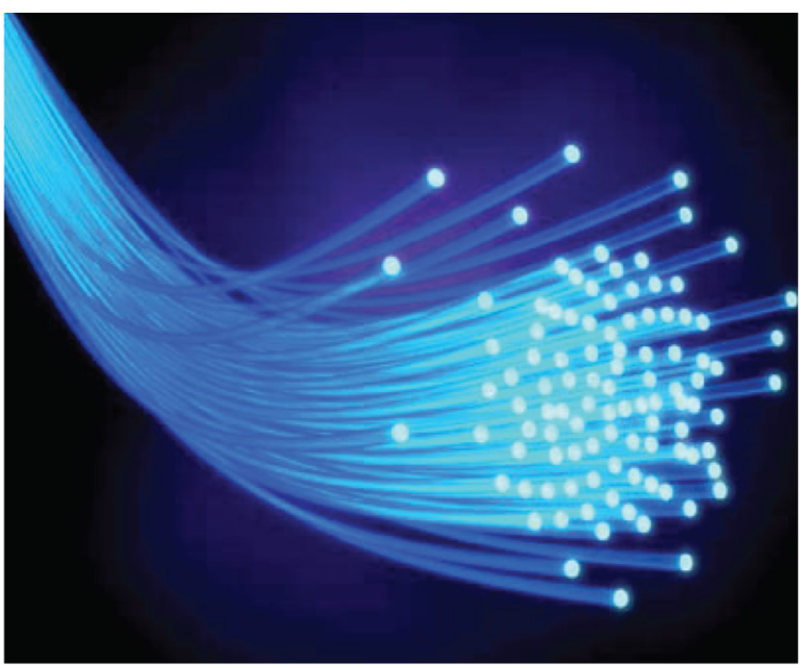
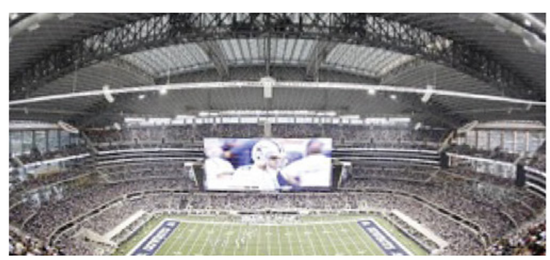
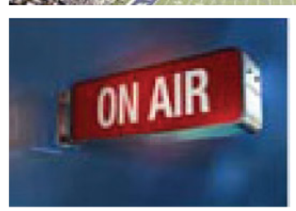
grass valley
A BELDEN BRAND

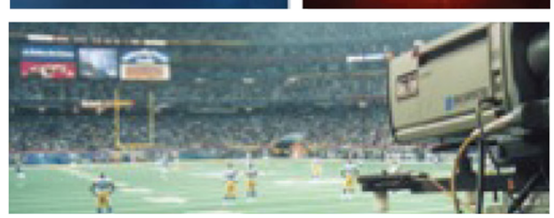
Fiber optics in sports production

APPLICATION NOTE









Grass Valley, a Belden Brand developed this guide to assist non-engineering broadcast professionals in making critical decisions about using fiber optic technology for sports production. Because of the vastly increased bandwidth requirements of high-definition television signals and the expansion of internal video operations in sports venues, fiber optics can play a huge role in cutting costs and enhancing the workflow of sports production.

As a non-engineering guide to the use of fiber optic technology in sports production, this document encompasses not only broadcast technology, but the internal video operations used in today's modern sports arenas and stadiums. Today, sports venues are producing their own content independently of broadcasters using networks of large video displays, electronic scoreboards, digital signage and remote cameras located throughout the venue. A single, pencil-sized fiber optic cable can replace miles of copper cable to serve all these media functions simultaneously.

Grass Valley has 20 years of innovative experience in applying fiber optic systems to live sporting events, from venues to remote broadcast trucks. We introduced fiber to mobile sports, and we created the familiar universe of fiber-based video and audio snakes that the industry has come to embrace, including Vipers, Cobras, Adders, Sidewinders, Pythons and the Rattler.

