Ultra Low Loss Split Y- Junctions: Application to QPSK- Lithium Niobate Modulators

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The use of especially suited low-loss split-Y junctions greatly reduces the optical losses of complex optical structures such as QPSK- modulators. Optical losses as low as -4dB were measured, including optical connectors on an optical window covering the entire S & C- telecommunications bands and part of the L- one.

Quadrature phase shift keying, lithium niobate, Y-junction, optical losses.

I. Introduction

Over the last few years, driven by the increase of data- rates in optical telecommunication, integration complexity is increasing in particular since Quadrature Phase Shift Keying (QPSK) -like modulation formats require the use of several interferometers nested inside one another; thereby increasing the number of Y-junctions per device [1][2]. Moreover the proximity of several high speed modulators on the same chips force to enlarge separation between the interferometers in order to avoid microwave and optical cross-talk [3]. Excess losses in Y- junctions can thus become a limiting factor in terms of optical budget in a link. They have to be reduced as the complexity of chip integration increases.

Besides different ways to design low-loss Y- junctions [4][5][6], we use and report on a specially designed split structure based on mode shaping. This design is easy to apply in technological processing and highly reproducible at industrial level in particular for lithium niobate integrated structures [7][8]. We report here the application of such split Y- junctions in complex structure like QPSK- broadband modulators that includes six Y- junctions per device. The resulting overall optical insertion losses are less than 4dB including optical connectors for 2x 25Gbs 1550nm- QPSK modulators integrated by titanium indiffusion on X- Cut $LiNbO_3$ substrates.

II. Description and Principle of Split Y-Junctions

Regular single-mode Y- junctions are based on a simple structure: one input single mode waveguide connected to two other ones with a separation angle, see Fig 1. They can be seen as the succession of, a straight guide section of width Wi, a tapered section where the width expands progressively from Wi to 2Wo+D, and a branching section of half angle α and width Wo [9]. This kind of Y- junction suffers from modal instabilities due to the large taper that supports higher order propagation modes. Theoretically, the truncated tip of size D is considered to be null. In practice, resulting from technological process limitations it is typically of the order of one micron. It induces optical losses that can reach 0.5 dB for wavelengths around 1550 nm.

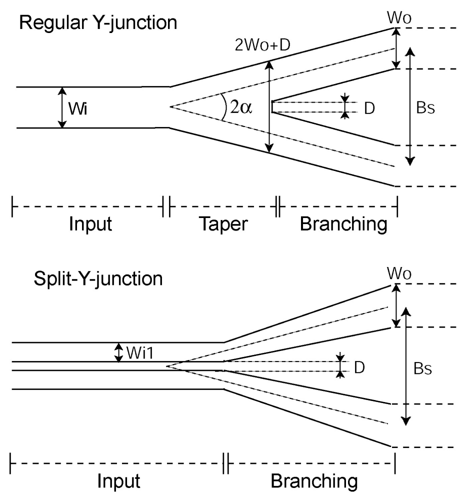

Fig. 1: Scheme of a conventional Y-junction (above) and of a split Y-junction (bottom).

A split Y- junction does not require the use of a tapered section. It consists in two symmetric waveguides structures placed side- by- side, see Fig 1. A first singlemode input section is made of two narrow straight waveguides of width Wi1, positioned in close proximity. The gap between them is D. The following part is a branching section of angle 2α where the waveguide width varies from Wi1 to Wo; Wo being the width of the output waveguides that have to be connected. For a suitable choice of Wi1 and D, the input section acts as an efficient mode filter- shaper. It insures a highly stable power splitting ratio; thus increases the resulting extinction ratios of the MZI using this kind of split junction [7]. As there is no longer truncation at the beginning of the branching section, no excess losses are generated at the transition.

Samples were made by titanium indiffusion in lithium niobate X-Cut wafers, including regular and split Y- junctions. Both kind of junctions had the same length and the same output separation. For conventional Y junctions, the optical losses were measured in the range 0.5-0.6 dB while they were in between 0.25dB and 0.38dB for the split Y- ones. The mean gain on excess losses expressed in dB, is 45% per Y-junction.The impact can obviously be noticeable as the number of junctions increases like for a Dual Parallel Modulator (QPSK) where six Y-junctions are required with large branch separation.

