3D Simulation of Integrated Optoelectronic Devices

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We present the three-dimensional (3D) simulation of photonic components within an integrated optical-electrical-optical (OEO) wavelength converter (Fig. 1). The converter design includes a 50 μm long waveguide photodiode (WPD) which detects the incoming signal at any wavelength of the C band, e.g., at λ_{in}=1530nm. The optical signal is converted into an electrical signal that directly modulates a sampled-grating distributed-Bragg-reflector (SGDBR) laser diode which is integrated with a semiconductor optical amplifier (SOA) for signal enhancement. The SGDBR laser can be tuned to emit at any wavelength of the C band, e.g., at λ_{out}=1550nm. The epitaxial structure of the different components is very similar. An offset multi-quantum-well (MQW) active region is grown on top of the waveguide region [1]. A ridge waveguide structure is etched through the MQW region. Passive device sections are formed by etching off the MQWs completely.

The self-consistent simulation includes band-structure and gain calculations for the strained quantum wells, carrier transport, optical waveguiding, and Bragg reflection [2]. Field effects on MQW gain and absorption (quantum confined Stark effect) are considered as well as free-carrier and intervalence band absorption. InGaAsP material parameters are adjusted based on recent publications [3].

Reverse bias causes the quantum wells to absorb light in the photodetector. Figure 2 shows that increasing light power leads to longitudinally non-uniform absorption due to band filling, which results in a non-linear detector response. Forward bias gives optical gain in laser and amplifier. Figure 3 shows the longitudinal wave intensity profile of the emitter. Within the SGDBR sections, each grating burst reflects part of the wave and gives a stepwise change in wave intensity. At low amplifier current (5 mA), the SOA region exhibits net optical loss and the optical intensity decays as the light approaches the right facet. Net amplification is observed at 20 mA SOA current. At even higher amplifier currents, more than 100% differential quantum efficiency can be achieved this way, i.e., each electron injected into the laser above threshold leads to more than one emitted photon, due to photon multiplication in the SOA region.

Further results will be shown in the presentation, including a comparison to measured device characteristics.

[1] B. Mason et al., "Widely Tunable Sampled-Grating DBR Laser with Integrated Electroabsorption Modulator," IEEE Phot. Techn. Lett., vol. 11, pp. 638-640 (1999).
[2] PICS3D by Crosslight Software, 2003.
[3] J. Piprek, *Semiconductor Optoelectronic Devices – Introduction to Physics and Simulation*, Academic Press, San Diego, 2003.

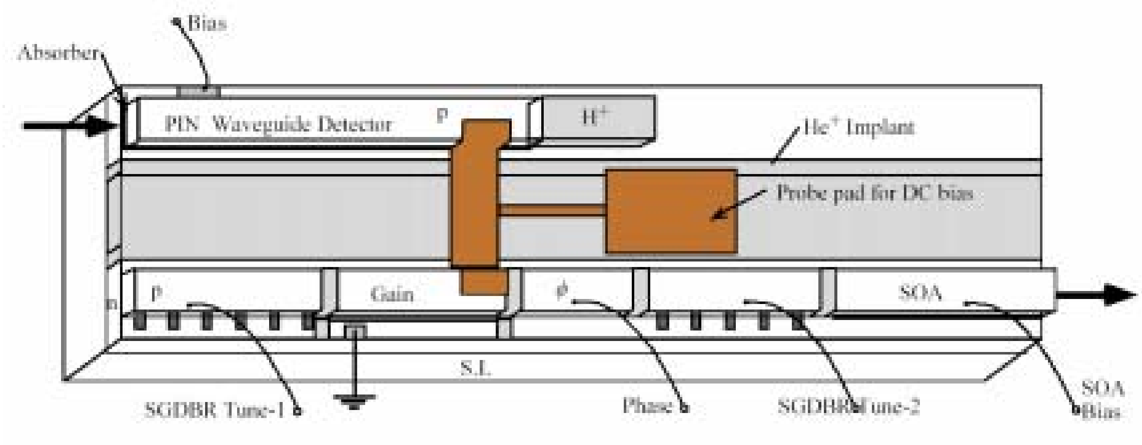
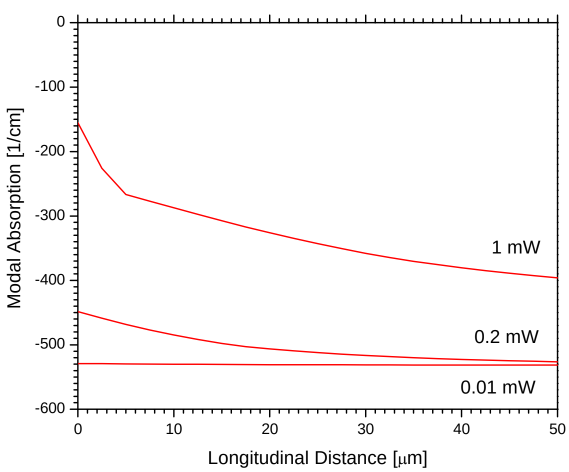


Fig. 1: Schematic view of the InP-based integrated OEO wavelength converter.



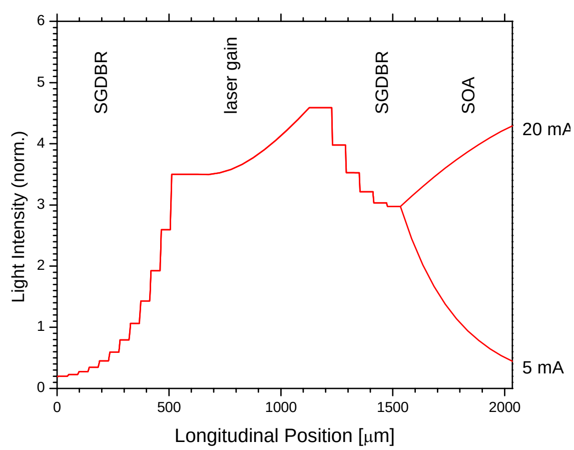


Fig. 2: Longitudinal profile of the detector band-to-band absorption with the input power as parameter.

Fig. 3 Longitudinal optical intensity profile within the emitter for 25 mA laser current and with two different amplifier currents.