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Novel Waveguide GaInAs/InP MQW Optical Deflector Using Comb Like Electrode

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1. Introduction

Optical switches and modulators are important devices for realizing the high-speed optical exchange systems and opto-electronic integrated circuits. As one of the device of them, we have researched the optical deflectors, which can deflect light in any three-dimensional direction. The optical deflector will be applicable as the 1×n optical switch in the optical exchange system or the free space optical deflector in the optical interconnection system. As a material for the high-speed operation of device, we have taken notice of the Quantum Confined Stark Effect [1] with applied electric field to the quantum wells.

In this report, we show the novel waveguide optical deflector using electric field refractive index change in the GaInAs/InP MQW under the comb like electrode. In the 200μm comb length refractive index region which included 40 number of triangle (8μm width×5μm height), we have obtained the deflected angle of 2.5-degree and 30nm bandwidth in the 1.55μm wavelength region.

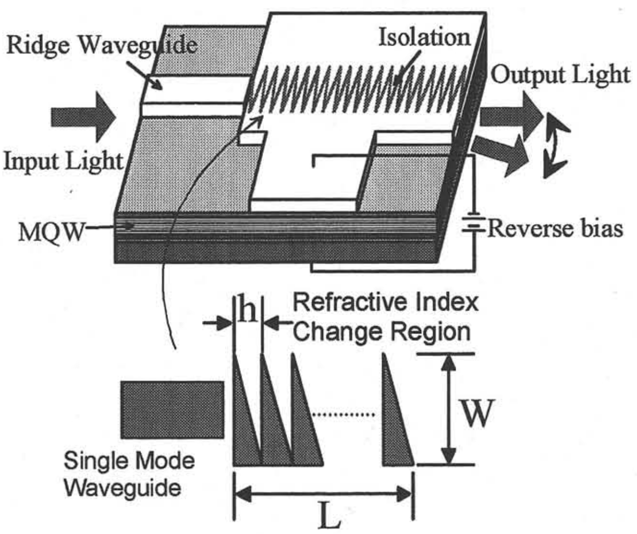

Fig.1 Device Structure

2. Device structure and operation principle

The schematic structure of the comb type optical deflector is shown in Fig.1. The ridge type optical waveguide is composed of the GaInAs/InP MQW structure. In the refractive index variation region, there is comb like electrode, which make the spatial phase change through the refractive index variation in the MQW waveguide by the applied electric field. The device structure is consisted of p-i-n structure and the electric field is applied to the i-MQW waveguide by the applied reverse bias voltage to the device.

Then we explain the operational principle of the device. The equal phase plane is perpendicular to the input waveguide before the incident of the refractive index distributed region. In the refractive index distributed region, the refractive index varies spatially for the input light, and the light suffers the phase difference. Hence the equal phase plane is inclined with the propagation of light, and the light is deflected.

We also show the numerical calculation of the comb type optical deflector. In the numerical calculation of the optical deflector, we used the Finite Difference Beam Propagation Method [2,3]. We analyzed this device as the two dimensional problem by using the equivalent refractive index method to the perpendicular of the substrate. The refractive index difference of the input waveguide for the lateral direction is assumed 0.1%, and the width of the waveguide is assumed 5μm to satisfy the single mode waveguide condition. The length L of the refractive index variation region is assumed 100μm, and we calculate the defection angle of the device.

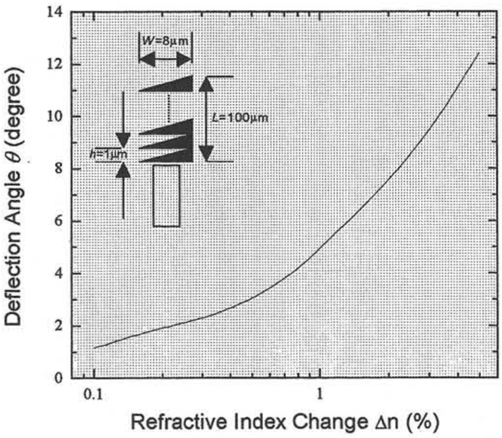

Fig.2 Numerical Analysis Using FD-BPM

Figure 2 shows the refractive index variation Δn dependence on the deflection angle θ. In the calculation, the height of comb of 1 μm and the width of comb of 8μm is obtained from the most suitable condition under the refractive index variation of 1% and the electrode length of 100μm. This means that it is possible to control deflection angle by changing the refractive index variation.

