

Whatever the viewpoint on the state of play in the telecom/datacom marketplace, it is undeniably the case that the VCSEL is here to stay. Moreover, the potential of this laser diode family is only beginning to be exploited. Much will depend on factors such as materials and device technology, applications and competition in the market from other laser types, of course, but a sur-

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vey of interested parties confirms an industry-wide optimism. Success has been mixed for what was once touted as a very promising new addition to the laser field. The same can be said for the companies which sprang up to exploit the technology. In this overview the fate of these is reviewed and the future prospects for VCSEL's are discussed.

VCSELS resurgent

Historically, like most III-V devices lasers have always taken longer than expected to reach commercialisation. Today the expectations have turned to the quantum cascade laser but it was only a few years ago that it was the VCSEL's turn.

Invented in the 1980s it took ten years before the first commercial devices were available. Now, the company responsible, Honeywell is no longer in the business even though its technology lives on with Finisar.

At one time VCSELS were the most popular subject for high-profile start-ups. Since then thanks to a tougher-than-expected technology and the downturn in the communications market segments these start-ups had their eye on, the industry has lost some of that number.

Attrition is a fact of life in high-tech markets, but it has not been all gloom. The VCSEL has estab-

lished a firm place in the business thanks to the good performance/cost combination of 850 nm devices.

This is a competitive market and players are looking to move to longer or shorter wavelengths to provide them with better margins. At the same time, other lasers are being repositioned to satisfy the need for more bandwidth at 10Gbit/s. This could, some say, act so as to squeeze out VCSELS. Overall there could be something of a VCSEL revival underway.

On the other hand it could be hype and in prospect is a more steady market. Much will depend on the restoration of the datacoms market. Without this VCSELS may be left on the sidelines satisfying a diminishing 850nm business and picking up crumbs in a diversified set of niche applications in sensing and instrumentation, etc.

"Logitech's MX1000 Cordless Laser Mouse uses a VCSEL for surface illumination," says Mark Alden, Semiconductor Products Group, Agilent Technologies, Inc. "We worked exclusively with Logitech to develop this revolutionary laser navigation sensor technology, and Agilent plans to make it available to other mouse manufacturers in mid-2005."



Longer wavelengths

Tom Hausken of Strategies Unlimited is amongst those who are sceptical of the chances for VCSELS at longer wavelengths. "The 1300 and 1550 nm range VCSELS are presumably cheaper than other laser types in this category but that remains to be proven. This is especially true given that a lot of the cost is in the packaging.

"There are also reservations about the reliability of what is after all relatively immature technology. These materials systems are new and so there will not be enough data on them. Besides the manufacturers are having to really stretch the technology to make them work at these longer wavelengths. So inevitably there will be reliability questions there."

On the other hand the price pressure is enormous. Even though edge emitters are produced with higher yield as in the past only VCSEL may have the chance to really face this threat over long time.

“Optimism for longer wavelength VCSEL products is hard to justify. The historic trend indicates that today’s suppliers of FP and DFB lasers will likely lower ASPs and make it very difficult for a new VCSEL operator to gain a foothold in the market.

“There is also the matter that the market conditions are not the same as they were when VCSELS took over the 850nm market.”

Indeed it may even be too late for the longer wavelength VCSELS. In spite of this, several companies are launching product and remain optimistic. Overall, the view is cautiously bright.

One thing is for certain, VCSELS will never be all things to everyone. For example, thanks to their small cavity, VCSELS are intrinsically lower output power devices, and thus VCSELS will likely not be able to compete in higher power applications such as fibre pumping or data storage etc.

With data storage now the biggest single application for lasers, this is bad news. The VCSEL can really best compete in the applications where required power is low.

But ULM-photonics Dr. Burghard Schneider explains that there are markets for VCSEL that target the real advantages: “On the other hand VCSELS are the ideal light source for spectroscopy being both transversal and longitudinal single mode.

