White Paper
HiSilicon Optoelectronics 10G PON Optical Module

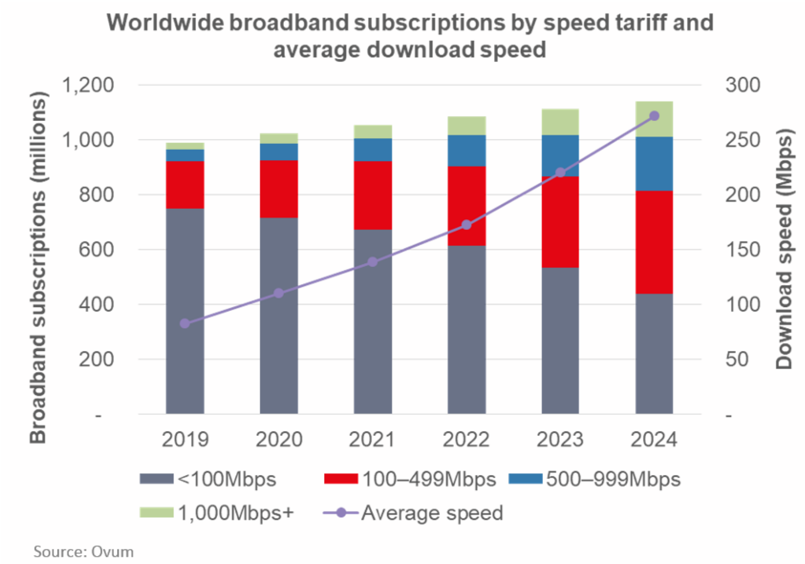
HISILICON OPTOELECTRONICS

CONTENTS

1. Gigaband Era is Coming

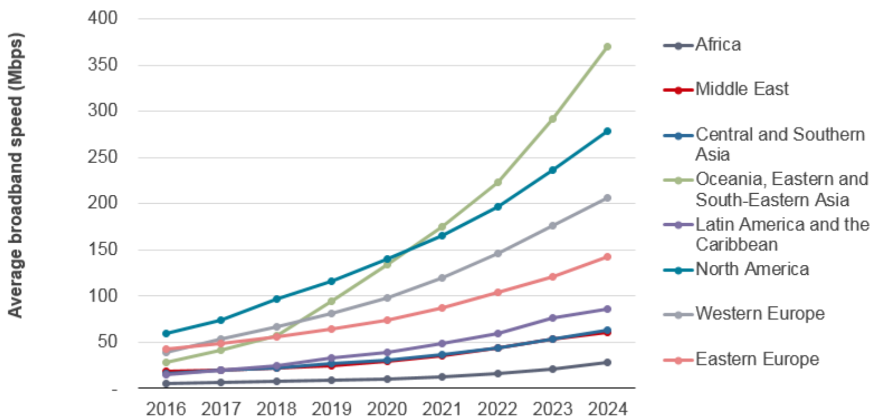
With the booming of global ICT technologies, broadband becomes an indispensable infrastructure at the access layer. With the emergence of new services, applications such as VR, cloud gaming, and home IoT pose higher requirements on fixed broadband rates. According to Ovum's research report, the demand on broadband rates will gradually increase in the next 5 years. By 2024, about 60% of users will require a bandwidth higher than 100 Mbit/s.

Figure 1-1 Ovum's forecast on the number of global broadband users and average download speed



According to third-party statistics, more than 270 operators around the world have released gigaband construction plans. In 2019, the Chinese government's work report clearly stated that gigabit access networks must be deployed in more than 300 cities to promote the "dual gigabit" era of fixed and mobile broadband. According to the market division in different regions, the average bandwidth rate in the Oceania and East (South) Asian markets is expected to reach 354 Mbit/s in 2024 thanks to increase in China, South Korea, and Singapore in the next 5 years.

