CHARACTERISTICS OF COPLANAR WAVEGUIDES WITH METAL COATING ON MULTILAYER SUBSTRATE:APPLICATION TO BROADBAND LiNb03:Ti TRAVELING WAVE LIGHT MODULATORS/SWITCH

D. BOURREAU - P. GUILLON

I.R.C.O.M., U.A. C.N.R.S. 356, Faculté des Sciences, 123 Av. A. Thomas,
87060 LIMOGES Cédex, FRANCE

ABSTRACT

We propose in this paper the design of non symetric electrodes for broadband electrooptic modulator with low drive voltage. Traveling wave electrodes lateraly shifted to reverse the direction of the applied electric field, are used to obtain a more constant phase variation.

The finite elements method is used to compute the electrodes characteristics taking into account both the electrodes and the buffer layer thickness.

Numerical results are given for LiNb03:Ti substrate at 1.52 um wavelength.

INTRODUCTION

To overcome materials limitation bandwidth in optical modulators, some authors (1) have proposed the concept of effective velocity matching based on device geometry : the traveling wave electrodes are lateraly shifted periodically to compensate the microwave optical walkoff.

We propose and analyze structures having a constant phase variation. In particular, it was shown that microwave losses effects at high frequencies can be compensated by increasing phase variation at these frequencies.

OPTICAL CHARACTERISTIC

In Fig.1 we give the geometry of a typical electroptic modulator composed of :

- two diffused titanium strips in which will be excited TM modes ,
- a coplanar microwave line,
- a Si02 buffer layer placed in sandwich between the optical waveguides and the metallic electrodes, to prevent optical reflection.

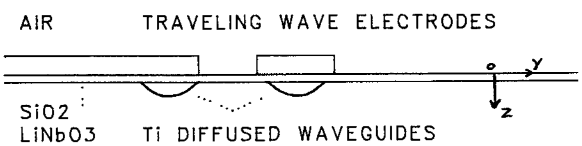


Fig1 : TRAVELING WAVE MODULATOR

Using results published in (2) and (3), to compute TM effective index mode, we have drawn (Fig.2) the optical coupled length Lc versus the distance D which separate the two titanium strips. W and e are respectively the titanium width and thickness, and, t and T are respectively the time and temperature diffusion.

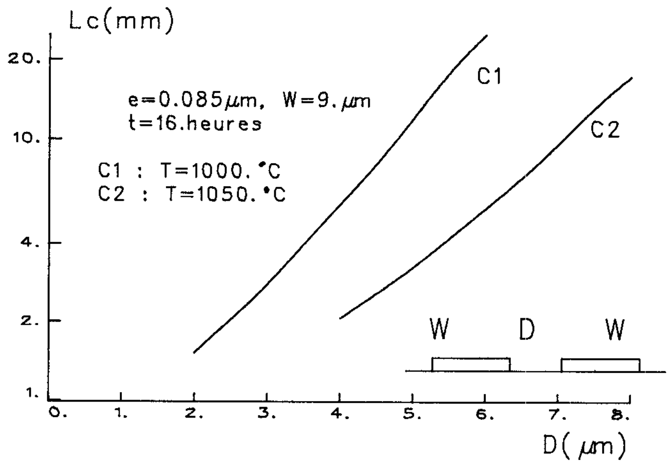


Fig2 : OPTICAL COUPLED LENGTH

MICROWAVE CHARACTERISTICS OF COPLANAR ELECTRODES

In (4) we have proposed a new method to measure the complex permittivity tensor values of electrooptic materials. For LiNb03 at 10 GHz we have measured :

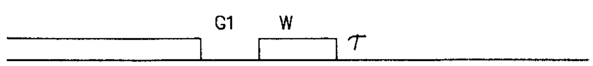
$E_{//} = 45.$

$E_{\perp} = 28.$

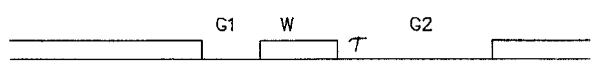
$tg(\delta) = 4.3\ 10^{-4}$

In traveling waves electrooptic modulator, we have to consider 2 types of coplanar electrodes (Fig.3). One with 2 no symetric metallic strips and the other with 3 no symetric metallic strips.

Fig3



a) ELECTRODE with 2 COPLANAR STRIPS



b) ELECTRODE with 3 COPLANAR STRIPS

1988 IEEE MTT-S Digest

In each case, the lowest width strip is the microwave conductor, and the others are the ground plane.

The electrodes characteristics have been computed by using the finite elements method. Using QUASITEM approximation, the fields along the propagation axis ($\vec{ox}$) are supposed equal to zero.

