

second wafer was grown on p+ (001) InP substrate. It consists of 0.2 μm p+ InGaAs layer, followed by 2 μm p InP layer and the same intrinsic InGaAsP and InP layers as the first wafer. The device fabrication starts by cleaving two approximately 8 \times 12 mm² samples from each of the grown wafers. The top 0.4 μm InP layer of p+ samples is removed. On n+ samples, a ridge waveguide structure with 2-3 μm width along the [110] direction is formed using standard photolithography and selective wet etching techniques. The n+ and p+ samples are then fused together at a temperature of 630°C in a hydrogen atmosphere for 50 minutes. In one case (fused sample A), the p+ sample was oriented so that its [110] direction was parallel to the waveguides on n+ substrate (i.e., anti-phase fusion). For fused sample B, the orientation of p+ sample was chosen to get the in-phase fusion. After fusion, p+ InP substrates for both samples are removed using HCl etching. Standard ohmic contacts were formed on both sides of the wafers to be able to apply a bias. Figure 1 shows the stain etched SEM pictures for both anti-phase (A) and in-phase (B) FVCs.

To characterize FVCs, a tunable laser source is used to input TE-polarized light through a lensed single mode fiber. The image at the output of coupler facet is recorded with an IR camera. First, the passive switching of the two FVC structures was characterized by changing the input wavelength [3]. The oscillation period of sample A (11nm) and sample B (13nm) matches very well with the different length of the couplers (sample A: 6.9mm long, sample B: 5.9mm long) (Figure 2). This shows that samples A

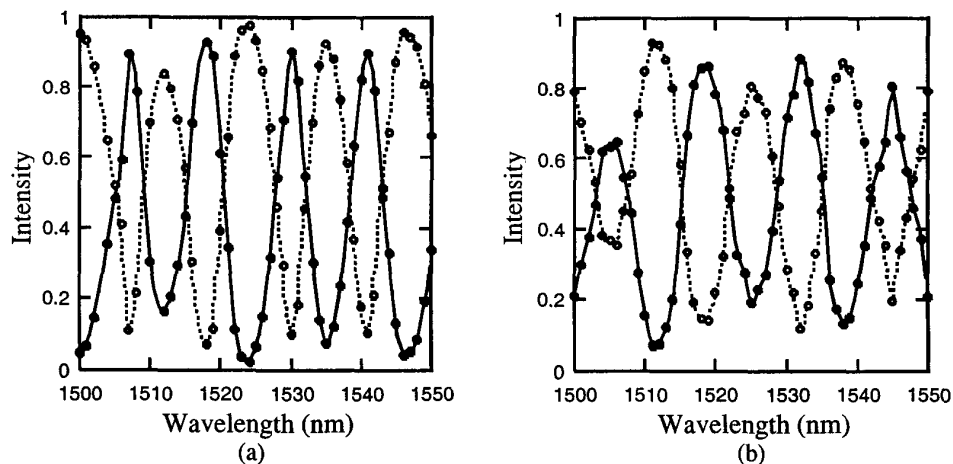


Figure 2. The light intensity at the output of upper (solid line) and lower (dash line) waveguides of (a) anti-phase, (b) in-phase FVCs as a function of wavelength.

and B have the same coupling length which is about 70 μm . Then a reverse bias is applied to both samples. The normalized intensities at the output of upper and lower waveguides as a function of bias voltage are shown in figure 3 (a) (sample A) and (b) (sample B). The anti-phase FVC switches at a bias of 12V while no switching is observed for in-phase fused sample B.

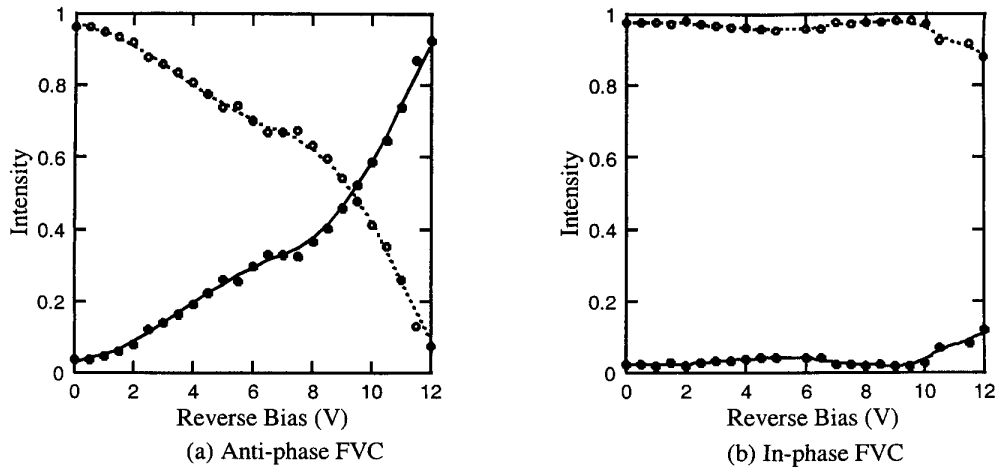


Figure 3. The light intensity at the output of upper (solid line) and lower (dash line) waveguides of (a) anti-phase, (b) in-phase FVCs as a function of reverse bias voltage.

It is known that the mechanisms of index change in p-i-n structures include linear electrooptic (LEO) effect, quadratic electrooptic (QEO) effect and free-carrier effect due to the modulation of the depletion layer. In the current structure, because of a thick $1.6\mu\text{m}$ intrinsic layer and because the operation wavelength is far away from the bandgap, the QEO and free-carrier effects are very weak. Furthermore, QEO and free-carrier effects should be same for both samples, because they are independent of the crystal orientation. Therefore, the LEO effect dominates in current FVC structures. The switching in sample A is due to the push-pull configuration which comes from the inverted crystal orientation. In sample B, the index change in upper and lower waveguides is the same, so the switching requires a much higher voltage.

In conclusion, a push-pull fused vertical coupler switch with crystal inversion symmetry has been demonstrated. Switching under 12 V reverse bias is observed for anti-phase FVCs while there is no switching for in-phase FVCs. The wafer fusion technique simplifies the complicate electrode configuration in conventional push-pull type couplers. Additionally, other novel devices can be demonstrated using different crystal structures integrated together.

References:

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