Characterization of cost-efficient OPT101 PIN photodiode as relative dosimetry in diagnostic radiology: An IOT application

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Abstract. OPT101 photodiode sensor dosimetry properties were investigated for various parameters to observe its capability as a relative dosimeter. Its characterization was done with PTW semiconductor detector for diagnostic radiology as a benchmark. OPT101 presented excellent output linearity relative to dose measured by PTW semiconductor for energy dependency and reproducibility test. A significant high sensitivity was observed against dose rates and mean energies and linear response against different source-to-detector distance, SDD. Results suggest the use of an Arduino IDE microcontroller as potential of utilizing an IoT application in input/output communication with the sensor and data processing.

Index Terms. OPT101 photodiode, relative dosimeter, Arduino IDE

1. Introduction
An ideal dosimeter must possess at least one of the characteristics for it to function as a radiation dosimeter, which are linearity, precision and accuracy, dose rate dependence, energy and directional dependency [1-2]. A photodiode is the alternative to the silicon diode dosimeter because of its has small size, real-time operation, low cost, high accuracy, and precision attainable in a wide range of doses [3-4]. The only lack of photodiode is its sensitivity that varied with temperature, dose rate, and its efficiency degraded over time. It is increasingly used for small field dosimetry in modern therapy techniques due to their finite size of the sensitive volume able to produce 18, 000 times current than that of an ionization chamber of equal sensitive volume [5]. In this work, the immediate read-out signal from the photodiode is facilitated by the used of IoT system applications from Arduino IDE software and Blynk app available in major mobile operating systems nowadays.

2. Method
OPT101 monolithic photodiode was connected onto the Arduino Uno board with LED connected within the circuit to ensure a closed loop is established. The whole transducer system is then exposed under x-ray irradiation alongside with PTW semiconductor detector (Freiburg, GmbH) for diagnostic x-ray. The photovoltaic signals were extracted (using a digital multimeter) under a set of exposure settings, including tube voltage (kVp), current-time product (mAs) and source-to-detector distance (SDD). Transducer performance analysis was based on signal linearity to mAs and air kerma, and sensitivity dependence on absorbed dose, energy, and dose rate.
On the other hand, Arduino code is written and compiled using Arduino interfacing software (Sketch) to collect the signal generated by the transducer and send it to the Arduino Uno board via USB cable. The whole system transducer with Arduino is optionally integrated with Blynk application via Wi-Fi, GSM, or Ethernet cables to monitor the dose response of the OPT101 photodiode on user’s mobile phone.

3. Results and Discussion
OPT101 photodiode dependency against kilovoltage peak (kVp) and dependency against current-time product (mAs), both indicated a linear behavior, with $R^2$ values of 0.964 and 0.999 respectively. Fig. 1. (a) OPT101 photodiode sensitivity dropped from 15.32 mV/mGy (at a dose rate of 0.83 mGy/s) to 3.74 mV/mGy (at a dose rate of 1.66 mGy/s) before becoming stable beyond dose rate of 2 mGy/s. While Fig. 1. (b) OPT101 sensitivity continuously fading from 2.65 mV/mGy (at tube voltage of 50 kVp) to 1.11 mV/mGy (at tube voltage of 70 kVp) and become stable beyond approximately 75 kVp tube voltage.

Fig. 2. illustrated that OPT101 signal linearity to dose determinant coefficients were 0.946 with a small signal detected per absorbed dose increment (0.6 mV/mGy). On the other hand, OPT101 photodiode sensitivity dropped from 15.3 mV/mGy to 2.5 mV/mGy in response with in a 20.7 mGy absorbed dose increment similar to what has been observed previously [6-8].

![Fig. 1. Sensitivity of OPT101 photodiode across different (a) dose rates (range 10 mA – 160 mA) and (b) X-ray tube voltage (at 100 mAs); both at 100cm SDD.](image1)

![Fig. 2. Output signal and transducer sensitivity as a function of dose (measured by PTW semiconductor dosimeter). This data was collected in the 10–160 mAs range, while the tube voltage and SDD were set to 80 kVp and 100 cm, respectively.](image2)
The results highlight two important parameters: (i) OPT101 photodiode has a potential to be optimized as a relative dosimeter in the future application of diagnostic x-ray detector with stated characteristic mentioned above. However, it has experienced a low radiation-induced signal/sensitivity possible due to less charge drift in increasing energy delivered to photodiode active area. Transducer sensitivity and response to X-ray beams is directly influenced by the energy required to form an Electron-Hole Pair in the transducer’s active region. Hence, this observation agrees with a previous study where photo transistor sensitivity decreased in response to increasing dose-rate [10]. Furthermore, considering the interaction events take place in lower x-ray energy (predominantly Photoelectric effect and Compton scattering) within the active area of photodiode, OPT101 photodiode having advantages of high sensitivity with immediate readout of dose values, low cost, and portability also could replace passive dosimetry such as thermoluminescent dosimeter (TLD) for dose measurements in diagnostic radiology.

Secondly, (ii) the whole transducer system can be well-versed into a sophisticated IoT integration with less set-up required (no laptop and messy cords, only Wi-Fi and Blynk server) for the future data collection as illustrated in Fig. 3. Arduino IDE can easily be connected to the cloud and build a no-code iOS, Android, and web applications to read and analyze real-time data coming from OPT101 sensor, control them remotely from anywhere (e.g. mobile phone) and receive important notifications.

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