Can You Use an FSO Link?

Accommodating Free-Space Optics with good installation and building design

A BBP Staff Report

We get a lot of calls from developers at their wit's end, looking for quick solutions to nasty little FTTH problems. High on our list of quick fixes is free-space optics (FSO), especially for covering short distances, 1000 feet or less. We know that these laser infrared devices are often used over distances of a mile or more. But our readers are most interested in bridging short gaps where laying fiber would be costly or inconvenient.

How does one design a building for easy installation and maintenance? What situations should be avoided? What works and what doesn't? How much power will be required? For indoor use, what kind of glass should it sit behind? What kinds of structures and construction cause the most trouble; for example, concrete or steel?

We asked a lot of FSO suppliers. Most of what follows was supplied by Canon's Canobeam staff, which has an active technician training program that helps answer these questions.

First, the good news: Given a good vantage point, FSO units can be set up quickly, and with no FCC licensing. Most companies' products can be installed outdoors, but they can also be installed indoors behind glass.

Like fiber, FSO is protocol-independent; it transmits any higher-layer protocol including Ethernet, SDH, ATM and TCP/IP. Like fiber, FSO can transmit up to multi-gigabit speeds, especially over a few hundred feet. Canobeam pioneered auto-tracking, which automatically moves the beam (within limits, described below) in response to vibration or movement of the building upon which the devices are placed. All Canobeam FSO models include auto-tracking, as do most devices from competitors.

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CANOBEAM **Site Survey Form**

Date 2/25/04	Customer Name & Contact Info JOHN SMITH 410-461-2296
Company Name SMITH & CO.	Street Address 2900 OSCAR BLVD. EASTON, MD
Surveyor & Company MIGUEL TEJADA - STREET WIRELESS	Phone number & Email address 410-259-1010
Check line of sight for:	**NOTES:**
Trees	NONE
Building Construction	NONE
Other obstructions	
Birds Nesting	NONE
Power Line	NONE
Local Atmospheric disturbances	NONE
Hot Surfaces (black surfaces will generate heat)	BLACK TAR SURFACE ON ROOF
Pedestrian or Vehicle traffic	NONE
Rooftop - Secure (restricted access)?	RESTRICTED ACCESS TO BADGED EMPLOYEES
Rooftop Rights (landlord permission to install on roof)?	CUSTOMER OWNS BUILDING-ABLE TO PENETRATE ROOF
Exhaust or Dust clouds	NONE
Exhaust Vents	NONE

Figure 1. First page of typical site survey form.

Building movement can occur even on a clear, calm day as metal and masonry expand and contract. There is a tradeoff between bandwidth and the ability to autotrack, especially at the maximum link distances the vendors advertise. The Canobeam's auto tracking system, for instance, can compensate for up to 2.4 degrees of movement. At a range of 500 meters, this is equivalent to an area of 20 meters. The tracking allows vendors to focus the infrared laser beam more precisely. At 1 kilometer the Canobeam's transmitted beam has a 1-meter diameter. FSO systems without tracking require

Weather Condition[1]	Light Haze	Thin Fog	Light Fog
Precipitation[2]	Light Rain/Snow @ 2.5mm/hr	Heavy Rain/Snow @25 mm/hr	Cloudburst/Snow @100 mm/hr
Attenuation/km	3dB	10dB	30dB
Visibility[3]	4333	1300	433
DT-110 Transmission Distance[3]	1750	1000	520
DT-120 Transmission Distance[3]	5490	2360	1010
DT-130 Transmission Distance[3]	3650	1720	780

Figure 2. Recommended transmission distances are calculated under conditions of more than 99.5 percent reliability based on actual visibility data in Tokyo, Japan. All distances expressed in meters. These values are calculated by transmission margin, beam divergence, Gaussian intensity distribution of light and are different from Canobeam's recommended transmission distance described in specifications. Visibility distances are approximate. Actual transmission distance should be considered with scintillation, backlight noise , and another factors.

1. E.J. McCartney, Optics of the Atmosphere, J. Wiley & Sons, New York, 1976.

2. T.S. Chu and D.C. Hogg, "Effects of precipitation on propagation at 0.63, 3.5, and 10.6 Microns," Bell Syst. Tech. J., 47, pp. 723-759, 1968.

closer to a 5-meter beam diameter at this distance. That's only 1/25th the power on the receiver's sensor.

