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Field Output Correction Factors of Novel Unshielded and Shielded Silicon Diode Detectors: SunSILICON and SunSILICON P

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ABSTRACT

Purpose: Determination of field output correction factors (FOCF) of SunSILICON and SunSILICON P.

Methods: The evaluation was conducted using Monte Carlo simulations and experimental measurements.

Results: The photon FOCFs for both detectors meet IAEA TRS 483 and AAPM TG 155 requirements. Electron field output factors measured with the unshielded silicon diode detector matched those measured with a Farmer-type ionization chamber within ±1%.

Conclusion: The novel silicon diode detectors SunSILICON and SunSILICON P are suitable for measuring field output factors in photon and electron beams, requiring only minor corrections

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INTRODUCTION

This study investigates the Field Output Correction Factors (FOCF) as described in IAEA TRS 483[1] and AAPM TG 155[2] of Sun Nuclear's two novel silicon diode detectors, the unshielded silicon diode detector SunSILICON (Model 1048) and the shielded silicon diode detector SunSILICON P (Model 1049).

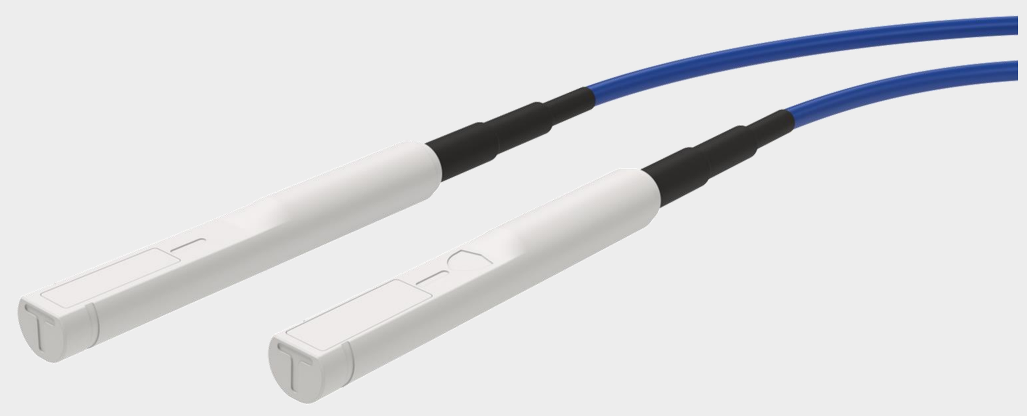

Figure 1: Unshielded 1048 SunSILICON (left) and shielded 1049 SunSILICON P (right) manufactured by Sun Nuclear Corp.

METHODS AND MATERIALS

The novel unshielded and shielded silicon diode detectors SunSILICON and SunSILICON P were characterized by means of Monte Carlo using the EGSnrc code system. To determine the FOCF, the dose deposition was calculated in the detector model and a "point-like" water voxel. A full linear accelerator head model was used to generate realistic square photon fields from 0.4 cm to 40 cm and square electron fields from 6 cm to 25 cm. Monte Carlo models of SunSILICON and SunSILICON P were created based on the manufacturer's drawings and material data.

The calculated data was validated in water phantom measurements using detectors featuring consensus FOCFs published in IAEA TRS 483 as reference for small fields, and compact-type or Farmer-type ionization chambers as reference for larger fields. For each small field measurement, beam centering was performed and dosimetric field sizes were determined by lateral beam scans.

Reference detectors included Standard Imaging's W1 scintillator, PTW's microDiamond, microSilicon, microSilicon X, Semiflex 3D, and Farmer chamber, IBA's CC04 and CC13, and Sun Nuclear's 1047 SNC600c and 1118 EDGE Detector depending on field size range and availability at the respective measurement site.

The measurements were performed using various linear accelerators, including Varian's TrueBeam and Elekta's Versa HD, with and without flattening filter, with nominal energies ranging from 4 MV to 25 MV. 4 MV and 25 MV measurements were conducted at the German national metrology institute PTB Braunschweig. Corrected small field reference measurements were intercompared to verify the preciseness of the measurements and the applied corrections. FOCFs for SunSILICON and SunSILICON P were determined by evaluation against the corrected reference measurements.

Analog simulations and measurements were performed with the unshielded silicon diode detector for common clinical electron field sizes and nominal electron beam energies ranging from 6 to 20 MeV.

