Solutions for high-performance optical transmission modules

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Today, information communications networks are being required to handle a whole host of information, such as Internet-based animated images, and other data, in addition to traditional, analogue telephone and facsimile communications. In order to cope with the growing size and diversity of communications traffic, there have been moves to increase capacity and functionality in communications networks by adopting optical networks like that illustrated in Fig. 1.

Oki Electric's solution in this field is based on its group of optical communications modules (an ONU module for ATM-PON systems, 2.5 Gb/s MINI-DIL type LD module and 10 Gb/s PD-TIA module) which are vital elements for achieving higher capacity and functionality, and lower communications fees, in the respective access networks, metropolitan networks, and backbone networks which make up the overall optical network structure. This paper will look at these different modules in turn.

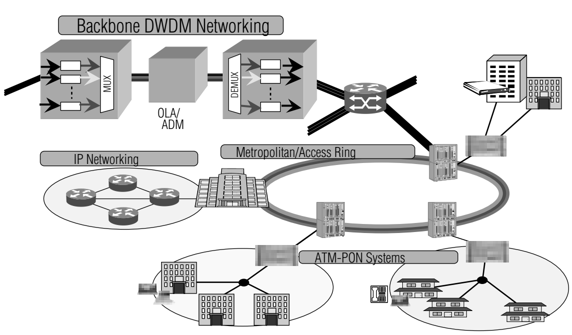


Fig. 1 Optical network

ONU optical module for ATM-PON systems

The ONU optical module for ATM-PON systems provides a solution for creating high-speed, low-fee access services. Fig. 2 shows the structure and external appearance of an ONU optical module for ATM-PON used for two-way communications in an access network, and Table 1 shows the specifications of this module. The WDM (Wavelength Division Multiplex) optical circuit which multiplexes (MUX) and de-multiplexes (DEMUX) 1.3 μm wavelengths and 1.5 μm wavelengths uses an optical waveguide (PLC : Planar Lightwave Circuit) fitted with a WDM filter. The PLC structure was chosen because it is more suited to compact integration and automated assembly than fibre coupler or space beam type designs, and therefore it is excellent for mass production and cost reduction.

Polyimide filters are used for the WDM filters in order to reduce costs. By fixing a polyimide filter to one face of the PLC, 1.3 μm band wavelengths and 1.5 μm band wavelengths can be multiplexed and

