Theoretical Analysis of Transient Processes in Lateral p-n Junction Photodiodes

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Quantum well (QW) structures with lateral injection are very promising building blocks for a variety of new devices [1,2,3]. Various optoelectronic devices incorporating lateral p-n junctions, such as light-emitting diodes, edge- and surface-emitting lasers, ultrafast photodiodes, etc. were proposed, fabricated, and measured. This communication deals with the development of an analytical device model for QW photodiodes with lateral p-n junctions. We use the model of such lateral junction photodiodes (LJPDs) for the analysis of their high-frequency performance.

The LJPDs under consideration (see Fig. 1) are assumed to be made of III-V materials heterostructures. They incorporate a QW formed by a narrow gap layer sandwiched between wide-gap undoped layers. A part of the QW is doped by donors while another one is doped by acceptors, so that a lateral p-n junction is formed. The QW is supplied with heavily doped regions of p and n types with related metallic contacts. Moreover, to make the absorption more effective and, hence, to increase the output signal a stack of QWs may be used. We consider LJPDs with the vertical and lateral light input. The developed model takes into account the features of the carrier transport in LJPDs and their geometry. It is assumed that the transport of electrons and holes is due to their drift under the influence of the electric field and diffusion. The self-consistent electric field distributions in the LJPD active region are calculated using two-dimensional Poisson equation.

We demonstrate the results of the calculation of the LJPD characteristics as functions of the signal frequency, bias voltage, and structural parameters. Some examples of the calculated dependences for AlGaAs/GaAs LJPDs are shown in Figs. 2 and 3. As seen from Figs. 2 and 3, the frequency dependent responsivity and the bandwidth strongly depend on the bias voltage and the QW doping level. The bandwidth of carefully designed LJPDs at properly chosen bias can be expanded well above 100 GHz.

It is shown that main potential advantages of LJPDs are associated with the possibility to combine very short transient times of the photogenerated carriers with a small capacitance, and a relatively large space charge of donors and acceptors in the LJPD depletion layer that markedly weakens the effect of screening of the electric field by the space charge of the photogenerated electrons and holes. An additional advantage of LJPDs over other counterparts is the ease of their integration and relatively soft technological requirements because the formation of a narrow active region in LJPDs does not necessitate the use of submicron processing.

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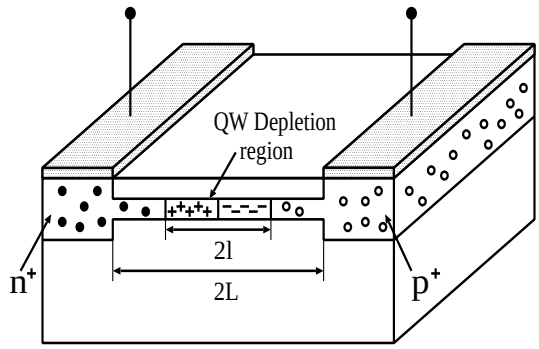

Figure 1: Schematic view of a LJPD.

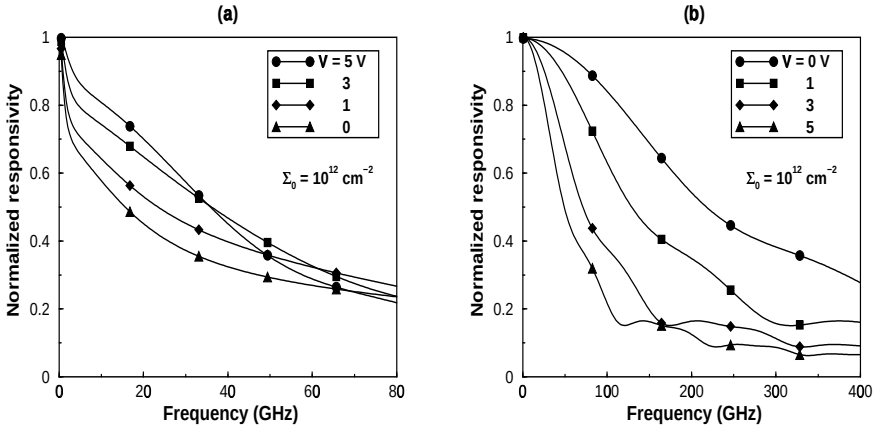

Figure 2: Frequency dependence of normalized responsivity of a LJPD with unfocused (a) and focused (b) input.

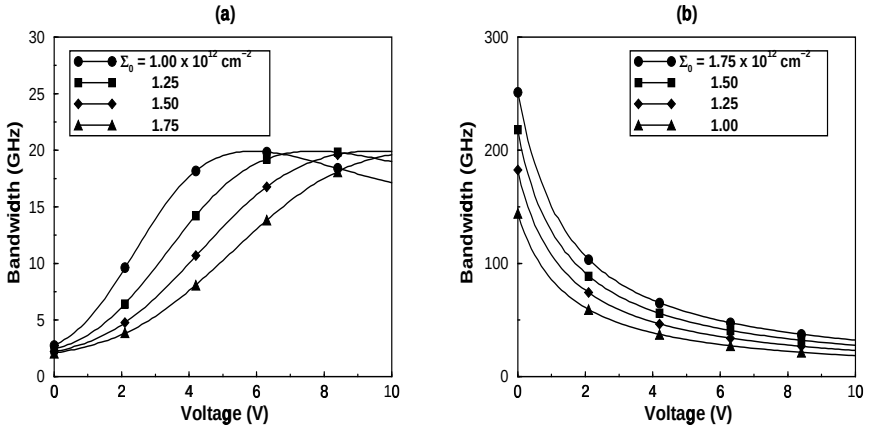

Figure 3: Bandwidth versus voltage for LJPDs with unfocused (a) and focused (b) input.