Methods of Optically Profiling Surfaces

Kumar Arumugam, Alex Caviness, Farzaneh Shabahang, Tara Newman, Dr. Stuart Smith, Dr. Tsing-Hua Her
Center for Precision Metrology, University of North Carolina at Charlotte

UNC CHARLOTTE

Introduction

This study revisits known methods for determining surface topography on engineering surfaces using optical reflection. Specifically examined are methods that illuminate a localized region and measure the subsequent reflection. Figure 1 shows the three profiling methods being studied. Two are interferometric and one uses confocal measurement principals.

The motivation of this study is to determine the limits of performance for measurement on engineering surfaces created by various manufacturing processes.

Schematic of Three Methods

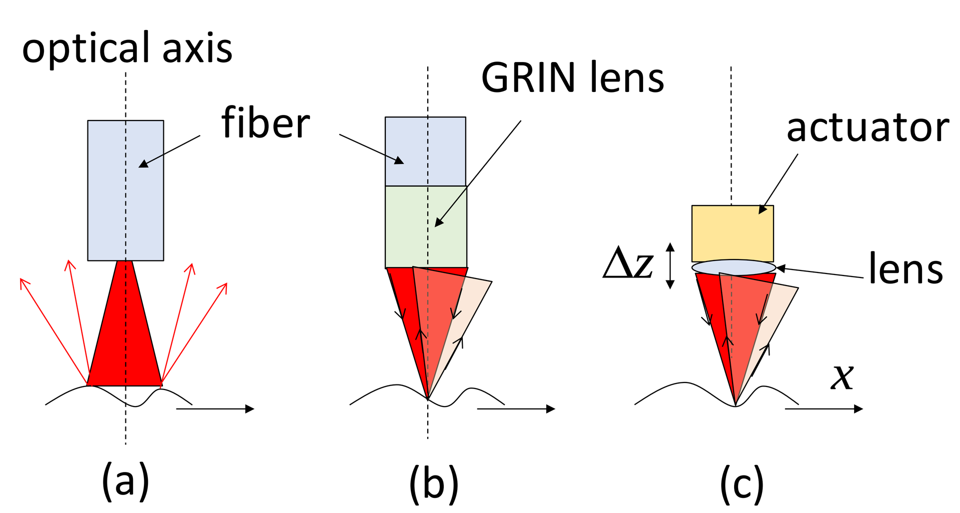

Figure 1: (a) An External cavity Fiber Fabry-Perot Interferometer (EFFPI) with a bare fiber tip emitting a diverging beam [1,2] (b) EFFPI with a Gradient Refractive Index lens attached to the tip of fiber emitting a converging beam (c) piezo-electrically actuated lens in a focus detecting probe emitting a converging beam

1. Interferometric Method

Figure 2 shows a schematic of EFFPI, which utilizes a frequency modulated laser source coupled through a 2X2 fiber to determine surface height variation. One configuration of this technique uses a bare fiber tip causing divergence of the beam. A diverging beam has the benefit of measuring greater surface height deviation ("range"), but is limited by increasing spot size (i.e. lateral resolution) with fiber-surface separation. Results of this configuration are explained in Section 1.2

A second configuration uses the same principle, but focuses the beam using a GRIN lens. This has the benefit of a smaller spot size and greater working distance, but the range is limited by Rayleigh length.

