

OPEN ACCESS

Toward 3D dosimetry of intensity modulated radiation therapy treatments with plastic scintillation detectors

To cite this article: M Guillot *et al* 2010 *J. Phys.: Conf. Ser.* **250** 012006

View the [article online](#) for updates and enhancements.

You may also like

- [Temperature dependence of BCF plastic scintillation detectors](#)
Landon Wootton and Sam Beddar
- [Development of a novel multi-point plastic scintillation detector with a single optical transmission line for radiation dose measurement](#)
François Therriault-Proulx, Louis Archambault, Luc Beaulieu et al.
- [In-line MRI-LINAC depth dose measurements using an in-house plastic scintillation dosimeter](#)
Levi Madden, Natalia Roberts, Urszula Jelen et al.



ECS
The
Electrochemical
Society
Advancing solid state &
electrochemical science & technology

DISCOVER
how sustainability
intersects with
electrochemistry & solid
state science research

Toward 3D dosimetry of intensity modulated radiation therapy treatments with plastic scintillation detectors

M Guillot^{1,2}, L Gingras^{1,2}, L Archambault^{1,2}, S Beddar³ and L Beaulieu^{1,2}

¹ Département de Physique, de Génie Physique et d'Optique, Université Laval, Québec, Québec, G1V 0A6, Canada

² Département de Radio-Oncologie, Hôtel-Dieu de Québec, Centre Hospitalier Universitaire de Québec, Québec, Québec, G1R 2J6, Canada

³ Department of Radiation Physics, The University of Texas M. D. Anderson Cancer Center Houston, Texas, 77030, USA

E-mail: mathieu.guillot.1@ulaval.ca

Abstract. In this work, we present a novel two Dimensional Plastic Scintillation Detector (2D-PSD) array designed to measure dose distributions generated by high energy photon beams from medical linear accelerators. This study aim to demonstrate that the dose distribution in the irradiated volume is not modified by the presence of several hundred plastic scintillation detectors (PSDs). The 2D-PSD consists of 781 PSDs inserted in a plastic water slab. The dose distributions measured with the 2D-PSD were compared to calculations from a treatment planning system (Pinnacle3, Philips Medical Systems) and with measurements taken with an ionization chambers array (MatriXX Evolution, IBA Dosimetry). Furthermore, a clinical head and neck IMRT plan was delivered on the 2D-PSD. A good agreement is obtained between the measured and planned dose distributions. The results show that the 2D arrangement presented in this work is water equivalent and transparent to x-ray radiation. As a consequence, our design could be extended to multiple detection planes, opening the possibility for 3D dosimetry with PSDs.

1. Introduction

Advanced radiation treatment modalities such as step and shoot intensity modulated radiation therapy (IMRT) and arc techniques (RapidArc, VMAT, Tomotherapy) can generate complex 3D dose distributions with high conformity to the target volume in the patient. These dose distributions have to be accurately measured for machine commissioning and during the frequent patient plan verifications to ensure a complete control of the dose delivered. Plastic Scintillation Detectors (PSDs) are a promising new technology for the measurement of complex dose distributions. They are characterized by a unique set of properties including: high spatial resolution, angular independence, energy independence and real-time readout [1][2][3]. PSDs use plastic scintillators to convert the absorbed dose to photon emitted in the visible spectral region. Optical fibers are commonly used to guide the scintillation photon to a photodetector. One Dimensional Plastic Scintillation Detector (1D-PSD) arrays has already been presented in the literature [3] [4].

Two main aspects will characterize the development of 3D-PSD arrays. Firstly, because PSDs have small sensitive volumes, 3D-PSD arrays are expected to be composed of many hundreds of PSDs to ensure a good sampling of the dose distribution. Secondly, the radiation beam will necessarily pass through many PSDs in such device. It is therefore important that the dose distribution is not modified by the presence of PSDs. This will require using detectors made from nearly water equivalent materials.

In this work, we present a novel two Dimensional Plastic Scintillation Detector array (2D-PSD) designed to measure dose distributions generated by high energy photon beams from medical linear accelerators. The aim of this study is to demonstrate that the dose distribution in the irradiated volume is not modified by the presence of several hundred plastic scintillation detectors (PSDs). We also evaluate the capacity of the 2D-PSD prototype to measure complex dose distributions generated from a clinical head and neck IMRT plan.

