TECHNICAL BRIEF

O K I   L A S E R   D I O D E   P R O D U C T S

OKI Laser Diodes

June 1995

OKI Semiconductor

INTRODUCTION

This technical brief presents an overview of OKI laser diode and edge emitting light emitting diode (EELED) products. LASER is an acronym for Light Amplification by Stimulated Emission of Radiation.

OKI Semiconductor manufactures a large variety of long-wavelength laser diodes and EELEDs in the 1310-nm and 1550-nm range. OKI also offers products in the 1240-nm and 1650-nm range for special test and measurement applications.

OKI offers a full line of laser products as shown in *"Ordering Information"* below. The general categories of OKI laser device modules available are shown in the following table.

General Categories of OKI Laser Device Modules

Type	Wavelength Range (nm)
DIP and Shrink-DIP Pulsed LD Modules	1240, 1310, 1550, and 1650
Coaxial Pulsed LD Modules	1310 and 1530
Miscellaneous Discrete Laser Diodes and LEDs	1300, 1310, 1480, 1550
DIP and Butterfly LD Modules	1310, 1480, 1550
Coaxial Pigtail LD Modules	1310, 1550
Receptacle LD Modules	1310
SLD and EELED Modules	1300, 1550

Refer to *"Ordering Information"* for a complete listing of OKI laser modules.

OKI Semiconductor has focused the design and development of its optical devices and modules on the communications marketplace. Products offered range from discrete devices in TO-Can packages to pigtailed modules in a variety of industry standard housings. The modules come with Thermo-Electric Cooling (TEC) in DIP, or Butterfly pigtailed packages and uncooled coaxial pigtailed packages.

With an ever growing demand for greater bandwidth and for transmitting higher capacity information, the role of fiber optic communication is becoming increasingly important. Fiber optics will be part of most next generation communication systems. These systems include SONET/SDH, ATM for data transmission, digital video transport, and telecom local loop access systems.

In all of these applications, fiber optic technology is an enabling technology. As such, fiber components will be growing at the same rate as the total system demand, but at a lower rate than the growth rate of the electronic components making up the system.

This technical brief is designed for those new to fiber optic communications as well as for the experienced fiber optic specialist. For an engineer new to fiber optic communications, the next three sections provide an introduction to this topic. For an experienced fiber optic specialist who wishes to make a selection of OKI parts, the following sections are of special interest:

- Device Technology
- Applications
- Ordering Information

LASER DIODE FUNDAMENTALS

This section contains a brief explanation of laser diode fundamentals. For a person new to the optical communications field, it provides information about basic operation of laser diodes and OKI laser diode products. For the experienced reader, this technical brief will help in making decisions concerning OKI laser diode products for specific applications.

Basic Physics Governing Laser Diode Operation

The most basic requirement for a semiconductor emitting photon is to have a direct bandgap semiconductor, such as Indium Galium Arsenide Phosphite (InGaAsP). InGaAsP is one of the most often used material for producing 1310-nm and 1550-nm range laser diodes. In this direct bandgap material, the most probable carrier recombinations are through direct electron-hole pair recombination. In this process, a photon carrying the wavelength corresponding to the energy gap is released.

Another fundamental physical process for understanding laser operation is the concept of spontaneous emission as shown in *Figure 1*. Due to thermal activity and other agitation, a direct bandgap semiconductor always emits a spontaneous photon when electron-hole pairs exist. Spontaneous emission is one of the initiators of laser diode lasing phenomena. Lasing refers to the emission of coherent light.

Spontaneous emission is characterized by its randomness in both amplitude and phase. LEDs rely on spontaneous emission phenomena to produce a light emission. As such, the light emitted is not coherent. and there is no wavelength selection mechanism in an LED structure. Consequently, the emitted light spectral content is relatively broad, since it is governed mainly by the material gain profile. The material gain profile in turn is governed by the electron and hole thermal distribution in the conduction and valence bands. The typical spectral width of communication grade LEDs is 50 nm to 80 nm.

