

## **IoP/Photonex 03 Meeting Interferometry as a Measuring Tool**

– **Stoneleigh, Warks. pm Thursday 9 October 2003**

### **ABSTRACTS OF PAPERS TO BE PRESENTED**

Coordinator: Dr A E Gee, Optical Science Lab., Dept of Physics & Astronomy,  
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Paper No 1. *Stroboscopic Interferometry for Active Device Characterisation*  
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White Light Interferometers/Profilers generate 3-dimensional surface images with sub-nanometre vertical resolution. Combining stroboscopic techniques with a Wyko NT1100 Optical Profiler, actuated MEMS devices can be effectively frozen at different points in their motion cycle and 3D device images acquired. The frequencies of the stroboscopic light source are automatically tuned to the device resonant frequency. Movies are generated showing 3D device motion. In and out of plane motion can be characterised together with switching times, settling times and resonant frequencies. This approach also provides the capability for packaged device characterisation and analysis of device performance as a function of temperature and pressure. The technique gives fast non-destructive device analysis. Applications will be presented including micro-actuators, gyros, cantilevers and optical sensors.

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Paper No 2. *Maximising Measurement Range in Multi-Frequency Interferometry*  
C E Towers, D P Towers, J D C Jones  
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We have recently introduced a novel process for optimising the dynamic range obtained in multi-frequency interferometry [1]. The dynamic range is defined as the product of the sub-fringe resolution and the number of fringes that may be ordered without ambiguity. The process is based on an optimisation criterion to utilise the minimum number of fringe frequencies to give the largest possible measurement dynamic range. The technique produces absolute order of interference data from an interferogram for a user-defined reliability in calculating the fringe order data. The algorithms presented have been generalised for  $n$  frequencies.

In this paper, we present a mathematical expression that defines a set of solutions to the optimisation criteria. Each solution defines the frequencies (or wavelengths) at which measurements should be made and from this data the algorithm to yield the fringe order information at the highest frequency, greatest sensitivity, may be found. Each algorithm and solution has different process reliabilities and can therefore be ranked in terms of their overall performance. The algorithms given are generic and are equally applicable to any metrological measurement using interferometry.

The method is demonstrated via a full-field shape measurement system employing a coherent fibre based fringe projector. Such a setup provides easy adjustment of a (synthetic) wavelength by varying the spacing between a pair of coherent sources. Example data is shown using 3, 4 and 5 wavelengths.

Ref.1 C E Towers, D P Towers, J D C Jones, Optimum Frequency Selection in Multi-Frequency Interferometry, Optics Letters, 28, Number 11, 1-3 (2003)

Paper No 3. *Resolution Limitless Optical Interferometer*  
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A new optical interferometer is reported that inherently has no limit in phase resolution. Instead of only using a single return beam of a laser as in a conventional Michelson interferometer, we invented a new beam-folding technique to direct the beam to travel more than one path thereby increasing its sensitivity of the interferometer. In our design, the optical arrangement is simple to construct and the number of paths can be increased to a very large value limited, perhaps, by the noise due to atomic vibrations. What this means is that extremely accurate displacement measurement can be made without resolution restrictions imposed by the wavelength of the laser. We have constructed a 10-path interferometer to track the position of a moving mirror. The resolution resolved with such a system is 10 times better than a conventional Michelson interferometer. That is, one fringe spacing corresponds to a displacement of 31.64 nm with the helium neon laser. With careful design, it is possible to adopt a 100-path system which increases the resolution further to a few nanometers per fringe. With our novel arrangement, optical interferometric techniques may now have a more important role in the area of nanotechnology where spatial resolutions down to picometres can be easily obtained.

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Paper No 4: *Interferometric Measurement of Fibre Optic Parameters*  
L.Cheryl, Data-Pixel, Cran-Gevrier, France &  
C. Peters, Ridgemount Technologies Ltd., Long Crendon, Bucks, HP18 9BB

### **Physical Parameters on Optical Connector End Faces**

In long haul, high bandwidth applications, an optical connector must be able to perfectly interface two optical fibers together in order to have the best optical continuity as possible.

Ideally, both ferrules and fibers come in contact and deform to a certain extent in order to form a neat interface over a central portion of the ferrule with no air gap. Having no air gap around the fiber-core region is essential in order to avoid large index of refraction changes along the optical path, hence avoiding a large amount of optical reflection into the source.