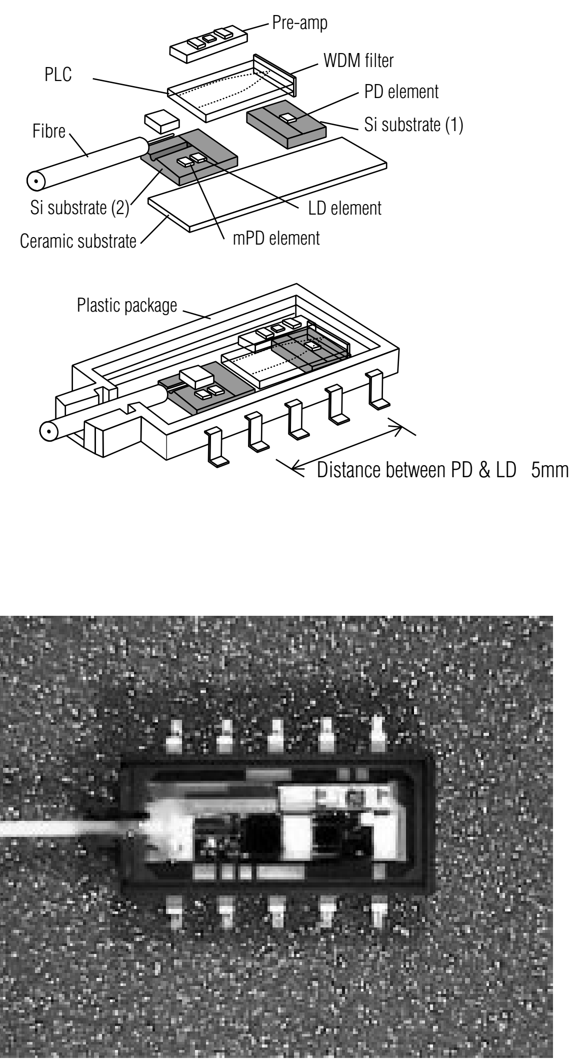


Fig. 2 Structural diagram and external view of ONU optical module for ATM-PON

Table 1 622.080 Mb/s ONU optical module specifications

Item		Symbol	Conditions	Min. value	Average value	Max. value	Unit
Transmitter	Optical output	P0	CW	1.6			mW
	Threshold current	Ith	—			40	mA
	Central wavelength	λc	P0=1.6mW, RMS	1280		1350	nm
	Spectral half-width	$\Delta\lambda$	P0=1.6mW, RMS(s)			2.1	nm
	Forward voltage	Vf	P0=1.6mW			1.45	V
	Operating current	Iop	P0=1.6mW			80	mA
	Rise / fall time	tr/tf	P0=1.6mW			0.5	ns
	Monitor current	Im	P0=1.6mW	200		1000	μA
	Tracking error	TRE	Im=const.	-1		1	dB
Receiver	Power supply voltage	Vcc	—	3.0	3.3	3.6	V
	Sensitivity	R	Pin=3μW, Vcc=3.3V	3.15	4.8		kV/W
	Frequency bandwidth	BW	-3dB, Pin=3μW	400	450		MHz
	Minimum sensitivity	Pmin	622Mb/s, NRZ BER=10^{-10}, PRBS2^{23}-1		-29	-28	dBm
	Maximum sensitivity	Pmax	622Mb/s, NRZ BER=10^{-10}, PRBS2^{23}-1	-6	-7		dBm
Optical reflection loss		ORL	λ=1550nm			-20	dB
			λ=1310nm			-10	dB

demultiplexed. The polyimide filter conforms to LWPF (Long Wave Pass Filter) specifications.

Reception wavelengths in the 1.5 μm band input from the fibre are passed by the filter, and received by the receiver PD (photodiode), whereas the 1.3 μm band light of the transmitter LD (Laser Diode) is reflected by the filter and output via the fibre.

The ATM-ONU optical module is used by driving the transmitter and receiver simultaneously, which gives rise to problems of electrical and optical cross-talk. In the module presented here, in order to avoid the problem of electrical cross-talk, a discrete mounting structure is adopted where the transmitter side LD element and the PD element in the receiver are electrically isolated. Previously, the transmitter LD and receiver PD have been mounted on the same Si substrate, which has required sufficient spacing between the LD and PD, strengthening of the GND, and other measures, to reduce electrical cross-talk. Therefore, the conventional structure obstructs advances in miniaturization and cost reduction. However, by adopting a discrete structure in which (1) a transmitter Si substrate mounted with a LD element and monitoring PD element, and (2) a receiver Si substrate mounted with a reception PD element, are connected respectively via an insulated PLC, and furthermore, by installing the Si substrate (1) and Si substrate (2) mounted on the PLC, onto a ceramic substrate and then mounting them with into a plastic package with a pre-amp, we have been able to strengthen electrical insulation, and therefore shorten the mounting distance between the LD element and PD element, without problems of electrical cross-talk. All this has meant that we can make the PLC more compact, whilst also lowering module costs.

To reduce optical cross-talk, on the other hand, it is especially important that the transmission wavelength, 1.3 μm, is shut out adequately in the receiver section, since simultaneous transmission and reception must be performed using a transmitter section of high signal power and a receiver section capable of detecting very weak signals. Our optical module reduces cross-talk by having a LWPF filter fitted in contact between the receiver side end of the PLC and the reception PD element, and by coating an optical termination resin onto the PLC chip.

The discrete structure adopted also makes it possible to control the yield rate for each individual component, providing opportunities to increase the overall yield rate of the module and simplify process control. The resulting module, designed for cost savings and mass production, has external dimensions of 17.5 (L) x 12.2 (W) x 3.4 (T) mm.

Characteristics of the ONU optical module for ATM-PON

Fig. 3 shows the error rate characteristics of this module when receiving a 622 Mb/s signal. The minimum sensitivity during simultaneous transmission and reception is –29 dBm (BER = 10^{-10}) or less in the temperature range –20°C ~ +75°C, and the corresponding power penalty is 2 dB or lower.

