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Original Citation

Hassan, Mothana A., Jiang, Xiang and Haydn, Martin (2012) Fast surface metrology using wavelength scanning and dispersive white light interferometry. In: Proceedings of The Queen's Diamond Jubilee Computing and Engineering Annual Researchers' Conference 2012: CEARC'12. University of Huddersfield, Huddersfield, p. 148. ISBN 978-1-86218-106-9

Centre for Precision Technologies
Computing and Engineering

Fast Surface Metrology using Wavelength Scanning and Dispersive White Light Interferometry

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Aim and Objectives:

- To introduce a new optical interferometery technique to measure surfaces at the micro and nano-scales based on the wavelength dispersive multiplexing technique with high speed imposition.
- To use a wavelength division multiplexing technique to scan a profile on a specimen and using this novel technique to evaluate the potential of applying to measure on-line surface profile.
- Profile measurement.
- To achieve fast measurement rate in > 10 kHz.
- To achieve high vertical resolution (< 1 nm).
- To achieve ambiguous vertical step height (205 nm).
- To design compact remote probe fibre link

Introduction:

The proposed experimental setup shown on the right. A Michelson interferometer is sourced by a super-luminescent light emitting diode (SLD) and a laser diode (for alignment only). The broadband light is laterally dispersed across a profile on the surface under test formed by a grating (G1) and collimating lens. Each wavelength interrogates a different point on the surface. The reference arm contains a piezo-electric translator that may be used to shift the interferometer phase. The interferometer output is monitored using spectrometer formed from a CMOS line array, grating (G2) and spherical mirror. Each monitored wavelength contains phase information related to the topography of the surface at one point on the profile. In this work the visibility of the interferometer and probe is compared with the zero order (reflected) beam from G1.

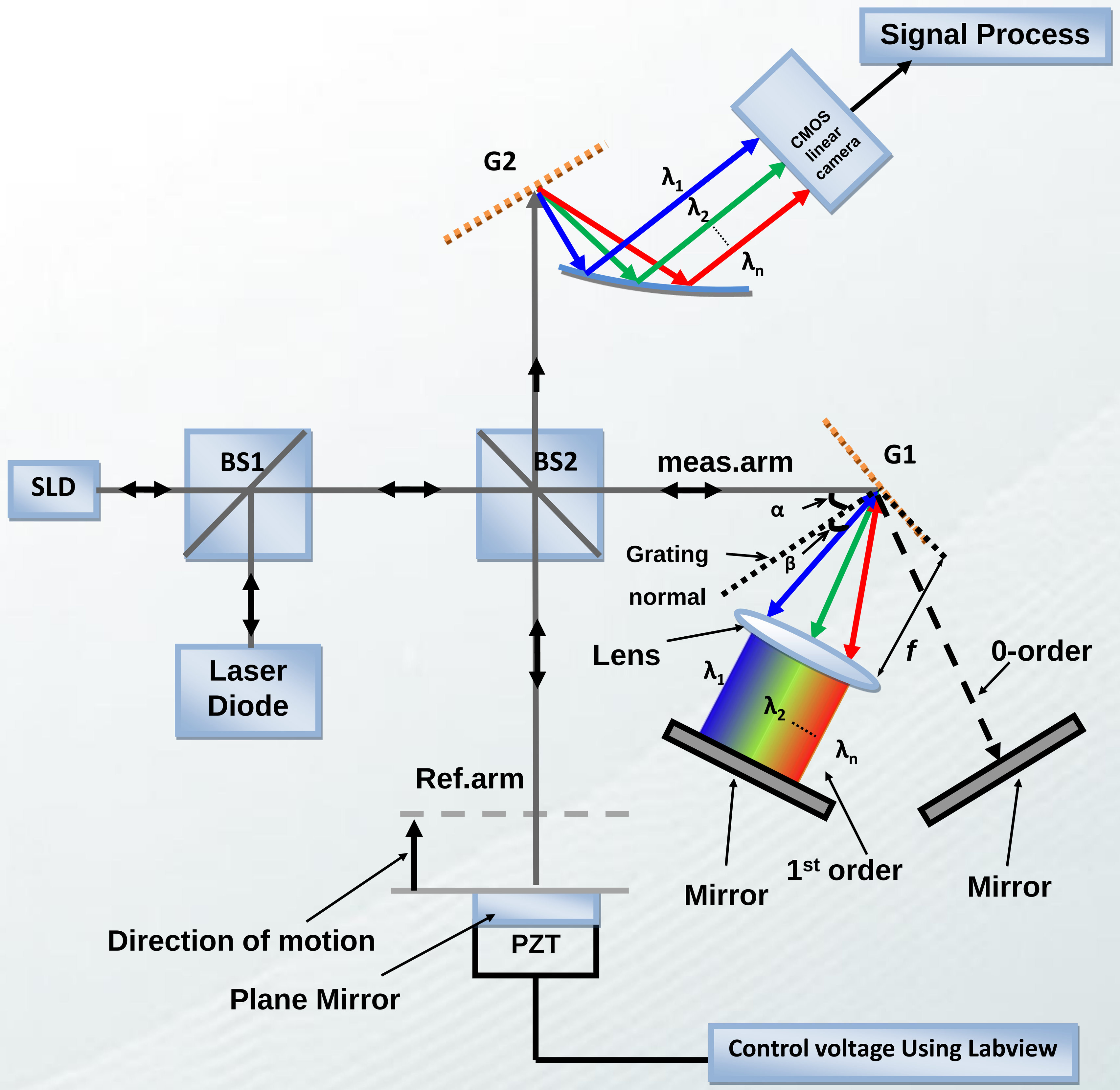
Phase Shift Interferometry:

