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Microwave Characteristics of Ge n-i-p waveguide photodetectors on Silicon-on-Insulator Substrate

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We present microwave characteristics of evanescently coupled Ge waveguide photodetectors grown on Si rib waveguides. At 1GHz and 40mA of photocurrent, an OIP3 of 36.49dBm is measured. Additionally, the maximum RF power extracted at 1GHz is 14.35dBm at 60mA of photocurrent and 8V reverse bias.

High-performance analog optical links require photodiodes (PDs) that have high power handling capability as well as high linearity. Surface illuminated PDs with Third order Output Intercept Points (OIP3) in excess of 50dBm and output RF powers up to 26dBm at 1GHz have been reported [1,2]. However, for higher frequency operation and more complex receiver functionality waveguide PDs are of particular interest because 1) they can overcome bandwidth limitations by incorporating a traveling wave design and 2) they have the potential to be monolithically integrated with other optical components. Typically, these devices are fabricated on an InP platform where the InGaAs absorber region sits on top of an InGaAsP waveguide [3]. The thermal conductivities of these two layers are ~0.05W/cm•K [4], which is a factor of 30 less than that of Silicon (1.5W/cm•K). Hence, at sufficiently high optical power levels heat flow out of the absorber region is restricted leading to thermal failure. Recently, we observed that the devices presented in this paper were able to dissipate to 1.003W of power (125.49mA at -8V) [5]. Here, we explore the potential of these devices for microwave applications by measuring their linearity and radio frequency (RF) response under small signal and large signal modulation.

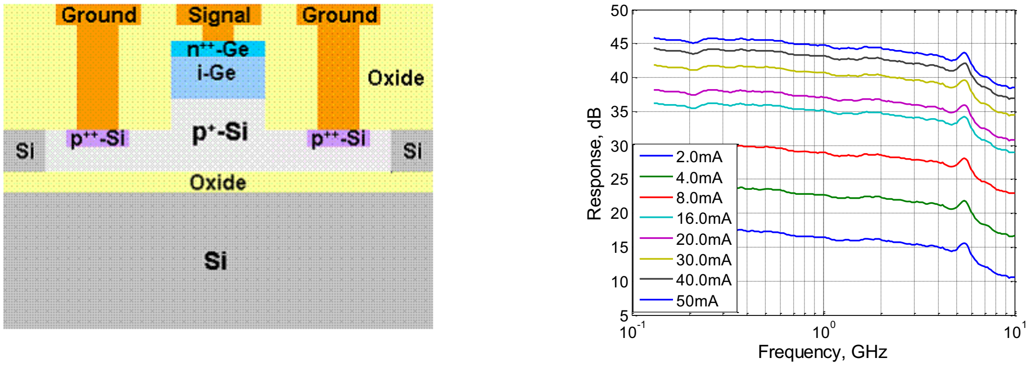

Fig.1a) Cross-section schematic of device 1b) Frequency Response Frequency response of 7.4µm X 500µm device at different photocurrent levels for a fixed reverse bias (5V)

Figure 1a) shows a cross section schematic of the device. The Ge waveguide detector is grown on top of a Si rib waveguide by a selective epitaxial process. Details of the growth and fabrication process can be found in [6]. The detectors in this work have dimensions of 7.4µm X 500µm and 7.4µm X 1000µm. Figure 1b) shows the small signal frequency response of a 500µm long device at different photocurrent levels for a fixed reverse bias (5V). It is well known that under high optical illumination space charge effects increase until they are comparable to the built in and external bias field causing saturation in the device and bandwidth degradation [7]. However, it is observed here that the 3dB bandwidth remains fairly constant at 4.38GHz, suggesting that space charge effects are negligible even at 50mA of photocurrent and 5V reverse bias.

Next, we measured the linearity of the device both as a function of bias voltage and as a function of photocurrent at a frequency of 1GHz. We used a standard two-tone and more complicated three-tone technique for this measurement [8]. Figure 2a) shows the OIP3 results from both measurement techniques, wherein theoretically, the three-tone OIP3 should be 3dB less than the two-tone OIP3 [9]. Also, the OIP2 was measured. It can be seen that with increasing bias the OIP3 increases and reaches a maximum of 36.49dBm at 8V. Additionally, it was observed that at lower photocurrents the OIP3 is actually lower even at higher biases. In the absence of space charge effects at relatively low photocurrents and high bias, one possibility for the lower linearity is voltage dependent

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responsivity [10]. Fig 2b) shows the output RF power of the device at 8mA of photocurrent and different frequencies as a function of voltage. Compared to a similar curve taken at 40mA (not shown) the variation with output power is much greater in this case.

