# Chapter 6

# General Conclusions

## 6.1 Conclusions

This is the first digital holography system that has been established in this laboratory. The fundamentals of the digital recording with CCD detector and numerical reconstruction of the digitally stored holograms have been described, implemented and tested. Due to the low spatial resolution of the CCD arrays (≈100 lines/mm), the angle between the interfering waves is limited to a few degrees. Consequently, the size of the objects used is limited to a few centimeters and need to be placed at a large distance of about a meter. The numerically reconstructed images of the test-object are clearly seen on the display monitor. While the quality of the images shown in Figure 4-6(b) and Figure 4-7(b) is poorer due to the printing quality.

The test experiments demonstrates that CCD cameras are in principle suitable as a recording media for holograms. The numerical reconstruction algorithm consists of the numerical realization of the Fresnel-Kirchhoff diffraction integral and Fresnel approximation. This has been successfully implemented with the use of the standard Fast Fourier Transformation (FFT) algorithm.

The established digital holography technique is then implemented in the more important field of holography - holographic interferometry. Two Fresnel holograms that represent two different states of a test object are recorded on the CCD detector. There are two routes to the reconstruction process. Two holograms in two different states can be superimposed to form a single hologram where subsequent reconstruction of the superimposed hologram produces an interferogram. Alternatively, if the phases of each individual object state are reconstructed, the interference phase can be calculated directly by comparing their phases. These approaches of the reconstruction process are summarized in Figure 3-8. To test the utility of the digital holographic interferometry, a simple example in laser metrology i.e. the out-of-plane displacement of a cantilever is chosen. The fringe pattern of the numerical reconstructed interference phase of the two different loading states of the cantilever (Figure 4-12) is much more apparent compared to the interferogram produced (Figure 4-11). By counting the number of fringe produced, the out-of-plane displacement of the cantilever can be easily and accurately determined.

A practical application of digital holography interferometry is designed and implemented. In this metrology system, the linear thermal expansion coefficient of various materials can be measured easily and accurately. There is very little sample preparation involved in the proposed method. Only short specimens (about 10cm) and small increase of temperature (0.1°C) of the specimen are required to produce a measurable fringe patterns. This is a simple and direct metrology tool for accurate measurement of linear thermal expansion coefficients compared to the other techniques [29-42] that need long specimens (about 1-1.5m) and large temperature differences to produce the measurable changes. The results of the technique for three common specimens (aluminium, brass and stainless steel) are summarized in Table

5-1. The results show that the digital holography technique is an accurate, yet simple and direct measurement tool in linear thermal expansion coefficient measurement. Since this is the first system developed in this laboratory, there are still improvements that can be carried out before it can become a routine metrology tool.

## 6.2 Future Work

The digital holography technique that has been described here offers new possibilities in laser metrology. Nevertheless, in order to become more applicable as a practical tool, a few necessary improvements have to be made.

The digital filtering processing of the holograms produced needs to be improved to produce better quality reconstructed images. Beside, a higher spatial resolution CCD arrays such as 1024×1024 pixels CCD cameras can be used as a recording medium to improve the quality of the image produced. CCD arrays with smaller pixel dimensions as compared to the present 8μm×8μm will definitely improve the system. Furthermore, implementing fringe-tracking algorithm [29] can produce more accurate and precise fringe measurements.

The digital recording, numerical reconstruction and digital evaluation have to be integrated into a single system to increase the speed of processing and to be more user-friendly.

Digital holography can also be used in several real practical applications in laser metrology. One of the applications of digital holography is underwater inspection and measurements [43]. Underwater holography is a technique that involves the recording of a hologram underwater and subsequently replaying the real image in air to obtain accurate positional and dimensional information. Since recording is carried out in one medium (water) and replayed in another medium (air), optical aberrations are introduced in the replayed image. In order to minimize this effect, the hologram is replayed not at the recording wavelength, but at the recording wavelength divided by the refractive index of water. The advantage of digital holography in underwater holography is in the replaying process where the replaying wavelength needed, can be accurately matched in the numerical reconstruction algorithm. Currently in the methods involving optical reconstruction, the replaying wavelength can only matched as closely as the wavelengths available from practical lasers in existence.