EVIDENT

A Primer on White Light Interferometry and White Light Interferometric Objective Lenses

White light interferometry (WLI) enables noncontact, wide-area, high-speed, and high-precision measurement of surface height with a wide dynamic range and a height resolution of 0.1 nm. Demand for this technology is increasing as miniaturization in industrial fields advances—for example, processing components such as semiconductors and liquid crystals. The high precision of WLI is also sought after for the measurement and characterization of surface topography.

In this paper, we introduce the optical principles of white light interferometry and WLI objective lenses.

Principles of White Light Interferometry

Figure 1 illustrates the principle of the Michelson interferometer. Light from the light source is split by a beam splitter into two paths, one in the sample direction (downward, blue) and one in the reference mirror direction (rightward, yellow). The light reflected from the sample's surface and the reference mirror are combined by the same beam splitter, forming interference fringes that are detected by a detector located at the top.

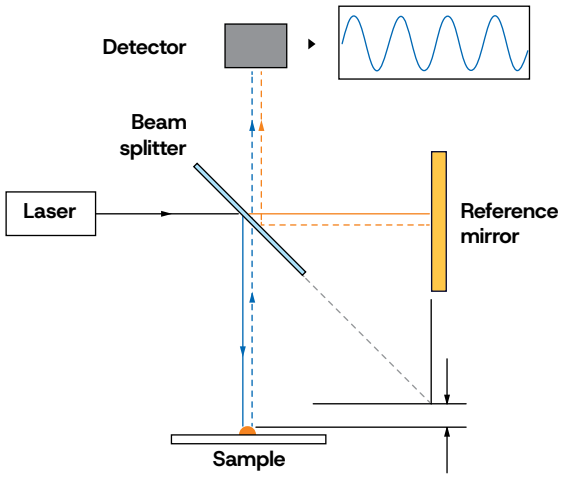

Figure 1. Illustration of the design and function of a Michelson interferometer

The phase difference is determined by the optical path difference between the two light paths. When the path lengths are equal, there is constructive interference, which produces a bright fringe. If there is a difference in path length of half a wavelength, destructive interference occurs and a dark fringe is produced.

When monochromatic light with a long coherence length, such as that emitted by a laser, is used as the light source, interference can occur even when the optical path lengths of the reflected sample light and the reference mirror light do not match. Figure 2 shows the interferogram for such a case.

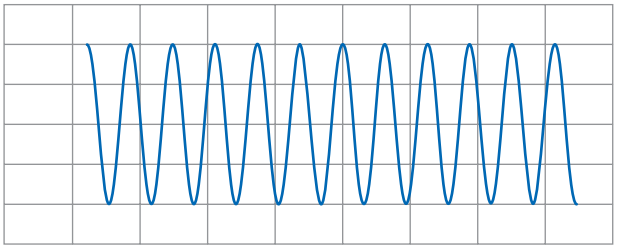

Figure 2. Interferogram of coherent light

When white light is used as the light source, interference fringes are formed at or near the point where the optical path lengths coincide, but the contrast of the interference fringes decreases when there is a difference in optical path length (Figure 3).

There are two main detection methods in white light interferometry: phase shifting and coherence scanning. Phase-shifting detection provides higher Z-resolution and is typically used for measuring smooth surfaces, whereas coherence scanning is used for measuring rough surfaces and step heights.

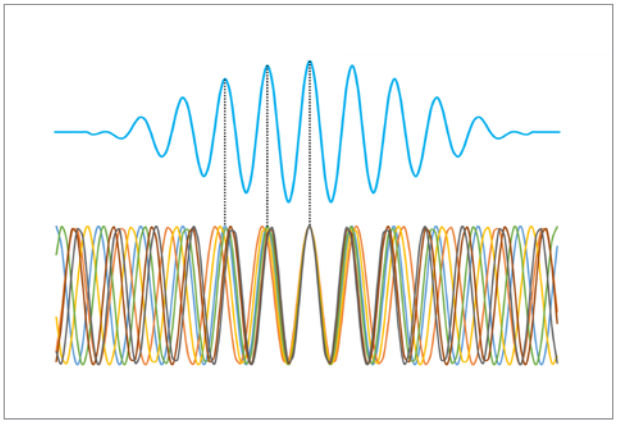

Figure 3. Interferograms of white light (top) and of individual wavelengths, i.e., red light, blue light, green light, etc. (bottom)

Coherence-scanning interferometry (CSI)

Detection of the peak of the envelope, also known as vertical scanning interferometry, or VSI (Figure 4).

