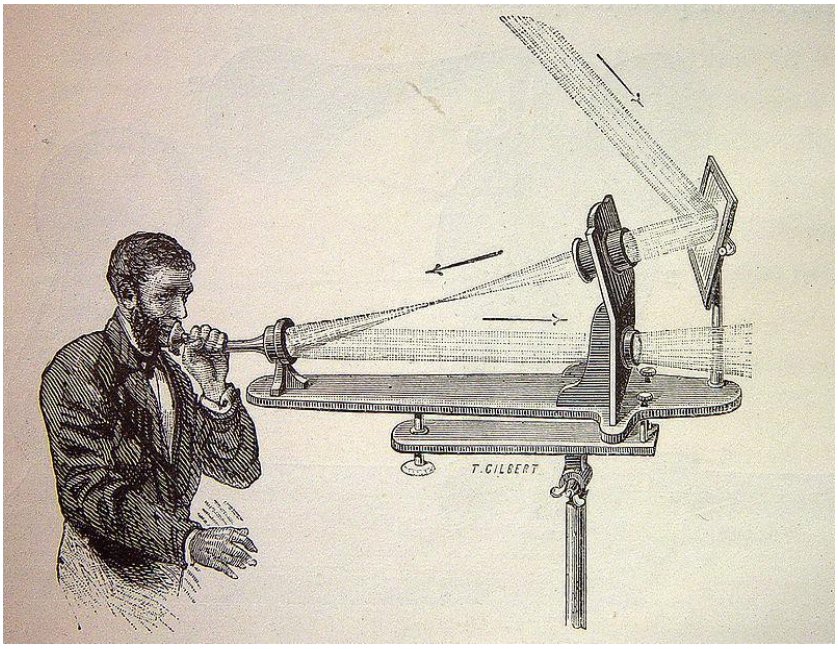
Technical White Paper

November 9, 2014

The History Of Free Space Optics

A Brief History of Modern Optical Communications

For all of recorded history, smoke signals and other visual cues have been used to convey simple messages across distances. These basic signals are often used in modern entertainment, since the visual signs are as dramatic as they are simple.



Since the advent of the telephone system, researchers in telecommunications have been attempting to use light instead of wires to communicate over long distances. Alexander Graham Bell has four patents on the photophone.[i] He was quoted as saying it would surpass the telephone, and was his greatest achievement.

The problem with the photophone is the same problem that has plagued every other attempt at light-based, Free-Space Optical (FSO) communications. The devices work perfectly in the in a structure, even in long ranged-testing. As soon as the photophone was taken into the field, its reliability dropped under 50% which clearly is unacceptable. The sun's intensity drowning out the data signal was the main problem for this device, and so the world built wire-based telephone systems.

The potential of light-based communications is on the forefront of major telecommunications companies today. As time moved on, fiber optics have become an industry standard, facilitating most of the internet's data traffic. Fiber optics is an extremely reliable form of optical communications which uses fiber to shield light from the atmosphere.

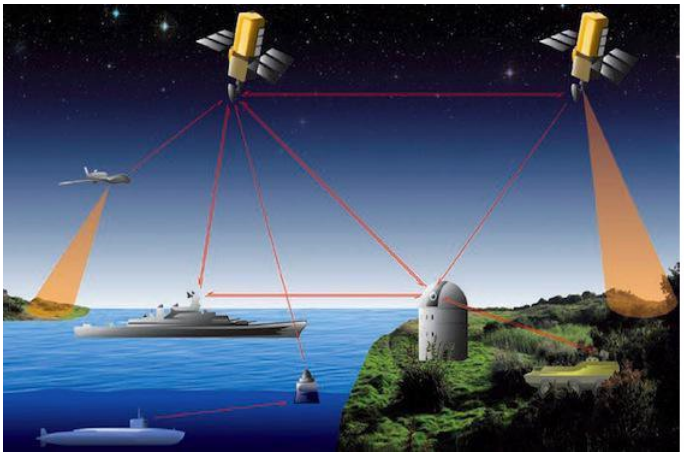
In hopes that a group will one day solve the reliability issues for FSO communications, there is a special reliability standard for these solutions. The standard is 10 times less reliable than for fiber – 50 minutes of downtime a year (a '4 9s' standard, 99.99% availability) verses 5 minutes of downtime a year (a '5 9s' standard – 99.999% availability). Major telecommunications companies would very much like to see FSO succeed today due to its advantages in addressing the growing demand for bandwidth.

