Multi-wavelength sources for Optical IO Co-packaged optics

Matthew N. Sysak, Radek Roucka, Nandita Aggarwal Chen Li, Fernando Luna, Sally El-Hemawy, John Frey, Manan Raval, Ken Wang, Li-fan Yang, Mark Wade, Chen Sun
Ayar Labs, Inc., 695 River Oaks Pkwy, Santa Clara, CA 95054
matt@ayarlabs.com

Abstract: 8 and 16 wavelength optical sources for optical IO applications are reviewed. A new CW-WDM MSA compliant, 16 wavelength source operating from 20 to 100ºC is presented.

1. Introduction

Silicon photonics combined with complementary metal–oxide–semiconductor (CMOS) electronics that utilize wavelength-division multiplexing (WDM) are now becoming mainstream for AI, optical computing, and high-speed Optical IO applications [1,2]. Over the last several years, laser arrays [3] and mode locked lasers (MLL) [4] have emerged as the preferred solutions to power these WDM links. To help standardize WDM sources, the CW-WDM multi-source agreement (MSA) has defined wavelength grids and power levels to help ensure interoperability between laser and chiplet developers [5].

In this paper we review previous work on 8 wavelength optical sources and introduce the first CW-WDM MSA compliant 16 wavelength optical source. The 16 wavelength SuperNova™ operates from room temperature up to >100º C and consists of a 200GHz spaced DFB laser array coupled to a splitter and combiner network. The output from SuperNova™ has 16 polarization maintaining fibers each carrying all 16 wavelengths, for a total of 256 addressable carriers. The multi-wavelength source is mode hop free and meets the 200 +/- 50 GHz MSA wavelength spacing requirements, with >40dB SMSR, <135 dB/Hz RIN, and <20 MHz linewidth across all channels and all operating conditions.

2. Ayar Labs SuperNova™ optical source

The architecture of both 8 and 16 wavelength SuperNova™ variants is shown below in Fig. 1. The SuperNova™ includes a N-element single frequency DFB array followed by an NxM splitting and combining network to route the laser wavelengths. The output of the combining and splitting network is coupled to an array of polarization maintaining fibers (PMF).

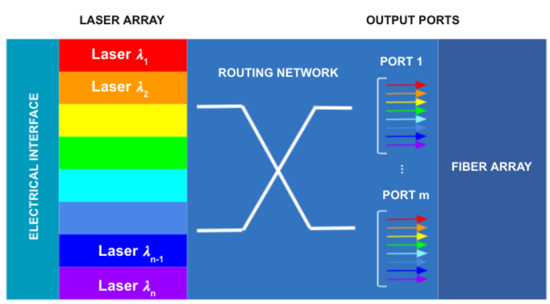


Fig. 1. SuperNova™ multi-wavelength source architecture

3. Results

Optical characterization of SuperNova™ is performed by placing the laser module on a temperature-controlled stage. The stage temperature is then ramped between room temperature and 100ºC and laser output spectra, RIN, and linewidth are recorded. Laser module temperature is measured using a thermistor inside the laser package.

Results from the 8 wavelength SuperNova™ multi-wavelength source presented previously [3] are summarized in Fig. 2. The 8-wavelength source operates from 15-100ºC with excellent Relative Intensity Noise and linewidth characteristics and supports 4 Tbps of bidirectional data transmission between two TeraPHY chiplets [6].

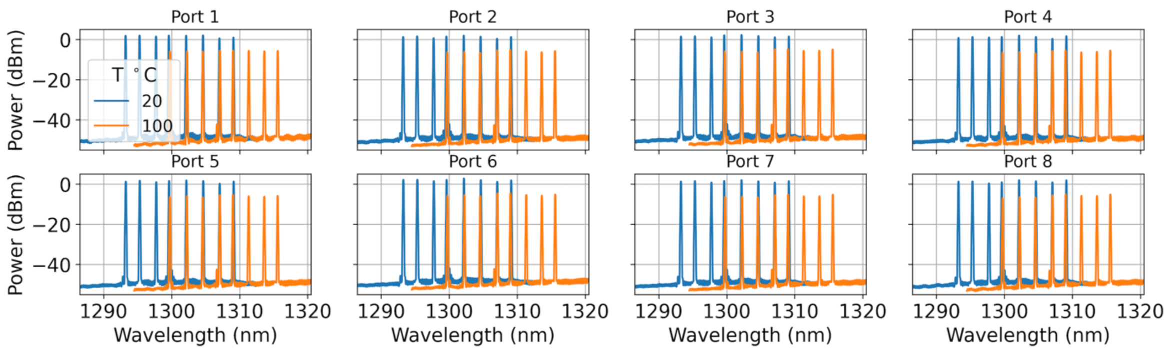


Fig. 2. Measured spectra from each output fiber from the SuperNova^{TM} optical source at 20ºC and 100ºC.