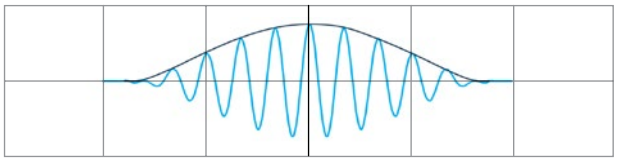

Figure 4. Envelope detection

Phase-shifting interferometry (PSI)

Detection of the phase difference in the wavefront by scanning the fringe interference at ¼ wavelength intervals (Figure 5).

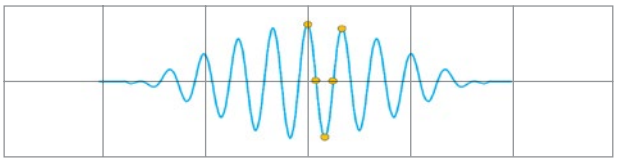

Figure 5. Phase detection

Configuration of White Light Interferometry Applied to a Microscope

Figure 6 shows a conceptual diagram of a white light interferometric microscope.

1. The light beam from the light source is split by a beam splitter in the white light interferometric objective lens, driven by a computer–controlled piezoelectric transducer (PZT) scanner.
2. The two light beams are then reflected at the sample and reference surfaces respectively.
3. They interfere with each other to generate interference fringes during a continuous vertical scanning.

In this system, the use of a white LED or similar light source with a short coherent length causes a white light interference effect, and interference fringes are only generated when the lengths of the optical paths of the light reflected from the sample surface (sample path) and from the reference surface (reference path) match.

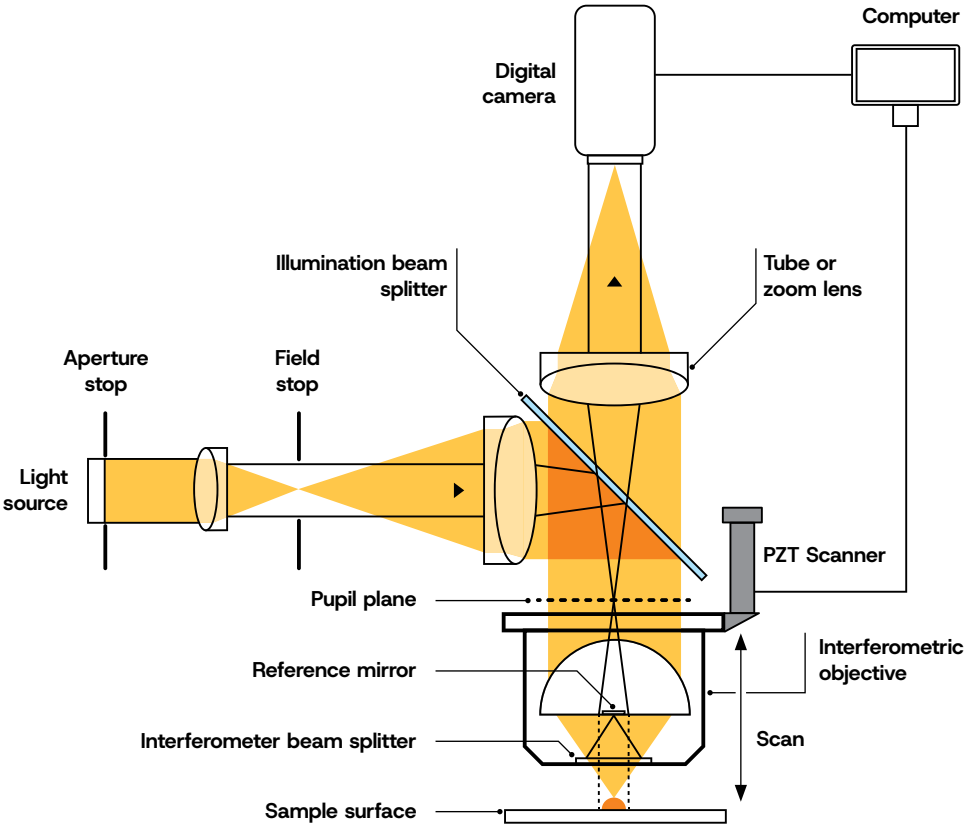

Figure 6. Overview of a modern white light interferometric microscope

Based on this principle, the position of the interference fringe peak at each point on the sample surface is acquired by scanning perpendicularly (Z direction) to the sample surface. At the same time, using the fringe scanning method, the unevenness of the sample surface can be measured with a resolution of 0.1 nm.

