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Effect of the magnetic field on the Cherenkov light collected by optical fiber dosimeter

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INTRODUCTION

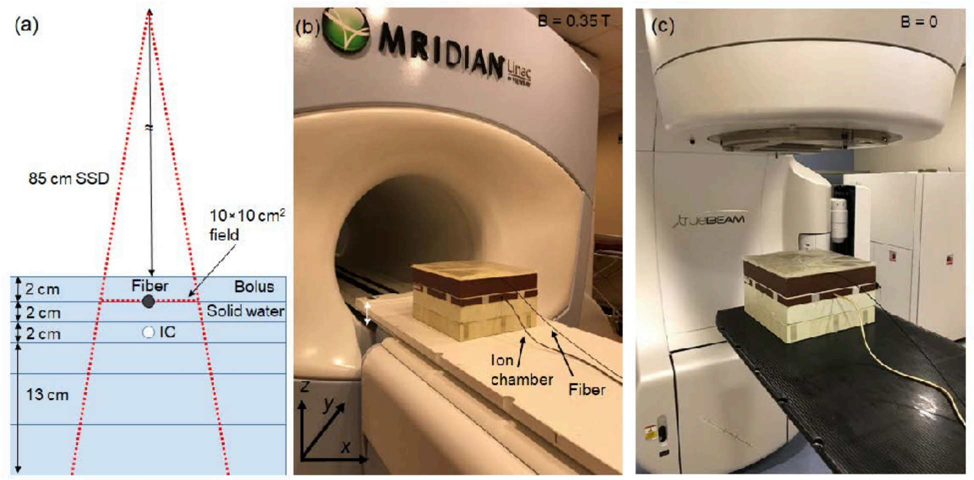
Fiber optic dosimetry is a promising technique for small field, *in vivo*, and real-time dosimetry. With the emergence of MR-guided radiation therapy systems in clinics, there is a need to characterize the response of such dosimeters in the presence of magnetic field [1-5].

In this study we analyzed the light response of transport fibers (un-doped fibers) with different core diameters at different depths in phantom in the presence and absence of a magnetic field with 0.35 T using optical spectroscopy.

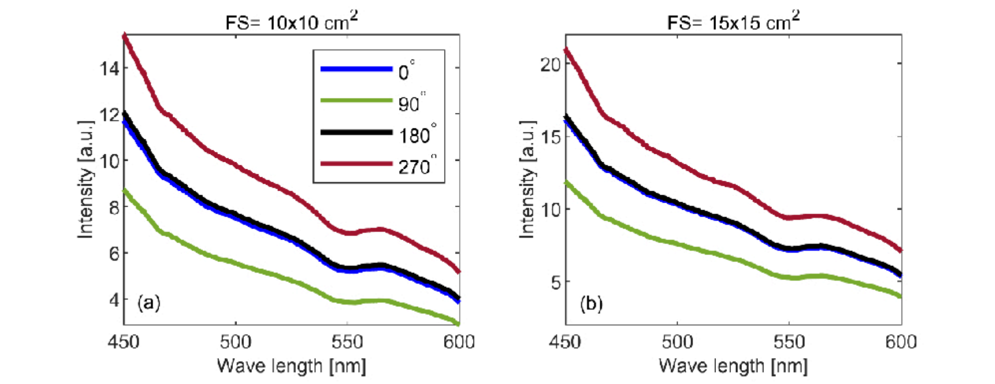
MATERIALS AND METHODS

Two 20-m-long plastic optical fibers (SH4001 and SH8001, Industrial Fiber Optics, Inc.) with poly(methyl methacrylate) (PMMA) core and fluorinated polymer cladding material were studied in this work. The nominal core diameter of fibers was 1 mm and 2 mm. The fibers were irradiated with 6 MV flattening filter free (FFF) photon using a TrueBeam™ Linac and an MRIdian™ MR-Linac with a 0.35 T magnetic field. The irradiation geometry was identical in both systems and the fibers received same amount of dose (2 Gy). The irradiation setup is shown in Fig. 1. The percent depth dose at 10 cm was 63.15% and 63.5% in water for a field size of 9.96 × 9.96 cm^2 and 10×10 cm^2 for MRIdian™ and TrueBeam™, respectively.

