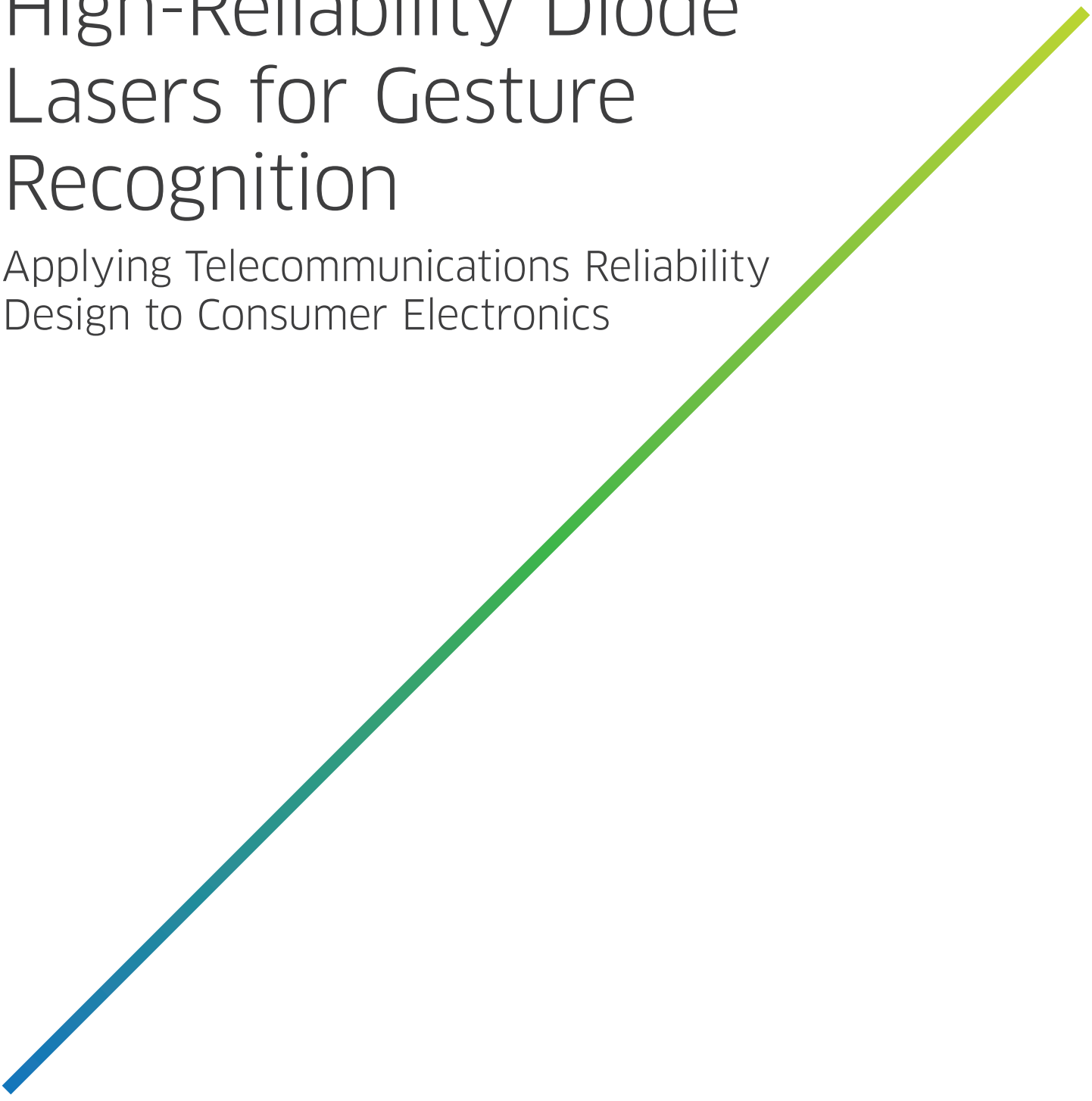
LUMENTUM

High-Reliability Diode Lasers for Gesture Recognition

Applying Telecommunications Reliability Design to Consumer Electronics



A wide range of consumer-electronics applications use single-mode Fabry-Perot diode lasers that operate at a wavelength range of 8xx nm. Applications include 3D depth recognition and magnetic storage. The reliability demands for components for these applications are extremely stringent and require a higher standard. Lumentum has demonstrated manufacturing scalability to very-high volumes without compromising on performance or reliability.

