# 10 Gigabit Ethernet (10GbE) and 10Base-T - RoadMap

Ethernet (10 Mbps) wasn't fast enough. Fast Ethernet (100 Mbps) wasn't fast enough. Even Gigabit Ethernet (1000 Mbps) wasn't fast enough. So IEEE recently finalized 802.3ae, which describes a 10 Gbps Ethernet WAN standard, which encapsulates Ethernet frames into SONET frames. GbE operates in full-duplex mode only and supports data transfer rates of 10 gigabits per second for distances up to 300 meters on multimode fiber optic cables and up to 40 kilometers on single mode fiber optic cables.

10GigE is a layer 2 alternative to layer 3, 10Gb POS (Packet-Over-SONET) transport. The next step, way in the future, is for 40 Gbps.

## 10GbE - a LAN or WAN Technology

Ethernet is a Layer2 technology, and is really aimed more at LAN's and access only to WAN's, but not the core WAN. If you are not running IP over Ethernet, then there is no need for an IP backbone - or is there? Well, how can you get the Ethernet frames to travel from one end, through a backbone network and across the U.S. to the other end? GbE only describes Layers 1 (PHY) and 2 (DataLink/MAC), and there are no Ethernet WAN backbones in existence today.

Therefore, to use 10GbE, you will need to either stay within a LAN environment, or connect to a provider that can route and encapsulate your frames for you via IP, ATM, Frame Relay, ATM, IP, etc. The best answer, today, is to have a service provider set up a Layer2 (Martini or Kompella draft) or Layer3 (RFC 2547) VPN for you on a high-speed MPLS network, and connect to it with 10GbE fiber access circuits..

## 10G-Base-T- LAN Technology

Backward compatibility with older Base-T standards

100M structured wiring reach allows for data center organization flexibility and Uniform transmission media (one type of connector for all situations)

Use of inexpensive cables – Such as CAT6, CAT6A

A roadmap to LAN on Motherboard

### Differences between standard and Fast Ethernet (10 and 100 Mbps) and 10GbE

- For access, GigE requires fiber to the premises
- Since 10GbE is a full-duplex only and fiber-only technology, it does not need the carrier-sensing multiple-access with collision detection (CSMA/CD) protocol that defines slower, half-duplex Ethernet technologies. In every other respect, 10 Gigabit Ethernet remains true to the original Ethernet model.

### Differences between 1 GbE and 10GbE

| Comparison of 1 GbE to 10 GbE | | |
|---|---|---|
| **Characteristic** | **1 Gigabit Ethernet** | **10 Gigabit Ethernet** |
| Physical Media | Optical and copper media | Optical media only |
| Distance | LANs up to 5 km | LANs to 40km<br>Direct attachment to SONET/SDH equipment for WANs |
| PMD | Leverages Fiber channel PMDs | Creates new optical PMDs |
| PCS | Re-uses 8B/10B coding | Establishes new coding schemes |
| MAC Protocol | Half-duplex (CSMA/CD)<br>+ Full-duplex | Full-duplex Only |
| Additions | Carrier extension for Half-Duplex | Throttel MAC speed |

# IEEE GbE Objectives

The IEEE formed an HSSG (High Speed Study Group) which set out the following objectives for GigE:

**1) Preserve the 802.3/Ethernet frame format at the MAC Client service interface.**

• Meet 802 Functional Requirements, with the possible exception of Hamming Distance.
• Preserve minimum and maximum FrameSize of current 802.3 Std.
• Support full-duplex operation only.
• Support star-wired local area networks using point-to-point links and structured cabling topologies.
• Specify an optional Media Independent Interface (MII).
• Support proposed standard P802.3ad (Link Aggregation)
• Support a speed of 10.000 Gb/s at the MAC/PLS service interface

**2) Define two families of PHYs**

- a LAN PHY, operating at a data rate of 10.000 Gb/s
- a WAN PHY, operating at a data rate compatible with the payload rate of OC-192c/SDH VC-4-64c