Market Opportunity for Free Space Optical Communications

The global market for telecom backhaul equipment was estimated to be worth $5B in 2012[ii] and is dominated by radio frequency (RF) transmission equipment. Over the following 5 years, total spend is expected to exceed $44B.[iii] With demand for mobile data expanding exponentially and RF spectrum availability drying up, network operators are searching for new alternatives to build out Infrastructure.

The telecom operators have clear standards – 5 9s reliability over 3 to 5 km (also called the "Last Mile Problem"). For unregulated, FSO Communications, the industry has actually lowered its standards to 4 9s over 3 to 5 km, which is a major concession. No Optical Communications manufacturer today can meet those standards when tests are conducted in inclement weather. This is easily verified by using a calibrated Bit Error Rate Testing (BERT) device.

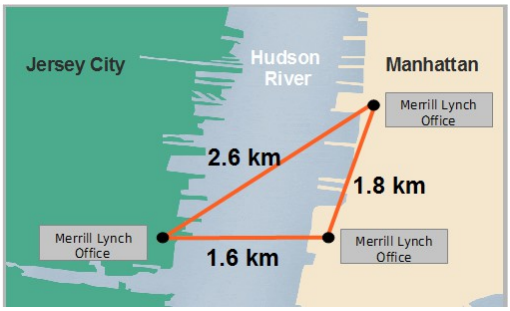
Free Space Optical Communications in the Modern Era



Free Space Optics is a fast, inexpensive, and rapidly deployable solution not limited by spectrum licensing. This offers unique advantages over technologies such as Microwave, RF, and Fiber. As evidenced in the below table, the principal limitation is the reliability.

The race to find a reliable solution using optical communications has captured the minds of major corporations and government agencies. DARPA[iv] has funded multiple programs, e.g. ORCA[iv] and ORACLE[iv], and most recently PULSE[iv], spending well over $150M USD in an attempt to realize their tactical vision[v] of optical battlefield communications (depicted left).

Commercially, AT&T backed Terabeam from 2000 – 2004,[vi] and the commercial sector took Terabeam very seriously. After the September 11th attacks in 2001, Terabeam fielded three links on three Merrill Lynch buildings in NYC, whose communications had previously run through the Twin Towers (depicted right).[vii] The link was up and running in seven days after the attacks, this pole-vaulted the company into instant credibility and brought awareness to FSO's unregulated and rapid deployment advantages.



There were numerous reports and research papers of government support after this link was set up. Reports from the Navy support FSO as a viable and cost effective means to provide infrastructure to a city.[viii] The problem has always been with reliability. Terabeam did the first research on this, which was vetted and evaluated by the FCC (see page 5).

The result was what the Merrill Lynch staff observed FSO in New York City: reliability was significantly less than 3 9s (99.9% availability) with the unit deployed. While this was a great short-term solution, the atmosphere-related down time simply became too much of a problem for long-term use. This graph shows that other major cities, where alternate technologies to fiber and RF are needed, wouldn't fare any better than New York City.

Terabeam produced some viable products and technical improvements, but didn't reach its goal of providing optical backhaul. Terabeam encountered the same problem as Graham Bell, later repeated by MRV's TeraScope line (now discontinued) as well as Maxima Corporation (now defunct).

