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A Silicon Photodiode Coupled with a Plastic Scintillator as a Radiation Therapy Detector

Shahin Ahmadi, MSc[1]; Alasdair Syme, PhD[1,2]; Thalat Monajemi, PhD[1]
[1]Dalhousie University, [2]Department of Medical Physics, Nova Scotia Health Authority

ABSTRACT

Silicon photodiodes offer compact and sensitive radiation detection but are limited by energy and dose-per-pulse dependence.

This study evaluated four commercial photodiodes and investigated coupling the selected detector with a BCF-10 plastic scintillator.

The photodiode–scintillator configuration increased signal output by approximately 80%, reduced dose-per-pulse dependence to within 1.2%, maintained excellent dose linearity ($R^2 \geq 0.99998$), and reduced low-energy photon-energy dependence by up to a factor of 2.73.

The proposed compact and low-cost detector demonstrates strong potential for photon beam dosimetry and routine radiotherapy quality assurance.

CONTACT

Shahin Ahmadi
Dalhousie University
6299 South St., Halifax, NS, B3H 4R2, Canada
Shahin.ahmadi@nshealth.ca
4316886870

INTRODUCTION

- Silicon photodiodes are compact, sensitive, low-cost detectors with real-time readout for radiation dosimetry.
- Their performance is limited by energy dependence and dose-per-pulse effects from direct radiation interactions.
- Coupling photodiodes with plastic scintillators enhances signal output and reduces direct radiation effects.
- Four commercial photodiodes were evaluated, and the best-performing photodiode was paired with a plastic scintillator and characterized for photon beam dosimetry and radiotherapy quality assurance.

METHODS AND MATERIALS

- Four zero-bias silicon photodiodes (Figure 1 shows the circuit) were evaluated for radiation hardness, signal stability, and energy response.
- The selected SFH2430 photodiode was characterized alone and coupled with BCF-10 plastic scintillators (0.5–5 mm thickness, Figure 2).
- Detector performance was assessed for dose linearity, dose-rate dependence, PDD, small-field output factors, and energy response using MV and kV photon beams.
- Figure 3 presents the experimental setup used for radiation damage, dose linearity, and average dose-rate dependency measurements.

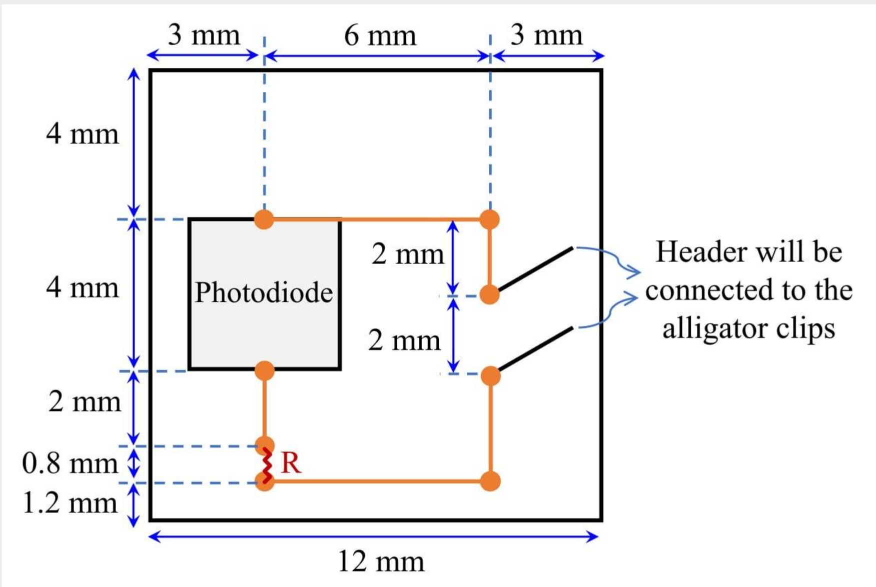

Figure 1. The photodiode circuit design.