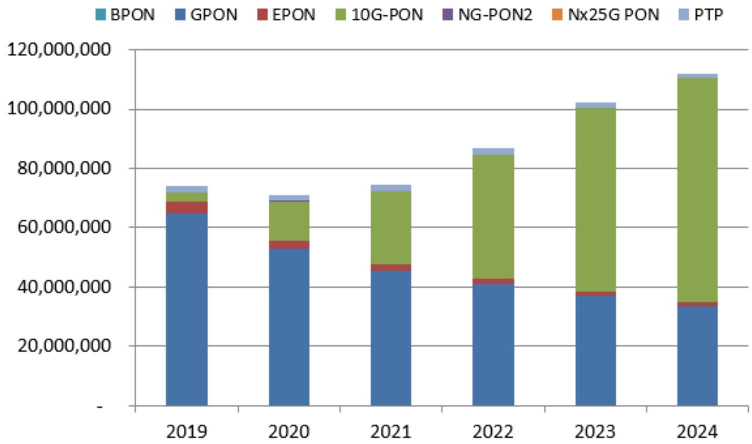
Figure 1-2 Ovum's forecast on the average broadband speed in different markets



The 10G PON based gigaband network features all-optical connectivity, massive bandwidth, and ultimate experience, and will be deployed in a large scale during gigaband construction. According to

LightCounting's prediction, the life cycle of GPON will gradually end in the next 5 years, the shipment of GPON will decrease, and 10G PON will become the mainstream solution in the industry. In the next 5 years, with the maturity of 10G PON technologies, the deployment of 10G PON (including XG/XGSS-PON OLTs) will increase significantly and steadily.

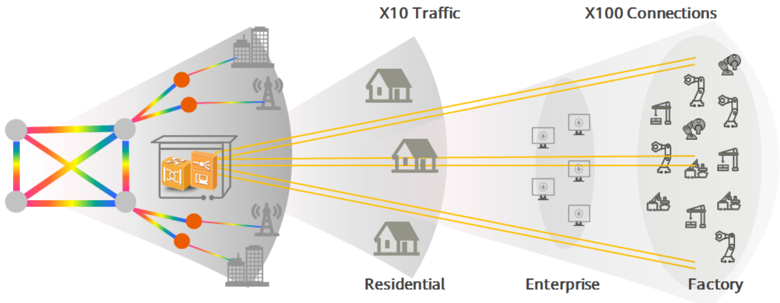
Figure 1-3 Forecast on FTTx Product Shipment by Category



2. Overview of 10G PON FTTx Application Scenarios

Compared with the previous generations of fixed access technologies, 10G PON gigabit broadband is a great leap forward in terms of bandwidth, user experience, and connection capacity. The maximum upstream and downstream rates are symmetric 10 Gbit/s, and the latency is reduced to less than 100 μs. These changes will drive fiber networks to break through the traditional boundaries of home broadband and bring more connection scenarios.

Figure 2-1 Various scenarios of the 10G PON architecture



In 2019, the Gigaband Network White Paper released by the China Broadband Development Alliance provides 10 commercial application scenarios of Gigaband networks based on 10G PON features, including cloud VR, smart home, gaming, social networking, cloud desktop, safe city, enterprise cloudification, online education, telemedicine, and smart manufacturing. The 10 scenarios can be summarized as follows:

1. Home broadband acceleration driven by network requirements such as entertainment and consumption of individual users
2. High-value vertical industries such as public safety, enterprises, and online education
3. Healthcare, smart manufacturing, and other scenarios that require precise network control

While GPON fibers connect households, 10G PON fibers will connect everything.

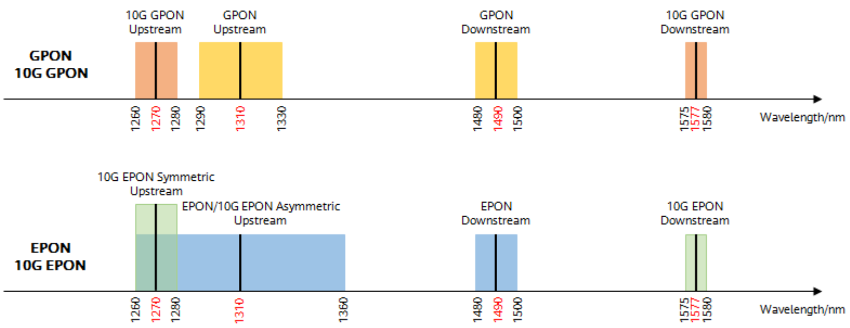
3. Trend of 10G PON Optical Module Technologies

With the maturity of PON standards and related industry chains, the 10G PON technology is developing gradually. Compared with 10G PON ONTs, 10G PON OLTs at the central office (CO) face more technical challenges.

