

The Heterodyne Profiler Redux

Paul R. Parise
Convergent Technologies, Madison, CT

Keywords: heterodyne profiling interferometer, HPI, surface roughness

Introduction:

The heterodyne profiling interferometer is a surface roughness measuring laser interferometer originally designed by Gary Sommargren in the early 1980's. The original prototype was built at Lawrence Livermore National Laboratory by Gary and his colleagues at Livermore. After Gary joined Zygo Corporation, Zygo developed and marketed a commercial version of this instrument under the name HPI (Heterodyne Profiling Interferometer). The original Zygo instrument was able to measure surface roughness to less than 1 angstrom, with a noise floor of about 1/10 angstrom. Due to the elegance and simplicity of Gary's optical design, the instrument is still used today, as the only surface roughness instrument that can achieve such high resolution and low noise.

In 2003, Convergent Technologies began a program to refurbish and update an HPI belonging to Zygo Corporation. While the system electronics, controls and computer were obsolete, the strength of the basic optical design warranted a complete redesign and replacement of all the supporting subsystems. The refurbished instrument continues in regular use in Zygo's measurement lab.

This paper outlines our experience in rebuilding this historic instrument. We will illustrate the changes in electronics and computers that have occurred in the 25 years since the HPI was developed. As a tribute to Gary Sommargren, we will illustrate the elegance of Gary's original optical design, which is still providing crucial surface roughness measurements, a quarter of a century after its invention; long after all the other parts of the original HPI instrument have become obsolete.

The Heterodyne Profiling Interferometer:

The basic optical design was devised by Gary Sommargren about 1980 (refer Optical Society of America, Applied Optics / Vol. 20, No. / 15 Feb 1981). Gary described a non-contact optical technique for surface profiling with a height sensitivity of the order of 1 angstrom.

Zygo productized the instrument and sold the first commercial product in 1987. The original HPI included a large, 19" rack-mount cabinet to contain the electronics and computer necessary to run the instrument. Critical optical adjustments for focus, illumination intensity, and starting optical phase were adjusted manually with knobs protruding from the cover.

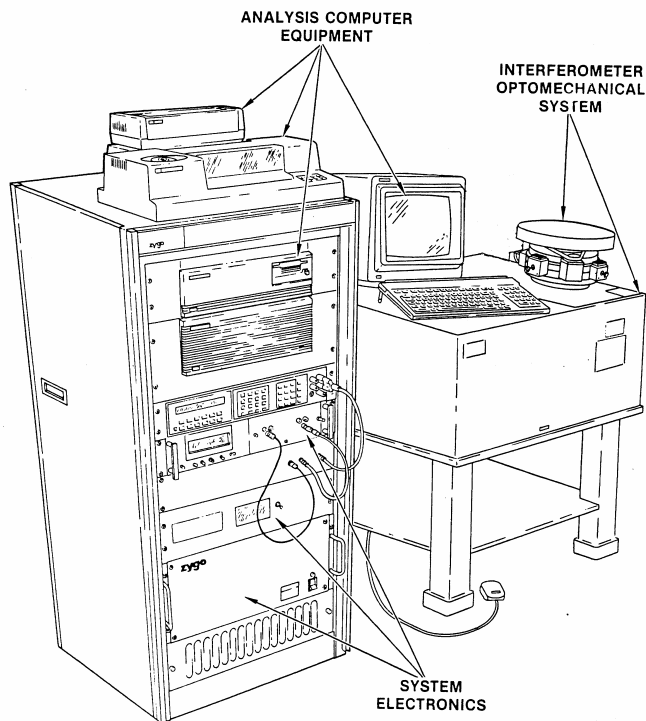


Figure 1: an illustration of the original HPI from the HPI manual (circa 1987). A 19" rack cabinet contains computer, phase meter and electronics necessary to run the HPI.

Focus was adjusted by reaching through an access door on the front of the machine and adjusting a micrometer while observing the light pattern on a special glass target.

Illumination intensity and starting phase of the interferometer were adjusted with control knobs protruding from the rear of the instrument.