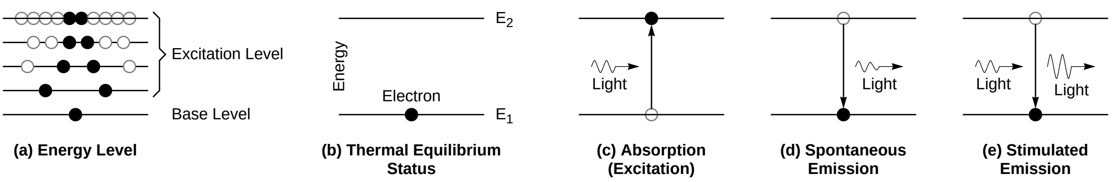

Figure 1. Transition Levels in a Direct Bandgap Semiconductor

To make a laser diode lase, that is, emit coherent light, at least two more mechanisms are needed. One of these mechanisms overcomes the intrinsic material absorption loss by producing gain in the lasing material. Gain is produced by a population inversion in the lasing material, that is, an excess of electrons in the conduction band over holes in the valence band. The population inversion is achieved in a semiconductor laser by carrier injection, or equivalently putting a current through the laser's gain or active region.

The second mechanism necessary for lasing (or oscillation at optical frequency) is feedback. This is obtained by designing a laser resonator containing the gain medium, to guide photons in the closed cavity. At each end of the cavity, semi-transparent mirrors are placed that provide the feedback and cause repeated coherent addition of stimulated emission events throughout the cavity. This dramatically increases the efficiency of the stimulated emission process.

With mirrors at both ends of the cavity, a physical phenomenon known as Fabry Perot (FP) filtering takes place. An FP filter is a recursive filter in which a pass-band repeats itself in a periodic way. The period is governed by the cavity length and the material index of refraction. Each pass band is known as a single FP mode.

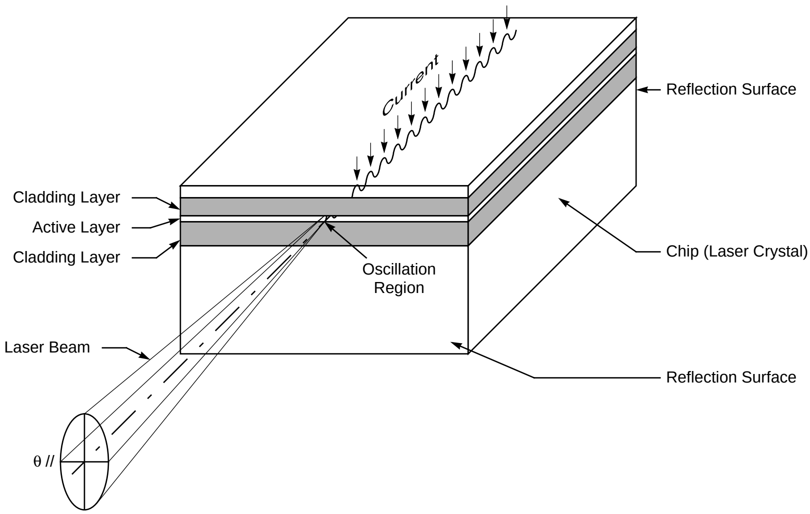

Figure 2. Fundamental Laser Diode Structure

A sustained population inversion caused by injection pumping of electrical current through the active layer combined with the FP filtering effect initiates lasing by the laser at a multiple pass band for each FP mode. In order for this to happen, the injection must be large enough to overcome the losses in the cavity (see *Figure 4*a).

When the injection pumping is just equal to the losses in the cavity, the injection current level is known as laser diode threshold current (I_{TH}). This is an important laser diode parameter. *Figure 3* shows the LI (light as current) characteristics.

