High Speed VCSEL-Based Parallel Optical Transmission Modules *

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Abstract: Design and fabrication of a parallel optical transmitter are reported. The optimized 12 channel parallel optical transmitter, with each channel's data rate up to 3Gbit/s, is designed, assembled, and measured. A top-emitting 850nm vertical cavity surface emitting laser (VCSEL) array is adopted as the light source, and the VCSEL chip is directly wire bonded to a 12 channel driver IC. The outputs of the VCSEL array are directly butt coupled into a 12 channel fiber array. Small form factor pluggable (SFP) packaging technology is used in the module to support hot pluggable in application. The performance results of the module are demonstrated. At an operating current of 8mA, an eye diagram at 3Gbit/s is achieved with an optical output of more than 1mW.

Key words: VCSEL; parallel optical transmission; 12 channel fiber array; modules
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1 Introduction

The rapid growing request for high bandwidth promotes the increase and development of optical internetworking. As a result, more and more optical links have been set up in the current network. In most of these links, data rates are required to be up to 10～40Gbit/s. At the same time, the link distance is actually less than hundreds of meters, as most of the network equipments are co-located within the same building. As we know, the link configuration in a special case is determined by the cost of the transceivers and fibers, the complexity of the matching electronics, and the assembly condition. For short distances, the cost of transceivers is dominant[1]. When the number of the optical connections is relatively large, the modules have a strong economic impact on the overall network. How to reduce the cost of the modules in short distances is a very important question on to the service providers. Compared with the expensive traditional serial optical modules, the use of a parallel optical transmitter is a more effective solution to achieve higher data throughput and lower cost[2]. The parallel optical systems are also called space division-multiplex, for the signals are transported in parallel through different optical links.

The use of VCSEL is an especially cost-effective way to develop parallel optical transmitters. These devices are considered to be the best light sources due to their excellent uniformity, low-cost fabrication, efficient fiber-coupling, low threshold current, convenient device testing, and high modulation bandwidth[3]. At 850nm, VCSEL has been widely used in parallel-fiber optical data communication over short distances.

2 Electrical and optical characteristics of VCSEL

The characteristics of VCSEL are strongly in-

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fluenced by the epitaxial structure and fabrication process. A 12 channel oxide-confined VCSEL array is adopted as the light source of our module due to their excellent electrical and optical confinement of carriers. This VCSEL array chip is 320μm wide, 2970μm long and 150μm thick with a 250μm pitch. Table 1 shows the typical characteristics of the high frequency bandwidth VCSEL arrays which can be used up to 4GHz per unit.

Table 1　Electrical and optical characteristics of VCSEL arrays

Parameter	Symbol	Value
Threshold current	I_{th}	4mA
Output power	P_o	1mW(I_F = 8mA)
Slope efficiency	η	0.3W/A
Wavelength	λ_p	830～860
Series resistance	R_s	50Ω
Beam divergence	θ	15°
Capacitance	C	0.5pF
Bandwidth	f_{3db}	4GHz

Figure 1 shows the typical light output and voltage versus current (L-I-V) curves for the 12 channel VCSEL array. Excellent device performance and uniformity have been achieved with low operating voltage and high power. The operating voltage across the VCSEL array at 1mW power is about 2V, which is suitable for 3.3V transmitter applications.

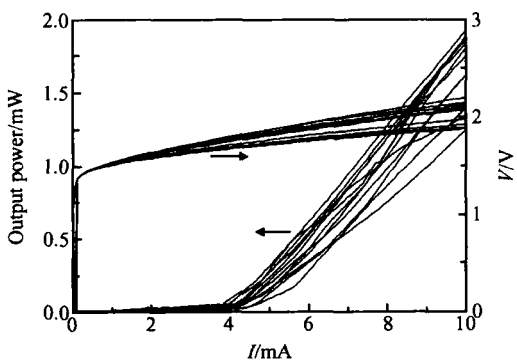

Fig. 1　Typical L-I-V curves for the 1×12 VCSEL array

3　Module structure and fabrication

Figure 2 shows the structure of the VCSEL-based module. The module consists of a VCSEL array chip, a laser driver array chip, a fiber ribbon with MT ferrule, and metal packaging. Driving VCSEL array at reasonable speed requires driver arrays[4]. The laser driver array chip is designed and fabricated in a commercial 0.35μm CMOS (MOSIS) process technology and operated under a 3.3V supply. The driver input is PECL compatible and should be AC coupled. The output is set with high impedance to realize the current modulation of the VCSEL array.

