OM-Giga
A GI-POF for High Bandwidth Data Communication

1. Introduction

With the advancement of information technology, the concept of home network has become reality that enables remote control of entertainment and information systems as well as home appliances through the convergence of telecommunication and broadcasting. In a home network environment, real-time communication for video conferencing, online shopping, VOD (video-on-demand), EOD (education-on-demand), medical consulting and security surveillance are possible. These various services are currently becoming more and more prevalent and are expanding into the field networks of various vehecles that include automotives, trains, airplanes and ships. Consequently, enormous amount of bi-directional data transmission occurs everywhere within homes and offices as well as in moving vehicles. Such high bandwidth data communication requires high-speed data transmission media for short distance (< 50 m) applications that are particularly appropriate for home and field networks. Polymer optical fiber (POF), especially Graded-Index polymer optical fiber (GI-POF), is such a medium that is capable of ultra-high bandwidth data communication.

The connection between service providers and end users starts from the long-distance Wide Area Network (WAN) and Access Network and then to the short-distance (typically within 50 meters) Local Area Network (e.g., home network). Subsequently, the final reach to the end users is mostly achieved by wireless connection. The long-distance WAN and Access Networks have implemented high bandwidth optical communication in mid 1980's using glass optical fibers (GOF), and the wireless connection to the end users is now achieved by high speed Wi-Fi and 5G. The wireless and wired communication technologies are complementary to each other as the advancement of wireless technology requires the progress of wired communication technology. The short-distance communication for LAN, that covers the region between the long-distance WAN and the wireless connection to end users, is currently achieved by copper cables at 1 Gbps level. However, at the data transmission rate of 1 Gbps or higher, the electromagnetic interference (EMI) becomes a very serious issue. Thus, optical rather than electrical communication is considered to be more appropriate and practical thereby making the use of GI-POF more desirable for short-distance applications less than 50 meters. The short-distance applications include (1) home/office networks with the point-to-point connections less than 50 meters, (2) field networks less than 10 meters, and (3) the connections between PCs and periferals and between (U)HD-TVs and set top boxes that are typically several meters (< 5m).

OM-Giga, that was introduced in 2004 by **Optimedia, Inc.** in Korea, is an MMA(methyl methacrylate)-based GI-POF for high-bandwidth applications. Since its introduction, more than 30 research labs and companies in Europe, USA and Japan have evaluated OM-Giga, and have proved its excellent characteristics and robust performance. OM-Giga is capable of data transmission at a rate greater than 3 Gbps within 50 meters, and greater than 10 Gbps within 10 meters that is well suited for all three short-distance application areas mentioned above. Due to its flexibility and a large diameter, it is easy to handle and the cost for connection and installation is low. Furthermore, as it does not contain any dopant to create a gradient refractive index profile, it has excellent thermal as well as long-term stability.

2. Unique Features and Characteristics of OM-Giga

The GI-POF manufacturing technology of Optimedia is called CRPM (Continuous Reaction with Partial Mixing) process. In this unique process, preforms (or thick rods) with a gradually varying refractive index profile are fabricated by copolymerization of several acrylic monomers. Subsequently, the preforms are drawn into fibers of various diameters (typically smaller than 1 mm). Depending on a specific need (or application), this process can readily vary the numerical aperture (NA) of the fiber as well as the dimension of the preform and fiber.

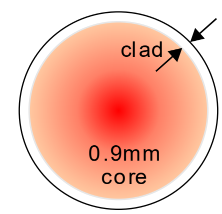
When OM-Giga was first introduced in 2004, the primary target application was the home/office networks at 1 Gbps level, and the dimension of the fiber was 1 mm in diameter with the jacketed diameter of 2.2 mm (OM-Giga-DE100). This fiber/cable dimension was simply to match the dimension of the low bandwidth SI-POF that was prevalent at that time. Now that the application areas have evolved into much higher bandwidth than 1 Gbps with shorter application distances (<10m), Optimedia has also introduced new products that have been optimized for such applications. Besides the standard product, that is OM-Giga-DE100 (1 mm fiber made into 2.2 X 4.4 mm PE jacketed duplex cable), two different types of fibers are currently offered:

(1) OM-Giga B075 & B100

fiber/core diameter:	0.75/0.675 & 1.0/0.9 mm
bandwidth:	> 3 Gbps-50m
attenuation:	200 dB/km (at 650 nm)

(2) OM-Giga B040

fiber/core diameter:	0.4/0.25 mm
bandwidth:	> 10 Gbps-10m
attenuation:	240 dB/km (at 650 nm)



OM-Giga B100

Here the fiber includes the core, in which the refractive index varies gradually from a high value at the center to a lower value toward the outer edge, and the clad which is a thin outer region with a constant refractive index. The clad is not a coated layer but is formed with the core at the same time in a single process. These are bare fibers without a jacket layer, and the jacketing can be customized to make a simplex, a duplex or a ribbon-type multi-channel cables. While the most appropriate data communication wavelength for OM-Giga is 650~680 nm that is red in the visible wavelength range, 850 nm VCSEL can be used if the application length is less than a couple of meters as in optical interconnects.

