LIGHTPOINTE™

LIGHTPOINTE WHITE PAPER SERIES

What is Free Space Optics (FSO)?

The Technology at the Heart of *Optical Wireless*

Communication by light is one of the oldest ways of signaling or sending messages between remote locations. The Colossus of Rhodes, shown below, was completed in 282 BC, after twelve years of construction, and is an early example of light signaling. When the colossus was finished, it stood approximately 33 meters, or 110 feet, high at the Dorian Rhodes harbor entrance and safely guided ships in, until a strong earthquake hit Rhodes in 226 BC.

Now, and more than 2000 years later, imagine a technology that offers full-duplex wireless gigabit Ethernet throughput and that also uses light to communicate information between remote locations. Imagine a technology that can be installed license-free worldwide, can be installed in less than a day and offers a fast and high return on investment (ROI). That technology is free-space optics (FSO). This line-of-sight technology approach uses invisible beams of light to provide optical bandwidth connections. It's capable of sending up to 1.25 gigabits per second (Gbps) of data, voice, and video communications simultaneously through the air — enabling optic connectivity without requiring physical fiber-optic cable. It delivers point-to-point communications at the speed of light. And it forms the basis of a new category of products — optical wireless products from LightPointe, the recognized leader in outdoor wireless bridging communications.

This short white paper is intended to provide valuable background and resource information on FSO technology. Whether you're a student, an engineer, account manager, partner, or customer, this paper provides the FSO insight you may require. And for providing high-speed connections, across Enterprises and between cell-site towers, it is one of the best technologies available.

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 technology — the foundation of LightPointe's optical wireless portfolio — has enabled the development of a new category of outdoor wireless products that can transmit voice, data, and video at bandwidths up to 1.25 Gbps. This optical connectivity doesn't require expensive fiber-optic cable or securing spectrum licenses for radio frequency (RF) solutions. FSO technology requires light. The use of light is a simple concept similar to optical transmissions using fiber-optic cables; the only difference is the medium. Light travels through air faster than it does through glass, so it is fair to classify FSO technology as optical communications at the speed of light.

The Colossus of Rhodes (282 BC)

To you, O Sun, the people of Dorian Rhodes set up this bronze statue reaching to Olympus when they had pacified the waves of war and crowned their city with the spoils taken from the enemy. Not only over the seas but also on land, did they kindle the lovely torch of freedom? *Dedicatory inscription of the Lighthouse*

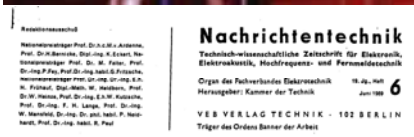
History

FSO technology for high speed and secure data transmission was originally developed by the military and NASA. By today, FSO has been used for more than three decades in various forms to provide fast communication links in remote locations. LightPointe has extensive experience in this area: its chief scientists were in the labs developing prototype FSO systems in Germany in the late 1960s, even before the advent of fiber-optic cable.

A copy of a page from the original FSO paper by Dr. Erhard Kube, LightPointe's Chief Scientist, which was published by the VEB Verlag Technik in Berlin, Germany, in the journal “Nachrichtentechnik” in June 1968, is shown on the right.

In Germany, Dr. Kube is widely regarded as the "Father of FSO Technology.” Dr. Kube is actively contributing to advancements in FSO technology at LightPointe.

Over the years, like fiber-optic communications, FSO technology has gained acceptance in the telecommunications industry. Most particularly in the enterprise campus networking environment. FSO technology enables bandwidth transmission capabilities that are similar to fiber optics, using similar optical transmitters and receivers, and even wavelength division multiplexing (WDM) operation through the air (free space) at speeds close to 40 Gbps has been successfully demonstrated. Due to the enormous bandwidth capabilities of FSO transmission and the worldwide unlicensed nature of the transmission spectrum, FSO technology has enormous upside potential for short distance wireless connections.