3.1 Smooth Upgrade, Requiring Coexistence of GPON and 10G GPON

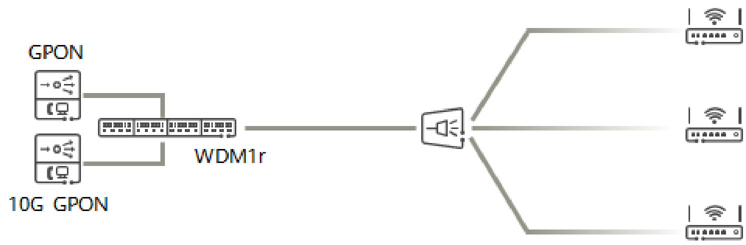
The mainstream PON standards come from the IEEE and ITU which define the EPON and GPON standards separately. GPON supports a higher link budget and split ratio. 10G EPON is backward compatible with EPON based on standard wavelengths, but 10G GPON is not directly compatible with GPON.

Figure 3-1 10G GPON & 10G EPON standard wavelength allocation



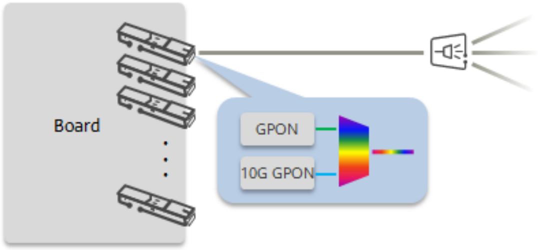
In practice, it is impossible to upgrade all users on a network from GPON to 10G PON at a time. For example, there are hundreds of millions of GPON ports in the current China market. To smoothly upgrade a GPON network to a 10G PON network and keep the ODN network unchanged, a multiplexer/demultiplexer WDM1r needs to be added at the CO to merge the 2 standards so that both GPON signals and 10G PON signals can coexist on the same ODN network.

Figure 3-2 10G GPON & GPON hybrid transmission



Multiple multiplexing/demultiplexing modes are available in the industry. In Figure 3-2, the WDM1r multiplexer/demultiplexer is deployed outside of the GPON and 10G PON modules and occupies the installation space. Another popular multiplexing/demulitplexing mode of the industry uses an optical component embedded in an optical module, that is, 10G GPON & GPON combo optical module.

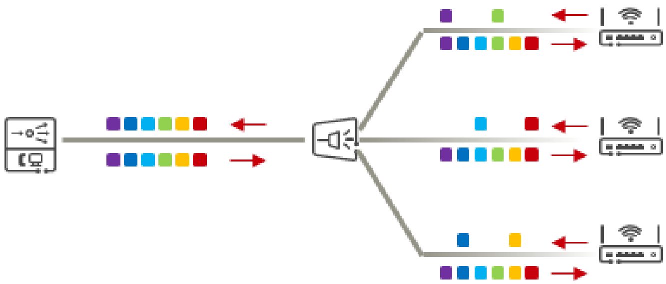
Figure 3-3 10G GPON & GPON combo optical module



3.2 Higher Rate, Requiring Higher Burst Performance

In a PON network, one OLT is connected to multiple ONUs, and the ONUs transmit signals to the OLT in TDM mode. In actual applications, the signals sent by each ONU vary in power and codes. This is the biggest difference between a PON network and other point-to-point (P2P) networks. Therefore, in the PON architecture, the OLT is required to quickly adapt to optical signals of different lengths or powers, to ensure that the optical signals are correctly converted into electrical signals.

Figure 3-4 Upstream and downstream signals in the PON architecture



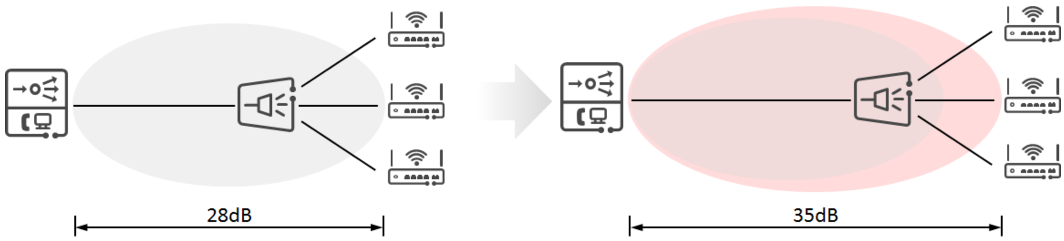
Therefore, the OLT is required to implement direct current offset correction (DCOC), and the burst technology is the basis of fast DCOC in the PON architecture. The main technologies rely on the 10G burst TIA electrical chip and related burst circuit design.