2. Methods and Materials

2.1. The 2D-PSD prototype

A picture of the 2D-PSD is presented in figure 1(a). The prototype is built entirely from nearly water equivalent plastic materials. It consists of 781 PSDs inserted vertically in a $3 \times 30 \times 30 \text{ cm}^3$ plastic water slab (Plastic Water DT, CIRS, Norfolk, VA, USA) with a uniform spacing of 1 cm, covering a $26 \times 26 \text{ cm}^2$ region. The 2D-PSD also has two 5 mm spacing detection lines positioned in a cross shape centered on the detection plane. Each detector consists of a 1 mm diameter and 3 mm long polystyrene plastic scintillating fiber (BFC-12, Saint-Gobain Inc., Paris, France) coupled to a clear plastic optical fiber of the same diameter. The plastic water slab containing the 781 PSDs is fixed in a specially designed acrylic water tank. The user has to fill the acrylic tank with water and add build-up materials on the top of the array prior to measurements. An image from a Computed Tomography (CT) scan of the 2D-PSD is presented in figure 1(b). The image was taken in a slice containing 53 PSDs spaced by 5 mm. Individual PSDs can not be distinguished from others water-equivalent materials on the image. For comparison, an image from a CT scan of an ionization chambers array (MatriXX Evolution, IBA Dosimetry, Louvain-La-Neuve, Belgium) is presented in figure 1(c). The presence of the 32 ionization chambers (air cavities and electrodes) can be clearly seen on the image.

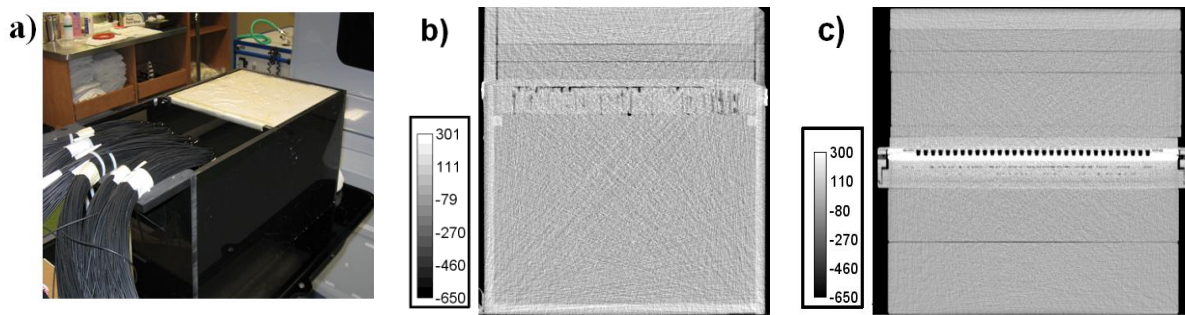


Figure 1. a) The two Dimensional Plastic Scintillation Detector array (2D-PSD). b) An image from a CT scan of the 2D-PSD. The slice contains 53 PSDs spaced by 5 mm. c) An image from a CT scan of an ionization chambers array (MatriXX Evolution, IBA Dosimetry, Louvain-La-Neuve, Belgium). The scale bar on the CT images is expressed in Hounsfield units.

2.2. Characterization of the water-equivalence

In current dosimetry protocols for external beams radiotherapy, the measured dose always refers to dose in water to emulate the conditions encountered in the patient. To characterize the degree of water-equivalence of the 2D-PSD prototype, the detector array was irradiated with a square field size $10 \times 10 \text{ cm}^2$ using the beam incidences 90° and 120° . Those beam incidences are interesting because the radiation beam is passing through many lines of detectors. The perturbation of the beam fluence by the detector materials can therefore be characterized. The same procedure was performed using the MatriXX ion chambers array. Both detector arrays were imbedded in an identical phantom made from Plastic Water slabs to reproduce the same scattering conditions. The dose distributions in the detection plane were also calculated with a Treatment Planning System (TPS) (Pinnacle³ Version 8.0m, Philips Medical Systems, Andover, MA, USA) with no heterogeneities corrections (dose to water). No corrections to account for the volume averaging of the ionization chambers in the MatriXX were applied to the calculations of the TPS.

2.3. Validation of an IMRT plan

A clinical head and neck IMRT plan (step and shoot) was delivered to the 2D-PSD to verify its capacity to measure complex dose distributions. The IMRT plan consists of six beam incidences (0° , 103° , 257° , 309° , 165° and 195°), each beam having five or seven different MultiLeaf Collimator (MLC) configurations. The dose distribution of the IMRT plan was also calculated on a CT scan of the 2D-PSD using the TPS.

