High-Bandwidth-Density Uncooled EML Array for up to 770 Gb/s/mm and 11 km Fiber Reach

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Abstract:. We demonstrate a compact EML array, featuring integrated RF routing and reduced channel spacing for high bandwidth density. The device delivers 770 Gb/s/mm, supports fiber reach of 11 km, and uncooled operation. © 2026 The Author(s)

1. Introduction

Modern data centers depend on optical interconnects, being optimized for bandwidth and density to meet the increasing requirements of the massive computational and storage resources. Electroabsorption modulated lasers (EMLs) have become a key technology for short-reach, high-speed optical transmission in such environments. They offer compact form factors, high extinction ratios, and low-chirp modulation at high speeds. Arrayed EMLs further enhance the bandwidth density, a critical metric for next-generation optical interconnects. Previous studies have reported bandwidth densities of 200 Gb/s/mm for EML arrays and 448 Gb/s/mm for DML arrays [1, 2]. In our earlier work, we demonstrated a cost-efficient EML array based on a single multi-quantum-well (MQW) layer stack, achieving 312 Gb/s/mm with RF contacts routed to the backside for integration with driver ICs or interposers [3]. In this work, we present an improved design that further optimizes performance, minimizes the array element spacing and therefore significantly increases the bandwidth density by more than a factor of two. The proposed EML array achieves up to 770 Gb/s/mm, supports fiber transmission up to 11 km, and operates at 25°C to 85°C without active cooling.

2. Device Structure

The demonstrated array of four EMLs is illustrated in Figure 1 (a) and (b). Each EML features a 350 µm long DFB laser in the O-band with an index-coupled grating and λ/4 phase shift for stable single-mode operation. To enhance single-mode yield, which is critical for arrays due to the exponential decrease in yield with the number of array elements, the rear facets of the DFB lasers are coated with anti-reflection (AR) coating. The forward-emitted light from each DFB laser passes through an 80 µm long electroabsorption modulator (EAM), with ground-signal-ground (GSG) contacts, the typical driver RF interface for single side driven transmitters. The GSG contacts are routed to the backside of the array via transmission lines, enabling short and direct interfacing with a driver array or interposer. To increase the output power, each EML integrates a 150 µm long semiconductor optical amplifier (SOA). The waveguides at the front facets are tilted and AR-coated to suppress back reflections into the laser cavity. The entire device is fabricated using a ridge waveguide structure. A single MQW layer stack based on InGaAlAs is employed [4], allowing for a simple manufacturing process and low optical loss. A key improvement in this design is the significant reduction of the pitch between adjacent EMLs to 375 µm, allowing for a higher bandwidth density compared to our previous designs.

(a) (b)

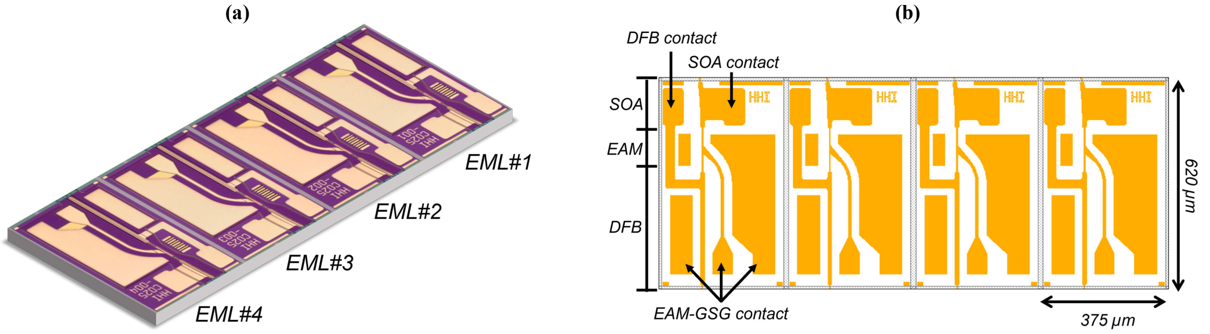

Fig. 1. Photograph of the fabricated EML array (a) and schematic layout of the EML array (b).

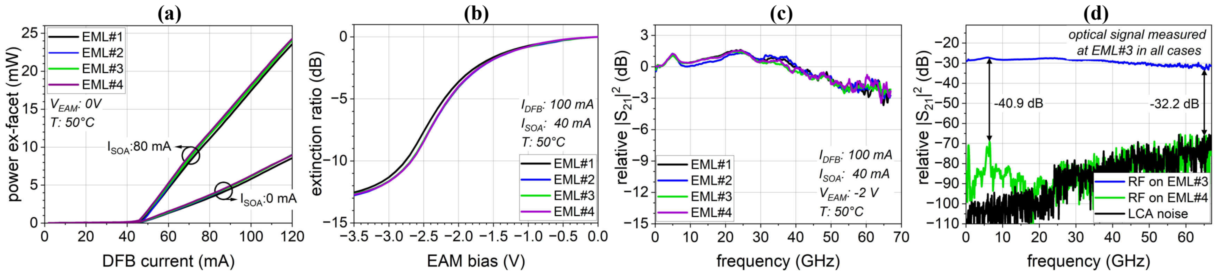

Fig. 2. Measured CW ex-facet output power versus DFB current (a), static extinction ratio versus EAM bias (b), small signal frequency response (c) for all EMLs in the array and crosstalk measurement (d). T = 50°C.