3.3 Full Senarios, Requiring a Higher Link Budget

Limited by the size, process, and heat dissipation of modules and systems, the optical power budget of XG/XGS combo PON in the early stage can reach only 28 dB or 29 dB, that is, class B+ specifications. This hinders the application and deployment of 10G PON in long-haul or high split ratio scenarios.

To achieve 10G GPON deployment in all scenarios and meet C+ and C++ specifications of GPON, the industry is continuously improving the component process and chip specifications of combo PON modules. According to the GPON C++ specifications, if the link budget can reach 35 dB, 10G GPON can achieve 20 km coverage, the split ratio can also increase from 1:64 to 1:128 in densely populated urban areas and 10G PON can apply to multiple scenarios such as reconstruction of ODN with weak light problem.

Figure 3-5 Higher link budget for larger coverage



In practice, on an ODN network, the optical path may deteriorate due to loose fiber connectors, dirty connector end faces, or peeling fiber sheath. The increasing number of users with weak optical signals will affect user experience. Therefore, reconstruction of weak optical signals is an issue that operators must resolve. It was learned that T-Operator in China required the optical attenuation fulfillment rate in 2019 to be greater than or equal to 97%, and M-Operator required the percentage of weak-light ONUs to be less than 1.8% and zero weak-light gigabit user in 2019. Against this background, a higher power capability helps operators smoothly upgrade their networks to resolve the issue of weak optical signals.

3.4 Better Anti-interference Capability Required on the ONU Side

Emerging services such as gaming and videos pose higher requirements on home Wi-Fi performance. When gigabit broadband is more and more popular, Wi-Fi 6 and 10G PON together provide users with Internet of Everything (IoE) connections. The access of diverse Wi-Fi signals on a variety of terminals and scenarios poses higher requirements on the anti-interference capability of 10G PON ONUs.

The ONU bidirectional optical sub-assembly (BOSA) uses the BOSA on board mode and does not have an embedded module, and the pins of the optical component are directly soldered on the circuit board. Therefore, the ONU BOSA has weak capabilities to resist against external signal interference and is prone to packet loss. RF design and optimization will be technical challenges for the 10G ONU BOSA.

4. Discussion on HiSilicon Optoelectronics 10G PON Optical Modules

HiSilicon Optoelectronics 10G PON optical modules for gigaband access include XGS combo PON OLT class B+/C+ optical modules, XG combo PON OLT class B+/C+ optical modules, and pure XGS-PON OLT class N1/N2 optical modules. These optical modules support multiple network construction modes including FTTH, FTTD, and FTTC, meeting the requirements of various service scenarios such as home access and enterprise access.

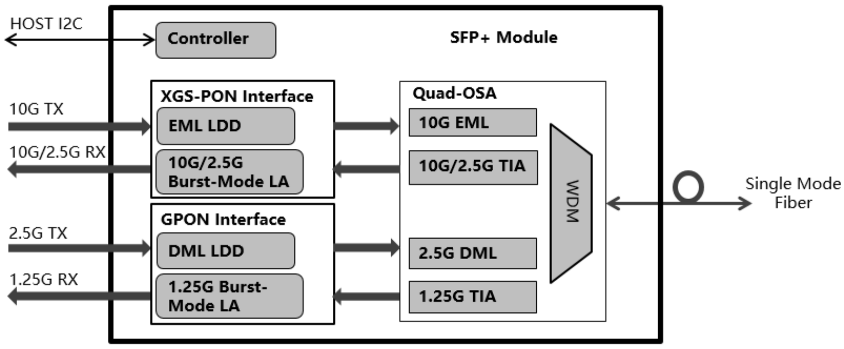
All HiSilicon Optoelectronics products use the SFP+ form factor. Compared with the XFP form factor solution, the SFP+ form factor solution significantly improves the port density per unit area. It supports twice the number of users connected in a subrack with the same size. However, it also poses great challenges to the power consumption, heat dissipation, and layout of optical modules. End-to-end optimization has been made from HiSilicon Optoelectronics chips to modules, achieving industry-leading performance and power consumption. The following describes the design architecture and key technologies of each type of optical module in detail.