3. Results

3.1. Characterization of the water-equivalence

Dose profiles on the central beam axis measured with the 2D-PSD, the MatriXX ion chambers array and calculated with Pinnacle³ are plotted on figure 2 for beam incidences 90° and 120° . The close agreement between the dose distributions measured with the 2D-PSD and calculated with Pinnacle³ (dose to water) is a clear indication that the dose is minimally perturbed by the presence of the 781 PSDs. The discrepancy observed between the dose measured with the MatriXX and calculated with Pinnacle³ is caused by the beam fluence perturbation from the presence of air cavities and electrodes in the irradiated phantom.

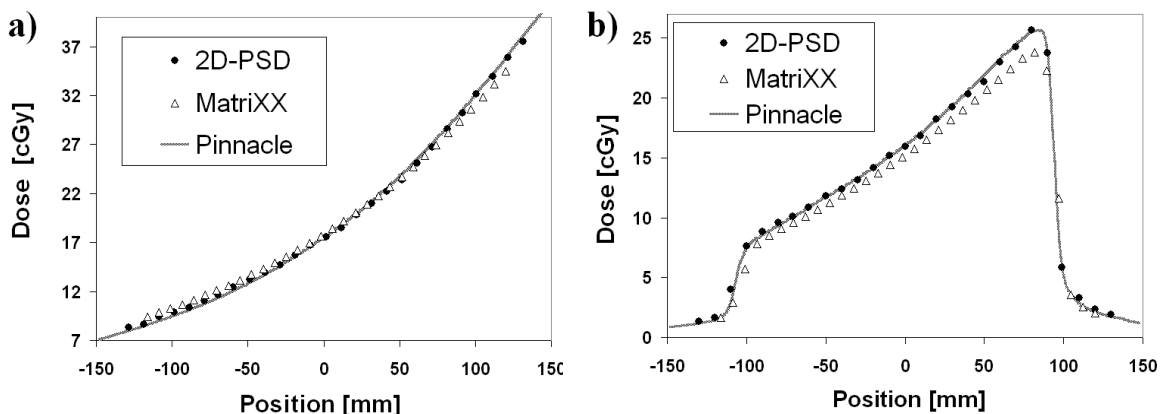


Figure 2. Dose profiles on the central beam axis measured with the 2D-PSD, the MatriXX

ionization chambers array and calculated with Pinnacle³ for various beam incidences : a) 90° b) 120°.

3.2. Validation of an IMRT plan

The total dose distribution measured with the 2D-PSD for the IMRT plan is presented in figure 3 (a). The results of the gamma evaluation performed on the measured and calculated dose distributions with Pinnacle³ are presented on figure 3 (b) [5]. For the total dose distribution of the treatment, the gamma evaluation was successful for 96 % and 99 % of the 781 detectors for dose tolerances and distances to agreement of (3%, 3mm) and (4%, 4mm) respectively. The gamma evaluation was successful for 92 % and 98 % of the detectors in the high dose region (dose higher than 50 % of the maximum dose) for the previously mentioned tolerances.

