Possibilities and Limits of Edge-coupled InGaAs/InP Heterojunction Phototransistors for Millimetric Applications

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We present the modeling and optimization of edge-coupled waveguide InGaAs/InP HPTs for microwave and millimeter wave applications. These devices can be used as photodetectors and for optical-optical mixing or electro-optical mixing. We aim to use them for optical control of microwave oscillator.

In order to study these devices an optical model and an electrical one were developed: by using a Beam Propagation Method (BPM), we considered the propagation of the light beam issued from a fiber, through the air-semiconductor interface to the end of the waveguide (figure 1). We used bidimensional and three-dimensional finite differences BPMs. We can thus calculate the quantum efficiency of the device, study the influence of light injection conditions (fiber size, injection angle, positioning of the fiber...) and optimize the epitaxial structure from an optical point of view.

We also used a 1D Energy Model issued from the Boltzmann Transport Equation. It accounts for the non-stationary effects resulting from the relaxation of the averaged carrier energy. Moreover, this model was coupled with an algorithm including the external circuit (Kirchoff equations). We thus study physical phenomena inside our HPT (figure 2), calculate dynamic characteristics and optimize the epitaxial structure from the electronic transport point of view.

In this communication we present the behavior of waveguide HPT, then a state of the art in microwave phototransistors. We discuss their possibilities and limits in terms of quantum efficiency, optical f_t and breakdown voltages.

We show that the optical structure of the waveguide HPT can be improved by adding a quaternary layer under collector and by using a lensed fiber for optical injection. External quantum efficiency of more than 60 % can then be achieved without anti-reflection coating. A well dimensioned HPT could then attain a 160 GHz optical f_t.

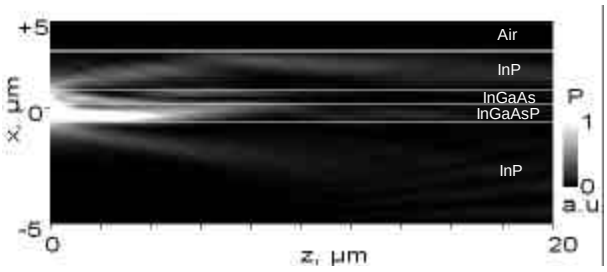

Figure 1: 2D-BPM modeling of light propagation issued from a lensed fiber in a waveguide HPT with a quaternary subcollector.

Breakdown considerations lead us to envisage the realization of Double Heterojunction PhotoTransistors for power applications. Their collector could be partially or totally in InGaAsP.

As a conclusion we present the optimal possibilities of such a device.

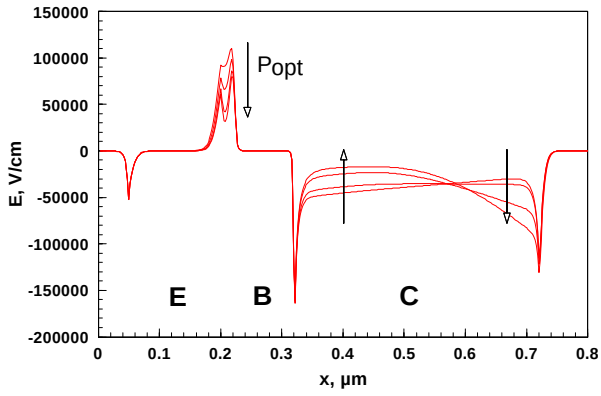

Figure 2 : modeled electrical field in a HPT for various incident optical powers (0, 1, 5 and 10 mW). V_{ce}=1.5 V, I_b=10 µA, l=1.55 µm.

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