Table 2 Product Line-up

Product	Transmission rate	Transmitter		Receiver				Schedule
		Optical output	Wavelength	Power supply voltage	Wavelength	Bandwidth	Sensitivity	
OL3902W	155.52Mb/s	1.6mW	1310nm	3.3V	1550nm	120MHz	12KV/W	CS 2/02
OL3907W	622.080Mb/s	1.6mW	1310nm	3.3V	1550nm	450MHz	3.15KV/W	ES 12/01 CS 4/02

ES: Engineering Sample CS: Commercial Sample

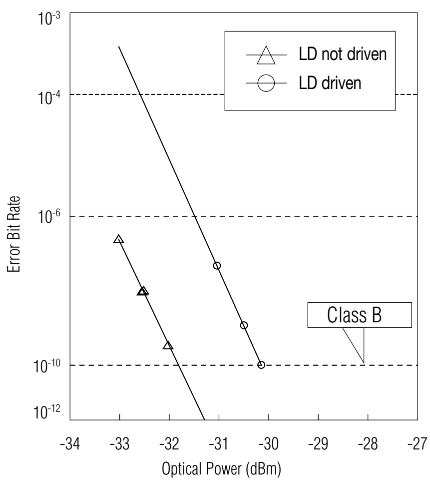


Fig. 3 Error rate measurement results (at 25 °C)

These favourable characteristics easily satisfy the Class B standard for minimum sensitivity recommended in ITU-T G983. The sensitivity is a stable 0.85 A/W, with a total variation including the pre-amp of less than ±1 dB (between –20°C ~ +75°C). The module also has good optical output characteristics, with a tracking error of ±0.6 dB or less (–20°C ~ +75°C) corresponding to a fibre output P0 = 1.6 mW (at 25°C). The optical reflection loss inside the module is –15 dB or less at the transmission wavelength, and –25 dB or less at the reception wavelength, both representing suitable results.

The product line-up and development schedule are illustrated in Table 2.

2.5 Gbps MINI-DIL type LD module

Fig. 4 shows an external view of the 2.5G LD module OL3312N which is currently under trial manufacture. Its dimensions are 13.2 x 7.4 x 4.0 mm, which conform to the size of a MINI-DIL. Flat type leads suitable for surface mounting are used, and the pitch is set to 2.54 mm. Fig. 5 is a cross sectional view of the OL3312N. We have coupled the LD chip optically with the fibre by passive alignment, on a Si substrate mounted in a ceramic package. The optical fibre is formed with a spherical lensed process in order to achieve high output in the passive alignment. Furthermore, an AR coating is provided on the spherical lens of the fibre, to prevent light reflected back by the fibre from adversely affecting the optical output. In this structure, the LD chip is bare chip mounted, so it requires encapsulating. A resin-encapsulated structure was adopted for the package, with the aim of simplifying the encapsulating process.

