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Proposal of a Novel Setup for Linac Monitoring Using a Specifically Designed Plastic Scintillator and a Spectrophotometer

F. MORENO-BARBOSA[1,2], R. PALOMINO-MERINO[1*], E. MORENO-BARBOSA[1], E. MIGUEL-CHUMACERO[1], O. MARTÍNEZ-BRAVO[1], B. D. E CELIS-ALONSO[1]

[1]Facultad de Ciencias Físico Matemáticas, Benemérita Universidad Autónoma de Puebla, Avenida San Claudio y 18 Sur, Col. San Manuel, Ciudad Universitaria, Puebla, Pue. C. P: 72570, México.

[2]Departamento de Radioterapia, Hospital del Sur, IMSS, Puebla, Pue. México.

[1*]**Email: palomino@fcfm.buap.mx**

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Abstract In this work we report the design, implementation and results of an alternative monitoring system for a linear accelerator (LINAC) used in medical therapy. The system proposed consist in aslab of scintillator plastic with awavelength shifter fiberoptically coupled to collect the light generated,and a Spectrophotometer Ocean Optics USB4000 as analyzer. The control was made with two computers, one into the therapy room and another, using a VNC (Virtual Network Computer) and Ethernet wire, outside of the room in order to avoid radiation exposure. The LINAC dose range covered was 1, 2, 3, 4, 5, 10, 20, 30 and 40 Monitor Units (MU) with 6 and 18 MeV energy photons. The spectrum obtained was compared with the measures of the LINAC ionization camera used to calibrate it. The results obtained allowus to propose this device as an alternative method to monitor the LINAC performance.

Keywords: LINAC, calibration, spectrophotometer, scintillation, radiotherapy.

1. INTRODUCTION

High-energy radiation is a powerful agent for cancer treatment. Approximately 40% of diagnosed cases are treated using X and Y rays or high-energy electrons. The evolution of the equipment available to the radio

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CHITKARA UNIVERSITY

oncologist starting with the X ray machines with some keV, the Cobalt or Cesium bombs with energies from 0.662 to1.25 MeV and more recently, the medical lineal accelerators with energies from 6 MeV up to 25 MeV for photons and electrons.

Nowadays market systems for the measurement of radiation are elements of a high cost, although various sizes and shapes, small items such as dosimeters require other systems are used for reading. Equipment such as Geiger detectors that economic and compact mostly has the disadvantage of measuring the passage of ionizing particles without further details.

This proposed system would have the advantage over existing in the market for more detailed information on the incident radiation by use of the spectrophotometer, this could allow the implement algorithms with which it would be possible to obtain more detailed information of the incident particles and not only to observe the passage of radiation in the environment.

The operation of LINAC´s in medical treatment must be monitored as continuously and rigorously as possible, because the geometric and dissymmetric accuracy applied to the patients depends of the predicted dosage calculated using the nominal operation parameters.

The performance of the LINAC may change abruptly due to electronic, mechanical or any components break down, or slowly due to the wear or ageing of the components. So, it is necessary to monitor at least two aspects of the LINAC operation: periodicquality control checking in all the equipment including the measuring instruments and a regular monitoring of the services of preventive or corrective operations made into the equipment and the measurements tools of the LINAC.

Actually, the irradiation of the patients were made using diagnostic techniques that allow us to define the target volume and the absorbed dose with high accuracy with the modern LINAC operating according the nominal parameters. In Mexico, the CNSNS (Comisión Nacional de Seguridad Nuclear y Salvaguardias) is the organization in charge to emit recommendations, regulations and safety and monitoring procedures related with any ionizing radiation generator, as lineal accelerators.

The costs in time or money of the procedures recommended by the CNSNS to regulate the operation of LINAC are sometimes high[6-1]. So, to establish new ways to fulfill the recommendation of the CNSNS in more efficient way are explored, as is proposed in this work, using less expensive materials and less time consuming procedures. In this case, we proposed to use a robust device extensively used in high-energy physics in order to monitor the performance of a medical LINAC.

