どんなランプが反射型ホログラムの再生に良いか

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What lamp reconstructs a good image for a reflection type Hologram

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For a Reflection type Holography such as using Lippmann Hologram, the image is usually reconstructed by incoherent light. In the incoherent light, sun light presents the best resolution for the image. However, sun light depends on the weather.

So, artificial light emitted by electric lamps such as a halogen lamp has been used frequently.

It has been considered that the better resolution was obtained by a narrower spread light.

In general, Beam angles are presented by lamp manufacturers. However, empirically, the narrower beam angle lamp does not always give better resolution for a Holographic image, especially for an image reconstructed on the deep position into the Hologram plate. Therefore, this investigation tried to obtain what function of the lamp corresponded to a better resolution for the deep image.

1 Introduction

In the reference book[1] a reconstructed image is shifted to x_i from original image position x_0 as following formula as shown in Fig. 1.

$x_i = x_0 + (\Delta Ri/Ri)Kz_0$ ----------------(1)

Where, Ri is the illuminated light wave length and ΔRi is deviated wave length. K is angles of a ray of light and z_0 is depth or extruded length. In this formula, Ri is selected freely, because spectral distribution of an incandescent lamp which was used in this experiment, has continuous wave length. Then, wave length is able to neglect in consideration. For "z_0", an arbitrary value is chosen previously. In this experiment, a Hologram was taken using a test chart located on "z_0": depth as an object. Then, x_i only depends on K. Generally, rays of a lamp spread in some angles. The deviation angles of K generally seem to correspond with beam angles of a reflector type lamp. Beam angles are presented by lamp manufacturers. However, empirically, the narrower beam angle lamp does not always give better resolution for a Holographic image, especially for a deep image.

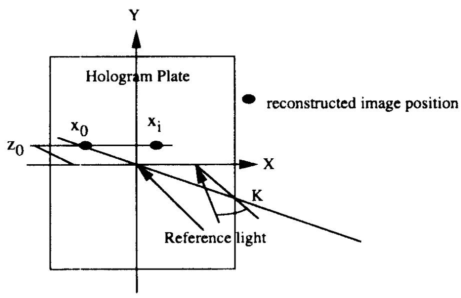

Fig. 1 Reconstructed image of Hologram

Therefore, this experiment started to make various light spread. Experiment was divided into two parts.

One was the preliminary experiment.

2nd experiment was planned in more detail and more precise than the preliminary experiment.

2 Preliminary experiment

2.1 Method

Experimental optical arrangement is shown in Fig. 2. In this figure, "Pr" is a Projector in which a 24V 150W Halogen Lamp was installed. "I" is an iris. "G" is a light diffuse glass plate. "P" is a pair of poralizer. "L" is a lens. "H" is a Hologram plate.

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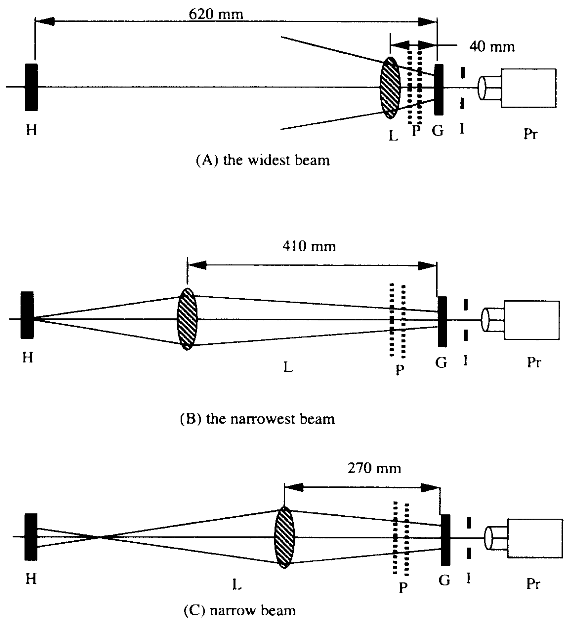

