Wireless Optical Communications with GaAs Solar Cells

Walter D. Leon-Salas[1], Xiaozhe Fan[1], Yizhou Zhang[1] and Sindhubala Kadirvelu[1,2].

[1]*School of Engineering Technology, Purdue University, West Lafayette, Indiana, USA* [2]*B. S. Abdur Rahman Crescent Institute of Science and Technology, India*

wleonsal@purdue.edu

Abstract: Modulation of the luminescent radiation of a GaAs solar cell to transmit information wirelessly is explored. The impulse response is measured to determine the transmission speed of binary symbols using square pulses.

OCIS codes: 060.2605, 060.4080.

Recently, a new solar-cell based optical communications scheme, dubbed Optical Frequency Identification (OFID) was reported in [1,2]. In this scheme, a solar cell is employed to transmit and receive data optically while harvesting radiant energy. Transmission of data with a solar cell is possible by modulating the luminescent radiation emitted by solar cells. Solar cells made out of direct bandgap materials, such as GaAs or CdTe, exhibit strong luminescent emissions in the infrared. The luminescent radiant flux of a solar cell is a function of the voltage across its terminals. In OFID, this relationship is exploited to modulate the luminescent radiant flux of a solar cell with data.

Fig. 1 a) depicts an experimental setup to demonstrate the working principle of OFID. In this experiment, a GaAs solar cell from Alta Devices is illuminated by a red LED (CREE XP-E) with an irradiance of 5.17 mW/cm^2 at a distance of 11 cm. The measured open circuit (OC) voltage and the short circuit (SC) current of the solar cell are 1.02 V and 15.6 mA, respectively. The red light stimulates a photo-luminescent (PL) response from the solar cell. The PL response is detected by a photo-diode and a trans-impedance amplifier and is also measured by a power sensor and a power meter (S120C and PM100D from Thorlabs). A voltage ramp ranging from 0 V to the OC voltage is applied to the terminals of the solar cell. Fig. 1 shows the measured power of the PL radiation emitted by the solar cell (P_{out}) as a function of the applied voltage V_{in}. Notably, P_{out} has an exponential dependence on the applied voltage. This exponential response can also be observed at the amplified output of the photodiode V_{out} (Fig. 1 c).
The SC, the OC and the maximum power point (MPP) are marked in the figure.

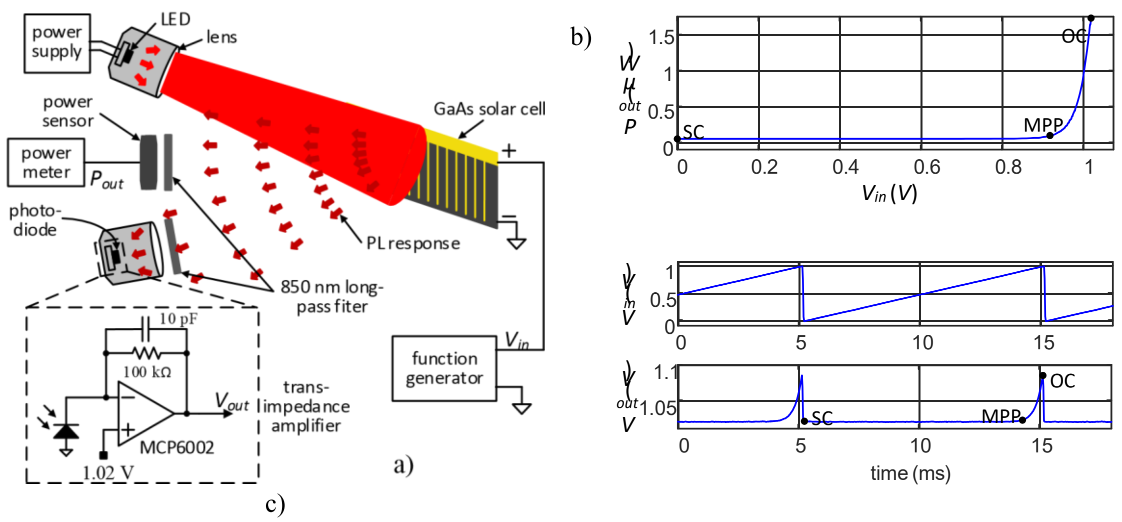

Fig. 1. OFID working principle. a) diagram of experimental setup; b) photo-luminescent radiated power vs. solar cell voltage (V_{in}); c) amplified photo-diode output (V_{out}).

The results in Fig. 1 b) and c) show that binary data can be transmitted with a solar cell using On-Off Keying (OOK) modulation by biasing the solar cell in OC for a binary 1 and in SC or MPP for a binary 0, or vice-versa. Two experiments were conducted to evaluate the rate at which data can be transmitted and received using OOK and a solar cell. These experiments were designed to measure the impulse response of the communication channel. The experimental setup and results are reported in Fig. 2.