Nachrichtentechnik

Technisch-wissenschaftliche Zeitschrift für Elektronik, Elektroakustik, Hochfrequenz- und Fernmeldetechnik

Organ des Fachverbandes Elektrotechnik 19. Jg., Heft 6 Juni 1969

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E. KUBE, KDT, Dresden

Nachrichtenübertragung mit Lichtstrahlen in der Atmosphäre

Mitteilung aus dem Institut für Nachrichtentechnik, Berlin; Dir.: Prof. Dr.-Ing. P. Fey

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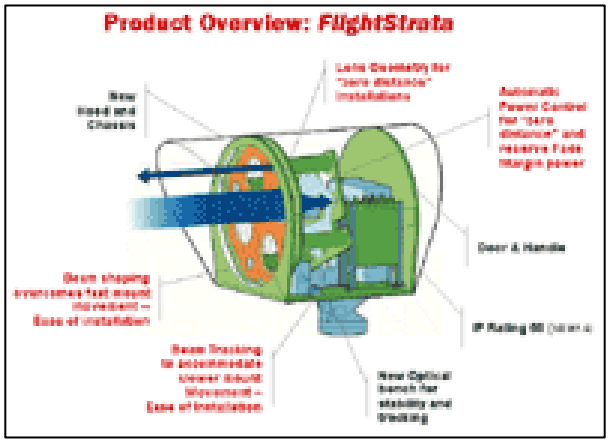
How it Works

FSO technology is surprisingly simple. It's based on connectivity between FSO-based optical wireless terminals, each consisting of an optical transceiver, which includes a transmitter and a receiver, to provide full-duplex (bi-directional) transport functionality. Each optical wireless terminal uses an optical source (Laser or LED), plus a lens or telescope that transmits light through the atmosphere to another lens receiving the information. The receiver itself is either a PIN diode or a more sensitive avalanche photo diode (APD). Some systems, like the LightPointe FlightStrata™ product line, include multiple, spatially separated transmission lasers. This approach on the transmission side, combined with the use of multiple, spatially separated receive lenses, adds additional redundancy and prevents smaller objects, like birds, from interrupting the optical beam. Additionally, the FlightStrata system is equipped with an active tracking system to keep the narrow beam aligned when the system is installed on more challenging and less stable installation platforms.

This FSO technology approach has a number of advantages:



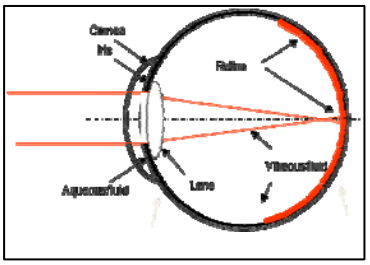
- Requires no RF spectrum licensing.
- Is easily upgradeable, and its open interfaces support equipment from a variety of vendors, which helps enterprises and service providers protect their investment in embedded telecommunications infrastructures.
- Highly secure due to narrow transmission beam
- Requires no security software upgrades.
- Is immune to radio frequency interference or saturation.
- Can be deployed behind windows, eliminating the need for costly rooftop rights.

FSO: Optical or Wireless?

Speed of fiber — flexibility of wireless. Optical wireless, based on FSO-technology, is an outdoor wireless product category that combines the speed of fiber with the flexibility of wireless. It enables optical transmission at speeds of up to 1.25 Gbps and, in the future, is capable of speeds of 10 Gbps and beyond using WDM technology. This is not possible with any standard microwave spectrum based, fixed wireless or RF technology. Optical wireless also eliminates the need to buy expensive spectrum licensing (it requires no FCC or municipal license approvals worldwide), which further distinguishes it from fixed wireless technologies.

Eye-safety: Is it safe?