4.1 XGS Combo PON OLT Class B+/C+ Optical Module

An XGS combo PON OLT optical module is an SFP+ module embedded with WDM1r to integrate a GPON OLT module and an XGS-PON OLT module. The GPON OLT module and XGS-PON OLT module work independently in WDM mode and support a smooth upgrade from GPON to 10G PON. XGS combo PON OLTs support 2 specifications of modules: class B+ and class C+. The optical link budget is 28 dB and 32 dB separately, adapting to different optical power budget scenarios.

Figure 4-1 shows the module architecture, including the quad-OSA (9.953 Gbit/s TX at 1577 nm, 2.488 Gbit/s TX at 1490 nm, 9.953 Gbit/s or 2.488 Gbit/s RX at 1270 nm, and 1.244 Gbit/s RX at 1310 nm), laser driver circuit, receiver circuit, power supply, and controller. It complies with the ITU-T G.984.2 and ITU-T G.9807.1.

Figure 4-1 Block diagram of the XGS combo PON optical module



The module connector receives 9.953 Gbit/s or 2.488 Gbit/s electrical signals from the board. The signals are amplified by the internal driver inside the optical module and then drive a 1577 nm EML optical chip and a 1490 nm DFB optical chip. The optical chips output stable laser signals, which are then multiplexed by a MUX and are output. In this way, conversion from electrical signals into optical signals is implemented.

After the optical module receives optical signals from an XGS-PON or GPON terminal, a DEMUX inside the optical module demultiplexes the signals into 1270 nm and 1310 nm modulated optical signals. Then the signals enter the optical component inside the optical module. An APD converts the signals into current signals, and a TIA converts the current signals into voltage signals. The signals are directly input to the burst LA inside the optical module for amplification. After being amplified, the signals are sent to the board through gold finger. In this way, conversion from optical signals to electrical signals is implemented.

The mainstream requirement of operators is the class C+ high-specifications combo PON optical module. Restricted by the capability of the industry chain, the yield rate of this module in the industry is far from the actual customer requirement. To ensure advanced technologies for the optical module, the HiSilicon Optoelectronics combo PON OLT optical module adopts the following key technologies to greatly improve the class C+ module supply capability and meet customer requirements:

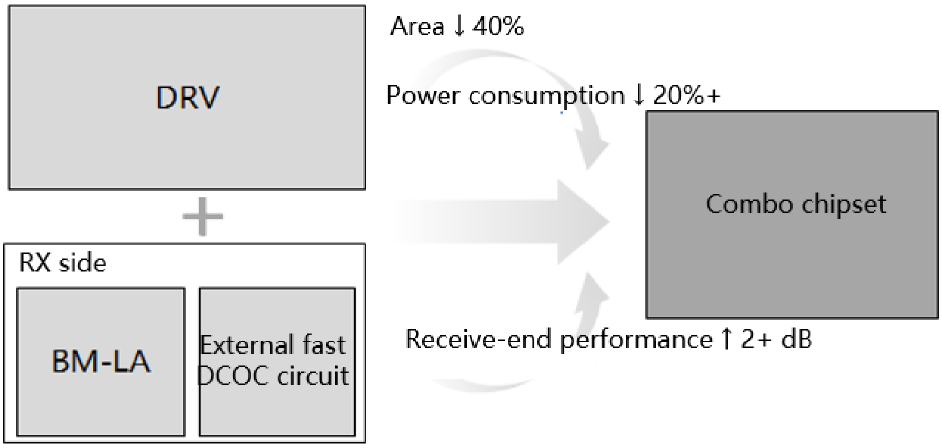
- **High-performance 10G/2.5G combo electrical chip (DRV and LA integrated)**

  Compared with the split DRV and LA solution used in the industry, the XGS combo PON solution requires 4 chips: 10G/2.5G and 10G/1.25G LA chips. When the SFP+ form factor is used, the PCB layout faces great challenges. In addition, to meet the high power budget of class C+ specifications, the DRV chip must have a strong drive capability and low power consumption.

