Design and Construction of a Laser Scanning Microscope for Surface Metrology

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Abstract

Laser Scanning Microscopy (LSM) has been used for a long time in the field of surface measurement and is today one of the most promising technologies for fast, accurate and repeatable metrology. This article presents the design and construction of a laser scanning microscope based on autofocus for high resolution surface metrology and for optical aberrations analysis. The developed system is introduced and the first experimental results and measurements are presented and discussed.

1 Introduction

Laser scanning microscopy is basically a technique for increasing contrast and resolution in optical imaging systems through the rejection of out-of-focus light [1, 2]. Images are acquired point-by-point and reconstructed with a computer, allowing optical sectioning and three-dimensional reconstructions of complex objects. Its first concepts were developed in 1957 by Marvin Minsky [3] and it is today an established and widely used technology [1, 2].

To avoid optical aberrations, laser scanning microscopes are normally built with complex and heavy optics [1, 4], what leads to costly systems with limited dynamics. The developed laser microscope (Fig. 1 and 2) aims at the development of a simple and versatile microscope for surface metrology and shall in the future offer an experimental set-up for the analysis of errors induced by optical aberrations. With that, instead of using complex optical systems to eliminate optical aberrations, simple optics can be used and their errors computationally corrected.

2 System Design

The constructed laser scanning microscope is based on the lateral scanning of samples through the deflection of a laser beam with a 2D tilting mirror, and on a depth scanning through the displacement of the objective with the help of an astigmatic autofocus sensor [4, 5].

Figure 1 illustrates the system configuration and its components. The system uses a hologram laser unit that generates a 650nm beam. The laser beam is collimated and then deflected with a 2D tilting mirror. The deflected laser is then focused on the sample through the objective. The laser reflects on the sample and returns through the objective to the mirror where it is once again reflected back into the hologram unit.

The lateral position of the scanning point is determined by the mirror angles and its depth by the displacement of the objective and the use of an autofocus procedure.

Autofocus is a feature that allows optical systems to always work in focus (Fig. 1). In the designed system, this is accomplished through the translation of the objective lens along the optical axis, and, by keeping track of this translation, it is possible to determine the depth of the point where the light beam reflects.

The used focus sensor is based on a hologram laser unit that works as a zero sensor [5]. It enables the determination of the system's focal point through an analysis of the reflected light and of the formed focal point image (Fig. 1).

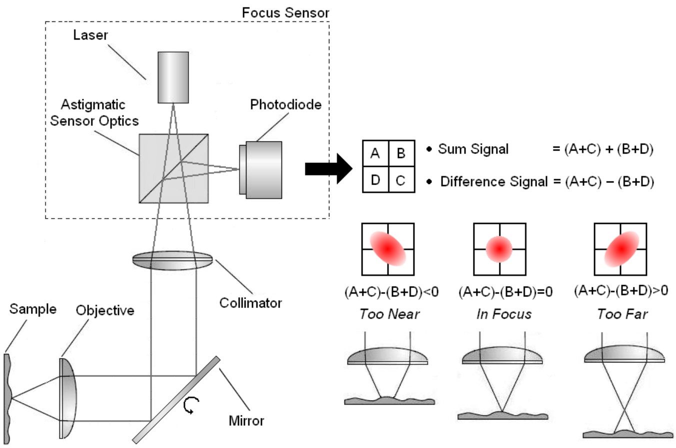

Figure 1: System Configuration and Autofocus Sensor

The scanning system (Fig. 2) was designed for surface metrology in millimeter range with high resolution. It uses an epiplan-neofluar objective with a focus length of 8mm and a working distance of 2mm and a tilting mirror platform based on piezo actuators. The translation of the objective is also done with piezo actuators.

The tilting mirror allows a movement of ±25mrad around two fixed perpendicular axes with a resolution of 5µrad, what offers a lateral scanning area of approximately 0.8mm x 0.8mm and a step width of 40nm. The translation stage allows a linear movement of 100µm of the objective with a resolution of 0.7nm.

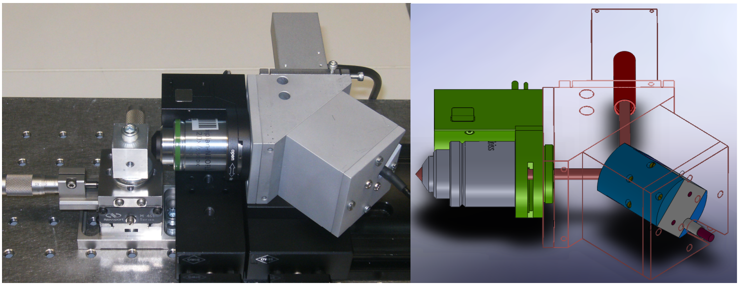

Figure 2: Developed Laser Scanning Microscope

3 Experimental Measurements

After the construction of the laser scanning microscope, the first experimental measurement was a plane mirror (Fig. 3a). These measurements are a first qualitative proof of the system's functionality.

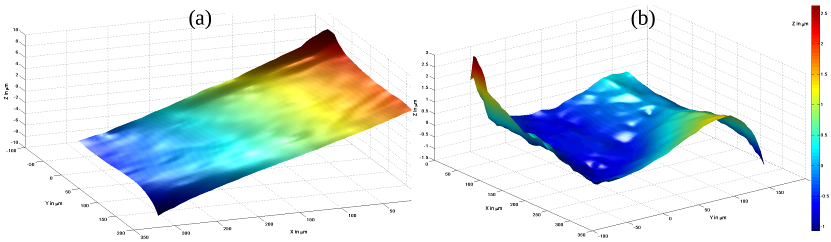

Figure 3: Measured Plane Mirror

The measured surface can then be used to observe and evaluate the system's field curvature. When the mirror is regarded as a perfect plane, then all deviations are due to the measuring system. Figure 3b shows the focus surface of the system with the used objective. As expected, the system presents a curvature caused by the suboptimal optical design. The focal surface is symmetrical and has a deviation of approximately 3.5µm. For implementing an error correction strategy it is vital to know the focal surface curvature. Therefore further investigations on the obtained surface are still needed, especially regarding repeatability of the measured deviations.

To illustrate the system capabilities and observe its performance under different situations, a series of samples where also measured. Two are shown in Fig. 4.

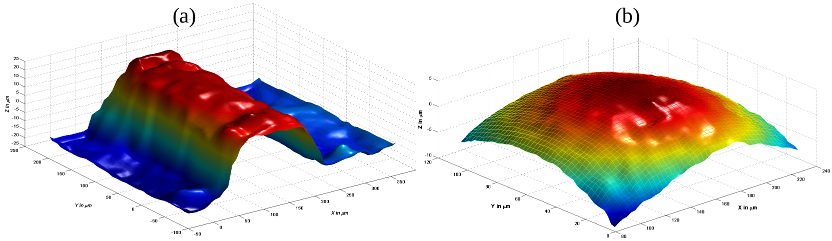

Figure 4: (a) Measuring of a Stamped Structure on a Coin Surface and (b) Measuring of a Steal Sphere with Ø=1mm

Both samples offer a known geometry, but roughness, surface defects and eventual shape deviations are unknown, so that the results serve for qualitative purposes only.

4 Conclusion

In this paper a simple and versatile microscope for surface metrology was presented and described. Its functionality was demonstrated through a series of experimental measurements in different samples and its field curvature experimentally determined. Future work includes a deeper analysis of the developed microscope, the analysis of the optical aberrations and error sources in the system and the development of correction strategies for these errors.

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