In order to ensure such working conditions, the symmetry of polishing of the ferrules end faces must meet very tight standardized criteria.

For such measuring these parameters, optical monochromatic interferometry in combination with phase shifting is ideally suited.

### **Optical monochromatic interferometry**

Interferometry is a non-contact optical technique whereby the topography of a surface such as a ferrule end-face can be measured with great precision (typically a few nanometers in  $Z$ ).

Quantitative and automated analysis of the surface topography is possible through the use of the well-known « phase-shifting » technique.

### **Phase-shifting technique**

The phase shifting technique is based on the idea that the shape of the surface to be measured is linked to the phase difference at each pixel of the image between the two interfering wave fronts. This technique enables an automation of the measurement process as well as a very high precision in the measurements.

Once the surface shape is calculated numerical analysis enables a fast and precise calculation and analysis of the surface symmetry parameters (i.e. Radius, Apex-offset, Undercut, etc.), which are then automatically compared to pre-set PASS/FAIL criteria as defined in the standards. An automatically generated report then summarizes the results.

### **Conclusion**

This article presented the optical monochromatic interferometry as a powerful tool for quality assurance in the production of optical patch cords. It enables full, fast and automated characterisation of the ferrule optical endface with great precision and ease of use.

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Paper No 5: *Grating encoders of improved resolution using optical interferometry*

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The precision manufacturing industry is heavily reliant on the use of high accuracy positioning and measurement systems in automated processes. The two main devices used for this purpose are the linear encoder and the interferometer, however, it is acknowledged in the manufacturing world that encoders offer several advantages over interferometers in terms of mechanical and environmental robustness as well as cost. Thus for the manufacturing of ~100 nm scale features in semiconductor electronic and photonic devices, there is a requirement for reliable nanometre resolution linear encoders.

The current approach to achieving sub-micron resolution encoders is to manufacture diffraction gratings with features of the order of 1 micron and to apply electronic interpolation; this results in a measurement capability approaching that of interferometers. However the manufacturing of yet smaller period gratings is difficult and costly, especially for large size and highly accurate gratings required for example for 300 mm wafer lithography.

The use of optical processing techniques in conjunction with relatively coarse gratings can however be implemented to realise nanometre resolution encoders; this helps to overcome the manufacturing difficulties especially in the case of long gratings. In particular, the interference of the  $\pm m$  diffracted orders can be used to provide  $2 \times m$  fold optical interpolation, the resulting fringes can subsequently be interpolated electronically. In this article, recent advances in the field of encoder systems are presented, the limitations on the manufacturing of high precision large gratings are discussed and the applicability of such optical processing techniques is analysed.

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Paper No 6. *Advances in homodyne interferometry for position feedback and machine calibration.*

W. Lee

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This presentation describes some of the recent advances in homodyne interferometry. These advances can provide homodyne systems with a number of key performance benefits over conventional heterodyne methods. The presentation will cover the following topics;

- Basic operating principles of homodyne and heterodyne interferometer systems
- Interference fringe generation in a polarised homodyne interferometer system
- A new integrated photo-sensor for interference fringe detection which provides high quality balanced output signals with minimal phase distortion
- Removal of DC drift, background light sensitivity and noise reduction
- High speed, low latency methods for sub-nanometre interpolation and counting of homodyne interferometer signals
- The use of fibre-optic beam delivery in homodyne and heterodyne systems

- Generation of industry standard sine and cosine quadrature position feedback signals for nanometre resolution, high feedrate position feedback with minimal latency
- Typical position feedback and calibration laser interferometer system performance levels

This presentation shows that homodyne systems can now deliver key performance advantages over heterodyne systems.

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Paper No 7: *PhaseCam<sup>TM</sup> Dynamic Interferometer System.*  
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4D Technology Corporation's PhaseCam is a dynamic interferometer system for non-contact surface metrology. The system incorporates an innovative technique to acquire high spatial resolution phase data in as little as 30  $\mu$ sec. This rapid data acquisition enables characterization of moving surfaces and measurement in challenging environments without vibration isolation. Applications for these vacuum compatible and multi-wavelength systems include production floor metrology, aerospace optical system testing, dynamic modal analysis, and ESPI. Phase movies and modal analysis of a resonating surface will be presented.

