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Design and Modeling a New Optical Modulator

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Abstract: A new opt modulator device using a Silicon Schottky Photodiode Device (s.s.p.d) is proposed. The s.s.p.d. is fabricated in laboratory and has been used to mix an intensity modulated laser beam with a high frequency. The effects of modulating the high frequency signal before mixing on the photovoltage enhancement of the s.s.p.d is studied. A significant reduction in the required drive level of the high frequency input signal was achieved. Such a mixer could be use in radar and other communication systems. *Copyright © 2009 IFSA.*

Keywords: Optical modulator; Silicon Schottky photodiode device

---

1. Introduction

The use of the optically scanned radio frequency field imaging had already been demonstrated [1] in experimental and theoretical work [2] has shown that the overall performance of the modulated radio frequency transducer (MRFT) on an imaging transducer of this type is superior to that of other available material.

During the last decade several mixers in different application has been designed. Such as diode mixers [3] and Microwave mixers [4] these are devices which utilize a non linear element (such as a Schottky barrier diode) to achieve conversion of an input high frequency signal to another (usually power) frequency. The present proposal is based on effect of the high frequency fields on photocurrent behaviour [5].

A Schottky barrier silicon photodiode becomes reversed biased when illuminated by a light beam of the appropriate wavelength. If the light beam is intensity modulated at a frequency $\acute{\omega}_p$ (pump frequency), then an AC. photocurrent components will be produced in the load in addition to the D.C. component.

The output photocurrent depends also on the instantaneous values of the applied high frequency signal. As a result, a simple high frequency optomodulator is obtained.

Section 2 deals with the fabrication and design of the Schottky diode for the Optomodulator, while section 3 describes the operation of the mixer. In section 4 the effect of modulating the input high frequency signal on the Photovoltage enhancement is discussed. Section 5 gives some results and conclusions.

2. Fabrication and Design

Having the correct high resistivity, a photoconductive silicon sensor is lapped on one side and highly polished on the other. In order to reduce the sheet resistivity of the polished on the other. In order to reduce the sheet resistivity of the polished surface, a semitransparent electrode (Aluminum) is formed on the polished surface by evaporation method. [6]. The Schottky diode is placed on a metal which is electrically earthed. The high power laser line scan is intensity modulated by using a signal generator.

3. The Operation of Opt Modulator

The operation of this modulator is based on the experimental arrangement of Fig. 1. Active Band pass filter circuit is used for processing the output of this modulator to extract required frequency components. The light intensity of laser beam is modulated at pump frequency $\acute{\omega}_p$, and is directed to one of the photoconductive elements of the Schottky diode. A high frequency field is used to bias the photodiode, and a local current source i (t) at carrier frequency $\acute{\omega}_c$ in the photodiode is generated [7]. This source is chopped at the optical pump rate $\acute{\omega}_p$, resulting in current sources at ($\acute{\omega}_c \pm \acute{\omega}_p$) in the photoconductor, as shown in Fig. 2.

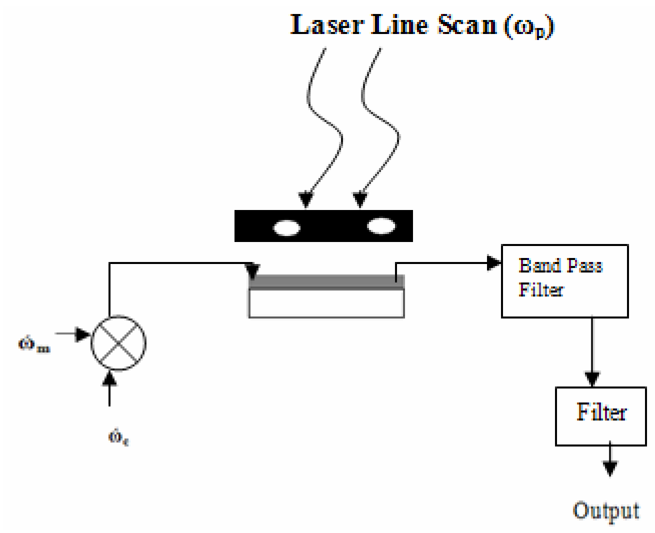


Fig. 1. Typical Opt modulator circuit.