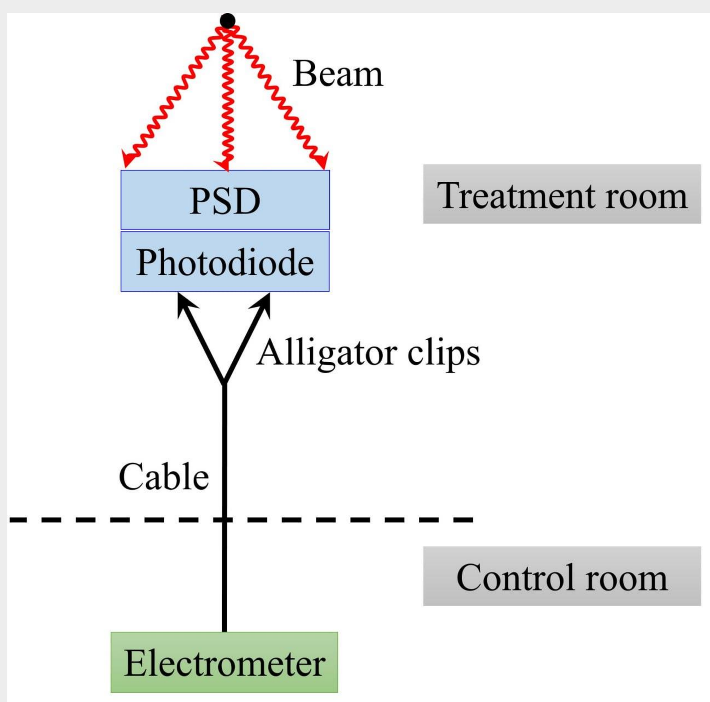

Figure 2. The measurement setup.

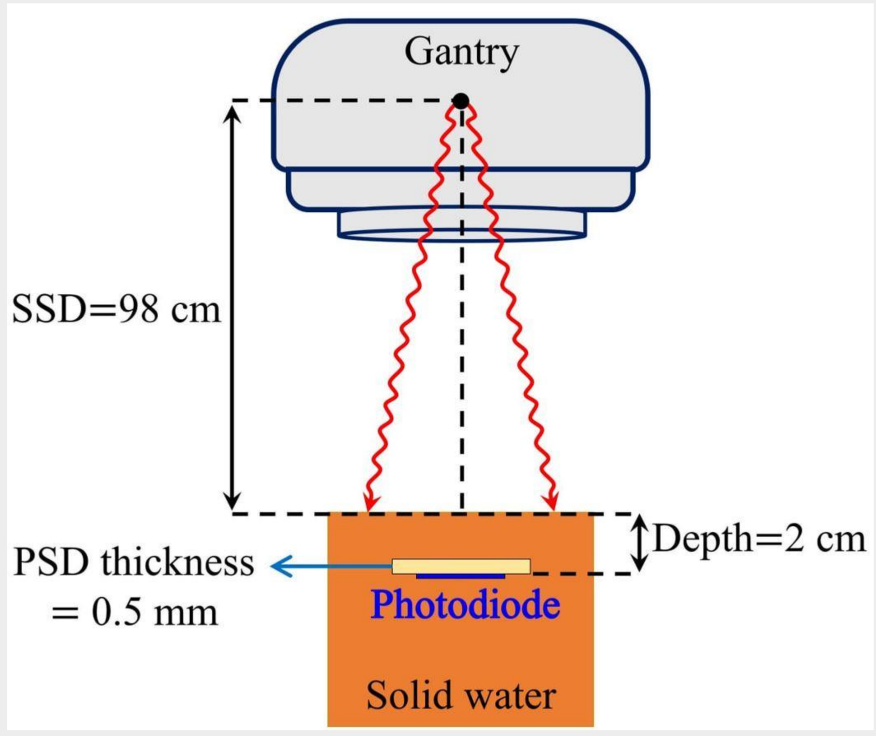

Figure 3. Dose rate and linearity measurements setup.

RESULTS

- SFH2430 showed the best performance among the evaluated photodiodes and was selected for further characterization.
- A 0.5 mm BCF-10 scintillator increased signal output by 80-82.2% (Table 1, Figure 4).
- The detector achieved excellent linearity ($R^2 \geq 0.99998$), low dose-rate dependence (<0.25%), and reduced dose-per-pulse effects (6.5% to 1.2%).
- Scintillator coupling improved PDD agreement with Eclipse calculations and small-field output factors compared to the results of microDiamond measurements within 3.1% (Figures 5–6).
- A 5 mm scintillator reduced the low-energy photon dependence of the response by factors of 2.73, 2.47, and 1.54 at 100, 180, and 300 kV, respectively (Figure 7).

Table 1. The signal magnitude change via a 0.5 mm thick plastic scintillator.