Fog is a bigger problem than rain for FSO devices, unless the downpour is intense; fog scatters the infrared laser beam. Rain tends only to partially block it.

Interfaces

Various models of FSO devices have different available interfaces, even from the same vendors. Usually, the correct interface has to be specified. For instance, the Canobeam DT-110 TP has an RJ-45 twisted-pair connector for Cat. 5 100BaseT copper cable.

The maximum cable length back to the network switch, router or other equipment is 100 meters. That's generous, but sometimes difficult to set up. Also, connection to this interface requires an Ethernet switch port configured for 100 Mbps full duplex.

The RJ-45 interface is passive, unlike an Ethernet port on a switch or a router, and will not auto-negotiate with an auto-sensing network device. That's not a problem, but network devices do have to be set accordingly.

Canobeam and many competitors have an extra 10BaseT connector for network management via the highly standardized simple network management protocol (SNMP).

For Fiber

The DT-110 MM has a multi mode fiber interface with an SC connector that allows the FSO device to be as much as 2 km away from the nearest network equipment. For 100Base FX, (Fast Ethernet over fiber) the Ethernet switch port connected to the Canobeam must also be configured for 100 Mbps full duplex. The DT-110 SM has a single mode fiber interface with an SC connector.

Some devices, like the Canobeam DT-130 LX, accept either multi mode or single mode fiber optic cabling with SC connectors. These should meet the IEEE 802.3z standard for Gigabit Ethernet LX interfaces. For multi mode 1000Base LX connections, you should consult with the switch or router manufacturer's operation and installation guidelines.

Some manufacturers, such as Cisco, require a special "mode-conditioning" patch cable when connecting to their multi mode LX interfaces. Without the patch cable, a high bit-error count could be possible due to receiver oversaturation. The type of fiber governs the maximum length of the fiber cable between the Canobeam and the network equipment. The maximum specified by Canobeam is 550 meters for 62.5/125 or 50/125 micron core MMF cables and 10 km for 9.5 micron core SMF cables, for instance.

Installation

These devices are meant to be professionally installed by experienced technicians. But before you bring them in, you can do a preliminary site survey to uncover obvious problems.

• Obstructions to line of sight

Figure 3. Canobeam FSO mounted on the edge of a roof; its beam will not be affected by heat or venting from the roof itself.

Scintillation or "hot air" can occur frequently over asphalt-covered roofs, parking surfaces or any other dark surfaces. Transmission disturbances will occur when the FSO's optical path traverses these types of surfaces. To protect the beam from scintillation effects, avoid installing over any heat-generating surface whenever possible.

- Transmission distance
- Mounting and stability
- Network equipment specifications/ connectivity

Canon requires that installers fill out a site survey checklist (Figure 1) and submit it with photos to the company before installation.

Detailed issues include:

- **New building construction nearby:** Construction cranes and other construction equipment can temporarily block the line of sight. So can planned new construction itself.
- **Growing trees.**
- **Vehicular traffic:** FSOs must be mounted high enough so that a truck or other tall vehicle does not interrupt the link. To pass under Interstate highway bridges, a truck must be less than 14 feet high.
- **Nesting birds**: Do not install an FSO device where the lens is adjacent or near a flat surface where nesting birds could block the beam.
- **Exhaust vents and chimneys:** Vented hot gasses (although invisible), as well as steam and smoke in the optical path, can cause link interruptions.
- **Scintillation or "hot air"** can occur frequently over asphalt-covered roofs, parking surfaces or any other dark surfaces. Transmission disturbances will occur when the FSO's optical path traverses these types of surfaces. To protect the beam from scintillation effects, avoid installing over any heat-generating surface whenever possible. If there is no alternative path, the FSOs must be installed as high above the surface as possible to minimize the heat effects.
- **Building maintenance personnel:** Mount far away from maintenance and window cleaner staging areas and high-traffic areas. Ask maintenance personnel where temporary maintenance gear may be placed, and the frequency with which window cleaning is performed. For window installations, the customer may want to request window cleaning during non-business hours or on select days. Optionally, a second pair of devices can back up a primary pair blocked by window cleaners or building maintenance personnel. The backup pair must be installed far from the primary pair.
- **Attenuation effects due to window glass** for devices mounted indoors. When an FSO is installed behind window glass, the beam may be attenuated depending on the glass characteristics (tinting/reflective, number of window panes). The angle the beam makes with the window is critical – the device should be approximately 5 degrees from perpendicular to the glass surface. If the FSO is perpendicular to the glass, the device's own light will be reflected back into its receiver, causing over-saturation. Installing behind glass at glancing angles will cause increased attenuation.

