Spatial coherence profilometry

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We present an optical interferometric sensor that measures the shape of the surface of an object. The principle of the measurement method is based on spatial coherence. Unlike to the white-light interferometry, the described method does not require a broadband light source, the interferometer is illuminated by a quasi-monochromatic extended light source.

1 Introduction

The utilization of the spatial coherence brings some advantages. The light source may be laser, the sensor does not suffer from dispersion [1], and the mechanical movement typical for white-light interferometry can be omitted. If a Michelson interferometer is fed by a broadband light source, a short correlogram develops. If the light source is quasi-monochromatic but extended one, a similar effect is achieved [2], [3], [4], [5].

2 Principle of the method

The setup is shown in Fig. 1. The light from He-Ne laser illuminates a rotating ground-glass plate which serves as a light source for a Michelson interferometer.

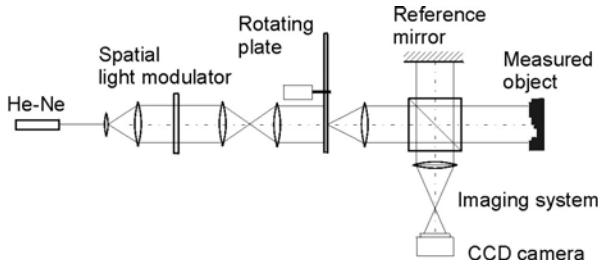

Fig. 1 *Setup of the spatial coherence profilometry.*

The fact that spatial coherence is used offers further possibilities. If the extended light source is not only a uniformly illuminated disc but has a form of concentric circles, as shown in Fig. 2, then the interference is observable not only with the zero path difference but also for a certain nonzero path difference *d*. This path difference *d* is connected with the density of circles in the light source. In this way the density of circles can be calibrated in the units of distance.

A spatial light modulator inserted into the light path as shown in Fig. 1, allows to generate the concentric circles and to change their density. In this way the mechanical movement of the object can be replaced by changing the density of concentric circles.

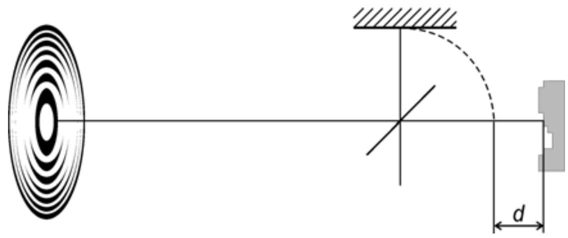

Fig. 2 *The influence of the structure of the light source.*

3 Results of the measurement

The results of the height profile measurements are shown in following figures. In Fig. 3, the intensity at one camera pixel is plotted as function of the density of circles when a mirror was used as a measured object. From the maximum of the measured curve, the distance between measured surface and a reference plane is determined as the arrow in Fig. 3 indicates.

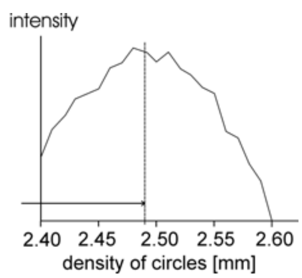

Fig. 3 *Intensity at one camera pixel as function of the density of circles.*

Such procedure is accomplished for every pixel and the height profile is measured. The cross-section of the height profile is shown in Fig. 4.

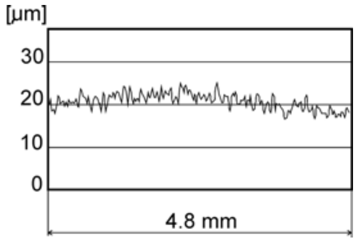

Fig. 4 *Cross-section of the measured height profile of the mirror.*

It is apparent from Fig. 4 that the measurement uncertainty is larger than that of white-light interferometry. This is caused by the form of the coherence function (the utilized light source is equivalent to a light source with a spectral width of 1.5 nm) and by the nonideal response of the spatial light modulator. Figure 5 shows measured height profile of Chinese coin.

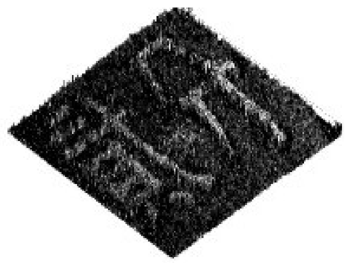

Fig. 5 *Measured height profile of a Chinese coin.*

4 Modification of the method

One interesting modification of the described system is to illuminate the Michelson interferometer by a homogenous extended light source. In this case the object must be moved. Such a system shown in Fig. 6 renders an analogy to white-light interferometer.

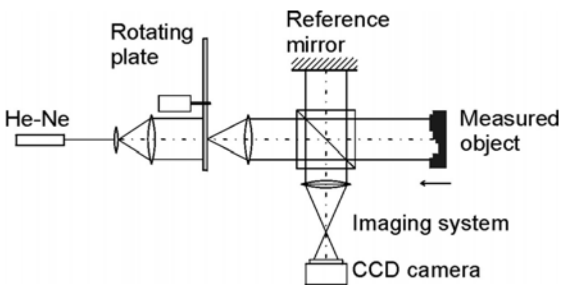

Fig. 6 *Modified setup of the spatial coherence profilometry.*

The correlogram of this system is shown in Fig. 7. It is apparent that the correlogram is longer than that of the white-light interferometry as it was mentioned above. The result of the measurement of the height profile by the modified method is presented in Fig. 8. Height profile of a mirror and of a part of the European 1 cent coin was measured.

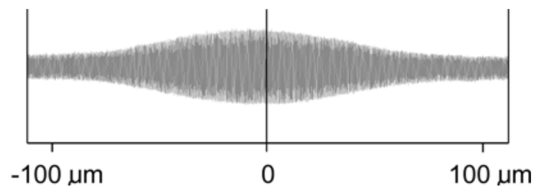

Fig. 7 *Correlogram of the modified system.*

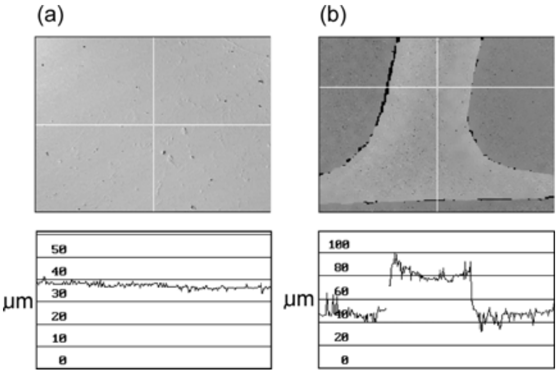

Fig. 8 *Measured height profile (above) and the cross-section of the height profile along the horizontal line (below) for (a) mirror and (b) European 1-cent coin.*

5 Conclusion

The results of the measurement confirm that the spatial coherence can be used for the profilometry. Its main advantage of this concept is that laser can be used as the light source of the interferometer.

References

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