Interferometric Homogeneity Test Using Adaptive Frequency Comb Illumination

Klaus Mantel*, Johannes Schwider**

*Max Planck Institute for the Science of Light, Erlangen
**Institute of Optics, Information, and Photonics, University of Erlangen-Nürnberg

mailto:Klaus.Mantel@mpl.mpg.de

To measure the homogeneity of glass plates, we illuminate a Fizeau interferometer with an adaptive frequency comb. In this way, the multiple beam structure of the interference phenomenon, which results from the nested cavities, can be avoided, and the signals from the different resonators can be easily separated. Moreover, linear homogeneity variations can be measured.

1 Introduction

Homogeneity tests require the measurement of a glass sample both in reflected as well as in transmitted light in order to separate the homogeneity variations from the geometric thickness variations of the sample. Various measuring processes combining the reflected and transmitted light measurements have been described [1-4]. For the measurement in transmitted light, the sample has to be inserted into an interferometric setup which leads to the formation of nested cavities. For laser illumination, the four boundaries of the glass sample and the two boundaries of the interferometer cavity give rise to six interference terms which form a complicated multiple beam phenomenon (see Fig. 1).

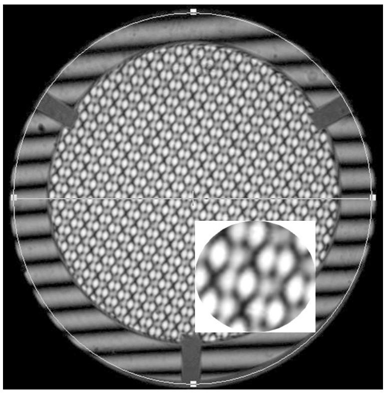

Fig. 1 *Multiple beam interference (with blow-up) in the central region where the specimen is located, contrasted against two beam interference in the rim region.*

If the cavity lengths are prime to each other it is possible to separate the single interference patterns from each other by using specially designed light sources. For instance, a tunable laser source may be applied [5]. In this work, we use a superluminescence diode (SLD) in combination with a tunable Fabry-Perot filter (FP) to generate a frequency comb illumination for a Fizeau interferometer [6]. By adjusting the optical path difference of the FP to the optical path difference of the selected cavity, only the interference fringes for this cavity will become visible and can be evaluated.

2 Setup

Figure 2 shows the interferometric setup. The SLD has a central wavelength of $\lambda_0 = 685$ nm, with a wavelength range of $\Delta\lambda$= 8 nm. The FP is combined with a length measuring unit to allow a convenient adjustment of the FP cavity length. A piezo transducer allows the use of phase shifting techniques by shifting one of the FP plates, even for rigid glass plates.

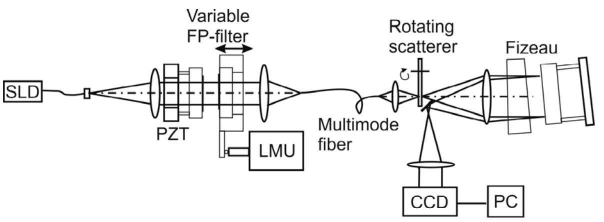

Fig. 2 *Experimental setup. Light source space (left) and Fizeau space (right) are connected by a multimode fiber.*

A rotating scatterer reduces the spatial coherence of the light source, giving rise to smooth interferograms. The specimen, which is placed between the Fizeau plates, is sharply imaged onto the detector. Light source space and Fizeau space are connected by a multimode fiber, but otherwise decoupled, so that a misalignment of the FP only leads to a loss in visibility.

3 Homogeneity Testing

A minimum set of three measurements is needed to determine the refractive index variation of the glass sample [1], see Fig. 3. By combining measurements of the specimen inside and outside the interferometer, the separation of the homogeneity variations from the geometrical thickness variations (as indicated by t_p) is achieved. Furthermore, a measurement of the empty interferometer eliminates phase contributions from the Fizeau plates, giving the homogeneity variations in an absolute manner.