Fig. 2 Experimental optical arrangement

The iris was opened to make 30 mm in diameter uniform bright disc on the glass plate. It's luminance was about 300,000 cd/m^2. Focal length of the lens: "L" was 150 mm. By the arrangement of the upper figure, a wider spread light was obtained. The light spread was 320 mm in diameter on the Hologram position. In this report, light spread values in diameter is defined as the bright part projected by the light is measured at 10% illuminance of the maximum values on the measurement plane. The illuminance of center of the light was 2300 lx (lux). For illuminance measurement, a IM-3 illuminance meter manufactured in Topcon Corp. in Japan, was used. The middle figure gave the narrowest light spread. It was 17 mm in diameter. The illuminance was regulated to the same value of the upper figure arrangement by inserted two poralizers. The lower arrangement gave the light spread of 47 mm in diameter. The illuminance was regulated to the same values. The tested Hologram was taken a test chart located on 4 mm depth from the Hologram plate. This test chart was manufactured by Newport Corp. in U.S. and it's model name was RES-2. The tested pattern consists of various sizes of 3 horisontal and vertical lines of the grating. In this experiment, vertical lines were only observed. Because many human visual MTF measrements have been implemented in vetical grating and this experimental results are easily compared.

First, a microscopic lens and CCD camera system was tried to use for the measurement. For the sake of a microscopic lens has capability to the same resolution of the human vision through the magnifying glass, it's magnification must be fairly large. However, a larger magnification microscopic lens has shorter focal length. In this time, an appropriate microscopic lens did not be found for the 4 mm deep image. Consequently, in this experiment, the human vision through the magnifying glass (2 times magnification) was used to measure the resolution of the image. The resolution value was measured by the pair lines per millimeter. An observer was N.N who was a 58 years old male. The minimum pattern observed by him using 2 times magnifying glass was over 15 pair lines /mm. Each measurement was implemented 5 trials in ascending and descending series and then the threshold value was obtained[2].

2. 2 Experimental results and discussion

Results are shown in Fig.3. In the figure, averaged values are plotted.

The best resolution was obtained by the widest spread light.

If a line is shifted to a space width according to formula (1), when the ray angles of light is deviated, the grating is not recognized. By general consideration, an amount of the ray deviation is supposed to correspond with the beam angles of a lamp. Then, the best resolution was expected to be obtained by the narrowest light spread. However, the result was ultimately inverse.

In illuminating engineering, beam spread of lamps or lighting fixtures must be measured at over 10 times

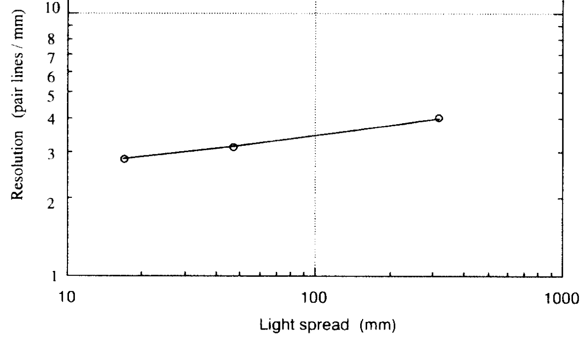

Fig. 3 Resolution vs light spread

distance of their sizes. Over such distance, rays of a lamp are simply spreading according to the increment of distance. When small area of a Hologram plate is illuminated at such distance, the rays should be considered as almost parallel light. However, in many cases, the Hologram has been illuminated at within 10 times distance of lamp sizes. This experiment was the same situation. The lens diameter was 100 mm, then the measurement distance must be over 1000 mm. But, in his experiment, observation was carried out at shorter distance. However, in spite of such shorter distance, the upper figure arrangement in Fig.4, presented better resolution. On the contrary, in the middle figure and the lowest figure, the resolution was worse. Then, next experiment planned to make clear why the resolution was differnt with the arrangements of the devices.