  The HiSilicon Optoelectronics XGS combo PON optical module uses an in-house 10G combo chip, which integrates a 10G DRV, 10G/2.5G BM-LA, and fast DCOC circuit. In addition, multiple power supply domains are used to supply power, reducing chip power consumption. Compared with the traditional split solution, the 10G combo chip has an area decreased by 40% and power consumption decreased by 30%.

The 10G/2.5G combo electrical chip has its area and power consumption greatly optimized. In addition, the fast DCOC circuit originally connected externally is integrated into the chip at the receive end. This shortens the length of wiring on the high-speed link, reduces the noise, and improves the receive-end performance by 2–3 dB.

Figure 4-2 Combo chipset



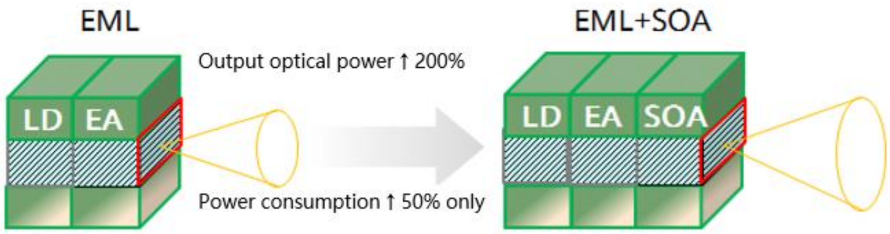
- **EML+SOA laser with low power consumption and high power**

The mainstream 10G laser for 10G PON in the industry is the EML solution. At the early stage, the EML has a low optical power efficiency, and the proportion of class C+ specifications is extremely low, which cannot meet market requirements. The optical chip vendors optimize the EML design to slightly increase the output optical power and partially meet the class C+ specification requirements. In addition, the SFP+ form factor is sensitive to power consumption. The power consumption should not be greatly increased when the optical power is increased.

To meet the requirements of the industry for high-power lasers, HiSilicon Optoelectronics Co., Ltd. develops lasers with low power consumption and high power and uses the EML+SOA monolithic integration solution. The key bottleneck of the transmit power chip is to improve the transmit power while ensuring long-term reliability and overall power consumption. HiSilicon Optoelectronics Co., Ltd. uses the innovative taper structure design and new doping solution to overcome the 3 major challenges: the growth quality of butt coupler joint, balance between power and power consumption, and chip heat dissipation capability, ensuring high performance and high quality of the chip.

Compared with traditional EML lasers, HiSilicon Optoelectronics in-house EML+SOA high-power lasers have the output optical power increased by 200% and power consumption increased by only 50%.

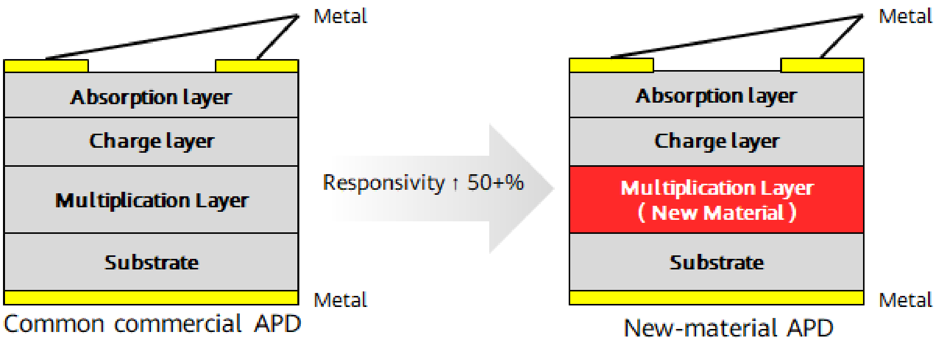
Figure 4-3 Schematic diagram of the 10G laser



- **APD with high performance**

  Compared with the traditional APD, HiSilicon Optoelectronics in-house high-performance APD uses a new ultra-low noise material for the multiplication layer, which reduces the NF coefficient of the system and greatly improves the responsivity. In addition, the innovative structure design and techniques are used to improve the APD bandwidth. The in-house high-performance 10G combo chipset is used to improve the overall sensitivity of the system and meet the high-performance requirements on the class C+ XGS combo PON module.