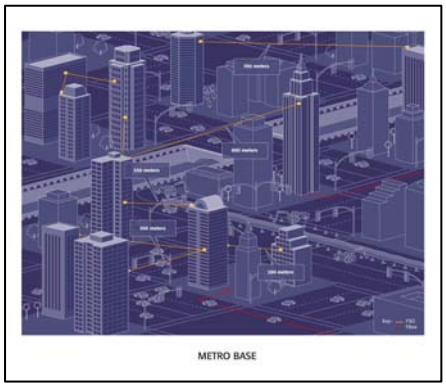
To those unfamiliar with FSO technology, safety can be a concern because the technology uses lasers for transmission. The IEC (TAG TC 76) team finalized an internationally recognized standard in the IEC60825-1 (Amendment 2) in 2001. The new standard unifies the previous European position on eye safety established under IEC60825-1 and the North American laser safety regulation as defined by FDA/CDRH.



Under the IEC60825-1 (Amendment 2) standard, specific laser classes were generated. Each class has specific labeling and warning instructions. Depending on the amount of power launched, the document outlines certain installation requirements that must be fulfilled to comply with the standard. The standard also contains definitions for specific hazardous zones in front of the laser power emitting system area that must be cleared for eye-safe viewing. The document also restricts installation of certain high power laser systems in areas easily accessible to the public. Within the new classification scheme class 1 and class 1M systems are totally eye-safe for viewing without or with an optical instrument such as binoculars. All LightPointe optical wireless terminals are tested by independent labs and classified as class 1M systems.

Market

Perspective


METRO BASE

Fueled by the ever-increasing demand for more bandwidth by enterprise customers and service providers world-wide, the lack of "last mile" connectivity has become a significant opportunity for companies offering high capacity access solutions. While many business buildings are within range of fiber-optic cable, most are not adequately connected as a result of prohibitive licensing requirements and the expense of having to dig up streets and neighborhoods. Most recent research numbers show that, to date, only about 10 percent of buildings worldwide are connected by fiber — yet 70 percent are within a mile of a fiber connection. As bandwidth demands increase and businesses turn to high-speed LANs, it has become even more frustrating to be connected to the outside world through lower-speed connections such as DSL, cable modems, or leased T1/E1 connections.

Further, most of the recent trenching to lay fiber has been to improve the metro core (backbone), while the metro access and edge — the "last mile" — have been ignored. Studies show that gaps occur in the metro network core, primarily due to cost constraints and the deployment of non-scalable, non-optical technologies. Metro optical networks have not yet delivered on their promise. High capacity at affordable prices still eludes the ultimate end-user.

"Last Mile" Access 101

There's a huge market opportunity for "last mile" access solutions — but which technology can best address the connectivity bottleneck? Fiber optic? Radio frequency/microwave radios? Millimeter-wave radios? Wire and copper-based technologies or FSO?

Fiber Optic Cable- High speed at premium pricing

It's the most obvious first choice. Without a doubt, fiber is the most reliable means of providing optical communications. But the digging, delays, and associated costs to lay fiber often make it economically prohibitive. Moreover, once fiber is deployed, it becomes a "sunk" cost and cannot be re-deployed if a customer relocates or switches to a competing service provider, making it extremely difficult to recover the investment in a reasonable timeframe.

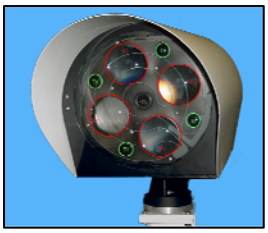
Radio Frequency (RF)/Microwave (MW) Radios- Robust but spectrum limited

Another option is radio frequency/microwave technology. Radio frequency (RF) radios offer a mature technology that can be deployed over longer distances. However, RF-based networks can require immense capital investments to acquire spectrum licenses. Also, lower frequency RF technologies using limited frequency channel bandwidth do not easily scale to higher capacity without using rather complex and expensive modulation schemes. While congestion of licensed spectrums is a big problem in more densely populated areas, the use of readily available unlicensed spectrums poses its own challenges due to interference and saturation in heavily congested RF environments. Unlicensed outdoor radio solutions are therefore not necessarily an option when guaranteed network throughput and longer term operation is required.