Further, in this experiment, there existed many problems have to be considered. Especially, the number of observer was only one and he was aged. Therefore, 2nd experiment was planned in more detail and more precisely, increasing the numbers of young observer.

3 2nd experiment

3.1 Method

Experimental arrangement is shown in Fig.4. Optical devices were same as the preliminary experiment. The resolution values for the Holographic image were measured by vision of 5 young males in this institute. Subject names were B.B, H.D, B.K, S.L and M.W. Their ages were from 25 years old to 34 years old. For the reference, the aged subject used in the above experiment was also measured. Their visual acuity were sufficient for this experiments. Light illuminance on the Holoram plate was regulated to keep at 2100 lx by inserted two polarizers. The tested

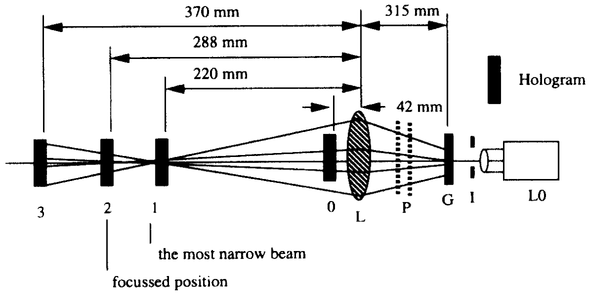

Fig. 4 Hologram position in the 2nd experiment

Hologram plates were two. One was taken by an object on the surface of a Hologram plate (0 mm depth), and another was the 4 mm depth image which was used in the previous experiment. For reconstruction of the image, locations of the Hologram were changed on 4 positions as shown in Fig.4, while other optical devices were not moved. In the figure, "0" position was the nearest to the lens. The light spread was 80 mm in diameter.

The most concentrated light was obtained at 270 mm from the lens. The "1" position was 220 mm from the lens, and the light spread was 32 mm. "2" position was the focused position.

Speckles which were caused by the glass appeared. It seemed to be a little hazard to observe the image. It's light spread was 40 mm in diameter. "3" position was located at after the focused position and it's light was uniformly distributed. It was 50 mm in diameter.

For the reference, an actual halogen lamp installed in a reflector was also measured. The lamp is 12V20W, Beam angles: 24°, BLV (Kaltlichtspiegel lampe) manufactured by Licht und Vakuumtechnik GmbH in Germany. Observing distances were 127 mm, 406.4 mm, and 609.6 mm from the front of the reflector. Corresponding illuminance values were 180,0001x, 18,000 lx and 7000 lx respectively. Each measurement was implemented 5 trials in the above described procedure.

3. 2 Experimental results and discussion

3. 2.1 Experimental arrangement

Fig.5 is experimental results of the experimental arrangement in Fig.4. In the figure, the solid line is the average of resolutiom values of all young subjects, dotted line is the average of aged resolution, and indications are corresponding to the average of individual subject trials. For the 4 mm depth Holographic image, the best resolution was obtained at the position "0" and followed by the position "3". At the smaller light spread position "1", the image resolution is the worst. Generally, a lens has spherical aberration. In this experiment, lens: "L" has the same characteristics. Then, at around the smallest light spread position, the rays of light came from periphery of lens are intersected each other as shown in Fig.4. Then, on the measurement point, the deviated angled rays of light exist. On the contrary, at the position of "0" and "3"