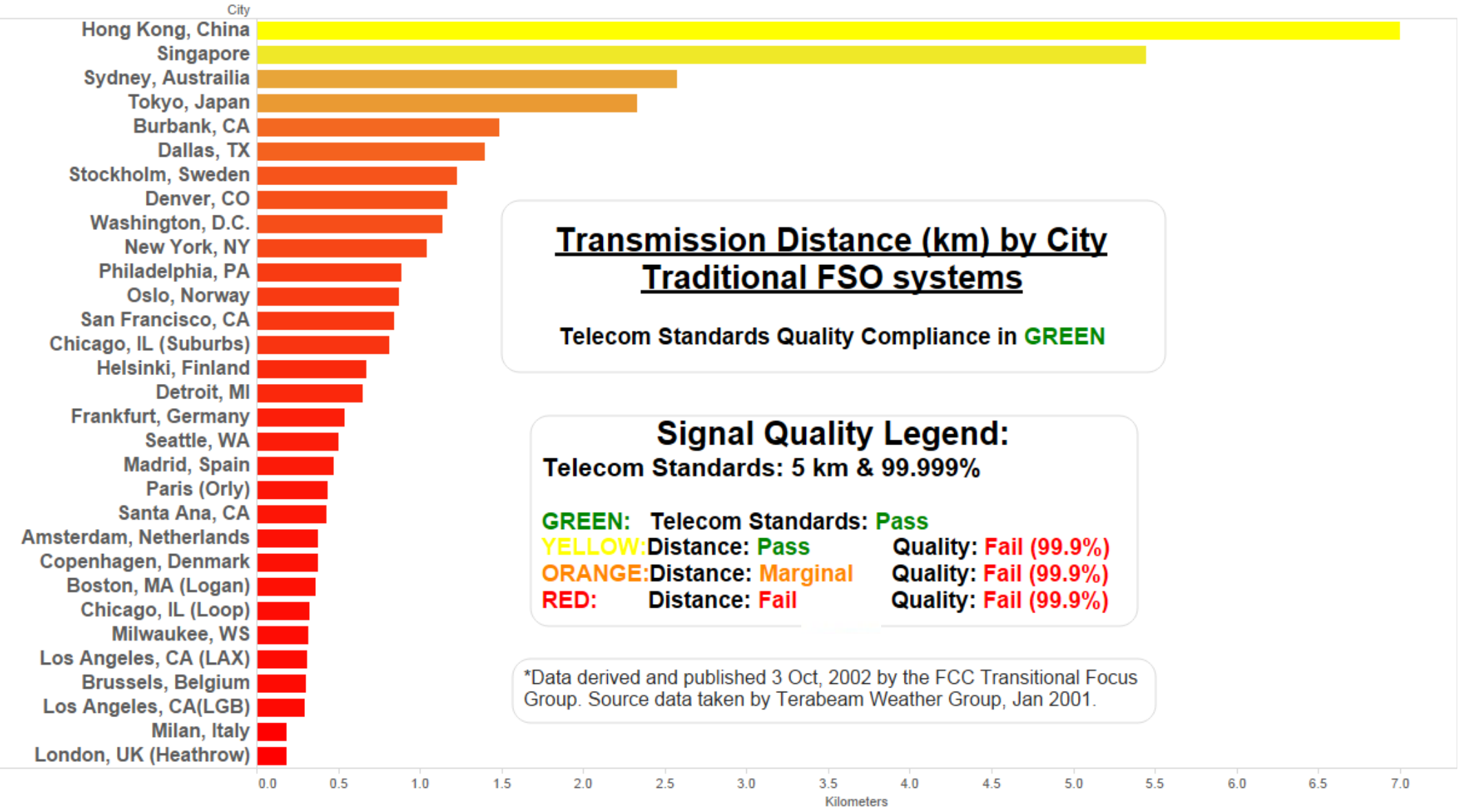
Addressing the problems created the atmosphere is the difference between success and failure in providing reliable (4 9s or 5 9s) communication through the air. Unchallenged, Licensed RF communications dominates the mobile backhaul market, a $5B a year market.[ix]

Free Space Optical Communications as a Business

With a total industry revenue of $34M,[x] the current commercial landscape of Free Space Optic equipment manufacturers consists of Light Pointe, FSona, Plaintree, Sky Fiber, Canon (Canobeam), AOptix (a recent entrant), and a few others. The technologies available today are primarily for niche applications and have not been widely adopted as industry standards for network communications or backhaul solutions.