The 16 wavelength SuperNova^{TM} relies on the same architecture as the original 8 wavelength source. The laser array contains 16-single frequency DFB lasers with center wavelength around 1300nm and target spacing of 200 GHz. The output from the laser source is coupled to a 16x16 splitting and combining network followed by an array of polarization maintaining fibers. All output fibers contain all 16 wavelengths for a total of 256 optical carriers. Spectra at room temperature and 100ºC is shown in Fig. 3 from each of the 16 output fibers. All lasers have >40dB SMSR with 200 +/- <50 GHz channel spacing at both room temperature and elevated temperature.

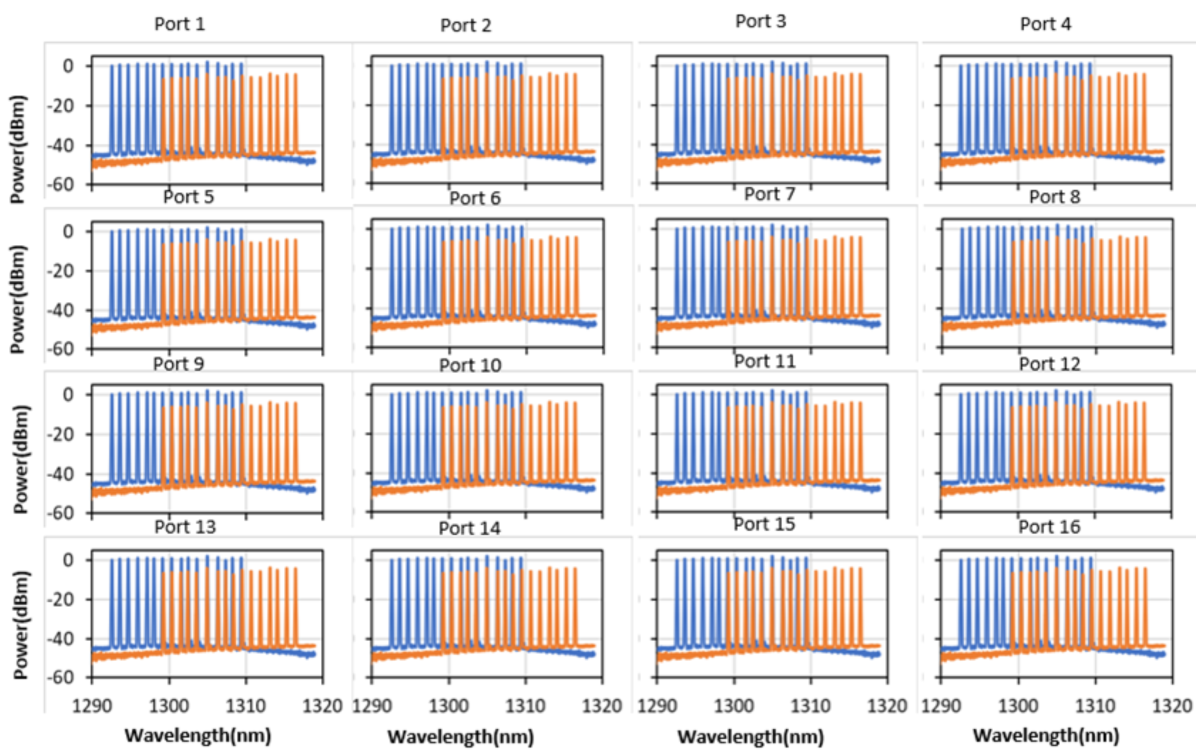


Fig. 3. Measured spectra from each output fiber from the SuperNova^{TM} optical source at 20ºC and 100ºC.

To show the SuperNova^{TM} wavelength stability over temperature, lasers are set to a fixed current and the peak wavelength and channel spacing is recoded at the output of the splitting and combining network as a function of stage temperature. Results are summarized for 3 different temperatures in Fig 4. Over the full temperature range the laser spacing is 199 GHz +/- < 50 GHz which meets the MSA requirements of 200 +/- <50GHz.

