LEDs vs. Laser Diodes for Wireless Optical Communication

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FSO is a line-of-sight technology that uses invisible beams of light to provide optical bandwidth connections that can send and receive voice, video, and data information. Today, FSO has enabled the development of a new category of outdoor wireless products that can transmit voice, data, and without expensive fiber-optic cabling or securing spectrum licenses for radio frequency (RF) solutions.

At the heart of Free Space Optical (FSO) technology is a modulated light source. A number of the systems available today use laser diodes; ClearMesh Networks is one of the few vendors that designed its system using Light Emitting Diodes (LEDs).

Each light source has distinctive differentiators, and thus reasons for using it in corresponding applications. LED-based systems have a number of advantages, the most obvious being cost and size. Not only is the optical sub-system design far less expensive, but the driving electronics are also more simplified. The result is that system cost per milliwatt for an LED based system is much lower, than for a laser diode design.

Part of the reason why LEDs are easier to drive lies in the stability of their performance. While laser diode output varies significantly over temperature range and lifetime, LEDs are generally more stable. This allows for a simple current driver modulator without temperature or output power feedback.

High power LEDs are generally of larger area, when compared to similarly powered laser diodes. Size does decrease the maximum frequency at which the LED can be modulated. Laser diodes can output higher power levels of coherent light from a smaller area, allowing for faster modulation and thus higher transport bandwidth designs.

The use of coherent laser light, however, also implies that the light can interfere with itself. In the atmosphere, various portions of a beam can take slightly different paths due to turbulence often caused by scintillation. The resulting self-interference creates fluctuating power levels at the receiver. LEDs, on the other hand, use incoherent light, eliminating self-interference altogether.

The larger device area of the LED allows for a wider collimation of the light beam which produces less energy density. However, the greater beam width also provides for a more robust link behavior in the presence of motion. When compared with a laser diode, the larger area of the LED does limit the extent to which light from the device can be collimated, e.g. by means of utilizing expensive high-grade optics. With a laser diode, more power can be collimated in a narrower beam and focused onto the receiving detector, leading to a longer maximum link length.

The choice of LED vs. Laser Diode as a light source in a wireless optical transmission product depends on the target application, and the related performance, cost and reliability requirements of the overall solution being designed.

Long range, very high speed (gigabit or more) point-to-point FSO systems require laser diodes. Such products compete with high-speed RF point-to-point solutions often based on millimeter wave transmission in the 60, 70, 80 and 90 GHz bands. Such systems require very precise optics and beam stability mechanisms that significantly increase product costs.

However, shorter range LED based systems can achieve high-speed optical system performance, while dramatically reducing the overall system size and cost. Both are mandatory requirements for the high-speed multi-point mesh networking market – requiring several optical links to be integrated in one low-cost, compact system design.

At a system cost comparable to multi-radio RF mesh solutions, the wireless optical mesh yields much higher mesh capacity and, more importantly, fiber-grade end-to-end transport quality. The latter point leads to unprecedented mesh scalability with up to 100 systems in one connected single-topology mesh without any noticeable degradation of service quality.

The table below compares features and design factors of LED vs. Laser Diode-based systems.

Feature	LED	Laser Diode
Modulation Speed	*100 - 300 MHz for high power*	*Can be 1 GHz and faster*
Power	*Depends on speed, limited to around 40 mW for high-speed*	*100's of mW available. Can also be optically amplified.*
Optical Bandwidth	*40 to 100 nanometers*	*< 1 nanometer*
Receiver Filtering	*Wide – increased noise floor*	*Narrow – lower noise floor*
Light Source	*Incoherent, no self-interference*	*Coherent, self-interference*
Minimum output beam divergence	*Wide (~0.5 degrees) due to the size of the LED*	*Narrow (~0.01 degrees), if built with high-grade optics*
Lifetime	*Long lifetime with little degradation of power levels*	*Medium lifetime, power levels degrade over time*
Temperature Dependence	*Little temperature dependence*	*Very temperature dependent*
Drive electronics	*Simple modulated current source*	*Compensating temperature and output power circuitry*
System Cost	*Low. Off-the-shelf optics and electronics*	*High. Special high-grade optics and compensating electronics*

When comparing LEDs to laser diodes, one can see that LEDs are more conducive to the qualities necessary for mesh networking. With a wider receive beam to compensate for atmospheric movement, higher temperature tolerance, simplified electronics requirements and decreased overall system costs, LED based optical systems are better suited to bringing the benefits of low cost, scalable, end-to-end fiber-grade transmission capacity to the high-growth mesh networking market.