High-Power, Efficient 1280nm WDM Source for Terabit Interconnects

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Abstract: *We present a proof-of-concept 8-channel WDM source for future Terabit interconnects, based on a highly efficient laser array. The array is composed of novel, record efficiency and high power DFB lasers operating at 1280nm, showing >250mW laser output power and laser efficiencies up to 36%.*

Keywords*: Optical interconnects, semiconductor lasers, wavelength-division-multiplexing*

Wavelength-division-multiplexed (WDM) data streams have been widely deployed in inter data center (DC) interconnects. Using WDM sources for intra-DC networks can bring scalability in bandwidth density needed to meet terabit ethernet requirements. Advances in Silicon Photonic (SiP) technology with co-optimized electronic circuitry have shown high-speed optical links at small foot-print and low-energy consumption [1]. Hybrid sources have showed peak efficiency up to 14% and peak power up to 18mW [2]. From advances in fiber coupling methods [3], efficient external laser sources can pave the way for cost competitive integrated SiP WDM transceivers.

In terabit-capable WDM interconnect networks, the laser sources can account for more than 30% of the link power budget [4]. This significant energy expense can be mitigated by using an architecture with an efficient high-power laser utilized as a central WDM source [5] in conjunction with passive [6] or active [7] optical power splitters. Furthermore, a centralized high-power WDM source for all the transceivers in the network allows for a localized thermoelectric cooler (TEC) design that can contribute to reducing transceiver control complexity and expenses.

To address the need for high-power WDM sources, we have proposed and demonstrated a concept for an integrated multiwavelength source for future terabit interconnect applications. The proposed source consists of a high-efficiency, high-power DFB laser array butt-coupled to a star coupler, as illustrated in Figure 1. The star-coupler multiplexes the input laser array signal and distributes these to many output ports, each containing the light from all input sources. The star coupler is designed for low excess insertion loss, while producing many copies of the optical signal to feed several transceivers. In this manner, a single WDM source can be cost-shared between a multitude of terabit optical interconnects. Assuming 10mW per optical channel power target, the required power from each source is several hundred mW, depending on output channel count. In our WDM source, we have utilized a novel, record efficiency, high power DFB laser array at 1280nm, forming an 8-channel WDM source, coupled to a 10x10 star coupler.

A new DFB laser technology has been developed for high output power and high wall-plug efficiency. Figure 2A shows the output power and efficiency for one particular laser implementation, where the back facet is high-reflectivity (HR) coated for improved front-facet efficiency. Peak wall plug efficiency around 36% is observed at ~4x threshold current, and peak power >200mW. Figure 2B shows lasing spectra obtained at room temperature for bias currents from 100mA to 500mA. Stable and highly single-mode emission is demonstrated.

For initial DFB laser array demonstration, we needed to yield an operational laser array consisting of eight DFB lasers placed on a single die at 127µm pitch, designed for 100 GHz wavelength spacing to form a source for an 8-channel WDM link. Figure 2C shows the output power from a single DFB laser from this array biased individually. The peak output power exceeds 250mW at >1A bias current. The peak efficiency at 700mA bias current is >17% from a single facet, or ~34% assuming symmetric emission from both facets, which is what is nominally expected. When all eight lasers are biased, >700mW of output power is generated at 4A bias current, as shown in Figure 2D. Improved output power and efficiency from the laser bar can further be achieved through p-side down mounting, where efficiency penalty for the array will be greatly reduced.

For the source demonstrator, the 8-laser array is butt-coupled to a planar lightwave circuit consisting of a 10x10 star coupler fabricated using a low-loss Silicon Nitride core buried in Silicon Oxide. Excluding the outermost ports, coupling loss is bound within a ~3-dB range. The absolute loss was measured between 19.6 dB and 23.4 dB, not including the outermost ports of the fiber array. With improved mode-matching and optimization of the laser, fiber and PLC structure, the insertion loss can be improved to a 12-16 dB range. A perfect NXN star coupler has an insertion loss of 1/N, or 10 dB in this case. Figure 3 shows the resulting normalized optical spectra from each of the output ports of the star coupler, each port containing the signal from the combined WDM source.

