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A NOVEL MICRO LIQUID IONIZATION CHAMBER FOR CLINICAL DOSIMETRY

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Absorbed-dose-based protocols [1,2] recommend calibration of clinical linear accelerators using air-filled ionization chambers for which an absorbed-dose to water calibration factor has been established in a ^{60}Co beam. The factor k_Q in these protocols involves the ratio of the mean restricted collision mass stopping power water-to-air, which is energy dependent. For high-energy clinical photon beams, the stopping power ratio water-to-air varies by up to 4%, whereas for electron beams the variation is even larger. For certain insulating liquids, however, the stopping power ratio water-to-liquid shows very little energy dependence, making a liquid-filled ionization chamber a potentially attractive dosimeter for clinical reference dosimetry. In this work some properties of two liquid-filled ionization chambers are investigated including ion recombination and variation of response as a function of energy for photon beams.

In this work we used an Exradin A14P planar microchamber with chamber body and electrodes composed of C552 plastic. This chamber was modified, reducing the gap between the cap and collecting electrode to 0.5 mm. The diameter of the collecting electrode is 1.5 mm and the nominal sensitive volume of 1.12 mm^3 was filled with isooctane. This chamber will be referred to as the MicroLIC. The energy response of the MicroLIC was compared to previous results [3] measured using the LIC 9902-mix chamber, developed by G. Wickman of Umeå University, Sweden. The sensitive volume of this chamber has a diameter of 2.5 mm, thickness of 0.35 mm and is filled with 60% isooctane, 40% tetramethylsilane by weight. The linear accelerator used was a Varian Clinac 21EX with nominal photon beam energies of 6 and 18 MV. Measurements were done in a $20\times20\times20$ cm^3 RMI Solid Water™ phantom at 10 cm depth with a 10×10 cm^2 field at the phantom surface. Absorbed dose was determined using an Exradin A12 chamber with an absorbed-dose to water calibration factor for ^{60}Co established at a primary standards laboratory. Corrections were applied for pressure, temperature, polarity and recombination according to the TG-51 protocol, and k_Q values from TG-51 were used along with a correction factor k_{ph} to account for differences in interaction properties of Solid Water™ versus water. k_{ph} was determined by Seuntjens *et al.* [4] and is 1.000 and 1.006 for the 6 and18 MV beams respectively.

Ion recombination

Johansson *et al.* [5] investigated general recombination in liquid ionization chambers by applying Boag's theory for gasses. We initially followed this method. The chamber response as a function of polarizing voltage between 600 V and 1000 V was studied. The SSD was set to 2 m to obtain a low dose per pulse, making general recombination negligible. The lowest pulse repetition frequency (100 MU/min setting) was used to ensure complete charge collection between pulses. The relation between ionization current and electric field strength was linearly fitted such that $i=(c_1+c_2E)\dot{D}$, where i is the ionization current, E is the applied electric field and $\dot{D}$ is the dose rate. The fit constants depend only upon initial recombination and were determined at the low dose rate. Since they were assumed to be dose-rate independent, they were used to determine the predicted ionization current in the absence of general recombination at a higher dose rate, which could then be inserted into Boag's formula [5] to determine the general collection efficiency. In our case, however, the predicted current was lower than the measured current, indicating that the Johansson model was inadequate to determine the current in the absence of general recombination. Therefore, for the purpose of this work, we estimated the general recombination using Boag's formula with the measured current.

Energy response

The response of the MicroLIC was measured on two separate days for the 6 and 18 MV beams with an SSD of 100 cm. The pulse rate setting was 100 MU/min to enable complete charge collection between pulses. Measurements were taken with polarizing voltages of + and −1000 V to account for polarity effects and recombination was corrected for as described above.

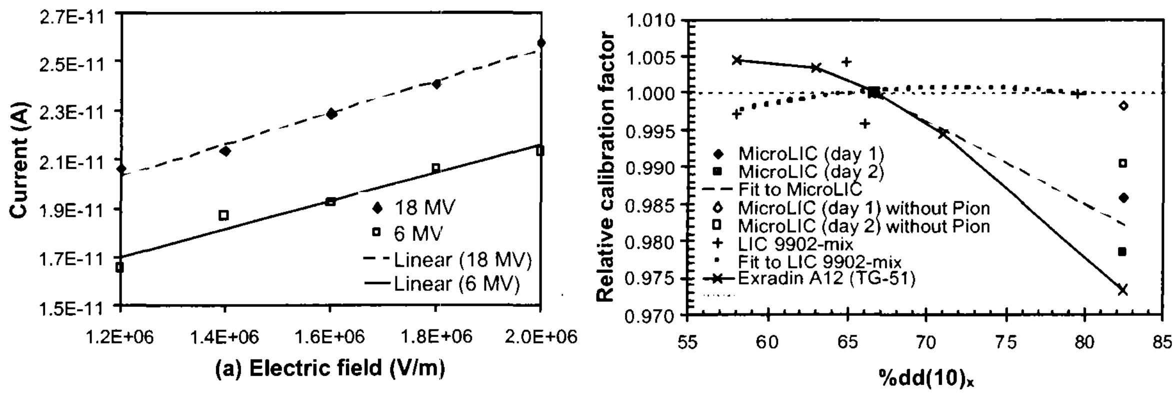

Fig. 1. (a) MicroLIC current as a function of applied electric field for 6 MV and 18 MV photon beams. (b) Relative calibration factor as a function of beam quality for the MicroLIC, LIC9902-mix [3] and Exradin A12 [1] chambers normalized to the response for the 6 MV photon beam. MicroLIC measurements from two days are shown both with (filled symbols) and without (open symbols) the ion recombination correction applied.

(a)	c_1 (C·Gy^{-1})	c_2 (C·m·Gy^{-1}·V^{-1})
6 MV	3.452×10^{-9}	1.953×10^{-12}
18 MV	3.493×10^{-9}	1.827×10^{-12}

(b)	P_{ion} (day 1)	P_{ion} (day 2)	P_{pol}
6 MV	1.0091	1.0084	0.9909
18 MV	1.0219	1.0209	0.9950

Table I. (a) Fit constants from MicroLIC response as a function of applied electric field. (b) Ion recombination and polarity corrections for the MicroLIC for 6 MV and 18 MV photon beams.

Fig.1. (a) shows the MicroLIC current as a function of applied electric field measured at the low dose rate. The dose rates were 2.93 mGy/s and 3.57 mGy/s for the 6 and 18 MV beams respectively and fit constants are shown in Table I. (a). The relative calibration factors of the MicroLIC, LIC 9902-mix and Exradin A12 as a function of beam quality for photon beams are shown in Fig. 1. (b). Values are normalized to the calibration factor for the 6 MV beam. Table I. (b) shows the ion recombination and polarity corrections applied to the MicroLIC measurements. Note that P_{ion} is determined using the measured ionization current, not the current in the absence of recombination estimated using Johansson's [5] model.

The ratio of the average calibration factor at 18 MV to 6 MV was 0.982±0.004 for the MicroLIC while for the LIC 9902-mix it was 1.000±0.003. Comparison with the ratio for the air-filled A12 chamber (0.973) indicates that liquid-filled chambers, consistent with expectations, tend to have superior energy-dependence characteristics. More investigation into the reproducibility of the MicroLIC response as well as ion recombination for this chamber is required. Also, modifications to the chamber design are being considered.

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