For a 3 metallic strips (thickness σ=3 um), we have drawn as an example the equipotential lines (Fig.4).

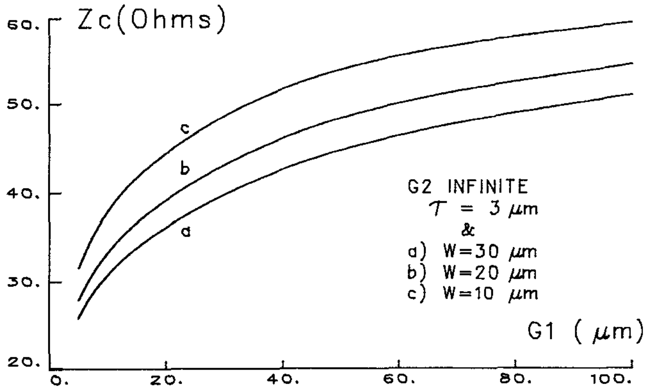
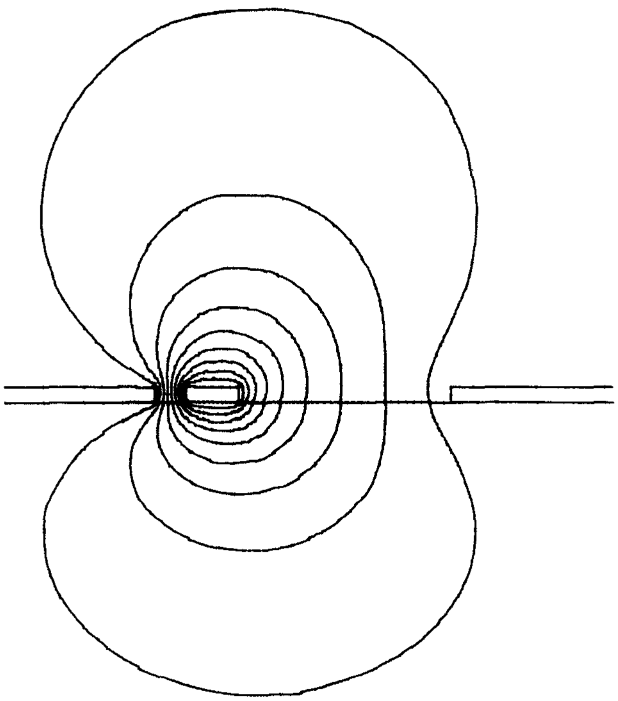


Fig5 : CHARACTERISTIC IMPEDANCE

We have also studied the characteristic impedance Zc and the effective permittivity εeff, that we can obtained with these two types of coplanar lines. Fig.5 and 6 are relative to the 2 metallic strip electrodes on $LiNbO_3$ substrate.



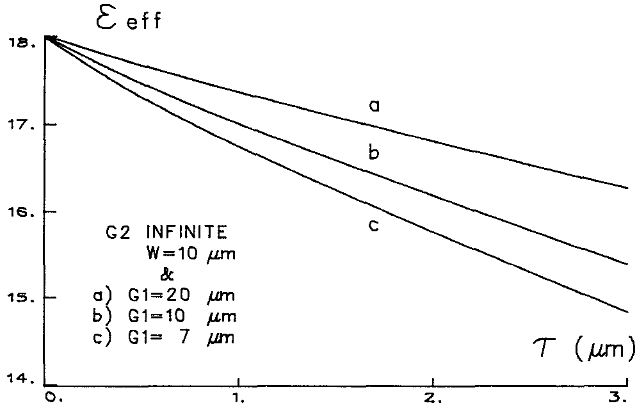


Fig6 : EFFECTIVE PERMITTIVITY

From this analysis, we can show first that the conductors thickness cannot be neglected, and that we cannot have simultaneously a matched 50 Ohms electrode and an optimum overlap integral.

However the SiO_2 buffer layer (εr=3.83) increases the characteristic impedance. Fig.7 and 8 relative to the 3 metallic strip electrodes, show the variation of εeff and Zc as a function of SiO_2 buffer layer thickness.

