Heterostructure Bipolartransistor combining Electroabsorption waveguide Modulator based on a multifunctional layer design for 1.55μm

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The epitaxial layer stack of a common heterostructure bipolar transistor (HBT) has some degrees of freedom, which make possible to integrate an electro absorption modulator (EAM) without decreasing electrical performance of the transistor. This layer stack enables the combination of optical waveguides, modulators and bipolar transistors yielding modulator and transistor as single or merged devices. The latter is similar to a modulator with integrated amplifier and therefore the complexity of the driver circuit can be reduced.

To achieve this the waveguide is integrated into the collector region. In usual transistor operation the base-collector diode is reverse biased, which results in high electric fields in the region of the optical waveguide. This is necessary to reduce the band gap, e.g. by means of the Franz-Keldysh effect in a bulk collector. A variation of the voltage at the collector, i.e. a variation of the electric field in the collector region, leads to a change in the optical absorption of the integrated EAM. This is realized by the common-emitter circuit with external load resistance. For different bias points, which are controlled by the base current, the transistor switches in the on or off-state and the modulator simultaneously gets transparent or absorbing.

In our approach the common design of a HBT (emitter-up) is adapted in the collector region where optical cladding layers were added to get an optical waveguide. The structure is grown on s.i.-InP by MOVPE as follows. First the n-doped sub-collector (InP) was grown, which acts also as the lower cladding layer. It follows the intrinsic collector made of InGaAsP ($\lambda<1.55\mu m$) as the optical waveguide core and an InP layer as the upper cladding of the optical waveguide. The stack is finished with base (p'-InGaAs:C) and emitter (n-InP) layers.

Then, isolated transistors and modulators were processed as well as merged devices. Experimental results are presented for all devices to show the functionality. The HBT's with an emitter area of $3\times10^2\mu m^2$ have collector currents of 5mA and current gains over 50 with collector-emitter voltages up to 6V. High-frequency values are $f_\text{t}=30\text{GHz}$ and $f_{\text{max}}=25\text{GHz}$. Mesa waveguide modulators with 200μm length and 9μm width exhibited a 3dB cut-off frequency of 6.5GHz (at 1.55μm).