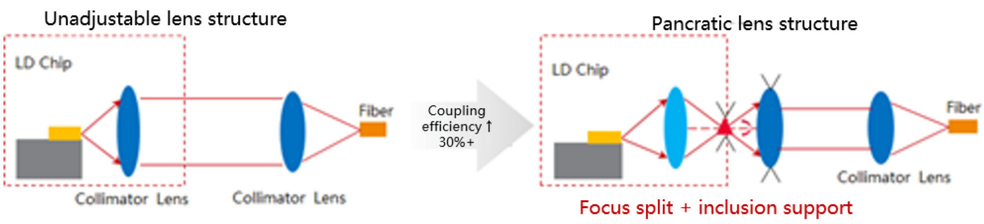
Figure 4-4 APD structure



- **Quad-OSA with high coupling efficiency**

  To integrate GPON and XGS-PON, a quad-OSA is used. The optical path is more complex than that with a BOSA or tri-OSA. As a result, manufacturing is more difficult, and the optical path loss is higher, reducing the light emission efficiency of the optical component. HiSilicon Optoelectronics Co., Ltd. optimizes and designs optical components and an optical path solution based on comprehensive 3D optical tolerance simulation and analysis results, and uses an in-house high-precision die bonding to greatly improve the coupling efficiency. Although the optical path complexity of the quad-OSA increases, the coupling efficiency is better than that of a BOSA. In addition, with the high-power EML+SOA laser, the yield of HiSilicon Optoelectronics Class C+ optical modules can be greatly increased.

Figure 4-5 Optical path design for high coupling efficiency

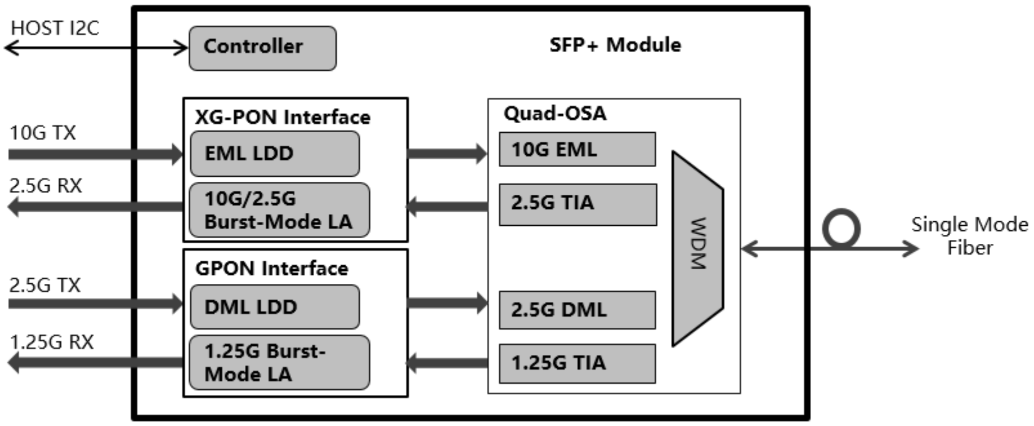


4.2 XG Combo PON OLT Class B+/C+ Optical Module

HiSilicon Optoelectronics XG combo PON OLT optical module is an SFP+ module embedded with WDM1r to integrate a GPON OLT module and an XG-PON OLT module. The GPON OLT module and XG-PON OLT module work independently in WDM mode and support a smooth upgrade from GPON to 10G PON. XG combo PON OLTs support 2 specifications of modules: class B+ and class C+. The optical link budget is 28 dB and 32 dB separately, adapting to different optical power budget scenarios.

Figure 4-6 shows the module architecture, including a quad-OSA, laser drive circuit, receiver circuit, power supply, and controller. The module complies with the ITU-T G.984.2 and ITU-T G.987.2.

Figure 4-6 Block diagram of the XG combo PON optical module

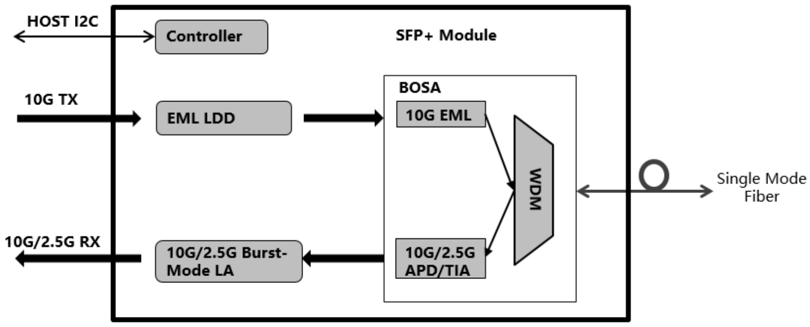


The working principle of the optical module is the same as that of the XGS combo PON OLT optical module. The difference lies in that the XGS combo PON OLT optical module does not support 9.953 Gbit/s burst receiving.

