8 Conclusions

The main conclusions that can be drawn from this piece of work are:

- An approach to Ronchi deflectometry has been proposed, allowing the measurement of surface topographies of both rotationally symmetrical and non-rotationally symmetrical surfaces. The approach is based on geometrical optics principles, so diffractive effects in the ronchigrams should be kept under a threshold value. In the present work this threshold has been fixed using the shear of the first diffracted order, which should be kept under T/8mm, T being the period of the considered ruling. A 50lpi ruling (T=0.508mm) was used in all the experiments.

- A Ronchi deflectometry experimental setup allowing the measurement of topographies and radii of curvature was designed, built and calibrated. The movement of the Ronchi ruling has been fully motorized in order to provide remote positioning of the ruling reliably and repetitively.

- Two sets of software algorithms were developed in C language. The first set allows remote motor control, data transfer between computers and ronchigram acquisition; it is intended to provide serial and parallel port communication of all the computers involved in the experimental setup. These algorithms were combined in order to perform in accordance with orders from a single master computer. The second set of software algorithms was developed in order to perform data processing of the acquired ronchigrams. These data processing algorithms are designed to measure the local normals of the sample surface at a set of known points, and to obtain the surface topography, which will lead to the measurement of radii of curvature through two-dimensional and three-dimensional fitting.

- Improvements in the sampling of the surface obtained using the Ronchi test were highly desirable, as under classic Ronchi setups only around one hundred data points are available in the sample surface. However, this improvement cannot be achieved by increasing the frequency of the Ronchi ruling, as important diffractive effects appear for frequencies over 50lpi (T=0.508mm).

- A phase-shifting technique allowing phase-shifting procedures to be applied to non-sinusoidal signals through selection of the most important terms of its Fourier series has been put forward. However, the signal obtained using the Ronchi test is spatially unstable, as the diffractive effects at the edges of the lines of the test are dependent on the curvature of the wavefront impinging on the Ronchi ruling. This entails significant differences in the shape of the signal measured in nearby pixels as the phase shifting process is carried on, which prevent the obtained signal from applying phase-shifting schemes to it, as the signal would vary throughout the phase-shifted data acquisition procedures.

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- The desired increase in the number of sampled points on the surface with no increase in the visible diffractive effects has been accomplished by combining slightly displaced ronchigrams. This was achieved through micrometric displacements of the encoder motors present on the Ronchi plane, and led us to call the technique "microstepping". The intensive sampling thus obtained needs to be limited so that the information to be processed is kept under reasonable limits.

- Six spherical concave surfaces of common ophthalmic lenses were successfully tested, allowing the measurement of radius of curvature values and surface topographies at three different positions of the sample, confirming the roughness of the technique and the calibration of the experimental setup.

- Measurement of non-rotationally symmetrical surfaces has been performed for the first time, to our knowledge. Six toroidal concave surfaces of common ophthalmic lenses were measured in twelve different positions each (three different distances from the Ronchi ruling to the surface by four different tilts around the surface symmetry axis), showing the ability of the technique to perform correct measurements regardless of the position and orientation of the sample.

- Radius of curvature measurements in both spherical and toroidal samples were measured using two-dimensional and three-dimensional fitting procedures. Both microstepped and non-microstepped results give very similar results in the measurement of radii of curvature. The measurements obtained are consistent with the reference values available through radioscopic measurements.

- Topographic measurements in both spherical and toroidal samples allow the surface residuals to be extracted from the best fit surface. Sub-micrometric surface features have been repetitively measured in microstepped measurements. In toroidal samples, these features have been shown to rotate when the surface is rotated. Non-microstepped measurements give low quality topographic measurements due to the small number of data points involved.

- When performing toroidal surface measurements, the equivalence of toroidal and spherocylindrical surface geometries has been proven under our experimental conditions, allowing the use of the spherocylindrical surface expression in order to perform three-dimensional fitting procedures on toroidal samples.

Future works

As the final section of the exposition, we will present some of the future objectives to be pursued starting from the available results.

- As a natural extension of the present work, the measurement of progressive ophthalmic surfaces will be accomplished, either from lenses or from moulds for organic lens manufacturing.

- The development of some improvements in the present experimental setup will lead to extending the range of measured surfaces, allowing a wider range of surface curvatures to be measured. Software algorithms may also be improved by using state of the art fringe detection and measurement techniques, together with improved integration algorithms, which would lead the technique to much quicker measurements.

- Additional work will be done to develop variations to the technique to allow convex surface measurements, thus improving the technique's versatility for all sorts of surfaces.

- The application of the technique to the measurement of samples other than ophthalmic lenses' surfaces is also being developed. This includes a wide range of measured components which include reflective surfaces: car tail and front light reflectors, telescope primary mirrors, precision measurements of metal surfaces, etc.

8.4