We've worked with major international events including the Winter and Summer Olympics, Major League Baseball, the Super Bowls, World Cup Soccer, World Cup Skiing, Formula One Racing, NASCAR Races, the X-Games and professional golf tournaments.

In addition, Grass Valley has upgraded about 30 U.S. college sports stadiums, as well more than 27 other venues including the Daytona Speedway, Fenway Park in Boston, and Yankee Stadium and Madison Square Garden in New York City.

Today's sports venues must be future-proofed for a constantly changing array of broadcast requirements. Though most high-definition television production is now uncompressed 1.5 Gbps, bandwidth requirements will soon double to 3 Gbps for 3D television or 1080p 2D production. Slo-mo cameras and other specialty devices may need 10 Gbps and beyond in the very near future. Only a fiber optic communications infrastructure can accommodate this kind of rapid growth.

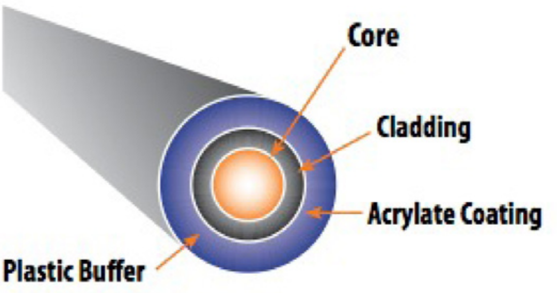
There are also the requirements for multi-venue control rooms, scoreboard and stadium signage systems, re-location of mobile units further away from venues for security, and faster set-up and tear down requirements before and after each event. Fiber offers the flexibility for this kind of quick adaptation, where traditional copper cable does not.

OB vans and their associated television "compounds" are being moved farther and farther away from the stadium for several reasons. First, productions are getting increasingly larger and all the "stuff" that we as viewers have come to rely on — such as first-and-ten computer generated lines for football, flying cameras and sophisticated graphics — all come with their own trucks and trailers. With all of these vehicles and engineers, there are obvious security concerns that must be considered, as well. But foremost for the venue itself is the control of the fan experience. Broadcast compounds close to the venue would consume space that might otherwise be used for concessions or other revenue or brand-generating efforts.

How Fiber Optic Technology Works

Fiber optic systems carry information between two points by using a light beam that passes through an extremely thin glass fiber strand. The primary purpose of any fiber optic system is to convert electrical signals into light signals, carry those signals over long distances and then convert them back into electrical signals.

OPTICAL FIBER CROSS-SECTION



Both digital and analog signals may be transmitted over a fiber optic system. Analog systems are modulated onto a carrier and shot down the fiber, while digital signals are moved by converting digital information into very rapid pulses of light corresponding to "ones" and "zeroes." Since digital signals are much more robust and reliable, as a practical matter, analog signals can first be converted to digital prior to optical transmission.

A fiber optic system is made up of the following four basic components—a transmitter, receiver, fiber cable and connectors:

The **fiber optic transmitter (TX)** converts an electrical signal into an optical signal and propagates the resulting signal along the fiber optic cable via a laser. In response to the electronic digital signal, the laser flashes on and off in rapid bursts, reproducing the digital ones and zeros.

Using a process called optical multiplexing, multiple digital signals can be transmitted simultaneously on the same strand of fiber optic cable. In a typical multicamera set-up, these signals might include HD/SDI, composite video, audio signals, return video, IFB, intercom, camera control, timecode, tally and remote focus/iris/zoom.

Time-division (TDM), Wavelength-division (WDM), Coarse Wavelength-division (CWDM), and Frequency-division (FDM) multiplexing can also be used to dramatically increase signal payloads.

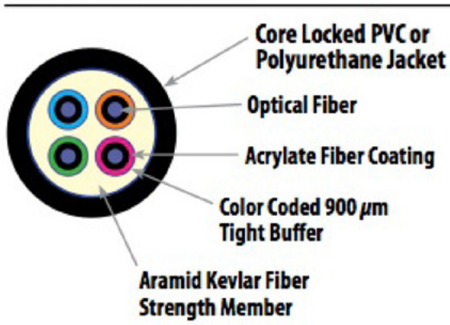
A **fiber optic cable** carries the signal-modulated light beam over a strand of transparent fiber that is thinner than a human hair. Though some shorter cables for consumer applications (e.g. Toslink) use plastic fibers, broadcast-quality systems employ glass fibers exclusively as they can be made with higher purity and drawn much thinner. The thinner the core, the higher its bandwidth capacity.