3. Experimental Results

The EML array was mounted on a temperature-controlled heatsink for characterization. Figure 2 (a) presents the ex-facet optical output power as a function of DFB current for each EML, demonstrating consistent performance among all four devices with a threshold current of approximately 55 mA. Increasing the SOA current to 80 mA results in an output power exceeding 24 mW. Figure 2 (b) depicts the static extinction ratio as a function of EAM bias. All EMLs exhibit identical performance, achieving a maximum extinction ratio up to 12 dB with an operational bias point at -2 V. Additionally, Figure 2 (c) presents the frequency response of the array, measured with an RF probe, comprising an integrated 50 Ω matching resistor. The results show that each EML achieves a high bandwidth of approximately 65 GHz. As crosstalk is an important factor in high-density arrays, a Lightwave Component Analyser (LCA) was used to measure the optical modulation of EML#3 during electrical modulation of EML#4. Figure 2 (d) shows that the measured crosstalk was lower than -32.2 dB (limited by setup noise at higher frequencies) and -40.9 dB for signals above the noise floor.

Subsequently, we evaluated the performance of the EML array for high-baud-rate PAM4 data transmission. The electrical PAM4 signal was generated using a DAC with 80 GHz analog bandwidth, operating at 256 GS/s. The generated RF signal was fed to the individual EMLs via an RF probe. Optical signals from each EML were coupled into a lensed fiber and then passed sequentially through an optical isolator, an optical amplifier (PDFA), a 2 nm bandwidth optical filter, a variable attenuator, and finally to a photodiode (100 GHz O-band photodetector module [5]). The PDFA and variable attenuator allowed to control the optical power incident on the photodiode. Electrical outputs from the photodiode were measured using a 256 GS/s oscilloscope with 110 GHz of analog bandwidth. Digital signal processing included root-raised cosine pulse shaping at both transmitter and receiver, with an adaptive roll-off factor of $(200\times10^9/f_s)$-1, where f_s is the symbol rate. A feed-forward equalizer was applied after down-sampling at the receiver. The bit error rate (BER) as a function of received optical power, measured for each of the

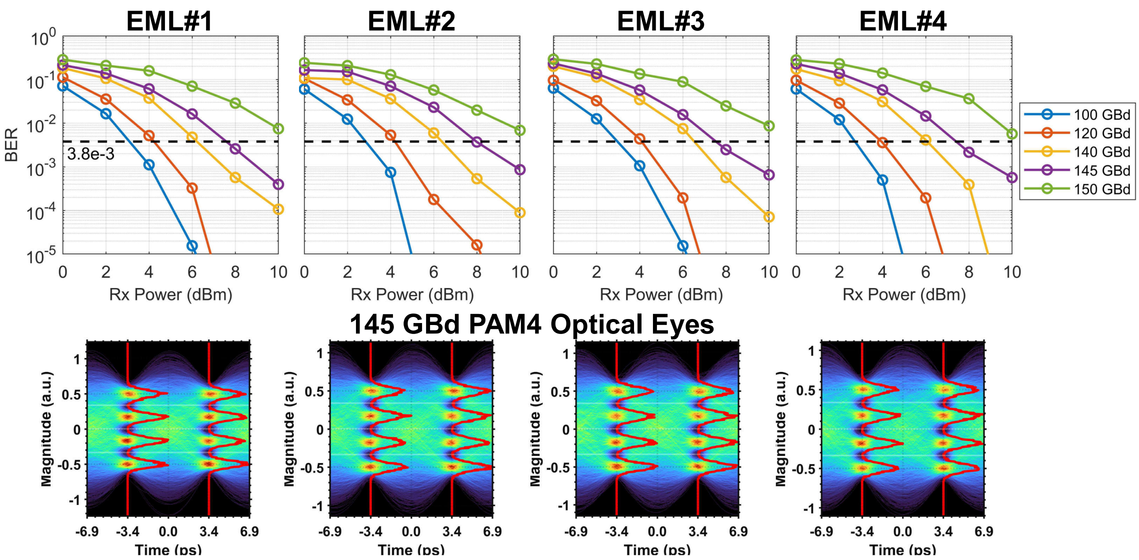

Fig. 3. Measured back-to-back BER for PAM4 modulation at different baud rates (top) and received optical eyes for 145 GBd PAM4 modulation at 10 dBm Rx power (bottom). I_{DFB} = 120 mA, I_{SOA} = 80 mA, V_{EAM} = -1.9 V, V_{pp_145GBd} = 1.2 V, T = 50°C.

