An experimental approach to air gap optimisation for a 'correction-less' small field diode

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Aim

A recent Monte Carlo based study has shown that it is possible to design a diode that measures small field output factors equivalent to those in water. This is accomplished by placing an appropriate sized air gap above the silicon chip (1) with experimental results subsequently confirming that a particular Monte Carlo design was accurate (2). The aim of this work was to test if a new correction-less diode could be designed using an entirely experimental methodology.

Methods and materials

Notes:

"KQ_{clin},Q_{msr}" = *Figure 1.*

"Equation" = Figure 2.

"$KQ_{clin},^{EDGEe}$" = Figure 3.

Output ratios (normalized to 30 mm) were measured on a Varian iX linear accelerator at a depth of 5 cm, SSD of 95 cm and square field sizes of side length 5, 6, 8, 10, 20 and 30 mm.

The experimental transfer of "KQ_{clin},Q_{msr}"

Output ratios using the above field sizes were measured with a commonly used diode detector (IBA, stereotactic field diode (SFD)), as well a Sun Nuclear EDGE diode customized by having the copper shielding removed (EDGEe). "KQ_{clin},Q_{msr}" was then calculated experimentally by transference from the SFD:

$$k_{Q_{clin},Q_{msr}}^{EDGEe_{clin},EDGEe_{msr}} = k_{Q_{clin},Q_{msr}}^{SFD_{clin},SFD_{msr}} \frac{OR_{SFD}}{OR_{DET}}$$

Fig. 2

References: Radiation Oncology, Princess Alexandra Hospital, Brisbane, Queensland - BRISBANE/AU

These results were compared to Monte Carlo calculated values of the EDGEe. The EGSnrc C++ user code cavity was used to simulate the EDGEe detector and "$KQ_{clin,}^{EDGEe}$" was found using the methodology in Charles et al (1).

Experimental optimization of air gap

The air gap size required above the EDGEe diode was optimized empirically. Nine different air gap "tops" were created using combinations of 3 different widths and 3 different depths (air depth = 0.3, 0.6, 0.9 mm; air width = 3.06, 4.59, 6.13 mm). Each was placed above the EDGEe and "$KQ_{clin,}^{EDGEe}$" was calculated using each air top and each field size as above.

The optimal air gap combination was found by observing the air gap size required to make "$KQ_{clin,}^{EDGEe}$" equal to 1 at all field sizes.

Images for this section:

$$k_{Q_{clin},Q_{msr}}$$

Fig. 1

$$k_{Q_{clin},Q_{msr}}^{EDGEe_{clin},EDGEe_{msr}} = k_{Q_{clin},Q_{msr}}^{SFD_{clin},SFD_{msr}} \frac{OR_{SFD}}{OR_{DET}}$$

Fig. 2

$$k_{Q_{clin},Q_{msr}}^{EDGEe_{clin},EDGEe_{msr}}$$

Fig. 3

Results

The experimental and Monte Carlo simulated "$KQ_{clin,}^{EDGEe}$" values agreed to within 0.7 %.

Figures 4, 5 and 6 show "$KQ_{clin,}^{EDGEe}$" as a function of air gap depth for all field sizes measured. The 3 figures display the results for an air gap width of 3.06, 4.59 and 6.13 mm respectively.

Increasing the air gap width from 3.06 to 4.59 mm decreased the sensitivity of the diode to the smaller field sizes; however a further increase to 6.13 mm had little effect. The optimal air gap depth was found to 0.6 mm.

The resultant output ratios measured using the optimized EDGEe diode were found to be equivalent to output factors in water at all field sizes; except at field sizes of 8 mm and 10 mm where they were approximately 2 % different (see figure 7).

Images for this section:

$$k_{Q_{clin},Q_{msr}}^{EDGEe_{clin},EDGEe_{msr}}$$

Fig. 3

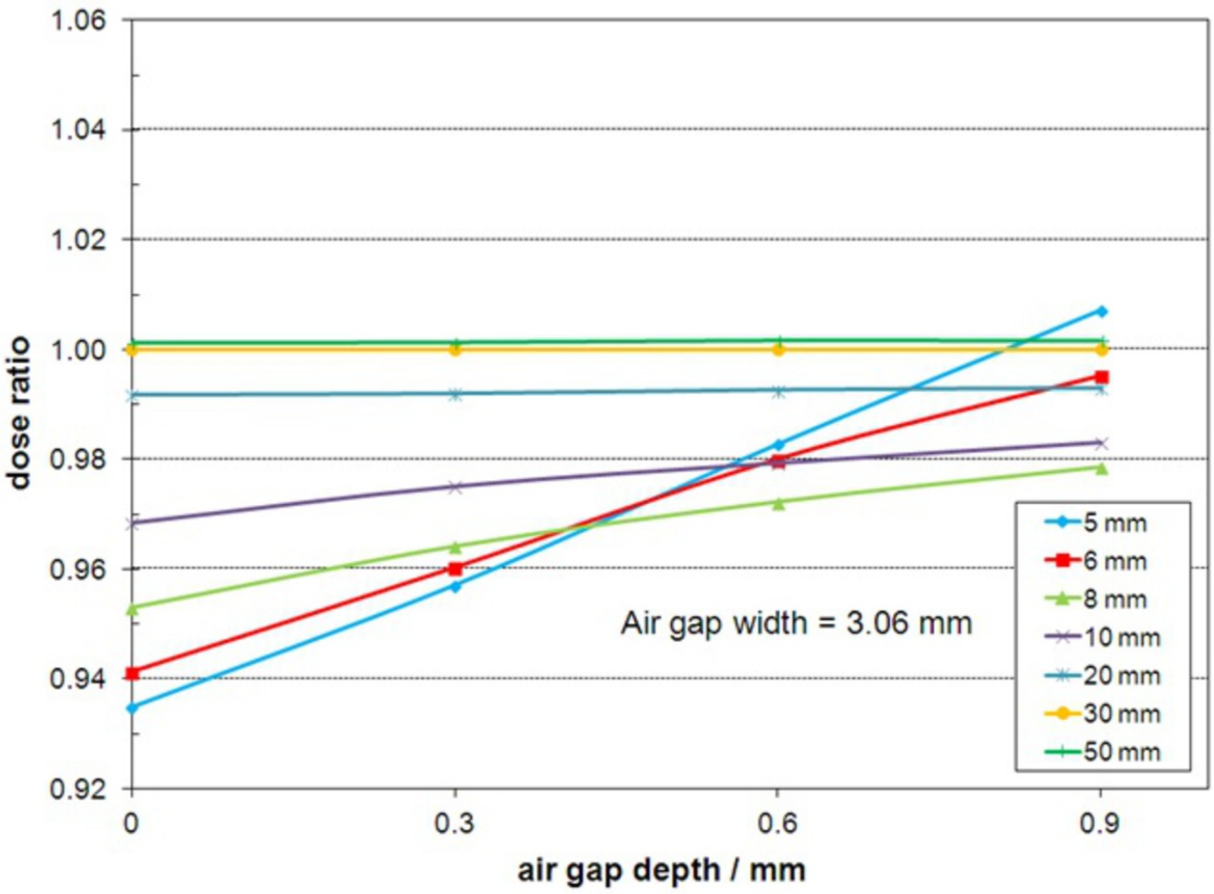

Fig. 4: KQclin(EDGEe) as a function of air gap thickness. Air gap width = 3.06 mm.