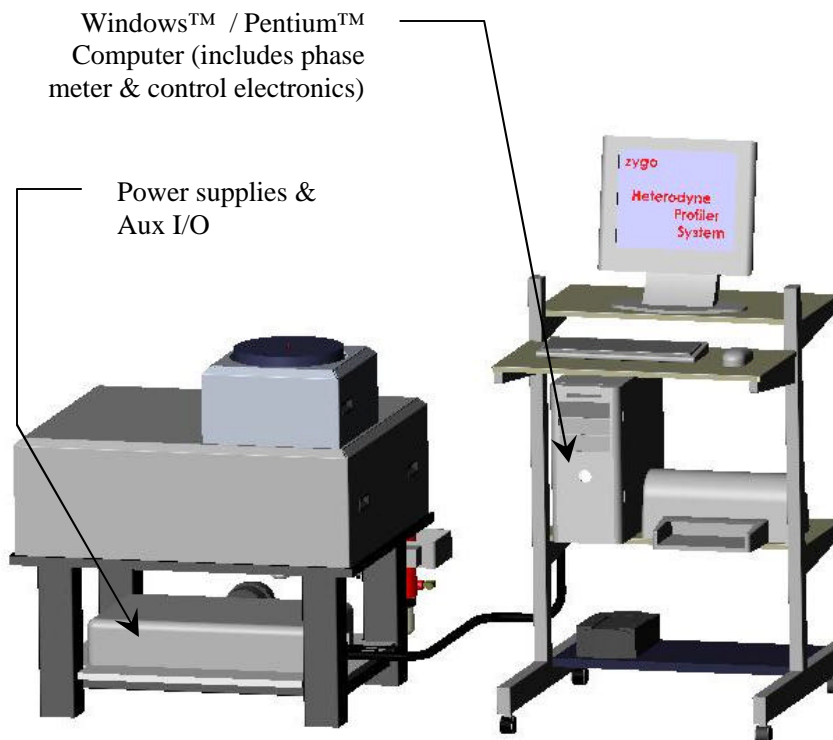


Figure 2: The refurbished HPI, completed in 2003.

The entire electronics rack was discarded, replaced with the Windows™ Pentium™ computer, add-on boards plugged into the PCI slots, and a custom software application.

Only Sommargren's original interferometer design was retained.

In 2003, Convergent Technologies undertook a project to refurbish an HPI which had been mothballed and placed in storage at Zygo Corporation. During the course of this program, we scrapped all the electronics. We redesigned and simplified the optical system and automated what were previously manual adjustments. Due to advances in computers and electronics in the last two decades, we eliminated an entire rack of electronics (22" x 34" by 50" high, weighing about 300 lbs) with a Windows™ Workstation computer with a special A/D board installed in the PCI slot.

During the process of redesigning and rebuilding the instrument, we were able to see many areas where the technology has advanced by leaps through the 1980's and 1990's.

In light of today's computers, original HP-300 computer that controlled the HPI is little more than a programmable computer. A significant part of the HPI operations manual was devoted to explaining how to work the computer. The refurbished instrument is controlled by a standard Window™ / Pentium™ workstation. The user interface is standard Windows™ look and feel. Operators are assumed to understand this interface intuitively.

The original phase measurement electronics consisted of a special electronic phase instrument and an HP Digital Multimeter to read the analog voltage output from the phase meter. This was replaced with a high performance A/D board plugged into the PCI slot of the computer and custom software which runs special DFT (discrete Fourier transform) calculations developed by Zygo for their current products.

About a mile of various types of wire and coax cable, in proprietary cable harnesses, was replaced by one RS-232 cable and one USB cable running between the HPI and its computer.

The optical system was redesigned and simplified. In addition, focus and intensity adjustments were automated. A "starting phase" adjustment, required due to limitations in the original phase meter was eliminated. However, the basic optical arrangement of interferometer was retained (see figure 3). This is a testament to elegance of Gary Sommargren's original interferometer design. After replacing broken optics and repairing the laser, the interferometer made surface roughness measurements of parts in the 2 angstrom range with repeatability well under 1/2 angstrom.

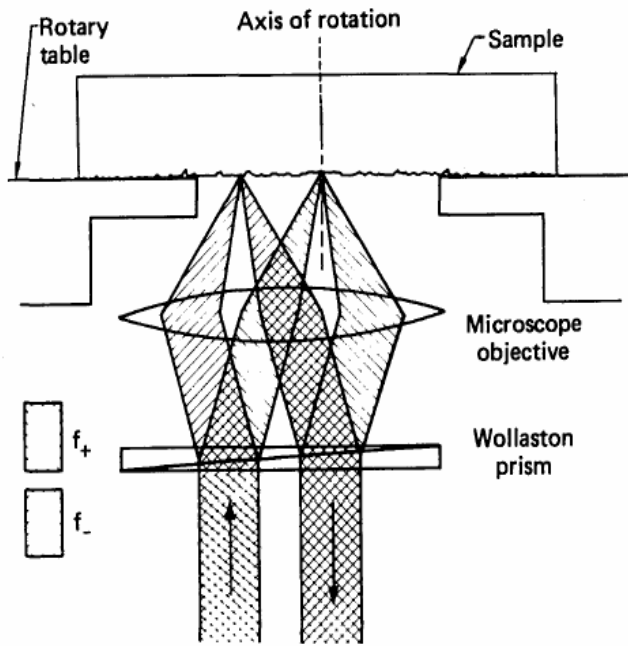


Figure 3: Illustration of interferometer optics described by Sommargren in 1980.

A two frequency, polarization coded, HeNe laser beam is split into two paths by a Wollaston prism and focused onto two spots on the sample by a microscope objective.

Light reflected from the two spots on the sample is collimated by the microscope objective and recombined by the Wollaston prism. The sample being measured is rotated so that one of the two illuminated spots lies on the axis of rotation.

Acknowledgements:

This paper is dedicated to Gary Sommargren, who spent most of his professional career making important contributions to the science and practice of interferometry. The HPI optics described here are simply one example of his work. I would also like to acknowledge the helpful discussions and advice of Ned Bennett, Peter De Groot, Frank Demarest, Chris Evans, Bob Smythe, and Carl Zanoni.

References:

- [1] Gary E. Sommargren, *Optical Heterodyne Profilometry*. Applied Optics / Vol. 20, No. 4 / Feb 15, 1981, pages 610 – 618
- [2] Zygo Model 5500 Heterodyne Profiler System Operation Manual OMP-0218, Zygo Corporation, Middlefield, CT