2. MATERIALS & METHODS

2.1 Setup description

The system proposed here basically consists of: a scintillator plastic slab, a wavelength shifter light guide and a commercial spectrophotometer as detector device, all system is controller by a computer and internal net (Figure 1).

The scintillator plastic was a studded slab of polyethylene (4.2 cm * 11.9 cm * 1 cm) doped with an1% of 2,5-diphenyloxazole (PPO) and 0.03% of 1,4-bis [2-(5-phenyloxazolyl)] benzene (POPOP) The sides of the slab have a reflective layer in order to avoid side light leaks. The scintillator slabswere developed by the MINO Sexperiment [5,3] and have shown to be reliableand easy and cheap to build and operate.

The wavelengthshifter light guide (WSLG)(Saint-Gobain Courbevoie, France, www.saint-gobain.com)had a polystyrene core and a PMMA (polymethyl-meta-acrylate) covering. The light collected over the strip was guided to the detector for the fiber itself.

Light detection was achieved by aspectrophotometer model UV-VIS USB4000 (Ocean Optics Inc., Dunedin, Florida, USA, www.http://oceanoptics.com/)coupled to the wavelength shifter light guide.

Optical coupling between the scintillator slab and the WSLG was achieved by etching a1 mm slot all around the side of the slab and gluing the WSLG to the scintillator with epoxy (BC-600, Saint-Gobain Courbevoie, France). To insulate the system of the environmental light, it was covered with a thick and dark commercial plastic tape. The other end of the WSLG was coupled to the spectrophotometerby a fastening system that allows centering the fiberand thus reduces losses in light collected by the fiber, and therefore in its intensity;the entire array was contained in a light tight box.

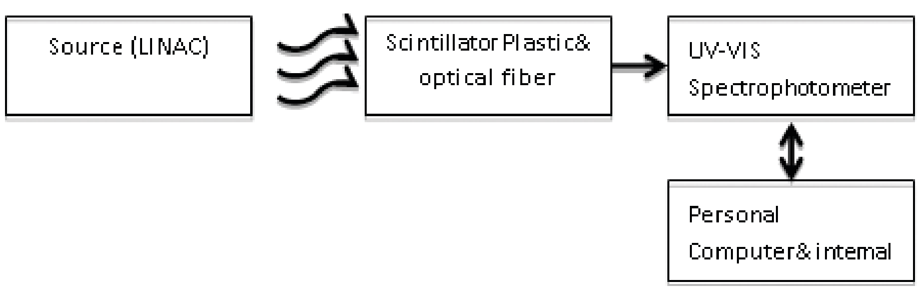

Figure 1: Schematic Diagram of the proposed system.

The LINAC used to assess the setup (LINAC in the radiotherapy department of the Hospital del Sur, Puebla, Mexico) was located inside a standard radiotherapy bunker in order to absorb primary and secondary radiation. The monitoring device had a laptopwith an external connection (Ethernet) by a virtual network computer (VNC) to get the data outside of the radiation area. This setup presented an extra advantage by the fact that we were able to obtain the energy spectra deposited in the scintillator slab in real time.

2.2 Setup assessment measurements

Figure 2 shows an image of the setup during the commissioning assessments. All measurements wereperformed with the treatment table at 100 cm distance source-surface (DSS). The collimator had am aperture of 4.2 cm by 11.9 cm, matching the scintillator slab. Measurements were performed withthe radiation beam perpendicular to the treatment plane and the gentry of the equipment set at 0 degrees. Atmospheric conditions of the room were recorded (594.4 kPa and 22°C). All the lights were switched off to prevent light leaks into the monitoring device. In order to evaluate the background radiation level of the bunker, signals were taken with all subsystem turn-on but unirradiated the slab, with the same integration time as the regular exposure; we consider periods of 11 seconds. Radiation with the LINAC consisted of photon beams with energy ofeither 6 MeV and 18 MeV. The range of deposited dose was 1, 2, 3, 4, 5, 10, 20, 30 and 40 monitorunit (MU), ten times for each value and

Figure 2: Experimental setup in the radiotherapy bunker. In this figure the experimental setup described in the text is presented. The monitoring device lies over the patient table.

with the necessary exposure time in each case. All these measurements were performed in the same day.