Fig. 2 a) shows a diagram of the experimental setup employed to measure the impulse response of the uplink channel, that is when the solar cell transmits data by modulating its luminescent radiation. In this experiment, the solar cell is illuminated by an LED. An NMOS transistor (M_1) is employed to switch the solar cell between SC and OC. A photo-diode and a trans-impedance amplifier are used to detect the PL response of the solar cell. Fig. 2 b) shows the impulse applied to the gate of the M_1 (V_{in}) corresponding impulse response V_{out}. The resulting impulse response has a duration of 17.9 μs, which would correspond to a maximum transmission speed of 55.8 kbps (if square pulses are used to represent binary symbols).

Fig. 2 c) shows a diagram of the experimental setup employed to measure the impulse response of the downlink channel, that is when the solar cell receives data. In this scenario, the LED output power is modulated with information. A voltage-to-current converter is employed to drive the LED. The solar cell was loaded with resistor R_{mpp} to bias the cell at the MPP to emulate the condition in which the solar cell harvests maximum energy while receiving data. Fig. 2 d) shows the input impulse V_{in} and the corresponding impulse response V_{out}. Notably, the resulting impulse response has a duration of 1.15 ms, which would correspond to a maximum reception speed of 868 bps. These transmission and reception rates are suitable for Internet-of-Things applications where low bit rate data, such as position, temperature or a simple identifier code, needs to be transmitted or received wirelessly. The advantage of using a solar cell as a data transceiver is that it allows simultaneous energy harvesting and wireless communications resulting in cost and space reductions.

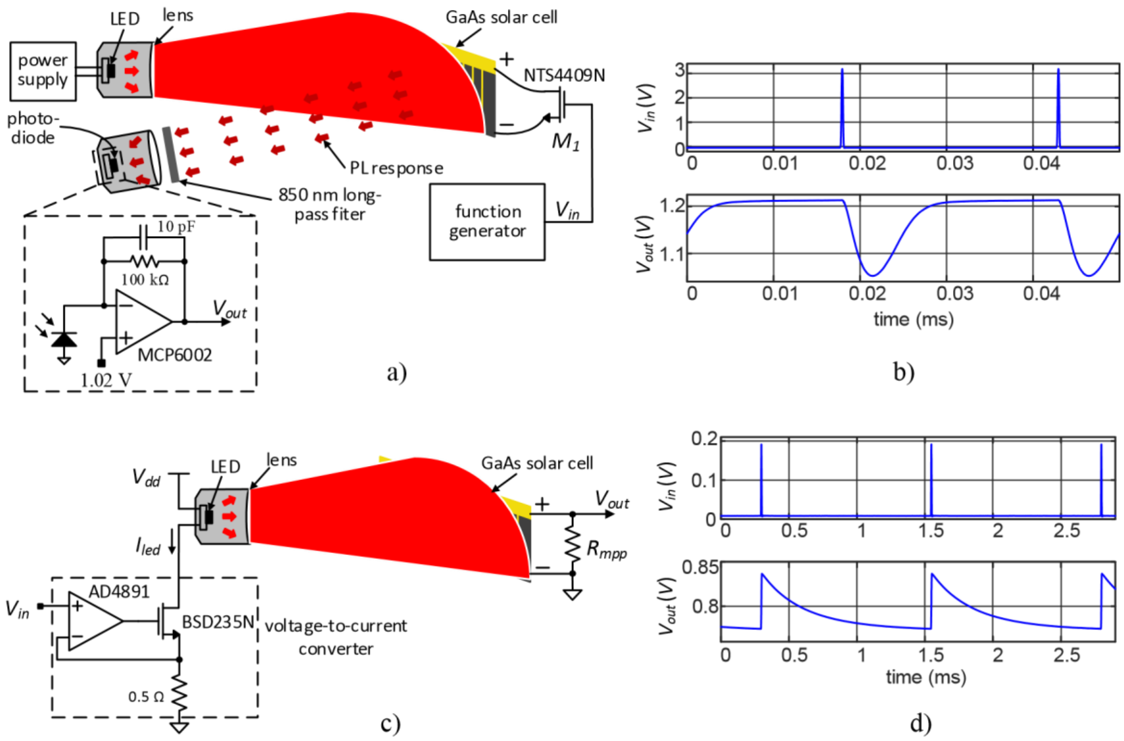

Fig. 2. Evaluation of the transmission and reception rates of a solar cell. a) experimental setup for PL modulation; b) PL impulse response; c) experimental setup for data reception; d) impulse response of solar cell.

References

1. W. D. Leon-Salas and X. Fan, "Solar cell luminescence modulation for Optical Frequency Identification," *IEEE Trans. on Circuits and Systems*, pp. 1-12, Sept. 2018.
2. W. D. Leon-Salas and X. Fan, "Exploiting luminescence emissions of solar cells for Optical Frequency Identification (OFID)," *IEEE Int. Symp. on Circuits and Systems*, May 2018.