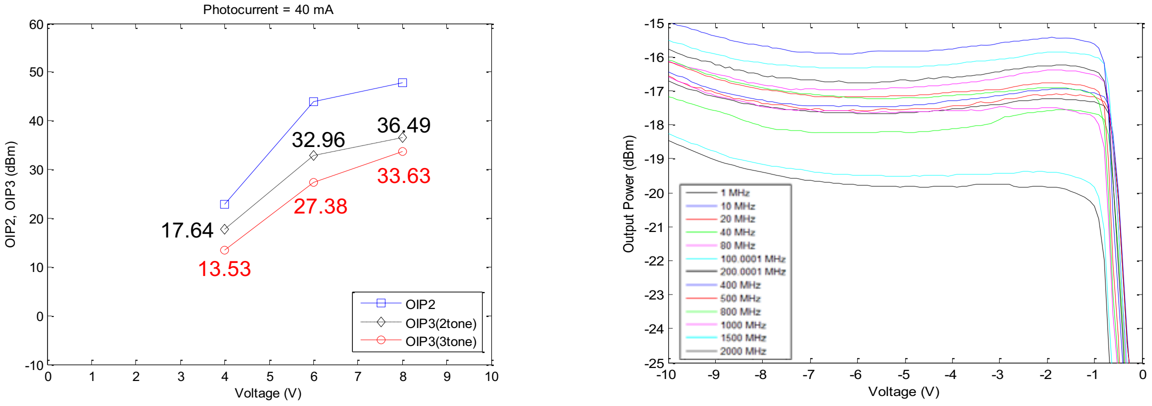

Fig. 2a) OIP3 and OIP2 at 1GHz and 40mA of photocurrent 2b) RF power dependence on bias voltage at different frequencies (photocurrent =8mA).

Fig. 3a) plots the photocurrent dependence of the output power up to 50mA at different bias voltage levels for a 7.4µm X 500µm. By driving an external intensity modulator 100% we measure the maximum RF power we can extract from a 7.4µm X 1000µm device before compression. The 1dB compression point is 14.35dBm at a photocurrent of 60mA and 8V reverse bias (Fig 3b).

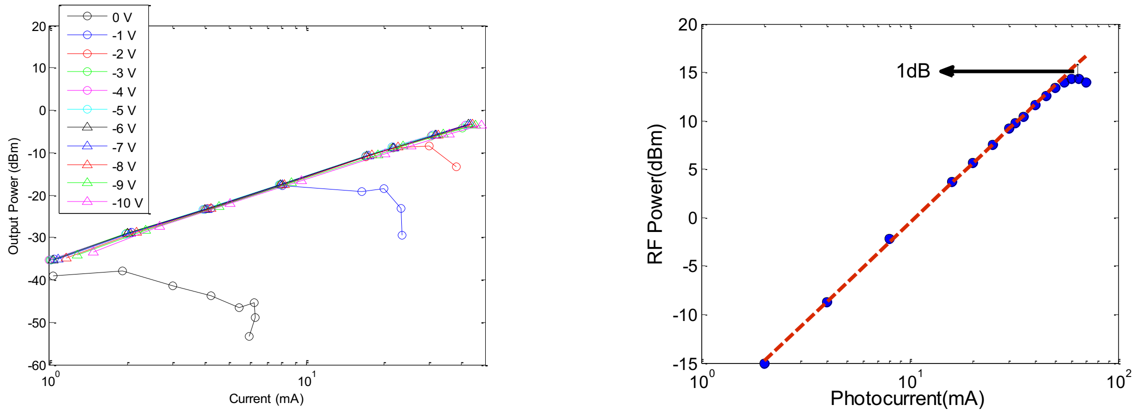

Fig. 3a) Photocurrent dependence of RF Power (Small Signal) 3b) Output RF power at 1GHz (Large Signal)

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