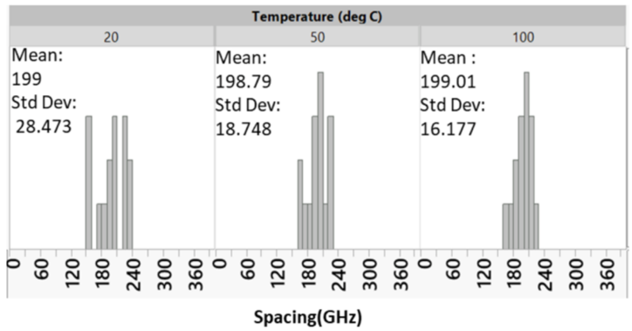
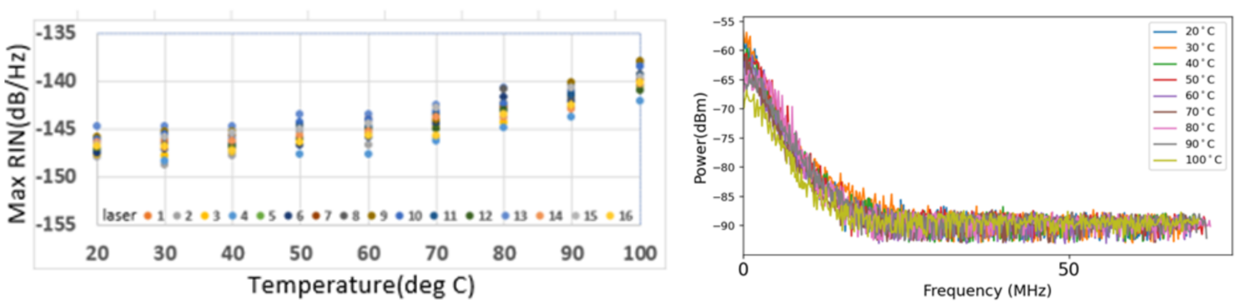


Fig. 4. Peak wavelength as a function of temperature for each of the 8 lasers across 8 ports. (b) Distribution of wavelength (laser) frequency separation at 20, 50, and 100ºC.

Finally, Relative intensity noise (RIN) and linewidth measurements are performed for each laser individually at the output of the splitting and combining network. RIN measurements span 10 MHz to 15 GHz and linewidth measurements rely on a delayed self-heterodyne technique [7]. Results are summarized over temperature in in Fig 5(a) and (b) respectively. For all lasers at all temperatures peak RIN is <-135dB/Hz and linewidth is <20 MHz when data is fitted by a Lorentzian lineshape.



(a) (b)

Fig. 5. (a) Peak relative intensity noise as a function of temperature for each of the 8 lasers across 8 ports. (b) Measured optical linewidth over temperature for each laser in the array at the output of the PLC.

4. Summary

We have reviewed our previous work on 8 wavelength multi-wavelength sources and introduced a new CW-WDM MSA compliant 16 wavelength optical source. The new 16-wavelength SuperNova^{TM} operates from room temperature to 100ºC meeting 200 +/- 50 GHz MSA requirements, RIN < -135 dB/Hz, and linewidth < 20 MHz.

5. References

[1] A. Atabaki. *et al.*, "Integrating photonics with silicon nanoelectronics for the next generation of systems on a chip", *Nature*, vol. 556, pp. 349-354, 2018.

[2] M. Glick, et al., "PINE: photonic integrated networked energy efficient datacenters (ENLITENED program)", *IEEE/OSA Journal of Optical Communications and Networking,* vol. 12, pp. 443-456, 2020.

[3] M. Sysak, et. al.,"An uncooled CW-WDM MSA compliant multi-wavelength laser source operating from 15-100°C for WDM CMOS applications", Proc. SPIE 12007, Optical Interconnects XXII, 120070L (5 March 2022).

[4] S. Liu et al., "High-channel-count 20 GHz passively mode-locked quantum dot laser directly grown on Si with 4.1 Tbit/s transmission capacity", Optica, Vol. 6, 2019

[5] https://cw-wdm.org

[6] M. Sysak *et al.*, "High Wavelength Count Laser Sources for WDM CMOS Optical Interconnects," *2022 28th International Semiconductor Laser Conference (ISLC)*, Matsue, Japan, 2022, pp. 1-2,

[7] T. Okoshi, K. Kikuchi, and A. Nakayama, "Novel method for high resolution measurement of laser output spectrum," Electon. Lett. 16, 630 (1980).