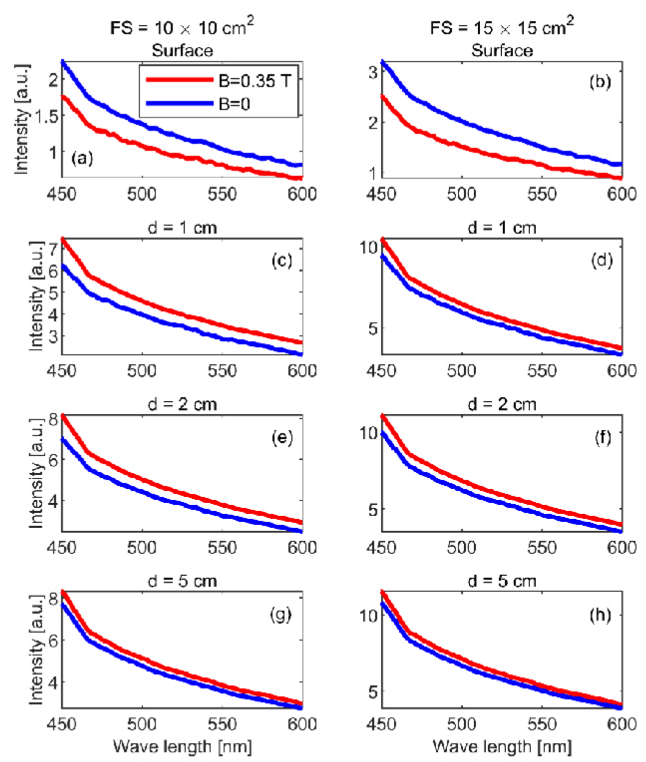
The fiber was placed between solid water phantoms placed at surface, depths of 1 cm and 2 cm and 5 cm. A total thickness of 15 cm virtual water phantom were placed underneath the fiber in order to provide sufficient backscatter. The fibers were irradiated under two field sizes of 10×10 cm^2 and 15×15 cm^2. The 2 mm fiber at depth of 2 cm and field size of 10×10 cm^2 was placed at 90°, 180°, and 270° relative to the couch direction which was considered at 0°. A fiber-coupled spectrometer was used for spectroscopy in 450 to 650 nm range with 2 nm resolution.



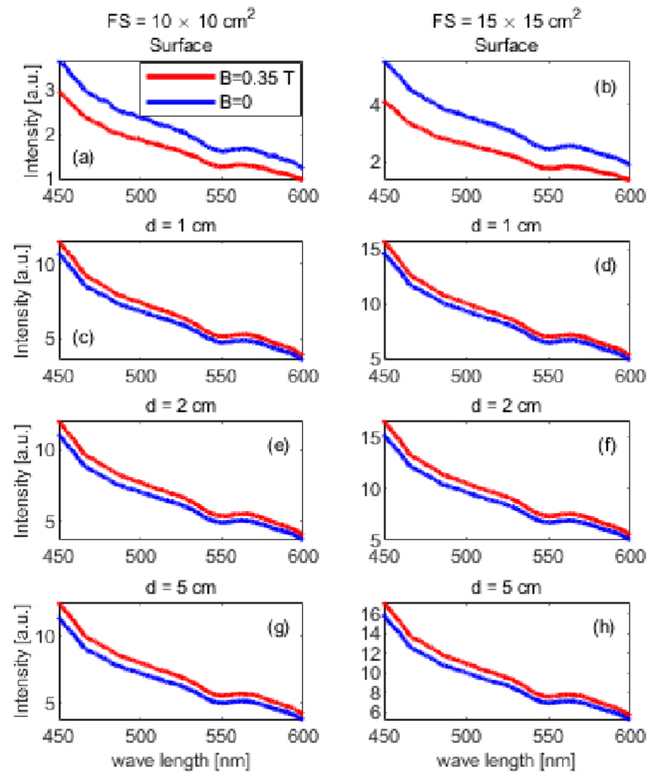
(a) Schematic of the irradiation geometry. Pictures of the experimental setup with (b) MR-guided MRIdian® linac (the table is retracted for presentation) and (c) TrueBeam™ linac.



