FRESNEL DIFFRACTION-BASED DISTANCE SENSING

A novel optical sensing technique for measuring absolute distances with high accuracy

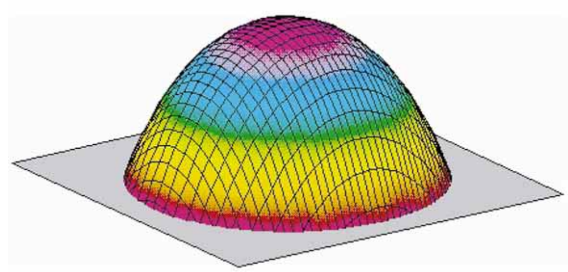
OVERVIEW

Fresnel diffraction-based distance sensing represents an entirely new technology in the field of optical distance measurement. Based upon the analysis of complex distance-dependent Fresnel diffraction patterns, this technique enables measurements previously found to be impossible or highly difficult to perform with traditional optical measurement techniques (interferometry, time-of-flight, and triangulation). Developed jointly between Oak Ridge National Laboratory and the University of Tennessee, various embodiments of this technique have been, and continue to be, developed. These embodiments range from a two-meter (continuous range) single-micron accuracy benchtop setup to a compact hand-held sub-micron accuracy proximity probe (shown above). Continued research promises to establish a new category of optical distance measurement devices with diverse applications ranging from robotic vision to sub-terrain mapping.

FEATURES

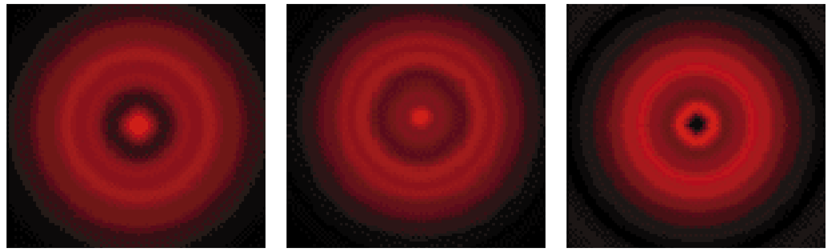
The final specifications of a Fresnel diffraction-based distance sensor are dependent upon the sensor's final configuration and intended application. However, some general features inherent to the technique include:

- Absolute distance measurements
- A high range-to-accuracy ratio
- Measurements in pulsed or continuous mode
- Minimal requirements on optical alignment
- Surface independent distance measurements
- High-speed measurements



3-D Profile of a 2-in. Diameter Hemisphere

THEORY



Although the creation and calculation of Fresnel diffraction patterns is a relatively complex task, the use of these patterns for distance measurement is actually quite simple. When light diverging from a surface passes through a circular aperture, a complex circular diffraction pattern results due to the wave nature of light. When acquired at a fixed observation distance, this complex pattern's intensity profile exhibits a very strong dependence on the unknown surface-to-aperture distance. Under the proper conditions, a diffraction pattern can be used as a "fingerprint" to identify, very accurately, the absolute surface-to-aperture distance. This can be easily demonstrated using the three figures above. The figures are patterns associated with an illuminated surface-to-aperture distance of 22.00 cm., 22.25 cm., and 22.50 cm., respectively (assuming an aperture diameter of 2.0 mm). The distinct differences between these three patterns allows one to visually identify the associated surface-to-aperture distance to within 2.5 mm. Employing current optical detection technology, this resolution can be greatly increased, allowing micron-accuracy measurements of surface-to-aperture distances over a large range.

APPLICATIONS

Development of the Fresnel Diffraction-based measurement technique continues at ORNL. Among the applications being pursued are:

- The monitoring of steel manufacturing processes in harsh environments
- Development of a high-accuracy non-contact Coordinate Measuring Machine inspection probe
- Pulsed high-accuracy distance measurements for use in long-term space-based experiments
- High-speed acquisition of 3-D environmental surroundings for use in improving robotic performance

For more information on the Fresnel diffraction-based distance measurement technique, please call:

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