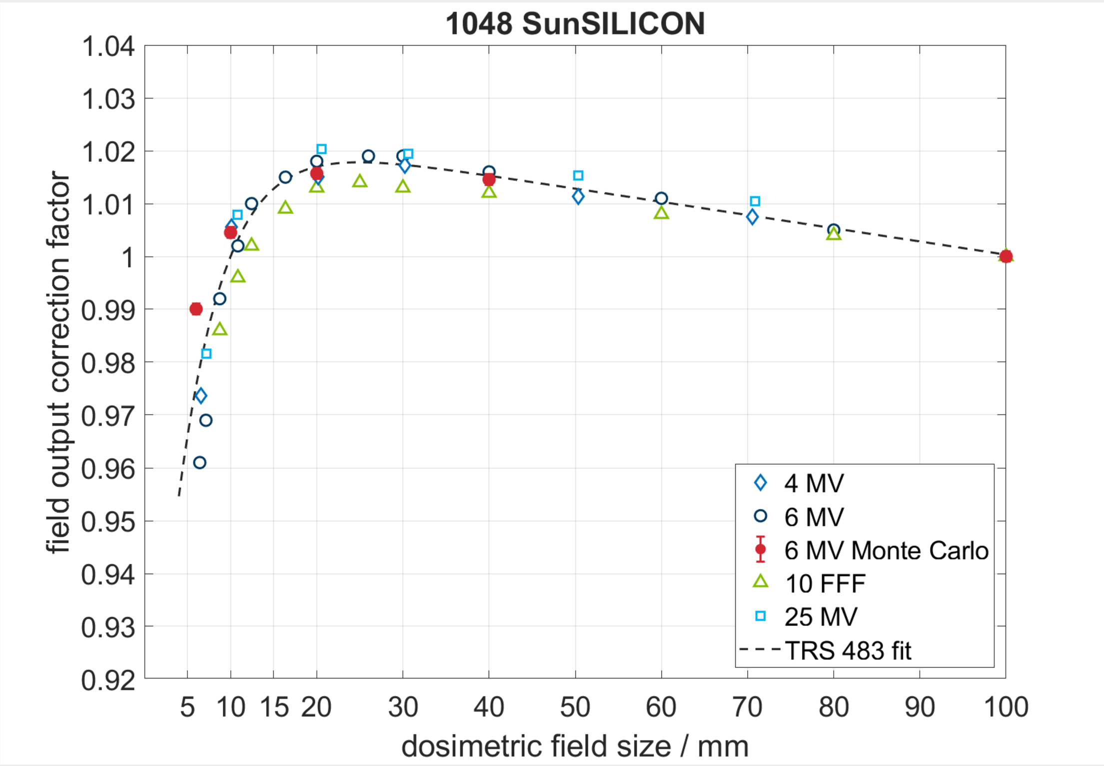

Figure 2: Measured and Monte Carlo simulated field output correction factors for 1048 SunSILICON for various photon beam energies.