A fiber optic cable may have a single or multiple fibers (1, 2, 4 or into the hundreds). Each fiber is surrounded by a protective plastic "buffer" material, similar to insulation on a wire. However, it is not doing the same job as insulation. Each progressive layer is adding to the safety and durability of the cable, which is also color coded to identify each core in multi-fiber cables.

The cables used in sports production, called "tactical cables," are identical to those used by the military in field operations for tactical battlefield applications. In fact, it was Grass Valley that coined and trademarked the terms Tac-1, Tac-2, Tac-4, etc. to signify 1, 2 or 4-fiber tactical cables for broadcast.

Tactical cables add a layer of kevlar-aramid yarn that further protects the glass inside. And finally, the polyurethane jacket has a slippery finish to prevent "burning" from other cables as they slide past during set and strike. When all of these components are made, the result is a cable that "core-locks" everything inside together so that the fibers do not move with respect to the kevlar and jacket. This is truly the key to making fiber cables survivable in the remote broadcast environment.

"TAC-4" – 4 FIBER CABLE



Tac cables are surprisingly flexible, and will not break when the cable is knotted or bent in normal use. As a general rule, one can treat a high-quality Tac cable as a similar sized coaxial cable and it will be very safe. A Tac cable is much more durable, and can routinely be used in much more hostile environments, such as flying cables in temporary self-supporting installations or where vehicle and/or foot traffic is expected.

The **receiver (RX)** accepts the light beam from the fiber in the cable, and converts the optical signal back to an electrical signal. Note that basic fiber optic receivers and transmitters can be quite small. Matched transmitter/ receiver pairs, like our Rattler system, can be only about three-inches long. They are powered by external DC power supplies or even powered USB ports.

Because the fiber optic cores are so thin, the two connecting cables must be in precise alignment for the light beam to couple properly from one cable to the next.

Connectors used to join fiber optic components fall into two broad groups:

The first is the *physical contact* connector, such as the ST, SC or Delphi. Using a pin or ferrule, these bayonet style connectors come into contact with each other via a mechanical alignment aid such as a ceramic sleeve. They have proven to be workhorses in television broadcast production.

Since the popular ST bears resemblance to a coaxial BNC connector, it was quickly adopted by users. There are other types of single fiber connectors, but most are generally deemed less reliable and too fragile for sports production.

When using multicore fiber optic cables in outdoor field conditions, a "ruggedized" expanded beam type of connector is preferred. The MX™ mini expanded beam optical connector is designed specifically for demanding field production applications. It provides the proven robustness of expanded beam technology in a very compact size.

In using the MX connector, a precision lens on one plug expands its single-mode light beam diameter about 45 times before a matching complementary lens on the mating plug refocuses the light back into the fiber core.

This dramatically reduces the negative effects of dust, debris and mechanical vibration. There is no physical contact between lenses, and each connector includes an integral threaded dust cover.

The MX connector is available in two- and four-fiber versions using the same compact shell. Both jam-nut and flange-mount receptacles are offered.

Fiber Optic vs. Copper: A Comparison

The following is a brief summary of the major differences between copper-based electrical transmission and fiber optic transmission in typical remote sports applications.

Bandwidth and Distance — Fiber optic systems are capable of much higher bandwidth than copper-based systems.

Single-mode fiber optic systems used in broadcasting can carry very high-bandwidth signals up to 5 km using a standard laser — more than sufficient for typical sports applications. Using an optional high-power DFB (distributed feedback) transmitter, effective distances can be extended up to 30 km.

