THE UNIVERSITY OF TEXAS
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Characterization of Optically Stimulated Luminescence Dosimeters for Use in Small Photon Beam Dosimetry

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RPC MD Anderson Radiological Physics Center

Introduction

The Radiological Physics Center 's (RPC) mission is to ensure consistency and dosimetric accuracy in radiation therapy from institutions participating in NCI funded clinical trials. The RPC accomplishes this mission through their external beam audit program which uses mailable optically stimulated luminescence detectors (OSLDs) to verify an institutions reported dose to the RPC measured dose to within a ±5% acceptance criteria [1]. With the increased use of small radiation fields due to the advent of new and improved technology, many institutions have requested a small field photon beam dosimetry audit capable of measuring dose accurately. The RPC currently has a full phantom program in place to measure small fields using thermoluminescence detectors (TLDs) but is limited to a >12.5mm field size and has a high uncertainty. The RPC is transitioning from TLDs to OSLDs and wishes to use only OSLDs to measure small field sizes in future remote audits.

This project aims to create a *mailable, OSLD full phantom capable of remote audits of small field sizes defined with cones or MLCs with accuracy suitable for RPC monitoring of clinical trial sites.*

Materials

Landauer's nanoDot OSLDs were used that have been carefully masked to define the active region (Figure 1). When read, signal will only be released from the area of interest while the remaining signal will be blocked by the mask.

Figure 1: nanoDot OSL Dosimeters with and without mask

A conical insert was designed and manufactured which houses a film insert for localization verification and two OSLD measurement points at 1.5cm and 7.5cm depth (Figure 2). The cone rests inside a 15 x 15 x 16 cm^3 full phantom prototype both manufactured out of high-impact polystyrene (ρ=1.04 g/cm^3) (Figure 3) which provides adequate backscattering characteristics.

Figure 2: The phantom prototype cone insert with film and OSLDs housing

Materials (continued)

Figure 3: Full phantom prototype

Methods

The first step was to determine the reproducibility of various mask sizes placed on the OSLDs. Once the appropriate mask size was determined, characterization of the OSLD followed.

OSLDs calculate dose by using the following equation:

$$\mathrm{Dose} = \mathrm{Reading} * \mathrm{ECF} * \mathrm{S} * \mathrm{K_L} * \mathrm{K_F} * \mathrm{K_D} * \mathrm{K_E} * \mathrm{K_{Sc}} * \mathrm{K_{FSD}} \quad (1)$$

Where:

Reading	raw OSLD reading
ECF	element correction factor
Sensitivity	system sensitivity [dose/counts]
K_L	linearity correction factor
K_F	fading correction factor
K_D	*depletion correction factor*
K_E	*energy correction factor*
K_{Sc}	*scatter correction factor*
K_{FSD}	*field size dependence correction factor*

ECF – corrects for individual differences seen within a batch by comparing a single OSLD with the average of the batch.

Sensitivity – determined by irradiating OSLDs to a specific dose under a controlled environment using a ^{60}Co beam to determine the dose/count conversion.

K_L – linearity correction of OSLD dose response. Multiple OSLDs were irradiate to doses between 50-300cGy. Dose per reading vs. dose was plotted and a linear fit was applied and values were normalized at 100cGy.

K_F – accounts for signal loss over time. The RPC has already determined the fading correction for this particular batch.

K_D – corrects for loss of signal between readings for a each OSLD. OSLDs are read three times each.

K_E – used to convert dose to acrylic miniphantom irradiated with ^{60}Co to dose to Hi-Impact polystyrene full phantom irradiated with a 6MV beam. This correction allows us to use the sensitivity specified earlier.

Methods (continued)

K_{Sc} – accounts for the scatter involved in the phantom that will allow us to use the K_E value determined during commissioning of a new batch of OSLDs.

K_{FSD} – many papers have published correction values for various detectors at small field sizes [2] due to the complexities from the departure of Bragg-Gray cavity requirements. Various detectors were used to determine dose and knowing all the factors in Eq. 1, we can solve for the field size dependence correction factor.

Results

After testing the reproducibility of the 1mm, 2mm, and 3mm masks, the results showed that the 2mm and 3mm masked OSLDs were reproducible to within 2% while the 1mm varied from 5-8%. The 2mm mask were chosen for the remainder of the project.

