Department of Technical Optics

Instructions for the experiment

Holographic interferometry
1. The goal of the experiment
The practical experiment serves to define and apply knowledge in the field of holographic interferometry. The student will learn the techniques for recording, reconstruction and evaluation of holograms as well as the basic methods of holographic interferometry.

2. Tasks for preparation: /1,2,3,4/

2.1 Familiarize yourself with the following topics:
Laser, coherence, coherence length, plane wave, spherical wave, interference, diffraction, Huygen principle, interferometer, image generation in photography, object wave, reference wave, image generation in holography, holographic interferometry, realtime technology, double exposure technique, time averaging technique

2.2 Explain the special properties of laser radiation!

2.3 Which intensity distribution you get when superimposing two plane waves on a hologram plate? Which intensity distribution you get in the superposition of a plane wave with a spherical wave?

2.4 Calculate the diffraction grate constant of the holographic grate, which can be generated with an arrangement as in Fig. 1:
\[ \lambda = 632.8 \text{ nm (He Ne - laser)} \]
\[ \alpha = 30^\circ \]
Object wave and reference wave are plane waves

2.5 At what angle would the first diffraction order appear on the grid shown in Figure 1?

2.6 The determination of the displacement path from the number of interference fringes can be made according to the following equation (1), if the direction of the displacement is known: (see Fig. 2).
\[ d = \pm \frac{N \cdot \lambda}{2 \cdot \cos \left( \frac{\alpha}{2} \right) \cdot \cos(\theta)} \]  

(1)

Discuss the equation (1)! /3/

What follows if \( \alpha \) and \( \theta \) are equal to zero, if only \( \alpha \) equals zero?

Fig 2: To the evaluation of the stripes on the hologram

In which direction is the sensitivity of the set up the greatest?

3. Experimental setup

Figure 3 shows the arrangement of the components on the base plate. Make sure that all these components are securely fastened and that the base plate can swing well. **Do not use a hologram plate now!**

Insert a ground glass into the plate holder and adjust this setup. Please note that unwanted reflections can occur in the beam splitter.

**Never look directly into the laser beam!**
A) Bell (time averaging), t = 8s, [sine wave generator parameters: 200mW, 1kΩ, 12A]
B) Bending rod (double exposure), 2x t = 3s
C) White tin (real time), t = 6s-8s

Fig 3: A) Experimental setup /2/, B) Special arrangement in the laboratory
4. Reconstruction of the hologram

To do this, replace the beam splitter with a mirror and adjust the reference beam. Take an exposed hologram from the box and insert it into the plate holder.
- Describe your observation.
- What do you observe when you insert the hologram "wrong way round" into the holder? Try all possible positions!

5. General for the production of holograms

5.1. Preparation
Convince yourself once again of the correct adjustment of the setup!
Add developer, stop bath (acetic acid) and fixer to the appropriate trays and prepare them. Make sure that all light sources, with the exception of the green light, are switched off or covered.

5.2. Carrying out the experiment
Only open the box with the unexposed hologram plates in a darkened room and immediately close it again. Carefully position the coated side with your knuckle (it feels slightly "velvety") and place the plate side-by-side in the holder. Wait at least a minute to complete the setup. Now you can do one of the experiments described under 6.
Turn the laser on and off for exposure. Depending on the brightness of the subject, you can choose with shutter speeds of approx. 2 - 4 s.
Avoid anything that could affect the hologram during the exposure (speaking, moving, ...!)

5.3. Exposure (room darkened)
Remove the exposed hologram plate and put the plate in an empty black transport box. In the lab, perform the following steps in succession:
Do not switch on the room lighting yet!
- Development: The plate about 3-4 min. into the bowl, with developer liquid while constantly moving.
- Stop: Immerse briefly in the acetic acid
- Fixing: The plate at least 4 min. Place in the bowl with fixative while constantly moving. Only now can the room lighting be switched on.
- Watering for about 5 minutes in a bowl with fresh water.
The hologram must now be completely dried drying cabinet in the air.

6. Experiments on holographic interferometry
After consultation with the supervisor, one or more of the following experiments must be carried out.
6.1. Real-time technology: Qualitative evaluation / 2,3,4 /

6.1.1. execution
The object used here is a white lacquered beverage can. Secure these securely to the base plate and adjust the structure so that the box is well lit.
Then, as described under 5., create a hologram of this can.
Make sure that nothing is changed in the structure and place the finished hologram back in the holder.
You should now see an overlay of the hologram image with the object. This should be covered by interference fringes.
If no interference is detected yet, the hologram is unlikely to be exactly at the position where it was recorded. Removing and replacing the hologram may then help.

