Novel Waveguide Photodetectors on InP with Integrated Light Amplification

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Our 1.55µm traveling-wave amplification photodetector simultaneously amplifies and absorbs the incoming light. The schematic cross section of the device is shown in Fig. 1. The top ridge waveguide hosts the bulk InGaAs detector, all other semiconductor layers exhibit a larger bandgap. The light is amplified by stimulated emission in the InGaAsP multi-quantum well (MQW) active region. The amplifier pn-diode is operated at forward bias whereas the detector diode is reverse biased. Electrical and optical confinement in the center of the device is provided by the ridge-waveguide structure as well as by underetching of the MQW (Fig. 2). The continuous amplification of the optical wave makes it possible to maintain an almost constant optical power along the waveguide despite the absorption. Such integrated amplification detectors have the potential to achieve simultaneously high saturation power, high speed, high responsivity, and quantum efficiencies well above 100%. We have previously presented a similar device concept based on GaAs [1].

We employ advanced three-dimensional device simulation to evaluate the device physics in detail and to study design options. The finite element model includes drift and diffusion of electrons and holes, thermionic emission at heterointerfaces, and a quantum-mechanical treatment of the MQW in order to compute the amplifier gain. The optical modes are calculated by solving the Helmholtz waveguide equation. Many different modes may travel in our waveguide structure (Fig. 3). However, only few of these modes exhibit a balance between photon generation in the MQW and photon absorption in the detector. Many other modes are strongly confined by the detector ridge and have little overlap with the MQW. Those modes decay quickly and exhibit little amplification. Another issue is the lateral current confinement in the MQW region. The simulations show that deep underetching is required to achieve sufficient modal gain. These design considerations are currently implemented in our fabrication process and experimental results will be presented at the conference.

[1] D. Lasaosa, J.-Y. Chiu, J. Piprek, and J. E. Bowers; 13th LEOS Annual Meeting, Rio Grande, 2000.

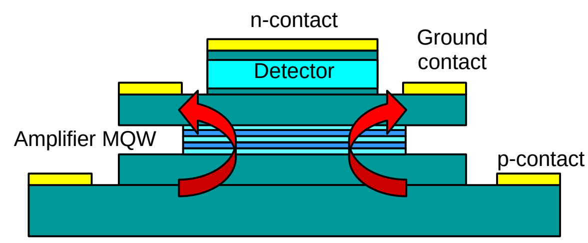

Fig. 1: Schematic cross-section of the traveling-wave amplification photodetector.

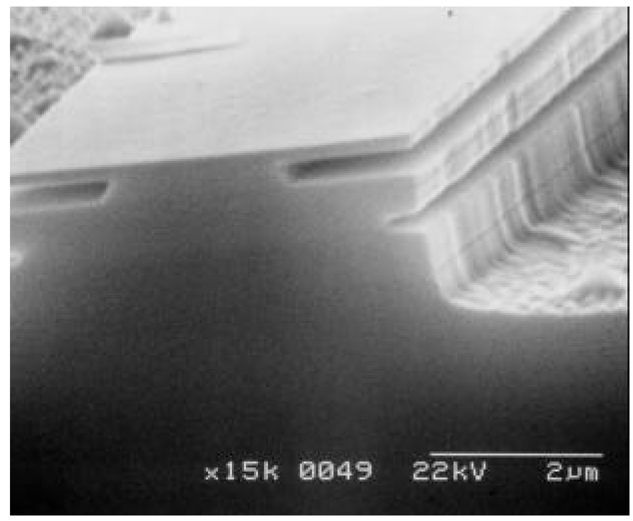

Fig. 2: Fabricated InGaAsP/InP detector after etching.

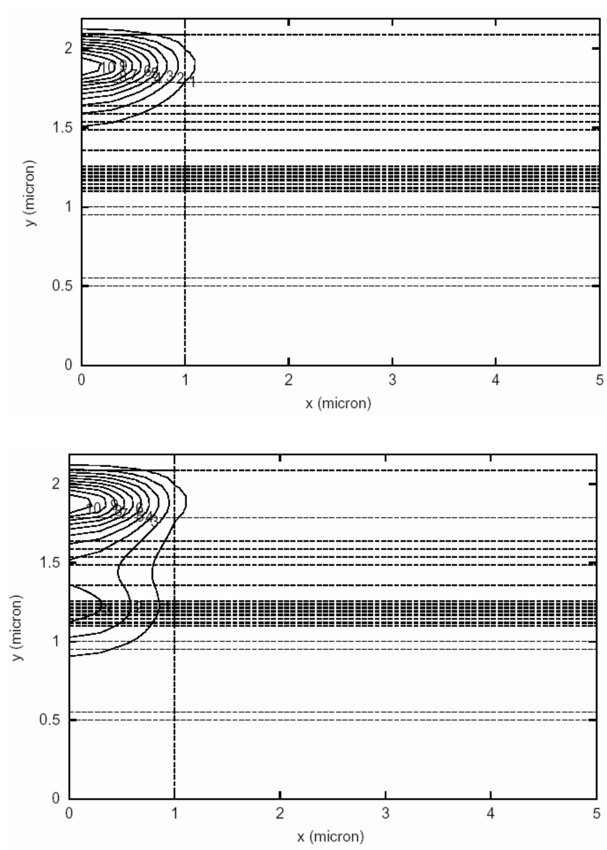

Fig. 3 Calculated optical mode profiles for half the cross section (the left border is the device symmetry plane).