AbstractID: 11294 Title: Theoretical Analysis of Fiber-Optic Scintillation Glass Arrays for High Quantum Efficiency Megavoltage Imaging and Image Guided Radiotherapy

Purpose:

In this work, we present a comprehensive theoretical analysis of a high performance megavoltage imager based on a fiber-optic scintillation glass array (FOSGA), a potential candidate for megavoltage computed tomography (MVCT) as part of image guided radiation therapy (IGRT). The FOSGA imager was studied in several prototype configurations using Monte Carlo simulations and linear cascaded systems analyses, and imaging performance was characterized by its modulation transfer function (MTF) and detective quantum efficiency (DQE).

Method and Materials:

Our imager consists of Tb-doped scintillation glass fibers inserted into a polymer-tungsten grid-housing. Material and structural specifications of the array are specially geared towards patented fabrication technologies for automated mass production and cost-benefit. Radiation detection characteristics were modeled using radiation transport simulations and coupled to a custom-written optical transport simulation program developed to specifically model the fiber-optic coupling mechanism in our detector. A linear cascaded systems analysis was conducted to evaluate the effects of all proposed system components, design parameters, and imaging performance metrics (MTF & DQE) were determined for these configurations.

Results:

Radiation transport calculations indicated high intrinsic imaging performance typical of thick high-Z scintillators with > 40% quantum efficiency for 5 cm thick arrays. Light transport simulations indicated limited coupling loss and optical cross-talk from scatter as optical conduction was dominated by Fresnel and total-internal-reflection events. Cascaded systems analyses revealed no significant quantum sinks while indicating that detector thickness was the limiting parameter affecting overall performance [DQE(0) > 0.25 and MTF > 0.5 at 1 cy/mm, significantly improved over current megavoltage detectors with DQE(0) ~ 0.01].

Conclusions:

With high DQE and significant cost-benefit compared to current megavoltage detectors and contemporary prototypes, a FOSGA imager can provide high portal image quality at low dose, which facilitates its extension to 3D verification via MVCT as a cost-effective IGRT solution.