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A2-1 A New Light Modulator Using Perturbation of Synchronism between Two Coupled Guides

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To materialize a new type of light modulator whose basic principle was proposed by Kurazono and others[1), a new semiconductor device is proposed and some experimental results are presented in this paper. This device can be used as a modulator as well as a directional coupler in optical integrated circuits.

As shown in Fig.1 this device consists of p^+,n,n^+,n, and n^+-type semiconductor layers. Two n-type layers operate as coupled optical waveguides (guide 1,2). If one applies reverse voltage v on the p^+-n junction, the width of the depletion layer gets wider, and because of the depletion of free carriers the refractive index of the depletion layer increases. So the propagation constant β_1 of guide 1 increases. Furthermore, if the device is made of electrooptic crystal with proper crystallographic orientation (refer Fig.1 in case of $\bar{4}$3m symmetry), further increase of β_1 is obtained due to the linear electrooptic effect in the depletion layer. Thus the synchronism and the power exchange between two optical waves are perturbed and the output light intensity from guide 1 or 2 is modulated by the reverse voltage. This is carried out most efficiently when the modulator length L is equal to the complete power exchange length L_0 (=π/2C, C:coupling coefficient). Design examples for GaAs are shown in Table 1.

GaAs samples were fabricated through applying semiconductor laser technology. Nominal design data for these samples are almost equal to those for example (1) in Table 1. The experimental arrangement is as Fig.2. He-Ne laser beam at 1.15μm is focused on the cleaved surface of the sample and the image of the output face is magnified by two lenses. By the sinusoidally vibrating mirror and the slit just in front of the photomultiplier, the light intensity profile at the output face is displayed on an oscilloscope. Figs.3~5 are photographs of the profiles. Since the distance from point A to B corresponds to approximately 5μm on the sample, they must be indicating the positions of guide 1 and 2 respectively. From Figs.3 and 4 for TE mode, it is considered that in the actual sample β_1(v=0V) is smaller than β_2(propagation constant of guide 2) by 24 X $10^{-4}\mu m^{-1}$. If this is the case and $\Delta\beta_1$ is equal to 3.9 X $10^{-4}\mu m^{-1}$, theoretical values for ΔI_1 in Fig.3 and ΔI_2[$=I_2(10V)-I_2(0V)$] in Fig.4 areabout -0.12 I_0, which are in fair agreement with the measured values (around -0.15 I_0). Fig.5 is for TM mode with focused light into guide 1, and comparing with Fig.3 the modulation degree is about a half of that in TE mode. This is reasonable because electrooptic effect is almost zero for TM mode. Details of the performance of this device will be discussed further.

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Ref.; 1) S. Kurazono et al: Trans.Inst.Elect.Commun.Engrs.Japan, 55-C,p.61,1972.

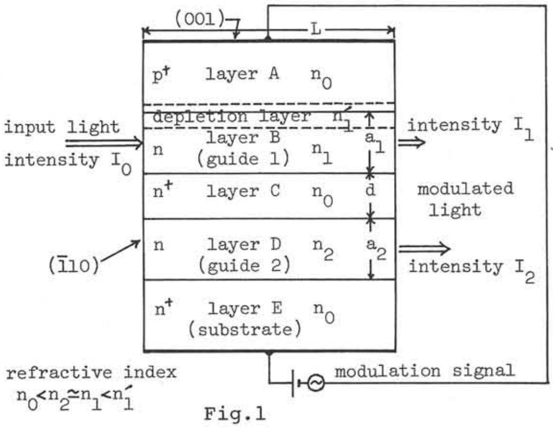

Fig.1

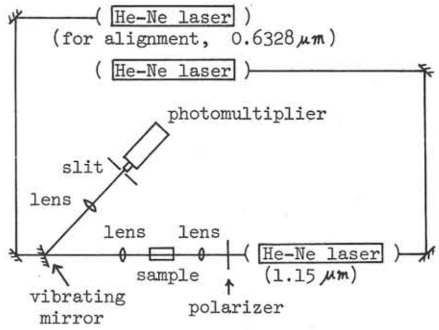

Fig.2 Experimental Arrangement

Table 1 Design Examples

[GaAs, λ_0=1.15μm, TE_0 mode, $n_1=n_2=3.45$, $\beta_1(v=0V)=\beta_2$, input light into guide 1, $I_2(v=0V)=I_0$]

	(1)	(2)	(3)	(4)
n_1/n_0	1.001	1.001	1.01	1.01
carrier concentration of layer A,C,E [cm^{-3}]	1.6 X 10^{18}	1.6 X 10^{18}	1.6 X 10^{19}	1.6 X 10^{19}
carrier concentration of layer B,D [cm^{-3}]	1.6 X 10^{17}	1.6 X 10^{17}	1.6 X 10^{17}	1.6 X 10^{17}
guide width $a_1(\approx a_2)$ [μm]	3.5	3.5	1.1	1.1
separation between guides d [μm]	1.5	3.1	1.4	2.2
modulator length $L(=L_0)$ [mm]	1.0	2.8	0.7	3.4
$\Delta\beta_1[=\beta_1(v=10V)-\beta_1(v=0V)]$ [$10^{-4}\mu m^{-1}$]	3.9	3.9	15.9	15.9
change in output light intensity from guide 1 $\Delta I_1/I_0$ [$\Delta I_1=I_1(v=10V)-I_1(v=0V)$]	0.016	0.12	0.12	1

(I) reverse voltage =0V

(II) reverse voltage =10V

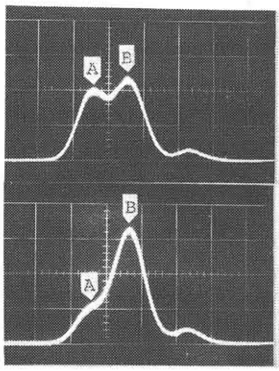

Fig.3 TE mode focused light into guide 1

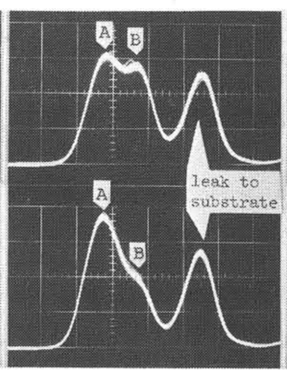

Fig.4 TE mode focused light into guide 2

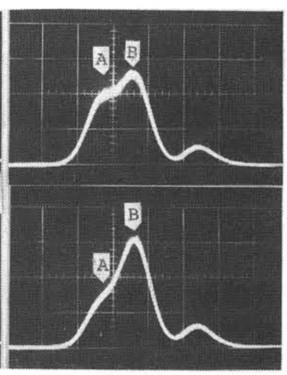

Fig.5 TM mode focused light into guide 1