4.3 XGS-PON OLT Class N1/N2 optical module

HiSilicon Optoelectronics XGS-PON OLT optical modules comply with the ITU-T G.9807.1 standards and support 2 specifications: class N1 and class N2. The optical link budget is 27 dB and 31 dB separately, adapting to different optical power budget scenarios. Figure 4-7 shows the module architecture, including a BOSA, laser driver circuit, receiver circuit, power supply, and controller.

Figure 4-7 Block diagram of the XGS-PON OLT optical module

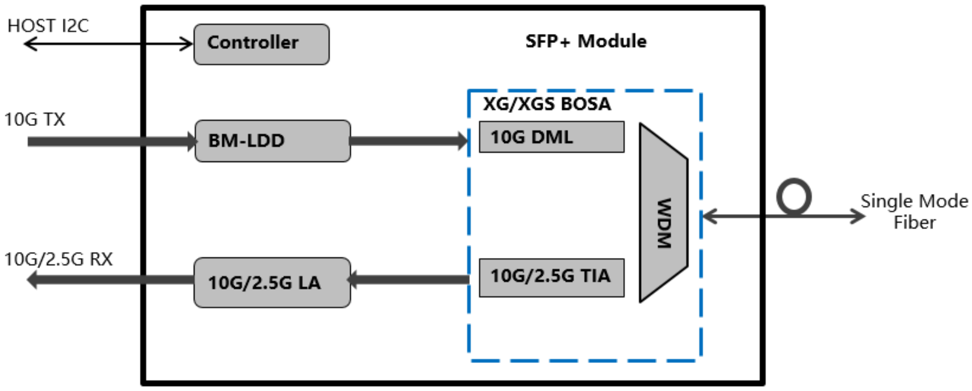


The working principle is the same as that of the XGS combo PON OLT optical module, but the XGS-PON OLT optical module does not support the GPON function.

4.4 10G PON ONU BOSA

HiSilicon Optoelectronics provides two types of 10G PON ONU BOSAs: XG PON BOSA and XGS PON BOSA. A BOSA is directly installed on the PCB of an ONU. Figure 4-8 shows the typical block diagram of an ONT.

Figure 4-8 Block diagram of a 10G GPON ONT



Mainstream ONUs in the industry are integrated with the Wi-Fi function. Wi-Fi signals cause obvious interference to the BOSA receiver sensitivity. As a result, the sensitivity deteriorates, and the specifications are close to the threshold or even do not meet the requirements. To cope with Wi-Fi interference, vendors take external shielding measures to reduce interference and improve the sensitivity performance. ONTs are sensitive to costs. The complex shielding measures greatly increase ONT costs.

To reduce the ONT cost, HiSilicon Optoelectronics Co., Ltd. improves the Wi-Fi interference resistance capability by optimizing wire bonding and form factor design. In addition, the high-performance APD with a new material brings a large margin of sensitivity performance. Therefore, the Wi-Fi interference-resistant design of ONTs is simplified. In this way, the ONT cost is reduced.

5. Summary

With the development of 10G PON standards and the maturity of the industry, bandwidth-hungry services are emerging, and favorable policies are being released in different countries, pushing access optical modules towards higher transmission rates. GPON is the mainstream standard of the previous generation, and accounts for a large proportion on global live networks. The GPON installed base will be gradually upgraded to 10G GPON to meet new service requirements.

XG/XGS combo PON optical modules have been widely used on devices at central offices. HiSilicon Optoelectronics Co., Ltd. has been focusing on the access optoelectronics field for more than 10 years and has made many technical innovations. HiSilicon provides a full series of end-to-end 10G PON optical module and component solutions with a variety of specifications, providing comprehensive and diverse pipes for the gigabit era of fiber connections.