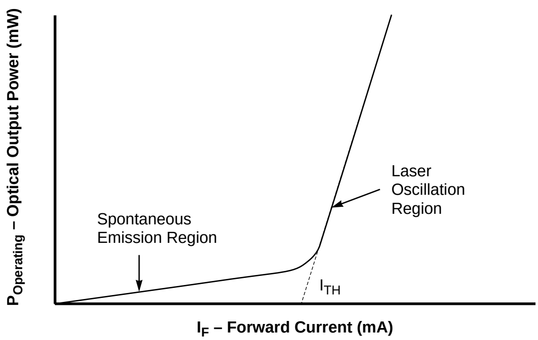

Figure 3. I-L Characteristic

Beyond the I_{TH} level, the injected carriers are converted to stimulated emissions with a relatively high efficiency. The efficiency with which an injected carrier is converted into a photon is known as quantum efficiency, another important laser parameter.

A stimulated emission event differs from spontaneous emission in several ways. The most basic way is that all the photons emitted by a stimulated emission event have the same phase and amplitude. Each photon is a duplicate of every other one. These emitted photons are said to have a high degree of coherency.

All Fabry-Perot modes that are above the threshold level are lasing simultaneously. These give multiple longitudinal spectral content in an FP laser diode. The typical Full Width Half Maximum (FWHM) spectral width of a communication grade FP laser is approximately 4 nm. There are many of these longitudinal modes in an FP laser as shown in *Figure 4*.

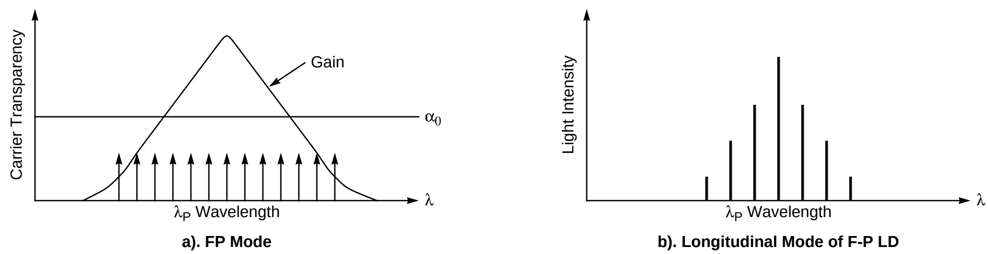

Figure 4. Emitted Optical Spectrum in FP Laser Diodes

In conclusion, there are three key parameters to remember:

- **Threshold current** - the current required to pump a laser beyond its threshold to a lasing condition.
- **Quantum efficiency** - the conversion rate of the injection current to the photon output.
- **Fabry Perot mode** - a lasing mode defined by the pass-band of inherent Fabry Perot filtering action in the cavity.

Process Technology

There are at least three distinct classes of material structure used for laser diodes. The oldest and simplest is the bulk material structure. In this type, the material properties directly influence the laser parameters as well as laser performance as it relates to temperature.

To provide better quality laser diodes, many improved materials and device designs have been developed. For example, materials having a "Quantum Well" structure are better at confining carriers than those with a bulk structure. Typically, there are several "quantum wells" in a laser diode, hence the name Multiple Quantum Well (MQW) laser diode.

MQW laser diodes have several advantages over the bulk type. One major benefit is increased efficiency. Another benefit is that the laser diode is more stable over a wider operating temperature range due to the reduced temperature dependence of material parameters in a QW material. In time, most manufacturers of laser diodes will convert their devices to the MQW type.

A third type is a modification of the MQW structure. It is known as Strained MQW. In this type strain (tensile or compression type) is applied to the material. Strain changes the fundamental material parameters including effective electron and hole masses. This can significantly reduce the threshold current by reducing the transparency carrier density. If properly controlled, this creates a still more efficient laser diode.

Device Technology

Previous sections have explained the most basic forms of laser diodes. Of these types, the Fabry Perot lasers always have multiple longitudinal modes as described above.

This type of laser is also the least expensive in its standard form. OKI offers both pulsed-type and Continuous Wave (CW) communication-type laser diodes. OKI offers pulsed laser diodes with a fiber pigtailed power level from 20 mW to 150 mW. They are typically used as OTDR instrument light sources.

For CW communication grade laser diodes, OKI offers a fiber pigtailed power level in the 100 μW to 25 mW range. These lasers are used in various optical communication systems, such as telecom access terminals, cable TV network return paths, and SONET or SDH optical transport applications.