**3) Define a mechanism to adapt the MAC/PLS data rate to the data rate of the WAN PHY**

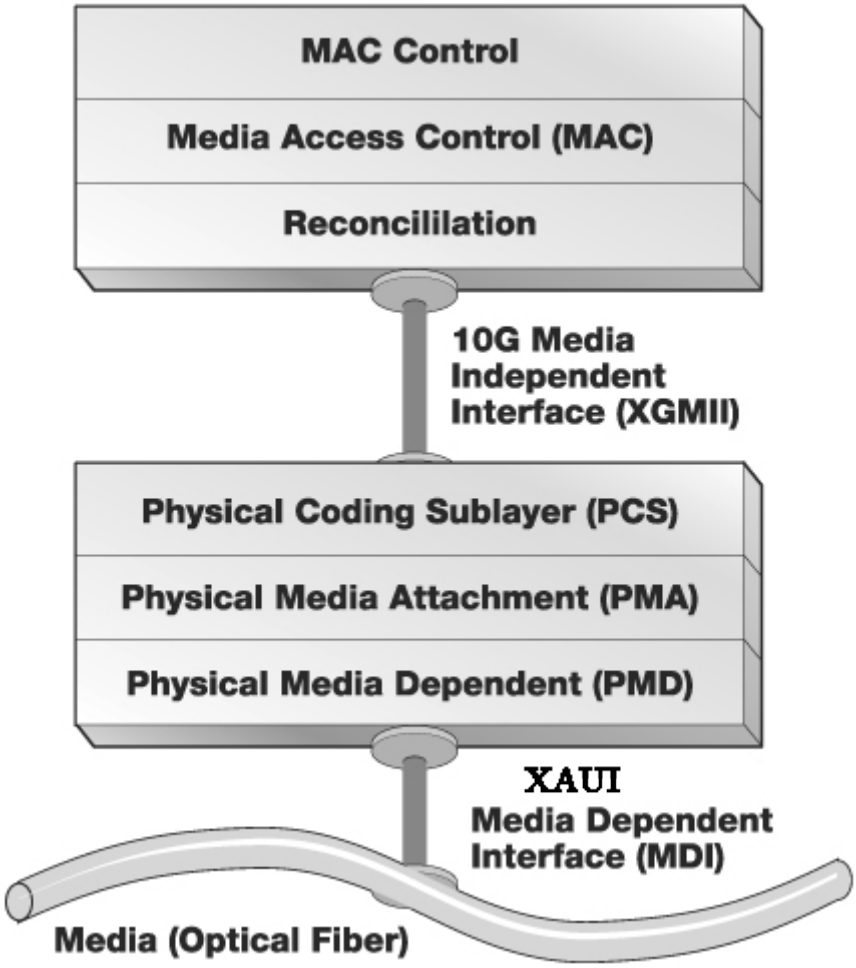
**4) Provide Physical Layer specifications which support link distances of:**

- at least 300 m over installed MMF (MultiMode Fiber)
- at least 65 m over MMF
- at least 2 km over SMF (SingleMode Fiber)
- at least 10 km over SMF
- at least 40 km over SMF

**5) Support fiber media selected from the second edition of ISO/IEC 11801 (802.3 to work with SC25/WG3 to develop appropriate specifications for any new fiber media).**

# XGMII (X=10) 10 Gb Media Independent Interface

Between the MAC and the PHY is the XGMII, or 10 Gigabit Media Independent Interface. The XGMII provides full duplex operation at a rate of 10 Gb/s between the MAC and PHY. Each direction is independent and contains a 32-bit data path, as well as clock and control signals. In total the interface is 74 bits wide.




Ethernet is fundamentally a Layer 2 protocol. An Ethernet PHYsical layer device (PHY), which corresponds to Layer 1 of the OSI model, connects the media (optical or copper) to the MAC layer, which corresponds to OSI Layer 2.

The 802.3ae specification defines two PHY types:

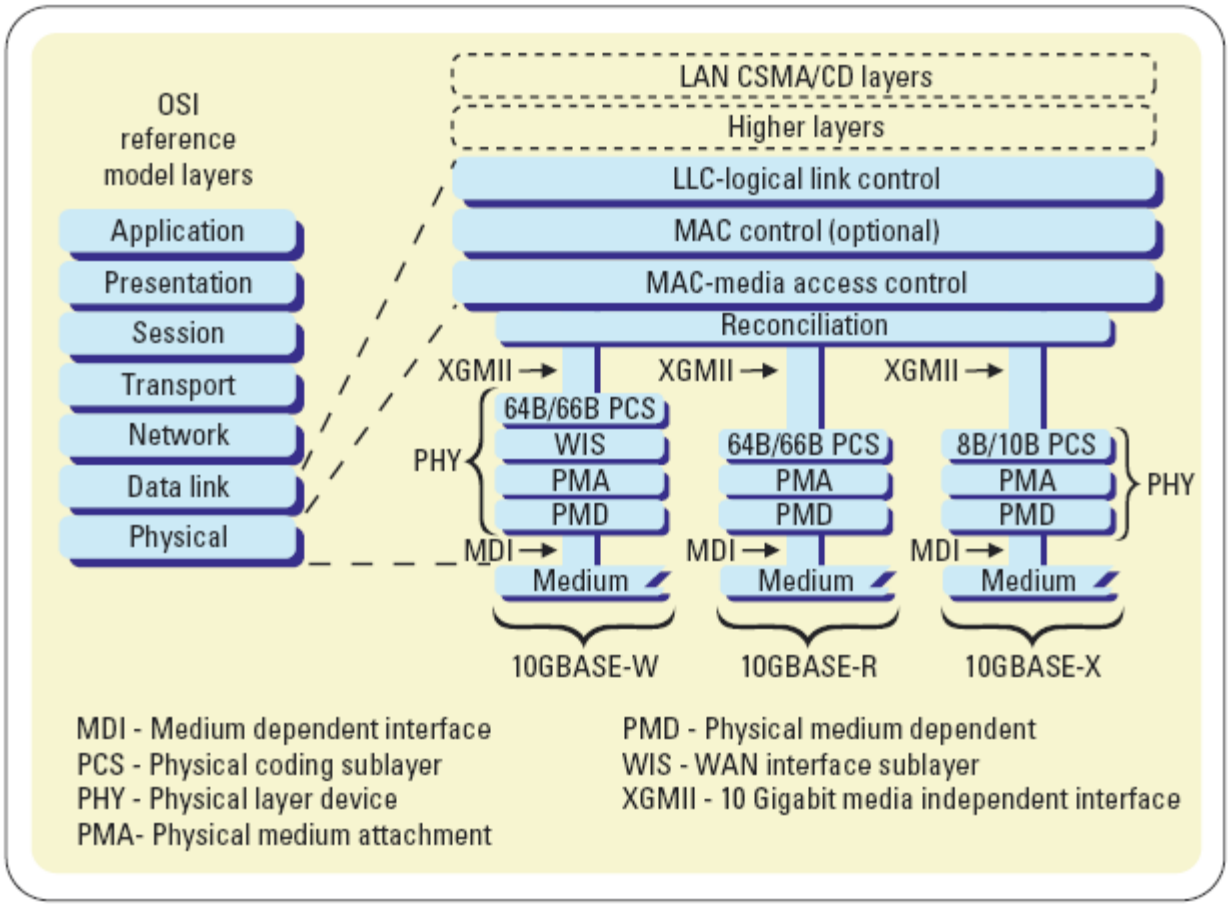
**LAN PHY** - for native Ethernet applications. There are two types of LAN PHY:

- **WWDM LAN PHY** - uses a physical coding sublayer (PCS) based on four channels or lanes of 8B/10B coded data. Each lane operates at 2.5 Gb/s with a coded line rate of 3.125 Gb/s.
- **Serial LAN PHY** - initially it appeared attractive to reuse the 8B/10B code used with Gigabit Ethernet, however it was soon realized that the resulting 12.5 Gbaud would require costly technical issues to be solved and raise the development cost of effective serial implementation. It was therefore decided to employ a more efficient 64B/66B code, which reduced the serial baud rate to 10.3125 GBaud.

**WAN PHY** - for connection to 10 Gb/s SONET/SDH - there is one type of WAN PHY:

- **Serial WAN PHY** - For this PHY an additional sub-layer known as the WAN Interface Sub-layer (WIS) is required between the PCS and the serial PMA. The position of this in the 10GBASE-W architecture is shown in Figure 1. The WIS maps the output of the serial PCS into a frame, based on SONET/SDH practice and vice versa, and processes the frame overhead including pointers and parity checks. The line rate is 9.95328 Gb/s.

The WAN PHY has an extended feature set added onto the functions of a LAN PHY. Ethernet architecture further divides the PHY (Layer 1) into a Physical Media Dependent (PMD) and a Physical Coding Sublayer (PCS). The two types of PHYs are solely distinguished by the PCS.




**MDI (Media Dependent Interface) -** the component of the media attachment unit (MAU) that provides the physical and electrical connection to the cabling medium. An MDIX (for MDI crossover) is a version of MDI that enables connection between like devices. MDI ports connect to MDIX ports via straight-through twisted pair cabling; both MDI-to-MDI and

MDIX-to-MDIX connections use crossover twisted pair cabling.

