Z28B - Digital holography

Physics Laboratory II
Faculty of Physics, Astronomy and Applied Computer Science, Jagiellonian University

In this experiment students perform a lensless Fourier transform holography. This kind of holography is a counterpart of a classical transmission holography — the hologram is recorded with a digital camera instead of a photosensitive plate. Finally, the hologram is reconstructed using mathematical methods on a computer. During this experiment students get familiar with a design and preparation of optical setups as well as with the field of Fourier optics.

Preparatory questions and problems

The laboratory starts with an oral test.

1. What is laser? What are the three basic components of every laser? What are the properties of the laser radiation? [1, 2]
2. Temporal and spatial coherence of light [1], appendix A in [2]
3. The idea of registration and reconstruction of a transmission hologram [3, 2, 4]
4. The mathematical description of digital holography [5, 6, 7], optionally [8]
5. What is a speckle pattern?
6. Design the optical setup for digital holography [5, 9]

Computational assignments

1. Calculate the maximum usable angle between the object and reference beam knowing that the pixel size of the camera used to register the hologram is 3.45 μm [3].
2. Basing on the result of the previous assignment calculate the maximum size of an object, knowing that the distance between the object and the camera sensor is 35 cm.

Apparatus and materials

A typical experimental setup is shown in Fig. 1:

1. helium-neon laser (He-Ne), power of 7 mW,
2. mirrors and beam splitters,
3. diverging and converging lenses,
4. neutral (gray) filters,
5. 5.0 MP Mono GigE Point Grey camera with software,
6. computer with AppFFT and Wolfram Mathematica software.

Experiment

A typical scenario of the experiment:

1. Preparation and optimization of the experimental setup. Observation and optimization of the interference fringes using the camera software.
2. Registration of the holograms and images of the object and reference beams.
3. Numerical reconstruction of the holograms using the Fourier transform.
4. Analysis of the reconstructed holograms — what are the sources of characteristic features of the reconstructed image.
5. Recording and reconstruction of about 20 images which differ by a delicate change of the angle of incidence of the laser beam on the object. The digital reconstruction of the holograms and averaging of the final images leads to a significant reduction of the speckles. The speckles are the result of the interference of the coherent laser light after reflection off a rough surface of the object.

Data analysis

The main result of the experiment are numerically reconstructed, optimized and interpreted holograms. The numerical reconstruction may be performed in the AppFFT software. It allows one to import the holograms in .bmp format, to perform a discrete Fourier transform, to save the final image to a file and optionally to average many images. If it is necessary, the program provides a way to find an optimal sharpness of one of the reconstructed images through multiplication of the hologram by a $\exp(ik_z d)$ propagation term, where d is a difference between the two distances: 1) object-camera and 2) a point from which the the reference beam diverges-camera. Using the Fourier transform of the image of the reference beam alone and the object beam alone allows one to analyze the characteristic features of the reconstructed holograms.

In the next step one has to reconstruct a series (about 20) of holograms differing by a slight change of the angle of incidence of the laser beam on the object. In this method, each reconstructed image differs

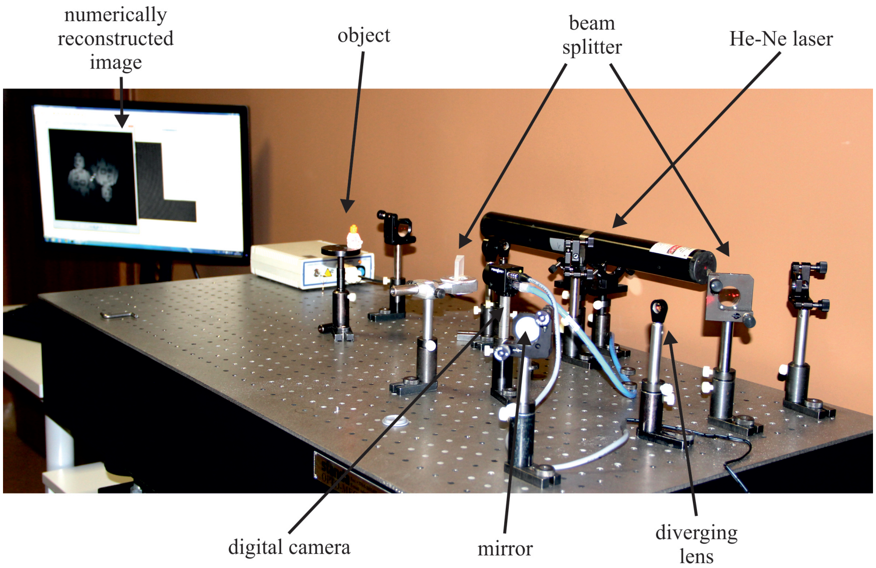

Figure 1: Experimental setup — digital holography

by a speckle pattern. This way, averaging of the reconstructed images reduces the speckle component in the final image. The averaging may be done in the AppFFT program.

Safety rules

- **Do not look straight into the laser beam!** Be careful especially when looking at transmission holograms.
- The laser light reflected off mirrors, bracelets, rings and watches may be dangerous as well.
- **Use safety glasses.**

References

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