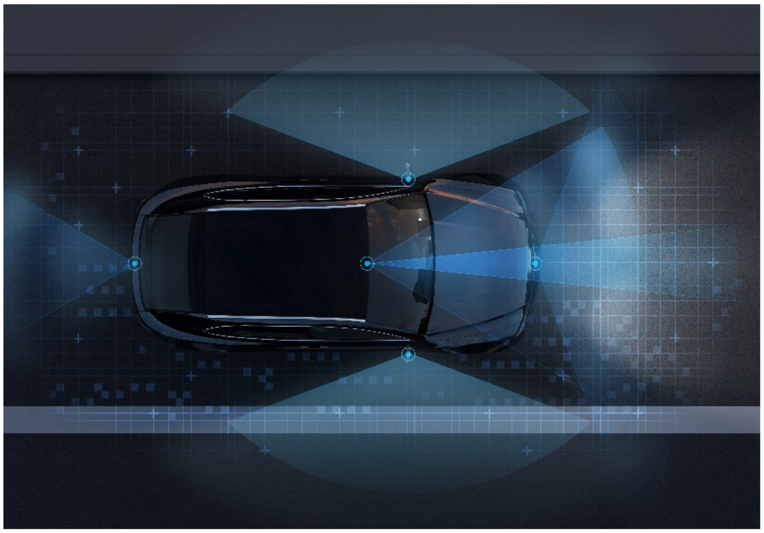
LiDAR: Measuring the measurement system is essential

The importance of precisely measuring LiDAR parameters and its impact on the performance and construction of LiDAR systems

Many experts believe LiDAR is one of the pivotal sensing technologies required to make partial to full autonomous vehicles possible. The most promising way seems to be combining LiDAR with other detection/ranging systems like cameras and radar products into a suite of detection & ranging systems allowing autonomous vehicles to use at least two independent redundant subsystems to provide high-resolution, 3D information about the surrounding environment with very low error rates. LiDAR is not only a key driver in the development of autonomous vehicles, it also prevails in numerous other application sectors from all kinds of mapping, industrial automation/robotics and smart city to aerospace, security & defense sectors. Just recently, the discovery of hidden archeological sites in the middle of overgrown jungle or monitoring of air pollution in cities were hot topics in the media.



While the benefits of LiDAR are indisputable, and the applications are wide, the development of these systems are still improving with respect to areas such as eye safety, power consumption, and overall system reliability. Knowing how the light source in these systems is behaving is critical to the success of the overall system. Measuring and understanding key LiDAR parameters such as average power or pulse energies, wavelengths, pulse duration, repetition rates, and beam divergence are critical to successful development of LiDAR systems.

Characteristics of LiDAR Systems

To choose the right measurement solution which will provide reliable results, it is important to understand the characteristics of the LiDAR system used. Most LiDAR systems are based on pulsed Time of Flight (ToF) distance measurement method. In creating reliable (adequate) flash ToF LiDAR with no mechanical moving parts, the intensity, phase and frequency of the transmitted signal needs to be precisely modulated to generate the nanosecond pulses with high peak power. The pulse energy then needs to be precisely measured for such LiDAR to reach long distances while complying with permissible exposure limits, thus a complex function of wavelength, repetition rate and energy per pulse.

Eye safety

As eyes of humans and animals are very sensitive to laser light the question arises: What can be referred to as being eye safe? Many automotive LiDAR systems are using 905 nm or 940 nm laser wavelengths. At those wavelengths is light easily transmitted to the retina. At 1550 nm wavelength in contrast, is the threshold for retinal damage much higher than at lower wavelengths, so higher powers and consequently longer ranges can be achieved. But even at 1550 nm wavelength LiDAR corneal damages could occur if the laser power is too high. When developing a LiDAR system, the complete picture needs to be considered. Therefore, measuring and precise determination of pulsed energy and power is crucial for knowing how to stay within eye safety limits of laser illumination. And LiDAR detectors themselves can suffer from overexposed laser illumination.

Measuring challenges

Typical flash LiDAR pulse durations are from few ns to few 100ns with pulse repetition rates (PRR) in kHz to MHz range. High PRRs are crucial to provide fast scanning and reliable 3D feedback on scanned environment. As here a combination of a high peak power with a low average power is used a special measurement approach is required, e.g. using power sensors with special frequency modes. Ophir integrating spheres in power range from 1µW to 30W can measure highly divergent beams as well. As pulse characterization is essential, Ophir´s IS1.5 integrating spheres (fig. 1) are equipped with fast photodiodes (FPDs) to accurately measure pulse-to-pulse energy. Additionally, a spectrometer can be connected to the sphere and all measurements can be performed in parallel. To overcome pulse stretching issues small sized spheres needs to be used. Another option to measure the pulse energy are pyroelectric and photodiode sensors. Those sensors can measure pulse rates up to 25 kHz and pulse energies down to 10 pJ at 900 nm and 30 pJ at 1550 nm.

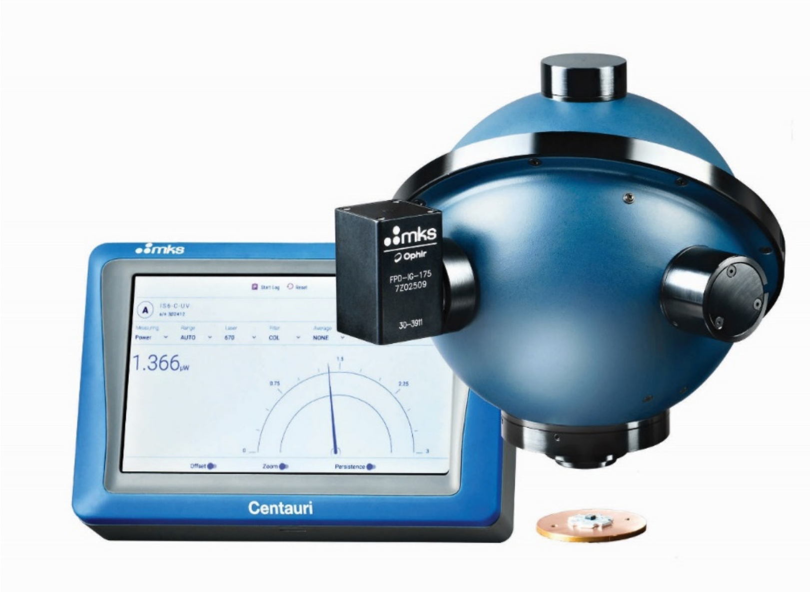


Fig. 1: The Ophir IS1.5 integrating sphere is equipped with a fast photodiode (FPD) to accurately measure pulse-to-pulse energy. Here together with a Centauri Energy Meter.

To ensure that the light source is operating at peak efficiency, measuring average power is essential to overcome issues in power consumption, which is critical to the performance of products such as battery-powered flying vehicles, like drones.

Another important aspect in terms of the accuracy of LiDAR systems is the quality of the evaluation of the returned signal in relation to the quality of the beam being sent out. If the performance of the light source is consistent and of high-quality, the signal received from the target is evaluated more accurately. Ophir´s camera-based beam profilers analyze beam quality, size, shape and divergence precisely, both in far field or near field set-ups.

Conclusion

Most will agree that providing robust and accurate LiDAR systems to the automotive arena is crucial to the evolution of self-driving vehicles. The measurement, analysis, and full characterization of light sources in these LiDAR systems is a small part of achieving this goal, but it is vital to the success of these programs.

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