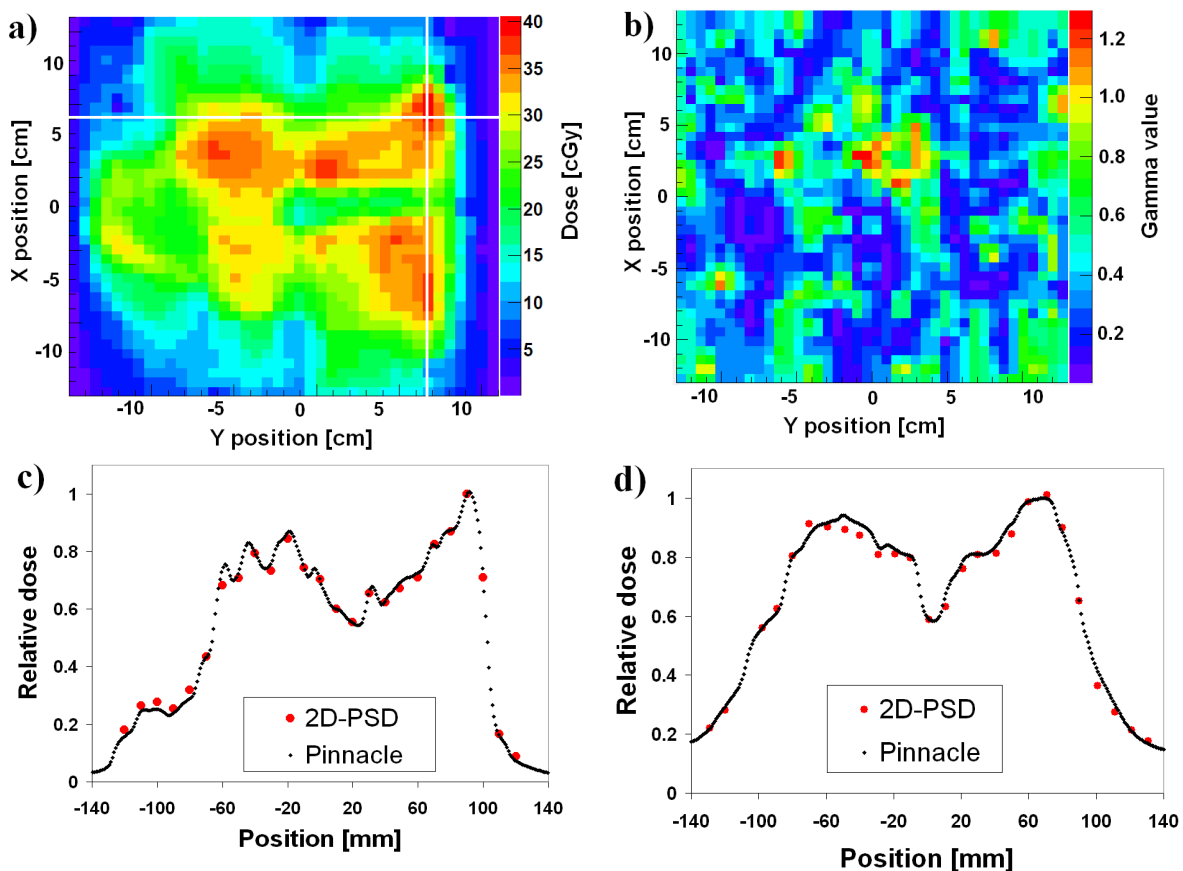


Figure 3. Results for a clinical head and neck IMRT treatment. Six beam incidences are used: 0°, 103°, 257°, 309°, 165° and 195°. a) The total dose distribution measured with the 2D-PSD. b) A color map of the gamma value (3 %, 3 mm) for the comparison of the measured and planned dose distributions. c) Comparison of the measured and planned dose profiles along the Y axis crossing the maximum value of the dose distribution (white line on figure 3(a)). d) Comparison of the measured and planned dose profiles along the X axis crossing the maximum value of the dose distribution (white line on figure 3(a)).

4. Discussion and Conclusions

In this work, we have presented a two dimensional plastic scintillation detector array technology composed of 781 sensors for quality assurance of IMRT treatments. The dose distributions measured with the 2D-PSD was compared to measurement taken with an ionization chamber array and calculations from a TPS. The presented results have demonstrated that the dose distribution in the irradiated volume is not modified by the presence of several hundred PSDs. This property is essential for the development of a future three Dimensional Plastic Scintillation Detector (3D-PSD) array because the radiation beam will pass through many PSDs in such device. As a consequence, our design could be extended to multiple detection planes, opening the possibility for 3D dosimetry with PSDs.

Acknowledgments

This work was supported by a National Sciences and Engineering Research Council of Canada (NSERC) reseach grant. M. Guillot would like to acknowledge NSERC for their financial support through a doctoral scholarship.

References

- [1] Beddar A S, Mackie T R and Attix F H 1992 *Phys. Med. Biol.* **37** 1883-90
- [2] Beddar A S, Mackie T R and Attix F H 1992 *Phys. Med. Biol.* **37** 1901-13
- [3] Archambault L, Beddar A S, Gingras L, Lacroix F, Roy R and Beaulieu L 2007 *Med. Phys.* **34** 1583-92
- [4] Lacoix F, Archambault L, Gingras L, Guillot M, Beddar A S and Beaulieu L 2008 *Med. Phys.* **35** 3682-90
- [5] Low D A and Dempsey J F 2003 *Med. Phys.* **30** 2455-64