2017

Effect of scattered electrons on the 'Magic Plate' transmission array detector response

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Publication Details

Alrowaili, Z. A., Lerch, M., Petasecca, M., Carolan, M. & Rosenfeld, A. (2017). Effect of scattered electrons on the 'Magic Plate' transmission array detector response. Journal of Physics: Conference Series, 777 (1), 012033-1-012033-4.

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Abstract

Transmission type detectors can provide a measure of the energy fluence and if they are real-time systems that do not significantly attenuate the radiation beam have a distinct advantage over the current method as Quality Assurance (QA) could in principle be done during the actual patient treatment. The use of diode arrays in QA holds much promise due to real-time operation and feedback when compared to other methods e.g. films which are not real-time. The goal of this work is to describe the characterization of the radiation response of a silicon diode array called the Magic Plate (MP) when operated in transmission mode (MPTM). The response linearity of MPTM was excellent (R2=1). When the MP was placed in linac block tray position; the change in PDD at phantom surface (SSD 100 cm) for a 10 × 10 cm^2 was -0.037 %, -0.178 % and -0.949 % for 6 MV, 10 MV and 18 MV beams. Therefore, MP does not provide a significant increase in skin dose to the patient and the percentage depth doses showed an excellent agreement with and without MPTM for 6 MV, 10 MV and 18 MV beams.

Keywords

response, effect, scattered, detector, electrons, array, 'magic, plate', transmission

Disciplines

Engineering | Science and Technology Studies

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2017 J. Phys.: Conf. Ser. 777 012033

(http://iopscience.iop.org/1742-6596/777/1/012033)

Effect of scattered electrons on the 'Magic Plate' transmission array detector response

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Abstract. Transmission type detectors can provide a measure of the energy fluence and if they are real-time systems that do not significantly attenuate the radiation beam have a distinct advantage over the current method as Quality Assurance (QA) could in principle be done during the actual patient treatment. The use of diode arrays in QA holds much promise due to real-time operation and feedback when compared to other methods e.g. films which are not real-time. The goal of this work is to describe the characterization of the radiation response of a silicon diode array called the Magic Plate (MP) when operated in transmission mode (MPTM). The response linearity of MPTM was excellent (R2=1). When the MP was placed in linac block tray position; the change in PDD at phantom surface (SSD 100 cm) for a 10 x10 cm^2 was -0.037 %, - 0.178 % and -0.949 % for 6 MV, 10 MV and 18 MV beams .Therefore, MP does not provide a significant increase in skin dose to the patient and the percentage depth doses showed an excellent agreement with and without MPTM for 6 MV, 10 MV and 18 MV beams.

1. Introduction

Quality assurance (QA) in radiotherapy is a high priority, due to the sophisticated nature of the treatment delivery [1]. One of the challenges of modern radiotherapy is to establish time efficient QA tests, which demonstrate that delivered treatments produce dose distributions to within acceptable tolerance to the dose as calculated by the treatment planning system (TPS) [2]. Therefore, the development of new QA tools is essential to keep pace with the latest available radiotherapy modalities for cancer treatment [3, 4]. Thus, there is a significant need for real-time detectors and *in vivo* verification for each VMAT fraction using transmission type detectors online during patient treatment delivery. This improves the current pre-treatment verification step as treatments can be verified for each delivery. Mainstream *in vivo* dosimetry systems currently available for megavoltage (MV) photon radiotherapy are restricted to point dose detector technologies such as diodes [5], thermoluminesce detectors (TLDs) and metal oxide field effect transistors (MOSFETs) dosimeters [6].These point dose measurement techniques while being very valid and useful, can be labour intensive and provide inadequate information with the dose only being determined at a single point [7]. Notwithstanding their limitations, these existing techniques are widely used in many facilities. Energy fluence measurements can be made and logged using the ionisation chamber upstream of the MLC. This combined with comparison of the measured and planned MLC leaf positions provides some level of *in vivo* QA. However there is no direct measurement of the 2D spatial distribution of the energy fluence downstream of the MLC yet upstream of the patient. There are other transmission detectors that have been stated in the literature; the IBA COMPASS detector [8], the Integral

Quality Monitoring system (IQM) [9], the DAVID system [10] and more recently the IBA dolphin online treatment monitoring. Though, all these detectors are ionization chambers based and some of them significantly attenuate the beam, increase the surface dose and the other can only provide online treatment evaluation after each fraction; not in real- time. A 2D silicon diode array, MP has been developed and designed to be placed between the MLC and the patient. It measures 2D fluence maps, so that dose profiles can be reconstructed for comparison with the TPS [11]. The system is designed such that measurements can be achieved simultaneously with the patient treatment so as to provide immediate real-time feedback leading to a very high level of QA in cancer treatment delivery. This study describes the performance characteristics of a 2D silicon detector array system, when operated in transmission mode to monitor the fluence during patient treatment for real time QA of megavoltage photon radiotherapy on a medical linear accelerator using three different energies 6 MV, 10 MV and 18 MV. Therefore, characterization of the detector in transmission mode was performed including dose linearity, reproducibility, energy response, the response of the array with different dose rates, the response of the array as a function of field size, transmission factor, and attenuation of the beam by MP, and back scattering effect.

