Diode Lasers in Next-Generation 3D Sensing Applications: Meeting the Challenges of Reliability and Scale

Open almost any newspaper, business magazine, or online technology news site, and there is inevitably coverage on virtual reality (better known as VR), augmented reality (AR), and 3D sensing. The overwhelming consensus is that they will change our lives. Products that we use every day, such as cell phones and automobiles, just will not be the same. It sounds exciting, but what is at the heart of this coming disruption? Advanced laser technology, and specifically, diode lasers.

Laser applications: today and tomorrow

Autonomous, self-driving vehicles which use laser ranging technology are already on the road today, and are predicted to become a mainstream commercial product before the end of this decade. Consumer and computing devices are now using diode lasers to enable innovative 3D sensing systems, transforming the user interface for gaming and adding biometric security features to mobile devices. Diode lasers are also an intrinsic element in smartphones for emerging applications such as Google's Tango, an augmented reality and simultaneous localization and mapping (SLAM) service for smartphones.

3D sensing is also finding its way into industrial and automotive control interfaces. In industrial equipment, for instance, 3D sensing using hand gestures allows operators to control computing equipment safely in hazardous environments. In vehicles, 3D sensing lets the driver control infotainment systems more quickly and safely than conventional buttons or touch-sensing methods.

Diode lasers drive these exciting 3D sensing applications. As a system manufacturer, how do you find the right diode laser supplier for your application? We take a practical approach to this challenge by giving you a framework to make the best choice.

Picking the right diode laser manufacturer

Diode lasers are set to proliferate in a variety of new markets. Many manufacturers in these markets will have little experience of using diode lasers and the other key components of a laser system, and no established relationships with laser component suppliers. What then are the key factors that system manufacturers should take into account when evaluating diode laser suppliers?

The fundamental requirements of a diode laser supplier will be common to nearly all system manufacturers:

- its products should offer predictable and reliable operation over a long lifetime
- it should be capable of supplying high-volume shipments of consistent quality
- it should be able to provide laser expertise to support design integration and compliance with eye safety regulations.

This paper shows how Lumentum is satisfying these requirements today for its consumer, automotive, and industrial customers.

Reliable operation of diode lasers

Diode lasers are at the heart of global optical communications networks that carry colossal quantities of voice and data traffic generated by people and businesses. Much of this traffic travels from one end point to another through subsea fiber optic cables that lie on the bottom of the world's oceans.

These subsea cable systems consist of multiple lengths of cable separated by repeaters designed to boost optical signal strength to compensate for light losses inherent in fiber optic cabling (see Figure 1). Each subsea repeater contains diode lasers, which drive the optical amplifier.

Thanks to the field-proven quality, performance, and reliability of its products, Lumentum (like JDSU before it) is the world leader in this market: it supplies more diode lasers to the telecom networking equipment industry than any other manufacturer. Lumentum has shipped more than 150,000 diode lasers into undersea applications. To date, *the failure rate of the Lumentum diode laser devices installed in submarine cabling systems is zero.*

Lumentum diode lasers are also the choice of the world's largest smartphone, computing, and gaming product OEMs for use in sophisticated 3D sensing systems. For gaming, the lasers enable users to control interfaces or play using gestures and body movements. In mobile devices, Lumentum lasers are used for biometric security applications including face recognition. More than 200 million Lumentum diode lasers are operating today around the world. The recorded field failure rate for this huge population of devices is less than one part per million.

The same design, fabrication, and test technologies are used in all Lumentum diode lasers, regardless of application. The main difference is the expected operating lifetime for the application. In the case of submarine equipment, the lifetime can be as long as 25 years as compared to five years or less for consumer applications. This is an important benefit for any manufacturer of high-volume consumer products that has a valuable brand and a reputation for high quality to maintain. In addition, the greater volume in which devices optimized for consumer applications are produced helps to lower their cost by comparison with telecom devices.

