DIGITAL HOLOGRAPHY AND APPLICATION IN LASER METROLOGY

BY

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Finally, I am eternally indebted to my family and my girl friend, Ms. S. H. Koay for their love, support and firm belief in my ability to carry this work through and to them I would like to dedicate this thesis.

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ABSTRACT

A digital holography system has been developed in this study. The object is recorded and the hologram is stored electronically with a charged-couple-device (CCD) camera without any focusing optics. The reconstruction of the digitally sampled hologram is done numerically with a computer. The algorithm and software for numerical reconstruction, which consists in a numerical realization of the Fresnel-Kirchhoff diffraction integral, are designed and implemented with two-dimensional and three-dimensional simple objects. The characteristics of the system have been studied. For the CCD camera (768×494 pixels) been used with spatial resolution of about 100 lines/mm, the angle between reference and object waves is limited to a few degrees. This limits the size of the objects to be recorded to a few centimeters and the distance between object and CCD-target to about a meter.

The system is also implemented in holographic interferometry. Two or more Fresnel holograms, which represent different loading states of the objects, are generated directly on a CCD-target and stored electronically. There are two approaches to calculate the interference phase resulting from the two states of the object in the reconstruction process. Firstly, it is determined from the interference pattern, which is generated by the superposition of the calculated intensity of the object waves. Secondly, it is directly calculated from the phases of the waves of both states. This second approach allows direct calculation of interference phase from the holograms without generating an interference pattern.

Finally, an accurate, simple and direct measurement system for coefficient of linear thermal expansion of materials based on the principle of digital holographic

interferometry is designed. This system is tested for three different common materials, namely aluminium, brass and stainless steel. The results obtained are compares favorably with the standard values.

The major drawback of the method is the low spatial resolution of CCD arrays. Consequently only small objects at large distance from the CCD-target can be resolved. However, with the present CCD camera, the quality of the reconstructed image is good especially when used in holographic interferometry and is comparable to that of conventional holographic techniques using photographic films.

ABSTRAK

Satu sistem holografi digital telah berjaya dibinakan dalam penyelidikan ini. Objek direkodkan dengan kamera CCD tanpa penggunaan sebarang optik memfokus dan hologram yang terhasil disimpankan secara elektronik. Pembinaan semula hologram yang disimpankan secara berdigit itu dilaksanakan secara berangka dengan komputer. Suatu aturcara pembinaan semula berangka yang terdiri daripada perlaksanaan kamilan belauan Fresnel-Kirchhoff telah berjaya dibina dan digunakan ke atas objek-objek dua dimensi dan tiga dimensi. Sifat-sifat sistem ini telah dikaji. Kamera CCD yang digunakan (768×494 pixel) mempunyai resolusi lebih kurang 100 garis/mm, dan ini menghadkan sudut di antara gelombang-gelombang rujukan dan objek ke beberapa darjah. Akibatnya, telah menghadkan saiz objek yang dapat direkodkan ke beberapa sentimeter dan jarak di antara objek dengan kamera CCD ke lebih kurang satu meter masing-masing.

Sistem ini juga telah digunakan dalam holografi interferometri. Dua atau lebih hologram Fresnel, yang mewakili keadaan-keadaan objek yang berlainan, dijanakan secara terus ke atas kamera CCD dan disimpankan secara elektronik dalam komputer. Terdapat dua cara untuk menentukan fasa interference yang terhasil dari dua keadaan objek itu semasa dalam proses pembinaan semula. Pertama, ia ditentukan dari corak interference yang mana terhasil dari penggabungan keamatan gelombang objek yang telah dikirakan itu. Kedua, ia dikirakan secara langsung dari fasa kedua-dua keadaan

objek itu. Cara kedua ini membolehkan penentuan fasa interference dari hologram tanpa menjanakan corak interference.

Akhirnya, suatu sistem pengukuran, yang berdasarkan prinsip holografi digital, yang tepat, mudah dan terus bagi mengukur pekali kembangan terma linear bahan-bahan telah direka. Sistem ini telah diuji dengan tiga bahan lazim yang berlainan iaitu aluminium, tembaga dan keluli. Keputusan yang diperolehi adalah setanding dengan nilai-nilai piawai.

Kelemahan utama teknik ini adalah akibat dari resolusi kamera CCD yang rendah. Akibatnya, hanya objek-objek bersaiz kecil yang berjarak jauh dari kamera CCD dapat direkodkan. Sesungguhnya, dengan kamera CCD yang sedia ada, kualiti imej pembinaan semula yang terhasil adalah amat memuaskan terutamanya dalam holografi interferometri, dan juga setanding dengan imej yang terhasil dari teknik holografi yang menggunakan filem.

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