2. Methodology

The prototype MP used in this study has dimensions of 10 x10 cm^2 with a 1 cm detector pitch. The MP has 121 pixels with sensitive volume of 0.6 x 0.6 x 0.05 mm^3 and is mounted on a 0.6 mm thick kapton substrate. The MP can be utilised as a transmission detector by mounting it on the linear accelerator head (in the accessory slot) normal to the radiation beam. The Source Detector Distance (SDD) of 58 cm indicates the position of MPTM, and the actual field size is 1.72 times smaller than that at 100 cm SSD. This mode of MP operation is designed to be used to verify the dose from IMRT and VMAT treatment delivery, in real-time and during patient treatment, by measuring the 2D energy fluence map of the modulated radiation beam [12]. The characterisation of the silicon diode array when operated in transmission mode was performed, including dose linearity the response of the array as a function of field size. Experiments were performed when MP placed in transmission mode (MPTM) using two Varian linear accelerator (Model 2100EX), one of which operated at the energies of 6 MV and 10 MV, and another which was operated at 18 MV. Different irradiation field sizes and a constant SSD of 100cm were used for both linac experiments. Every pixel of the 2D detector array is readout independently by a multichannel charge to frequency converter preamplifier called TERA06 system. The flat field correction statistics of MP121 response before and after the equalisation was applied. The differential response is calculated. The variation in the response of all 121 detectors relative to the average response was less than 3% and less than 1% before and after flat field correction for 6 MV, 10 MV and 18MV beam energies respectively.

3. Results

The linac pulses frequency dependence range used (100-600 MU/min) of MPTM which was excellent. The percentage standard deviation across the array of frequency pulses range from 100 MU/min to 600 MU/min was 2.384%, 1.711% and 3.325% for 6 MV, 10 MV and 18 MV respectively. The response of the MPTM array was found to be linear with clinically useful range of 1 MU to 800 MU for 6 MV photon beam with different dose rate repetitions range from 75 MU/Min to 600 MU/Min. The adjusted regression coefficient R^2 was found to be 1 and error bars are calculated by two standard deviations over three repetitions as shown in figure 1. All the 121 pixels, in transmission mode, present a reproducibility better than 1.27% (2SD), 1.18 (2 SD) % and 0.40 (2 SD) % for 6 MV, 10 MV and 18 MV beams respectively. Part of this work focuses on how having the MLC fully retracted or matching the shape of the linac jaws influences the response of the MPTM. It is very significant in the context of the intended characterization of the MP array when used in transmission mode, so as to be able to study the effect of the MLCs on MPTM response data. The 6 MV, 10 MV, and 18 MV radiation fields that used here are made up of photons, electrons positrons and photo neutrons in the case for 18 MV. All data has been normalised to the response of the MP detector in a 10x10 cm^2 field size. The variation in central detector response of the MP in case of MLC matches the jaw and jaw only was increases with decreasing of the field size. Significant increasing (> 15%) occurs for field sizes less than 2x2 cm^2 with MLC retracted with the response being lower in the case where the MLC matches the jaw (> 12%) as shown in figure 2 (a) lower panel .The response of the MP detector (with 1 mm build up) was investigated for the same energies, field sizes and scenarios as well as shown in figure 2 (b) lower panel. In this case the variation in central detector response of the MP increased with increasing of the field size. Deviation (> 12%) observed for field sizes less than 2x2 cm^2.