Photodiode model	6 MV(%)	6 MVFFF(%)	10 MV(%)
VEMD5060X01	6(0.53%)	5.2(0.45%)	7.1(0.64%)
BPW34S	3.1(0.62%)	1.9(0.43%)	4.6(0.57%)
VEMD5510CF	2.4(0.84%)	1.6(0.55%)	3.8(0.78%)
SFH 2430	80.1(0.47%)	80(0.59%)	82.2 (0.73%)

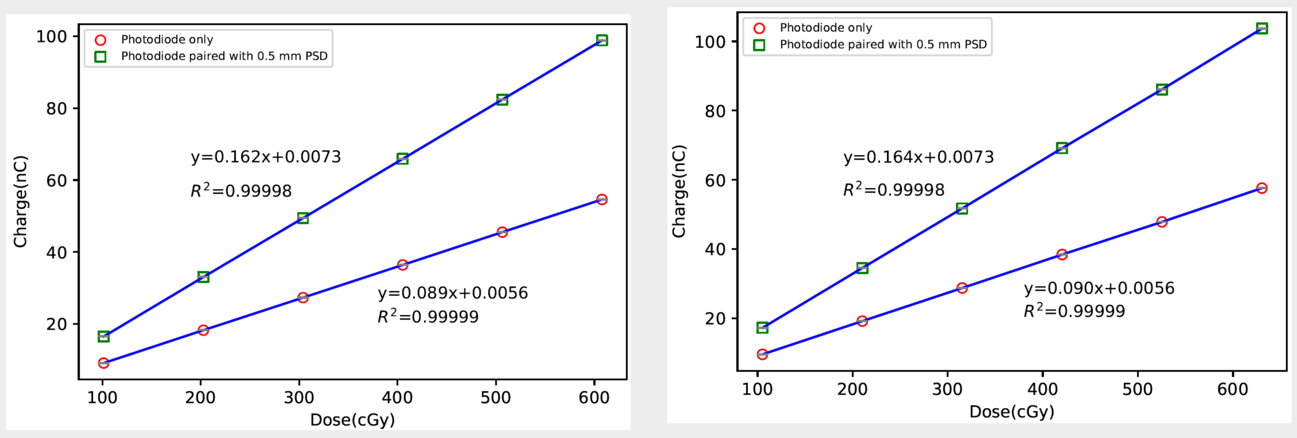

Figure 4. The charge response to 6 MV (left) and 6 MVFFF (right) photons.

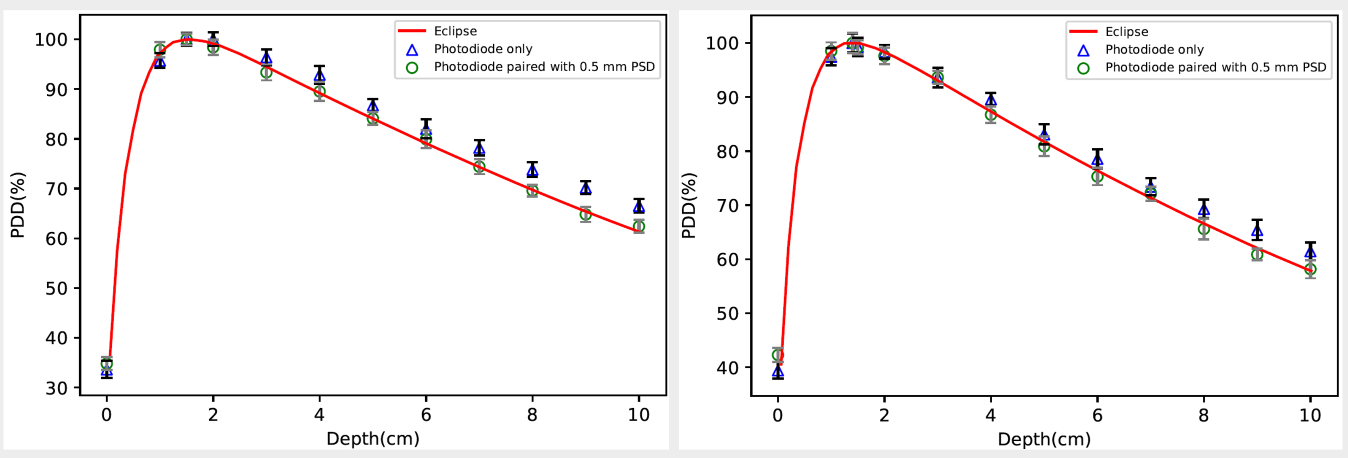

Figure 5. The depth dose for 6 MV (left) and 6MVFFF (right) photons.