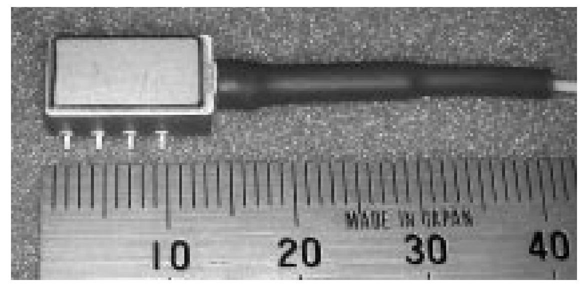


Fig. 4 External appearance of OL3312N

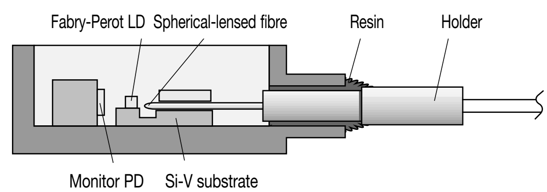


Fig. 5 Cross section of OL3312N

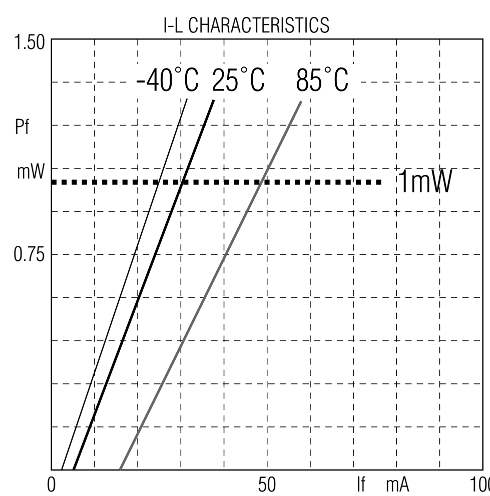


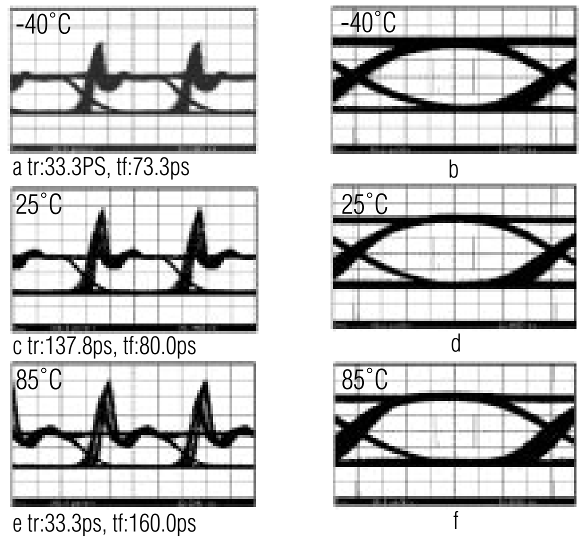
Fig. 6 Optical characteristics of OL3312N

Characteristics of the 2.5 Gb/s LD module

The 2.5 Gb/s LD module is a solution designed to increase traffic capacity in metropolitan and backbone networks. A sample module was manufactured and evaluated. Fig. 6 shows the optical characteristics of the OL3312N module. The horizontal axis represents operating current, and the vertical axis, the optical output of the fibre. Measurement temperatures of –40°C, +25°C and +85°C were used.

Table 3 lists the main characteristics of the OL3312N. From Fig. 6, we can see that an optical output of 1 mW was satisfied at all measurement temperatures.

Fig. 7 illustrates the rise and fall conditions and the eye pattern of the OL3312N, at respective temperatures of –40°C, +25°C and +85°C. Other measurement conditions were set to: transmission rate 2.5 Gb/s, extinction ratio 14 dB, NRZ system, random pattern 2^{23}-1, and peak power 1 mW. Figs. 7a, c & e show the rise time (tr), fall time (tf) and waveform corresponding to each measurement temperature. These figures are perfectly acceptable compared to the standard value of 150 ps. Figs. 7b, d & f show the eye pattern when an electrical filter is inserted. There were zero failed samples at any of the



- Transmission rate : 2.5 Gb/s
- NRZ system
- Peak power : 1 mW
- Extinction ratio : 14 dB
- Random pattern : 2^{23} –1

Fig. 7 OL3312N : tr, tf and eye pattern

Table 3 List of OL3312N characteristics

Parameter	Condition	Min. value	Standard value	Max. value	Unit
Fibre output	Continuous light	1			mW
Operating current				150	mA
Threshold current	Start of lifespan	1.5		40	mA
	End of lifespan			1.5Ith-BOL	mA
Central wavelength	2.5 Gb/s, random pattern 2^{23}-1 NRZ, peak power : 1 mW	1266		1360	nm
Spectral line width	Optical output : 1 mW, root mean square			4	nm
LD forward voltage	Optical output : 1 mW			1.5	V
Monitor current	Optical output : 1 mW (room temperature / start of lifespan)	300		2000	μA
10-90% rise/fall time	Optical output : 1 mW		150		ps
Input impedance			25		Ω
Optical reflection loss		6			dB
Tracking error	(Room temperature – worst case temperature)	-1.5		1.5	dB
PD dark current	Inverse voltage : 2.2V			1	μA
PD capacity	Inverse voltage : 2.2V			20	pF
Thermistor resistance	Measurement temperature : 25˚C	9	10	11	kΩ
B constant of thermistor resistance			3435		K

Table 4 Development schedule

Product	Transmission rate	Optical output	Wavelength	LD	Schedule	Notes
OL3314L	10Gb/s	0.5mW	1310nm	DFB	ES 3/02 CS 5/02	Built-in Bias T
OL3312N	2.5Gb/s	1mW	1310nm	FP	ES 11/01 CS 5/02	Built-in Bias T
OL3311L				DFB		
OL5311L			1510nm			