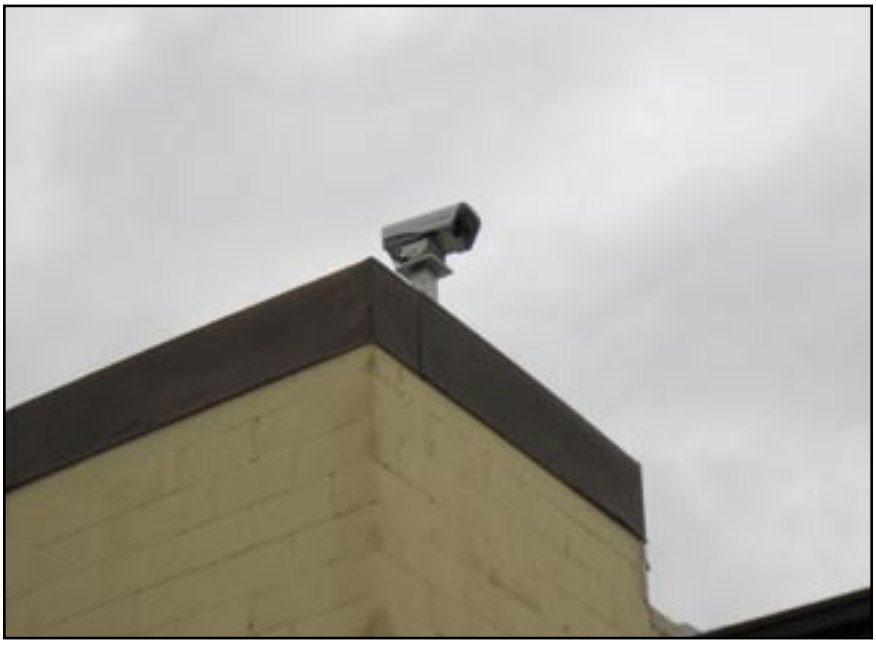

Figure 4. Heavy post mount clears the parapet.

Another issue is orientation of the beam direction. If installed East-West it is possible one of the FSO devices could go into "Sun Protection" mode. This occurs for Canobeam devices when sunlight enters the receiver within 0.3 degree of the beam transmitted by the other FSO in the pair. Should this occur, the device will shut down the re-

Figure 5. Indoor mount. Note how the FSO is tilted a bit, relative to the glass. See text for details.

ceiver, interrupting the optical path. The Canobeam can take up to 6 minutes to recover and resume transmitting. This exists to protect the receiver.

Thus, if possible, avoid an installation where sunlight could enter the receiver lens at the same angle as the laser beam. This is a rare condition, but could occur even at high noon if the two devices are installed so that one is at an extremely high elevation.

If the situation is unavoidable, install a wall-like sunshade behind the device in the direction of the sun, to block the sunlight from entering the opposite receiver.

Transmission Distances

It sounds obvious, but distances should be checked carefully, on a site plan or map, or with a rangefinder. Less obviously, FSO devices have minimum as well as maximum transmission distances. For the Canobeam DT series, for instance, the allowable ranges are:

- DT-110: 20-500 meters (65ft. to .31 mi.)
- DT-120: 100-2000 meters (328ft. to 1.24mi.)
- DT-130: 100-1000 meters (328ft. to .62mi.)

Excessive light input can occur if devices are too close. When that happens, FSO devices go into sun protection mode to protect the receiver. The Canobeam devices have a "Low" power position for short distances.

Longer distances are always possible, especially in dry climates. But system reliability tends to suffer as distances are extended beyond manufacturers' limits. Some vendors are also overly optimistic about range.

Mounting

Even with built-in auto-tracking, FSO devices should always be mounted on a rigid frame or surface. Auto-tracking exists to compensate for movement from wind, temperature, and other environmental factors, not to make up for a loose mount. To achieve as rigid a mount as possible, consider the following mounting recommendations:

- Mount with penetrating mounts to a concrete or masonry structure (a steel structure is a second option if a concrete or masonry mount is not possible).
- Mount to a solid, stable platform with penetrating mounts (the mounts are bolted to the rooftop) wherever possible. Some rooftop environments may not permit penetrating mounts. A platform or tripod weighed down by heavy concrete or masonry blocks,

Thin facades look much more rigid than they really are. Canobeam reports one customer who attached the FSO to a false-wall facade on a rooftop constructed of thin metal beams. Even worse, the angle of the facade directed wind directly to the Canobeam and caused it to move independently of normal building sway.