The difference is best illustrated using an optical spectrum analyzer. A standard laser has a rounded peak centered somewhere near its noted wavelength. A DFB is much more refined with a "spike" centered exactly on its given wavelength. The spike is more resistant to changes in wavelength as it moves along the optical fiber. Thus it is capable of much longer distances and is a requirement of CWDM optical muxing.

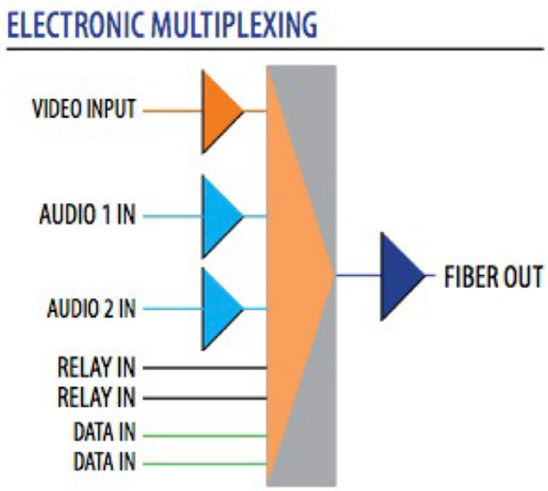
Copper coaxial and triaxial cables can carry high bandwidth signals a short distance, and lower bandwidth signals a longer distance. Some types of high-grade copper coaxial cable are capable of carrying 3.0 Gbps (the equivalent of 1080p HD video) for distances up to 100 m; however, these extremely low-loss cables use a foam dielectric that is susceptible to crushing — making them suitable for studio installation but questionable for rugged sports applications. As a practical matter, the use of copper cables for HD-SDI bandwidth signals in even moderately hazardous field deployment is limited to distances of about 100 m.

Multiple Signals ("Signal Agnostic") — Multiple signals of any type — audio, video or data — can be multiplexed using a single fiber optic cable. The only restriction is the total bandwidth available, and in sports applications this is rarely an issue with single-mode fiber. In contrast, with copper-based systems, the analog and digital video signals and auxiliary data streams often require use of different cables—each with its own unique connector.

Bidirectional Communication — A fiber optic system can transmit signals in both directions simultaneously with no bandwidth limitations. Copper systems can transmit in only one direction at a time over any given signal pair; digital networks can mimic bidirectional communication by rapidly switching between transmit and receive, but this effectively cuts bandwidth in half.

Cable Weight and Bulk — Fiber optic cables are extremely small and light compared to the required copper equivalents. A tactical grade fiber optic cable is about 1⁄4-inch in diameter and weighs about 10 pounds per thousand feet. A typical coaxial cable weighs about four times as much, and the equivalent amount of multiple bundled copper cables needed for a sports camera application could weigh more than 20 times as much.

Copper is far bulkier, especially when longer runs are required. This equates to more space and weight in the TV truck/OB van or higher shipping costs when moving cable from job to job. It is always best to install far more fiber optic cable than estimated for original needs.



EMI/RFI Noise and Ground Loops — Fiber optics are inherently immune to all kinds of electromagnetic interference (EMI) and radio frequency interference (EMI). Also, because a tactical fiber optic cable contains no electrical conductors, it cannot contribute to ground loops. All copper cables are susceptible to both EMI and RFI. This can be limited with cable shielding, but shielding adds to bulk and weight. Also, the cables' metallic conductors and shields can contribute to ground loops.

Environmental Conditions — Fiber optic systems are generally immune to interruption by moisture or immersion in water, as there is no electrical current to "short out." All electrical connections, in contrast, need to be fully moisture protected.