Another class of device available is the Distributed Feedback (DFB) laser diode. The single most important distinction between the FP laser diode and the DFB laser diode is the spectral content of the emitted light.

A DFB laser emits a single mode optical spectrum, unlike a FP laser diode which emits multiple longitudinal mode optical spectra. A typical spectral width of DFB lasers, measured at Full Width Half Maximum (FWHM) under CW with no modulation and well above threshold, is tens of MHz compared to hundreds of GHz for the FP laser. The emitted spectrum more nearly approaches an ideal monochromatic light source than the FP laser. *Figure 5* illustrates this.

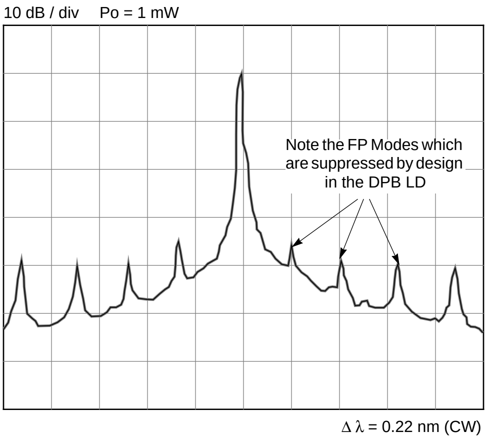

Figure 5. OSA Plot of DFB Spectrum

One of the main goals of a single frequency spectrum laser is to match the transmission characteristics of fiber optic cables and to lase at the critical frequency where the fiber transmission characteristics are near optimum. Single frequency lasers, such as DFB lasers, can transmit information over longer distances than FP lasers for a given data rate. Single frequency lasers also have a higher information capacity compared to FP lasers for a given fiber cable transmission distance.

OKI provides both FP and DFB devices. A typical DFB costs 10 times more than an FP laser. This cost difference relates to the greater fabrication complexity of the DFB devices.

Packaging Technology

Optical Electronic Packaging is different from traditional electronic packaging. This uniqueness arises from the opto-mechanical domain parameters. A laser diode module in any package format has a pigtail fiber attached, as shown in *Figure 6* and *Figure 7*. The attached pigtail fiber could be a single mode fiber or a multimode fiber. The choice is determined by the application.