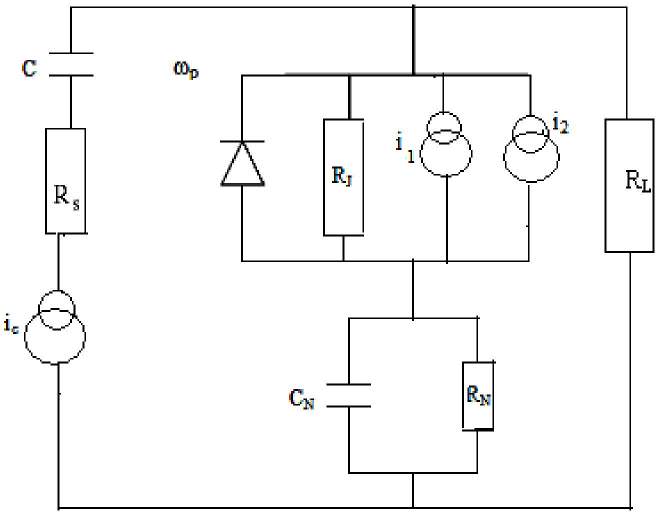


Fig. 2. The equivalent circuit of the Opt modulator device.

This mixing process can be depicted mathematically as follows: If the light intensity is sinusoid ally modulated at $\acute{\omega}_p$, before being passed through the object passed through the object then the silicon bulk resistance R_n can be expressed as:

$$R_N(t) = [R_N(t) - \Delta R_N(1 - \text{Cos } \acute{\omega}_p t)] \tag{1}$$

where R_N is the nominal dark resistance; ΔR_N is the amplitude of the sinusoidal change in the dark resistance due to the image of the object.

Now if the high frequency generated current source, i, through of as being a shunt voltage source (Norton's theorem),V_c Cos $\acute{\omega}_c t$, and then the current through the photoconductor can be written as:

$$i_c(t) = \frac{V_c \text{ Cos } \acute{\omega}_c t}{R_N(t)\ \{1 - [\Delta R_N(t)/ R_N]\ (1 - \text{Cos } \acute{\omega}_p t)\}} \tag{2}$$

Using the binomial theorem [8]. Therefore:

$$i_c(t) = C_1 \text{Cos } \acute{\omega}_c t + C_2(t) \text{ Cos } (\acute{\omega}_c \pm \acute{\omega}_p)\ t + C_3\ (t) \text{ Cos}(\acute{\omega}_c \pm 2\acute{\omega}_p)\ t + \ldots.. \tag{3}$$

C_1: is constant, $C_2(t)$, $C_3(t)$: are proportional to line scan of image.

3. Using a Modulated High Frequency

A modulated high frequency carrier may be used to bias the photodiode instead of using a monotone carrier (ω_c). The high frequency signal is partially modulated at a very low frequency (ω_m) signal.

$$V_o(t) = A \text{ Cost} + (A_m/2) \text{ Cos } (\acute{\omega}_c \pm \acute{\omega}_m) \tag{4}$$

The Eq. 3 could be reduced to:

$$i_c(t) = C_1 \mathrm{Cos}\ \acute{\omega}_c t + C_2(t)\ \mathrm{Cos}\ (\acute{\omega}_c + \omega_m \pm \acute{\omega}_p)\ t + C_3\ (t)\ \mathrm{Cos}(\acute{\omega}_c + \omega_m \pm \acute{\omega}_p)\ t + \ldots\ldots.$$

After the band pass filter (tuned to the $\acute{\omega}_c$ -$\acute{\omega}_p$ frequency), with $\omega_m << \omega_c$. Then:

$$V_o\ (t) = k\ (t)\ \mathrm{Cos}\ (\acute{\omega}_c \pm \omega_m - \acute{\omega}_p)\ t \tag{5}$$

where k (t) bears the image information, and could be detected by simple diode detector followed by a Low pass filter as shown in Fig. 1.

The use of modulated h.f signal shows a significant effect on the required r.m.s values of h.f. signal and on the photovoltage enhancement as shown in Fig. 3, Fig. 4 and Fig. 5. For ω_m= 1 kHz, ω_p= 200 kHz, ω_c= 250 kHz. We also get a photoconductive effect producing side bands at ($\omega_c = \omega_p$) which are filtered out as shown in Fig. 6. The line scan on two holes analog image before and after filtered out is shown in Fig. 7.

