Simulation of Tri-sensor Deflectometry for Freeform and Structured Specular Surface

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1.Introduction

Freeform and structured specular surfaces have been widely used in optics, aerospace and MEMS/NEMS fields. For example figure 1 shows a multi-mirror arrays for James Webb Space Telescope. This typical component has 18-22 sliced mirrors of 50 nm RMS form accuracy and 5 nm Rq roughness, measurement of which recently suffers from time-consuming and complexity . Our research aim is to explore a tri-sensor deflectometry for fast measuring the form of this kind of complex surfaces .

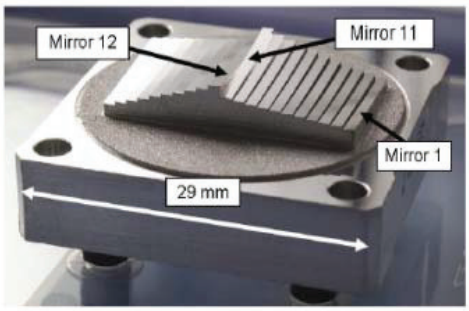

Fig 1 The monolithic multi-mirror arrays on the Mid-Infrared Instrument (MIRI) Spectrometer Optics for the James Webb Space Telescope

2.Sensor Principle

The LCD screen controlled by a computer generates a sinusoidal fringe pattern on its rear projection screen. The CCD cameras capture the distorted fringe pattern via the detected specular surface. By analysing these distorted phase data, the slope and position information of this detected surface will be calculated.

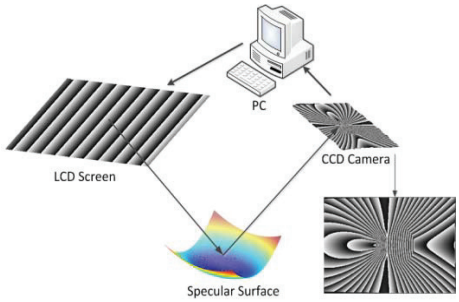

Fig 2 Principle of phase measurement deflectometry

3.Objectives

The objectives of this project are to create a fast form measurement system and investigate its corresponding algorithms for high precision measurement. The 3D model of this device is shown in figure 3, which consists of three cameras and a LCD screen. These three cameras are fixed spatially around the detected surface.

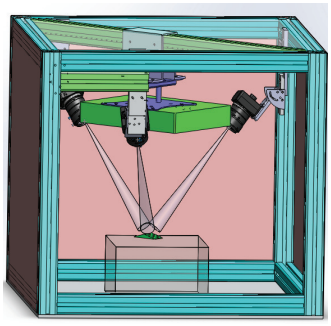

Fig 3 3D model of tri-sensor deflectometry

4. Simulation

A horizontal and vertical sinusoidal fringe pattern acting as a LCD screen, and a under-test surface $z = \frac{x^2}{6} + \frac{y^2}{5}$ are simulated. The fringe patterns is "seen" by three cameras via this detected surface.

❑ Phase unwrapping algorithm

Natural, exponential and optimum frequency selection algorithms are used to unwrap the captured phase data.

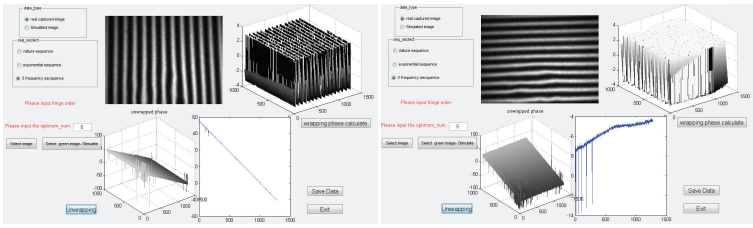

Fig 4 Phase unwrapping interface (left: vertical fringe pattern; right: horizontal)

❑ Integration process from each camera data

For each two cameras, the computed unwrapped phase can be used to obtain slope and position information. Integration of the three set of data will calculate the surface topography.

5. Results and discussion

Due to some blinds for each camera, each two cameras could only calculate a sectional information for the whole surface, while integrating the three set of data is a little time-consuming and complex.

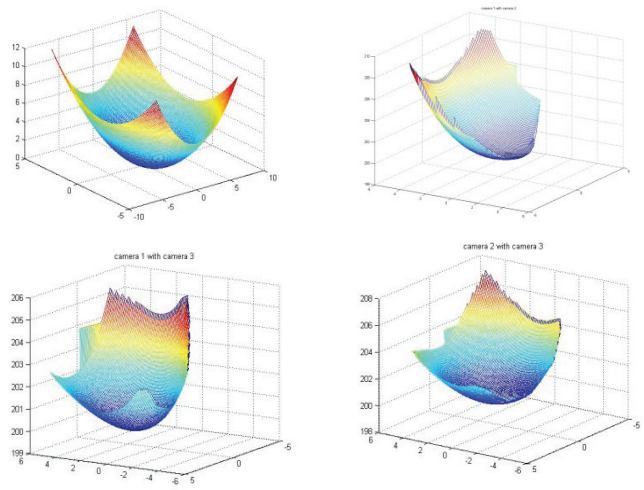

Fig 5 Integration simulation of tri-sensor deflectometry

6.Future Work

- ❑ Set up a practical device with LCD monitor
- ❑ Deduce an integration algorithm and its optimization
- ❑ Calibration of this instrument (camera's internal and external parameters; geometrical relation between cameras and LCD screen)
- ❑ Uncertainty analysis and errors compensation

7.Acknowledgement

The author gratefully acknowledge the supervisors and other staffs of the Centre for Precision Technologies in Huddersfield University of UK and Hebei Science and Industry University of China.