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Low Voltage Ridge Guide $LiNbO_3$ Mach-Zehnder Modulator

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Mach-Zehnder type interferometric (MZI) modulators based on lithium niobate ($LiNbO_3$) are key components in today's optical communication systems. Despite their excellent properties, future optical networks will require devices of lower drive voltage (V_π) and even higher bandwidth capability (40 GHz or higher). In particular, values of $V_\pi \leq 2$ V would allow using much cheaper driving electronics. This was our motivation to develop MZI modulators with two novel characteristics: (i) the whole interferometer including Y-junctions consists of low loss ridge waveguides of strong light confinement [1]; (ii) a special electrode structure – designed for high bandwidth operation - enables low drive voltages.

A novel "Surface-Compact Coplanar Waveguide" (SCCPW) electrode structure was developed (Fig. 1, left) [2]. In contrast to the conventional CPW structure, sometimes used on ridge guides, two narrow electrodes are placed on top of the ridges accompanied by one semi-infinite ground electrode on the same level. Trenches are etched into the planar substrate to fabricate ridges with vertical guiding obtained by Ti-indiffusion. The results of numerical simulations show that the SCCPW design considerably improves the traditional approach of a CPW electrode on a ridge structure. Calculated values of voltage-length product ($V_\pi L$), microwave effective index (n_{eff}^{MW}), and impedance (Z) are shown in Fig. 1, on the right.

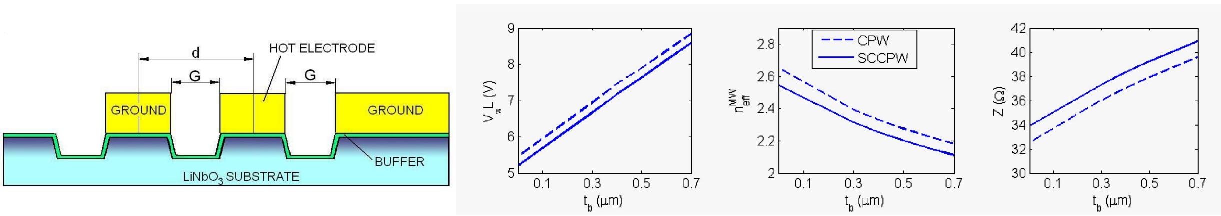

Fig. 1 Left: Cross section of the novel SCCPW electrode structure. Right: Modelling results comparing voltage-length product, effective microwave index, and characteristic impedance for CPW and SCCPW electrode structures.

A number of MZI-modulators have been developed. The fabrication procedure consists of wet etching of the whole interferometer ridge structure, of Ti-doping of the ridges using a self-aligned photolithographic technique, of the deposition of a SiO_2 buffer layer to optically isolate the electrodes, and of the electrode definition via Cr/Au deposition. Micrographs of two sections of a fabricated interferometer are shown in Fig. 2.

The measured propagation losses are 0.4 dB/cm (TM) in 8-9 µm wide, 3-4 µm high ridge guides. A modulator extinction ratio of -20 dB has been achieved (Fig. 2). At low operation frequencies a V_π voltage of 2.14 V and a voltage-length product $V_\pi L$ of 5.35 Vcm have been measured (Fig. 2). This is a significant improvement in comparison with results previously published for ridge guide modulators with $V_\pi L > 8$ Vcm [3,4].

Though the devices were designed for high bandwidth operation, their RF-properties could not yet be tested. This is due to the fact that a growth of the electrode thickness by electro-plating was not possible in our lab. With thick electrodes of low Ohmic losses a bandwidth exceeding 40 GHz can be expected.

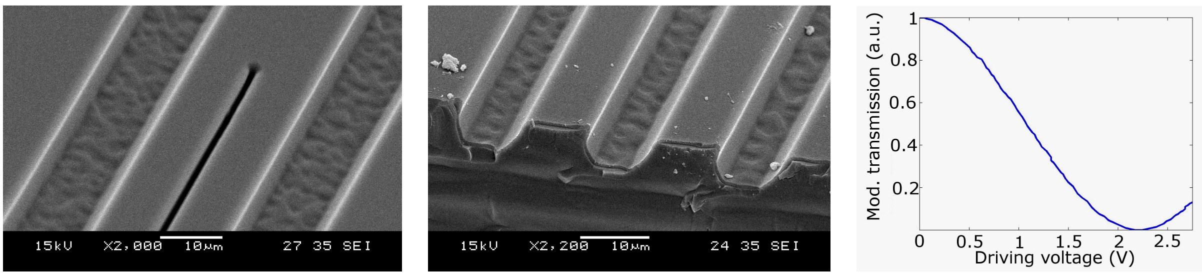

Fig. 2 Left: SEM micrographs of a ridge Y-splitter. Middle: The two ridge guide interferometer arms coated with a SiO_2 buffer layer. Right: Modulator transmission versus the applied driving voltage.

References

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