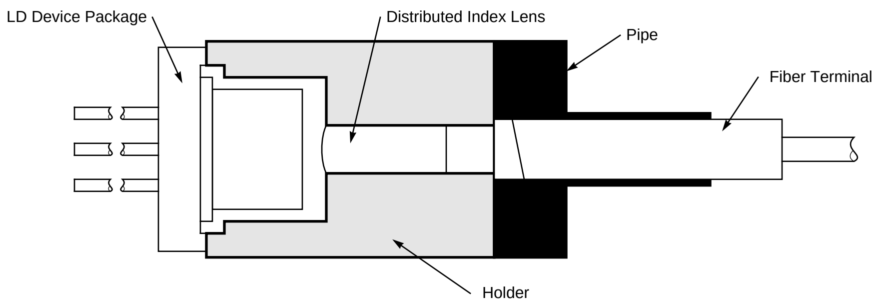

Figure 6. OKI Laser Diode Coaxial Package Cross-Section

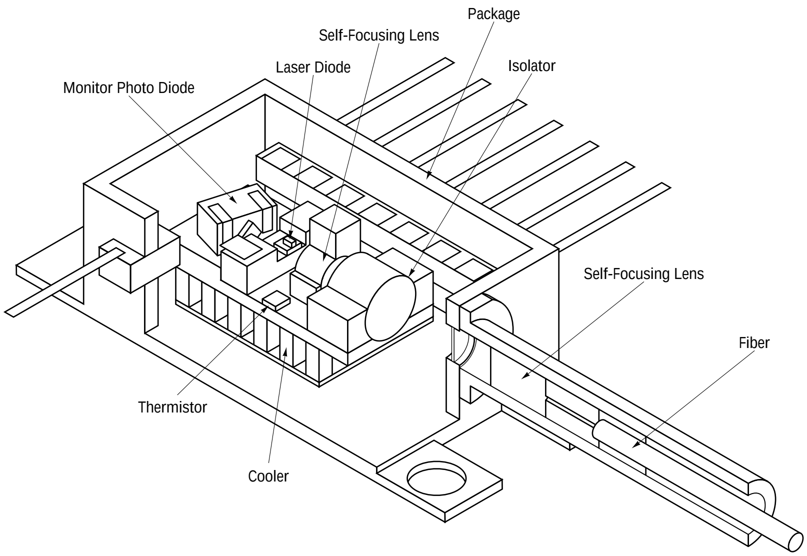

Figure 7. OKI Laser Diode Package Cutaway View, Showing Thermo-Electric Cooling

Currently, very high performance module laser diodes are packaged with a built-in thermo-electric cooling unit (TEC). The main purpose of the TEC is to keep the laser diode die near a constant operating temperature. The TEC is based on the cooling and heating of certain alloys depending on the sign of the current into the cooler. This is known as the “Peltier” effect

Constant operating conditions result in more stable laser spectral characteristics, as well as more stable electrical driving parameters of the laser. This results in nearer to optimum system performance.

OKI offers a variety of TEC laser diodes, from pulsed laser diodes and FP lasers for communication to DFB lasers. OKI also offers three types of TEC packages. They are conventional DIP ("60", "61", "64"), thinner DIP ("204") and butterfly ("112", "104") pigtail module. Refer to the product numbering system in *"Ordering Information"* .

For less demanding applications and for newer generation laser devices, TEC can be eliminated from the module. This type of module is known as an "Uncooled" laser diode module. Proper elimination of the TEC unit can simplify the laser driving electronics.

Without a TEC unit, a laser diode is exposed to the environmental conditions. This means that spectral width, threshold current and other important laser diode parameters change as the operating environment changes. Designers must understand the trade-off among these parameters to make a sound decision in choosing the appropriate operating point of the selected laser diode. The general goal is to meet a set of system target specifications, usually based on acceptable operation over a broad temperature range.

Uncooled laser diodes are generally slightly less expensive than their cooled counterparts for the same category of device. OKI offers a full range of uncooled pigtailed laser diode modules suitable for almost any application in optical communication.

APPLICATIONS

Laser Diodes by Application Area

Laser diode applications in optical communications can be grouped into three distinct types.

- Test and measurement as testing tools in optical communication systems being built
- Telecommunications and video distribution system applications
- Data communications

OKI's laser diode products offer all of these types.

Laser Diodes by Modulation Format & Speed

Another way to group laser diodes is by modulation format and speed. There are two major modulation formats currently in use.

- Digital format: binary ON and OFF control of the light output.
- Analog format: Either AM or an FM modulation controls the light output.

Figure 8 shows direct analog and digital modulation. Applications increasingly require a digital modulation format. For applications where signal quality is most important, the digital modulation technique is the technique of choice.

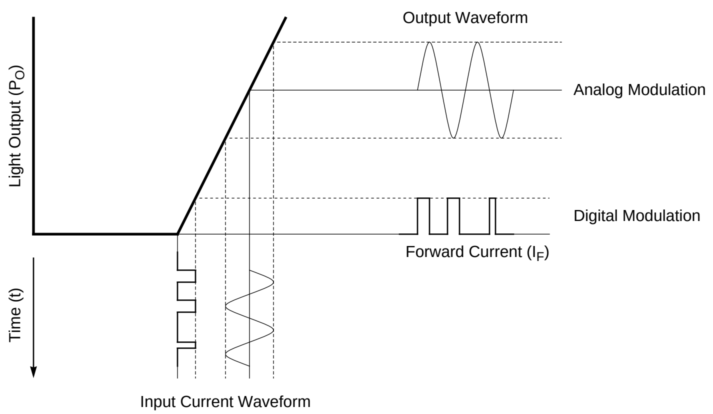

Figure 8. Optical Power versus Driving Current for an LED and Laser Diode

Digital optical communication is a serial type of transmission system. Any signal, whether parallel digital data or analog, must first be converted into serial bit streams. In the case of parallel analog signals, analog-to-digital conversion must take place and then the digitized signal must be serialized. In digital transmission, there are several industry standards organizations governing a number of applications standards. The standards are classified by their bit-rates within a specific standard as shown below.