White Light Interferometric Objectives

A white light interferometric objective lens is mounted on the white light interferometer, and it has an interference part (beam splitter and reference mirror) inside. The performance of this component directly affects the measurement accuracy of the white light interferometer; thus, the interferometric objective lens can be regarded as the heart of the system.

Interferometric objectives are divided into three types based on the arrangement of the beam splitter and reference mirror.

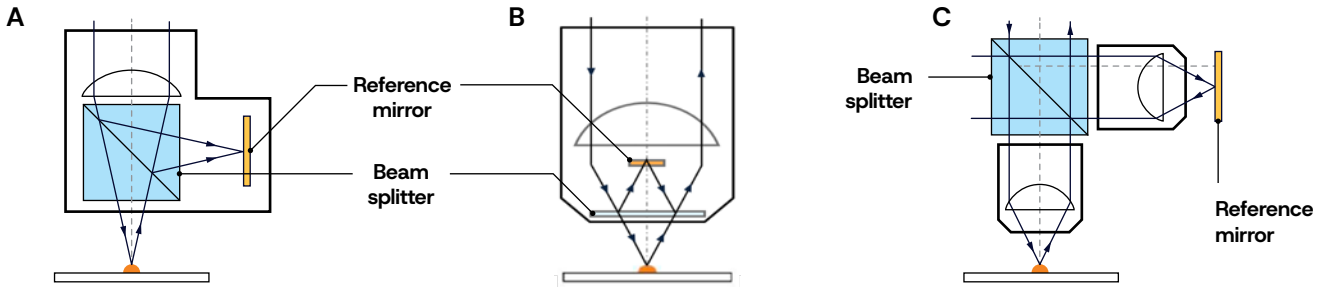

Figure 7. WLI objective lenses (left to right): Michelson type (A) Mirau type (B) Linnik type (C)

The Michelson type, shown in Figure 7(A), is suitable for low-magnification lenses with a long working distance (WD). Its beam splitter prism is placed within the long working distance to bend the rays, and its reference mirror is set laterally.

The Mirau type, shown in Figure 7(B), is suitable for high-magnification lenses with a large numerical aperture (NA). Because of the large numerical aperture, the lens is compactly constructed by placing two parallel plates at its tip: one plate serves as the beam splitter, and the other plate as the reference mirror in the center.

The Linnik type, shown in Figure 7(C), consists of two objective lenses, a reference mirror, and a beam splitter placed just before the objective lens. Although Linnik objectives are more costly due to the use of two objective lenses, they have the advantage of providing longer working distances than the other two types.

The characteristics of each of these three interferometric objective types are summarized in Table 1.

	Numerical aperture	Working distance	Magnification	Features
Mirau type	Large	Short	High	Compact, easy to use
Michelson type	Small	Long	Low	Wide field of view
Linnik type	Small to large	Short to long	Low to high	Longer working distance

Table 1. Comparison of interferometric objective lenses by type

Large Numerical Apertures in White Light Interferometry

Mirau–type objectives offer the advantage of larger NAs for precise 3D surface measurements. To meet the increasing demand for precise measurements of surface topography, WLI Mirau objective lenses have been developed with enhanced NA performance. For example, Evident's series of WLI Mirau optics have high NAs up to 0.8, enabling the capture of more light from smooth surfaces with steep slopes and fine structures. (Figure 8).

Figure 8. Evident's WLI Mirau objective lenses. Left to right: 10X (NA 0.3), 20X (NA 0.6), 50X (NA 0.8), and 100X (NA 0.8).

This higher NA allows optical profilometers to perform precise 3D geometrical measurements of surface variations and minute features on sloped and complex samples (Figures 9 and 10).

