Proton Linearity and Energy Dependence of Optically Stimulated Luminescent Detectors for Remote Audits of Proton Beam Calibration by the Radiological Physics Center

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RPC Radiological Physics Center Excellence through Quality Assurance

Conclusions

The optically stimulated luminescent detector (OSLD) showed an excellent dose linearity as well as energy independence for 160-, 200-, and 250-MeV proton beams from the MD Anderson Cancer Center Proton Therapy Center. The OSLD is adequate to replace the thermoluminescent detector (TLD) in the Radiological Physics Center (RPC) remote audit QA program for beam outputs at participating proton treatment centers.

Introduction

OSLDs have become the dosimeter of choice for applications ranging from personal dosimeters to checking beam outputs. OSLDs are gradually replacing TLDs as passive dosimeters because of many advantages over TLDs: OSLDs are re-usable, are re-readable, do not need temperature and weight control, have a light-tight seal, have a short readout time, etc. The RPC has found that OSLDs are reliable for x-ray and electron beams and has started using OSLDs for x-ray and electron outputs in their remote audit program. Our preliminary proton studies showed an excellent linearity and energy independence of OSLD for various proton energies.

Purpose

This study validates the use of OSLD by the RPC for the remote audit program for outputs at participating proton treatment centers. The RPC recently replaced TLDs with OSLDs for remote audits of x-ray and electron beams because of the dosimetric superiority and convenience of OSLDs over TLDs. Our preliminary studies by the RPC have shown the dosimetric stability of OSLD for proton beams. The purpose of this study was to confirm our preliminary findings using the actual setup that will be used for future remote audits of proton beams. This OSLD study was performed using the standard RPC remote audit electron phantom and proton beams from the MD Anderson Cancer Center Proton Therapy Center.

Materials/Methods

Standard RPC remote audit electron phantom. Two nanoDots™ are shown, at two different depths.

For this study, we used aluminum oxide (Al_2O_3:C) nanoDots™ OSLDs (Landauer, Glenwood, IL) and proton beams from the Proton Therapy Center. As an OSLD phantom, we used a standard RPC remote audit electron phantom with two detector inserts at two depths. To provide side scatter, we inserted three scatter rings, and slabs of water-equivalent plastic phantoms were added to the top of the phantom to provide an adequate depth. The center of Spread-out Bragg peak (SOBP) was placed halfway between the detectors to cover both OSLDs with 100% of the center of modulation (COM) dose.

We performed two sets of studies using OSLDs: (1) a dose linearity study and (2) an energy dependence study for various proton energies. For both studies, a reference setup (field size = 10 × 10 cm^2; 10 cm SOBP) was used with the beam isocenter located at a depth halfway between the detectors. With the electron phantom, the two detectors were separated by 4.1 cm water-equivalent (effective) depth; therefore, both detectors were placed well within the 100% COM dose region of 10cm SOBP.

For the dose linearity study, we used a 250-MeV proton beam with doses of 25, 50, 100, 200, 300, and 350 cGy at the isocenter. This linearity study was compared with the previous OSLD commissioning study done with ^{60}Co.

For the energy dependence study, two sets of independent measurements were done using 160-, 200-, and 250-MeV proton beams. Each energy beam was delivered with the reference setup with 100 cGy. ^{60}Co measurement (300 cGy) was performed as a standardization process for both linearity and energy dependence studies. Between 6 and 11 days after irradiation, the OSLDs were read out with a Landauer MicroStar reader at the RPC.

Materials/Methods (continued)

Proton dose per monitor unit (MU) was calculated as follows:

$$Proton\ Dose/MU = ROF \cdot SOBPF \cdot RSF \cdot SOBPOCF \cdot OCR \cdot FSF \cdot ISF \cdot CPSF,$$

where
ROF = relative output factor,
SOBPF = SOBP factor, RSF = range shift factor,
SOBPOCF = SOBP off-center factor,
OCR = off-center ratio, *FSF* = field size factor,
ISF = inverse-square factor, and
CPSF = compensator and patient scatter factor.

