Abstract

Background: While calorimeters are the most common absolute dosimeter and are used as the primary radiation standard in standards labs around the world, these devices are traditionally position insensitive. Currently, there are no methods to do absolute dosimetry in multiple dimensions using calorimeters or other absolute dosimeters.

Purpose: The purpose of this work is to present the design for a two-dimensional nine-voxel solid-core calorimeter array which can provide absolute dosimetry for megavoltage photon beams in multiple dimensions during a single irradiation. The proof-of-concept work for this ultimate goal is to start with a single voxel which can then be duplicated to measure at multiple locations at once.

Methods: Material determinations were based on material characteristics, thermal properties, availability, and safety of use. The sizing of the components in each voxel were optimized based on simulations of dose deposition and heat transfer for varied dimensions, feasibility of machining the components, and allowing for comparisons with other dosimeters. The voxel spacing was determined using a finite-element method based numerical heat-transfer study. Various prototypes of a single voxel were constructed and the most advanced was tested against an A12S ionization chamber. The shell of the array was also constructed, and three voxels were built into it. The central voxel was also compared against the A12S chamber and relative doses were determined for the adjacent voxels to compare their response to the expected response from the ionization chamber.

Results: The dose determined with the single voxel agreed with the A12S ionization chamber within 0.1%. The dose determined with the central voxel of the array agreed with the A12S within 0.7%. The relative doses for adjacent voxels also agreed with the A12S within each other's

uncertainties for a 4x4 cm^2 radiation field. However, with a 20x20 cm^2 field, the adjacent voxels no longer agreed, yielding a dose significantly lower than expected. All of the voxels exhibited an undesired thermal decay following irradiation, although not significant enough to affect the results. For all of the calorimeter measurements, the uncertainty on the doses was very high, caused primarily by the measurement of temperature change due to uncertainties on when exactly the beginning and end of the irradiation occurred.

Conclusions: This work details the design process for creating a multi-dimensional absolute dosimeter. The finalized calorimeter design takes into account material properties, radiation transport through components, heat flow, and ease of manufacture. Dose comparisons between an ionization chamber and a single-voxel prototype as well as the center voxel of the array agreed within 0.7%. In larger field sizes, the calorimeter measured doses off the central axis were smaller than expected, and it is believed that the aluminum phantom is the primary cause. Uncertainties in the calorimeter measurements were high primarily due to variations in temperature calculation between measurement runs. Performing additional measurements for better statistics should help reduce the uncertainties.