A Novel On-Line Treatment Verification System Based on Silicon Strip Detectors for Measuring 2D Axial Dose Maps in Radiotherapy

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Motivation: The aim of this work is to design a dose verification system in axial planes for complex radiotherapy treatments using the silicon strip detector technology.

Materials and Methods: The experimental set-up is based on two phantom prototypes designed to house the silicon detector for characterization and treatment verification measurements. The first phantom is a polyethylene slab, placed below a variable number of solid-water slabs, which was used to fully characterize the detector in terms of linearity, reproducibility, uniformity, depth dose, penumbra and output factor measurements. The second one is a cylindrical phantom, made out of polyethylene, which was designed to recreate conditions close to those normally found in clinical environments and to perform 2D treatment planning verifications. As an innovation, the active area of the detector is positioned within the cylindrical phantom parallel to the beam axis and perpendicular to the phantom symmetry axis, i.e. in an axial plane. The cylindrical phantom can be rotated around its symmetry axis by means of software especially developed to control the rotation remotely and to acquire signals from the silicon strip detector. This system has been used to study the dosimetric response of the detector as a function of its angle with respect to the irradiation beam. A feasibility study [1] was performed using a Single-Sided Silicon Strip Detector (SSSSD), model W1(SS)-500, manufactured by Micron Semiconductor, Ltd. The detector was tested with radiation fields delivered by a Siemens PRIMUS and a Siemens ONCOR linac, both operating at the 6 MV photon mode, at the Virgen Macarena Hospital (Seville, Spain). The signal produced by a discrete read-out electronics was calibrated to dose by comparing with calculations performed with the treatment planning system (TPS) used at the hospital (Philips Pinnacle[3]). For a given treatment plan, the strip signals for each angular position are processed with an in-house reconstruction algorithm, based on the Radon transform, to get the 2D dose map in the axial plane. The treatment head, phantoms and detector were modeled with the Geant4 toolkit, so that the experimental measurements could be compared with Monte Carlo calculations as well [2].

Results: Test measurements carried out with the SSSSD placed within the slab phantom showed that the linearity and uniformity are within a 0.5% tolerance. The depth-dose response agreed within 1% with respect to measurements performed with an ionization chamber detector. These results agreed with Monte Carlo calculations within uncertainties. With the cylindrical phantom, the calibrated dose measured by our set-up agreed within 2% with the TPS calculations for the strips at the edges of the detector and within 1% for the central strips at all rotation angles. These results were also reproduced with Geant4 simulations. Finally, the reconstruction algorithm shows a good agreement with the axial dose map calculated with the TPS, taking into account the spatial resolution of the detector, fixed by the strip width.

Conclusions: A novel detection system, based on the silicon strip technology was designed, built and tested. The results obtained in the feasibility study with the first prototype [1] are good and compatible with our purpose of developing a detection system capable of obtaining 2D dose maps in axial planes to verify complex radiotherapy treatment plans. Further improvements are under development. Among others, a new detector, based on the BB7 silicon technology from Micron Semiconductor Ltd., is being manufactured with a novel design, which includes a smaller pitch and a larger active area. Monte Carlo simulations show promising results with the planned set-up.

References:

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[2] M. A. Cortés-Giraldo et al., *Prog. Nuc. Sci. Tech.* **2**, 191-196 (2011).