# Fully Integrated Serial Dual-Polarization Electro-absorption Modulator PIC in InP

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With the advent of stokes space modulation [1], polarization multiplexing no longer is only relevant for coherent long haul communications. In this work, we propose and demonstrate a novel serial configuration to generate true dual-polarization (DP) electro-absorption modulated data from a single chip.

The fundamental idea of the proposed PIC relies on the fact that ordinary multi quantum-well (MQW) based electro absorption modulators (EAM) only operate on TE-polarized light, which is a consequence of the heavy- and light hole splitting in the normally compressively strained MQWs.

A schematic of our DP-EAM PIC is shown in fig. 1(a). For incident light, only the TE component will be modulated by the signal applied to the first EAM. The entire polarization state is then turned by 90°, effectively swapping the TE and TM components. The second EAM will only modulate the previously unmodulated component and leave the already modulated component unaffected. The serial nature of this design brings two advantages: no splitters or combiners are needed, and there is no routing which requires bends. All this makes the design more compact and reliable. Most critical in this concept is a polarization converter (PC) with a high polarization-conversion efficiency. We reported on PCs in [2] recently. With respect to [2], here we introduced tapers to the design to lower the PC insertion loss. The PC is oriented perpendicular to the large flat of the wafer (as opposed to parallel to the large flat in [2]), resulting in a circular sidewall instead of a slanted one, see fig. 1(c). This enables an identical orientation of the PCs and the EAMs.

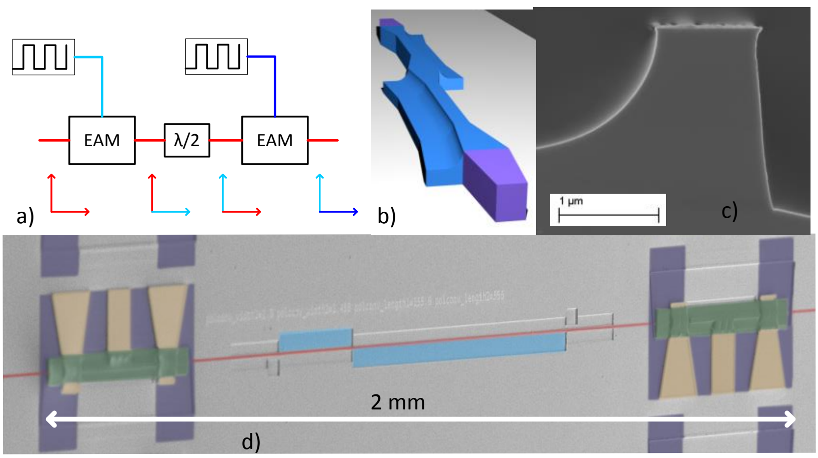


**Fig. 1. a): Schemtic of the proposed configuration. b): 3D view of the polarization converter (PC). c): SEM picture of the PC's cross section. d): colorized SEM photo of the fabricated device as in a), comprising two EAMs and the PC of b).**

We fabricated the proposed PIC using our generic InP foundry technology. After introducing the PC into the integration platform as described in [2], we now added an EAM structure into the platform. No modifications were done to our standard fabrication process. The PC is around 900 µm in length, and the EAMs feature an active length of 200 µm each. A SEM picture of the fabricated device is shown in fig. 1.

At first, we carried out measurements of the individual EAM and PC structures. The results are shown in fig. 2. The PC shows ~1 dB of loss for TM polarized light, but 1 dB more in TE mode. We attribute this to a yet non-optimal design of the tapers in the different sections of the component. Due to a higher series resistance on this particular wafer run, the bandwidth is limited to around 11 GHz. We also measured the voltage-dependant birefringence of the EAM to gain a deeper understanding of the overall device.

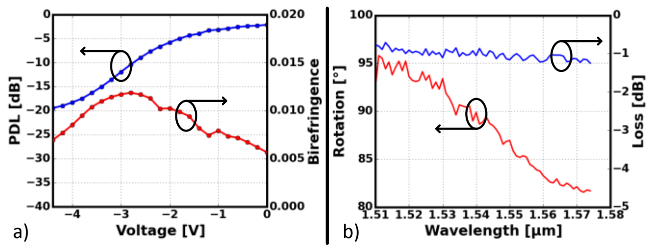


**Fig. 2. Experimental characteristics of the EAM at 1575 nm (a) and the polarization converter (b). The insertion loss of the EAM at 1575 nm and 0 V is 7 dB for TE and 3 dB for TM. The TM insertion loss is independant of the bias voltage.**

Experimental results are shown in fig. **3**. We measured the Müller matrices of the integrated device at different bias voltages of the two EAMs. To visualize this, we plot the trajectory of the total device's exiting Stokes vector when sweeping the biases of the two EAMs (for a given incident Stokes vector). The resulting trajectory spans a half-circle on the Poincaré sphere, so a full transition from TE-polarized light to TM-polarized light. To further verify the PIC performance, we performed a data transmission experiment with 12.5Gbit/s per polarization. Clean eye diagrams were achieved.

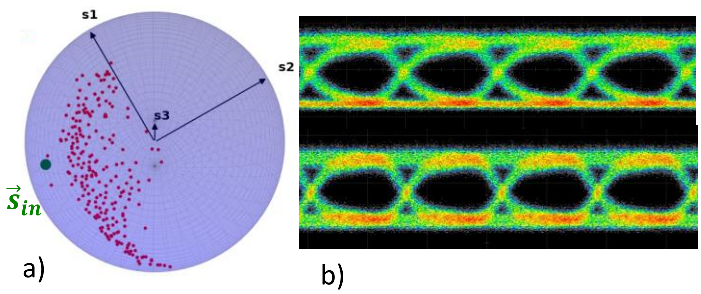


Fig. 3. **a): Trajectory on the Poincaré sphere of the DP-EAM when sweeping the two bias voltages. The Stokes vector of the incident light is the big green dot around (0,-1,0), corresponding to a 50/50 mix of TE and TM. The output Stokes vectors are the smaller dots. b): Eye diagrams at 12.5Gbit/s for the TE (top) and TM (bottom) polarization.**

In conclusion, we proposed a novel DP-EAM structure featuring a serial design. We have successfully implemented the device on our generic photonic integration platform and demonstrated data transmission in both polarization states.

References

[1] M. Morsy-Osman, M. Chagnon, and D. V. Plant, "Polarization division multiplexed intensity, inter polarization phase and inter polarization differential phase modulation with stokes space direct detection for 1λ×320 Gb/s 10 km transmission at 8 bits/symbol," ECOC 2015

[2] Moritz Baier, Francisco M. Soares, Martin Moehrle, Norbert Grote, and Martin Schell, "A New Approach to Designing Polarization Rotating Waveguides," ECIO, Warsaw, 2016.