<u>OM-Giga B075 (or B100)</u>: This product has the bandwidth capability of greater than 3 Gbps at a distance within 50 meters, that is three times higher than that of Cat-6 cable which is currently used for 1 Gbps networks. Self-driving cars are expected to have more than 6 high-resolution video cameras as a part of varous sensors, each of which is expected to have a data transmission rate higher than 3 Gbps. **B075**, which has a bit smaller core diameter than **B100**, is a very suitable product for such application. One of the most important characteristics of these GI-POFs is the fact that they are free from EMI. In addition, replacing copper cables with GI-POF is expected to reduce the weight of a car significantly (~ 25 kg).

Property	**OM-Giga B075**	Remarks
Diameter (core)	0.75 (0.675) mm	
Diameter variation	± 5%	95% confidence interval
Tensile Strength	> 35 N	at break
Bending Radius	25 mm	
Operating Temperature	-30 ~ 70 °C	
Attenuation at 650 nm	< 220 dB/km	measured by OTDR
Bandwidth	> 3.0 Gbps	at 50 m

<u>OM-Giga B040</u>: It is a product optimized for ultra-high bandwidth applications that require a data rate of 10 Gbps at a distance less than 10 m. This product is especially appropriate to make HDMI, DP (DisplayPort), and/or USB 3.1 hybrid cables. Somewhat more detailed characteristics of this product are given in the following page.

OM-Giga B040

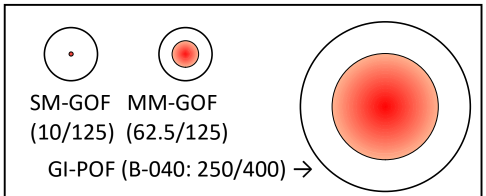
OM-Giga-B040 is an MMA-based GI-POF for ultra-high bandwidth (> 10 Gbps) very short distance applications (< 10 m). Its outer diameter is 400 μm with the effective core diameter of 250 μm and its optical and physical properties are as follows:

Property	**OM-Giga B040**	Remarks
Diameter (core)	400 (250) μm	
Diameter variation	± 5%	95% confidence interval
Tensile Strength	> 12 N	at break
Bending Radius	0.5 mm	360° turn
Operating Temperature	-30 ~ 70 °C	
Attenuation at 650 nm	< 240 dB/km	measured by OTDR
Bandwidth	> 10 Gbps	at < 10 m

As the demand for bandwidth continues to grow explosively, new application areas emerge that require the use of optical fibers. Such application areas include optical interconnects for networking equipment and hybrid cables for mobile devices. Although glass optical fibers can be used for such applications, GI-POF offers numerous advantages over multimode or single mode GOF.

Optical Interconnects:

Ever-growing bandwidth requirements for networking equipment demand EMI-free, compact, light-weight, and most of all, low-cost interconnects for rack-to-rack, board-to-board, and chassis-to-chassis connections. Optical interconnects that are made of multiple strands of OM-Giga-B040 can meet such requirements especially when the application length is shorter than 10 meters. Its outer diameter of 400 μm is large enough allowing B040 to retain all the advantages of a POF such as easy handling and flexibility, yet it is small enough to make the cable compact and light. Furthermore, the large core dimeter of 250 μm, that is 4 times larger than that of multi-mode GOF as shown in the figure, allows more forgiving tolerances when aligning transceivers with the fiber. This larger alignment tolerances enable low-cost connectorization and cheaper transceivers while maintaining ultra-high bandwidth.

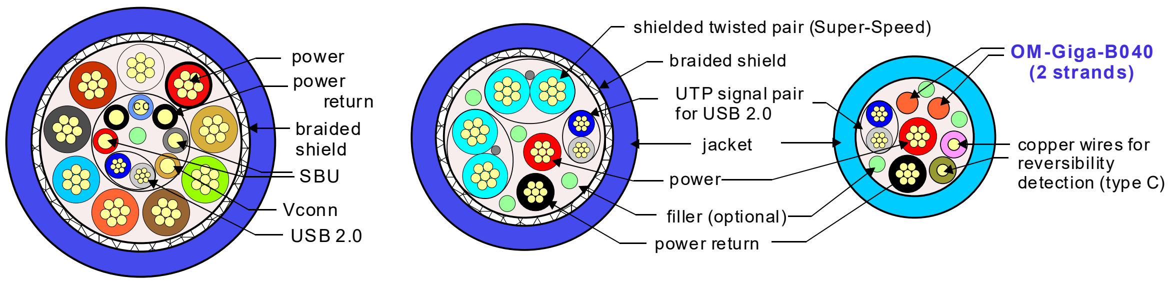


Core and fiber diameter comparison

Hybrid cables for mobile devices:

Hybrid cables such optical HDMI cables have long been used for some special applications requiring a long distance connection (> 10 m). To date, GOFs have been used mostly to make such hybrid cables. However, recent advancement of mobile devices now offers significant opportunities for hybrid cables even for very short distance applications (< 2 m). USB 3.1-type C cable is such an application.

USB cable that was introduced for human input devices such as keyboards and joysticks more than 20 years evolved into Hi-Speed USB 2.0 in 2001 to support a data rate of 480 Mbps. The USB 2.0 cables are ubiquitous as they are broadly used to interconnect mobile devices as well as to charge such devices. Now that the communication speed of mobile devices has become extremely fast even supporting ultra-high definition displays (4K resolution and beyond), USB has also evolved into Super-Speed USB 3.0 in 2009 supporting 5 Gbps data rate and further into Super-Speed⁺ USB 3.1 in 2014 for 10 Gbps.

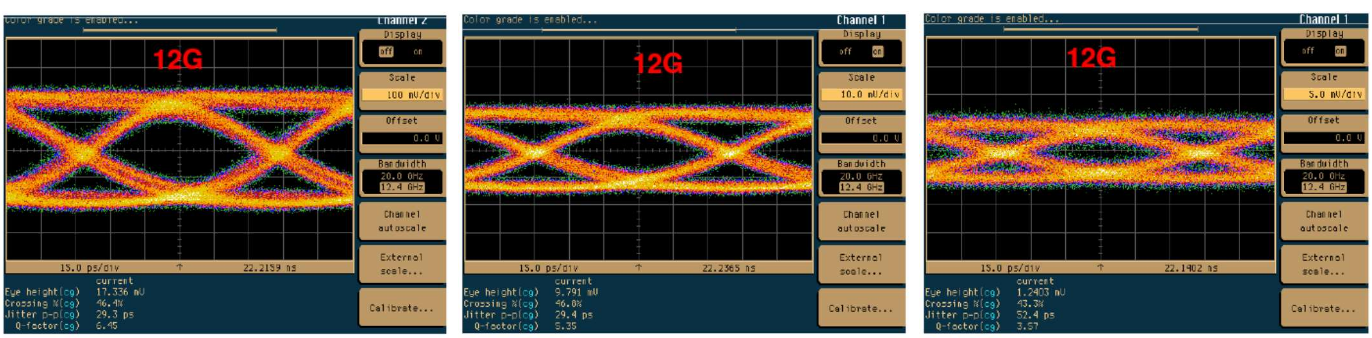


USB 3.1 w/ DP (generation 2) | USB 3.1 w/o DP (generation 1) | Hybrid cable (w/o DP) (B040 replaces Super-Speed Pairs)

Furthermore, VESA has adopted USB 3.1 type C (USB-C) for their DP (DisplayPort™), and major consumer electronics manufacturers are gradually incorporating it into their products. Consequently, demand for USB-C cables is expected to grow significantly. As the USB-C cables will be mostly for mobile devices, compactness or small diameter of the cable is of utmost importance. As the figures given above indicate, however, it is virtually impossible for copper cables to be thin if they are to meet all functional specifications for USB-C. Hybrid USB-C, however, can be very compact as thin optical fibers can replace the bulky super-speed shielded differential pairs. Furthermore, optical fibers enable elimination of braided shield thereby making the cable even more compact and flexible. B040 has proven to be very appropriate for such application. Its optimized outer diameter and the core dimeter offer all the advantages of POF.

The hybrid cable shown in the figure is without the DP functionality. However, addition of more B040 to impart the DP function will not increase the cable diameter significantly. As B040 is an MMA-based GI-POF, the most appropriate Tx is 650 or 680 nm VCSEL (or LD). However, 850 nm VCSEL can be also used if the application length is shorter than 2 m. Furthermore, the bandwidth of B040 at this short length will be greater than 20 Gbps. The eye diagrams given below show the ultra-high bandwidth capability of B040.

Eye Diagrams of OM-Giga B040



Base Line (Optimized with Picometrix O/E) | 3m OM-Giga B040 (direct connection from Tx to Rx) | 6m OM-Giga B040 (3m+3m using a coupler)