SONET (by ANSI) / SDH (by ITU):

- SONET OC-1: 51 Mbs
- SONET OC-3 or SDH STM-1: 155 Mbs
- SONET OC-12 or SDH STM-4: 622 Mbs
- SONET OC-48 or SDH STM-16: 2.488 Gbs
- SONET OC-192 or SDH STM-64: 10 Gbs

ATM (Industry Consortium):

- OC-3: 155 Mbs
- OC-12: 622 Mbs

Fiber Channel (Industry Working Group):

- FC 1/4 speed: 266 Mbs
- FC 1/2 speed: 531 Mbs
- FC full speed: 1.062 Gbs

OKI fiber optic components offer products in all the categories of bit-rates mentioned above.

Analog optical communications resemble analog communications in the traditional electronic domain. In current analog optical communications, the two main formats used are VSB-AM and FM. VSB-AM is used in a video distribution network system. There is also an application in which a quasi-analog modulation, such as QPSK, is used.

OKI plans to offer products that cover devices for video distribution applications in the near future. Currently, OKI has analog products for quasi-analog application oriented devices.

ORDERING INFORMATION

OKI's laser and EELED products are shown below.

DIP & Shrink-DIP Pulsed LD Modules

Part Number	λ (nm)	Package Characteristics	P_F [1] (mW)	I_{OP} Max (mA)	Operating Temp. (°C)
OL364A-40/P20	1310	14-pin DIP 12.5mm height TEC SMF	40	500	-20 ~ +65
OL364A-60/P20			60	550	-20 ~ +65
OL364A-80/P20			80	550	-20 ~ +65
OL364A-100/P20			100	750	-20 ~ +65
OL364A-120/P20			120	800	-20 ~ +65
OL3204A-40/P20		14-pin DIP 9mm height TEC SMF	40	500	-20 ~ +65
OL3204A-60/P20			60	550	-20 ~ +65
OL3204A-80/P20			80	550	-20 ~ +65
OL3204A-100/P20			100	750	-20 ~ +65
OL3204A-120/P20			120	800	-20 ~ +65
OL564A-25/P20	1550	14-pin DIP 12.5mm height TEC SMF	25	600	-20 ~ +65
OL564A-40/P20			40	600	-20 ~ +65
OL564A-60/P20			60	600	-20 ~ +65
OL564A-80/P20			80	700	-20 ~ +65
OL564A-100/P20			100	800	-20 ~ +65
OL5204A-25/P20		14-pin DIP 9mm height TEC SMF	25	600	-20 ~ +65
OL5204A-40/P20			40	600	-20 ~ +65
OL5204A-60/P20			60	600	-20 ~ +65
OL5204A-80/P20			80	700	-20 ~ +65
OL5204A-100/P20			100	800	-20 ~ +65

1. OKI standard pulse condition: 10µs pulse width and 1% duty cycle.

Coaxial Pulsed LD Modules

Part Number	λ (nm)	Package Characteristics	P_F [1] (mW)	I_{OP} Max (mA)	Operating Temp. (°C)
OL395C-20/P20	1310	SMF PCB-mountable flange	20	600	-20 ~ +50
OL395C-40/P20			40	600	-20 ~ +50
OL395C-60/P20			60	800	-20 ~ +50
OL394C-20/P20		SMF Panel-mountable flange	20	600	-20 ~ +50
OL394C-40/P20			40	600	-20 ~ +50
OL394C-60/P20			60	800	-20 ~ +50
OL399C-20F/P20		MMF PCB-mountable flange	20	200	-20 ~ +50
OL399C-40F/P20			40	300	-20 ~ +50
OL399C-60F/P20			60	400	-20 ~ +50
OL399C-150F/P20			150	750	-20 ~ +50
OL595C-20/P20	1550	SMF PCB-mountable flange	20	500	-20 ~ +50
OL595C-40/P20			40	750	-20 ~ +50
OL595C-60/P20			60	800	-20 ~ +50
OL594C-20/P20		SMF Panel-mountable flange	20	500	-20 ~ +50
OL594C-40/P20			40	750	-20 ~ +50
OL594C-60/P20			60	800	-20 ~ +50