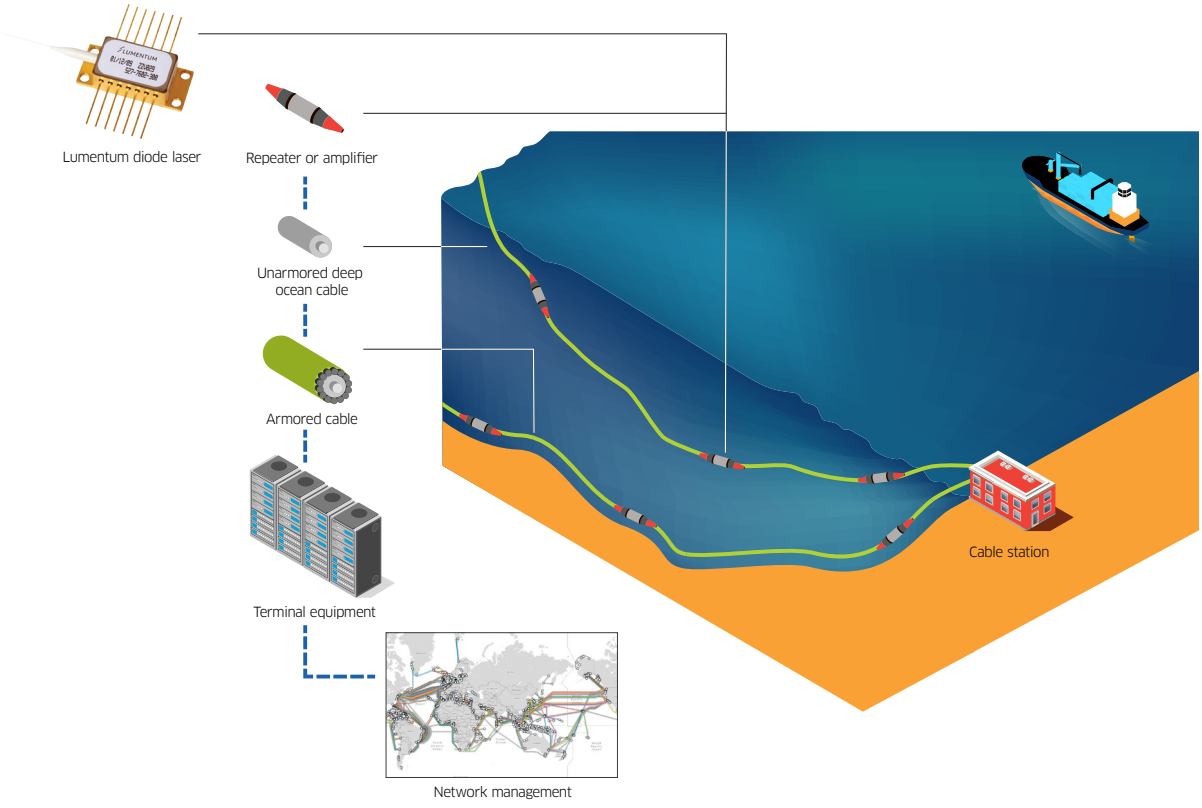

Figure 1: Subsea cabling, which includes Lumentum diode lasers, carries vast amount of internet and voice traffic

The reliability of Lumentum diode lasers is the result of expert product design and proven wafer fabrication processes. Lumentum and its predecessor entities have been fabricating the highest quality diode lasers chips since 1978 as a result of our unique high reliability state-of-the-art manufacturing processes. This has given Lumentum a unique ability to develop and refine reliability models, which it can share with customers on request.

Lumentum uses data-driven methods to optimize the burn-in process applied to new diode lasers. Like all production processes, the chip fabrication process has a small amount of variation inherent in it: different diode lasers from the same production batch may have slightly varying physical properties, and some of this variance may have a material effect on the electrical and optical characteristics of the diode.

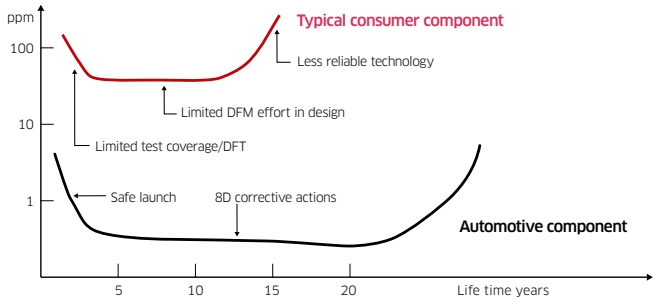

Figure 2: Burn-in identifies potential infant failures

As a result of these variations, a very small number of diode lasers will be at risk of 'infant failure'—a failure very early in the operating lifetime of the device (see Figure 2). Lumentum uses a burn-in process to identify and eliminate devices with infant failures. Diode lasers that fail during the burn-in process are scrapped; those that pass are deemed to be sound.

This burn-in process has to be carefully controlled. If the burn-in conditions are insufficiently severe, faulty diode lasers might pass and be shipped to the customer. If too severe, however, there is a risk of causing latent damage to sound diode lasers that could impair their performance or reduce their operating lifetime.

Long experience of wafer fabrication and wafer testing, validated by performance data from the field, and backed by proprietary Lumentum chip manufacturing know-how, enable Lumentum to continually refine and optimize burn-in and other production processes in order to achieve the best combination of cost and reliability for each customer's requirements.