# XAUI (X=10GbE) 10 GbE Attachment Unit Interface

Pronounced “Zowie” - the XAUI is the 10GbE MDI. Remember the old AUI's that ancient Ethernet (over large coax, or "frozen garden hose") drops with their BNC connectors used?? Well, this is the same thing only faster. The XAUI is an interface extender, and the interface, which it extends, is the XGMII. The XGMII is a 74 signal wide interface (32-bit data paths for each of transmit and receive).

**The XAUI is not mandatory, because the XGMII can be used to directly attach the Ethernet MAC to its PHY. However, most applications want the extender for both physical workability, and for adaptation to Fiber Connectors.**

The XAUI may be used in place of, or to extend, the XGMII. The XAUI is a low pin count, self-clocked serial bus directly evolved from Gigabit Ethernet. The XAUI interface speed is 2.5 times that used in Gigabit Ethernet. By arranging four serial lanes, the 4-bit XAUI interface supports the ten-times data throughput required by 10 Gigabit Ethernet. The XAUI employs the same robust 8B/10B transmission code of Gigabit Ethernet to provide a high level of signal integrity through the copper media typical of chip-to-chip printed circuit board traces. Additional benefits of XAUI technology include its inherently low EMI (Electro-Magnetic Interference) due to it’s self-clocked nature

The XAUI is the actual physical interface for GbE, and has 70 pins. The XAUI is a full duplex interface that uses four (4) self-clocked serial differential links in each direction to achieve 10 Gb/s data throughput. Each serial link operates at 3.125 Gb/s to accommodate both data and the overhead associated with 8B/10B coding. The self-clocked nature eliminates skew concerns between clock and data, and extends the functional reach of the XGMII by approximately another 50 cm.

Conversion between the XGMII and XAUI interfaces occurs at the XGXS (XAUI GbE Extender Sublayer).

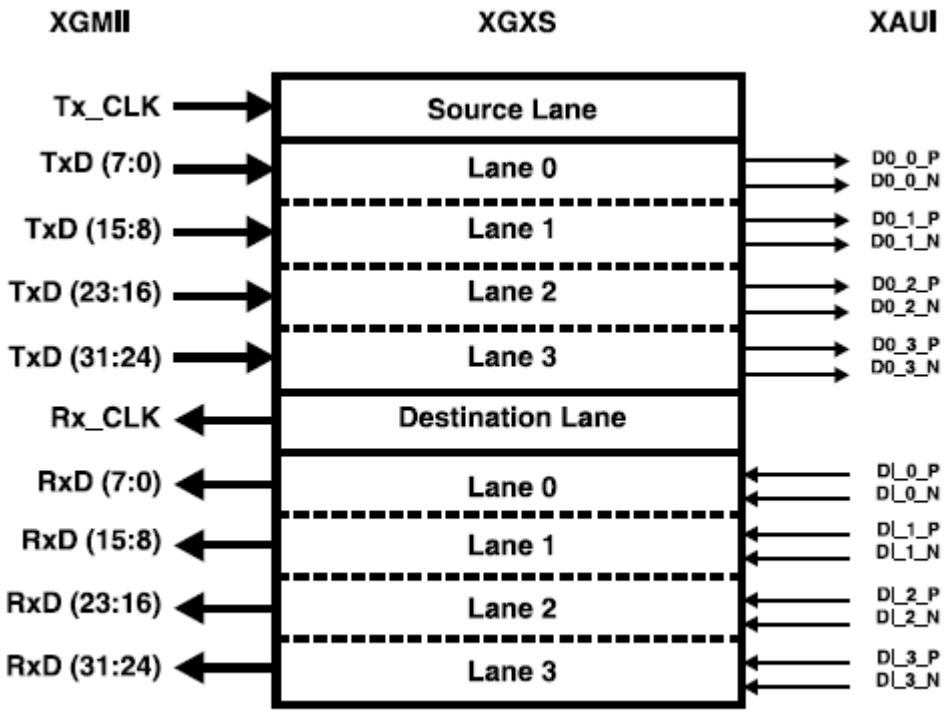


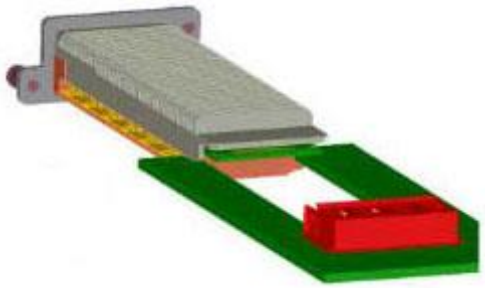

Figure 2: XGMII to XAUI at the XGXS

# 10 GbE Transponders (AUI to Fiber adapters)

Like the original AUI's that required Transceivers to convert the AUI to RJ45 - you will need an additional adapter unit called a *Transponder*, to convert the XAUI interface to a standard fiber interface, such as an "SC" jack.

