112 Gbaud optical PAM8 modulation based on segmented thin film lithium niobate modulator

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Abstract: We experimentally demonstrate an optical transmission of 112 Gbaud PAM8 based on a segmented thin film lithium niobate modulator in an IMDD link. The Vpp of two single-ended RF signals are 2.5V and 3.5 V.

1. Introduction

With the development of artificial intelligence, 5G and cloud-based service, massive data is generated which leads to an ever-increasing demand for the transmission data rates of optical transmission system. As the electro-optical (EO) modulator plays an important role in optical transmission systems, the high-speed EO modulator technology has received intensive research attentions. High-speed modulators have been demonstrated based on different materials. Among these materials, thin film lithium niobate (TFLN) is a promising approach for high-speed modulators. Recently, high-speed modulators with 3-dB bandwidth of 100 GHz [1], > 100 GHz [2], and 170 GHz [3] have been reported in previous research.

However, owing to the moderate EO coefficient of the TFLN material, TFLN modulators with low driven voltage (< 3 V) require a long modulation section (> 1 cm) [4]. Such a long device length is difficult to adapt to the compact transceiver package, such as QSFP-DD (quad small form factor pluggable double density) [5]. Hence, several folded TFLN modulators which can reduce the length of modulation section have been demonstrated. In [6], a 100 Gbaud folded TFLN modulator with length of 10 mm was reported. Based on the poled TFLN waveguide, a folded TFLN modulator with bandwidth of 55 GHz was achieved [7]. And a folded TFLN modulator with length about 3 mm was demonstrated [5]. What's more, a 4 mm long folded TFLN modulator with bandwidth of > 67 GHz was obtained by using air-bridge structures [8].

Despite the folded structure, segmented modulator is another efficient approach to reduce the device length. By dividing a modulator along electrode of length into shorter segments, the device size is more compact and a higher bandwidth can be achieved [9]. In this study, we firstly demonstrate a segmented TFLN modulator with two 5 mm long segments. The high-speed transmission measurements were performed up to 112 Gbaud PAM8, and the Vpp of two single-ended RF signals are 2.5V and 3.5 V.

2. Device Fabrication

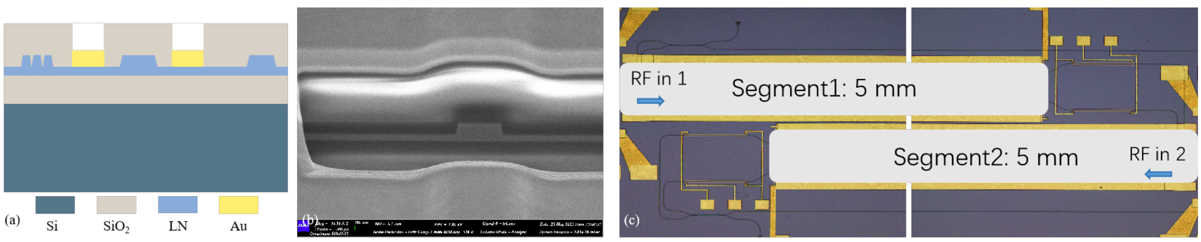

Fig. 1. (a) Schematic of the TFLN waveguide structure. (b) SEM image of the TFLN ridge waveguide. (c) Optical microscopy image of the segmented TFLN modulator.

The schematic of the TFLN waveguide structure is shown in Fig. 2 (a). An X-cut LNOI with 400 nm TFLN and 3 μm BOX layer wafer (from NanoLN) is used as the substrate. The fabrication process involves three main steps: 1) a single step electron beam lithography. 2) fluorine-based reactive ion etching. 3) lift-off of the Au film.

Subsequently, a 2 μm SiO_2 upper cladding layer was deposited. The device fabrication was completed by opening the pad. The scanning electron microscope (SEM) images of the fabricated TFLN waveguide are shown in Fig. 2 (b). And the optical microscopy image of the segmented TFLN modulator is shown in Fig. 2 (c). The length of two segments are 5 mm.

3. Results

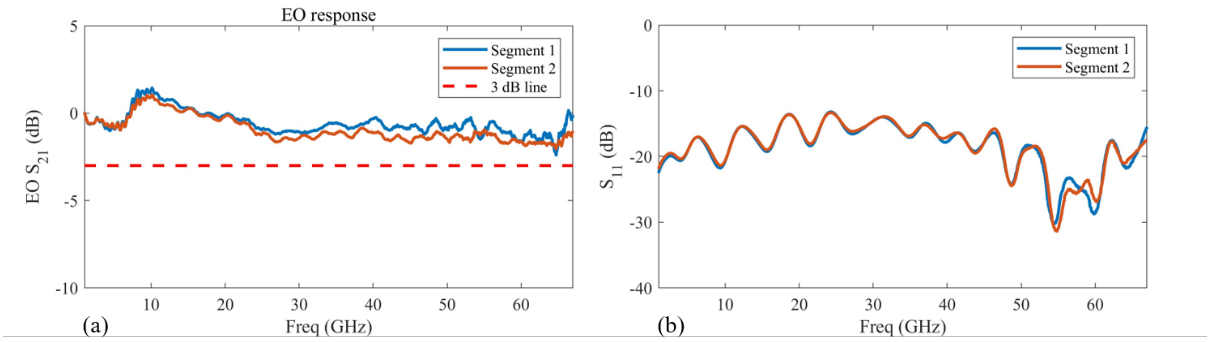

Fig. 2. Measured EO (a) S_{21} and (b) S_{11} of the segmented TFLN modulator.

