Exploring an economical optical setup for inline digital holography experimentation

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Digital holography is the technique where a hologram is digitally created through the interference of the object and reference waves. The purpose of this study is to design and investigate the effectiveness of an economical optical set-up. The optical set-up will be designed for inline digital holography. This was done by creating and using a device that utilizes inline digital holography to collect the reference wave and applying saturation analysis on the images. A control group along with an experimental group utilizing a ND32 filter were conducted.

Keywords: *holography, digital, economical*

Holography refers to the technique in which the wavefront diffracted from an object is recorded through the interference of light, and the medium containing the information is referred to as a 'hologram'(Tahara et al., 2018). Digital holography, then, is when the recording medium can digitally transfer the information into a computer. This is usually achieved through a digital camera and thus allows for the reconstruction and display of the hologram image in a computer monitor. Thus, digital holography has the capability for real-time production of hologram images and quantification of extremely small measurements, limited only by the recording medium (Linquist, 2018). The ability to quantify extremely small measurements at high speeds indicates that digital holography has the potential to be used as an extremely precise and accurate instrument.

Holography requires two waves: the object wave and reference wave to generate interference information required for producing holograms. This is usually done by splitting the source beam into two. This makes the system extremely sensitive to vibrations alongside other variables. Inline digital holography does not require the splitting of the source beam, which stabilizes the system with the drawback of necessitating some transparency in the object being analyzed (Linquist, 2018).

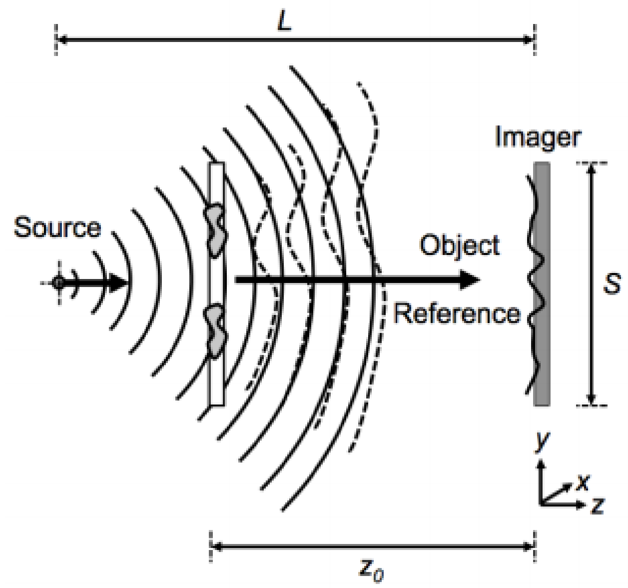

Figure 1. Inline digital holography. The reference beam is a point source, typically a laser focused through a pinhole. The object is mostly transparent. Weak scattering waves from the object creates the object beam whereas the reference beam stays an expanding spherical wave. The reference beam source is located some distance L in front of the imager chip surface and the object is at a distance of z0. The physical size of the imager is S (Linquist, 2018).

Due to the simplicity of the digital holography design, economical equipment is desired. This research seeks to explore the plausibility of using economical equipment for accurately conducting digital holography experiments.

Methods

An economical optical setup suitable for inline digital holography research was proposed. The setup included a 5 mW, 532 nm wavelength laser, microscope objective lens, raspberry pi camera, and a raspberry pi. Following the inline digital holography setup, the objective lens was placed between the imaging medium and laser in order to expand the laser light. This design was extremely small and compact, which allowed it to function in very limited spaces with no drawbacks.

Secondly, the raspberry pi camera responsible as the recording medium was modified. This was done through the removal of the lens using a custom, 3D printed removal tool, exposing the imaging chip directly. The camera was programmed to collect the reference wave as an image in the form of a .bmp file.

For the control group, the distance between the microscope lens and the raspberry pi camera was adjusted at various distances between 25cm and 40cm and the reference wave was collected through the raspberry pi camera. Another experiment repeated the same procedure but with the addition of an ND32 lens, which reduces the amplitude of the laser light. A final experiment was conducted where images were instead collected at the bitmap of 256 color instead of the default 24-bit. The collected images were processed using Matlab to generate a graph of the saturation of the pixels vertically down the center of the image.

Results

For all three groups, the Matlab graphs had displayed a small region in the center where saturation levels were plausible for digital holography, however the majority were too high for digital holography reconstruction. The control group and 256 color displayed extremely similar results with especially high saturation levels throughout the image, which made the reference wave invisible. Furthermore, the reference wave was not visible in the small region where saturation levels were low. The ND32 group displayed regions of high saturation but also regions where the reference wave was visible. The optimal distance for the ND32 group was determined to be between 25 and 35 cm, anything outside of the range produced extremely saturated images where the reference wave was not visible.

Discussion

The results indicate that the economical equipment has the potential to conduct inline digital holography research. While the images were saturated, the ND32 group displayed that the system could detect the reference wave in portions of the image, and thus, with some changes to the setup, should be able to provide better images. The results were constrained by possible variations due to possible inaccurate measurements in the distance. The vertical setup made it difficult to accurately change the distance between the recording medium and light source. More research is needed to further explore the ND32 setup, featuring experimental groups that make adjustments to the ND32 control group. Such research could feature adjustments in the distance between the microscope lens and laser in order to determine the optimal intensity of light, through a similar Matlab analysis.

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