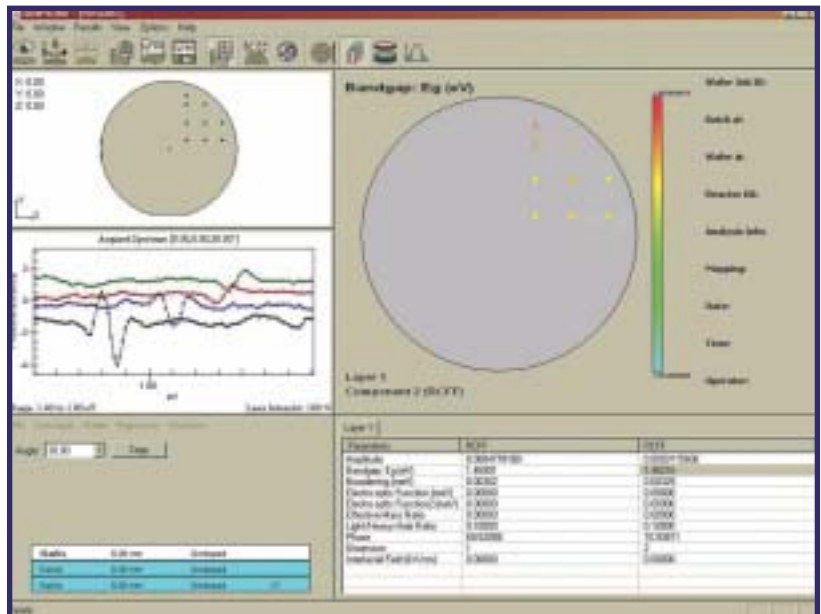
“Single mode applications allow quantitative detection of, for example, oxygen (@759nm) and moisture (@795nm). Analytics is a nicely growing market. VCSELS are also used as cheap 852nm single mode sources for activating Cs and Rb for use in atomic clocks. Plus these are not only used for scientific approaches but also in future GPS systems - a million dollar market. High performance at a cheap cost - that is the chance for VCSELS!”

650-680 nm VCSELS

While some big names like Honeywell and Infineon have got out of VCSEL components, others still have an interest. For example, JDSU has acquired technology but as yet has released no word as to when or if it might ever sell to



“We are seeing strong interest in our Omniprobe Photorefectance Spectrometer products due to the increasing role played by VCSELS in a wide range of markets,” says VP Business Development Optical Metrology Innovations, Chris Russell. “Omniprobe enables compound semiconductor wafer manufacturers to perform non-destructive characterisation on the epiwafers in a production environment.”



the merchant market. More likely its interest is in having key technology for its transceiver modules for datacoms at 10Gbit/s and beyond. Key technology is also required for specific regions such as Japan.

Here, Hamamatsu Photonics has already started production for communication products plus Furukawa recently announced its forthcoming debut into the VCSEL competition.

Though the main focus for VCSELS remains in the infra-red, there are a number of players pushing the technology out to longer and shorter wavelengths. For example, Ireland-based Firecomm has developed 650-680nm VCSELS which have opened up many new applications such as medical and data reading/capture as well as for fibre optic comms.

Firecomms' 664nm VCSEL in TO46 Package.



Firecomm's CEO Declan O'Mahoney said that, "We are developing these 650-680 nm VCSEL-based transceivers enabling visible light to run through large core plastic fibre at modulations up to 3.2Gbit/s.

"As POF is easier to install than copper at these data rates it is opening up a large new market for lower cost networking."

The company has also developed one of the competitors to VCSELS, resonant-cavity LEDs for red wavelength applications. "We can thus offer complete transceiver products for IEEE 1394 and MOST applications as for automotive and home networking."

ULM-photonics' GM Dr. Burghard Schneider adds: "Automotive companies such as DaimlerChrysler and BMW are making approaches to change their MOST application based on plastic optical fibre and LED today with PCF and 850nm VCSEL in future. Improved power budget over the link and higher bandwidth compared to LED solution are key.

"For these mass volume approaches VCSEL vendor ULM-photonics developed and qualified VCSELS that show an extraordinary stability over temperature, which is the main challenge beside reliability. Automotive applications have to be qualified in the range from -40°C to + 125°C."

VCSEL vs. EEL

Europe is also home to one of the leading commercial VCSEL epiwafer firms: IQE of Cardiff, Wales, as well as various component companies.

Iwan Davies, Engineering Manager at IQE, said: "VCSELS are implicitly simpler and therefore

cheaper to produce than the well established edge-emitter lasers due to on-chip testing of the devices. However, manufacturing tolerances on VCSEL growth are much tighter, so require control of the thickness of layers to within 0.3% or better."

Andrew Joel, VCSEL Product Manager at IQE adds that: "VCSELS are now finding their way into new applications away from datacom where traditionally they have been dominant. Companies are looking at using these devices in more consumer / PC related areas such as optical mouse and chip to chip interconnect applications. In these markets the volumes required are very much larger."

Given their domination of the data storage market, it is perhaps surprising that Japanese companies are not conspicuous in the VCSEL field.

This is despite the field having been started by Professor Iga at Tokyo Institute of Technology in the 1980s. "Interestingly we are now seeing strong demand for VCSEL parts from the Japanese market, which has not traditionally been at the forefront in the commercialization of this technology. Several major Japanese corporations there have recently announced product offerings using VCSELS.

