Twenty-five gigabit per second transmitter using pre-emphasis

Yukito Tsunoda, Mariko Sugawara, Hideki Oku, Satoshi Ide, and Kazuhiro Tanaka

Employing a novel driver to compensate data signal degradation enables an affordable 25Gb/s transmitter with 10Gb/s standard vertical-cavity surface-emitting lasers.

High-performance computing (HPC) systems and high-end blade servers are currently being developed for larger scale, more complex simulations in the fields of life and earth sciences. Naturally, these systems also require high-speed, high-density interconnections between racks, modules, and chips. However, conventional electrical interconnection technologies are approaching their critical limit owing to the limited bandwidth of electrical channels. The wide bandwidth of optical signals, on the other hand, makes optical interconnections a promising solution to this restriction.

To introduce optical interconnections in computing systems, the optical interface not only must be high speed but also small and affordable. Direct modulation using vertical-cavity surface-emitting lasers (VCSELs) is a suitable means of assuring these properties. In fact, 10Gb/s optical interconnections using VCSELs have already been reported and are starting to appear in some HPC systems. According to Ethernet and InfiniBand standards, the market demand for bandwidth has been increasing steadily and soon will reach 25Gb/s/lane. Although VCSELs operating at this rate have been explored as transmitter elements for optical interconnections, using commercial 10Gb/s standard VCSELs for a 25Gb/s transmitter is actually an effective way of reducing costs. Here, we describe just such a configuration using pre-emphasis technology.

The intrinsic optical dynamics of 10Gb/s VCSELs are slow, which in turn degrades the data signal. For this reason, we applied a pre-emphasis pulse-shaping technology to achieve 25Gb/s. Figure 1 shows a schematic of our VCSEL transmitter. By enhancing the high-speed signal in advance, the device driver compensates for the laser’s lack of speed and improves the output waveform.

Designing the proper conditions for pre-emphasis requires a rigorous simulation environment. We measured 10Gb/s VCSELs and modeled them based on the rate equation model. Figure 2(a) shows the output waveform of one of these devices. We were able to get around the degraded waveform observed at 25 Gb/s by applying finite impulse response (FIR) pre-emphasis technology. Figure 3 shows a schematic of the operating principle. We generated the pre-emphasis signal by adding or subtracting delay signals from the main signal. We propose a ‘three-tap’ pre-emphasis, which consists of two delayed signals and a combiner circuit. Figure 2(b) shows the simulation result.
Figure 3. Principle of finite impulse response pre-emphasis. The pre-emphasis signal is generated by adding or subtracting delay signals from the main signal.

Figure 4. The fabricated transmitter module consists of an anode-drive-type 10Gb/s standard VCSEL and our driver IC on a transmitter board. MT: Mechanically transferable.

of the VCSEL output waveform using the three-tap architecture: both the rising and falling edges of the output waveform improved.

We used these results to develop a new 25-Gb/s pre-emphasis VCSEL driver IC. A pre-emphasis component splits the input signal along three paths to generate the main signal and the two delay signals. A combiner generates a pre-emphasis signal by adding or subtracting delay signals from the main signal. Finally, an additional component supplies the bias current and pre-emphasis modulation signals to an anode-drive-type VCSEL.

We fabricated a simple 25Gb/s optical transmitter using an anode-drive-type 10Gb/s standard VCSEL and our driver IC (see Figure 4). The VCSEL optical output is coupled to a multimode fiber through a microlens array. We tested the transmitter at room temperature with input data consisting of a 25Gb/s $2^{31} - 1$ pseudo-random bit sequence. Figure 5(a) and (b) shows the optical output waveform without and with pre-emphasis, respectively. In both waveforms, the average output power of the laser is 1.8mW and the optical modulation amplitude is 1.4mW. The extinction ratio of these waveforms is 3.3dB. Our technique reduces the rise and fall time of the signal, and it improves the VCSEL output waveform.

In summary, we report the use of a novel driver IC to generate a pre-emphasis signal that achieves good waveforms at 25Gb/s with 10Gb/s standard 850nm VCSELs. This technology reduces the cost of the 25Gb/s transmitter. Our next step will be to develop a suitable receiver to realize optical interconnections at this rate.

Author Information

Yukito Tsunoda, Mariko Sugawara, Hideki Oku, Satoshi Ide, and Kazuhiro Tanaka
Fujitsu Laboratories Ltd.
Kanagawa, Japan

References