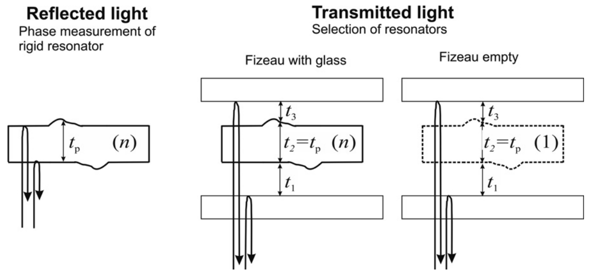

Fig. 3 Minimum set of measurements for the homogeneity test.

Owing to the frequency comb illumination, another combination of measurements is possible, which could not be realized with conventional light sources. Figure 4 shows the cavities used. Again, the systematic errors of the setup are eliminated.

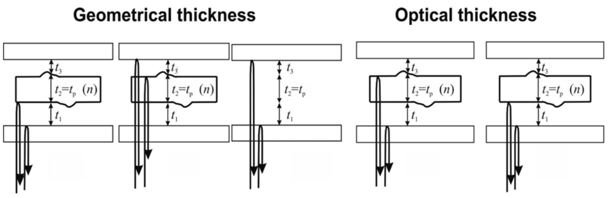

Fig. 4 Alternative set of measurements for the homogeneity test.

4 Tracing Tilt

In our setup, the reference plate of the Fizeau cavity has to be readjusted after the removal of the specimen. This makes the determination of linear homogeneity variations difficult, since linear functions are ambiguous in Fizeau setups. To monitor the alignment state of the reference plate, the outer rim region of the interferogram is used, see Fig. 5.

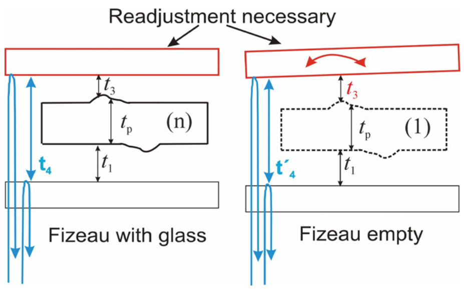

Fig. 5 The rim region of the reference plates is used to trace the tilt.

A change in the alignment state of the reference plate manifests itself in a linear phase function in the rim region, which can be evaluated so that the corresponding homogeneity measurements can be corrected accordingly. Since drift processes cannot be completely excluded, we believe that such a tracing procedure is necessary in any case.

5 Preliminary Experimental Results

The sample under test showed a thickness of 11.33 mm, a diameter of 45 mm, and a nominal refractive index of n = 1.51347. Figure 6 presents the homogeneity variation of the sample, measured with the reflected/transmitted light scheme of Fig. 3, represented by a Zernike polynomial of degree 16. For practical reasons, the linear function has not been determined.

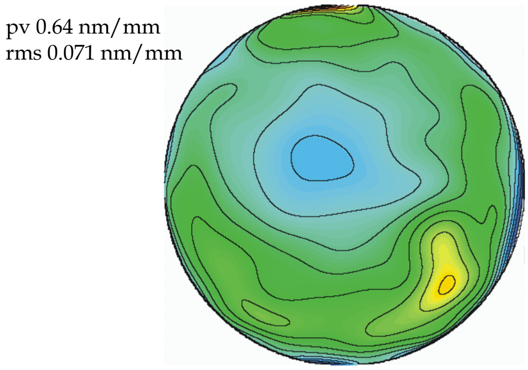

Fig. 6 Measurement result reflected/transmitted light, Zernike fit (degree 16).

The reproducibility of the procedure is of the order of 0.2 nm/mm pv and 0.03 nm/mm rms. A comparison of the reflected/transmitted light scheme with the geometrical/optical thickness scheme shows agreement within the reproducibility.

6 Conclusions

In this work, we presented a novel approach to the homogeneity testing of plane glass samples. A frequency comb light source allows the arbitrary separation of cavities, enabling different measurement schemes, some of them previously impossible with conventional light sources. Linear homogeneity variations can also be detected, preferably if the tilt status of the Fizeau reference plate is monitored.

References

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