"In addition to the 850nm wavelength we also see increasing interest in visible wavelength range for automotive and consumer applications using POE. Here we have initial products based on RCLEDs, which place very similar demand upon the epitaxial growth, but we might expect a migration to VCSELS as data rate requirements increase."

Fibre-in-the-Car

Many of the start-ups were dedicated to 850nm VCSELS and higher in other words for tele- and data-coms. Other companies like Firecomm are focussed on shorter wavelength products such as for 'Fibre-in-the-Car' and 'Fibre-in-the-Home' which should see major growth over the next 2-5 years. Other companies have seen softness in key application segments such as LAN, SAN and metro comms.

Karlheinz Gulden of Avalon Photonics adds that "Single mode is becoming important now. I attribute the ongoing success of Avalon to our mix of VCSEL products, comms, sensing and other applications. Now that datacom is showing signs of becoming once again a growing market, it should pay off that we were diversified.

"Previously, while still being part of CSEM, we started on sensing but now our portfolio is even-

ly balanced and we expect it to stay that way. We are not exclusively datacom because sensing also has volume enough and has a higher price. So we have a mixture of some niche low volume with higher price plus some higher volume with lower price. We have our own ISO certified fab so we can address all but

the very high volume markets. Having survived the market downturn, we are very experienced, and versatile/flexible. It may have been underestimated by some start-ups what was needed to get VCSELS into genuine production."

Dr Gulden says that the VCSEL array market has been very disappointing. "But it is now recovering - we have had to adjust our business since this was one of the technologies we were launched on. We have had to refocus on sensing because the datacom market for arrays was just not happening.

"Demand for arrays may pick up when there is better demand for higher data rate systems such as medical or defence applications it will first be niche then later build into better volume.

"Arrays are best for 10Gbit/s and above and this would have been a good market for us had this taken off like it was hoped. Today the volume is in 1- and 2-Gbit/s with designs in 4Gbit/s just starting but this could be the big market next year."

So for today's datacom market Avalon's VCSEL are seeing good take up in the short, under 300m, links where edge emitters or DFB cannot compete. "This is basically short reach links at 1Gbit/s data rate with a single laser at 850nm for LANs, SANs and such like. But prices have been dropping and competition is strong."

High Power VCSEL

Unfortunately, thanks to 'September 11th' free space optics (FSO) based communication equipment suddenly came to the fore. Within hours, destroyed networks at 'ground zero' were restructured with FSO equipment.

Companies like Lightpointe, MRV and Terabeam are targeting these areas where the need is for a quick set up of links, e.g. in Eastern Europe, China and Africa as well for the military. With VCSELS in the power range from 12 to 60mW (such as from ULM-photonics) edge emitters are systematically being replaced in FSO equipment.

High power VCSEL are also used for range finders, homing devices and for lighting application.

"The main market is the automotive industry," says Dr. Burghard Schneider: "VCSELS with high power - up to 1W pulsed - are an ideal substitute for radar or edge emitter based systems: Even in night vision systems the light source should be a VCSEL - cheaper, reliable and monolithic arrays are individually addressable to monitor the beam shape!

"We should not forget the printing market where the ability for monolithic arrays brings VCSEL into play. This could either be multimode or single mode VCSEL - depending on the technology used. Xerox has already invented a VCSEL-based printer so surely other printing companies will follow soon."

Chip-to-chip

VCSELS can be a key component in the fibre optic communications sector by providing the highest performance at lower cost in high-speed optical networks.

VCSEL technology could also help take the industry into the next generation of computing and communications, including photonic interconnects for board-to-board and chip-to-chip applications.

With all-optical out of favour, however, this market potential will likely be for the longer rather than medium term. VCSELS have the advantage of being able to be set up as monolithic arrays. Large numbers of channels allow even to dream of optical computing using 256 channels.

Looking longer term there is also the attraction of all-optical chips and chip-to-chip interconnects.

For example, Intel has announced a commitment to such technology where it could utilise 1310 nm VCSEL emitters working in concert with silicon because it is transparent at this wavelength.

In future telecom equipment, long wavelength VCSELS could enable greater bandwidth and distance performance in multimode fibre, and lower cost light sources for single-mode fibre applications.

Long wavelength VCSELS also provide a path to overcoming eye-safety problems in applications like Parallel Optical Data Links. They will provide the cost and performance benefits of today's short wavelength VCSELS, but offer the additional benefits of transmission in the 1300nm window.