Characterization of Ge on-chip and InGaAs discrete photodetectors

Carlos Bortoloto
Divisão de Concepção de Sistemas de Hardware
Centro de Tecnologia Renato Archer
Campinas, Brazil
FEEC, UNICAMP
carlosbortoloto@gmail.com

***Abstract* — An InGaAs discrete photodetector (PD) and a photonic integrated circuit comprising a Ge photodetector (PD) were experimentally characterized by measuring their photovoltaic response as well as their linearity regarding optical input power applied. These Photodetectors as well as their opto-electric characteristics are amply used in the telecommunication field with several applications as sensors, for example.**

Keywords* — *photodetector; characterization; labview; InGaAs; Germanium

I. Introduction

Photodetectors have demonstrated a great variety of applications in the areas of telecommunications, data communications, chip-to-chip communications and even intra-chip data communications, as well as applications as sensors. And so comes the importance to characterize these devices, for use and experimental developing of devices for different applications. In this work, we present the characterization of an on-chip integrated Ge photodetector and a discrete InGaAs photodetector, which are key elements in photonic applications.

II. Characterization

The integrated photodetector was part of a chip design developed at CTI with the Opsis-IME process design kit (PDK) of photonic devices [1]. The chips were manufactured at IME in Singapore. The photodetector was part of a detection system and it is shown in Figure 1.

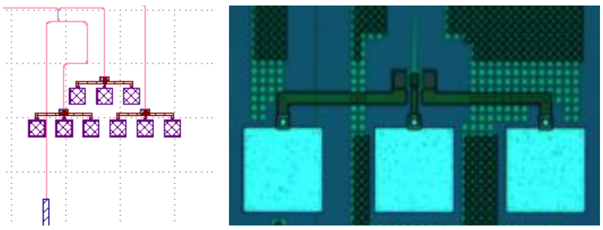

Fig. 1. *Circuit layout. Micrograph of on-chip Ge photodetector device used.*

Light was coupled to the circuit through a lateral nanotaper I/O on the chip. Coupling loss is highly dependent on the type of fiber used. We used lensed fibers from Já! Tecnologias which had a radius of 5 µm. The optimization of polarization state was applied to maximize TE (Transverse Electric) mode coupling. In addition, prior to reaching the photodetector, it had a 50% splitter. There was no additional structure allowing direct measurement of incident power in the Ge photodetector. Furthermore, the datasheet documentation on the Ge photodetector process reports data obtained through vertical grating couplers, which have 4.4 dB loss, similar to what the developers report in ref [1].

A printed circuit board was designed with Proteus Design Suite CAD Software and manufactured using an LPKF Protomat S Series circuit board plotter to allow wire bonding to the different circuits on the chip.

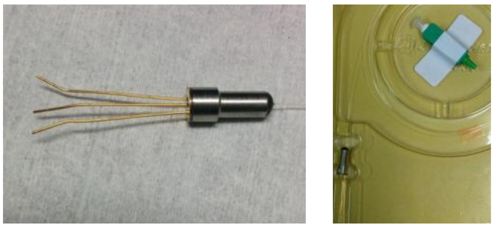

Fig. 2. *InGaAs discrete photodetector device connectorized*

Figure 2 show the InGaAs discrete photodetector used. It was manufactured by JDS Uniphase. It has a responsivity, according to the manufacturer of 0.92 A/W at a wavelength of 1550nm.

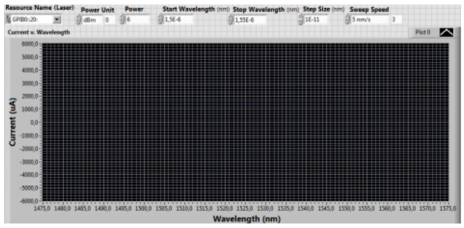

Fig. 3. *Labview .vi front panel developed to set photocurrent vs wavelength measurement*

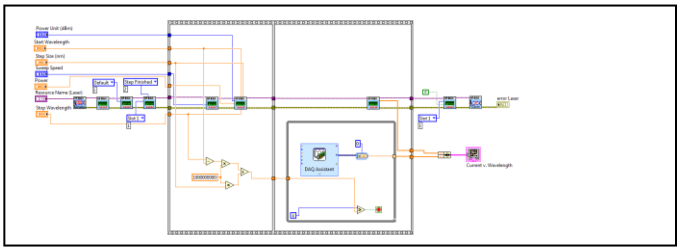

Fig. 4. *Labview .vi block diagram developed to measure photocurrent vs wavelength*

A vi (virtual instrument – labview's .vi file), shown in figures 3 and 4, was developed in the Labview software environment to perform measurements using a National Instrument's Data Acquisition device (NI DAQ), in sync, with a tuneable laser and optical power sensor (models 81980A and 81636B, respectively) from Keysight Technologies. A precision source and measurement equipment (model B2902A), also from Keysight, was used to apply a bias voltage to the photodetector.

Using basic sub vi's provided by the laser's manufacturers, it was possible, at first, to perform wavelength sweeps, acquiring optical power. Then, through the NI DAQ it was possible to measure the current of the biased photodetector while the laser performed a wavelength scan. The rate of acquisition of electrical current was set so that each sample was acquired for every wavelength step of the tuneable laser.

Figure 3 shows the front panel of the developed vi. It has controls to set the optical power, start and stop wavelengths, wavelength step size of the laser and sweep speed, as well as a graph of current vs. wavelength to show the results, which can also be exported to Microsoft Excel.