ES: Engineering Sample CS: Commercial Sample

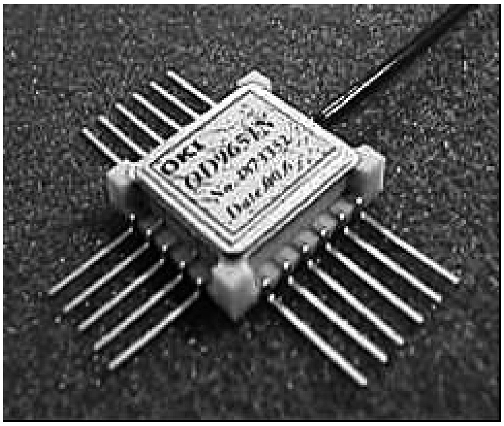


Fig. 8 External view of 10 Gb/s PIN-AMP module

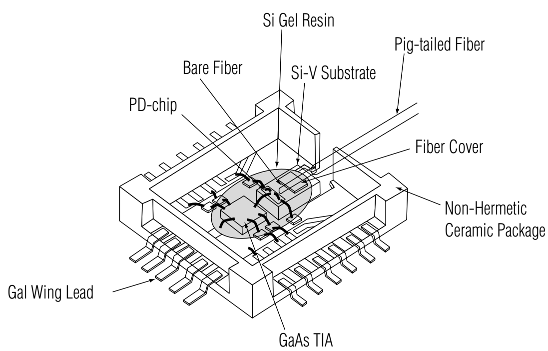


Fig. 9 Structure of 10 Gb/s PIN-AMP module

measurement temperatures, and good eye openings were obtained.

Here, we have manufactured samples of a 2.5 GLD module OL3312N using passive alignment, and obtained good characteristics in sample evaluation tests.

We are currently developing other LD devices using this technology. Table 4 shows the corresponding product line-up and development schedule.

10 Gb/s PIN-TIA module

The 10 Gb/s PIN-TIA module provides a solution for high speed and high capacity in metropolitan and backbone networks. Fig. 8 shows the composition and external appearance of the 10 Gb/s PIN-AMP module we have recently completed. The external dimensions of the module are 9.4 mm x 10.25 mm x 2.15 mm.

The structure is illustrated in Fig. 9. The module is built by mounting a TIA and Si-V-grooved substrate, and the like, on a ceramic substrate formed with a microstrip line which is impedance matched within the package. The main feature of the module is that these elements can be mounted by a lens-less system, without self alignment, because a marker for PD mounting is provided on the Si substrate, and the

