In situ surface roughness measurement

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Abstract

Measuring surface roughness or finish is one the more difficult measurements to make on large mirrors or lenses. In general, the measurand is too large to place on the stage of a surface-roughness measuring microscope, so an indirect measurement must be made using replicas. The long mechanical path between interference objective and sample on traditional microscope based profilers make these instruments prone to vibration due to the environment which disturbs temporal phase shifting measurements.

Introduction

We introduce a new surface roughness measuring topographer specifically designed for large samples such as astronomical mirrors. However, the topographer is also capable of measuring samples as small as 12 mm in diameter when it is inverted. After briefly discussing the short-comings of using replicas, we describe the MicroFinish Topographer (MFT) and its features. We then give examples of data from both large and small samples taken without the aid of any vibration isolation.

Traditional roughness measurement of large optics

The traditional method of obtaining surface roughness measurements from large optics is to make replicas of the surface and then measure the replicas on standard roughness measuring microscopes. However, there are numerous drawbacks associated with getting good replicas. It takes times and skill to make replicas, particularly on steeply curved mirrors because a dam must be made to contain the replicating compound. In addition, the residue from the compound is difficult to remove from the surface and may lead to coating adhesion issues.

MicroFinish Topographer design

The MicroFinish Topographer (MFT) is designed to sit directly on the surface being tested via three nylon balls (see Fig. 1). A set of fine adjustment screws directly over the balls allow adjustment for tip, tilt and focus. The heart of the MFT is a Point Source Microscope (PSM)[1] that mates with the housing containing the adjustment screws. A PZT actuator and 10x Mirau objective take the place of a standard bright field objective on the PSM. The PZT is driven by 4Sight software[2] which also analyzes the fringe data produced by the Mirau objective.

Because the MFT sits directly on the surface being tested, any vibration perpendicular to the surface being tested is transferred directly to the compact and stiff MFT so the relative distance between the Mirau objective and the surface remain constant to the nm level. Another advantage of this agreement is that once fringes are found and fluffed out, the MFT may be slid on the balls with almost no change in the fringe pattern. This makes it easy to take roughness measurements in several areas of the surface in a minimum of time.

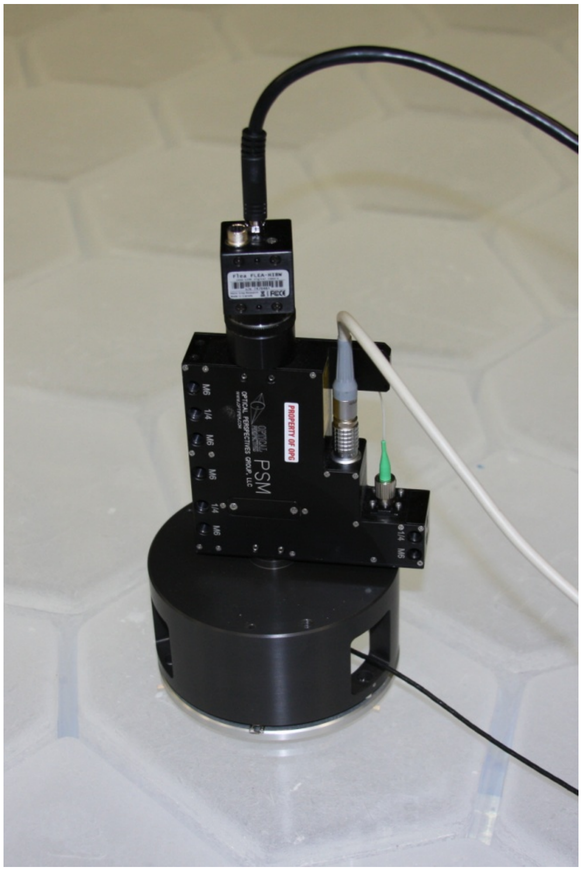

Fig. 1 The MFT sitting on the 8.4 m Giant Magellen Telescope segment being polished at the SOML. Photo credit, John Davis, SOML

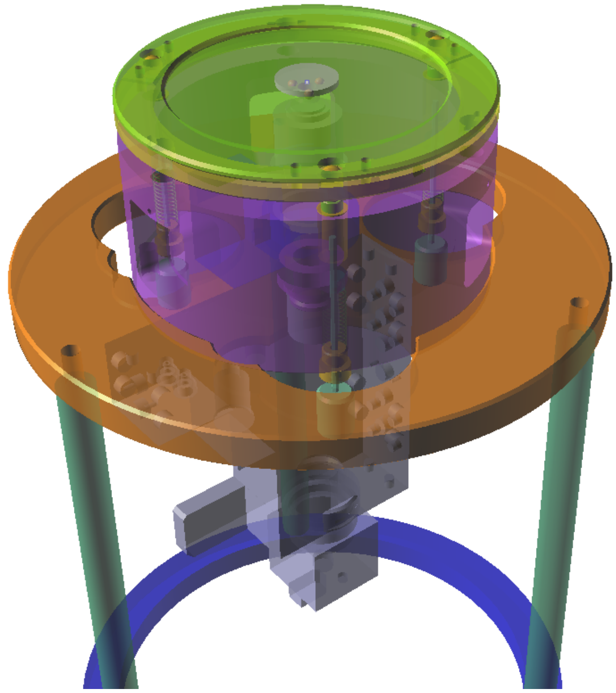

Fig. 2 The inverted MFT with a 20 mm diameter sample sitting on 3 balls above the Mirau objective. As with the configuration in Fig. 1, the three adjustment screws permit adjusting the sample in tip, tilt and focus.