There are varying numbers of pins on these - some have up to 200 or even 300 pins.

But the most common is the 70-pin. For example, this transponder is sold by http://www.xenpak.org/ - Xenpak is defined specifically for 10-Gig Ethernet transponders and is connected through the IEEE XAUI interface. The transponder must therefore include the 64B/66B PCS block. The XAUI interface is a 4-channel, 3.125-Gbit/s interface with 8B/10B encoding. XAUI extends the XGMII interface to 50cm and has a 70-pin, 2-row connector.



- **Four wide XAUI interface (Lane 0,1,2, and 3)**
- **Compliant for all IEEE 802.3ae mediums**
  - **850 nm Serial**
  - **1310 nm WWDM, 1310 nm Serial**
  - **1550 nm Serial**
- **Hot Pluggable**
- **SC duplex fiber optic connector**
- **Industry standard 70 pin XAUI electrical connector**

# 10GbE Port Types

The IEEE has defined a total of seven optical physical layers for 10-Gig Ethernet; these are shown in Table 1.

| Device | Range | Optics | PCS | WIS | Fiber |
|---|---|---|---|---|---|
| 10GBASE-LX4 | 300m MMF / 10km SMF | 1310nm WWDM | 8B/10B | No | Multimode or singlemode |
| 10GBASE-SR | 300 m | 850nm | 64B/66B | No | Multimode |
| 10GBASE-LR | 10 km | 1310nm | 64B/66B | No | Singlemode |
| 10GBASE-ER | 40 km | 1550nm | 64B/66B | No | Singlemode |
| 10GBASE-SW | 300 m | 850nm | 64B/66B | Yes | Multimode |
| 10GBASE-LW | 10 km | 1310nm | 64B/66B | Yes | Singlemode |
| 10GBASE-EW | 40 km | 1550nm | 64B/66B | Yes | Singlemode |

**Table 1: the seven IEEE 802.3ae Port Types**

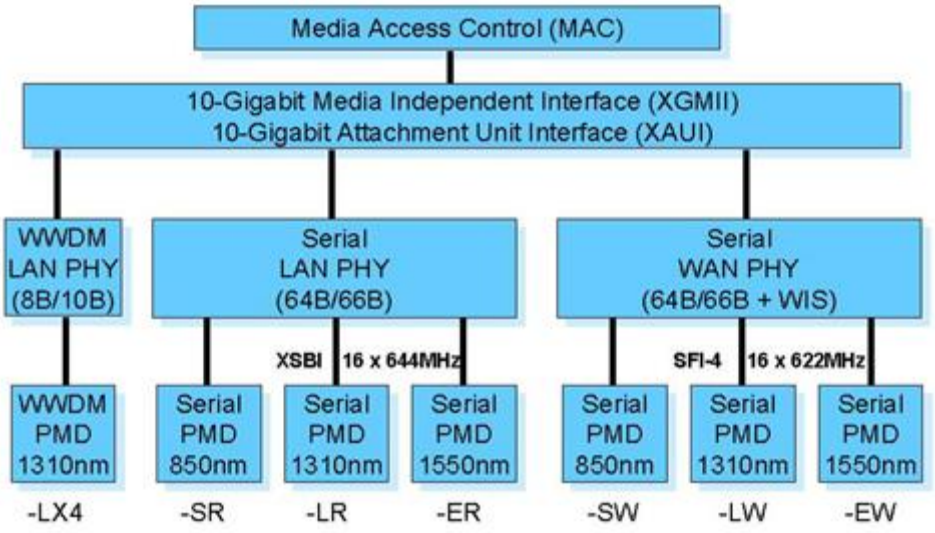
**10GBASE-LX4** - uses Wide Wavelength Division Multiplexing (also called coarse WDM). This is an inexpensive option for the enterprise that supports cheap multimode fiber for short distances and expensive single mode fiber for longer distances. This physical layer maintains the 8B/10B encoding for the Physical Coding Sublayer (PCS) from 1-Gig Ethernet. The resulting 13-Gbit/s data stream is split into four 3.125-Gbit/s signals and multiplexed onto the fiber through a 1310nm laser.