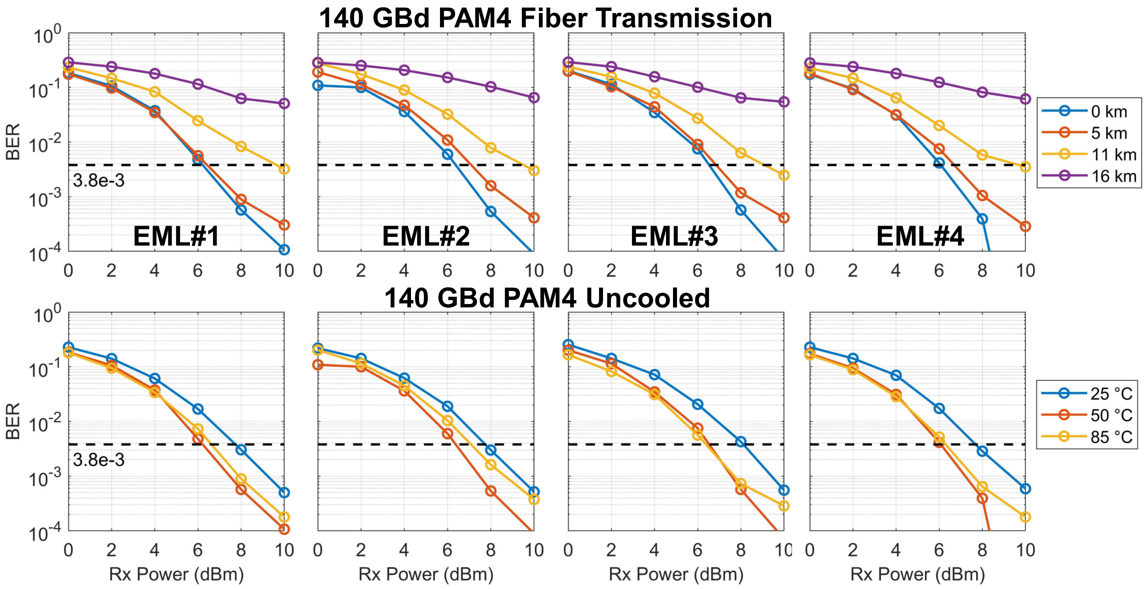

Fig. 4. Measured BER for 140 GBd PAM4 fiber transmission (top) and uncooled operation (bottom). $I_{DFB\text{-}25°C} = I_{DFB\text{-}50°C} = 120$ mA, $I_{DFB\text{-}85°C} = 80$ mA, $I_{SOA\text{-}20°C} = 40$ mA, $I_{SOA\text{-}50°C} = 80$ mA, $I_{SOA\text{-}85°C} = 60$ mA, $V_{EAM\text{-}25°C} = -2.6$ V, $V_{EAM\text{-}50°C} = -1.9$ V, $V_{EAM\text{-}85°C} = -1.0$ V, $V_{pp} = 1.2$ V,, T = 50°C.

four EMLs individually, is depicted at the top of Figure 3. A dashed line marks the legacy 7% HD-FEC BER threshold at $3.8\text{x}10^{-3}$ for reference. The four EMLs exhibit similar performance characteristics. At 145 GBd PAM4, all EMLs in the array achieve a BER below the FEC threshold, corresponding to a single channel bit rate of 290 Gb/s and a bandwidth density of 770 Gb/s/mm. The averaged optical output power ex-facet was around 10 dBm per channel. Figure 3 (bottom) presents the measured optical eye diagrams at 145 GBd for reference. In a further experiment, the bit error rate (BER) was measured after fiber transmission for 140 GBd PAM4 modulation. A standard single mode fiber of up to 16 km in length was placed between the optical isolator and the PDFA within the experimental setup. All four EMLs exhibit BER values below the FEC limit for fiber lengths up to 11 km (see Figure 4, top). Device performance was also evaluated under uncooled operating conditions. As shown in Figure 4 (bottom), each device operates across temperatures from 25°C to 85°C, with BER values remaining under the BER threshold, demonstrating uncooled operation.

4. Conclusion

We report the first demonstration of an EML array achieving a bandwidth density of 770 Gb/s/mm, supporting fiber transmission distances of up to 11 km and allowing uncooled operation. Each EML in the array exhibits a high extinction ratio, a modulation bandwidth of 65 GHz, and an average modulated output power ex-facet of 10 dBm. The device is based on a single MQW layer stack, thus enabling cost-effective fabrication. This technology presents a strong candidate for compact, cost-efficient transmitters in optical interconnects, high-speed Ethernet, co-packaged optics, and data center transceivers.

5. Acknowledgement

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