The following formula was used to calculate dose from OSLD readings after proton irradiation.

$$OSLD\ Dose = Rdg \cdot S \cdot ECF \cdot K_F \cdot K_L \cdot K_E \cdot K_d\ ,$$

where
Rdg = raw photomultiplier tube counts,
S = system sensitivity factor of the MicroStar reader which converts counts to dose,
ECF = element correction factor of a nanoDot™,
K_F = post-irradiation signal fading factor,
K_L = dose linearity correction factor,
K_E = energy dependence factor, and
K_d = readout depletion factor.

The post-irradiation signal fading factor K_F was determined by

$$K_F = 1/\ [1.005 \cdot (d)^{-0.0072}]$$

where *d* is the number of days from date of irradiation to date of reading.

The readout depletion factor K_d was calculated by

$$K_d = 1/(an^2 + bn + c),$$

where *a* =-5.148 x 10^{-6}, *b* =-1.277 x 10^{-3} and c = 1 and n is the sequential number of the reading for a nanoDot™.

For the dose linearity study, the dose linearity correction factor K_L was obtained from the linear fits of 250-MeV proton beam readings.

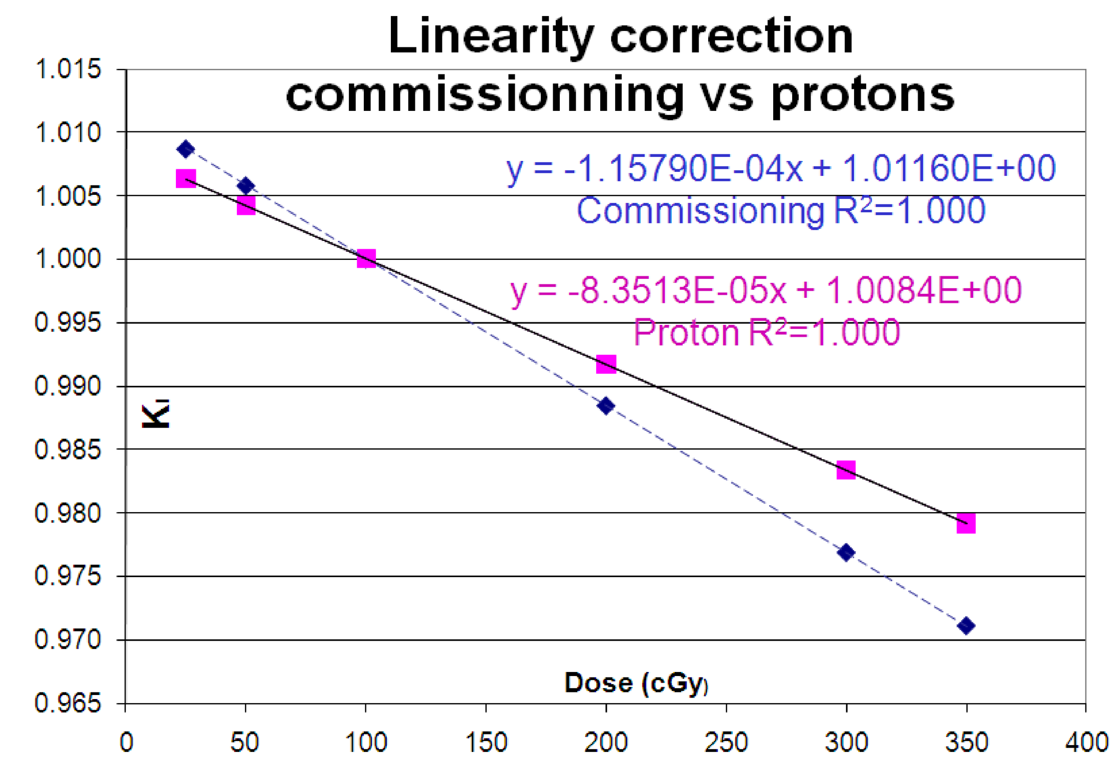
For the energy dependence study, K_L from ^{60}Co measurement was used as follows:

$$K_L = \alpha\ (raw\ dose) + \beta,$$

where α =-0.00011579 and β = 1.01160000

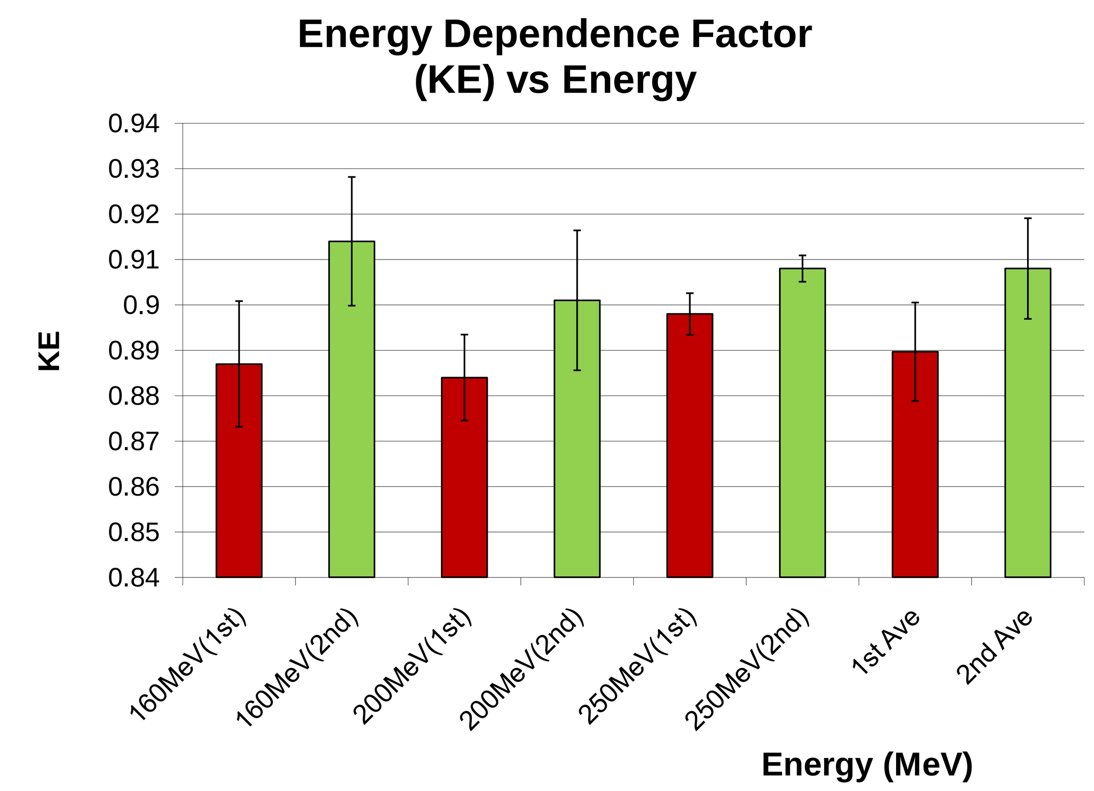
Results

The dose linearity study showed an excellent linearity of K_L versus dose for the dose range of 25 to 350 cGy for a 250-MeV proton beam similar to the photon commissioning OSLD linearity.



Both photon commissioning and proton linearity studies show excellent linearity of response versus dose with R^2=1.000 for both graphs. $y = K_l$ (dose linearity correction factor) and x = Dose.

The two sets of energy dependence studies showed that the K_E variation is within ±0.8% for three different proton energies. Therefore, we concluded there is no energy dependence of the proton beams and decided to fix K_E as a constant 0.9 relative to ^{60}Co standard used by the RPC.



Energy dependence factors (K_E) of 160-, 200-, and 250-MeV proton beams from two independent sets of measurements. Error bars represent ± one standard deviation.

References

Kerns J, Ibbott G, Johnson V, Kry S, Sahoo N, and Followill D Characterization of Optically-Stimulated Luminescent Detectors (OSLDs) in Photon & Proton Beams. *Med. Phys*. **37**, 3452 (2010); doi:10.1118/1.3469485

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