Introduction

3D optical metrology using structured light projection is now a well established technique for the rapid gathering of 3D coordinate details of a device under test (DUT). The technique is completely non-contact and lends itself well to areas such as automated optical inspection (AOI) of manufactured parts in inline assembly processes. In such applications, the whole surface height distribution of the DUT can be calculated and compared with a reference in seconds.

Generally, structured light based measurement systems work using the principle of triangulation, where a series of light points (pixels) are projected as a pattern onto the surface of the DUT. The deformation of the projected pattern by the DUT is captured by the system camera and compared with the original (reference) pattern of the projector. Each pixel is identifiable through pattern coding techniques and, as both the angle of the projector and angle of the camera are known, triangulation can be used to determine the height for each pixel (coordinate point).

System Overview

A structured light 3D optical metrology system typically consists of a projection unit, image acquisition unit (camera) and a processing/analysis unit. Synchronisation between the projection unit and the camera is important for accurate and efficient image capture.

The workflow for such systems usually consists of the following steps: (1) one time system calibration using calibration patterns, (2) projection and capture of structured light patterns, (3) pattern decoding/fringe analysis-phase unwrapping and (4) 3D coordinate calculation/height mapping and point cloud construction.
Microdisplay Based Projection

While various solutions for image projection exist, a microdisplay based projection engine is an ideal candidate. A microdisplay based solution enables a high resolution projector capable of showing limitless pattern variations, allowing flexibility in pattern/algorithm design.

The ForthDD SXGA microdisplay is a high resolution (1280*1024 pixel array) device well suited for creating structured light patterns.

The microdisplay is binary in nature (each pixel is only ever on or off). Pixel intensity is created using pulse width modulation (PWM) resulting in a linear greyscale response. This is particularly important for techniques employing sinusoidal phase-shifted patterns. Further, as the microdisplay is a reflective device, all the pixel circuitry is located behind the pixel mirror enabling a very small in inter-pixel gap (or high ‘fill-factor’). The fill-factor of ForthDD SXGA display is >96% enabling the projection of high fidelity images with little discernable pixel structure.

Driver Solutions

In 2007 ForthDD consulted with 3D optical system manufacturers to define the requirements for a 3D optical metrology specific driver interface.

The ForthDD SXGA-3DM is a flexible, reconfigurable microdisplay driver designed to allow user generated patterns to be displayed according to user required timings without the need for a real-time video input.

Image data is stored in on-board flash memory along with the user generated command sequences for controlling image timing. The system is capable of storing up to 768 (1-bit) or 96 (8-bit) images. Additional flash memory exists for storing user information (e.g. calibration data). A PC based GUI development tool and API library are available for controlling the system over the USB or RS-232 interfaces.

Due to the fast switching nature of ForthDD microdisplay devices, the system can operate up to 240Hz (8-bit images) or 3.2 KHz (1-bit images).

The system contains a bi-directional synchronisation port for synchronising other system components such as the system camera.
Development Environment

A full development kit is provided in the form of ForthDD software development suite MetroCon. This is a GUI based development environment that allows the user to load images, define image exposure times and define triggers allowing the projection of a series of complex image patterns.

Optical Considerations

ForthDD’s microdisplays use ferroelectric liquid crystal on silicon (FLCOS) technology. Each pixel acts as a controllable polarisation converter (quarter wave plate) which, when used with polarisers, can allow light to or stop light from exiting the system. Thus, each pixel is effectively a binary switch.

There are two typical optical architectures for metrology applications: on-axis and off-axis.

On-axis display architectures use a polarising beam splitter (PBS) where the illumination and projection optics are perpendicular or normal to the z-axis of the microdisplay. This option is suitable for when the projector is positioned vertically over the DUT.

The off-axis architecture works without using a PBS. The illumination is incident upon the display at angle to the microdisplay’s z-axis and the polarisation gate is created by two crossed polarisers (a pre-polariser and an analysing polariser).

This arrangement is especially suited to metrology applications where off-axis DUT illumination is required to meet the Scheimpflug principle for tilted focal planes.

Another optical architecture that may be applicable to some metrology systems is a hybrid one where the off-axis architecture is used in combination with a PBS.

Summary

A microdisplay based projector system is well suited for the application of structured light projection in 3D optical metrology. The high resolution, high fill-factor and linear response of ForthDD’s display technology, coupled with the flexibility of the -3DM driver interface make it a good choice for 3D optical metrology system builders.