It was determined that K_L = -0.0002 × *Dose* + 1.0245 where *Dose* is the nominal dose in cGy. The equation in Figure 4 is the same determined by the RPC during commissioning of unmasked OSLDs within the same batch. This remote audit tool an institution to deliver 200cGy at d_{max} therefore K_L = 0.9755.

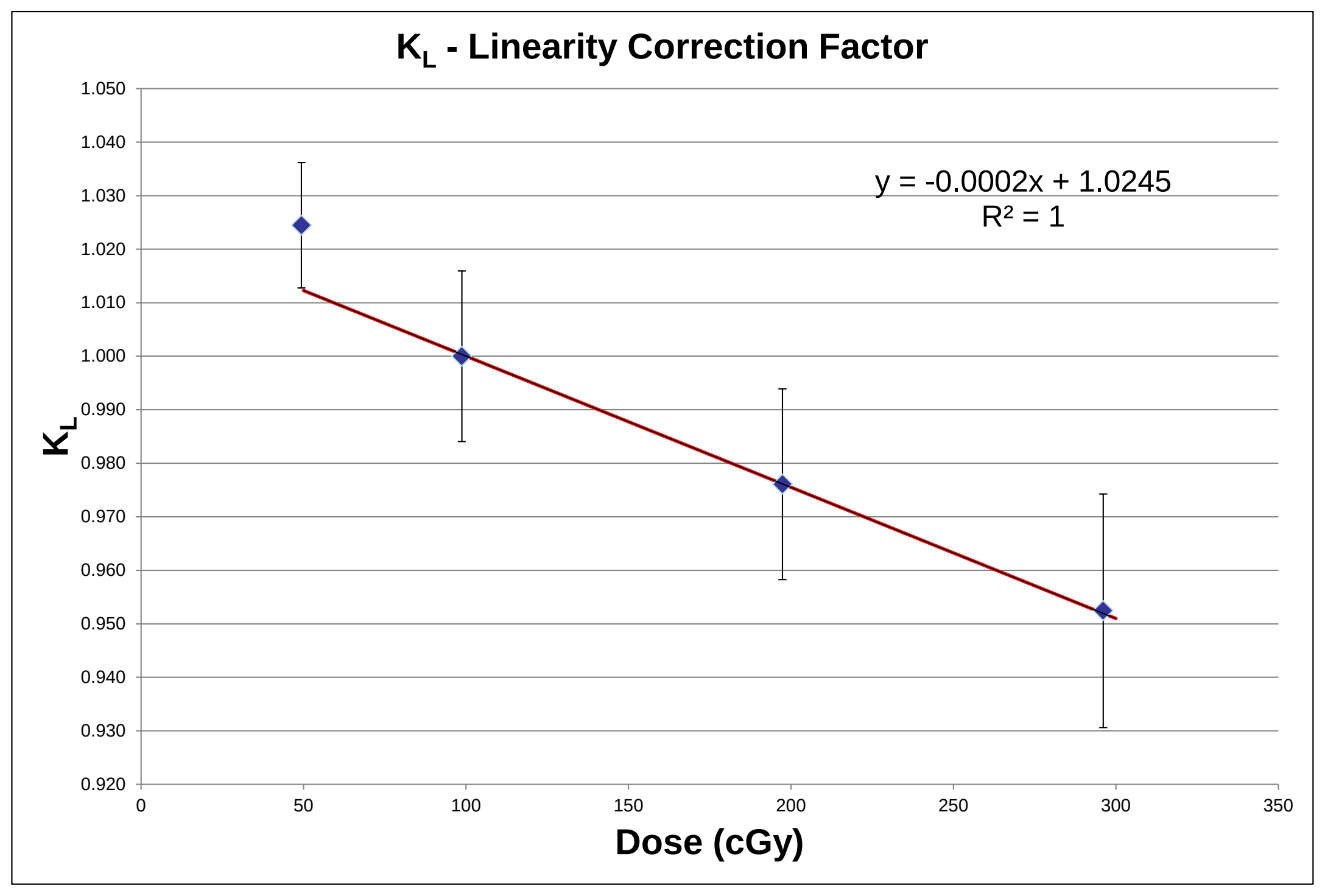

Figure 4: Linearity correction factor plotted with one standard deviation

ECF values obtained during commissioning for unmasked OSLDs cannot be used for masked OSLDs. The distribution is shown in Figure 5.