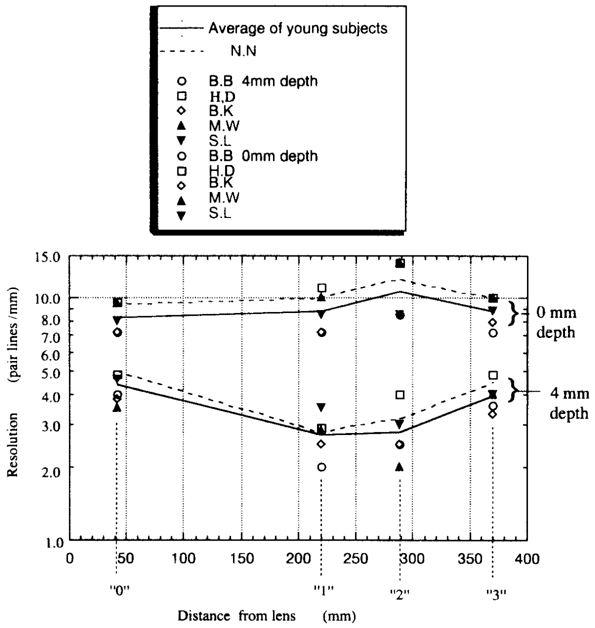

Fig. 5 Resolution on the distance from the lens

position, the least intersected rays of light should be given.

For the 0 mm depth Holographic image in Fig.5, almost same high resolution were obtained for all positions , but in detail, at the focused position: "1", the best resolution was obtained. This position gives the best spatial coherency. For the 0 mm depth object, so strictly a parallel ray of light was not needed as the deep image, but spatial coherency was more effective in spite of a little speckles. However, feature of the Holography presents in posibility of 3 dimentional image observation. Therefore, a deep Holographic image is important to be obseved.

From this speculation, ray tracing for the experimental optical arrangement was investigated. For the ray tracing, black cover having 3 pin holes were put on the diffuse glass. Then, patterns projected on the plane of above measurements positions by a ray of light through the pin holes, were obtained. From these patterns, ray tracks on the horizontal plane passing through the center of the lens, was drawed in Fig. 6. In the figure, ray tracks are drawn in the scale of 1/2 of images on the measurement positions. In the figure, intersecting rays of light around "1" and "2" positions are recognized. On the contrally, rays at "3" positions are the least intersecting but they are almost parallel light when the observation is done on the center. Moreover, rays on the center at "0" position are almost parallel light obviously.

3. 2.2 Actual lamp

Next, actual lamp results are shown in Fig.7.

In the figure, the nearest distance shows the worst resolution. The 2nd focus position of the reflector seemed to be at about 130 mm from the reflector. At

