Visible Light Communication for indoors navigation with a-SiC:H photodetectors

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***Abstract* — In this paper a photodetector working as an active optical filter device is used to detect modulated visible optical signals for applications based on Visible Light Communication (VLC). The proposed application demonstrates the viability of indoor positioning using VLC technology established by the modulation of indoor ultra-bright RGB white LEDs. The signals of the internal red and blue chips of the white LEDs were modulated at specific frequencies and the generated photocurrent was measured by a pin-pin photodetector based on a-SiC:H/a-Si:H. This device operates as a visible optical filter with controlled wavelength sensitivity through the use of adequate optical biasing light. Thus it is able to detect different wavelengths which allow the detection of the individual components of the tri-chromatic white LED. This possibility is the basis for the indoor location algorithm. We demonstrate the possibility of decoding four transmission optical channels supplied by two different wavelengths of white LEDs modulated under different bit sequences. The identification of the signals received by the photodetector allows the location identification of the photodetector position and supplies indoor navigation.**

Keywords: amorphous SiC technology; Visible Light Communication; indoors positioning.

I. Introduction

VLC technology makes use of the visible part of the light spectrum to modulate specific wavelengths and encode and transmit information [1]. The most common optical sources are the widely used white LED lamps that can also be easily modulated, fulfilling the VLC requirements. An interesting application of VLC technology is for indoor positioning and navigation resources. Its use can be extended from in-house navigation to guide users inside large buildings [2] to location detection of products inside large warehouses.

We propose a communication system operating in the visible range using 4 ultra-bright white RGB and a photodetector device based on 2 stacked multilayered a-SiC:H/a-Si:H structures that act as optical filters [3]. LEDs enable four transmission optical channels supplied by the modulation of different frequencies of the internal red and blue chips. The chance of tuning the spectral device sensitivity is analyzed and discussed using several optical bias conditions that induce different modulations of the electrical field along both front and back structures, amplifying or cutting specific wavelengths. This enables the identification of the transmitted individual input channels and allows the photodetector location identification. The assignment of the identified signal to the location is the basis of the proposed position algorithm. A decoding strategy based on the evaluation of the output photocurrent complex Fourier coefficient for the detection of optical signals is presented and discussed.

A. Experimental setup

The experimental setup used for the detection of the signals emitted by the white LEDs included four white LED lamps framed at the corners of a square as if assembled on the ceiling (Fig. 1). At a fixed distance the photodetector device was centered inside this square.

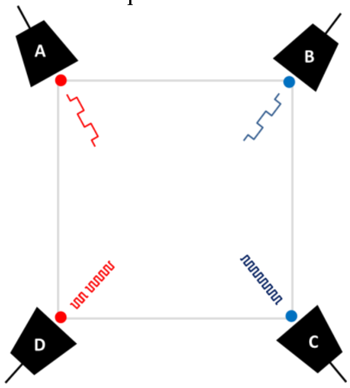

Fig. 1. Configuration of the experimental setup showing the position of the white LEDs and the wavelength and frequency of the modulation chip..

B. Photodetector configuration

Fig. 2 shows the simplified cross-section structure of the device used to detect the transmitted information. It is a multilayer heterostructure composed by two pin structures built on a glass substrate and sandwiched between two transparent electrical contacts. The front pin a-SiC:H photodiode is responsible for the device sensitivity in the short wavelengths of the visible range due to its minor thickness (200 nm) and higher bandgap (2.1 eV). The back pin a-Si:H structure works in the complimentary past of the visible range, collecting the long wavelengths.

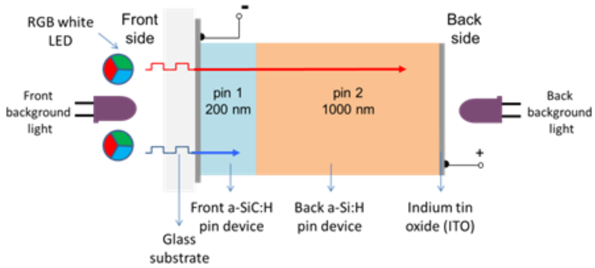

Fig. 2. Simplified cross-section view of the photodetector.