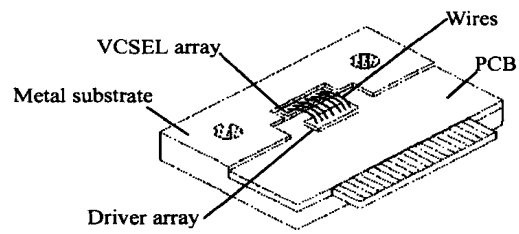

Fig. 2　Structure of the VCSEL-based module

The module is fabricated in several steps. Firstly, using conducting resin, the VCSEL array is attached to a metal substrate, and the driver is attached to a printed circuit board PCB at the position designated by alignment marks. The PCB with the driver is then mounted on the metal substrate. The VCSEL array and driver array are interconnected by bond wires on a 250μm pitch. To achieve high modulation speed, the connecting wire should be kept short to reduce parasitic inductance. Next, the output light of the VCSEL array should be well coupled into the 12 channel fiber array with lower loss. The light-emitting apertures on the VCSEL array have a 250μm pitch, 10μm diameters and 15° divergence angles. To achieve better coupling efficiency, the lights are directly butt-coupled into the fiber array with a 250μm pitch. In our module, a standard MT multi-fiber (62.5/125μm) connector ferrule is fixed by microscope to align with the VCSEL array. In order to reduce the reflection, the coupling end of the ferrule has an 8° angle[5]. The other ends of the fiber array are 12 fan-out fibers with FC adaptors which could be directly connected to a power meter. By watching the display of the

power meter, we could adjust relative position and angle of the VCSEL array to the MT ferrule. At proper position and angle, the best coupling efficiency of 1 to 12 channel is achieved[6]. After accurate location, the MT ferrule is fixed to the assembly by E-OONS resin. Finally, all the electronic and optical components are packaged into a metal packaging to get better signal integrity and better stability. The packaging is designed as the small form factor (SFP) pluggable package technology, which is usually used in serial optical transceivers. An industry standard edge connector is adopted to transmit electrical signals from the boards to the modules. This advance allows the feature of hot pluggable to parallel optical links. The design parameters for our parallel optical transmitter are summarized in Table 2.

Table 2 Design parameters for the module

Parameter	Value
Light source	VCSEL array(850nm)
Data rate/ch	3Gbit/s
Number of channels	12
Supply voltage	3.3V
Package	SFP
Electrical interface	PECL
Optical connector	MT(12 channel)
Fiber type	62.5/125μm MM fiber
Module dimension	45mm×23.2mm×8.8mm

4 Characteristics

To gain the capabilities and limits of the parallel optical module, small-signal analysis and large-signal analysis have been done. The output signals from the fan-out cable are separately sent to a photodetector (NEW FOCUS Model1580), then to the measurement equipment. Figure 3 shows the frequency response for one channel of the module measured by a network analyzer (HP8757C). As can be seen from the plot, the maximum 3dB bandwidth obtained from the instrument is greater than 3GHz at 8mA.