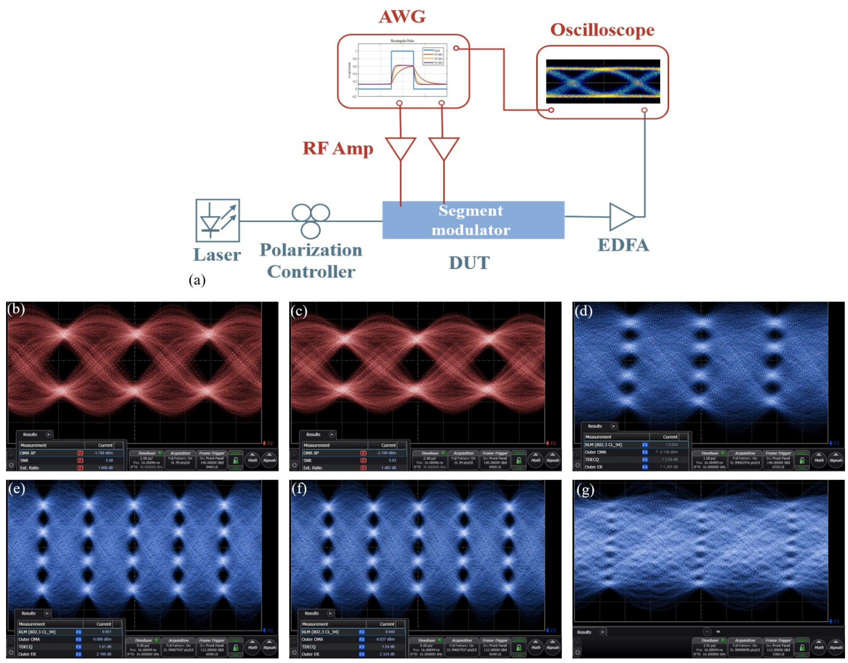

Fig. 3. (a) Experimental setup for an optical transmission experiment. 140 Gbaud OOK optical eye diagram of (b) segment one and (c) segment two. (d) Optical generated 140 Gbaud PAM4 optical eye diagram. 112 PAM4 Gbaud optical eye diagram of (e) segment one and (f) segment two. (g) Optical generated 112 Gbaud PAM8 optical eye diagram.

After fabricating the MZM, RF measurements including small-signal and large-signal characterization were performed. The characterizations of small signal were performed using a 67 GHz lightwave component analyzer (LCA, Ceyear 6433L). The light was coupled in and out from the MZM by two grating couplers. A 67 GHz GSG high-frequency RF probe were used to apply RF signal to one segment of the modulator. The measured EO S_{21} parameters of two segments are shown in Fig. 3 (a) and (b). Obviously, the 3 dB EO bandwidths of two segments are all larger than 67 GHz. And the S_{11} return losses are smaller than -10 dB.

Figure 3 (a) shows the large signal experimental setup for an optical transmission experiment with the segmented TFLN modulator. Two RF signals from two channels of a 256 GSa/s arbitrary waveform generator (AWG, Keysight M8199A) are used, one for each segment. The two RF signals are sent to 60 GHz, 22 dB amplifiers (SHF, S804B) and connected to two 67 GHz RF probes. A series wide-bandwidth oscilloscope (Keysight, N1030A) with 65 GHz sampling module was used to detect the optical signal. Firstly, each segment of the modulator was measured. Figure 3 (b) and (c) show the output optical eye diagram at 140 Gbaud on-off keying (OOK) modulation format. The extinction ratio of two segments are 1.688 dB and 1.482 dB. Figure 3 (e) and (f) show the output optical eye diagram at 112 Gbaud PAM4 modulation format. Moreover, two independent data streams- the least-significant bit (LSB) about half the amplitude of the most-significant bit (MSB) - drive the two segments, effectively generating a higher level optical signal [10]. Figure 3 (e) shows the optical eye diagram at 112 Gbaud PAM4 generated by two OOK independent data streams. And figure 3 (f) shows the optical eye diagram at 112 Gbaud PAM8 generated by a PAM4 data stream (LSB) and a OOK data stream (MSB). The Vpp of the LSB RF signal is 2.5V while the Vpp of the MSB RF signal is 3.5 V.

4. Conclusion

We have reported a segmented thin film lithium niobate modulator. The EO bandwidth of each segment (5 mm) is larger than 67 GHz. An optical transmission of 140 Gbaud PAM4 and 112 Gbaud PAM8 were experimentally demonstrated. By utilizing the segmented structure, the modulator size is more compact and a higher bandwidth can be achieved.

5. Acknowledgements

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