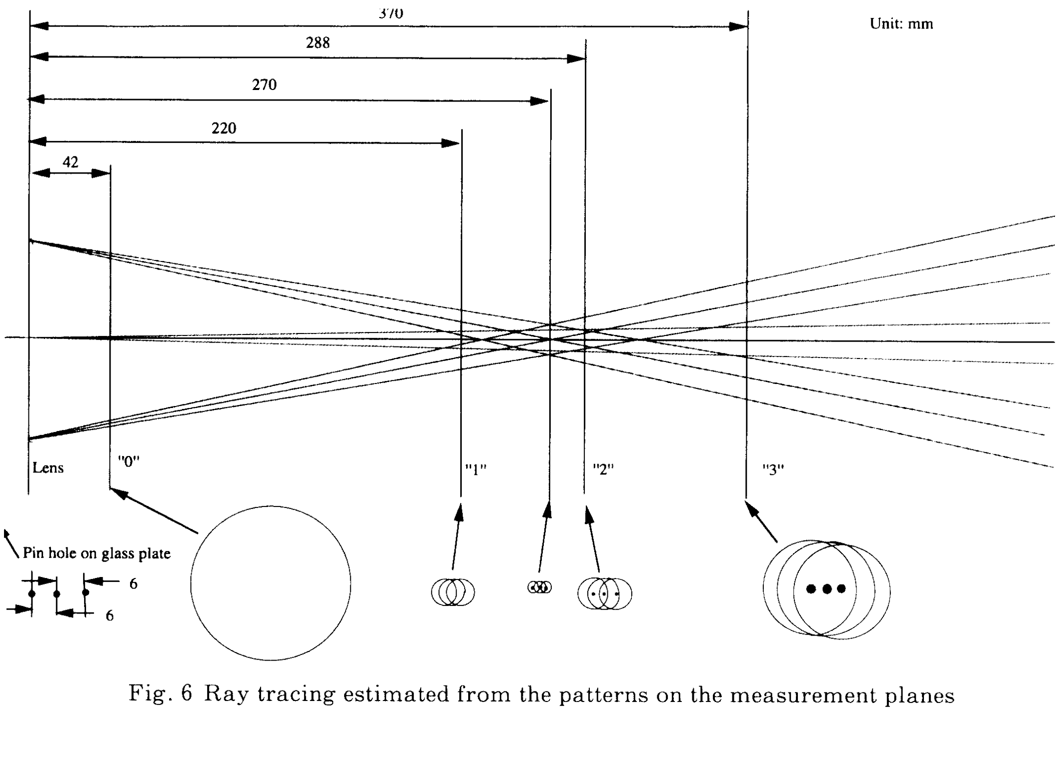

Fig. 6 Ray tracing estimated from the patterns on the measurement planes

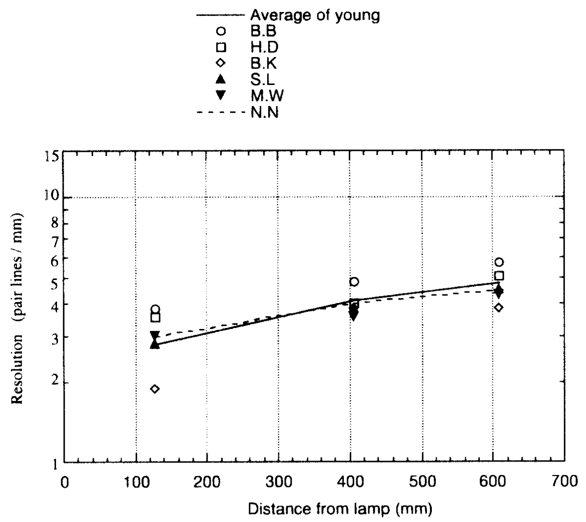

Fig. 7 Resolution for actual lamp

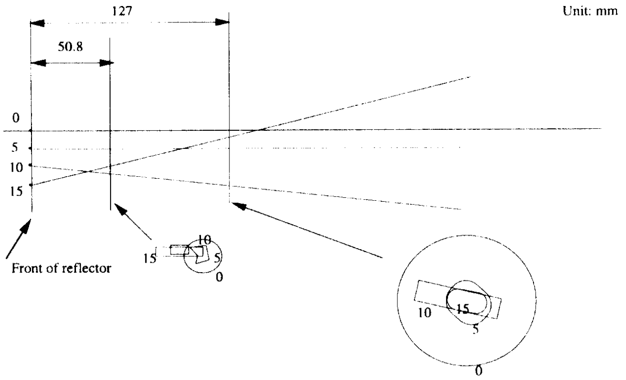

Fig. 8 Ray tracing estimated from patterns of measurement planes for an actual reflector lamp

127 mm position, the rays of light were the most concentrated. It is similar to the position "1" or "2" in the previous experiment. At this position, the rays of light mixed with various oriented rays. At sufficiently long distance, the resolution expects the good result. The least deviated rays of light is obtained at over 400mm which is 10 times of the reflector diameters.

For the same as above ray tracing, a black mask having a pin hole, was put on the face of the reflector. In this time, the pin hole was moved perpendicular to the direction of the reflector axis. Obtained patterns were not clearly, but the center of the patterns in each 5 mm increment were traced in Fig. 8. In the figure, rays at 127 mm from the reflector are intersecting. Then, the resolution was expected to be worse. At a sufficiently long distance, the deviated lights are diverged, then only the least deviated light (almost parallel light) will be left on the center of the light spread.