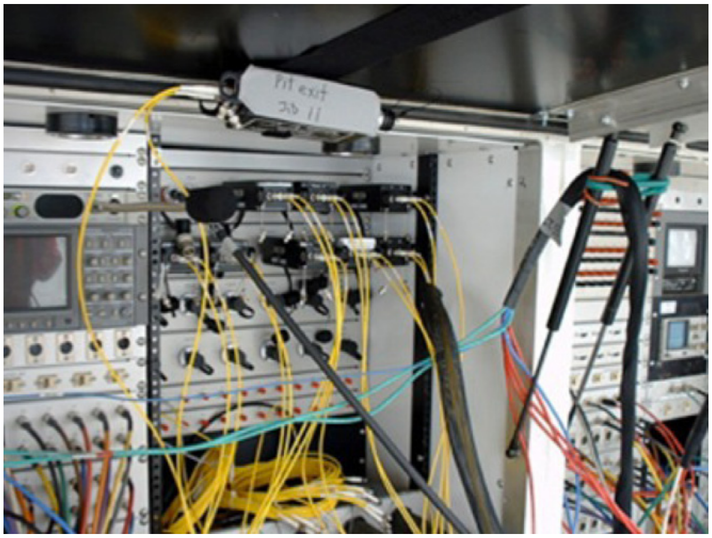
With fiber optic systems, greater attention must be paid to dust and dirt. In field applications, the use of PC (physical contact such as STs, SCs, Neutrik and Delphi) connectors requires maintaining contact between the two fiber strands to prevent the intrusion of microscopic particles and maintain precise alignment of the cores.

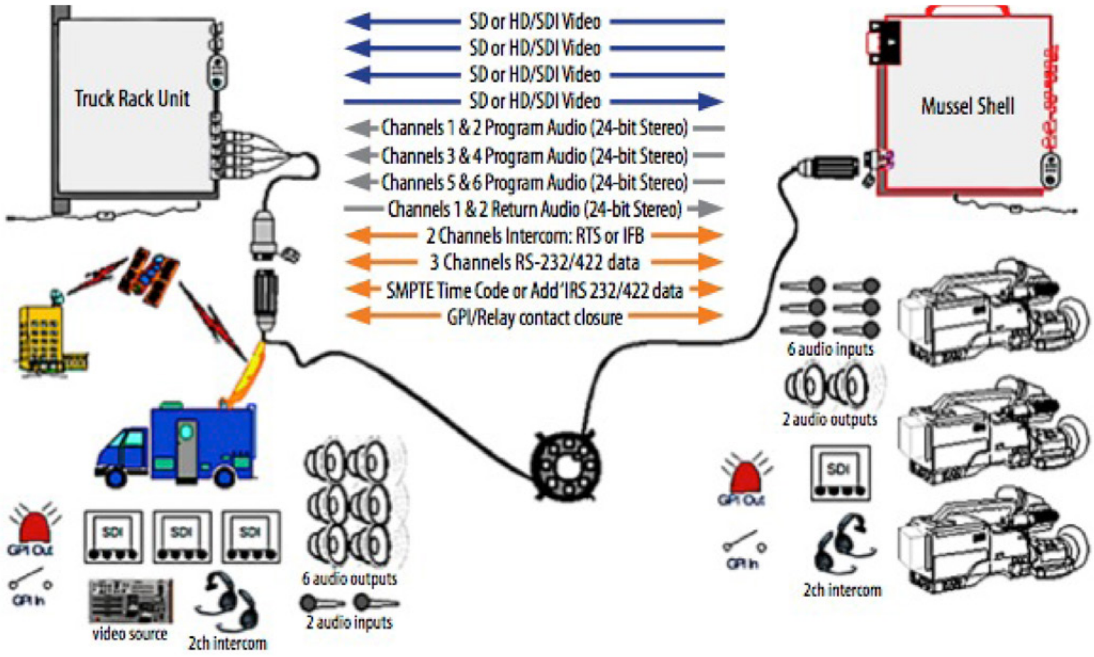
Connectors that are regularly mated and unmated in the field are recommended to be of the expanded-beam

type that allows light rays to pass around dust particles. Optical connectors of any type should be cleaned routinely. Dry dust and dirt, in small amounts, rarely cause problems with electrical connections.

Why is Fiber Optic Technology Preferred for Modern Sports Production?

Fiber optic cable is now used to replace copper cable in a wide range of sports video systems. In early sports productions, broadcasters used multiple copper cable runs between cameras and a remote truck for switching and control. Such cable is very heavy, bulky, manpowerintensive and subject to RF and EM interference. In some stadiums and arenas, it took days to run cable in advance of a television broadcast. This is made dramatically worse at large outdoor venues like racetracks and skiing venues.