A Higher Standard

Lumentum is the worldwide leader in high-reliability diode lasers used in the most demanding applications such as undersea, space, and communications systems. These applications require components that operate with very-low failure rates. Lumentum has applied its experience designing and qualifying high-reliability semiconductor lasers for consumer-electronics applications while meeting required cost constraints.

The reliability requirement of consumer applications is to have a very-low failure rate during the first year or years of operation. Lumentum diode lasers are typically specified to guarantee less than 0.5 percent failure in this period. Note that reliability decreases at higher temperatures and at higher output powers. Lumentum has proprietary laser-fabrication technology, screening methods, and models that guarantee reliability at elevated temperatures and higher output powers. Lumentum can also predict failure rates at intended operating conditions.

Failure-rate and environmental-resistance (for example, thermal stress) standards for telecommunications applications are more stringent and are designed to eliminate any packaging-induced failures. Lumentum has carefully selected packaging technologies, assembly methods, and materials that ensure thermal performance and reliability.

The following sections will discuss the performance and reliability of Lumentum 8XX nm diode lasers relative to alternate sources of infrared illumination.

Efficient and Precise Light Sources

Due to their spectral precison and electrical-to-optical conversion efficiency, diode lasers are often the preferred light source for consumer-electronic applications. These applications are characterized by a limited source of electrical power and a high density of components—factors that drive the need to minimize dissipated thermal power. And, the lasers are used together with other optical components (for example, filters and sensors) which are wavelength sensitive, requiring tight wavelength control over a wide temperature range.

Compared to an LED, a Lumentum diode laser has clear advantages:

Parameter	Lumentum Diode Laser	LED
Optical power	500 mW	500 mW
Wavelength	800–900 nm	850 nm
Spectral width	0.1–0.5 nm	30 nm
Efficiency (electrical to optical)	55%	25%
Rise time	~1 ns	5–10 ns

Figure 1: Comparison of a Lumentum multimode NIR diode laser to a typical LED at similar power and wavelength

LED-based illumination systems are further disadvantaged by the limited selection of wavelengths and poor illumination accuracy. The quantum efficiency (QE) of sensors is much higher at the lower wavelengths used by low-wavelength lasers. Commercial, off-the-shelf LEDs have broad illumination cones that often put as much as 50 percent of the light outside the volume of interest. These two factors, coupled with the benefits highlighted in the table above, can result in a five- to ten-fold improvement in overall system efficiency by selecting a laser-based design.

Lumentum offers a wide portfolio of diode-laser products for the consumer-electronics industry. Our lasers are available in single- or multitransverse-mode designs, at powers ranging from 50 mW to 1000 mW, and at wavelengths from 810 to 860 nm. Our laser design and reliability modeling enable using the lasers at elevated temperature ranges approaching 65°C while still maintaining negligible failure rates.

Single-Mode Diode Lasers

This advanced diode laser features an index-guided, single-mode waveguide to provide high power, low astigmatism, narrow spectral width, and a single-spatial-mode Gaussian far field. And, it operates at high powers with low operating current. The plot below shows optical power vs. current curves at various temperatures. These diode lasers are extremely reliable at temperatures and powers as high as 60°C at 200 mW.