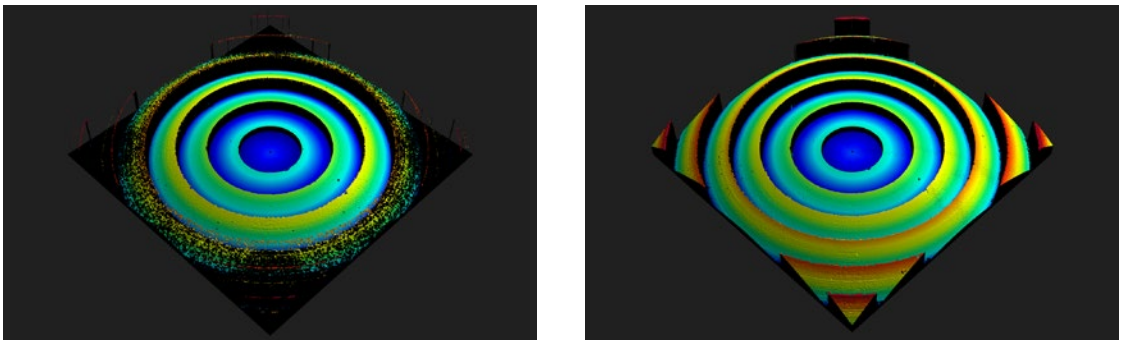

Figure 9. A Fresnel lens sample imaged with a conventional WLI 20X objective (NA 0.4, left image) and Evident's 20X WLI objective (NA 0.6, right image)

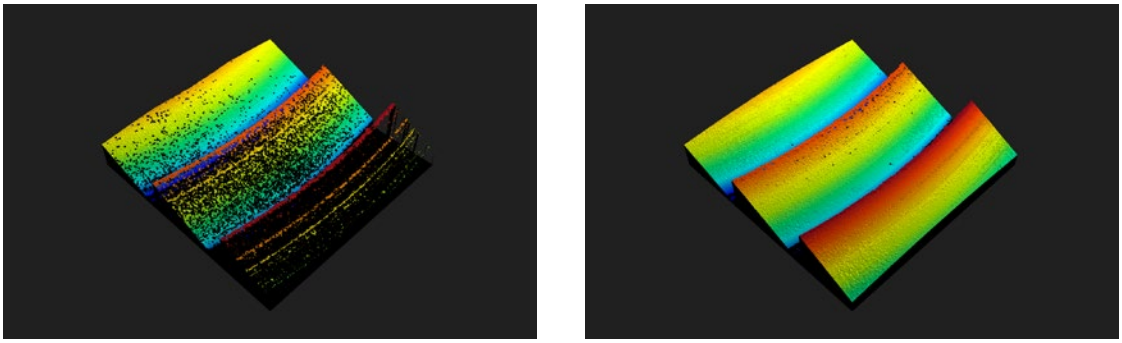

Figure 10. A Fresnel lens sample imaged with a conventional WLI 50X objective (NA 0.55, left image) and Evident's 50X WLI objective (NA 0.8, right image)

In the Fresnel lens sample images of Figures 9 and 10, the slopes in the peripheral region are steeper than those in the central area. The left and right images captured using WLI objectives have equivalent magnifications but lower and higher numerical apertures. In the left image, increased noise in the peripheral slopes from a lower NA WLI lens leads to measurement failure. In contrast, the right image, acquired using higher NA WLI objectives, shows improved performance by capturing more light at the periphery, enabling effective measurement.

Conclusion

White light interferometry delivers precise, noncontact measurement of surface topography with vertical resolution in the nanometer or even sub-nanometer level, making it essential for applications in semiconductor manufacturing, optics inspection, and other precision engineering industries. Among available designs, high numerical aperture WLI Mirau-type objectives—such as those developed by Evident—are engineered to deliver high performance in capturing fine details on steep or complex surfaces, supporting effective measurement. As demand for accurate 3D metrology increases, these advanced objectives support manufacturers and researchers in addressing stringent quality and performance requirements.

To learn more about Evident's WLI objectives, please **visit our website** or contact your local Evident OEM representative.

Evident Corporation
Shinjuku Monolith, 2-3-1 Nishi-Shinjuku,
Shinjuku-ku, Tokyo 163-0910, Japan