Impact of Scintillator Size on Stemless Plastic Scintillation Detector Measurements

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INTRODUCTION

Plastic scintillation detectors (PSDs) are advantageous as high energy dosimeters due to their near water-equivalency, long usable lifetime, and high spatial resolution. However, one major drawback with PSDs is Cerenkov radiation produced in the optical fiber stem, contaminating the signal. We have fabricated a new class of detector by coupling an organic scintillator to an organic photodiode creating a stemless plastic scintillation detector (SPSD). This design eliminates the need for an optical fiber to carry the signal. This detector could produce the well-documented benefits of a fiber-based PSD system while removing the Cerenkov radiation produced in the optical fiber stem.

AIM

To assess the impact of scintillator size when coupled to an organic photodiode for dosimetric measurements such as output factors and PDDs.

METHOD

- Organic diode composition – Glass slide substrate, ITO bottom electrode (~100 nm), P3HT/PCBM active layer (~100 nm), aluminum top contact (~100 nm; defining ~3x3.25 mm² active area), and epoxy encapsulation
- Eljen (~5x5x5 mm³; EJ-204, EJ-208 or EJ-260) or Saint-Gobain (~3x3x2 mm²; BC-400 or BC-412) scintillators placed on opposite side of glass
- Output factors of Varian TrueBeam accelerator were measured for a 6 MV photon beam (1x1 cm² to 25x25 cm²)
  - Non-scintillation contribution to signal (i.e. Compton current induced in the wires) was measured with no scintillator placed on the diode
  - Output factors compared to Exradin A12 ion chamber (4x4 cm² to 25x25 cm²) and semiflex 31010 micro ion chamber for smaller field sizes

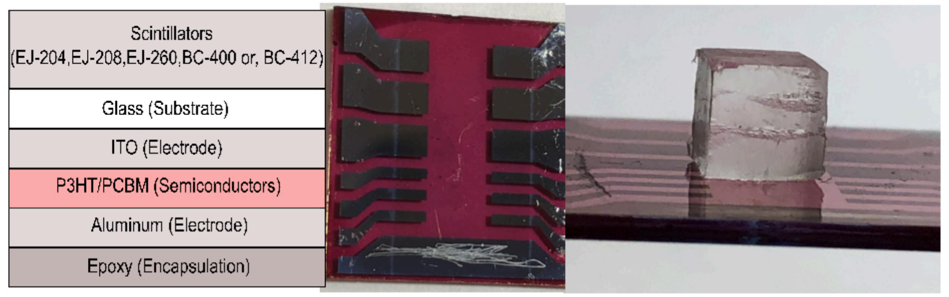

Figure 1. On the left is the schematic showing the materials that make up the various layers of the SPSD. In the middle is an image of the fabricated photodiode. On the right is an image of the photodiode with the scintillator placed on top.

RESULTS

Uncorrected Data

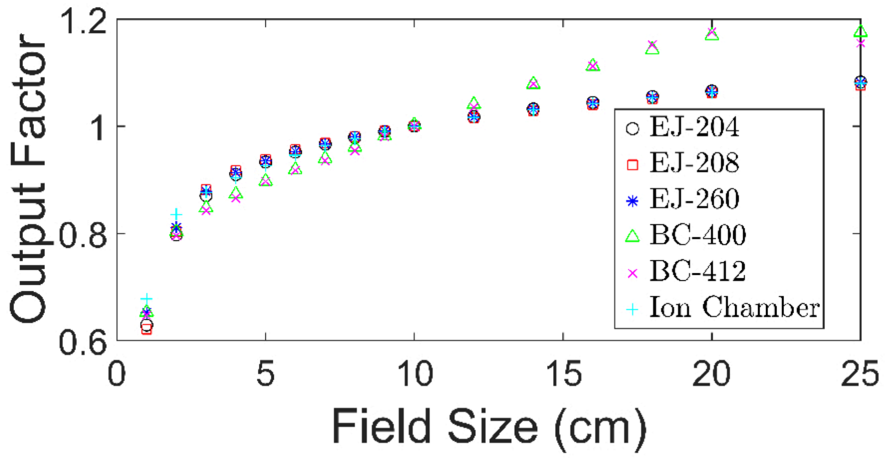

Figure 2. Output factors measured by coupling 5 different scintillators to an organic photodiode compared to ion chamber measurements.

- Large scintillators (Eljen; ~5x5x5 mm³)
  - Less than 1% deviation from ion chamber for field sizes 3x3 to 25x25 cm²
  - Under-response likely due to volume averaging for smaller field sizes
- Small scintillators (Saint-Gobain; ~3x3x2 mm³)
  - Large over-response above 10x10 cm² field size and under-response below 10x10 cm² field size.