1.1 Experimental facility - External cavity Fiber based Fabry-Perot Interferometry

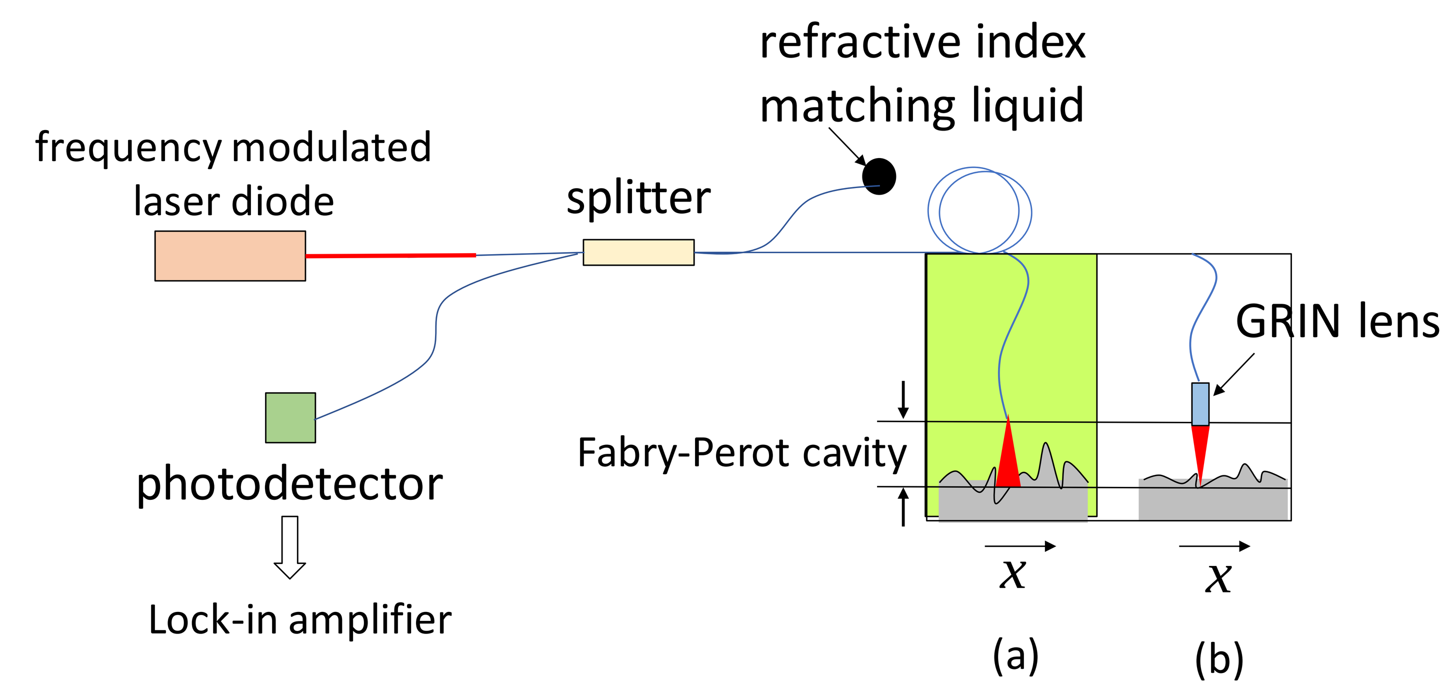

Figure 2: Schematic of two modes of operation of Fabry-Perot interferometer
(a) bare fiber tip causing a diverging beam (b) GRIN lens causing a converging beam

