Traveling-wave Amplification Photodetector (TAP detector)

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High speed, high efficiency, low noise and high saturation power are the characteristics desired for detectors in high bit-rate long-haul optical communication systems. We present modeling and initial experimental results on Traveling-wave Amplification Photodetectors (TAP detectors). These novel monolithic devices combine optical gain and absorption in a traveling-wave structure, providing high-responsivity and high-speed performance, without sacrificing saturation power. Electrical isolation between gain and absorption contacts can be achieved by ion implantation, combined with impurity-induced disordering [1],[2]; this significantly reduces the absorption in the isolation region. Two configurations (shown in Fig. 1) were studied.

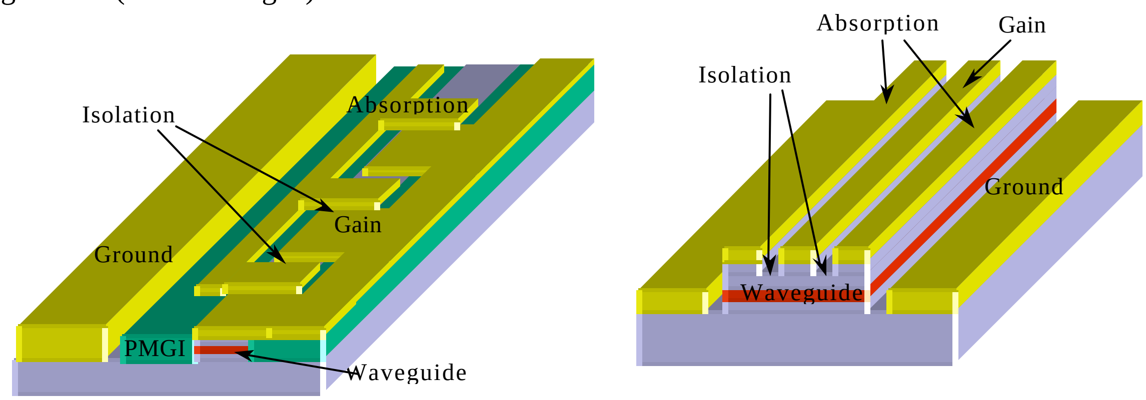

Fig. 1. TAP detectors with sequential (left) and parallel (right) configurations.

TAP detectors with a sequential configuration present an optical waveguide with longitudinally alternating periods of optical gain and absorption. The input optical signal is amplified and partially absorbed several times providing, for the same saturation power, higher gain than traditional Traveling-Wave Photodetectors (TWPD's) with optical preamplification. A period length of 50μm was assumed, in order to avoid microwave signal resonances up to at least 100GHz; each isolation region is 2μm. The microwave propagation characteristics (shown in Fig. 2) were found using a combination of ABCD transmission matrix and distributed photocurrent [3] models. Devices with up to 8μm of absorption length per period present low microwave losses (<13cm^{-1} up to 100GHz), characteristic impedance close to 50Ω, and effective microwave propagation index between 1.5 and 2 times larger than the optical one, resulting in the gain-bandwidth products shown in Fig 2. The first gain section is assumed be longer and independently biased to provide an optical gain of 10; the devices are also assumed to be 50Ω terminated in both sides [4].

TAP detectors with a parallel configuration feature a single waveguide with three longitudinal contacts separated laterally: the one in the center is forward-biased in order to provide gain, and the two on the sides reverse-biased for detection. Beam Propagation Method (BPM) calculations yielded gain and absorption confinement factors of Γ_{gain}=11% and Γ_{abs}=1.5%, respectively, for the main mode in devices with 1μm wide gain, absorption and isolation regions. We can define a pump current dependent net modal gain as $\Delta g = \Gamma_{gain} g - \Gamma_{abs} a_{opt} - a_{loss}$, where g, a_{opt} and a_{loss} are the material optical gain, absorption and modal losses, respectively. After finding the microwave propagation characteristics, using a distributed element model, we can calculate the gain-bandwidth product for parallel TAP detectors, as shown in Fig. 3, for different device lengths and different net modal gains; the gain being introduced in a distributed way, the bandwidth of the device doesn't barely depend on Δg, even for long devices. Since the confinement factor in the absorption region is small, these detectors do not only provide similar gain-bandwidth products than conventional TWPD's [5], but their saturation power is about 20 times larger.