Figure 4 shows a 3Gbit/s eye diagram for one channel of the module. The stream generated from the pulse pattern generator (Advantest D3166) is

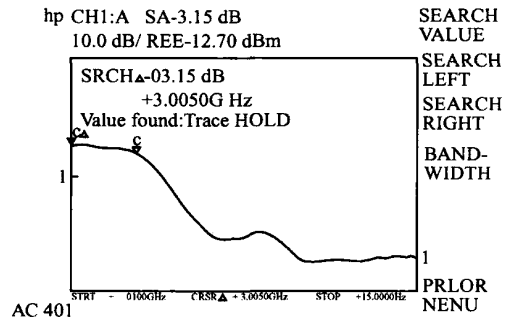

Fig. 3 Small-signal frequency response for one channel of the module

made using a 2^{31} - 1 NRZ (non return to zero) PRBS (pseudo random bit sequence). The eye diagram is obtained at a wide-bandwidth oscilloscope (Agilent Infiniium DCA 86100A) with a bias current of 8mA. The wide open eye pattern shows good modulation performance.

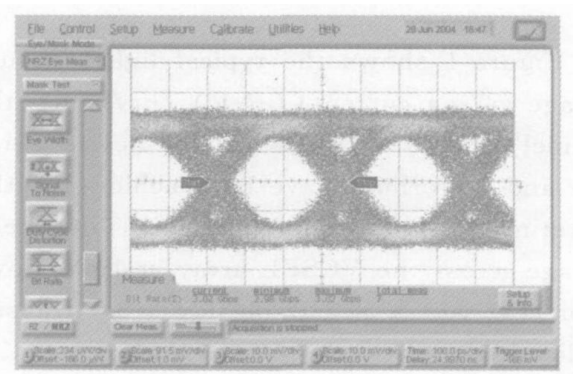

Fig. 4 Eye diagram for the module at 3Gbit/s

5 Conclusion

We have developed 12 channel VCSEL-based parallel optical transmitters that are capable of transmitting 36Gbit/s of data throughput. They use the small form factor pluggable packaging to achieve the "hot pluggable" solution to the parallel optical transmission systems. These pluggable modules with high bandwidth and cost-effectiveness are very attractive for backplane and short range datacom applications. In the coming years, continuing technology advances will improve the performance (bandwidth and distance) of VCSEL-

based parallel transceivers and widen their market space significantly.

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References

[1] Debaes C, Vervaeke M, Baukens V, et al. Low-cost microoptical modules for MCM level optical interconnections. IEEE J Sel Topics Quantum Electron, 2003, 9(2): 518

[2] Kosaka H, Kajita M, Sugimoto Y. Multidimensional VCSEL-array push/pull module fabricated using the self-alignment mounting technique. Components, Packaging, and Manufacturing Technology, 1998, 21(4): 471

[3] Katsura K, Usui M, Sato N, et al. Packaging for a 40-channel parallel optical interconnection module with an over-25-Gbit/s throughput. IEEE Trans Advanced Packaging, 1999, 22(4): 551

[4] Prather D W, Venkataraman S, Lecompte M, et al. Optoelectronic multichip module integration for chip level optical interconnects. IEEE Photonics Technol Lett, 2001, 13(10): 1112

[5] Hwang Hwan Sung, An Jae Yong, Kim Myeong-Hyun, et al. VCSEL array module using (111) facet mirrors of a V-grooved silicon optical bench and angled fibers. IEEE Photonics Technol Lett, 2005, 17(2): 477

[6] Cook C, Cunningham J E, Hargrove A, et al. A 36-channel parallel optical interconnect module based on optoelectronics-on-VLSI technology. IEEE J Sele Topics Quantum Electron, 2003, 9(2): 387

基于垂直腔面发射激光器的高速率并行光发射模块*

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摘要: 报道了关于并行光发射模块的设计与制作. 优化设计、制作并测试了 12 信道并行光发射模块, 单信道传输速率可达 3 Gbit/s. 采用波长为 850nm 的垂直腔面发射激光器作光源, 激光器与驱动电路芯片直接用金丝连接. 输出光束直接耦合进入 12 信道的光纤阵列中. 采用小型化可插拔封装结构以便在应用中实现热插拔. 模块的测试结果表明, 在 8mA 的工作电流下, 测到 3 Gbit/s 的清晰眼图.

关键词: 垂直腔面发射激光器; 并行光传输; 12 信道光纤阵列; 模块

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