1. OKI standard pulse condition: 10µs pulse width and 1% duty cycle.

DIP and Butterfly LD Modules

Part Number	λ (nm)	P_F Min (mW)	I_{TH} (mA)	SE Min (µW/mA)	I_{OP} Max (mA)	Operating Temp. (°C)	PD [1]	Notes
OL3280A	1310	1.5	20	50	–	-20 ~ +65	Y	14-pin shrink DIP module, 9mm height TEC, MMF
OL360A		2	20	70	–	-20 ~ +65	Y	14-pin DIP module, 12.5mm height TEC, SMF
OL360A-5		5	20	–	140	-20 ~ +65	Y	
OL361A-40		40	50	–	400	-20 ~ +45	Y	
OL364A-40 [2]		40	50	–	400	-20 ~ +45	N	
OL461A-50	1480	50	50	–	500	-20 ~ +45	Y	
OL4112N-60		60	40	–	600	-20 ~ +65	Y	Butterfly module TEC, SMF, isolator
OL4112N-80		80	40	–	600	-20 ~ +65	Y	
OL4112N-100		100	40	–	650	-20 ~ +65	Y	
OL5280A	1550	1.5	30	40	–	-20 ~ +65	Y	14-pin shrink DIP module, 9 mm height TEC, MMF)
OL560A		2	30	50	–	-20 ~ +65	Y	14-pin DIP module, 12.5 mm height TEC, SMF
OL560A-5		5	30	–	140	-20 ~ +65	Y	
OL561A-25		25	55	–	400	-20 ~ +45	Y	
OL564A-25 [2]		25	55	–	400	-20 ~ +45	N	

1. PD=Photo Diode for laser monitoring.
2. Can also be used in Pulsed Wave applications.

Coaxial Pigtail LD Modules

Part Number	λ (nm)	P_F Min (mW)	I_{TH} (mA)	SE Min (µW/mA)	I_{OP} Max (mA)	Operating Temp. (°C)	Notes
OL391C-03	1310	0.3	15	15	–	-40 ~ +85	3-pin coaxial module w/(PD, SMF)
OL3492C-03			15	15	–	-40 ~ +85	4-pin coaxial module w/(PD, SMF), PCB mountable flange
OL3497C-03			15	15	–	-40 ~ +85	
OL391C		1	15	50	–	-40 ~ +85	3-pin coaxial module w/(PD, SMF), PCB mountable flange
OL392C			15	50	–	-40 ~ +85	4-pin coaxial module w/(PD, SMF), PCB mountable flange -91, -92, and -97 suffixes indicate different pin-outs
OL397C			15	50	–	-40 ~ +85	
OL3492C			15	50	–	-40 ~ +85	
OL3497C			15	50	–	-40 ~ +85	
OL392B			20	50	–	0 ~ +65	4-pin coaxial module w/(PD, SMF, isolator), DFB
OL3492B			20	50	–	0 ~ +65	4-pin coaxial module w/(PD, SMF, isolator), DFB, PCB mountable flange -91 and -97 suffixes indicate different pin-outs
OL592C-03	1550	0.3	20	50	–	-40 ~ +85	
OL592C		1	20	50	–	-40 ~ +85	
OL597C			20	50	–	-40 ~ +85	
OL5492C			20	50	–	-40 ~ +85	4-pin coaxial module w/(PD, SMF), PCB mountable flange
OL5497C			20	50	–	-40 ~ +85	
OL592B			20	50	–	0 ~ +65	4-pin coaxial module w/(PD, SMF, isolator), DFB
OL5492B			20	50	–	0 ~ +65	4-pin coaxial module w/(PD, SMF, isolator), DFB, PCB mountable flange