Millimeter-wave (MMW) Radios- More spectrums but global challenges

High capacity point-to-point MMW radio solutions have entered the commercial market in the United States several years ago. Initially, the spectrum band ranging from 57…64 GHz was opened as an unlicensed band for public use. This was followed in 2003 by a FCC ruling to open two 5 GHz MMW frequency bands from 71…76 GHz, 81…86 GHz, and an additional frequency band of 3 GHz ranging from 92…95 GHz for licensed use. The FCC action consequently resulted in opening a total of 20 GHz of spectrum for unlicensed and licensed use. Several other countries such as England, Ireland, and Australia have adopted the US. ruling governing the 70/80 GHz frequency bands. Other countries are partially following the opening of spectrum in the MMW bands, but due to complex national regulatory environments, the rules and regulations are not completely harmonized. In Europe, the Conference of European Posts and Telegraphs (CEPT) and the European Telecommunications Standards Institute (ETSI) are working in parallel on a harmonized standard for operation of MMW radios in the 70/80 GHz frequency bands. However, and although the ETSI proposal is in the final draft stage, no deadline has been set so far.

Wire and Copper – Readily available but not scalable



This option includes wire and copper-based technologies (i.e. cable modem, T1s/E1s or DSL). Although copper infrastructure is available almost everywhere and the percentage of buildings connected to copper is much higher than fiber, it is still not a viable alternative for solving the "last mile" connectivity bottleneck. The biggest hurdle is bandwidth scalability of copper wires. Copper technologies may ease some short-term pain, but the inherent bandwidth limitation makes them a marginal solution, even on a good day.

FSO Technology — High speed for shorter distances

FSO technology offers a highly competitive and high capacity “last mile” access alternative for shorter distance applications. It offers the speed of fiber with the flexibility of wireless. Given its optical foundation, bandwidth scalability, speed of deployment (hours versus weeks or months), re-deployment and portability, and cost-effectiveness (on average, one-fifth to one-tenth the cost of installing fiber-optic cable), optical wireless products combine many of the positive attributes of competing “last mile” access solutions. Furthermore, the worldwide license-free nature of the infrared optical spectrum makes it a perfect candidate for overcoming regulatory obstacles in any part of the world.

Deploying FSO Systems

While fiber-optic cable and FSO technology share many of the same attributes, they face different challenges due to the way they transmit information. While fiber is subject to outside disturbances from wayward construction backhoes, gnawing rodents, and even sharks when deployed under sea, FSO technology is like any other wireless transmission technology subject to a different set of potential disturbances. Many of these can be avoided by following simple installation guidelines and with thorough network planning and design. In general, one should consider the following when deploying FSO-based optical wireless systems:

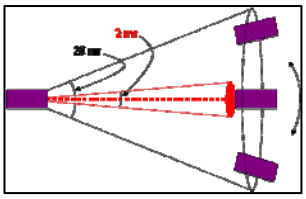
Line-of-Sight

Like any other high frequency wireless technology, FSO is a line-of-sight technology. Locations to be interconnected must have free line-of-sight. Because the beam of an optical communications system is very narrow a simple visual confirmation of the line-of-sight is sufficient. Unlike with radio system there is no additional “path clearance” needed to take the Fresnel zone propagation into consideration.

Temporary Obstructions

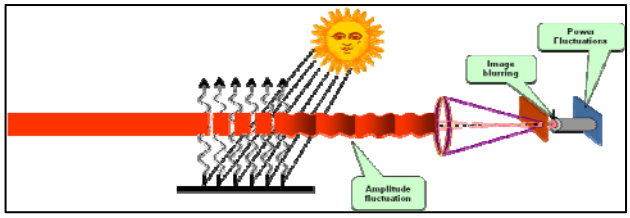
Flying birds or construction cranes can temporarily block a single-beam FSO system, but this tends to cause only short interruptions, and transmissions are easily and automatically resumed. Ethernet based protocols that resend traffic in case of a short interruption of the network connection typically compensate for these kinds of short term interruptions. In case the network does not tolerate even short temporary interruptions, the LightPointe FlightStrata™ product line incorporates a multi-beam system architecture of spatially diverse transmitters and receive lenses to address temporary obstructions.