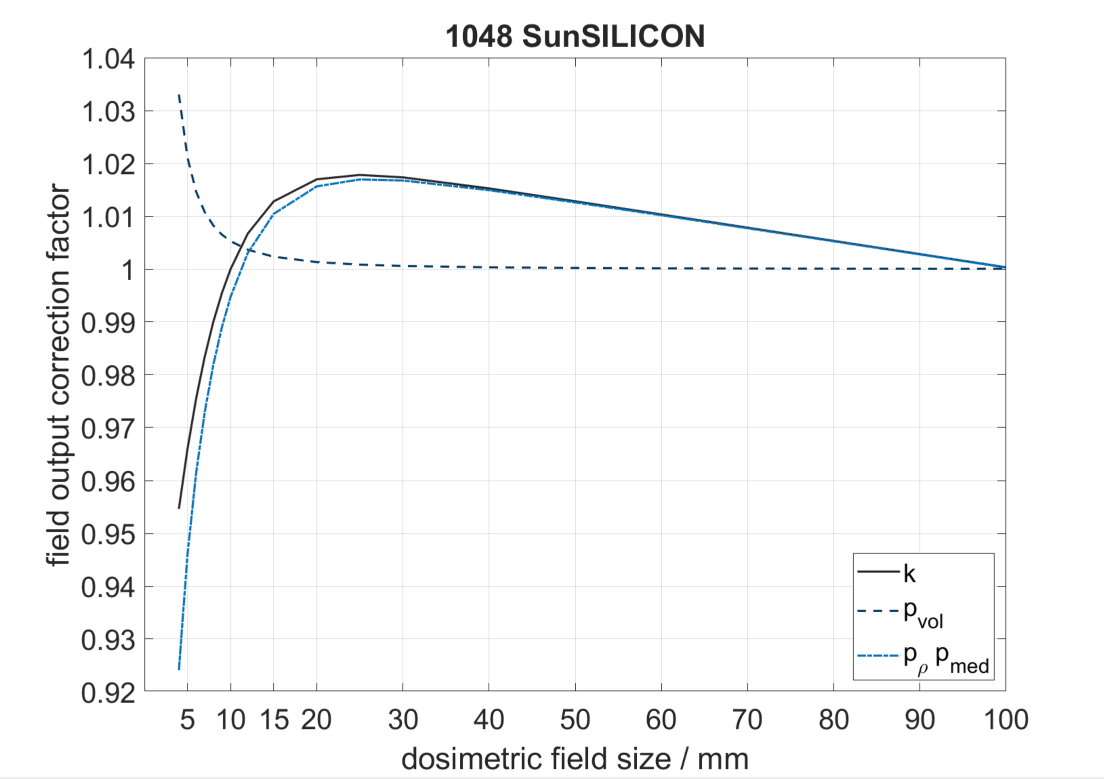

Figure 3: 1048 SunSILICON field output correction factors k broken down into contributing effects: volume perturbation p_{vol}, as well as density and medium perturbations $p_\rho \cdot p_{med}$, the interplay of which achieves an improved overall dosimetric performance.

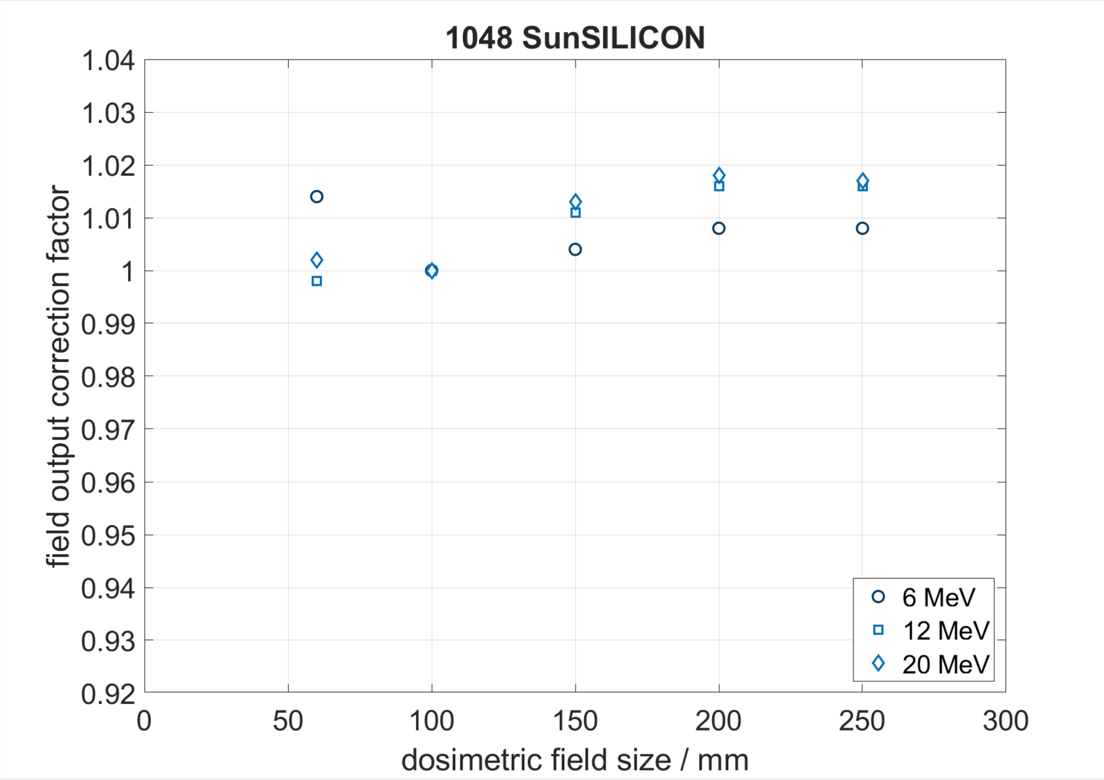

Figure 4: Measured field output correction factors for 1048 SunSILICON for various electron beam energies.

