WHITE PAPER

Overview of a Novel LED-Based Detection and Ranging Technology

LEDDAR® Technology Overview

Leddar (acronym for *light-emitting diode detection and ranging*) is a patented sensing technology developed by LeddarTech, a successful spin-off of Canada's leading optics and photonics research institute, *Institut national d'optique (INO).* This innovative approach, based on the time-of-flight of light principle, has enabled the use of LED lighting, either in the visible or infrared spectrum, for detection and ranging.

What Makes It Better?

Contrary to collimated emitters (lasers), the Leddar sensor's LEDs and emitter optics are used to create a diffused beam covering a wider area of interest. The receiver collects the backscatter of the reflected light from objects in the beam and, using full-waveform analysis, detects the presence of objects in each segment of the beam, measuring the distance of the detected objects (based on the time taken by the light to return to the sensor). Accumulation and oversampling techniques are used to maximize range, accuracy and precision.

Leddar technology also allows for a high level of versatility, and a wide range of optics options are available for the sensor modules, providing a variety of beam patterns for different needs. For example, in response to current market needs, the technology is presently being offered in the form of two main adaptable platforms: 1) a small and cost-effective single-element module, which provides a narrow, yet conic beam that is particularly suitable for applications like level sensing, proximity detection, etc., and a 2) multi-element module, which offers a much wider beam and provides lateral discrimination abilities, suitable for applications that might traditionally use laser scanners, or multiple sensors.

This unique sensing technology presents multiple advantages. The use of a diffused light beam results in increased robustness of detection of specular surfaces. Another benefit is high robustness of detection under harsh weather conditions such as rain or snow. Aligning the sensor is also easier, which results in fast and simple installation. Additionally, the multi-element receiver provides detection and ranging for multiple segments of the beam without any moving parts. This makes for a more compact, reliable and rugged assembly, all of which translate to an extended service life.

Time-of-Flight Principle

Leddar sensors use LEDs to generate very short light pulses, typically 100,000 pulses per second. The time-of-flight (ToF) principle essentially consists in measuring the time taken by a light pulse to travel from the sensor to a remote object and to return to the sensor. The range *R* of the detected object is deduced from the measured full round-trip time *T* of the light pulse using the simple relation $R = c\,T / 2\,n$, where *c* is the speed of light in vacuum and *n* denotes the refractive index of the medium in which the light pulse propagates.

Depending on the characteristics of the target's surface, the light pulse is either absorbed, totally reflected, or reflected diffusely. This causes different irradiances of the echo pulse at the receiver, which are measured by the Leddar sensor. This measured irradiance depends on the distance measured by the ToF principle and the angle of incidence that can be determined by imaging-collecting optics that focus the reflected beam on the sensor's photodetectors. A 16-element photodetector is typically used in Leddar sensors (shown in Figure 1).

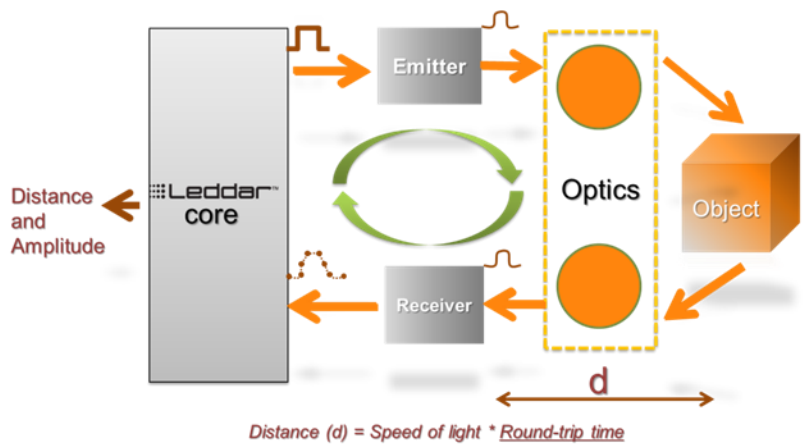

Figure 1. Signal travelling through the main components of a Leddar sensing module