Fiber optic cable can dramatically lower the weight, reduce costs, and allow the multiplexing of various signals through a single, rugged lightweight cable. In many modern sports venues, fiber installations are built-in permanently and use push-pull SC or standard telecomtype ST connectors in a central patching area in the venue. In these cases it is KEY that the fiber infrastructure is properly maintained and managed to insure continued high performance.

In the past two years, there has been a dramatic increase in the use of video within the sports venue due to a flat economy and poor ticket sales. To draw fans away from their home HDTV sets, sports venues on both the college and professional level are enhancing the video capabilities of their scoreboards, displays and LED-based surfaces inside venues.

The installation of a fiber optic infrastructure is now essential to the success of most modern venues. When the costs of a fiber system can be spread among the many interests that can use it — including point of sale, security, public address, in-house video and television broadcasting — the costs AND benefits can be shared.

Due to constantly changing technology, there's an effort to future-proof these facilities so they can handle virtually any kind of digital signal at any bandwidth. The most important attribute for fiber in sports venues can be summed up in a single word: flexibility.

The installation must have "plug and play" capability with a wide range of television remote trucks—from the smallest standard definition to the largest 3D unit. Plus the fiber must serve different "masters" and multiple functions simultaneously—be it broadcast to the outside world or internal video for scoreboards, displays and monitors throughout the venue.

Sports venues have essentially become "studios" producing programming for a global television audience. As sports grew bigger, these facilities simply outgrew copper cable. Fiber solves many problems, while being cheaper to purchase and install than copper.*

New security concerns means many venues want television remote trucks parked further away from the facility than in previous times, resulting in longer cable runs. This is no problem with fiber, where multiple signals can easily be multiplexed over a single fiber core. Another example of a permanent install might be a fiber cable out to a "ped" in a distant lot where an uplink truck would have the ability to "see" satellites that might otherwise be blocked in the broadcast area.

Fiber extends the capabilities and lowers the weight of mobile units. Since fiber solutions are more compact, they free space on OB trucks for other revenue producing equipment such as specialty cameras and playback devices.

A typical football game requires six or more OB trucks. Fiber can be used to link these vehicles together quickly, providing for a quick "park and power" upon arrival at the venue. Routers and video walls need to be linked for submix, VTR and "first and ten" line graphics. Intercom matrix extensions and outboarding must be connected. All this happens in a fraction of the time with fiber compared to copper-based looms.

Every sports venue needs at least two small fiber optic cables, easy ST connectors, and AC power controlled from the OB truck area on a separate power breaker.

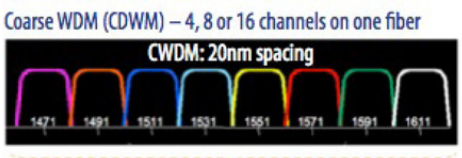
Glossary

Aramid — An extremely strong synthetic fiber that woven into fiber optic cables to add tensile strength. A well-known trade name is Kevlar.

Bandwidth — In digital systems, bandwidth is the highest data rate a system can transmit without unacceptable losses. In digital TV applications, bandwidth is specified in Megabits per second (Mbs) or Gigabits per second (Gbps).

Bend radius — The smallest radius around which a coaxial or fiber optic cable can bend before excessive attenuation causes signal loss.

Cladding — A layer of glass or other transparent material with a lower refractive index than the core. The cladding confines light within the core and promotes propagation of light down an optical fiber.



Coarse Wavelength Division Multiplexing (CWDM) — A passive optical process by which multiple signals may be combined into one light beam for transmission over a fiber optic cable.

Core — The extremely thin glass fiber that serves as the light conducting part of a fiber optic strand. The core has a higher refraction index than the surrounding concentric cladding material.

CWDM — See Coarse Wavelength Division Multiplexing.

DFB laser — Distributed feedback laser, a high-output design that enables long distance transmission (up to 30 km) over single-mode fiber.

Dielectric — The insulating material used in coaxial cables to separate the core conductor from the shield and maintain the separation at a constant distance. Lowloss cables use a foam dielectric that is more susceptible to crushing than solid dielectrics.