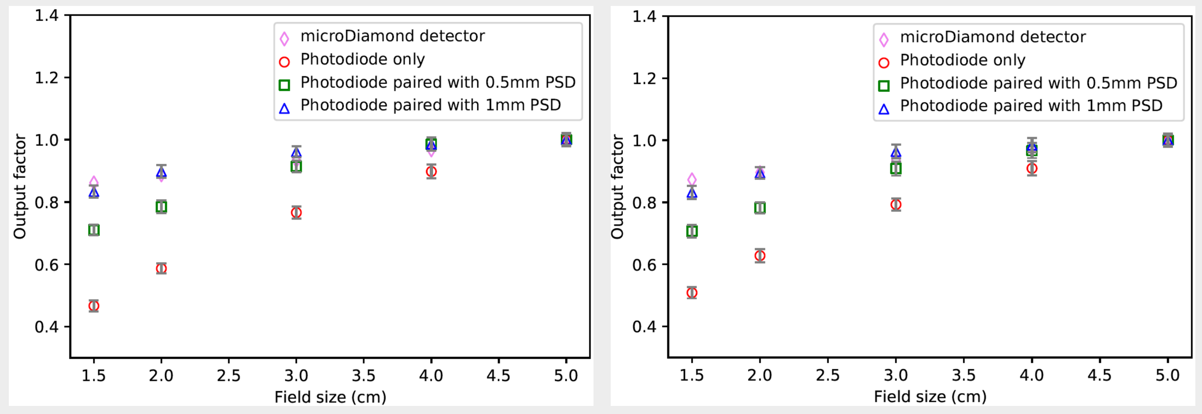

Figure 6. The small field output factor for 6 MV (left) and 6MVFFF (right) photons.

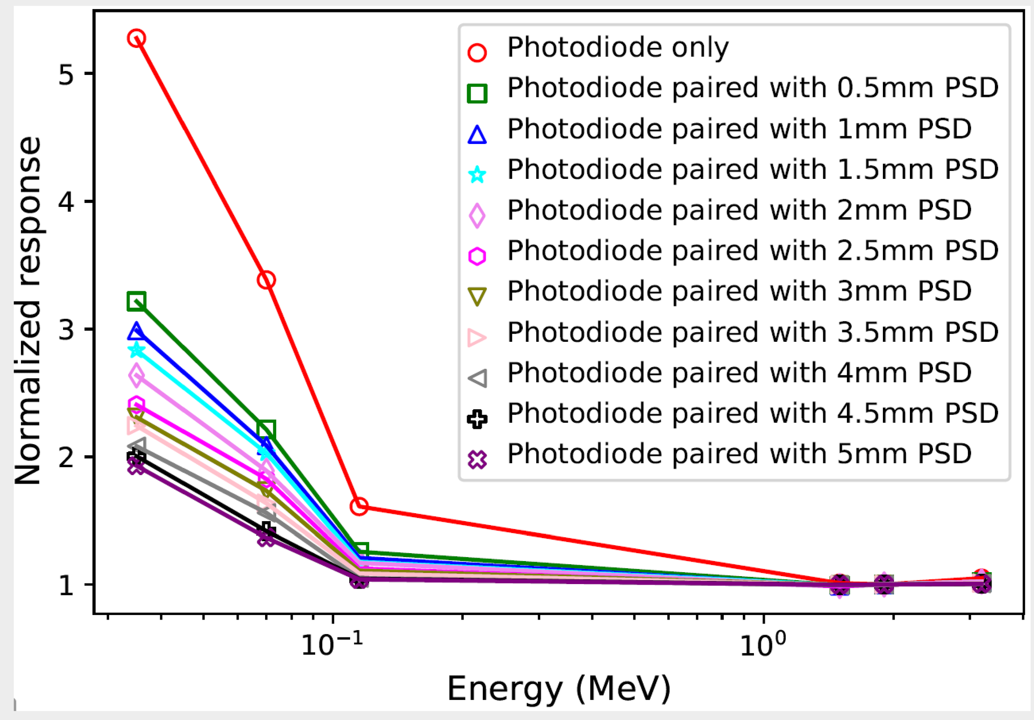

Figure 7. The energy response of the detector to different thicknesses of scintillator.

DISCUSSION

- The plastic scintillator converts radiation into visible light, reducing direct silicon interactions and improving detector sensitivity and stability.
- Scintillator coupling increased signal output by ~82%, while reducing dose-per-pulse and energy dependence.
- The detector showed good agreement with Eclipse PDD calculations and microDiamond measurements, supporting its use for radiotherapy QA.
- Adjustable scintillator thickness enables performance optimization; however, thicker scintillators require consideration of effective measurement point shifts.

CONCLUSIONS

- A compact silicon photodiode–plastic scintillator detector was successfully developed for photon beam dosimetry.
- Scintillator coupling improved sensitivity, dose-per-pulse response, PDD accuracy, small-field measurements, and low-energy photon response with stable performance across clinical conditions.
- The proposed detector provides a simple, low-cost, and reliable alternative for radiotherapy QA, with potential for further clinical optimization.

REFERENCES

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2. D J. A. Posar, et al., Characterization of a plastic dosimeter based on organic semiconductor photodiodes and scintillator, Physics and Imaging in Radiation Oncology 14 (2020) 48–52.