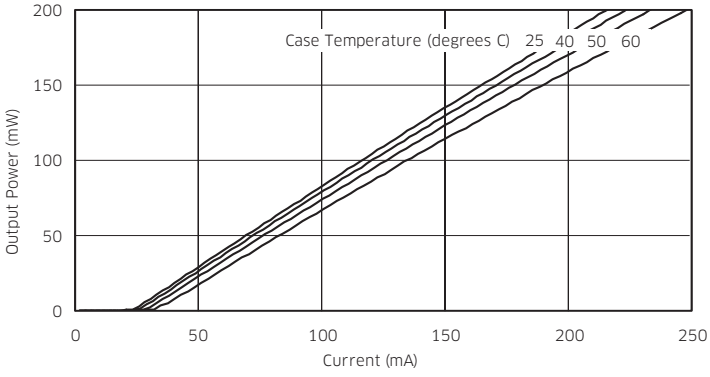


Figure 2: Power vs. current plots of 830 nm single-mode lasers in TO-56 packages at temperatures ranging from 25°C to 60°C

Laser Characteristics	Symbol	Min.	Typ.	Max.	Unit
Minimum kink-free power	Pk	220	—	—	mW
Center wavelength	λo	815	825	835	nm
Threshold current	I_{th_25}	—	35	50	mA
Operating current	I_{op_25}	—	240	280	mA
Operating voltage	V_{op}	—	1.9	2.2	V
Photodiode sensitivity	—	.8	4.0	10.8	µA/mW
FWHM beam divergence					
Parallel to junction	θ//	—	8	—	degrees
Perpendicular to junction	θ⊥	—	16	—	degrees

Figure 3: Key optical characteristics for single-mode diode lasers at 25°C. A full list of product offerings is at www.Lumentum.com.

Pulsed Operation

Many consumer-electronic applications require a laser to be modulated at frequencies that require short rise and fall times; Lumentum diode lasers have stabilization times of less than 1 ns. Note that at very-fast rise times, there is a tendency for the laser to overshoot the rated power and care must be taken to properly select pulse conditions to maintain the reliability of the laser. An example of laser stabilization and overshoot appears in Figure 4.

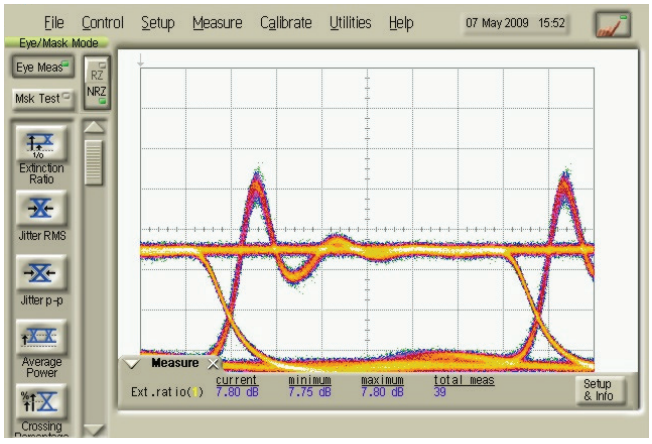


Figure 4: Rise-time measurements of a Lumentum diode laser demonstrating a stabilization time of 600 ps

For fast-pulsed applications, Lumentum will specify a laser such that failures from possible power overshoot can be mitigated. The user should contact Lumentum to discuss pulsed operation since mounting and drive-circuitry design can influence rise and fall times.

Reliability

Lumentum diode lasers undergo extensive qualification and receive continuous monitoring and testing. Examples of acceleration-and qualification-test data appear below. The devices can operate to much higher-than-rated powers, currents, and temperatures without failures or slow degradations. Environmental testing ensures that the packaging designs are robust and suitable for the intended use conditions.

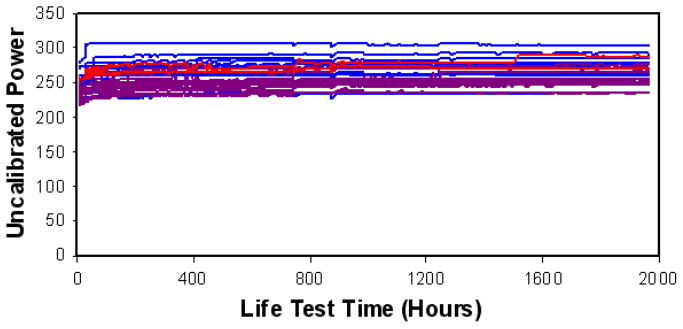


Figure 5: Example of an extended lifetest of a 200 mW single mode diode laser. Test condition: 90°C, 240 mW.