Expanded beam connector — A design wherein the fiber core of each cable terminates in a small lens which expands the light beam so it can pass around any microscopic particles before capture by the opposing lens. Though expanded beam connectors are more robust than physical contact (PC) connectors, they do exhibit higher optical losses.

HD-SDI (High Definition Serial Digital Interface) — A standard for uncompressed transmission of digital HD video signals as defined by SMPTE 292M. HD-SDI requires minimum system bandwidth of 1.5 Gbps.

Hermaphroditic connectors — Connectors that can function as EITHER gender, allowing any cable with the same connector type to be connected at either end.

Multimode fiber — A fiber optic cable with a core strand of sufficient thickness for light rays to reflect off the cladding at multiple angles, allowing multiple paths (modes) of transmission through the fiber strand. Multiple modes cause modal dispersion, which limits bandwidth and effective transmission distance.

Multiplexing — A process by which two or more signals are combined into one. Electrical systems use Time Division Multiplexing (TDM) and Frequency Division Multiplexing (FDM). Optical systems for broadcast applications use Wave Division Multiplexing (WDM) and Coarse Wave Division Multiplexing (CWDM); many broadcast systems use electrical multiplexing prior to optical multiplexing.

Optical loss budget — The amount of optical loss ("light dimming") from cable length and connectors that a fiber optic system can tolerate before it fails to meet operating specifications.

Receiver — The component in a fiber optic system that receives the light signal and converts it into an electrical signal. Many receiver units also incorporate signal demultiplexing functions.

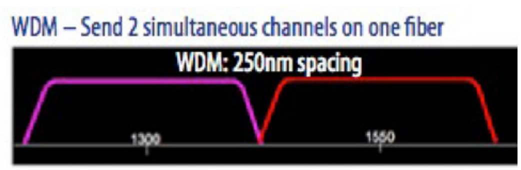
Single-mode fiber — A fiber optic cable with an extremely small core that allows light rays to only pass longitudinally, without reflecting off the cladding at multiple angles. Single mode fiber is not subject to modal dispersion, and therefore can transmit higher bandwidth signals over longer distances than multimode fiber.

SMPTE hybrid cable — A special type of cable, defined by SMPTE standard 311, which comprises two singlemode optical fibers and four copper electrical conductors. The cable carries video signals (HD-SDI capable) between a camera and the associated camera control unit (CCU), and also supplies power to the camera.

Transceiver — A single hardware unit that incorporates the function of both a transmitter and a receiver.

Transmitter — A device that contains a light source, usually a laser, as well as electronic circuits for converting electrical signal to optical signals. Many transmitter units also incorporate signal multiplexing functions.

Wavelength Division Multiplexing — A technique by which multiple signals are propagated through a single fiber by transmitting them at different wavelengths.



WDM — See Wavelength Division Multiplexing.

Distance and Bandwidth

Signal type	Composite NTSC	Component SDI	HD-SDI	1080p/50 1080p/60
Data rate	143 Mb/s	270 Mb/s	1.5 Gb/s	3.0 Gb/s
SMPTE standard	259M	259M	292M	424M
Coax 1	381 m	262 m	N/A	N/A
Coax 2	573 m	326 m	87 m	58 m
SM Fiber 1300 nm	5,000 m	5,000 m	5,000 m	5,000 m
SM Fiber 1550 nm DFB	30,000 m	30,000 m	30,000 m	30,000 m

This chart shows the distances for five methods of signal transmission: two coaxial cable, and three fiber optic. For purposes of simplicity, only one signal per cable is assumed; however, the fiber cables are capable of carrying multiples of each signal or other auxiliary signals, either multiplexed on one fiber or in a multicore fiber cable.

* A rule of thumb in the United States is $100,000 worth of fiber saves $1 million worth of copper in a venue.

grass valley
A BELDEN BRAND

WWW.GRASSVALLEY.COM
Join the Conversation at **GrassValleyLive** on Facebook, Twitter, YouTube and **Grass Valley - A Belden Brand** on LinkedIn.