialize one-step holopixel .

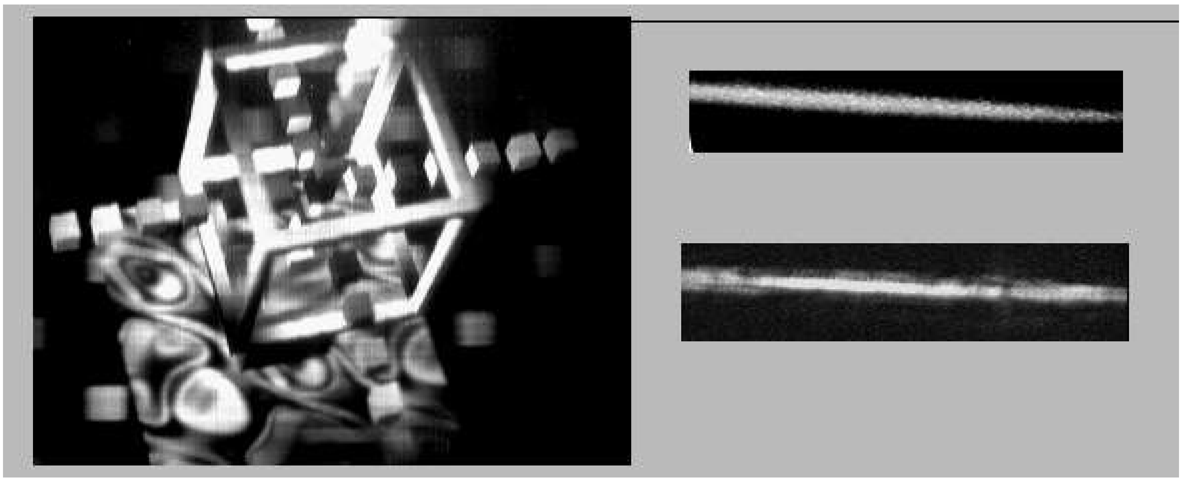


Figure 10. One -step H2 hologram projection of the holopixel. Illuminating spot size 0.12 mm, projection screen distance 100 cm, picture width 30 cm.

5. Conclusion

The discussion started with the question "is it possible to compare holograms made with different recording techniques". This is not really possible due to the fact that most parameters are not under constant control. One of the most important ones is the object itself.

In the near future one-step holo printers will evolve to acceptable or even high quality 3D printers. When that is the case those holograms can be compared with each other. To be measured parameters should be: holopixel size, number of recorded views surface artifacts.

6. Acknowledgments

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