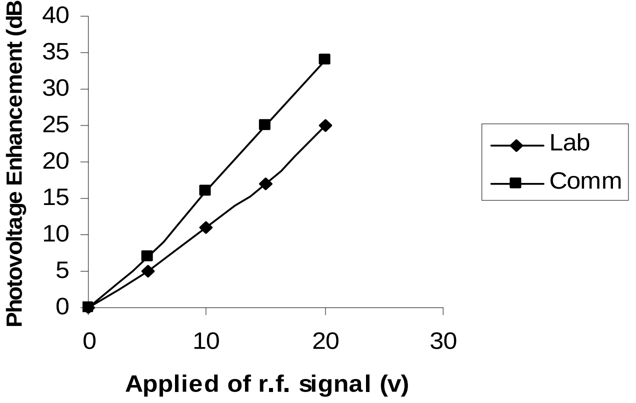


Fig. 3. The induced of V_{dc} by applied r.f. voltage for laboratory and commercial optomodulator device.

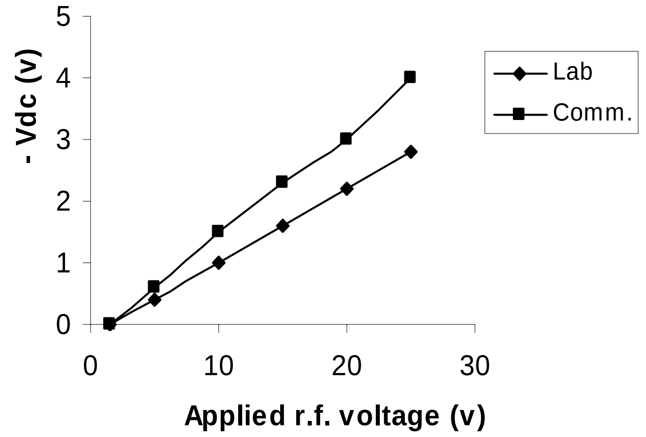


Fig. 4. The photovoltaic enhancement under r.f. signals biasing.

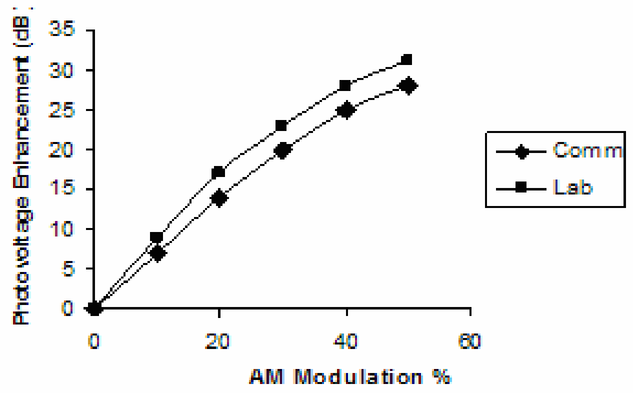
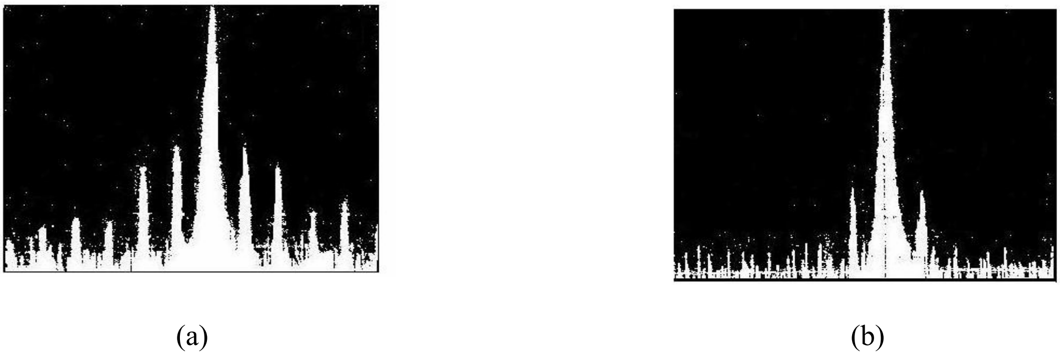


Fig. 5. The photovoltage enhancement against the percentage of AM modulation.



(a)

(b)

Fig. 6. The photoconductive effect spectrum before and after filtering.