The reliability challenge each of these technologies face is related to performance in adverse weather conditions. As evidenced by recent independent tests, the current reliability of modern FSO technology is 99.999% at 500 m in fair weather condition and 99.995% in fog and rain.[xi,xii,xiii,xiv] To address the quality gap needed for backhaul, FSO manufacturers are adopting unlicensed backup RF systems to compliment the optical technology. The dual technology systems do not achieve both the reliability and speed needed by customers simultaneously. Unlicensed RF units used simply cannot match the laser's unregulated throughput abilities.

In the government sector, there is an understanding that overcoming the atmosphere is paramount. As a result, the Naval Research Lab (NRL) has maintained a permanent 32 km test facility at Chesapeake Bay, VA, since 2007, for use by anyone who can solve the military's FSO needs.[xv]



Conclusion: There is no **Green** - Traditional FSO is not able to meet telecom standards in any major city across the world.

The Technical Opportunity

Fog Optics is an applied research company that produces the most effective products for high quality, high bandwidth free space optical communications today, and to will continue to achieve the highest communications rates terrestrially or extra terrestrially in the future. Fog Buster is the flagship product innovation that specializes in providing a reliable transport layer in all weather conditions.

Reports of lasers going through the atmosphere better than expected, or with some unusual traits, are being made by researchers internationally. There are currently four basic points of view:

- Theorists state that light is light, and the two factors that matter are power and wavelength. This, while academically sound, ignores reported real world data[xvi]
- Some experimentalists report occurrences of lasers dealing with atmospheric problems better than predicted, but have no further comment[xvii]
- Other experimentalists publish data without comment, but make a suggestion of possible application in their conclusions[xviii]
- A few experimentalists publish data and actively make the case for applications[xix]

None of these entities, however, has been able to implement a solution like Fog Optics. Most researchers either stay neutral on the topic, or solicit funds to try and reproduce the experiments.[xx] What is missing from the knowledge in the field is a clear explanation of light's behavior in adverse conditions: one that guides whole laser system designs for optimal quality in conditions found outside the lab.

While researchers are pursuing an explanation and engineers are incrementally advancing their models, Fog Optics has a solution today to address industry needs and provide significant growth opportunities for its customers. Free Space Optic Manufacturers may license Fog Buster to upgrade their products and achieve a 99.999% reliability over 3km – 5km (exact range dependent on specific design decisions) to meet telecom needs for backhaul infrastructure.

Fog Optics has no need to enter academic debate, or to disclose the designs of its patent protected Fog Buster system. There is 500+ GB of field data which supports our claim of to achieve 99.999% in inclement weather, far more packet-level data than any other group, commercial or academic. This data is available to independent verification parties and potential business partners for review and verification.

Our goal is to enable our partners to be the leaders in the FSO space to command a new mobile backhaul market, entrenching their products as the new solution for bandwidth and reliability. Such a burgeoning market would be a golden opportunity for partnership in a cloudy world.

