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Development of a proton range dosimeter using 96-layer acrylic disks and thin-film copper indium gallium selenide solar cells

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Background and Purpose

Proton pencil beam therapy requires precise range verification due to the steep dose gradients at the distal region of the Bragg peak. Although commercial multi-layer ion chambers (MLICs) are commonly used for this purpose, they have inherent limitations such as low sampling rate and small sensitive volume. To address these challenges, we developed a novel range dosimeter aimed at improving range verification accuracy.

Materials and Methods

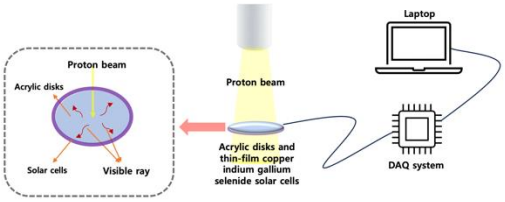

Figure 1. Schematic diagram of the experimental setup

The proposed dosimeter comprises 96 acrylic disks, each 15 cm in diameter, stacked together and coupled with strip-type copper indium gallium selenide (CIGS) solar cells. When irradiated by protons, the acrylic disks emitted photoluminescence, which was converted into voltage signals through the attached solar cells. These voltage signals were captured using a high-speed data acquisition (DAQ) module operating at up to 50 kHz. To enhance the signal-to-noise ratio, each acrylic disk was coated with a reflective film.

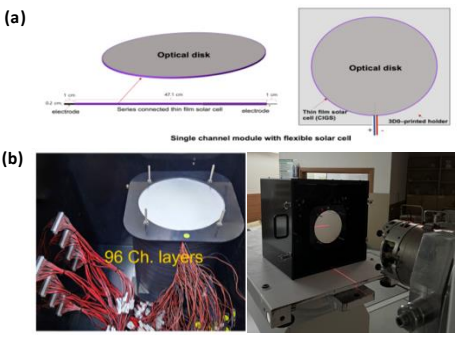

Figure 2. (a) Single channel module with flexible solar cell (b) 96-channel range dosimeter

Result

Despite the presence of a quenching-like effect, the dosimeter achieved a mean range difference of 0.60 ± 0.41 mm compared to the ion chamber across proton beam energies of 102.7–190.0 MeV when the beam was positioned at the center of acrylic disk.

Energy	Range (Solar-cell)	Range (Ion chamber)	Error
102.7MeV	80.72 mm	81.1 mm	0.38 mm
120.9MeV	107.81 mm	108.7 mm	0.89 mm
136.4MeV	134.52 mm	134.5 mm	0.02 mm
154.8MeV	166.83 mm	167.2 mm	0.37 mm
172.7MeV	201.35 mm	202 mm	0.65 mm
190.0MeV	239.92 mm	240.4 mm	0.48 mm

Table 1. Proton range comparison between the solar-cell dosimeter and the ion chamber

The range difference remained within 1 mm for lateral shifts up to 4 cm, but increased to 3.25 mm at 6 cm shift, likely due to calibration at the center position.

Position	Range (Solar-cell)	Range (Ion chamber)	Error
Center	166.83 mm	167.2 mm	0.37mm
2cm	167.96 mm	167.2 mm	0.76mm
4cm	166.29 mm	167.2 mm	0.91mm
6cm	163.95 mm	167.2 mm	3.25mm

Table 2. Range difference between the solar-cell dosimeter and the ion chamber as a function of lateral beam shift.

Conclusion

The developed range dosimeter shows potential for application in proton pencil beam therapy. Its relatively high sampling rate, large sensitive volume, and acceptable range accuracy suggest that it could be useful for range verification under clinically relevant beam delivery conditions.

Acknowledgement

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