3. 2.3 Other speculations

By the way, the aged person is not so deteriorated in comparison with young persons as shown in Fig.5. Conversely expressing, recent young persons may not have good visiual ability.

In this experiment, a diffuse glass was used to get a uniform luminance light source. For getting more concentrated light, the diffuse glass was removed and measurement was again implemented by the aged subject, N.N. Corresponding positions of "1" presented the 3.2 pair lines /mm resolution. At focused position, the filament pattern appeared. The size of the patten was 6 mm＊10 mm. As it became hazard to observe the image, the resolution was 3.0 pair lines / mm. At the corresponding position of "3", 5.1 pair lines /mm of the resolution was obtained. These resolution values seems to be a little improved, but not to be drastically improved. This results show the optical arrangement is more important factor for the resolution than the size of a light source.

4 Summarized discussion and conclusion

From the experimental results, the most desirable light for the deep image is as parallel rays of light as possible (Fig.9). However, it does not correspond strictly to the smaller beam angles presented by lamp manufacturers , when the observing distance is rather small to the lamp. Orientations of the rays of light illuminated on the observing position had to be considered. Feature of Holography is 3 dimensional image obtained. Then, the most important light is good at the deep Holographic image. Then, the least deviated

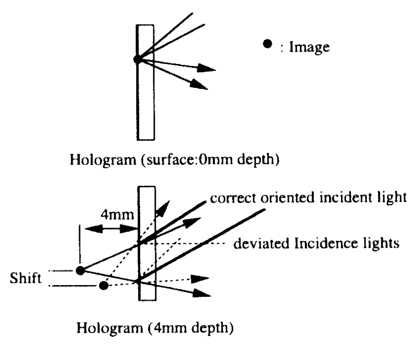

Fig. 9 Surface image and deep image by varied angled lights

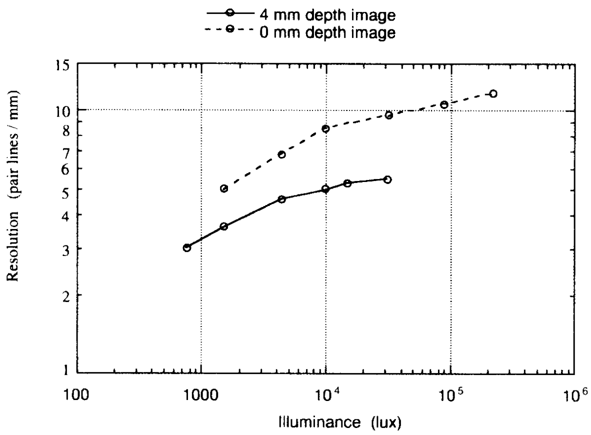

Fig.10 Resolution vs illuminance on the Hologram Data were accumlated all data of young and aged.

angled rays of light must be chosen. In many cases, a Hologram are observed by the human eye directly, then, the illuminance of the image is important.

For the human vision, the resolution of a pattern is also depend on the luminance of a pattern. Fig.10 shows the resolution values, when the illuminance on the Hologram was varied in the above experimental arrangement.

Then, summarizing these results, the most desirable lamp system for reconstruction of the Lippman Hologram is follows. The lamp has higher intensity light and the least deviated rays contained in it's light. To express more concretely, the size of a light source must be chosen relating to the size of an optical device which is collimating light. For example, a halogen lamp, combining with a lens which is around 100 mm in diameter and focus length is 150 mm, must have a smaller sized light source. In general, low voltage and high wattage lamp must be desirable (for example under 24V and over 100 w). In small lamps, more stronger light output is expected by high presure discharge lamps. These lamps must be combined with a sufficiently large reflector or lens. Further, observation carried out at sufficiently large distance after the focused position is the most desiable. When the measurement distance is shorter than 10 times of the light sources, the precausion must be paid avoiding the intersecting point of the rays of light.

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6 Reference

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