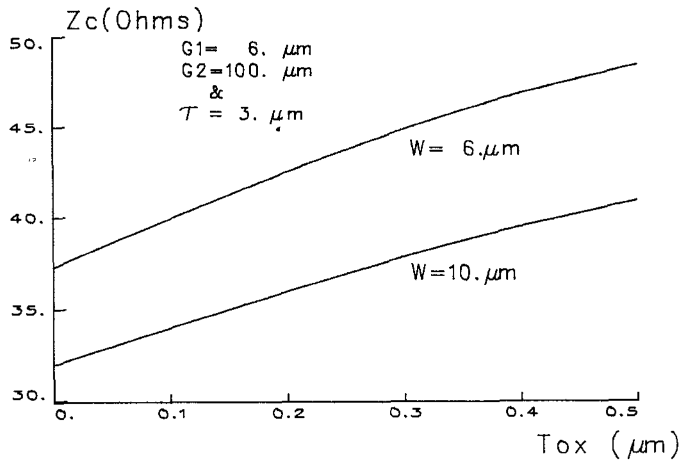


Fig7 : CHARACTERISTIC IMPEDANCE

Fig4 : EQUIPOTENTIAL LINES

W=10. μm
G1= 6. μm Zc=31.68 Ohms
G2=40. μm εeff=14.45
T = 3. μm

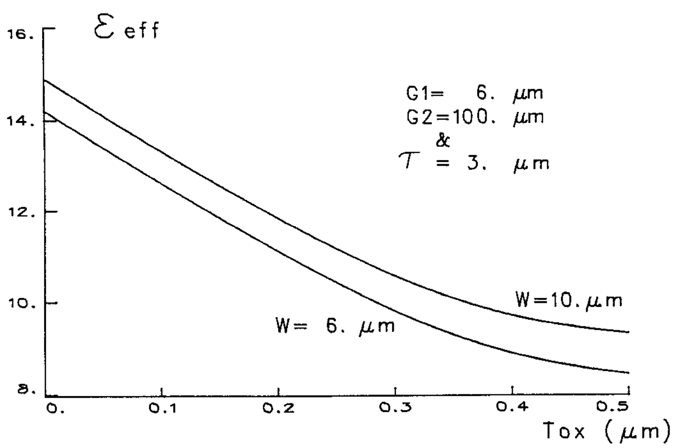


Fig8 : EFFECTIVE PERMITTIVITY

So in conclusion, it is shown that in the electrooptic traveling wave modulator analysis, it was necessary to take into account both electrodes and substrate dimensions to optimize the electrode characteristics (Zc & εeff). These parameters are very important for the optimization of electrooptic traveling wave modulator characteristics.

INTENSITY MODULATOR

For periodic shift and reversed electrodes, it has been shown that the induced phase shift was also periodic. But some other geometries of structures permit to obtain more constant phase shift.

Non periodic structures of modulator devices are presented in Fig.9 ; we note them :

II case : intermitent interaction

IE case : increase efficiency

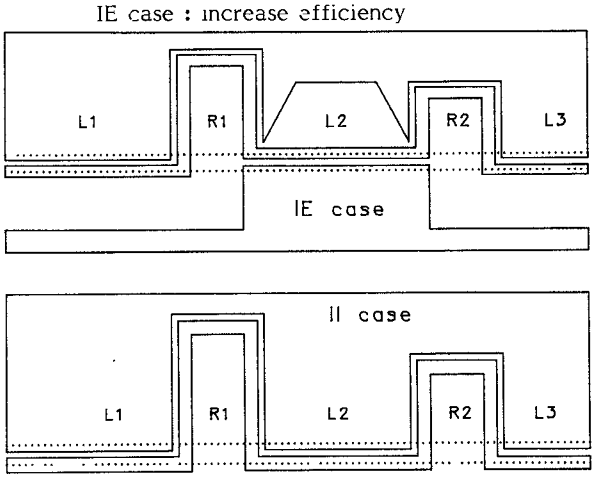


Fig9 : ELECTRODES DEVICES

The uniform case and the phase reversed case are equivalent respectively, to the II and the IE case, with Ri=0 (i=1,N).

Phase results should be interesting only for MACH-ZHENDER modulators, but in this paper we consider essentially directional couplers which have 2 inputs and 2 outputs.

The static characteristics of such directional couplers are obtained by multiplying the transfert matrix of each element of the N length (Li, i=1,N) electrodes (5).

Numerical results give the minimum drive voltage for an optimum optical coupled length and for a determined total circuit length. In Fig.10 we give as an example an operational diagram for :

