

# Edge-coupled Waveguide InGaAs/InP Heterojunction Phototransistors

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Heterojunction Phototransistors (HPTs) are promising devices for high-performance optical fibre telecommunication systems for digital or microwaves applications at long wavelengths (1.3 and 1.55  $\mu\text{m}$ ). They simultaneously detect and amplify an optical signal, thus combining the functions of a PIN photodiode and a HBT. Unlike avalanche photodiodes (APD), they exhibit an internal gain owing to transistor effect without high bias voltage and excess noise due to avalanching.

We present the study, the realisation and the characterisation of edge-coupled waveguide InGaAs/InP heterojunction phototransistor (unlike most of the phototransistors which are top-illuminated). Such a structure can absorb light efficiently and be used for microwave and millimetre wave applications.

Two terminals HPTs were fabricated from epitaxial layers grown in our laboratory by gas source MBE on a n+ InP substrate. The structure is very similar to the one previously proposed by British Telecom. We demonstrated for the first time their potential for mixing [1] : gain nonlinearities at low input optical power permits to mix two demodulated (?) optical signals thus producing an electrical signal resulting from the beat of the two modulated (?) signals. For comparison, we also fabricated top-illuminated HPTs using same epitaxial layers.

With a modified epitaxy we fabricated edge-coupled three terminals HPTs. We will present the technology of this device. Measurements give an estimated optical gain unity frequency  $f_i$  of 40 GHz. We will also present the mixing of a microwave optical signal and an electrical microwave signal applied to the base.

In order to optimise our device we developed modelling tools :

< 2D and 3D Beam Propagation Methods (BPM) are used to model light propagation along the waveguide. We can thus calculate the quantum efficiency of the device, study the influence of light injection conditions (fibre size, injection angle, positioning of the fibre...) and optimise the epitaxial structure from an optical point of view.

> We use an Energy Hydrodynamic 1D model including the base circuit to model the microwave behaviour of these devices. We thus study physical phenomena inside our phototransistor, calculate static and dynamic characteristics and optimise the epitaxial structure from the electronic transport point of view.

We present first results obtained with these models.

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.

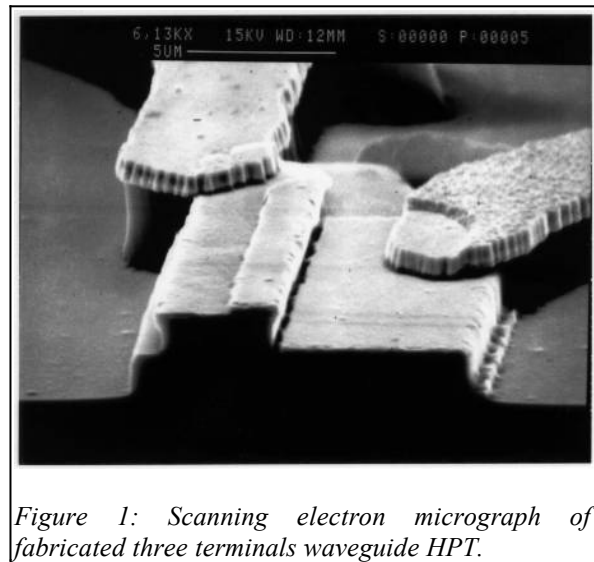


Figure 1: Scanning electron micrograph of fabricated three terminals waveguide HPT.

## References :

- [1] J. Van de Castele, J.P. Vilcot, J.P. Gouy, F. Mollot et D. Decoster, « Electro-optical mixing in an edge-coupled GaInAs/InP heterojunction phototransistor », *Electronics Letters*, 23<sup>rd</sup> May 1996, Vol. 32, n°11, pp. 1030-1032.