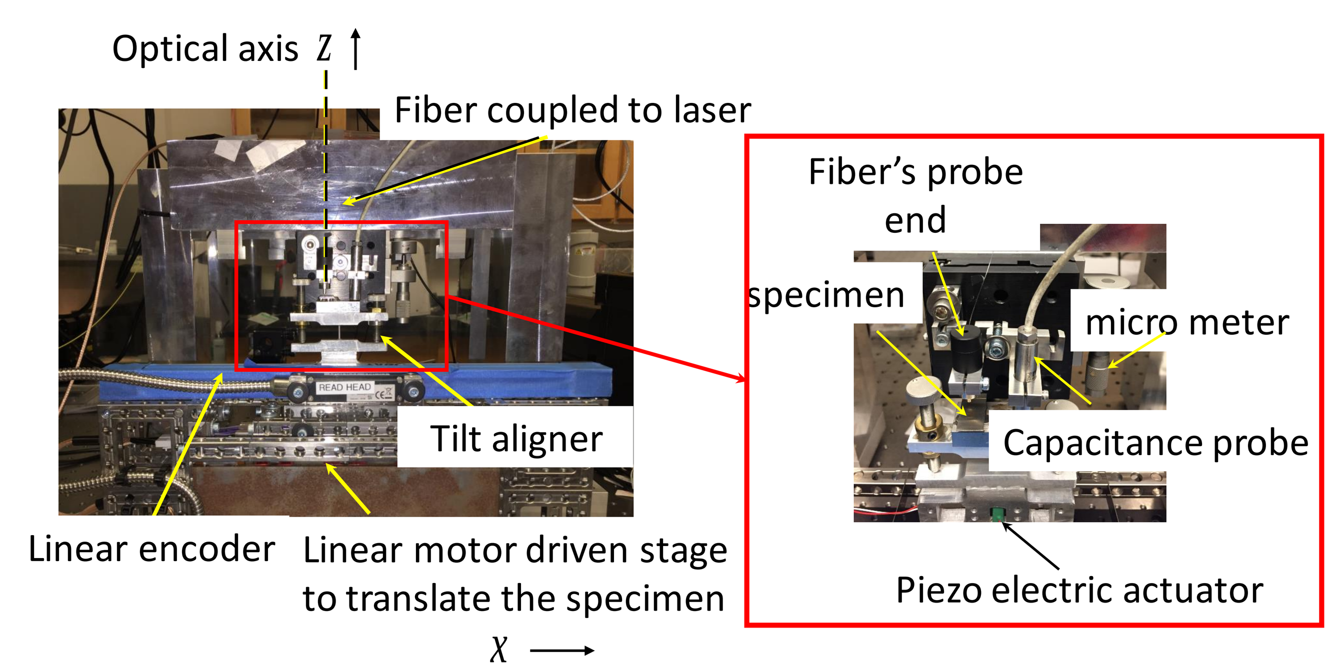

Figure 3: Photograph of the experimental facility showing probe end and the stage mechanism to translate the specimen perpendicular to optical axis