III. APPLICATION TO X-CUT $LiNbO_3$ QPSK- MODULATOR

A QPSK modulator is composed of two sub-Mach-Zehnder interferometers nested inside a larger one as described on Fig. 2.

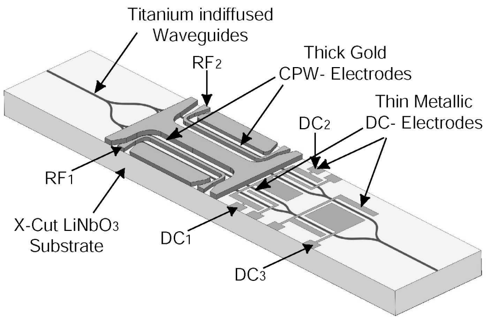

Fig.2: X-Cut LiNbO3
Broadband QPSK modulator chip design.

The waveguide structure is made by titanium indiffusion in X-Cut $LiNbO_3$ substrate. The optical waveguide pattern, as depicted in Fig 3, includes six split Y- junctions. Each split input section is made as described in previous section. The Y-output branching separations, center to center, are 25µm ("g" in Fig. 3). The two main input-output split- Y- junctions are followed by S-bent waveguides so as to reach a 140 µm- gap ("G"). The total length of the structure is 60 mm.

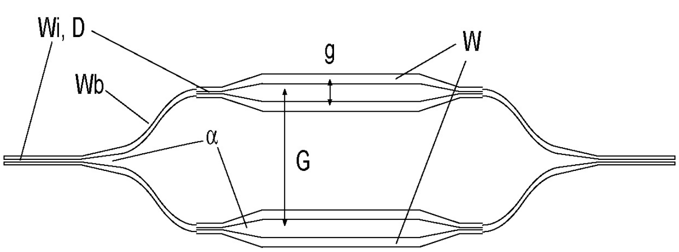

Fig. 3: scheme of the optical waguide structure of the fabricated QPSK modulator using split-Y junctions.

A set of RF and DC electrodes are fabricated on the top surface as for a broadband intensity modulator. The chips are optically polished and pigtailed with polarization maintaining, ended by APC- connectors. The optical losses and the static extinction ratio have been measured from 1460 nm to 1580 nm, covering the entire S- and C- telecommunication bands and part of the L- one. As seen in Fig. 4, the resulting insertion losses are about –4 dB over the whole wavelength range, including connectors, which is to our knowledge far below what has been reported to date on X-cut Ti:$LiNbO_3$ QPSK modulators. The resulting extinction ratios are better than 30dB, showing highly stable power propagation and splitting in all the Y- junctions.

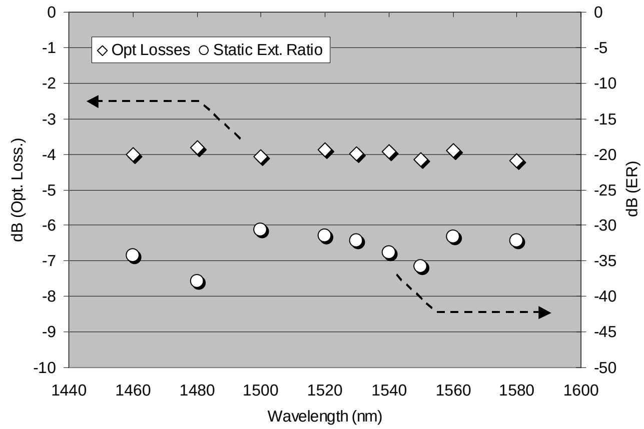

Fig. 4: Plots of optical losses and static extinction ratios vs. optical wavelength.

IV. CONCLUSIONS

We have fabricated a broadband QPSK modulator integrated in X-cut lithium niobate by titanium indifusion using very low-loss split Y- junctions. The resulting optical losses including optical connectors were as low as -4 dB from 1460 nm to 1580 nm. This represents a net gain of at least 2dB compared to the insertion losses of QPSK modulators based on standard Y- junctions. The measured extinction ratios were better than 30dB in the same optical bandwidth.

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