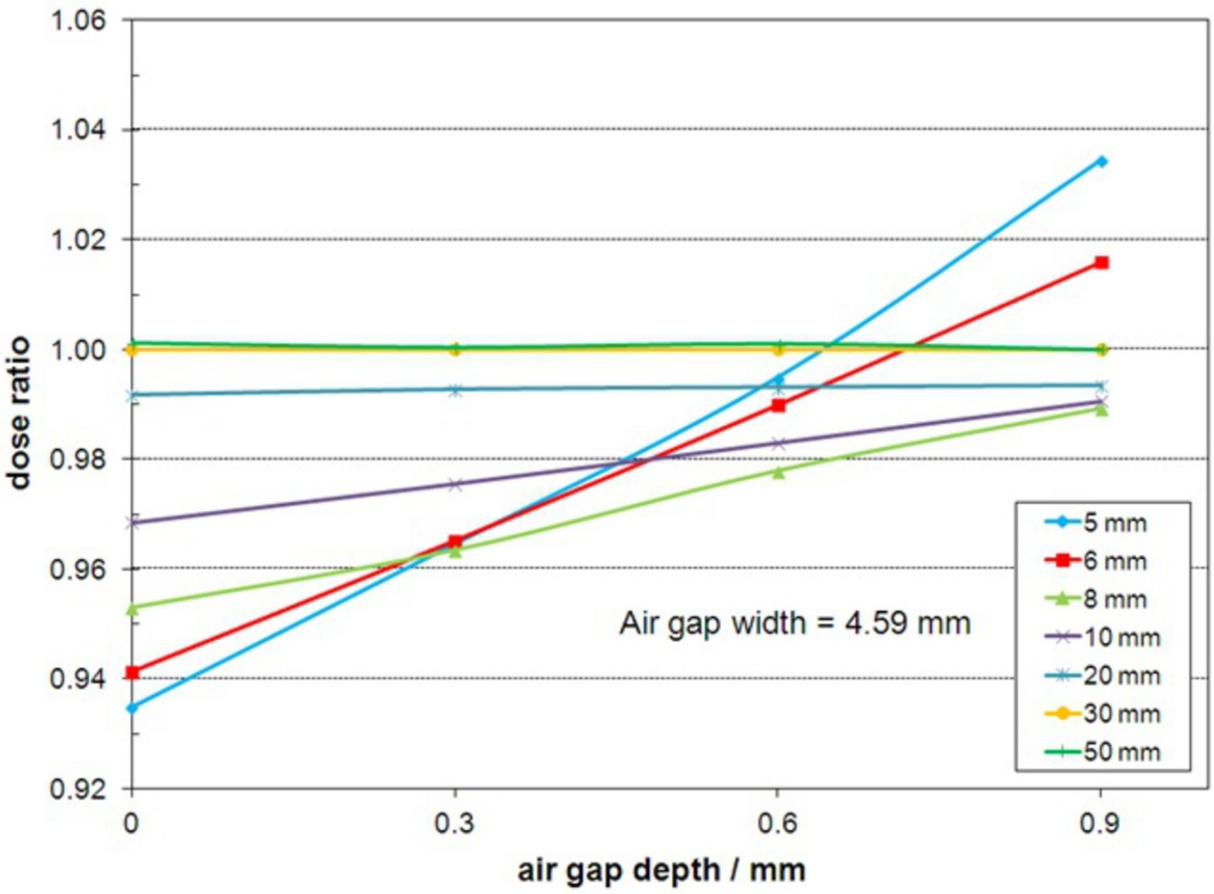

Fig. 5: KQclin(EDGEe) as a function of air gap thickness. Air gap width = 4.59 mm.

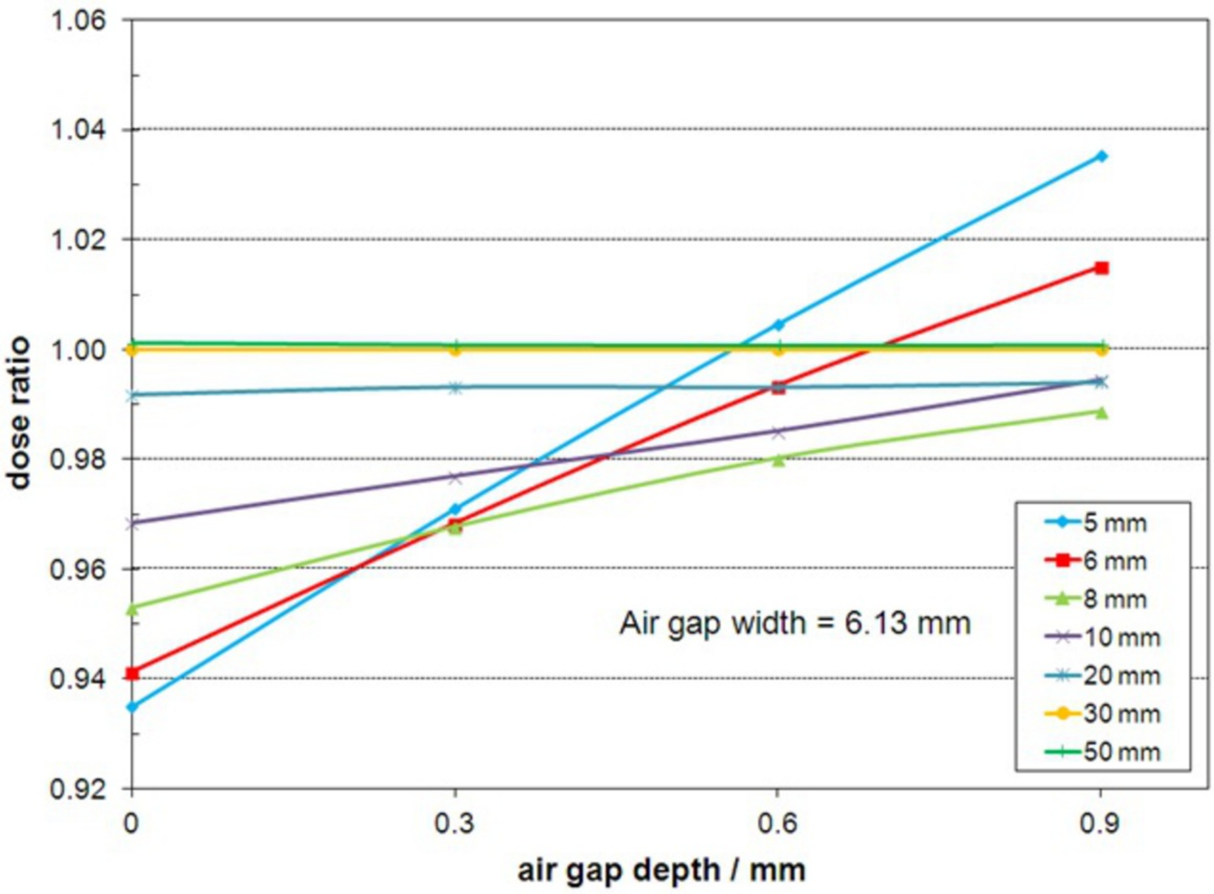

Fig. 6: KQclin(EDGEe) as a function of air gap thickness. Air gap width = 6.13 mm.