Corrected Data (Subtract Non-scintillation Signal)

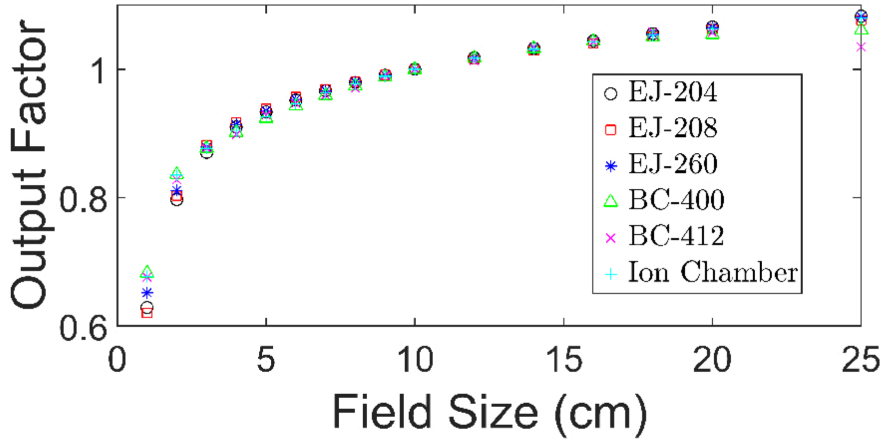

Figure 3. Output factors corrected by subtracting the non-scintillation signal (measured without the scintillator present) from the SPSD measured signal shown in figure 3.

- After subtracting non-scintillation signal (measured without the scintillator in place), the small SPSDs matched the ion chamber measurements within 1% for field sizes 1x1 to 20x20 cm²
- Non-scintillation signal is more significant for the smaller scintillator due to decrease in signal from the scintillator

Small Field Output Factors

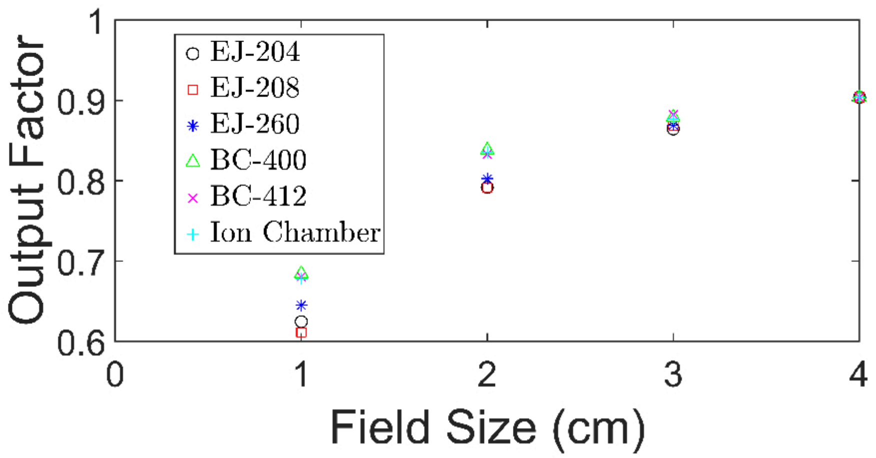

Figure 4. Output factors normalized to the value measured with a 4x4 cm² field size and compared to a micro ion chamber.

- Re-normalizing Output factors to 4x4 cm² field
  - Large scintillators show an under-response at 1x1 and 2x2 cm² field size due to volume averaging
  - Small scintillators match ion chamber down to 1x1 cm²
  - Non-scintillation signal accounts for less of the signal for small fields

PDDs (6 MV)

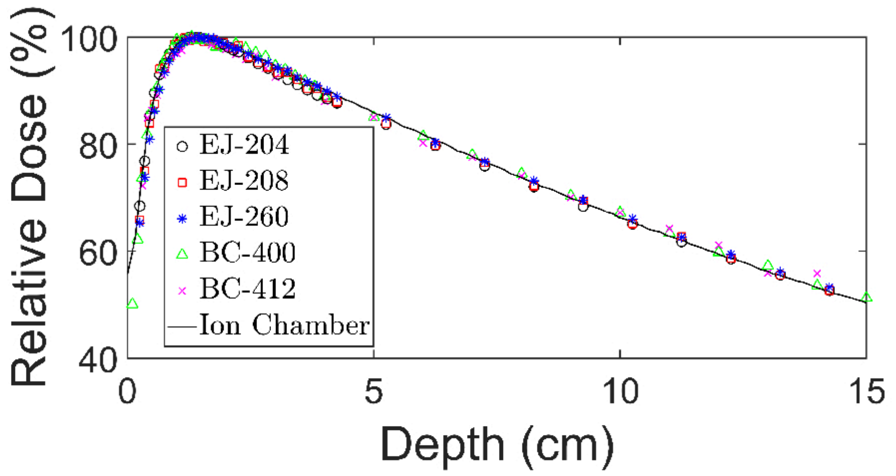

Figure 5. PDDs of the five SPSDs compared to an ion chamber measurements. The depth corresponds to the depth midway through the scintillator

- The depth of measurement for the SPSDs were taken to be at mid-depth into the scintillator
- All SPSDs matched the PDD measured with the ion chamber to within 2%
- Similar agreement was found with a 10 MV photon beam (data not shown)

SUMMARY

Larger scintillators had less than 1% deviation from the ion chamber for output factors of field sizes 3x3 cm² to 25x25 cm², but exhibited an under-response at smaller field sizes likely due to volume averaging.

Smaller scintillators have a large non-scintillation contribution. After correcting for the non-scintillation signal the small scintillators exhibited better output factors for small fields.

Non-scintillation signal is more significant for smaller scintillators due to decrease in signal from the scintillator.

PDDs measured with the five SPSDs matched ion chamber measurements within 2% for 6 and 10 MV photon beams.

FUTURE WORK

Measured data (not shown) demonstrate signal is generated in the metallic electrodes and connectors. Future work will attempt to minimize the non-scintillation signal through:
- Use of conducting organics
- Use of wire bonding to reduce the footprint of the electrodes

Apply the detectors to patient specific applications.

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