High performance laser arrays for tunable and parallel link applications

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The integration of multiple lasers with different characteristics on the same semiconductor chip allows implementation of next-generation high-speed data link applications.

The increasing demand for bandwidth capacity continues to drive the emergence of technologies that carry data over both long distances and short links. In long-haul applications, the technology of choice is dense wavelength division multiplexing (DWDM), where nearly a hundred different closely spaced wavelength channels are transmitted over a single mode fiber, each lane currently carrying 10Gb/s of traffic. In this approach, laser manufacturers have had to manufacture and inventory the hundred different codes required for all the various wavelength channels. Additionally, users frequently need to switch wavelengths in a given system, and modifying the hardware manually can be time-consuming and expensive. In short distance interconnect applications, needs can be equally acute. Server farms and parallel computing platforms require a high density of fast interconnects, and handling hundreds of fiber interconnections to get the desired aggregate bandwidth can represent an overwhelming task.

In DWDM systems, tunable lasers can solve the logistics of handling different parts for different wavelengths, but in the past, cost, performance, and reliability have been serious issues. There are as many tunable lasers designs as graduate students and scientists working on the topic, but unfortunately, most approaches are not suitable for deployment. In the past, many serious and well-financed efforts addressed this challenge, and hundreds of millions of dollars were spent on this effort. Companies such as CoreTek (acquired by Nortel for $1.3B) and Bandwidth proposed an elegant solution using a vertical cavity laser with a micromechanically movable top mirror to adjust the cavity length. Others, such as Iolon, selected a more traditional external cavity approach using micromechanical actuators to reduce size and cost. Most of these approaches were either too expensive or could not achieve the required performance.

Various tunable laser solutions are still being used, with Intel providing an external cavity laser, and JDS Uniphase (through their purchase of Agility Communications) and Bookham using a multi-segment laser, but the dominant market approach has now shifted to using an integrated laser array. Just as fabricating multiple similar transistors on silicon is no more complicated than fabricating a single transistor, companies such as Santur Corporation and Furukawa make simultaneous laser arrays on an InP wafer. The lasers are identical in every aspect other than wavelength, which is determined by the grating pitch. To get a tunable laser, one simply activates the laser element of the proper wavelength in the array. Some thermal tuning is used to fine tune the output, and either a switch or an integrated coupler.

Figure 1. Schematic of a tunable laser integrating different wavelength elements on a single chip. The output wavelength is changed by switching between different elements. An optomechanical switch diverts the beam to the output.

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routes the light from the selected emitter to the fiber. This simple approach is not significantly more expensive than the single fixed-wavelength laser solution and displays equally good reliability and performance. Figure 1 shows a schematic of such a tunable laser. In addition to the laser array and the optical switch, a complete package also includes a monitor photodiode and a wavelength locker assembly.

Single-frequency laser arrays can have a much more significant impact if all the elements are used simultaneously. In this case, all the signals can be generated on the same chip in one package. A wavelength combiner is generally used to route all the signals into the same output fiber. This was demonstrated for the LX4 standard (4 wavelengths running at slower speeds to get an aggregate 10Gb/s bandwidth) by Santur and more impressively by Infinera in a breakthrough research paper generating 40 WDM channels at 40Gb/s for a combined output of 160TB/s out of a single package.

Parallel arrays are also demonstrating their potential in short distance interconnect applications. Unlike vertical cavity lasers and ribbon fiber, which can be cumbersome due to connector and fiber handling issues, distributed feedback arrays can use a single fiber by multiplexing wavelengths. Figure 2 shows a Santur 12-element chip with a multimode combiner for use with a single multimode fiber. These chips can be made at low cost and high yield and represent promising solutions for the fabrication of inexpensive interconnects. Various embodiments of this approach, in either cooled or uncooled packages, at different wavelength spacings, and with different laser structures, are being developed for various applications. For example, in the current discussions on the 100Gb/s Ethernet standard, 4 channels at 25GHz or 10 channels at 10Gb/s are the two strongest candidates. Inevitably, parallelism will be required as speeds increase, and integration is clearly able to provide the lowest cost option.

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References