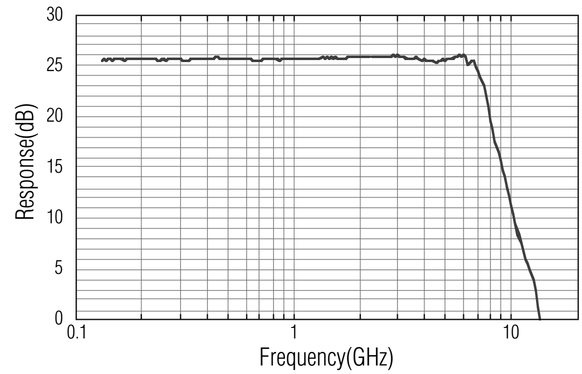


Fig. 10 Frequency characteristics

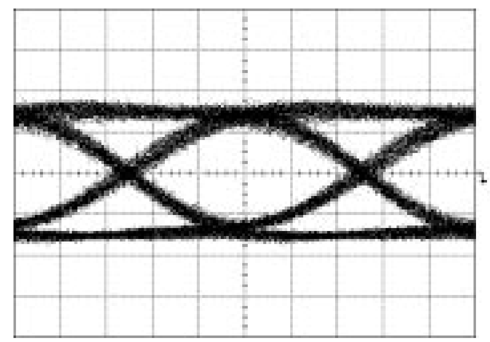


Fig. 11 Output waveform

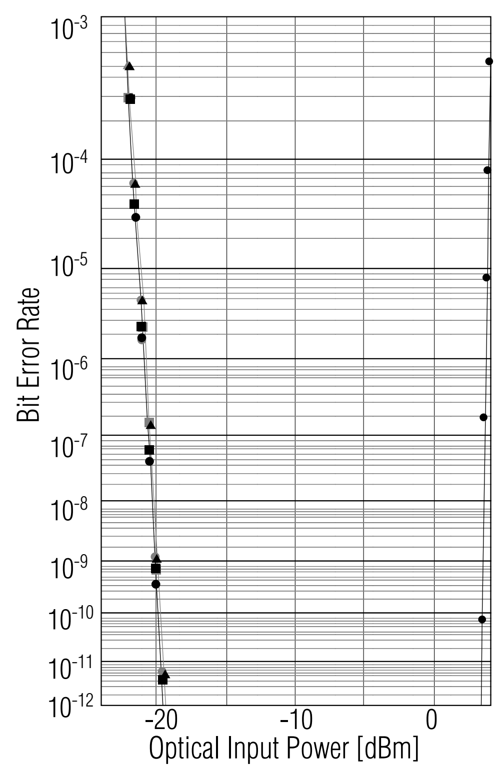


Fig. 12 Error rate characteristics

Table 5 10 Gb/s PIN-AMP module (OD9651N) specifications

Item	Symbol	Conditions	Min. value	Average value	Max. value	Unit
Wavelength	λ		1280		1580	nm
Sensitivity	Rpd	λ=1550nm	0.7	0.8		A/W
Frequency bandwidth	BW	f3dB, Pin=-10dBm	7.0	7.5		GHz
Transimpedance	Zt	Pin=-10dBm, RL=50Ω	57	60		dBΩ
Max. sensitivity	Pmax	9.953Gb/s, NRZ PRBS2^{31}-1ber10^{-12}	0	2		dBm
Min. sensitivity	Pmin	9.953Gb/s,NRZ, PRBS2^{31}-1ber10^{-12}		-20	-18	dBm
Input computed noise current density	In	Average: 0.5GHz~BW		10	12	pA/√Hz

Table 6 PIN-AMP product line-up

Product	System	Transmission rate	Freq. band	Max. sensitivity	Min. sensitivity	Schedule
OD9651N	OC-192, STM-64	9.95328Gb/s	7.5GHz	0dBm	-18dBm	
OD9652N		10.664Gb/s	8.5GHz	-3dBm	-17dBm	CS 1/02
OD9653N		12.5Gb/s	10GHz	0dBm	-15dBm	ES 1/02 CS 6/02

ES: Engineering Sample CS: Commercial Sample

substrate is formed with a V-shaped groove for installing the fibre.

This structure provides excellent advantages over a butterfly type system using lens-based coupling, from the viewpoints of compact integration, mass producibility and cost reduction.

Characteristics of the PIN-TIA module

Fig. 10 shows the frequency characteristics of the 10 Gb/s PIN-TIA module. Good characteristics of sensitivity η = 0.9 A/W and trans impedance 60.3 dBΩ were obtained.

In Fig. 11, we can see the output waveform (Ta = +25°C, 20 mV/div, 20 processing step/div) of the PIN-TIA module at 10 Gb/s (NRZ, pseudo-random pattern (PRBS) 2^{31}-1), Pin = -10 dBm, extinction ratio 8.6 dB). This confirms that a good eye opening is obtained.

Fig. 12 shows the measurement results for error rate (10 Gb/s, NRZ, PRBS 2^{31}-1, extinction ratio 8.6 dB). In the temperature range of Ta = +0 – +70°C (■ : +0°C; ▲ : +25°C; ● : +70°C), the minimum sensitivity is –19.3 dBm (BER 10^{-12}), and the maximum sensitivity is + 3.5 dBm (BER 10^{-12}), so results are stable with respect to temperature fluctuation, and reception over a wide dynamic range is possible. Table 5 lists the specifications of the 10 Gb/s PIN-TIA module (OD9651N).

Product line-up and development programme

We have released two types of PIN-TIA module : the OD9651N for 10 Gb/s signal rates (9.95328 Gb/s, OC-192, STM-64), and the OD9652N for 10.7 Gb/s communications (10.664 Gb/s, FEC). We have also completed trial manufacture of a third model, the OD9653N, designed for 12.5 Gb/s operation. This product line-up and corresponding development schedule are indicated in Table 6.

From here on, in response to demands for greater functionality, we will be driving forward with development of high-gain modules (with built-in limiting amps) for the data communications market, and 40 Gb/s reception modules aimed at even faster networks,

Conclusion

This essay has presented the optical communications components developed by Oki to provide solutions for increasing capacity, improving functionality and reducing communications fees in optical network systems.

Alongside the three key factors of low cost, high functionality and high speed, our future research will also be directed towards achieving greater functional integration.

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