(a)

(b)

Fig. 7. The line scan of two holes before and after filtering.

4. Conclusions

The advantage of the modulation technique would be a reduction in the required drive level on the signal by a factor of 90 %. Such a decrease reflects a significant reduction in the thermal noise which may be generated by the heating effects of the silicon surface.

This technique enhances the amplification gain for week light modulated signals and could be used for image processing.

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Guide for Contributors

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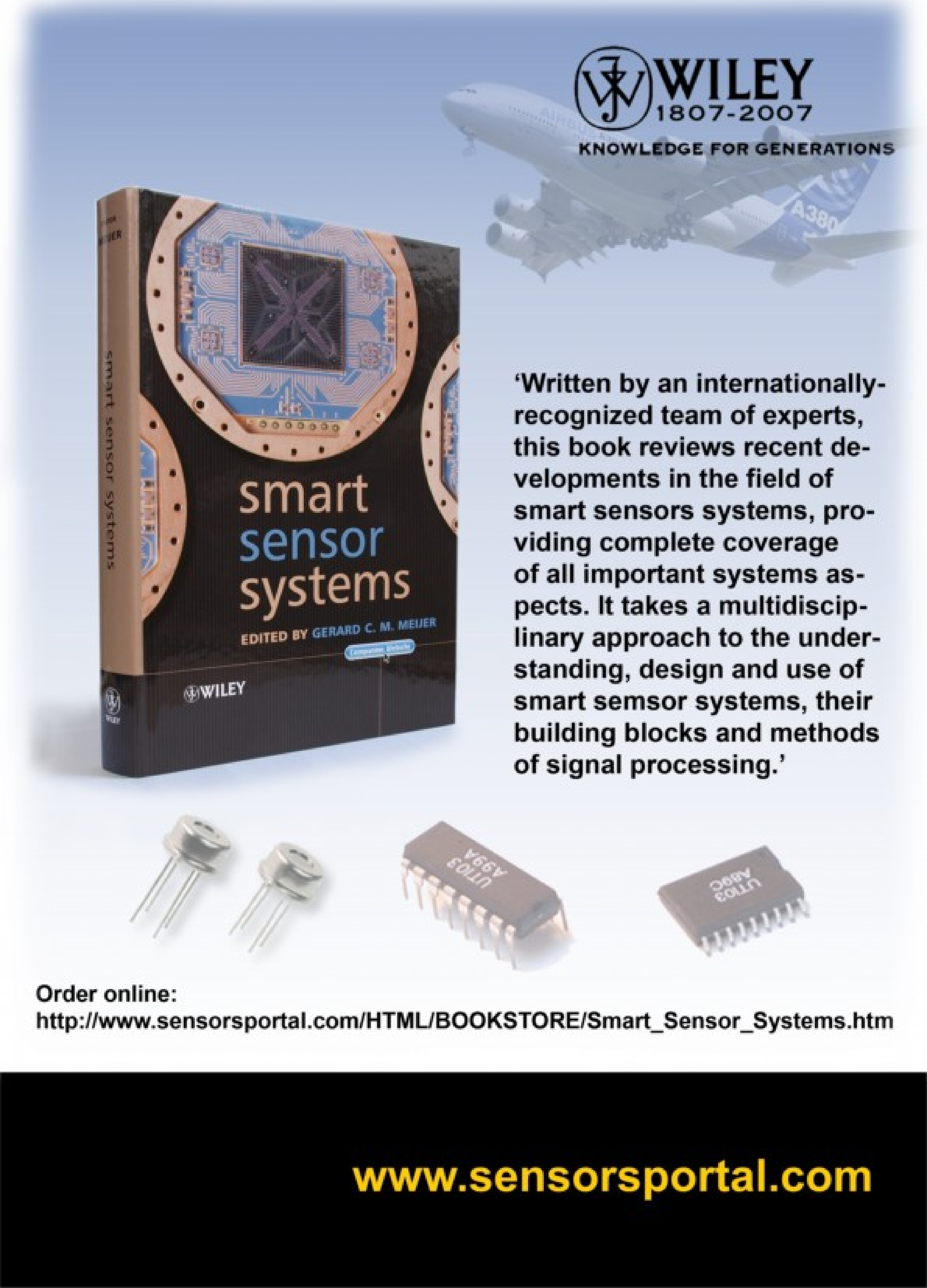

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