N=4, L1=L4 and L2=L3=2*L1

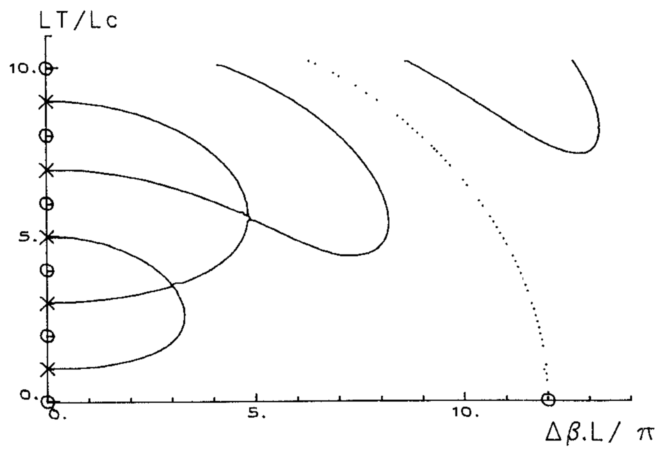


Fig10 : OPERATIONAL DIAGRAM, N=4, L2=L3=2*L1=2*L4

We can note that a non symetric length electrodes circuit destroys the cross and parallel states. However, some values of integer ratio L/Lc, should be interesting for modulation ; here : L/Lc=2.

To estimate the bandwidth, we first compute the electrode dimensions to have an optimum overlap for a given optical coupled length ; the electrode gap (G) is taken equal to the distance between the 2 dielectric waveguides, and generaly the electrode width is equal to the titanium diffused width.

We have also choosen to match the electrodes to 50 Ohms, for minimum microwave reflection losses.

The optical coupled length is taken equal to 7.5 mm, Nm and No are the microwave and the optic indexes, which are respectively equal to 3.4 and 2.14.

With a microwave attenuation equal to 1 dB/cm/$\sqrt{Ghz}$, we give in Fig.11 the bandwidth for the non symetric case. The meanders are supposed to be not coupled.

L1=7.5 L2=5.25 & L3=1.75 mm

R1=0 & R2=0 or 1.75

For non symetric structures, the drive voltage and the bandwidth increase, but the analysis of the circuit parameters permitsto optimize simulameously these two characteristics.

CONCLUSION

We have extended optical modulation electrodes to non symetric structures. Then we have shown that choosing appropriate circuits characteristics we can increase bandwidth of this type of electrooptic devices.

We have also shown that the electrodes and buffer layer thickness cannot be neglected.

ACKNOWLEDGMENT

This work is support by a grant of the CNET (Bagneux FRANCE) (Contract N° 66.6B.018).

We also acknowledge M. AUBOURG who help us to solve numerical problems.

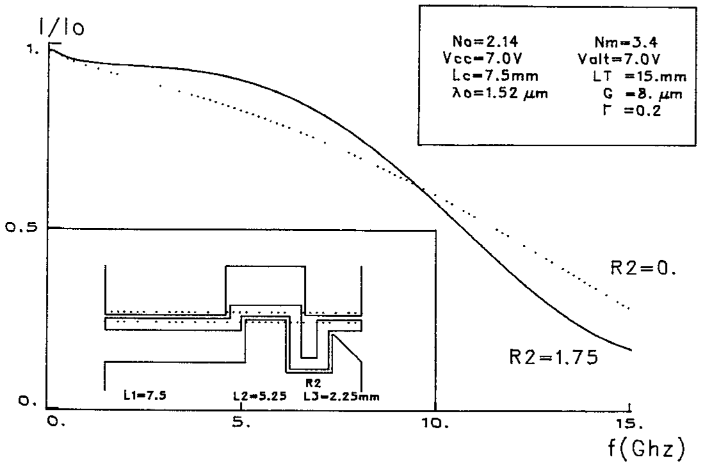


Fig11 : BANDWIDTH for &o=1.dB/Cm$\sqrt{Ghz}$

REFERENCES

[1] **Rod. C. ALFERNESS, S.K. KOROTKY & E.A. MARCARILI,** "Velocity Matching Techniques for Integrated Optic Traveling Wave Switch/Modulators", IEEE JQE, Vol. QE-20, N°3, March 1984.

[2] **S. FOUCHET, A. CARENCO, C. DAGUET, R. GUGLIELMI & L. RIVIERE,** "Wavelength Dispersion of Ti Induced Refractive Index change in LiNb03 as a Function of Diffusion Parameters", Journal of Lightwave Technology, Vol. LT-5, N°5, May 1987.

[3] **J.C. BAUEMERT & J.A. HOFFNAGLE,** "Numerical Method for the Calculation of Mode Fields and Propagation Constants in Optical Waveguides", Journal of Lightwave Technology, Vol. LT-4, N°11, November 1987

[4] **D. BOURREAU, M. CHATARD-MOULIN, P. GUILLON** "Complex permittivity Measurement of Optoelectronic Substrate", Electronic Letters, 27 March 1986, Vol.22, pp. 399-400

[5] **HERWIG KOGELNIK & RONALD V. SXHMIDT,** "Switch Directional Couplers with Alternating dB", IEEE JQE, Vol. QE-12, N°7, July 1976