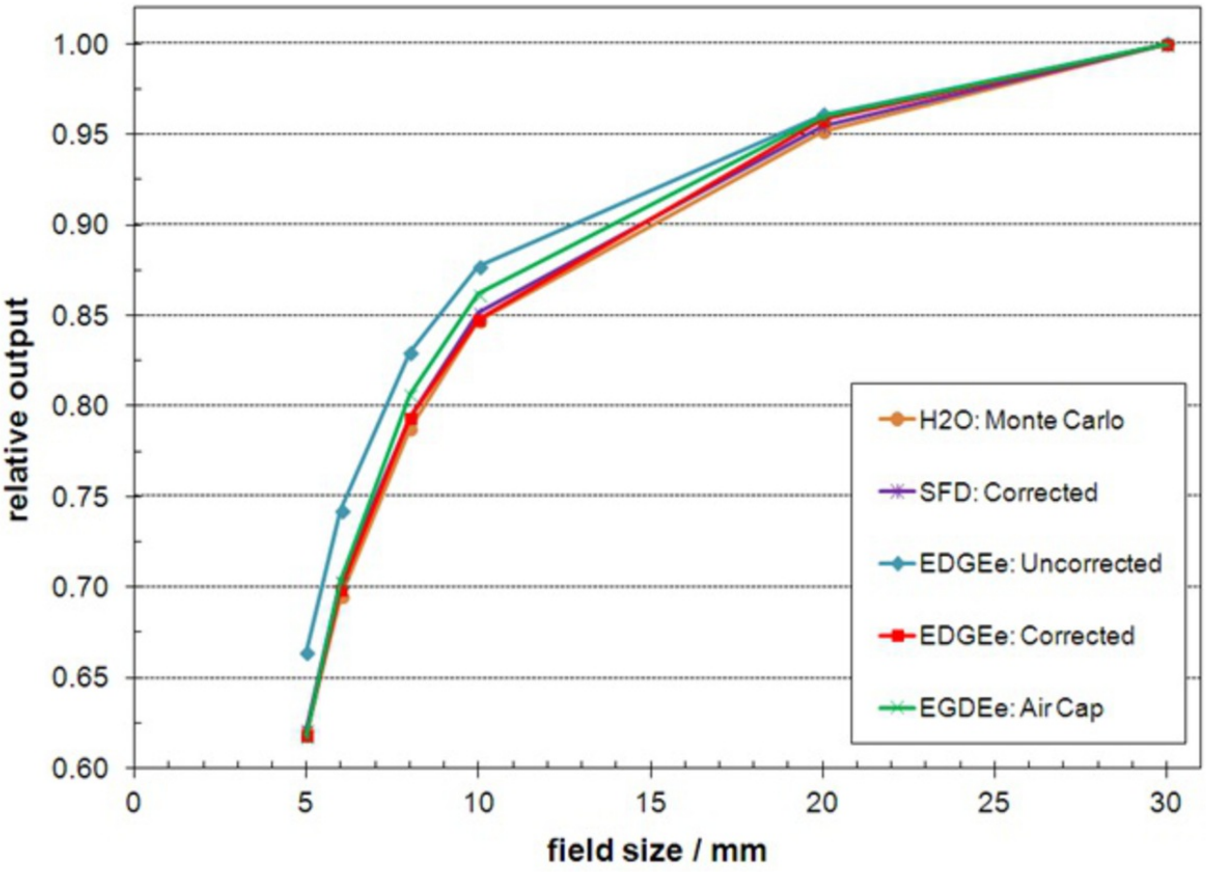

Fig. 7: Output ratios measured using detectors as shown in the legend. Data labelled "corrected" have had kQclin,Qmsr values applied. Detector-less MC values also included for comparison.

Conclusion

The EDGEe detector can be made "correction-less" for field sizes of 5 and 6 mm, but was ~2% from being "correction-less" at field sizes of 8 and 10 mm. The reason that the EDGEe diode was not able to be fully optimized could be attributed to the additional material in the detector such as the surrounding brass.

Different materials will perturb small fields in different ways. A detector is only "correction-less" if all these perturbations happen to cancel out. Designing a "correction-less" diode is a complicated process, thus it is reasonable to expect that Monte Carlo simulations should play an important role in the initial design. Experimental measurements are also required to confirm the Monte Carlo results.

Personal information

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References

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