The principal concept idea behind the interferometric method of surface measurement is the reference and object beams interfere after reflection. The intensity of the resultant interference beam is detected by; a solid state device such as a CCD camera, photographic film or photo-detector. The interference signal can be described as:

$$I = I_r + I_o + 2\sqrt{I_r I_o}\cos(\delta)$$

Where I_r, I_o are the irradiance reflected from the reference mirror and object respectively and δ is the phase shift between them. The visibility measurement definition is

$$V = \frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$$



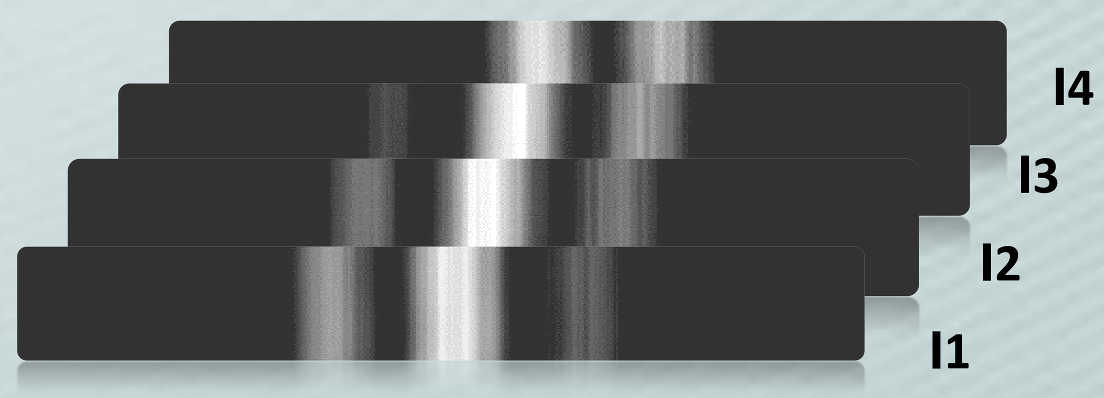
Experiment setup

Interferometery for Surface Profiling:

The Carré phase shifting algorithm is potentially the most useful for the experimental apparatus in this work as equation below, because it does not require a specific value of phase shift, it only requires each shift to be identical but the disadvantage is that it has nonlinearities in the phase shift .

$$\phi(x) = \tan^{-1}\left\{\frac{\{[3(I_2 - I_3) - (I_1 - I_4)][(I_1 - I_4) + (I_2 - I_3)]\}^{1/2}}{(I_2 + I_3) - (I_1 + I_4)}\right\}$$

The intensities detected by pixels (x) of the CCD camera that correspond to one point on the test surface as shown in the figure below:



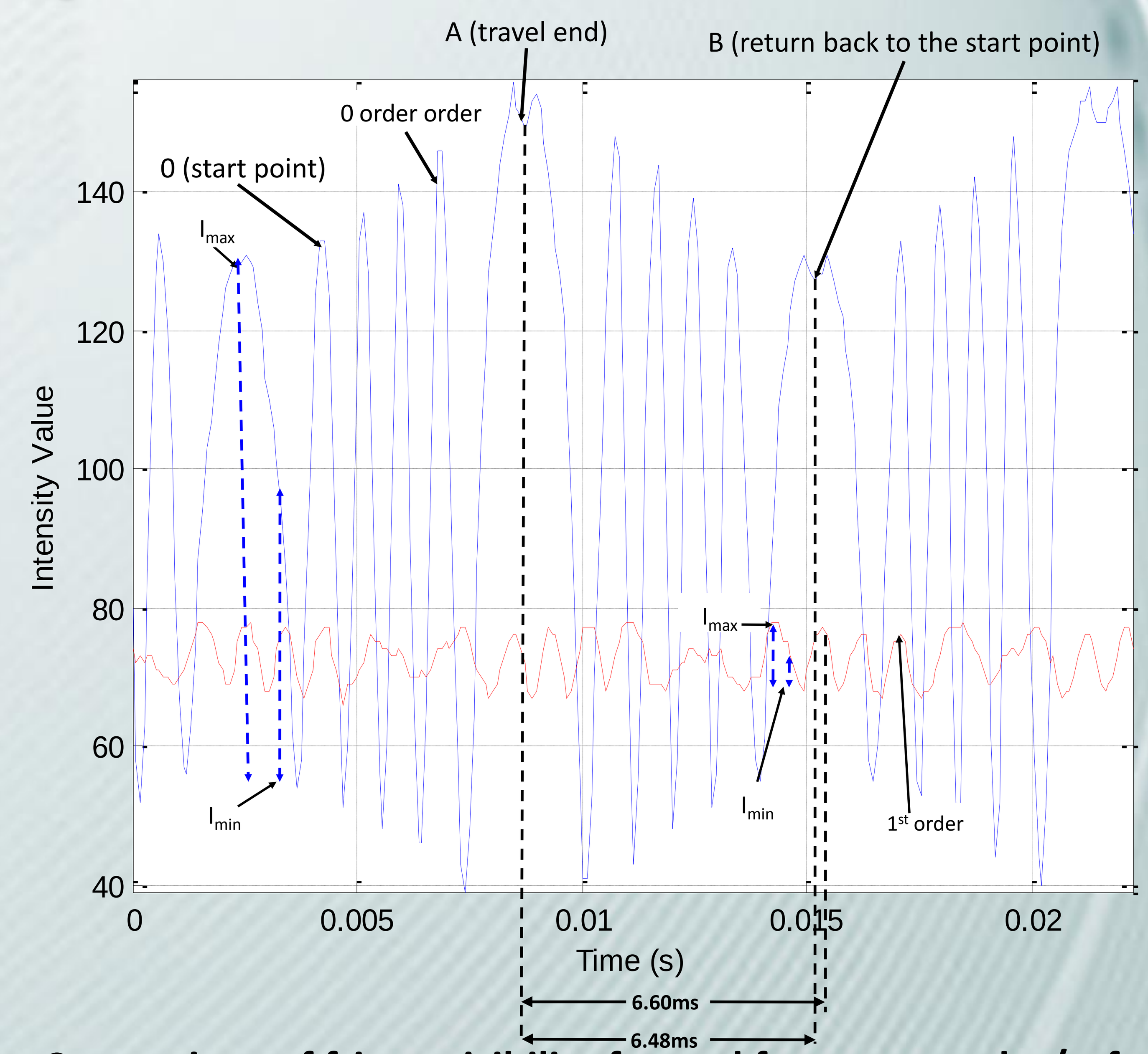
CMOS camera frames

the surface height $h(x)$ can be calculated for any continuous phase distribution:

$$h(x) = \frac{\lambda}{4\pi}\phi(x)$$

Results:

The fringes for 0-order and 1st order have intensity that varies in time as shown in figure below . The computer recorded the intensity $I(x)$ by using successive CMOS camera frames.



Comparison of fringe visibility formed from zero-order/reference (blue) and first order/reference (red) beams.

CONCLUSIONS :

Fringe visibility is a key factor for the effective operation of any interferometer, as it directly affects the signal to noise ratio, and thus the resolution of the instrument. An important aspect of developing this instrument is the optimisation of the fringe visibility formed by the diffracted first order light, returning from the specimen under test, and the reference beam. Other future work will be to develop the spectrometer and phase shifting elements of the experimental setup as well as any required signal processing methodologies.

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