Receptacle LD Modules

Part Number	λ (nm)	P_F Min (mW)	I_{TH} (mA)	SE Min (μW/mA)	I_{OP} Max (mA)	Operating Temp. (°C)	Notes
OL3802N-01	1310	0.1	20	5	–	-40 ~ +85	4-pin FC receptacle -02 and -04 suffixes indicate different pin-outs
OL3804N-01							
OL3802N-05		0.5		25			
OL3804N-05							
OL3802N		1		50			
OL3804N							
OL3812N-01		0.1		5			4-pin SC receptacle -12 and -14 suffixes indicate different pin-outs
OL3814N-01							
OL3812N-05		0.5		25			
OL3814N-05							
OL3812N		1		50			
OL3814N							

SLD and EELED Modules

Part Number	λ (nm)	P_F Min (mW)	I_{TH} (mA)	SE Min (μW/mA)	I_{OP} Max (mA)	Operating Temp. (°C)	Notes
OE360S	1300	0.4	150	–	–	-20 ~ +65	DIP w/(PD, TEC, SMF); SLD
OE362G-004		0.04	100				DIP w/(TEC, SMF); EELED
OE362G-010		0.1					
OE382G-008		0.08					DIP w/(TEC, MMF); EELED
OE396G		0.01					Coaxial module w/(SMF)
OE3496G		0.04					Coaxial module w/(SMF); PCB mountable flange
OE562G	1550	0.02					DIP w/(TEC, SMF); EELED

Miscellaneous Discrete Laser Diodes and LEDs

Part Number	Device Type	λ (nm)	P_F [1] (mW)	I_{th} (mA)	Operating Temp. (°C)	Package Notes
OL327N, OL3631N	FP	1310	5	10	-40 ~ +85	Also in 07, 17, 627 pin-out
OL327B, OL3631B	DFB	1310	5	20	0 ~ +70	
OL527N, OL5631N	FP	1550	5	10	-40 ~ +85	Also in 627 pin-out
OL527L, OL5631L	DFB	1550	5	15	-40 ~ +85	
OL403N-100	FP	1480	100	50	-20 ~ +50	Sub-carrier
OL403N-120	FP	1480	120	50	-20 ~ +50	
OE306G	EELED	1300	0.4	–	-10 ~ +65	3 pins TO-Can
OE506G	EELED	1300	0.2	–	-10 ~ +65	

1. OKI standard pulse condition: 10 µs pulse width and 1% duty cycle.

Device Type

A&C : FP (Bulk Structure)
B : DFB (Bulk Structure)
G : ELED
H : ELED (Wide Temp Range)
S : SLD
N : FP (MQW Structure)
L : DFB (MQW Structure)

FP : Fabry Perot.
DFB : Distributed FeedBack
ELED : Edge Emitting LED
MQW : Multi-Quantum Well
SLD : Surface Emitting LED (Super Luminescent Diode)

SMF Single-Mode Fiber Pigtail
MMF Multi-Mode Fiber Pigtail

Isolator : Optical isolator between laser and fiber pigtail.
PD : Photo diode included in package for laser monitoring.
TEC : Thermo-electric cooling.

OKI's part numbering scheme is straightforward and allows you to select the function to meet the correct part number to meet the application, as shown in *Figure 9*.

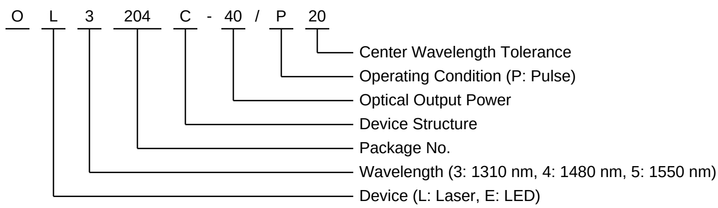

Figure 9. OKI Part Numbering Systems

For additional information or product specifications, contact your regular OKI sales representative or refer to the listing on the back cover of this technical brief.