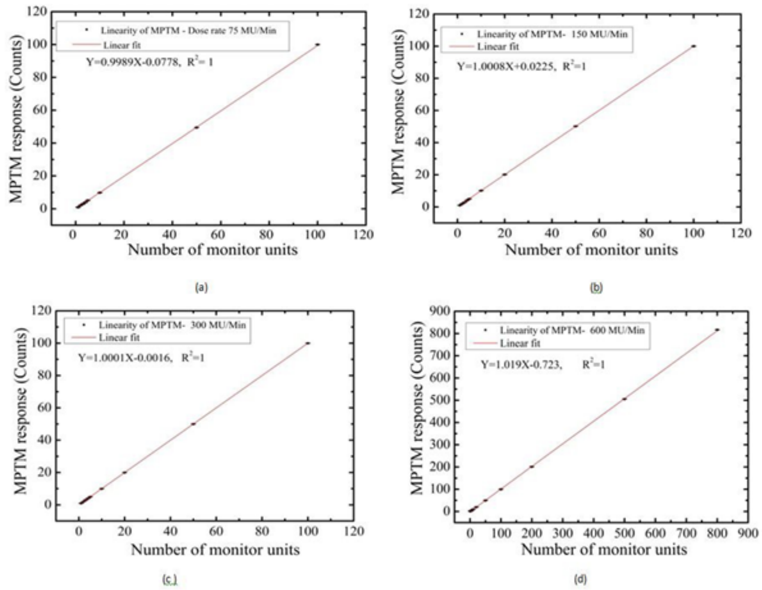

Figure 1. MPTM central detector response vs dose with different linac pulses frequencey for 6 MV photon beam and 10x10 cm^2 field size.

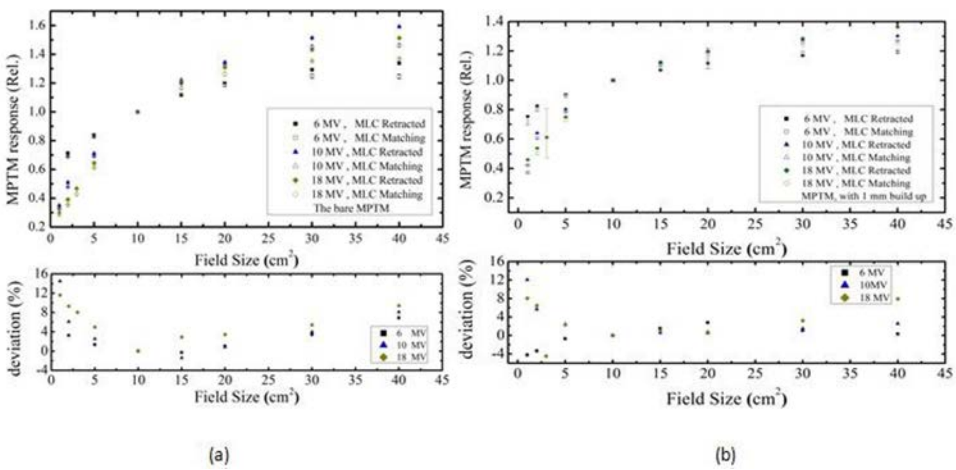

Figure 2. Normalized response of bare MPTM defined by the JAWS only or JAWs and MLC for 6 MV, 10 MV and 18 MV beam energies: (a) MPTM with no build up and (b) MPTM with 1mm solid water. Lower panel: relative deviation of the central detector response with MLC retracted relative to MLC is matching JAWs.

4. Conclusion

The radiation response of the MPTM in terms of uniformity of 2D detector array in an electronic equilibrium and the central detector response in transition mode were investigated for 6 MV, 10 MV, and 18 MV radiation fields. It was demonstrated excellent uniformity of the 2D detector array within 2%. The effect of scattered electrons from jaws and MLC which contributed to the central detector response is different in case of the bare MPTM and with 1mm build up to avoid scattered low energy electrons contribution additionally to photons. As expected MLC reduced scattered from jaws electrons contribution to the central detector for all photon energies with high efficiency for 6 MV photon beam that determined by average energy of scattered electrons. The effect is more pronounced for small fields 2x2cm^2 and less. However in the case of 1mm build-up the effect is reversed for 6 MV field that explained by larger dose enhancement due to photon interaction with build-up material than for 10 and 18 MV fields making this effect dominant in comparison to electron contribution. Effect of scattered electron contribution to the response of the MPTM vs field size should be taking into account when MPTM is used for photon energy fluence map measurements.

5. References

[1] Greer P B *et al* 2007 *Med. Phys.* **34** 4389-98
[2] Vial P *et al* 2008 *Med. Phys.* **35** 1267-77
[3] Hill R F *et al* 2008 *Radiat. Meas.* **43** 1258-64
[4] Hill R *et al* 2014 *Phys. Med. Biol.* **59** R183-231
[5] Essers M and Mijnheer B J 1999 *Int. J. Radiat. Oncol. Biol. Phys.* **43** 245-259
[6] Qi Z Y *et al* 2011 *Int. J. Radiat. Oncol. Biol. Phys.* **80** 1581-88
[7] Wendling M *et al* 2006 *Med. Phys.* **33** 259-73
[8] Venkataraman S *et al* 2009 *Phys. Med. Biol.* **54** 3173-83
[9] Islam M K *et al* 2009 *Med. Phys.* **36** 5420-8
[10] Poppe B *et al* 2006 *Phys. Med. Biol.* **51** 1237-48
[11] Alrowaili Z *et al* 2015 *J. Instrument.* **10** P09019
[12] Alrowaili Z *et al* 2016 *J. Appl. Clin. Med. Phys.* **17** 85-98