Volume availability of the right diode laser

A second important requirement of a diode laser supplier is to maintain high shipment volumes to meet the needs of large customers in the consumer electronics, automotive, and other markets.

Here again, the Lumentum track record can give potential customers confidence that it can meet their needs. In fact, Lumentum is one of just a handful of manufacturers worldwide that can meet the requirements of high-volume buyers of vertical-cavity surface-emitting lasers (VCSELs) or edge emitters. And Lumentum is already a high-volume supplier of diode lasers to various end-product markets:

- Lumentum ships illumination lasers for 3D sensing in mobile devices, gaming consoles, and other consumer electronics products in volumes of hundreds of millions per year. These lasers operate at wavelengths in the range 800-950 nm, and with a power output from as low as 200 mW to as high as tens of watts.
- In the telecom and networking equipment market, Lumentum ships 1 W single-mode lasers (9xx nm, 1400-1500 nm wavelengths) to individual customers in volumes of up to 500,000 units per year.
- Commercial lasers with an output power of up to 200 W for a wide variety of applications are typically shipped to customers in volumes of up to 50,000 units per year.

Lumentum benefits from a long history and unique depth of experience in laser chip production: its processes are very well understood, and the yields that it achieves from these processes are extremely predictable. Moreover, Lumentum enjoys strong partnerships with multiple optical chip foundry partners, which provide a high degree of protection against the risk of unpredictable geographical, technical, or financial events that could curtail production at any one production location.

An additional advantage of sourcing products from the market leader is choice and flexibility: Lumentum offers a very broad range of laser products. Customers can evaluate lasers of different types, maximum power ratings, and wavelengths, and readily find a device with specifications which closely match the requirements of the application.

Superior laser integration expertise
A broad product portfolio and integration expertise enable Lumentum to provide more effective support and guidance to system designers.

For example, the performance of some applications are measured by their signal-to-noise ratio (SNR). One method for improving SNR is to filter out the background sunlight using a narrow spectral bandpass filter, aligning the wavelength of the laser illuminator with an atmospheric attenuation wavelength of ~940 nm (see Figure 3).

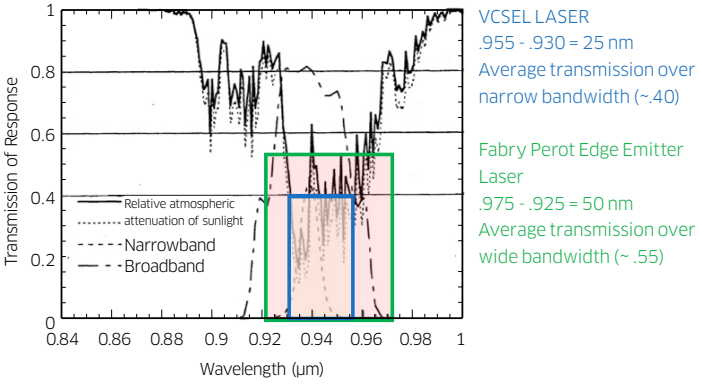

Figure 3: The use of a filter with a narrow bandwidth can reduce interference from the background sunlight, but also requires a narrow-bandwidth laser illuminator

In examples such as this, Lumentum can provide impartial advice on the comparative advantages and drawbacks of each type of laser. Lumentum can also give optical system design support appropriate to its products. The broad product offering from Lumentum includes various laser types, including VCSELs, distributed feedback (DFB) edge emitters, and Fabry-Perot edge emitters. For instance, the use of a VCSEL or DFB edge emitter enables the use of a relatively narrowband optical filter of around 25 nm bandwidth, because of their limited wavelength shift over temperature, while a Fabry-Perot device will typically need to be paired with an optical filter of around 50 nm to take account of its greater temperature-related wavelength shift.

The implications of this choice on factors such as immunity to interference from external light sources need to be considered carefully. By taking advantage of the technical expertise available from Lumentum, customers can enhance their chances of creating an effective product design that is right the first time.

Lumentum technical expertise also extends to the important issue of eye safety. Here again, it is the combination of optical system components, as well as the specification of the laser itself, which determine whether a design is compliant with relevant regulations.

Every application has its unique characteristics and Lumentum will help customers to understand the trade-offs affecting eye safety, including wavelength, optical power, field of view, and distance from the user, to achieve the optimal balance between size, cost, and performance, and facilitate customers' efforts to comply with eye safety regulations.

Sourcing from an industry leader
This paper has described the important parameters by which a consumer electronics or automotive OEM should evaluate a potential supplier of diode lasers. The mission of Lumentum is to provide quality and reliability at scale, while giving customers the broadest choice of products to enable them to closely match the characteristics of the laser to the requirements of their application.

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