1.2 Results of surface profile measurements using a bare fiber tip configuration

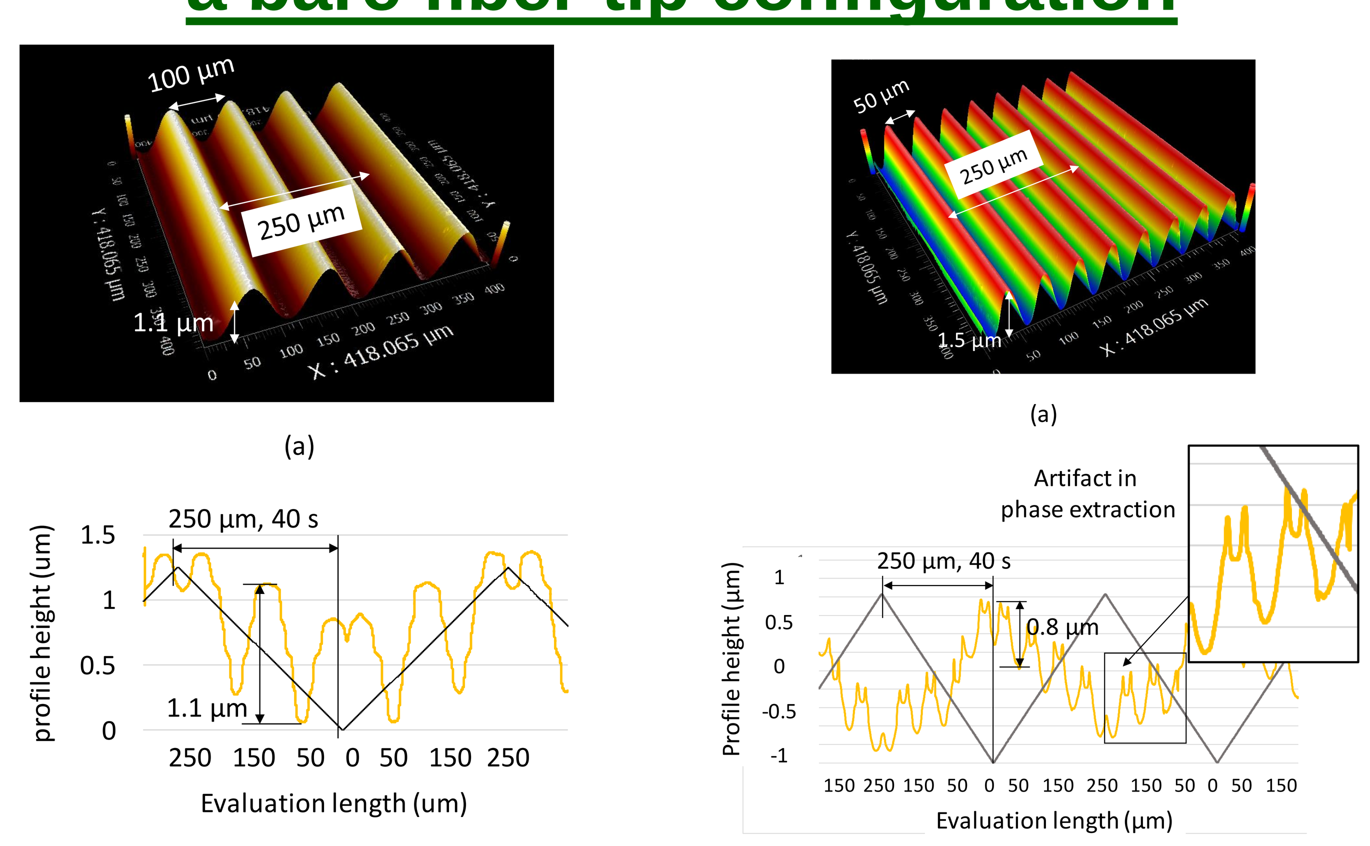

Figure 4: Surface image captured by (a) Coherence Scanning Interferometer (Zygo Nexview, 20X obj, S-filtered with a cut-off of 2 µm) [3] , (b) Surface profile measured by the fiber based surface profiler. Note: sampling length 250 µm does not follow ISO 4288 suggestion of 4 mm [4]

1.3 Future work

To improve lateral resolution, a GRIN lens will be used. To achieve higher bandwidth of measurement, an Acousto-Optic Modulated laser and an FPGA post-processor will be utilized, see Figure 5.

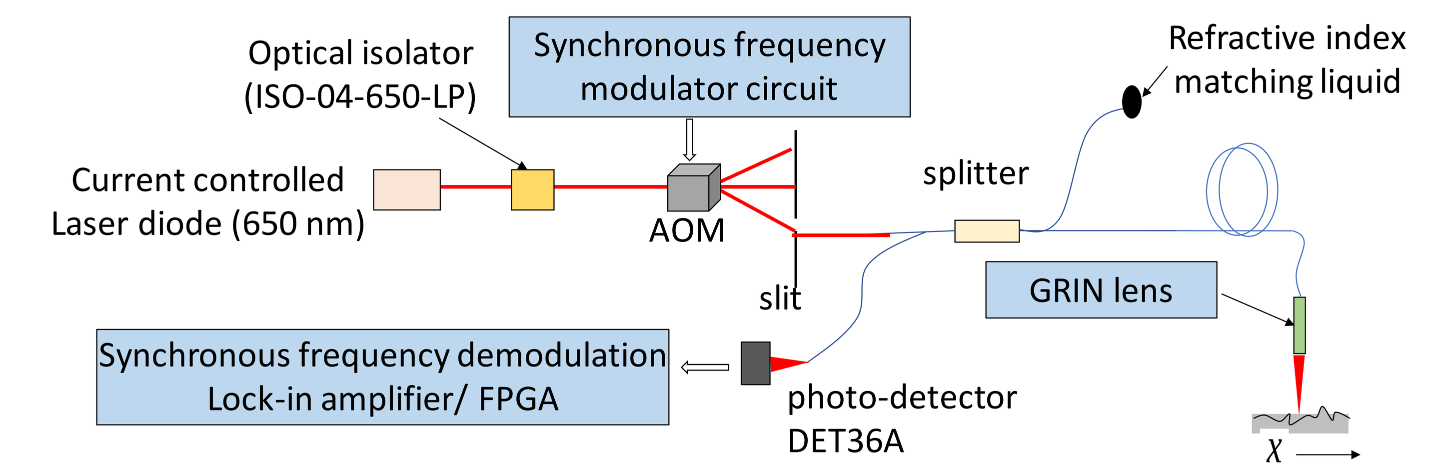

Figure 5: A future implementation of EFFPI showing GRIN lens and synchronous modulation and demodulation components

2. Confocal Focus Detect

The confocal probe method shown in Figure 6 utilizes the oscillation of the focal point along the optical axis. When the focal point is coincident with the specimen surface, a peak in intensity is recorded by a photodetector. This information helps to reconstruct the profile of the surface as the specimen is traversed perpendicular to the optical axis. This has the advantages of both eliminating the need for coherent light and being absolute relative to lens position. A preliminary assembly lacking the piezo modulation of lens is shown in Figure 6. In early testing, the specimen will be modulated in z, and translated in x.