Beam Pattern

The multiple-element photodetector has a rectangular sensing area. The purpose of the emission optics of a Leddar sensor is to direct as much of the emitted light from one or more LEDs into a pattern that best fits the photodetector geometry. The purpose of the reception optics is to collect the backscatter of light from objects in that beam onto the photodetector. The combined emission and reception optics solution can be designed to obtain different beam widths. LeddarTech currently offers optics options with beam widths of approximately 3°, 9°, 18°, 24°, 34°, 45° and 95°. Figure 2 illustrates a simulated emission beam pattern of a Leddar sensor with an overlay of the matching segments provided by the reception optics corresponding to the photodetector elements.

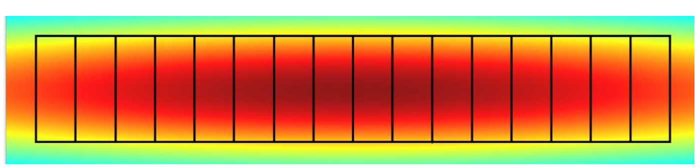

Figure 2. Emission beam pattern and match to a 16-element photodetector

How Does It Work?

The LED source is pulsed at a rate of approximately 100,000 pulses per second. The light pulses propagate through the detection area and reflected light is captured by the optics and the photodetector. The sensor signal is amplified and the signal acquisition is synchronized to the pulses.

An oversampling scheme using multiple light pulses is implemented to improve the resolution of the acquired signal. Typical oversampling values are 4 or 8 which produces a digitized signal with an increased number of samples for improved accuracy and precision. In addition to oversampling, an accumulation process is accomplished in order to improve the signal to noise ratio. The oversampling value and number of accumulations influence the detection/measurement, the range, accuracy and precision of the measurements. The performance of the sensor can thus be optimized with these parameters to meet the requirements of the application.

Detection and Distance Measurement

The detection and distance measurement is performed by the sensor's processor, using the acquired signals (one per photodetector element). The signals consist of a series of values representing light amplitude at incremental distances from the sensor. The number of samples in the signal is chosen according to maximum range required.

The amplitude of each sample is an indicator of the quantity of light reflected back from a given object at that specific distance. The amplitude depends on distance, size, reflectivity and angle of the object with respect to the sensor.

An object will be detected by the sensor if a light pulse above a predetermined threshold is found. The threshold at which a peak in the trace is interpreted as the presence of an object depends on the signal-to-noise ratio. LeddarTech determines the default threshold level for each sensor based on the signal-to-noise ratio. A threshold table is applied in the detection processing of the traces, and a threshold offset parameter is provided on most sensors in order to adjust this threshold table. The offset can be set to increase or decrease the sensitivity of the sensor. This can be used to ignore the presence of objects returning weak signals or to maximize detection of such objects and filter false detections in the application software.

Another setting available on Leddar sensors is the LED intensity. LED intensity control can be set to manual mode or automatic mode. In manual control mode, the setting is adjusted by the operator to best fit the application. In automatic control mode, the sensor will dynamically adjust the LED intensity based on the amplitude of the signal for objects detected in the sensor beam. With this control, a sensor model can be used for a wide range of applications with different range requirements and also be used in applications where objects can both be very close or far from the sensor.