By adding a support stand as in Fig. 2, the MFT can be inverted and samples as small as 12 mm in diameter can be measured. The green support plate in Fig. 2 has a series of balls on larger bolt circles with increasing heights as the bolt circle diameter increases so there is no size sample that cannot be measured with the MFT. Another advantage with this approach to small samples is that one sample of the same diameter after another can be set on the three balls and have the fringes nearly perfectly aligned for the next measurement independent of the sample thickness or wedge.

MFT performance

Initial measurements with the MFT were made on a laboratory work bench under typical workday conditions with a desktop computer sitting within 300 mm of the test. A fire-polished sample was used that had an average roughness of about 0.55 nm rms for repeatability measurements. The standard deviation of individual measurements from the mean of 5 was .05 nm rms. An example of the average data is shown in Fig. 3.

At the other end of the spectrum, a dirty polished glass sample with a high spatial frequency roughness was measured on the inverted MFT to give an average of 6.95 nm rms. In spite of a makeshift stand to hold the MFT inverted the standard deviation of the differences from the mean of 10 measurements was 0.22 nm rms. The mean surface is shown in Fig. 4.

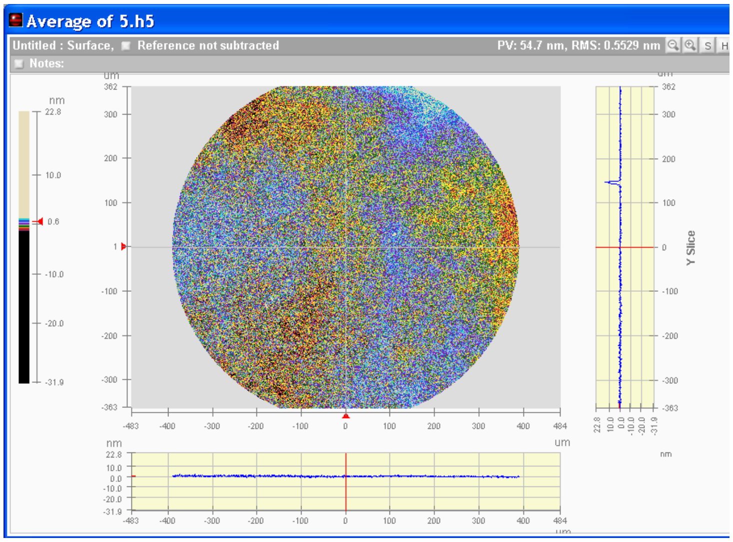

Fig. 3 The average of 5 measurements of a 0.55 nm rms surface measured with the MFT sitting on the surface. The standard deviation of the differences from the mean of 5 was 0.05 nm rms.

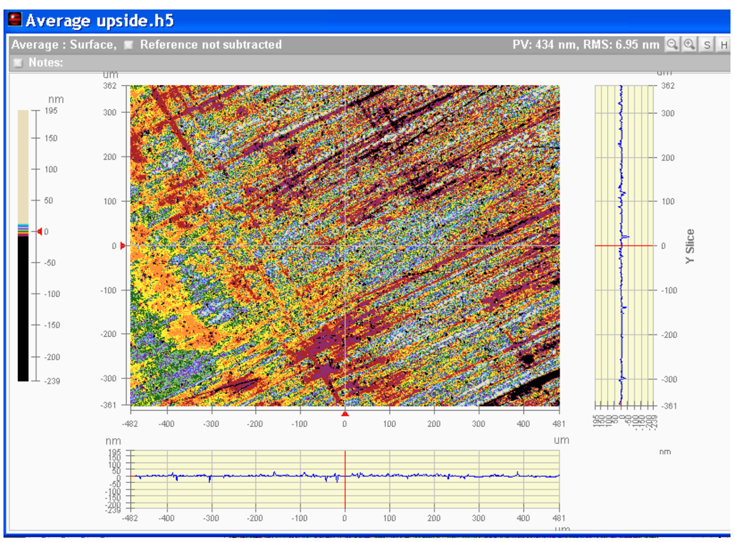

Fig. 4 The average of 10 measurements of a dirty polished glass surface measured at 6.95 nm rms on the inverted MFT. Even though the surface had a high spatial frequency structure the standard deviation between differences from the mean was 0.22 nm rms.

Conclusion

We have shown that a simple interferometric surface roughness interferometer can give reliable measurements without the need for vibration isolation because of careful attention to the kinematic design of the mount that couples the MFT to the surface it is measuring. Further, the MFT is not limited to roughness measurement as the PSM can be easily removed from the mount to be used for alignment, autocollimation and imaging.

References

[1] R. E. Parks, “Versatile Autostigmatic Microscope”, Proc SPIE, 6289, (2006)
[2] 4Sight© is an interferometric analysis software package sold by 4D Technology, Tucson, AZ