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Integrated Photonic Lithium-Niobate Electric-Field Sensor utilizing a Y-fed Balanced-Bridge(YBB) Mach-Zehnder Interferometric Modulator

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We designed, fabricated and characterized a compact and highly sensitive integrated photonic electric-field sensor based on a Ti:$LiNbO_3$ 1×2 YBB-MZI modulator driven by a patch dipole antenna. The modulators have been formed from titanium-diffused lithium Niobate waveguides at the wavelength of 1.3 μm. The YBB-MZI modulator consists of a 3 dB directional coupler at the output and has two complementary output waveguide as shown in Fig. 1(a). For electric-field sensing, a dipole patch antenna arranged on one arm of the MZI structure, as shown in Fig. 1(b) induces the electric-field on one of the two arms of the MZI, which results in a change of refractive index and an unbalanced modulation.

The waveguide width is 7.5 μm and the splitting angle of the Y-branch is 0.6°. The gap width between two adjacent waveguide of the directional coupler is 5 μm and the parallel coupling length L_c is 2.8 mm. The distance between the inner edges of two output waveguides is 50 μm. The length and gap of the modulation electrode connected to the dipole patch antenna are 10 mm and 12 μm.

When no voltage was applied, the optical output powers of the two branches were almost identical. It was observed that the switching voltage applied to modulate the light power of either branch from a bar state (maximum intensity) to a cross state (minimum intensity) was ~16.6 V, corresponding to a light-extinction ratio of ~14.7 dB as shown in Fig. 2(a). The spectrum outputs for input of 20 dBm to the TEM cell at frequencies of 10, 50 and, 70 MHz, respectively have been measured. The measured rf power received at the photo-detector was measured to -101.5, -110.9, and -122.2 dBm, at the frequencies. The noise floor is about -130 dBm. The internal electric-field of 29.8 V/m in the TEM cell produces an SNR of 28.5, 19.1, and 7.8 dB, respectively at the frequencies. Therefore, the minimum detectable electric-fields are ~1.12, ~3.3, and 12.13 V/m, respectively based on $E_{min} = 29.8\times10^{(-SNR/20)}$ V/m at the frequencies.

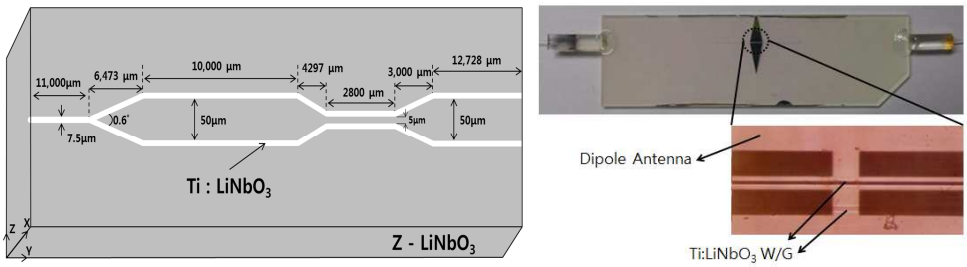
The Fig. 3(a) shows the sensitivity curves at frequencies of 10, 50 and 100 MHz. We can confirm that the graph shows almost linear response for applied electric-field intensity from 0.293 V/m to 23.2 V/m, even though some data were not on the line, yet very close. The device has a dynamic range of about ~22, ~18, and ~12 dB at frequencies of 10, 50, and 100 MHz, respectively. Moreover, the measuring frequency response of the sensor at rf input power of 20 dBm was obtained in the TEM cell, showing almost flat response from 1 MHz to ~50 MHz, as seen in Fig. 3(b).

In conclusion, a 1×2 Y-fed balanced-bridge Mach-Zehnder interferometer which can be used as an integrated-optic electric-field sensor has been presented. Modulators have been formed from titanium-diffused lithium niobate waveguides at the wavelength of 1.3 μm. A dc switching voltage of ~16.6 V and an extinction ratio of ~14.7 dB are measured. For a 20 dBm rf power, the minimum detectable electric-fields are ~1.12

V/m and ~3.3 V/m corresponding to a dynamic range of about ~22 dB and ~18 dB at frequencies 10 MHz and 50 MHz, respectively. The sensors exhibit almost linear response for the applied electric-field intensity from 0.29 V/m to 29.8 V/m.

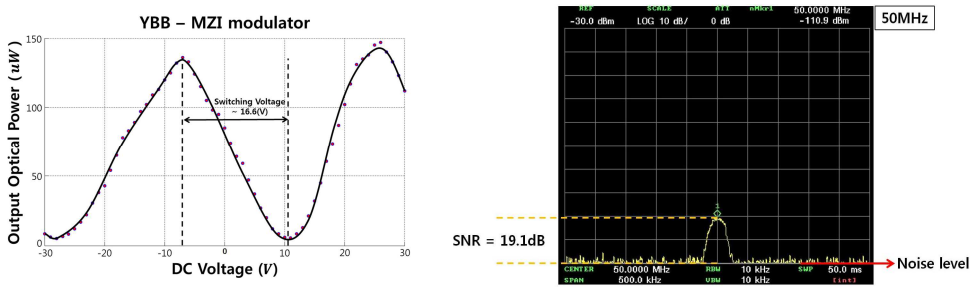
References

[1] H. Jung, *Integrated-Optic Electric-Field Utilizing a Ti:LiNbO₃ Y-fed Balanced-Bridge Mach-Zehnder Interferometric Modulator With a Segmented Dipole Antenna*, Journal of the Optical Society of Korea, vol. 18, no. 6, pp. 739-745, 2014



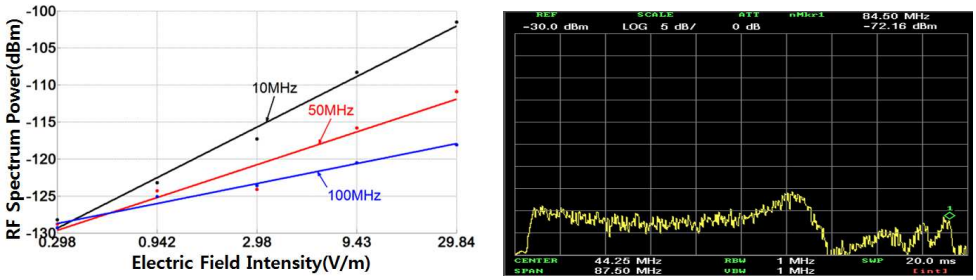
(a) **(b)**

Fig. 1. Schematic diagrams and dimensions of (a) YBB-MZI structure and (b) photograph of fabricated device with dipole patch antenna arrangement and pig-tailed optical fiber.



(a) **(b)**

Fig. 2. (a) Measured optical output power intensity versus applied dc voltage (b) RF spectrum of 50 MHz input signal with a power level of 100 mW.



(a) **(b)**

Fig. 3. (a) Photodetected signal power versus electric-field strength at different frequencies (b) the frequency response of the sensor.