In conclusion, we study a novel type of device, the traveling-wave amplification photodetector (TAP detector). We show that, in a sequential configuration, these devices produce more gain than classical TWPD's with optical preamplification for the same saturation power, while in a parallel configuration they present gain-bandwidth products similar to those of classical TWPD's, with much larger saturation power.

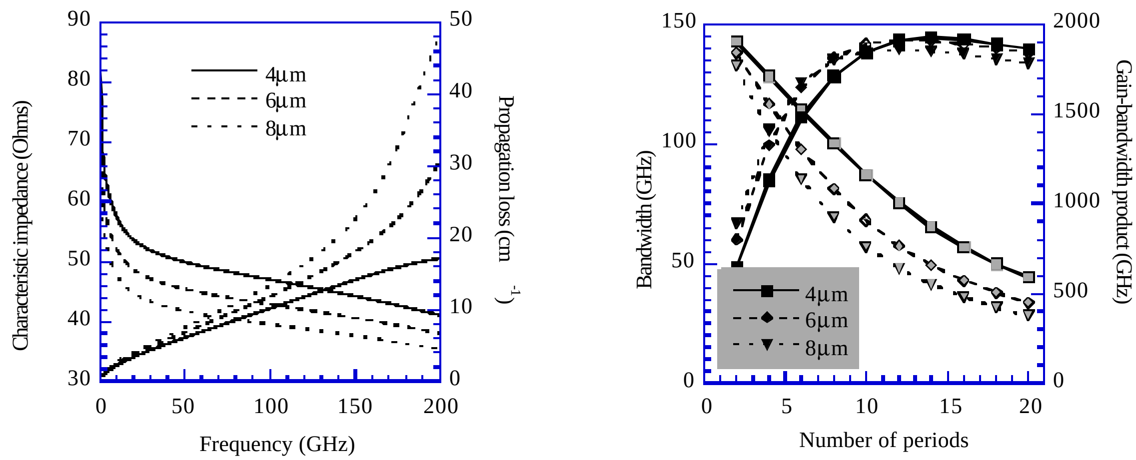

Fig. 2. Left: Microwave characteristics of sequential TAP detectors for different detection section lengths; period length is 50mm. Right: Bandwidth (empty symbols) and gain-bandwidth product vs. number of periods for different detection section lengths.

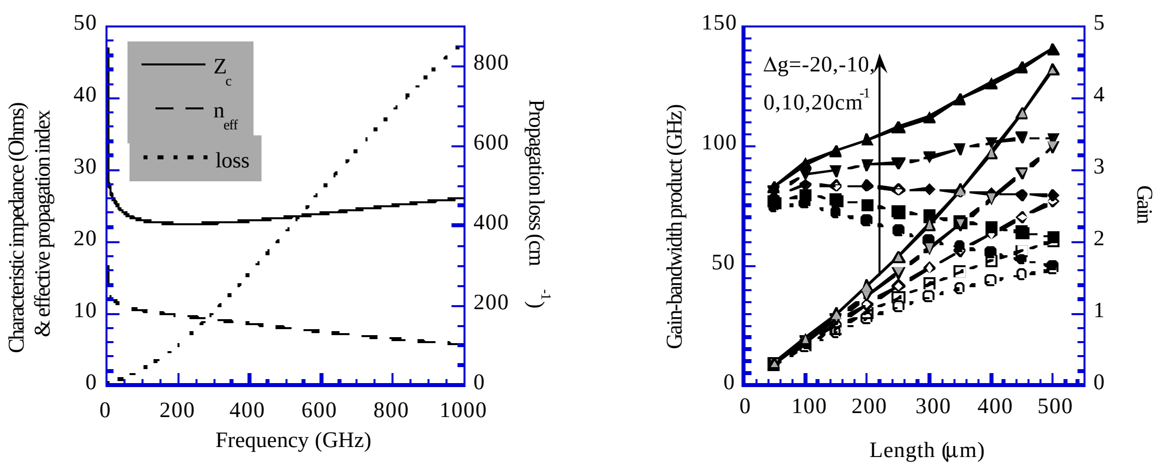

Fig. 3. Left: Microwave characteristics of parallel TAP detectors. Right: Gain (empty symbols) and Gain-bandwidth product (full) vs. device length for different net modal gains.

References:

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