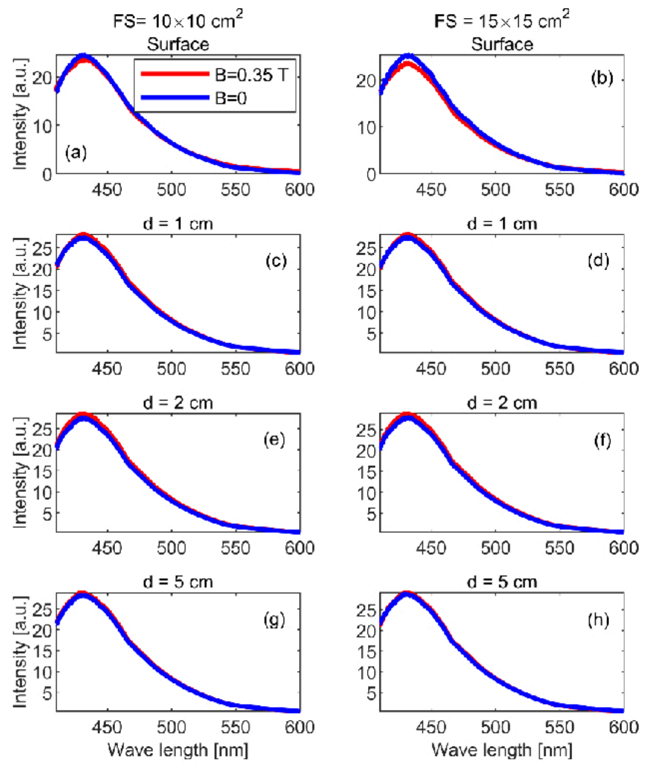
Cherenkov radiation spectra measured using the 2-mm-core fiber in the presence of magnetic field and depth of 2 cm when the fiber is 0°, 90°, 180° and 270° irradiated under field sizes of (a) 10×10 cm² (right) 15×15 cm².



Cherenkov radiation spectra measured using the 1-mm-core fiber in the presence (red) and absence (blue) of magnetic field at the (a, b) surface and depth of (c, d) 1 cm, (e, f) 2 cm, and (g, h) 5 cm irradiated under field sizes of (left) 10 × 10 cm² (right) 15 × 15 cm².



Cherenkov radiation spectra measured using the 2-mm-core fiber in the presence (red) and absence (blue) of magnetic field at the (a, b) surface and depth of (c, d) 1 cm, (e, f) 2 cm, and (g, h) 5 cm irradiated under field sizes of (left) 10 × 10 cm² (right) 15 × 15 cm².



Scintillation signal measured using the 2-mm-core fiber in the presence (red) and absence (blue) of magnetic field at the (a, b) surface and depth of (c, d) 1 cm, (e, f) 2 cm, and (g, h) 5 cm irradiated under field sizes of (left) 10 × 10 cm² (right) 15 × 15 cm².

RESULTS

The presence of the magnetic field increased the Cherenkov signal at all depths except at surface. The Cherenkov signal was reduced at the surface. The Cherenkov signal was increased by approximately 10% at 1, 2 and 5 cm depths for both the 1 mm and 2 mm fibers. On the other hand the signal was reduced at the surface by approximately 20% for both fiber sizes.

The signal was increased by 25% and decreased by the same amount when the fiber was placed at 270° and 90°, respectively. No difference was observed when the fiber was rotated by 180°.

There was no significant change in the scintillation signal at 1, 2 and 5 cm depths . However, the scintillation signal was reduced at surface by approximately 7% for both fiber sizes.

We believe that this increase in the amount of Cherenkov radiation is connected to the change in the trajectory of the liberated electrons. The reduction in Cherenkov and scintillation signals at surface is due to the sweep of contaminating electrons from the primary field by the magnetic field [6].

CONCLUSIONS

Scintillating fiber optic dosimeters have unique practically advantageous properties including the ability to perform *in vivo*, real-time measurements with high spatial resolution. These detectors are also MR compatible which makes them an attractive candidates for dosimetry in MR-Linac systems.

Cherenkov light is one of the components of the total optical signal of a plastic scintillator detector. Our results show that the amount of Cherenkov signal measured by bare optical fibers changes in the presence of a magnetic field. The amount of change depends on factors such depth of measurement and direction of the fiber.

REFERENCES

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