3. Experimental Results

In the following, we show the experimental results of the fabricated comb type optical deflector. The fabricated device was consisted of n-i-p GaInAs/InP MQW structure. The wafer was grown by low pressure MOVPE, and MQW contains 40 pair of 10nm GaInAs well and 9nm InP barrier. And the electric field is applied to the MQW by applying reverse bias to the n-i-p structure. In this deflector, the patterning of the comb electrode is important, and we fabricated this region by using electron beam lithography. The width of comb W was 8μm, the height of comb h was 5μm and the length of the electrode L was 200μm. The input waveguide was ridge type waveguide, and it fabricated by selectively etched the p-InP cladding layer. We obtained the 0.1% lateral refractive index difference by controlling the height of ridge. The width of the waveguide was 5μm.

In the measurement, we inputted 1.55μm-band tunable laser light to the single mode waveguide by the lensed facet optical fiber, and we observed the output light by using the infrared visicon camera.

Figure 3 shows the relation between the applied voltage and the deflection angle, intensity where the input light wavelength was 1.55μm. The deflection intensity is defined as the ratio of the power between with and without applied electric field. By increasing the applied voltage to the device, the deflection angle was increased, and it was proportional to the second power of the applied voltage. This because that the refractive index variation in the quantum well by the Quantum Confined Stark Effect with applied electric field is proportional to the second power of the applied electric field. From this figure, we obtained 2.5-degree deflection angle at maximum and from these experimental results, we can estimate about 0.4% refractive index variation in the MQW waveguide. When the applied voltage was increased, the deflection intensity was decreased, and this is because of the increase of the absorption in the waveguide.

Figure 4 show the input light wavelength dependence on the deflection angle. We observed the deflection in the longer wavelength of 1.545μm. At the shorter wavelength of 1.545μm, there are large absorption by the applied electric field, and we could not observe the output intensity. From this figure, there were about 30nm operational wavelength bandwidth that was between 1.56μm and 1.59μm.

4. Conclusions

We have fabricated the comb type optical deflectors using InGaAs/InP MQW structure in the 1.55μm wavelength range. We obtained the around 2.5-degree deflection angle by the 12.5V applied voltage with the 0.4% refractive index change.

References

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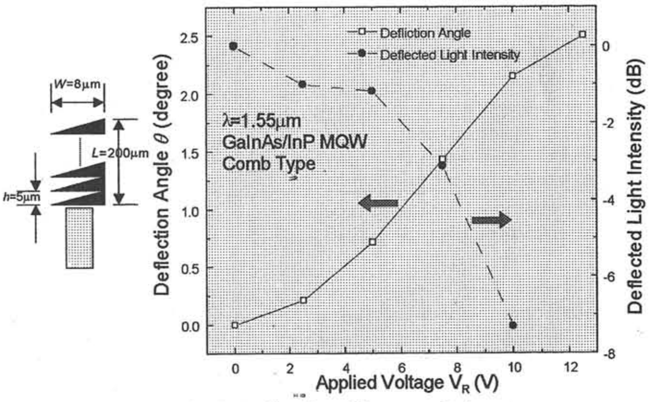

Fig.3 Deflection Characteristics

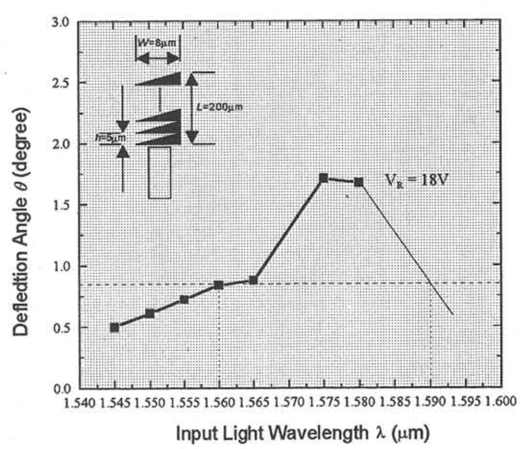

Fig.4 Input Light Wavelength dependence on Deflection Angle in Comb Type Optical Deflector