A 5V voltage was applied to the PD as the laser performed a sweep, starting at 1525nm, and photogenerated current was measured for each wavelength step of 0.1nm. The result is seen on figure 5 and agrees with the manufacturers data, presenting a constant response in this wavelength.

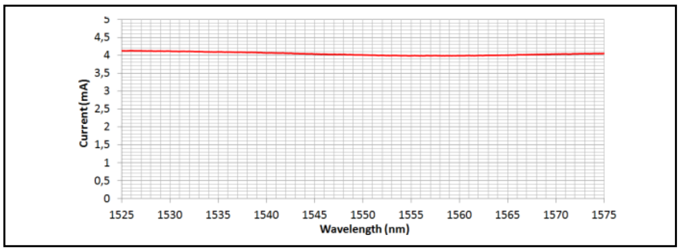

Fig. 5. *Photocurrent of the InGaAs PD in mA as the tuneable laser is scanned from 1525 to 1575nm with 5V reverse bias applied*

We applied different optical power input values on both photodetectors, a tuneable laser was used to set the optical power at a wavelength of 1550nm. At each optical power value set, a reverse voltage was applied while measuring the photogenerated current through the pin junction.

Figure 6 shows the photovoltaic response of the integrated Ge photodetector for three different optical power inputs, starting at -0.2V. The vertical scale is in mA.

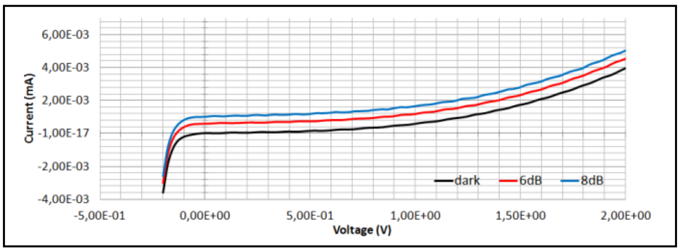

Fig. 6. *Photocurrent response of Ge on-chip photodetector as the applied reverse voltage is varied from -0.2 to 2V for 6dBm, 8dBm and no optical power input (dark).*

Figure 7 shows the photocurrent response from the InGaAs photodetector with varying reverse voltage, starting at -1.5V, with the same input optical power values set in the Ge PD measurements. It is possible to see that the InGaAs PD has a response that spans a greater voltage interval, having the 8dB curve only hitting its constant value of about 6.2mA around 2V while the Ge PD does it at around 0V for the same optical power input.

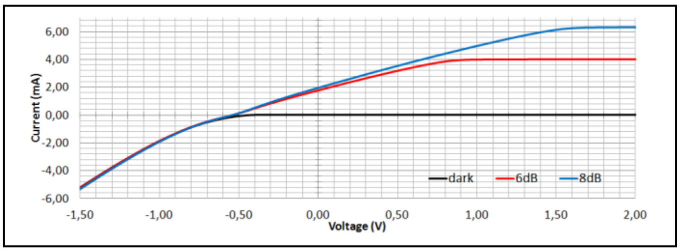

Fig. 7. *Photocurrent response of InGaAs photodetector as the applied reverse voltage is varied from -1.5 to 2V for diferent optical power input values.*

It is possible to see that the InGaAs PD conducting threshold is more sensible to changes in optical power input, going from 1 to 1.8V reverse as optical power increases from 6 to 8dB, whereas the Ge shows practically no variation. Both photodetectors present a gain of +50% in the same optical power interval.

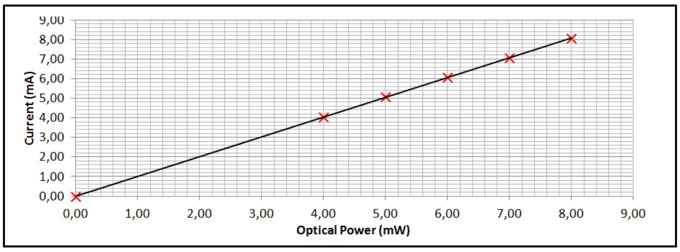

Fig. 8. *Linearity of PD photogenerated current in mA and optical power in mW with applied reverse voltage of 5V*

Figure 8 shows the linearity of input optical power and photogenareted current of the InGaAs PD. The graph scales are in mA and mW. It gives the responsivity of the photodetector to be constant at 1550nm, as expected, being aproximately 1.01 A/W. This deviation from the manufacturer value is likely due to the bias voltage applied to perform the measurements, as an increase in reverse voltage affects electrical characteristics of the PD, as its capacitance, for example.

III. Conclusions

We have developed an automated opto-electronic characterization setup and used it to characterize two photodiodes, a discrete fiber-coupled InGaAs PD and an IC integrated Ge PD. At this point, uncertainties in the total coupled power for the Ge PD prevented us from determining that devices responsivity. Various curves can be generated automatically, such as photocurrent vs. voltage, photocurrent vs. power, and photocurrent vs. wavelength. We compared device operation through the I-V response of the devices.

Acknowledgment

This work is part of a PIBIC fellowship. Special thanks for advising by Dr. Roberto Panepucci, and technical staff at FACTI and CTI. Thanks to CNPq for financial support.

References

[1] Tom Baehr-Jones et al. "A 25 Gb/s Silicon Photonics Platform", arXiv:1203.0767 [physics.optics]

[2] Jeff Hecht, Understanding Fiber Optics, 5th ed. New Jersey: Prentice Hall, 2006.