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Development of a 3-dimension scintillation dosimeter for small irradiation fields control in pencil beam scanning proton therapy

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In proton therapy, the treatment of tumors smaller than 3 cm is limited by the uncertainties of the treatment planning system and the spatial resolution of control detectors. Moreover, with pencil beam scanning (PBS) technique, the treatment plan is structured as a sum of pencil beams (PB), each delivered in several fractions of variable intensity called bursts (blind golfer algorithm). To answer these issues, we developed a high spatial and temporal resolution dosimeter called SciCoPro to control treatment plans.
This dosimeter (Figure 1) is based on a cubic plastic scintillator of 10x10x10 cm3 and a fast camera capable of reaching 1 kHz (the beam delivery frequency). A mirror allows to see two views of the scintillator. The setup can record each delivered burst and reconstruct pencil beams'characteristics (energy, position and intensity). An algorithm is being developed to calculate the dose distribution from SciCoPro's images. By projecting both views of the cube in the 3D space, the algorithm reconstructs the scintillation map before converting it into dose distribution. The system performances were assessed with customized irradiations at different intensities: 0.02 to 1 Monitor Units (MU) per PB and with clinical treatment plans.

The setup was proved to be able to measure the characteristics of each burst, for intensities as low as 0.002 MU and showed very good accuracy and precision on the PB characteristics: below (0.60 ± 0.25) mm, (33 ± 147) keV and (3.8 ± 5.0) x10-3 MU, whatever the PB intensity. Regarding the 3D dosimetry, the implemented algorithm can compute the scintillation map of individuals PBs (Figure 2) and full treatment plans. The conversion into dose distribution, which requires the implementation of optical and scintillation quenching corrections, is still under progress.

We developed a very promising scintillation dosimeter adapted to blind golfer algorithm in PBS able to control the characteristics of all the PBs of a treatment in a single irradiation measurement. Moreover, the algorithm already developed as led to the reconstruction of the 3D scintillation distribution, and will be upgraded for 3D dose distribution reconstruction.

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