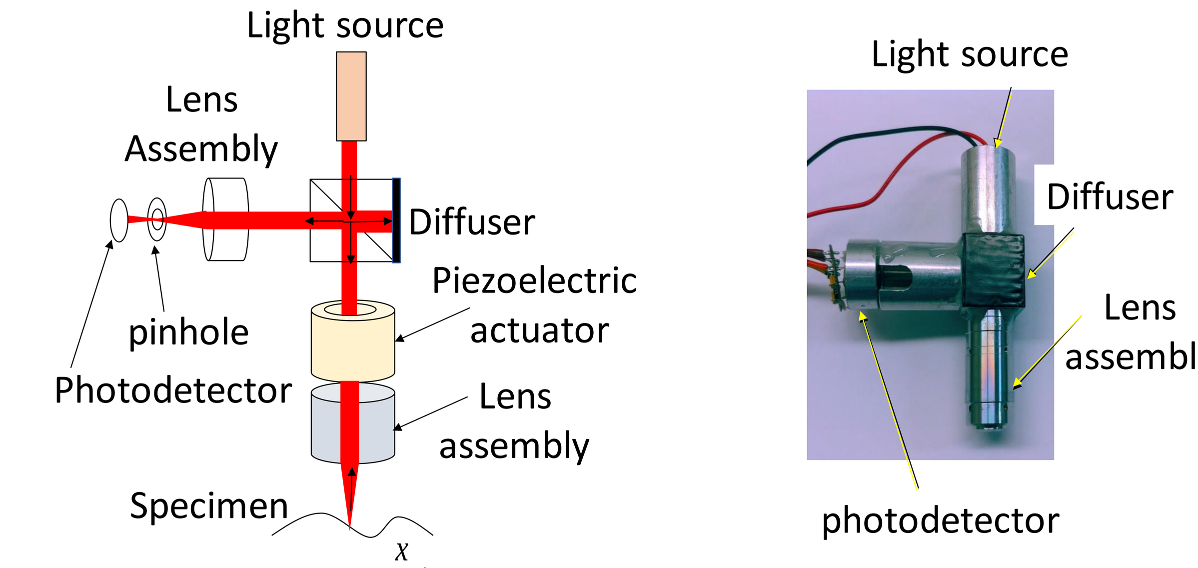

Figure 6: Schematic (left) showing the assembly of the confocal based surface profiler, picture (right) showing the preliminary build of the probe

Conclusions

Working principles of an interferometric and a focus-based probe for measuring surface deviations are discussed. Experimental facilities have been constructed and are being improved for testing these methods. Preliminary results using the bare fiber tip method on periodic surfaces with amplitudes up to 1.5 µm and lateral periods down to 50 µm have been obtained. Work to establish the limits of both amplitude and lateral resolution are in progress.

We would like to thank the industrial affiliates of the Center for Precision Metrology.

[1] Wilkinson and Pratt, Analytical method for low finesse, external cavity, fiber Fabry-Perot interferometers including multiple reflections and angular misalignment, Applied optics, 2011; Vol 11, No. 53, p. 4671 – 4680, **[2]** Nowakowski, Development of a miniature, multi-channel, extended range Fabry-Perot Fiber-optic laser interferometer system for low frequency SI-traceable displacement measurement Proc. EuSPEn, 15, 157-158, **[3]** ISO 25178-3 Geometrical product specifications (GPS) – Surface texture: Areal – Part3: specification operators, International Organization for Standardization, Geneva 2012, **[4]** ISO4288, Geometrical product specifications (GPS) – Surface texture: Profile method- Rules and procedures for the assessment of surface texture, International Organization for Standardization, Geneva 1996