Figure 6. Canobeam swivel mount.

Figure 7. Pelco wall mount.

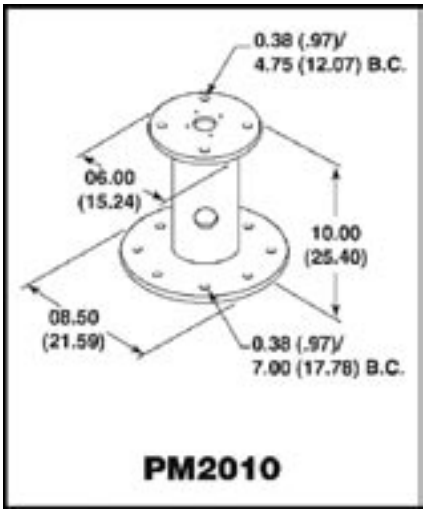

Figure 8. Pedestal mount.

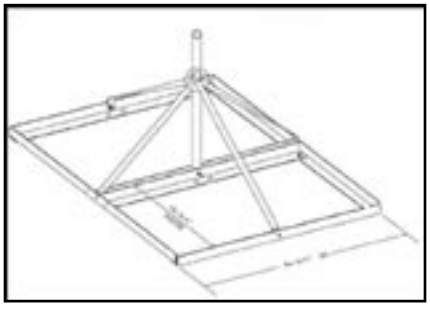

Figure 9. Rohn/Radian FRM238 non-penetrating mount.

or sandbags, is an option where penetrating mounts are not possible. In general, the mounting frames should be metal, not wood. Wood warps and shrinks enough to cause alignment problems over time.

- Corners are typically the strongest rooftop location on which to mount.
- Identify potential sources of vibration such as HVAC equipment, elevator headhouses and other enclosures with compressors or motors. Avoid installing the equipment in these locations. It is often tempting to do so, because such devices typically have an existing electrical connection that could be used to power the FSO.
- With a pole mount or pedestal mount installation, the lowest possible mounting position is always the best option. If a high mount is necessary to avoid a hot surface or an obstruction, take care to properly brace the mounting brackets to ensure complete rigidity. A 3 to 4-inch diameter pole is recommended to provide maximum stability.

Also, attach an FSO on the roof edge closest to the direction of the transmission beam. This helps keep the beam away from heat-emitting dark surfaces or exhaust vents. Raising the mount helps avoid these issues, if the closest edge is unsuitable. Use only installation materials and methods capable of supporting four times the maximum expected load, to allow for wind and other forces.

Typically, a mount then fits between the FSO device and the mounting frame or pole, to allow fine-tuned aiming adjustments. For the Canobeam products, the Canon FA-100 Tilt/Swivel Head bolts directly to Canobeam DT-100 Series units to allow for vertical and horizontal adjustments during alignment. Included with the FA-100 are four screws to attach the mount to the DT-100 Series unit and four more to attach to mount adaptors (described below). The FA-100 has separate locking bolts next to each center axis bolt and circular cutouts on the bottom of the unit for swiveling action and lockdown.

Another popular mount, the Pelco AH2000, has shared center axis/locking bolts. Pelco (www.pelco.com and many independent distributors) also sells a wall mount, the WM3026, made of heavy aluminum. It supports a maximum load of 300 pounds. The Pelco PM2010 Pedestal mount has a height of 10 inches and is compatible with the FA-100 Pan/tilt head. The Pelco PP200 Parapet mount mates directly with the FA-100 Tilt/Swivel mount in order to mount a Canobeam to the inside of a parapet. The maximum load for the mount is 175 lbs.