Building sway/seismic activity



A stable installation platform and a solid mount are very important to ensure long term reliable operation of an FSO installation. The movement of buildings can upset receiver and transmitter alignment. LightPointe's shorter distance FlightLite™ products use a beam with a wider divergence angle to maintain connectivity between remote terminals. In case of a longer distance deployment and/or if the platform is potentially prone to slight movements or sway, the FlightStrata™ product is a more desirable solution to guarantee long term alignment stability because it is equipped with an active beam tracking system that automatically keeps the terminals aligned.

Scintillation



Heated air rising from the earth or man-made devices such as heating ducts create temperature variations among different air pockets. This can cause fluctuations in signal amplitude which leads to "image dancing" at the FSO-based receiver end. LightPointe's unique multi-beam system is designed to address the effects of this scintillation. Called "Refractive turbulence," this causes two primary effects on optical beams.

Environmental Impact - Rain, Fog, Snow

Like any other wireless transmission system, an optical wireless link has a “Link Budget” or a “System Fade Margin” to simulate the impact of environmental factors that increase the attenuation of the signal path. To maintain 100% connectivity, it is therefore desirable to design a system with a link budget that is sufficient to overcome any kind of environmental impact over the anticipated deployment distance.

Rain has an impact on the transmission path and the signal is attenuated differently depending on the rain fall rate, typically measured in mm of rain/hr. For most parts of the Continental United States and Europe the rain rate exceeds about 40 mm/hour, less than 1 hour per year. Such a rain rate can

be translated into an attenuation of approximately 17 dB/km. By knowing the system link budget, one can easily calculate the system availability over the course of a year and calculate potential outages due to rain.

The real challenge, however, to FSO-based communications is not rain but fog. Fog is vapor composed of water droplets, many of them only a few microns in diameter. These small particles, on the order of the actual infrared transmission wavelength, increase the amount of signal attenuation and hinder the passage of light through a combination of absorption and, primarily, by scattering light. In areas that are prone to heavy fog events it is recommended to shorten the distance between terminals by using multiple-hop FSO connections, thereby reducing the distance between individual locations. If this is not possible, the addition of network redundancies can be implemented by using an alternative network path such as a T1/E1 connection, DSL connection or RF radio link. Although all of these redundant solutions typically work at a slower speed when compared to the FSO system, in conjunction with automatic failover switching protocols like rapid spanning-tree (RST) or routing protocols like open shortest path first (OSPF) the network connection can be maintained during dense fog events. Just as an example, if a gigabit Ethernet FSO system is operational 99.9% of the time the slower speed alternative path will be used only 0.1% of the time. In most cases this is a very viable approach and guarantees that connectivity is maintained 100% of the time. Designing a network connection with a redundant or alternative path is always a good practice since it ensures that connectivity is maintained even in case of a catastrophic failure, which can never be excluded and typically can not be repaired on short notice.

About LightPointe

LightPointe was founded in 1998 and has become the global market leader for high capacity wireless outdoor bridges with over 5000 systems deployed in over 60 countries worldwide and in vertical markets such as Health Care, Education, Military & Government networks, large and small campus enterprise networks, Wireline and Wireless Service Provider networks. Over the last 10 years the company has established a unique diversified product portfolio based on high capacity Free Space Optics (FSO) and Millimeter Wave (MMW) technology. With more than 10 patents granted in the FSO, RF/MMW and in the hybrid bridging solution space LightPointe has established a strong IP and patent portfolio position manifesting the company's technology leadership position.

LightPointe has a long list of global customers including but not limited to Wal-Mart, DHL, Sturm Foods, Siemens, Sprint, AOL, FedEx, BMW, Lockheed Martin, Dain Rauscher, Barclays, Nokia, Deutsche bank, IBM, Corning, Cisco, Huawei just to mentioned a few. For more information please visit the Lightpointe website at www.lightpointe.com