6.1.2 Observations
- How are the interference fringes going?
  Describe the course or document it by a sketch (only qualitative) or a photo!
Gently push on one point of the can!
- Describe or sketch the change of the interference fringes.
Put a rubber band around the can!
- Description / sketch.
Fill water into the can!
- Description / sketch.

6.1.3 Evaluation
From the course of the interference fringes, reconstruct the type and course of the occurring deformations. Describe them or make sketches again (e.g., a cross-section at the place of the dent, the rubber band, etc.)
Estimate the sensitivity with which deformations can be detected.

6.2 Double Exposure Technique: Quantitative Rating / 2,3,4,5,6 /

6.2.1 Implementation
Replace the beverage can from Fig. 3 with the flex strip assembly.
Adjust the object beam so that at least the lower part of the strip and the scale are well lit.
Adjust the micrometer screw so that the spindle touches the bending strip and bends slightly.
Note the position of the micrometer screw.

Now create a hologram of the bending strip as described under 5.
- Exposure this time only about 2-3 s!
- Do not develop the hologram plate yet!
- Adjust the micrometer screw by 3-10 divisions instead. (practice in the light before)
- Exposure the same hologram plate again for about 1-2 s.
Only now should you develop and fix the hologram plate.
Read off the adjustment of the micrometer screw. Estimate intermediate values as well.
Also determine the angles $\alpha$ and $\theta$ (see Fig. 2).
6.2.2 Observation
If you reconstruct the finished hologram, the bending strip would have to be covered with horizontal interference fringes. Use the side scale to count and measure the number of interferences per unit length.

6.2.3 Evaluation
From your measurements, determine the deflection as a function of the location on the bending strip (the bending lines) and plot it graphically. Using the equation in 2.6, calculate the displacement d.
The micrometer screw is 15 cm above the clamping point. Draw the readjusted adjustment path into the graphic at this point.
The equation for the bending line of a clamped beam is / 6 /:

\[ d = K \cdot x^2 (3l - x) \]  

(2)

with:
d = deflection at the point x
x = distance from the clamping point
l = length of the bending beam (here 15 cm)
K = material and shape constant of the bending strip
Determine the factor K from their measured values. Compare the course of this function with that of your measurements. Extrapolate the bend line Gln. (2) and discuss possible deviations from the measured displacement of the micrometer screw.

6.3 Time averaging technique

6.3.1 Setup

Fig.: Setup for the time averaging technique

Use the same structure as for the real-time technique (see 6.1), but with the bell as object. Place the bell over the loud speaker as shown in Figure 4. Make sure that the bell is firmly clamped to the holder and the holder also does not resonate when the bell is activated!
6.3.2 Implementation
Connect the speaker to the output (0-2V, 4Ω) of the sine wave generator. Select a voltage of 1V and a frequency of about 400 Hz. Change the frequency in the range around this 400 Hz until you can hear a clear roar. This roar indicates that you have tuned the resonant frequency of the can and have it vibrate. Now cover the sine wave generator and create a hologram of the swinging bell.

6.3.3 Evaluation
Describe your observations or make a sketch of the hologram.
- How are the interference fringes and how many stripes are visible?
- Would there be more or less stripes at higher amplitude (set on the sine wave generator)?
- What does the shape of the stripes say?
- If you did not set the resonance frequency correctly, what would you watch?
- If you have tried the real-time technique, compare the results of both experiments.

7. Literature

/2/ Fa. Newport
    Anleitung: Projects in Holography
/3/ Ostrowski, Ju. I.: Holografie
    Harri Deutsch Verlag, Frankfurt 1989
/4/ Kiemle, H.: Einführung in die Technik der Holografie
    Akadem. Verlagsgesellschaft Frankfurt 1989
/5/ Heymann: Experimentelle Festkörpermechanik
    Fachbuchverlag Leipzig 1986
/6/ Hagedorn: Technische Mechanik
    Teubner Studienbücher, Stuttgart 1988
/7/ Schröder,G: Technische Optik
    Vogel Würzburg 1990

Literature for further studies:

/8/ Ostrowsky, Ju. I.: Interferometry by Holography
    Springer Series in Optical Sciences 18;
    Springer Verlag, Berlin, Heidelberg, New York 1982
/9/ Osten,W: Digitale Verarbeitung und Auswertung von Interferenzbildern
    Akadem. Verlag, Berlin 1991