Future Si-photonics based terabit optical interconnects will require highly efficient and high power optical sources. In this paper, we have presented an integrated high power 1280nm DFB laser array for this application. Single laser output power exceeds 250mW, peak laser efficiency is 36%. A proof-of-concept integrated 8-channel WDM source is demonstrated with a total of 10 output ports, each containing a copy of the combined output from the efficient lasers. In addition, these high-power, high-efficiency DFB lasers could find use in other DC architectures which require high bandwidth communication with minimal power consumption.

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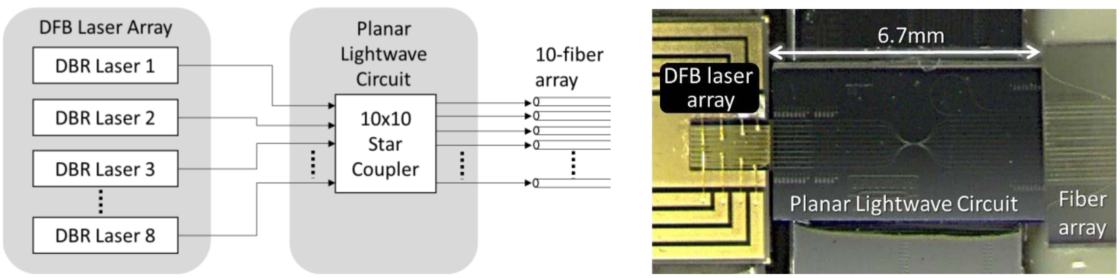
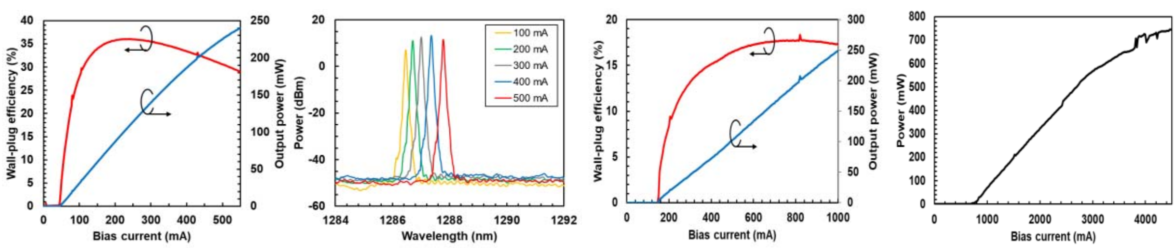


A B

Fig. 1: A) Diagram of 8-channel WDM source and B) photo of assembled proof-of-concept demonstrator.



A B C D

Fig. 2: A) Output power and efficiency along with B) spectral performance showing single-mode output of a single DFB laser. C) Output power and efficiency for single quarter wavelength shifted DFB laser out of front facet. D) Total output power and efficiency for full 8-laser array when mounted p-side up. All data taken with temperature-controlled stage at 20ºC.

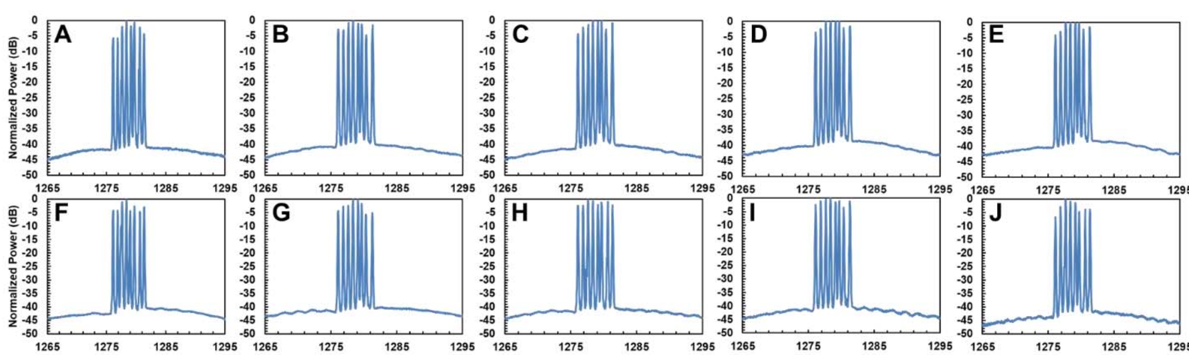


Fig. 3: Normalized optical spectra from each of the output ports of the star coupler (A-J), each port containing the signal from the combined WDM source.