For non-penetrating mounts, Canobeam recommends the Rohn/Radian FRM 238 due to its low, 30-inch mast height (www.criticaltowers.com). This mount is optimal for roofs with low or no parapet. For non-penetrating installations that require a mounting height above 30 inches, Canobeam recom-

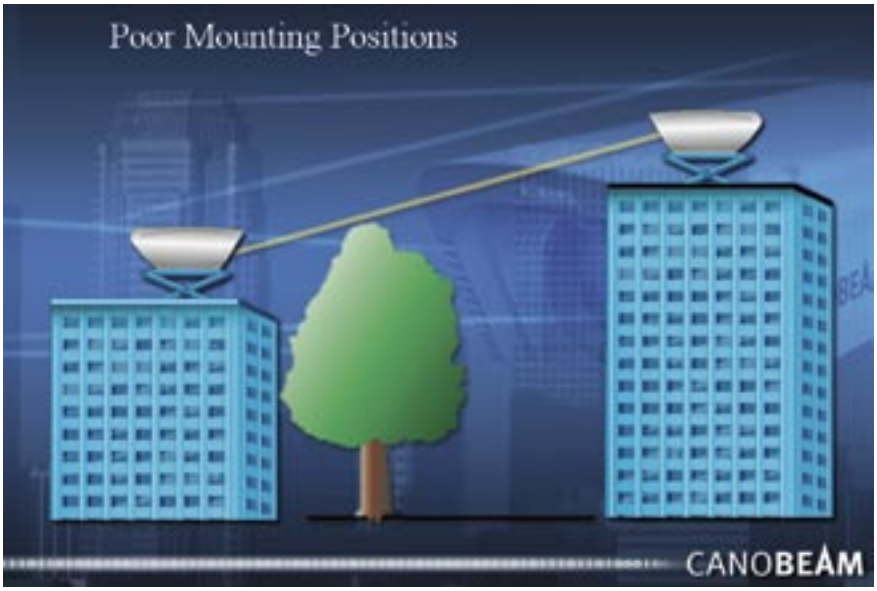

Figure 10. Growing trees can cause problems.


Figure 11. Conduit adapter.

mends the Trylon 5.951.0049.005 (see www.trylon.com).

Non-penetrating mounting adapters designed to mate with the FA-100 Tilt/Swivel mount and similar products from other vendors are available from Hutton Communications (www.huttononline.com). They can mount to either 2 3/8 inch or 4 inch diameter masts.

FSO vendors say a common problem with today's curtain wall construction is that thin facades look much more rigid than they really are. Canobeam reports one customer who attached the FSO to a false-wall facade on a rooftop constructed of thin metal beams. Even worse, the angle of the facade directed wind directly to the Canobeam and caused it to move independently of normal building sway. On windy days the link would become unstable even with auto-tracking enabled.

Another bad example involved an FSO on plywood supports on top of a sagging floor in an abandoned building. The building was subject to frequent vibrations from trucks passing on the heavily traveled street adjacent to the building. The wood platform and wood supports moved with the vibrations and the sagging floor and altered the original FSO alignment.

Another customer, rather than installing into the concrete ledge, chose to install on the railings. The horizontal u-channel that supported the mount did not provide enough lateral stability because there was too much spacing between vertical railing supports.

FSO units are sometimes combined with RF links because their availability tends to be complementary; the radio tends to operate in fog when the FSO might not. The FSO handles rain well, while RF links often fail under those conditions. But putting everything on one mast is not wise unless the mount is carefully designed for stability and ease of maintenance. If the RF antennas have a large surface area, wind can cause additional mast movement. The FSO could also be affected if any maintenance work is performed on the antennas.

The Canobeam (and all other FSOs we checked) conforms to FCC Part 15 (ICES-003) standards on electromagnetic interference. That is, they don't cause problems. (For more information see www.fcc.gov/oet/info/rules/part15/part15_7_12_04.pdf.) FSO devices themselves, however, may not perform adequately in environments subject to strong electromagnetic waves.

For indoor installation, remember that condensation tends to form on window glass in winter and can attenuate the beam. This not only reduces the transmission range, but also can completely cut off transmission. If condensation will be a problem, install a defroster/defogger that blows air on the window glass.

Generally, glass windowpanes are not perfectly flat. The imperfections in the "flat" glass can cause the window to act as a lens, changing the angle of the beam and affecting the transmission range. Older buildings can have imperfect glass. In these instances, as well as for tinted glass, do a transmission test to check.

Power and Other Connections

FSO units are not heavy power users. Most run on AC 100-240V, 50/60Hz and draw about 20 watts. Canon offers an optional 48 VDC power supply as well. The bottom of the DT-100 series has a 1.57-inch (4 cm) cutout provided to pass power and network cabling to the interior. For outdoor installations, the cutout should be sealed airtight to keep any liquids or dust from entering the unit. Typically, this involves using a weather-tight conduit adapter. For Canobeam products, the adapter is (part # 134628-000) from Anixter (www.anixter.com, 224-521-8000). **BBP**

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