3. RESULTS AND DISCUSSION

Several spectra from the LINAC were obtained in order to evaluate the level of background radiationand also the spectrophotometer electronic dark noise at the same ambient conditions of the bunker. These values were the systematic count level and were subtracted to the spectrawhen the beam was on.

In Figure 3(a,b) baseline values obtained at different exposures (Arbitrary units vs. Exposure) and in two differentconditions, from 1 MU of deposited dose all the way up to 40 MU´s. The median of each measurement was used as a representative value and compared with each single spectra obtained (Y axis), using a 100 spectra as sample. The variation obtained of the baseline was less than 5%.

As the recording device of the spectrophotometer was a CMOS detector, it was affected by the direct hit of environmental photons inside the bunker. To correct for hot pixels, we use a standardmedian filter. Figure 4a show the spectra obtained with all the hot pixels and without remove the baseline level. After the reduction procedure spectra like the one in Figure 4b were obtained. A pulse function was used in order to fitthe shape of the obtained spectra. Based on the results of the fits the integral was calculated and related with the energy deposited by the LINAC in the scintillator. Figure 5 shows the relationship between exposure (MU) and the total area calculated. Astrong lineal relationship was found between the energy deposited by the LINAC and the light measured by the spectrophotometer. This suggests that the setup presented here is of high precision and utility for the job it has been created

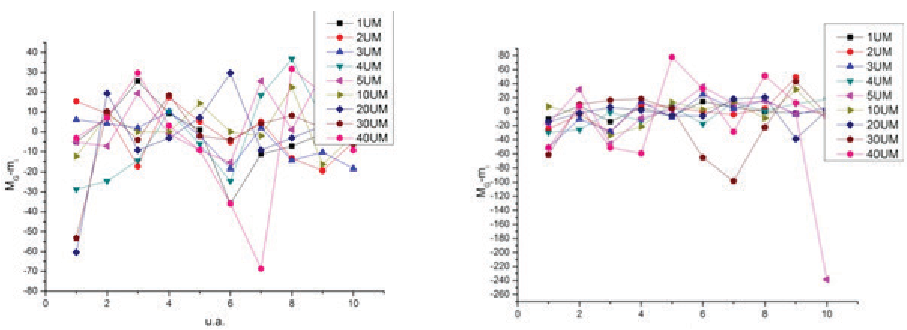

Figure 3: Baseline the values of the baseline variation range compared with the median for several exposures a) lights and LINAC off, b) lights and LINAC on.

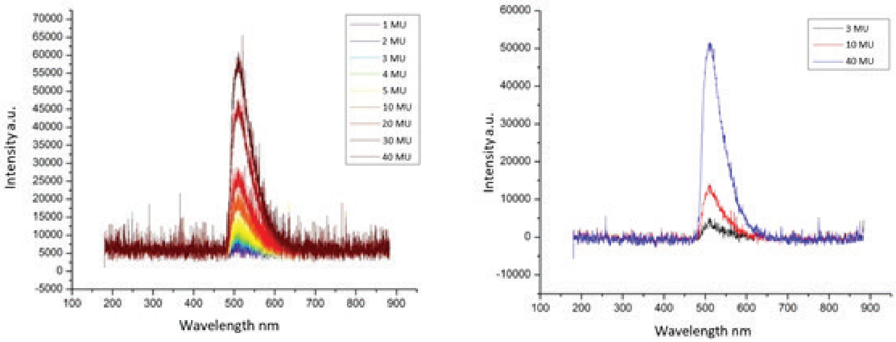

Figure 4: Signals of spectra a) A series of spectra of the system in which one can observer the noise level and the hot pixels included. B) Representatives spectra after subtract the baseline ant the hot pixels using a median filter. TheY-axis is in arbitrary units.