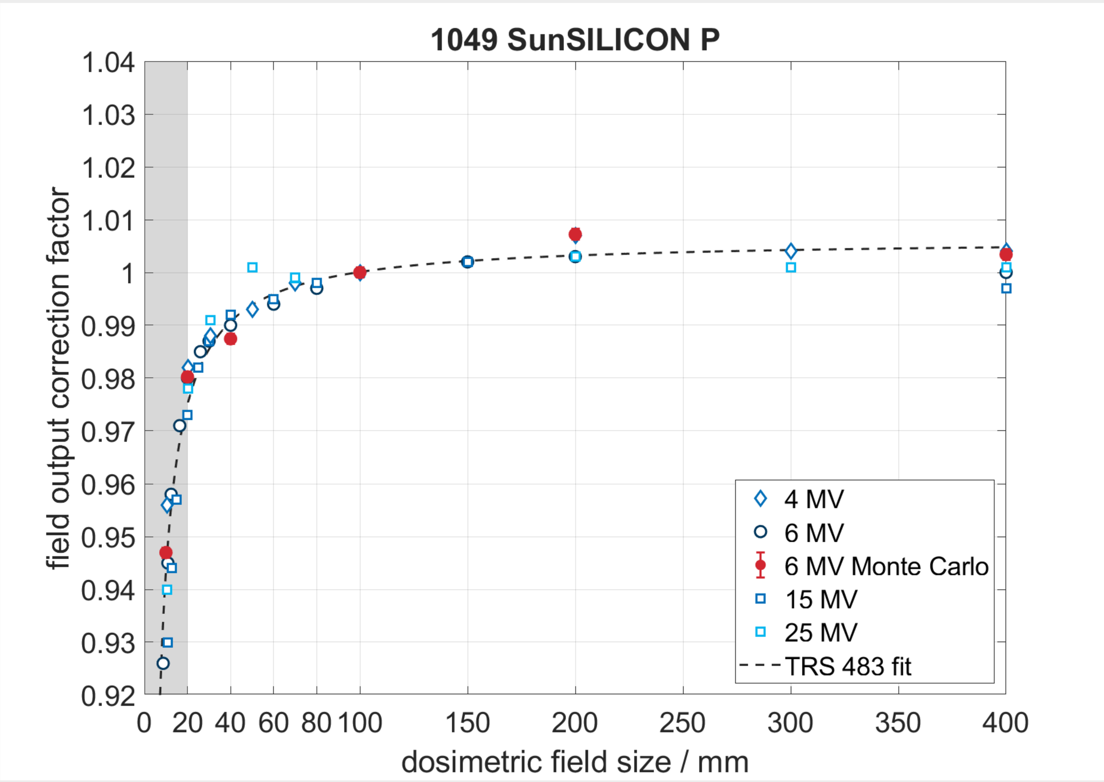

Figure 5: Measured and Monte Carlo simulated field output correction factors for 1049 SunSILICON P for various photon beam energies. Grey area is outside of manufacturer's specifications.

RESULTS

The photon FOCFs determined by Monte Carlo simulations showed excellent agreement with measured data. As required by TRS 483[1] and TG 155[2], FOCFs remain within 1.00±0.05 for all field sizes within the intended range of use stated by the manufacturer, see Table 1.

Electron field output factors measured with the unshielded silicon diode detector matched those measured with a 1047 SNC600c Farmer-type ionization chamber within ±1 %, see Figure 4.

Table 1. Tabulated data of fitting functions displayed in Figures 2 and 5. Shaded cells are outside of manufacturer's specifications.

Field size / mm	SunSILICON	SunSILICON P
4	0.955	---
5	0.966	---
6	0.975	---
7	0.983	---
8	0.990	---
9	0.995	---
10	1.000	---
12	1.007	---
15	1.013	---
20	1.017	0.975
25	1.018	0.981
30	1.017	0.985
40	1.015	0.991
50	1.013	0.994
60	1.010	0.996
70	1.008	0.997
80	1.005	0.999
90	1.003	0.999
100	1.000	1.000
150	---	1.002
200	---	1.003
300	---	1.004
400	---	1.005

DISCUSSION

Figure 3 reveals how fluence perturbations affect the overall FOCFs and indicates the limitations of high-density detectors in small photon fields. As thoroughly discussed in IAEA's TRS 483[1], the experimental determination of FOCFs is subject to high uncertainty at small field sizes. Yet, the congruence of the presented data recorded at four different sites and by six different persons, as well as their excellent agreement with Monte Carlo simulations, allow for high confidence and demonstrate that SunSILICON and SunSILICON P meet and exceed the requirements of TRS 483[1] and TG 155[2]. The beam energy dependence of the FOCFs is within measurement uncertainty, which aligns with previous observations[1].

CONCLUSIONS

This study demonstrated, both through Monte Carlo simulation and experimentally, that the novel unshielded and shielded silicon diode detectors SunSILICON and SunSILICON P are suitable for the measurement of field output factors in photon and electron beams and only requires minor corrections.

REFERENCES

1) International Atomic Energy Agency, Dosimetry of small static fields used in external beam radiotherapy, Technical Reports Series No. 483, IAEA, Vienna (2017).

2) Das, Indra J., et al. "Report of AAPM Task Group 155: megavoltage photon beam dosimetry in small fields and non-equilibrium conditions." *Medical physics* 48.10 (2021): e886-e921.