Lumentum evaluates its assemblies and packages by subjecting the devices to environmental stress tests that are similar to those used in the telecom industry. These include: thermal cycling (-40°C to 85°C), damp-heat storage (85% RH, 85°C), low-temperature storage (-40°C), and mechanical shock and vibration (1500 G). The qualification results on Lumentum laser designs show a <10% change in all specified electro-optical parameters through each of these tests. A full qualification report is available upon request.

Environmental Test	Test Condition	PASS/FAIL
Damp heat	500 hrs./85% RH	PASS
Temperature cycling	–40°C to 85°C	PASS
Accelerated aging	1000 hrs./60°C	PASS
Low temperature storage	500 hrs./–40°C	PASS
Shock and vibration	1500 G, MIL-STD 883	PASS
Electrostatic discharge	175 V – Machine Model 500 V – Human Body Model	PASS PASS

Figure 6: Summary of qualification tests required for all product releases. All products undergo harsh environmental testing before becoming qualified.

Vertical Cavity Surface Emitting Lasers (VCSEL)

Lumentum Fabry-Perot diode lasers have extreme power densities (~1 W single-transverse mode) and very-high efficiencies without compromised reliability. These attributes make them suitable for applications such as gesture recognition where overall efficiency and high power densities are critical.

In contrast, VCSELs are much lower-power lasers (~1–10 mW) with lower efficiency. They are more amenable to wafer-scale testing and assembly. And, they are scalable to extremely high-volume applications. The short cavity length of a VCSEL limits its maximum attainable efficiency and power density. However, their natural wavelength stability with changing temperatures and their ease of manufacturing make them a suitable light source for datacom transponders. With these products, only low-power digital optical signals are required. Higher-power illumination can be made with arrays of VCSELs on a single chip.

Parameter	Fabry-Perot	VCSEL
Efficiency (electrical-to-optical power)	55%	35%
Single-mode emitter power	~200–1000 mW	~200–1000 mW
Wavelength tuning	0.3 nm/°C	0.07 nm/°C
Manufacturing scalability	Good	Very good

Figure 7: Comparison of Fabry-Perot and VCSEL laser performance

Depending on the requirements of the consumer application, VCSEL or VCSEL arrays may be suitable options for illumination. Lumentum is an established industry leader, shipping products from both technologies in very-high volumes from our facility in San Jose, CA.

Lumentum maintains very active design and product-development teams and actively seeks collaboration with customers on new applications for consumer electronics.

High-Volume Wafer Fabrication and Assembly

The Lumentum wafer-fabrication facility in San Jose, CA has been producing a wide portfolio of diode lasers for over 20 years with continuous consolidation improvements and equipment upgrades. Fabry-Perot and VCSEL lasers in the infrared wavelength range are currently in production and are shipping in high volumes.

Manufacturing partner locations throughout Asia perform the assembly and testing of final products. Our partnerships with the leading contract manufacturers ensure the capacity and cost structures to meet the needs of the consumer-electronic industry.

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Lumentum is a Worldwide Leader in Optical Technology
Lumentum designs and manufactures products for fiber-optic communications, as well as for markets where our core optics technologies provide innovative solutions for industrial, commercial and consumer applications. Our fiber-optic components and modules are deployed by system manufacturers for the telecommunications, data communications and cable television industries. We also offer products for display, security, medical and environmental instrumentation, decorative, aerospace and defense applications.

Lumentum high power laser products power the transmission of data, voice, and Internet information over fiber optic networks to meet the needs of telecommunications, data transmission, dense wavelength division multiplexing (DWDM), and cable television applications. They enable customers to meet the bandwidth needs of increasing Internet, data, video, and voice traffic by expanding their fiber optic communications networks much more quickly and efficiently than would be possible using conventional electronic and optical technologies.

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