Percentage of deposited dose with depth (PDD) analysis was performed with the obtained curves, using two different setups of the LINAC; first for a 40 mm x 40 mmof field and 6MeV energy and second, the same aperture field but with 18 MeV. As it can be observed in Figure 6, the PDD curve for the first configuration showed that the 90% absorbed level of the applied dose was reached if the cross section of the scintillator slab is 420 mm^2 and 20 mm thick. For the higher energy, the values obtained were 500 mm^2 and 50 mm respectively.

The scintillator slab used in our experimental setup had the following dimensions as established in the methods section42mm×119mm×10mm (height, width, thickness). Based on this fact and the results of the PDD analysis, it is possible to explain Figure 5. Here at18 MeV beam fitted curve

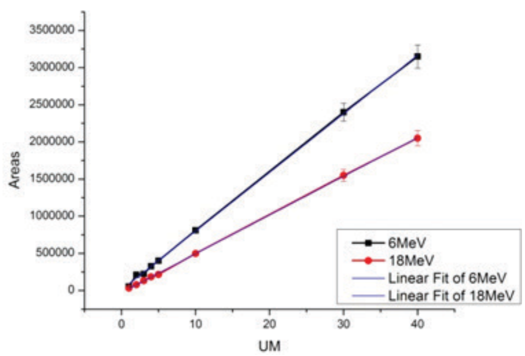

Figure 5: This plot shows the exposure in UM and the integral (arbitrary units) of the spectra obtained.

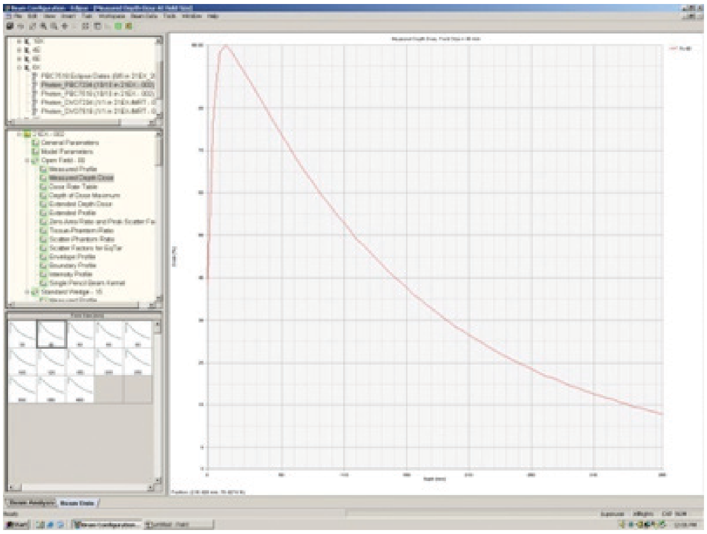

Figure 6: Curve of percent depth dose (PDD), with a field of 40X40 mm with bean energy of 60MeV.

had lower energy deposited than the 6 MeV. The size of the scintillator slab was smaller than the radiation lengthto absorb all the photons with18 MeV.

4. CONCLUSIONS

In this work we presented a setup based on a novel scintillator plastic that can be used to monitor the performance of a medical LINAC´s. It is characterized by being: cheap, easy to buildand offering results in real time. Here a commercially available and portable spectrophotometer was used as recording device together with a scintillator slab optically coupled with awavelength shifter light guide. To the author's knowledge, the proposal presented here is new for these applications. As shown; the linear response to exposure, the portability and the robustness of this system allows the setup to be considered as a viable alternative to the detectors used on a daily basis for LINAC performance.

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Moreno-Barbosa, F.
Palomino-Merino, R.
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