Fringe Measurement Techniques

There are two methods of acquiring and measuring fringes for the evaluation and testing of optical surfaces and systems. These are static fringe analysis and phase shift analysis. Since the measurements are acquired using different practical techniques, there will be differences in the results obtained from each method. This application note will highlight how the measurements are made, whilst application note IF002, "Comparison of Fringe Analysis Measurement Statistics" illustrates the differences through some practical measurements.

Static fringe analysis

Static fringe analysis employs a framegrabber to digitally capture fringes produced using standard interferometric techniques and software to analyse the fringes. Simple measurements are illustrated in Figure 1a. Typically, 200-300 digitised points are taken along the fringes using maxima and minima selection routines or fringe centre determination through 'fringe thinning', with results as shown in Figure 1b
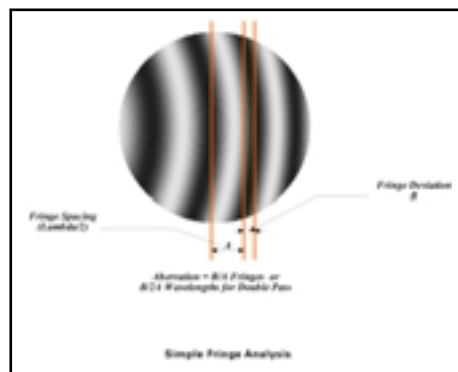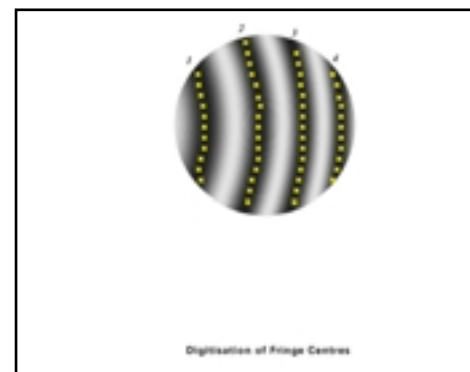

Figure 1a

Figure 1b

Static fringe analysis typically offers an accuracy of around lambda/20 and has the benefit that the software results can be verified manually for simple peak to valley measurements. Software offers far more sophisticated analysis including calculation of the rms wavefront deviation, and other derived functions such as the Strehl Ratio, MTF, Point Spread Function and Encircled Energy Function. To get the most out of this software, users will almost certainly have to intervene to manually shift measurement points that have been misplaced. This may be due to changes of contrast in the interferogram, or points placed midway between a fringe and the edge of the pupil. Static fringe analysis does not provide many data points within the test pupil so that data at other points must always be interpolated or extrapolated. The wavefront shape is often approximated by fitting Zernike coefficients to the available data, enabling the calculation of Seidel Aberrations. This is normally fine for interpolated zones of the test pupil but for large order coefficient fitting, extrapolated data at the edge of the pupil can vary widely from the actual wavefront. Ideally, measurements should always be made over a larger area than required and the aperture reduced in software. Other extrapolation methods such as Spline fitting or simply linear extrapolation will give different results especially for peak to valley measurements. The software can also flag pass/fail criteria based on irregularity, power, peak to valley wavefront value and rms wavefront aberration.

Phase shift analysis

Phase shift analysis can improve accuracy by capturing the fringes with several different phases of the reference beam. This permits calculation of absolute phase for every pixel within the pupil, which increases accuracy and repeatability of measurements to around lambda/100, and allows the sense of the fringe perturbation to be identified as a wavefront retardation or advance. The technique involves using a piezo transducer to move the reference optic by around lambda/2 and utilising dedicated phase shift analysis software to provide full analysis of circular, multiple, low contrast and nulled fringes. The software can be extremely versatile, and can feature masking facilities which enables data to be acquired using a variety of transparent or opaque masks as user-adjustable circles, ellipses, rectangles and polygons. This allows information to be obtained from different parts of the optical surface under test. These display formats can be extended to all measured data, such as aberration fields, MTF and slope field. Results can be displayed directly in terms of ISO and DIN standards. An example screen display from phase analysis is shown in Figure 2.
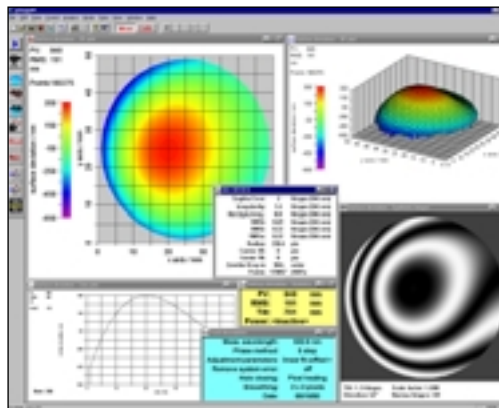
Figure 2

Phase measuring interferometry is the more accurate technique since it offers higher density and uniform sampling of the interference pattern, and better phase resolution. Because the multiple measurements are made at different times, the measurement is more susceptible to vibration than static fringe analysis.

However, despite the sophistication of the software currently available, it should be emphasised that automatic fringe or phase shift analysis is not a deskilled function and an understanding of what is happening in the optical system can still be very important in the interpretation of results. This is of particular importance in infrared applications where diffraction plays a bigger role. Systematic errors may bias the results in one direction. These may be due to misalignment, distortion due to gravity, or distortion due to the mounting technique employed for components. Flimsy components especially should be mounted mimicking their final application mount and orientation.