Numerical analysis of polarization sensitivity in strained bulk semiconductor optical amplifiers

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Abstract

The polarization dependence of 1.55-μm semiconductor optical amplifiers (SOAs) based on tensile strained bulk InGaAsP has been analyzed numerically, focusing on the strain relaxation in the active layer.

SOAs are widely used as gate switches, amplifiers, and wavelength converters and are key devices for photonic networks. In these applications, polarization insensitivity of the gain is essential. A tensile-strained bulk rectangular active layer is an attractive way to realize polarization insensitivity for a wide range of wavelength and carrier density [1, 2]. The significant point in the design is the choise of the strain for polarization independence. However, under the assumption of uniaxial strain as used in strained quantum wells, numerical results give a smaller strain than that given in experimental results [3]. In a buried strained quantum wire, it is known that, when the aspect ratio of the active layer facet is small, strain introduced in the epitaxial layer is relaxed [4]. The aspect ratio of a bulk SOA should be small because of the polarization insensitivity; therefore, this effect is considered to take place. Therefore, strain relaxation in the active layer are considered to be important for polarization dependence in strained bulk SOAs.

The polarization dependence of strained bulk SOAs is analyzed numerically, taking strain relaxation into account. Figure 1 shows the facet of the SOA active layer that we analyzed. The active layer is sandwiched by separate confinement heterostructure (SCH) layers whose band-gap wavelength is 1.18 μm. The active layer is buried with InP. In this work, the active layer thickness H_{act} is 0.2 μm, the SCH layer thickness H_{SCH} 0.1 μm, and the cavity length 300 μm.

The effective strain in the active layer is evaluated by the linear static analysis based on the finite element method. Figure 2 shows the strain value in the center of the active layer. Solid lines are for the buried mesa stripe case illustrated in Fig. 3(a), and the dotted line is for the slab structure case in Fig. 3(b). The lattice constant of the InP substrate a_0 and that of InGaAsP active layer a_{act} are selected so that $(a_0 - a_{act})/a_0 = -0.001$. Compared with slab structures, the strain value is reduced in buried mesa stripe structures. In the case of the active layer width $W = 0.8$ μm, the strain in the growth direction ϵ_{zz} relaxes from 0.1 to 0.07 %. Therefore, relaxation of strain occurs in the strained bulk SOA as seen in the strained quantum wire. The gain spectrum was calculated based on the k.p method taking the effects of strain relaxation in the active layer. Figure 4 shows the strain dependence of the difference of gain between TE and TM polarization. The numerical results agree with experimental results.

Therefore, we should take into consideration the effect of strain relaxation in buried structure when estimating the strain value for polarization insensitivity.

References

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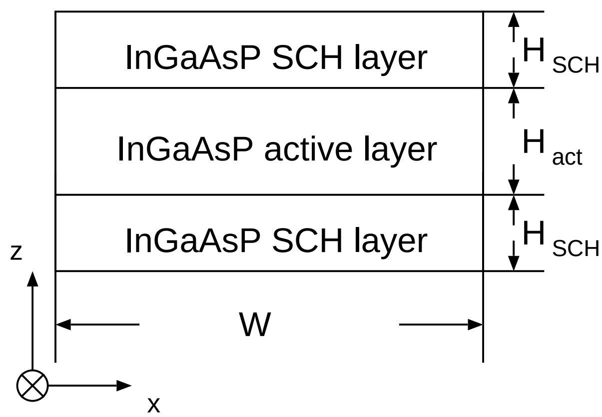

Figure 1: Cross section of SOA active layer.

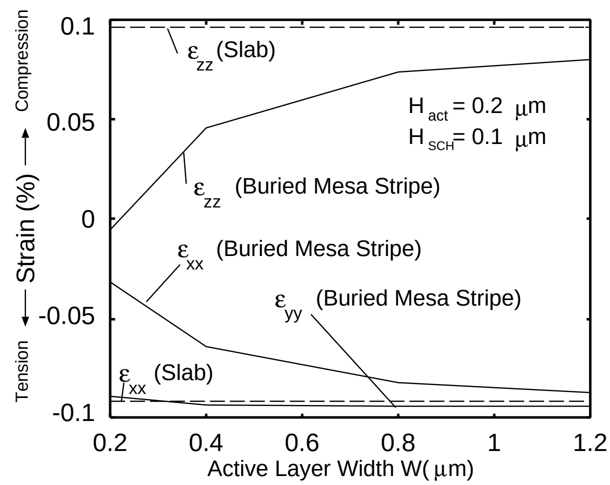

Figure 2: Strain relaxation effect in the active layer. The horizontal axis is active layer width W and the vertical axis is effective strain ϵ. Solid lines show the InP-buried case and dotted lines slab case.

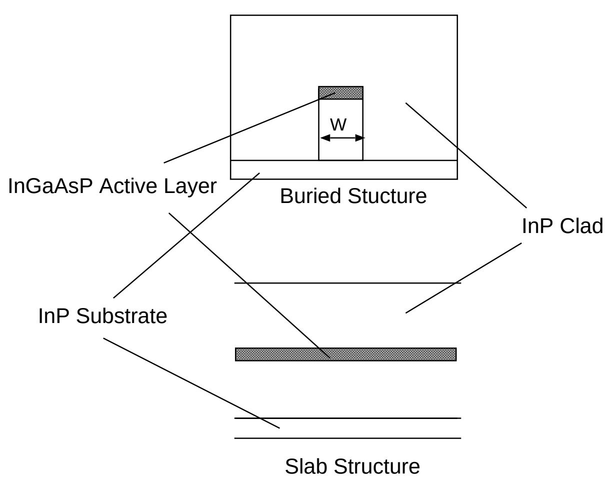

Figure 3: Cross section of (a) buried mesa stripe and (b) slab structure.

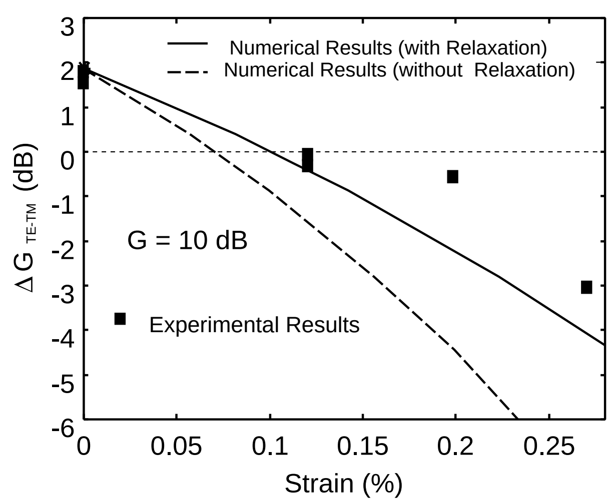

Figure 4: Strain dependence of the difference of gain at gain $G = 10$ dB. Horizontal axis is tensile strain value. Points show the experimental results, solid lines show the numerical results with the strain relaxation effect, and dotted line show the numerical results without the strain relaxation effect.