Birefringent Scatterplate Phase Shifting Interferometer

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ABSTRACT

A new phase shifting scatterplate interferometer is realized by exploiting the polarization characteristics of a birefringent scatterplate. The advantages of this design are that it does not require any optical components to be placed near the surface under test and, the hot spot and background intensity, which are inherent to scatterplate interferometers, are eliminated. The theory of the interferometer is presented.

1. INTRODUCTION

Interferometers can have fantastic surface height measurement accuracy. Generally, in a phase shifting interferometer environmental effects limit the measurement accuracy and repeatability. One way of reducing the sensitivity to these effects, is to use a common-path interferometer such as the scatterplate interferometer. Unfortunately, the same feature that makes common-path interferometers attractive also makes them difficult to phase shift. The test and reference beams traverse the same path making them difficult to separate. The challenge is to produce a variable phase difference between the two beams. In the case of the scatterplate interferometer two research groups have met this challenge: Huang et al and Su et al [1,2]. Both methods exploit polarization to separate the test and reference beams by placing a quarter wave plate near the test surface. The method presented here also uses polarization to achieve the goal of phase shifting. However, it does not require optics to be placed near the test surface, allowing the interferometer to be conveniently packaged. In addition, the hot spot produced by the beam that traverses directly through the scatter plate on both passes, is eliminated. As a result, there is no need to block out the hot spot when data is collected, making phase shifting less complicated.

2. QUALITATIVE THEORY

Before the operation of the interferometer as a whole can be understood it is necessary to independently examine the workings of the birefringent scatterplate shown in figure 1. The appropriate aperiodic pattern with inversion symmetry is etched into a calcite retarder using reactive ion etching. An index matching oil chosen to match the extraordinary index of the calcite is then pressed between the calcite and a glass slide. The end result is that light polarized along the optical axis of the crystal does not see the rough surface and passes directly through the scatterplate, whereas light polarized perpendicular to the optical axis is scattered. This is the property that will allow the interferometer to be phase shifted without placing a quarter wave plate near the test surface.

It is instructive to examine the operation of this phase shifting scatterplate interferometer qualitatively. The schematic diagram of the interferometer is shown in figure 1. If the polarization elements such as the wave plates and polarizers are removed, it is a conventional scatterplate interferometer discussed at length by several authors [3,4,5]. Polarizer P passes linearly polarized light oriented at 45° with respect to the optical axis of the calcite scatterplate SP. Therefore, the polarization components parallel to the optical axis of the crystal and orthogonal to it have equal amplitudes. The component parallel to the optical axis will see the extraordinary index of the crystal and the perpendicular component will see the ordinary index. An electro-optic modulator (EOM) produces a variable phase difference between the two orthogonal components of polarization and spatial filter SF removes the high spatial frequencies from the beam. The "point" source created by the spatial filter is imaged onto mirror M2, the surface under test. The scatterplate is located at the center of curvature of mirror M2 and scatters only the component of the beam which, is polarized perpendicular to the optical axis of the crystal. The parallel component passes through the scatterplate and focuses on mirror M2 becoming the reference beam. Both the test and reference beams pass through quarter wave plate Q, whose fast axis is aligned at 45° to the crystalline axis of the scatterplate, twice producing a 90° rotation in the polarization of each. As a result, on the second pass through the

Part of the 18th Congress of the International Commission for Optics: Optics for the Next Millennium
San Francisco, California • August 1999 SPIE Vol. 3749 • 0277-786X/99/$10.00

scatterplate the reference beam is scattered and the test beam passes directly through. Notice that there are no direct-direct or scattered-scattered beams, thus eliminating the hot spot and background intensity respectively. In addition, the reference and test beams are distinguished by having orthogonal polarization orientations. The inversion symmetry designed into the scatterplate maintains the coherence necessary to observe interference. Lens L2 images mirror M2 onto the observation plane through analyzer AN, which serves to extract the parallel components of the test and reference beams for observation of interference fringes. Consequently, the interference fringes can be phase shifted by adjusting the electro-optic modulator.

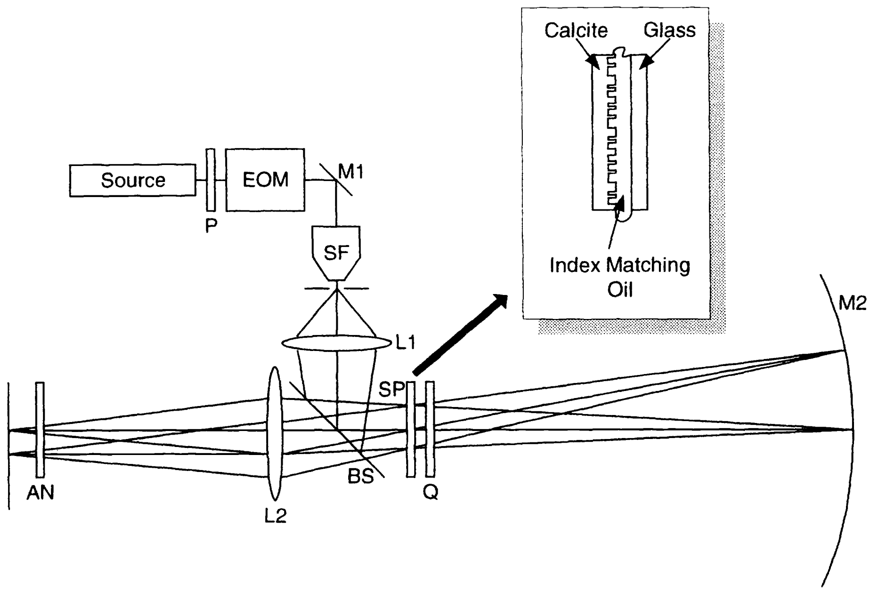

Figure 1: Phase shifting scatterplate interferometer using a birefringent scatterplate

3. CONCLUSION

A new phase shifting scatterplate interferometer is presented which uses a linearly birefringent scatterplate. The design has two distinct advantages. It does not require optics to be placed near the test mirror and the background intensity and hot spot, which are characteristic of more conventional scatterplate interferometers, are eliminated. Placing the quarter wave plate near the scatterplate allows the interferometer to be conveniently packaged making the system easier to use. In addition, complications based on the size and alignment of the quarter wave plate are avoided. Eliminating the hot spot makes phase shifting less complicated because there is no need to block out the hot spot when data is collected.

ACKNOWLEDGMENTS:

The calcite retarders for this research were provided by Optics For Research Inc.

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