C. Optoelectronic characterisation

The characterization of the optical sources was done through the measurement of the output spectra of each biased chip junction of the RGB white LED with the driving current. In Fig. 3 it is plotted the normalized output spectra of the red and blue chips of the RGB white LEDs.

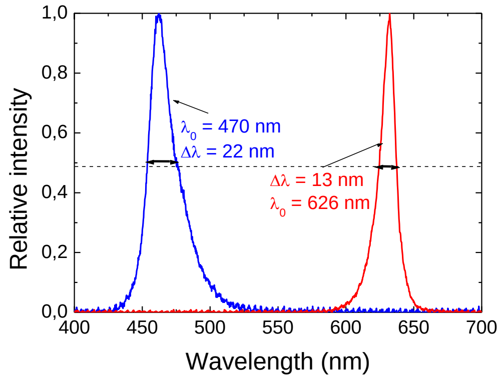

Fig. 3. Output spectra of the red and blue chips.

The output spectra cover the wavelengths assigned to the blue, green and red regions, with wavelengths centered, respectively at 470 nm and 626 nm. The full width half height (FWHH) is 22 nm for the blue chip and 13 nm for the red chip, which is in agreement with the usual design of these chips adjusted for the white color perception.

D. Results

In order to analyse the photocurrent signal when the red and blue chips of the tri-chromatic white LED are transmitting a different signal, the internal LEDs were pulsed using different time dependent biasing currents. The location identification is based on the analysis of the device photocurrent, which results from the optical excitation induced by the optical signals. Thus it is important for the system to be able to detect the combination of two, three of four optical signals. The output photocurrent signals measured under different optical bias conditions are displayed in Fig. 4.

Results show that the signal measured under back illumination is similar to the signal measured without background illumination, which is due to the presence of both red and blue wavelengths that exhibit opposite behaviours under back illumination. The red light quenches the signal and the blue one amplifies it. On the other hand, the photocurrent under front illumination results in an amplified signal due to the high amplification factor of the red light.

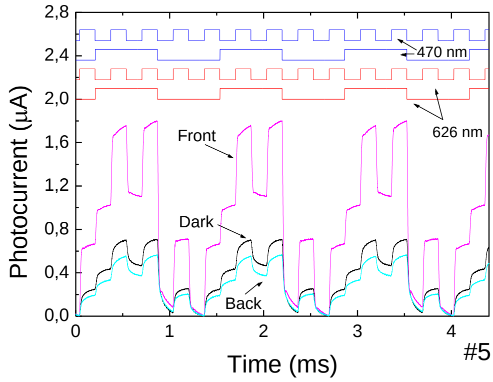

Fig. 4. Photocurrent measured without and under front and back optical bias when the device is at the central position.

E. *Decoding strategy*

As proof of concept we have developed a computer program to detect the position of the sensor relative to the LEDs based on the measured photocurrents. The program uses two simple steps. In the first step, taking advantage of the colour filtering properties of the photodiode, front biasing is used to detect the red wavelength and back biasing to detect the blue wavelength. Because signals of two different frequencies may share the same light wavelength an additional step is necessary to detect which frequencies are present. The modulus of the complex Fourier coefficient of the photocurrent is calculated for each of the relevant frequencies and compared with a predefined threshold value.

F.Conclusions

A novel wireless transmission system based on VLC technology was designed and its viability analyzed using tri-chromatic white LEDs. The performance of the transmission system was assessed by using tri-chromatic white LEDs pulsed with different frequencies, each assigned to a red or blue wavelength. Results show that the output photocurrent signal can be related to the input optical signals informing about detector position and enabling navigation tools.

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