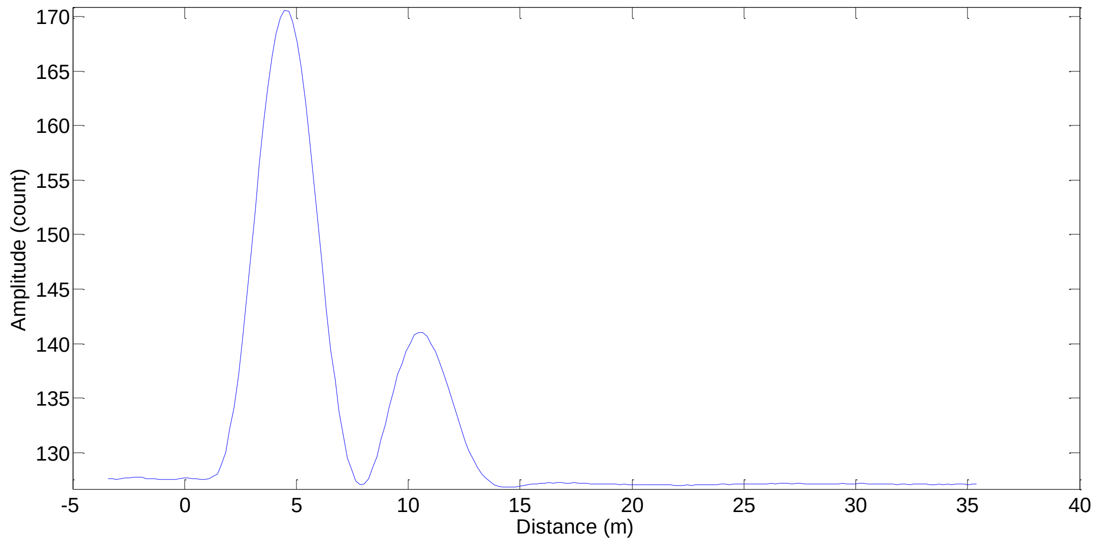

Figure 3. Sample trace, where the x-axis is a time axis, scaled into distance, and the y-axis is the light amplitude.

Figure 3 illustrates a typical trace signal for one segment. In this example, the sensor is collecting light reflected back by two separate objects. Full waveform analysis performed by Leddar sensors provides the capacity to detect multiple objects in the same segment. This is possible if the closer object is smaller than the illuminated area for that segment. The beam can then illuminate another object that isn't completely "shadowed" by the closer object.

Benefits of Leddar Technology

When compared to other detection technologies such as laser scanners, radar, video, thermal imaging, ultrasonic and passive infrared, Leddar excels on the widest range of performance criteria, due to its ruggedness, rapid data acquisition, 16 independent segments (multi-element platform) and simultaneous acquisition capabilities. Optimized for detection and ranging up to 100 m or more, Leddar can efficiently and cost-effectively serve multiple industries.

In addition, this technology is available in various module forms, with or without enclosure. As an opto-electronic technology, it can easily be adapted to almost any final application.

Of particular benefit to developers and integrators is the technology's unmatched cost/performance ratio, its ability to detect multiple objects in each segment and lateral discrimination (multi-element platform), its long detection range with low-power LEDs, real-time object-tracking capabilities, detection in adverse weather conditions, and ocular safety.

Integrating with the Leddar Modules

Because of their compact size and flexible interfaces, Leddar sensing modules can be easily integrated into any system, enabling developers and integrators to use this advanced method in their own products.

The modules were designed to facilitate both mechanical and software integration. Namely, the included software development kit provides sample code for developers to quickly integrate sensor data into their application software. There is also a choice of popular communication interface options (e.g., USB, RS-485 and UART), and additional headers are also available for custom expansion. As for the receiver, one can choose from several beam options, ranging from 3° to 95°.

Conclusion

This innovative sensing technology can greatly change the way detection and ranging capabilities are integrated in a wide range of industries and applications. Not only can it make these functions more accurate, more reliable and more robust, but it can also make the entire solution more cost-effective. To encourage developers to see how well the technology works and how easily it is integrated, a low-cost evaluation kit is readily available for trial purposes. For more information on this patented* technology, visit leddartech.com.

Leddar is a registered trademark of LeddarTech Inc. Leddar technology is covered by one or more of the following U.S. patents: 7635854, 7640122, 7855376, 7895007, 7917320, 8159660, 8242476, 8310655, 8319949, 8436748 and 8619241 or international equivalents. Other patents pending.