Contact

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[i]Illustration of the photophone's transmitter, originally from: El mundo físico : gravedad, gravitación, luz, calor, electricidad, magnetismo, etc. / A. Guillemin by: Guillemin, Amédée, published by: Barcelona Montaner y Simón, 1882

[ii]2012 Market Size from Infoetics - infonetics.com/pr/2012/2Q12-Microwave-Equipment-Market-Highlights.asp

[iii]2018 Market Size from Infoetics - infonetics.com/pr/2012/1H12-Macrocell-Mobile-Backhaul-Market-Highlights.asp

[iv]DARPA is the advanced research agency for the US department of Defense, and stands for Defense Advanced Research Projects Agency. Other program acronyms used were:
ORCA: Optical RF Communications Adjunct
ORCLE: Optical & RF Combined Link Experiment
PULSE: Program in Ultrafast Laser Science and Engineering

[v]Figures taken from Department of Defense Fiscal Year (FY) 2010-2014 Budget Estimates, Defense Advanced Research Projects Agency, Justification Book Volume 1, Research, Development, Test & Evaluation, Defense-Wide, and the DARPA PULSE funding figures in the RFP issued in 2013

[vi]Staff Writer, "Terabeam Cuts its Losses," Telephony, Vol. 245 Issue 8, p8, April 2004

[vii]Image taken from FCC Transitional Group Report on Link Availability, FSO Technologies, Published for Limited Release, Oct 3, 2002. Full Report Available Upon Request.

[viii]John Sprague, "Free Space Optics and Wireless Broadband Radio Frequency Technology: Bringing High-Speed Network Access to the Last Mile", Naval Postgraduate Thesis, March 2002, pg 43-50.

[ix]Richard Webb , "$44 billion to be spent over 5 years on mobile backhaul gear, driven by IP/Ethernet and microwave", Infometrics, October 24, 2014. Available online at: http://www.infonetics.com/pr/2012/1h12-macrocell-mobile-backhaul-market-highlights.asp

[x]Coffey, Valerie, "Free-Space Optics Market Up 11% in 2013", Optics and Photonics News, Jan 31 2013

[xi]Miloš Wimmer, et all. "MRV TereScope 700/G Laser Link" CESNET Czech Republic Study. Available at: http://archiv.cesnet.cz/doc/techzpravy/2007/mrv-terescope-700/

[xii]E. Korevaar et all, "Caracteristicas de propagacion atmosferica para los FSO comerciales", SPIE Proceedings, SPIE Vol. 4530 p. 84, 2001.

[xiii]Brian Chen chief reviewer, Authors and Contributors were Unnamed professionals working for Nanyang Technical University and Agilent Technologies, "A Trial-Based Study of Free-Space Optics Systems in Singapore", Report Owned by Info-Communications Development Authority of Singapore, Oct 2002, pg 37-40.

[xiv]Independent Evaluation of various traditional commercial FSO systems by System Support Solutions, Inc. (http://systemsupportsolutions.com/) Report summary available upon request.

[xv]C. Moore, et. all "Overview of NRL's maritime laser communication test facility," SPIE Proceedings Vol. 5892, Pg 40-51, 2005

[xvi]Various technical papers by theoretical physicists, starting with: D.G. Kocher, "Prediciton of Optical Landing Guidance System Performance in Cat. III-a Minimum Weather," USAF Technical Note 1973-47, Nov 8 1973

[xvii]Coherent equipment at Antartica Test site during a snow storm. Available at: http://www.laserfocusworld.com/articles/print/volume-48/issue-10/world-news/spectroscopy-femtosecond-laser-measures-atmospheric-radical-traces-in-antarctica.html?goback=.gde_110741_member_173936531

[xviii]N. Newbury, et all, NIST, Boulder, Co. "A Free-Space Link for Comparison of Optical Clocks", PULSE Proposer's Day, Arlington, VA, July 17, 2012. Available upon request.

[xix]I. Kim, et. All, "Advances in Communications: New FSO provides reliable 10 Gbit/s and beyond backhaul connections", Laser Focus World, Oct 14, 2013. Available at: http://www.laserfocusworld.com/articles/print/volume-49/issue-10/features/advances-in-communications-new-fso-provides-reliable-10-gbit-s-and-beyond-backhaul-connections.htm

[xx]Virginia Military Institute press release. http://www.vmi.edu/Content.aspx?id=10737426827