**10GBASE-xR (Sr, LR, and ER)** - designed for use in the enterprise and put a single 10-Gbit/s signal through the laser. These physical layers include a much more efficient 64B/66B encoding, resulting in a 10.3-Gbit/s data rate on the line. An 850nm laser with multimode fiber is defined for short distances, and 1310nm or 1550nm lasers with singlemode fiber are defined for longer distances.

**10GBASE-xW (SW, LW, EW) -** designed for use in the WAN and require the same line rate as Sonet. These physical layers use the same 64B/66B encoding, with a WAN Interface Sublayer (WIS) that is basically a cut-down Sonet framer. This sublayer packs the Ethernet packets into Sonet frames for transmission over a Sonet network. Again, three laser wavelengths are supported for different distances.

The 10-Gig Ethernet distances are defined as 300m for short reach, 10km for long reach, and 40km for extended reach. One issue starting to emerge is that as laser technology is further developed, cheaper 1310nm lasers are able to drive distances defined for the more expensive 1550nm transponders in the IEEE specifications.

In a 10-Gig Ethernet system, the 10-Gig Media Access Controller (MAC) is connected through either the XGMII or its XAUI to the physical layer. This is illustrated in Figure 2.



# GbE - Gigabit Ethernet

GbE is virtually the same as 10GbE except for that it can run over copper or fiber (10GbE is fiber only). The copper adapters are different, of course, than the optical connctors. Here we do not delve into GbE except to list some of the connectors used - in order to differentiate them with the 10GbE XAUI and Transponder media connection interfaces.

## 1000 Mbps (1 Gbps) SFP (Small Form-factor Pluggable)

The SFP is similar to the 10 Gb transponder, except that it is used with copper, and is for GbE (not 10 GbE). Some SFP's will also auto-sense and can therefore be used for Ethernet (10 M), Fast Ethernet (100 M), and Gig Ethernet (1000 Mbps = 1 Gbps). Here is an example of an SFP:

Xmultiple offers three different models of Gigabit Copper SFPs to accommodate different types of applications. The SFP-GC model supports Gigabit Ethernet with a 1000Base-TX interface and is designed for Layer 0/1 network devices. The SFP-EFG module supports Ethernet, Fast Ethernet and Gigabit Ethernet via a speed and duplex auto-negotiating 10/100/1000Base-TX interface. It is also designed for use in Layer 0/1 devices. The third model is the SFP-GA-R which is designed for ruse in Layer 2 or above devices such as switches and routers. It supports GbE with 1000Base-TX interface. All three SFPs support MDI/MDI-X auto detect.

# GigE Connectors

## Copper SFC's - Small Form-factor Pluggable

RJ-45 1 Gb GigE (1000base-T) **(SFP-17)**
RJ-45 1 Gb GigE (1000base-T) **(GBC-15)**
DB9 1 Gb GigE (1000base-CX) **(GBC-10)**
HSSDC 1 Gb GigE (1000base-CX) **(GBC-20)**
HSSDC2 GigE (1000base-CX)

## Optical GBIC's - GigaBit Interface Connectors

**SC Optical** 1 Gb Single & Multi Mode

1 Gb Multi Mode - Short-Wave GigE (1000base-SX) (**GBC-30)**
1 Gb Single Mode - Long Wave GigE (1000base-LX) (**GBC-31)**

**LC Optical SFP Pluggable**1 Gb Single & Multi Mode

1 Gb Multi Mode - Short-Wave GigE (1000base-SX) (**GBC-40)**
1 GB Single Mode - Long Wave GigE (1000base-LX) (**GBC-41)**

**LC Optical SFF Board-Mount** 1 Gb Single & Multi Mode

1 Gb Multi Mode - Short-Wave GigE (1000base-SX) (**GBC-50)**
1 Gb Single Mode - Long Wave GigE (1000base-LX) (**GBC-51)**

**NOTE: the original 1 Gbps Ethernet was dubbed "Gigabit Ethernet". But with the advent of 10 Gbps Ethernet - many simply call it the same name - GigE and GbE. The official, correct term is "10GbE", but since the *real* GigE (1 Gbps Ethernet) is not very common, calling the 10 Gbps version, "GigE"**