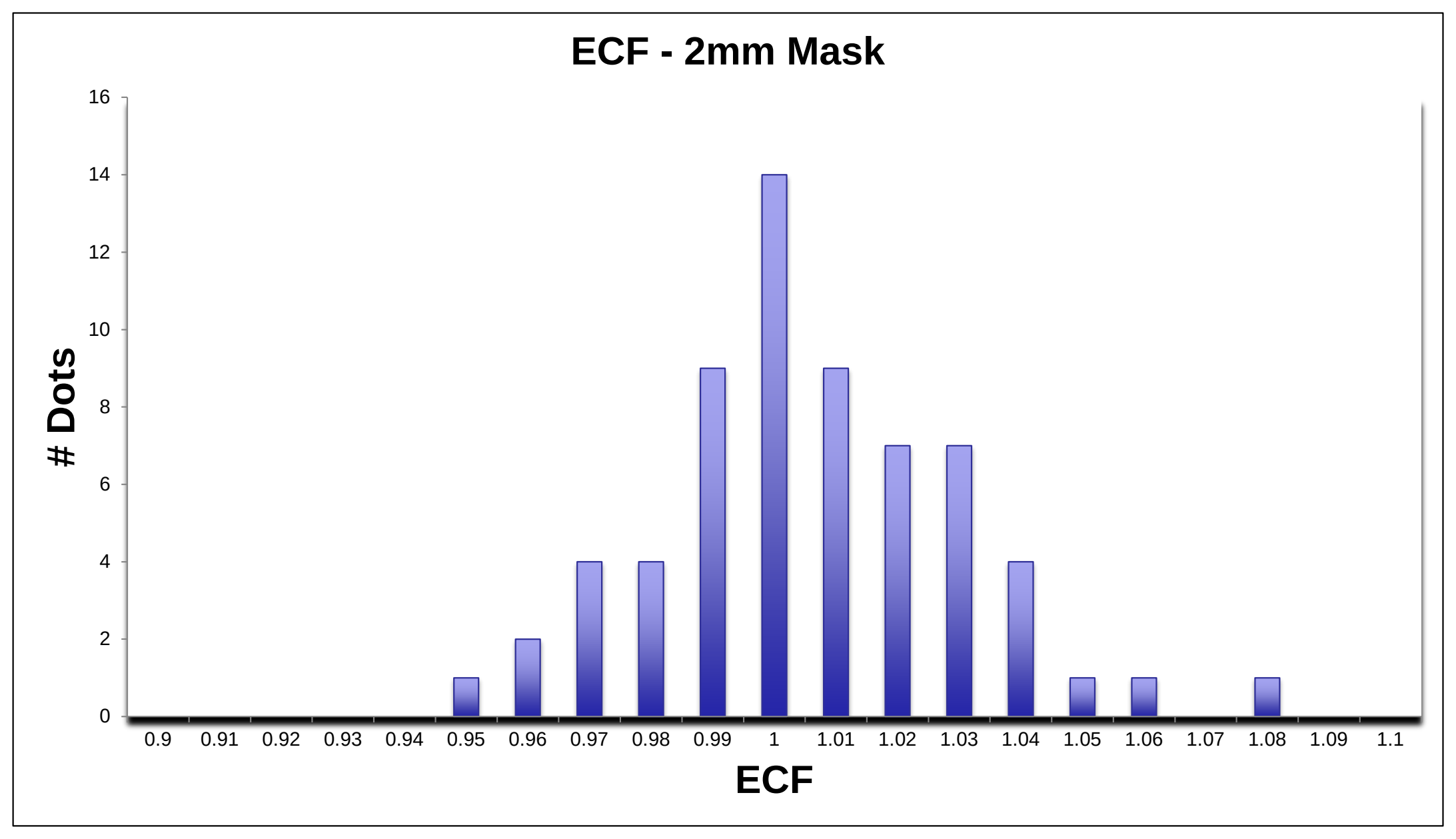

Figure 5: ECF values for masked OSLDs

The K_E x K_{Sc} correction factor was determined to be 1.025. However the RPC plans on using the K_E determined during commissioning of 1.011 therefore an additional K_{Sc} correction of 1.015 need to be applied. K_{Sc} has also been verified in other experiments.

Results (continued)

K_{FSD} was determined for field sizes down to 1cm x 1cm and the results are shown in Figure 6.

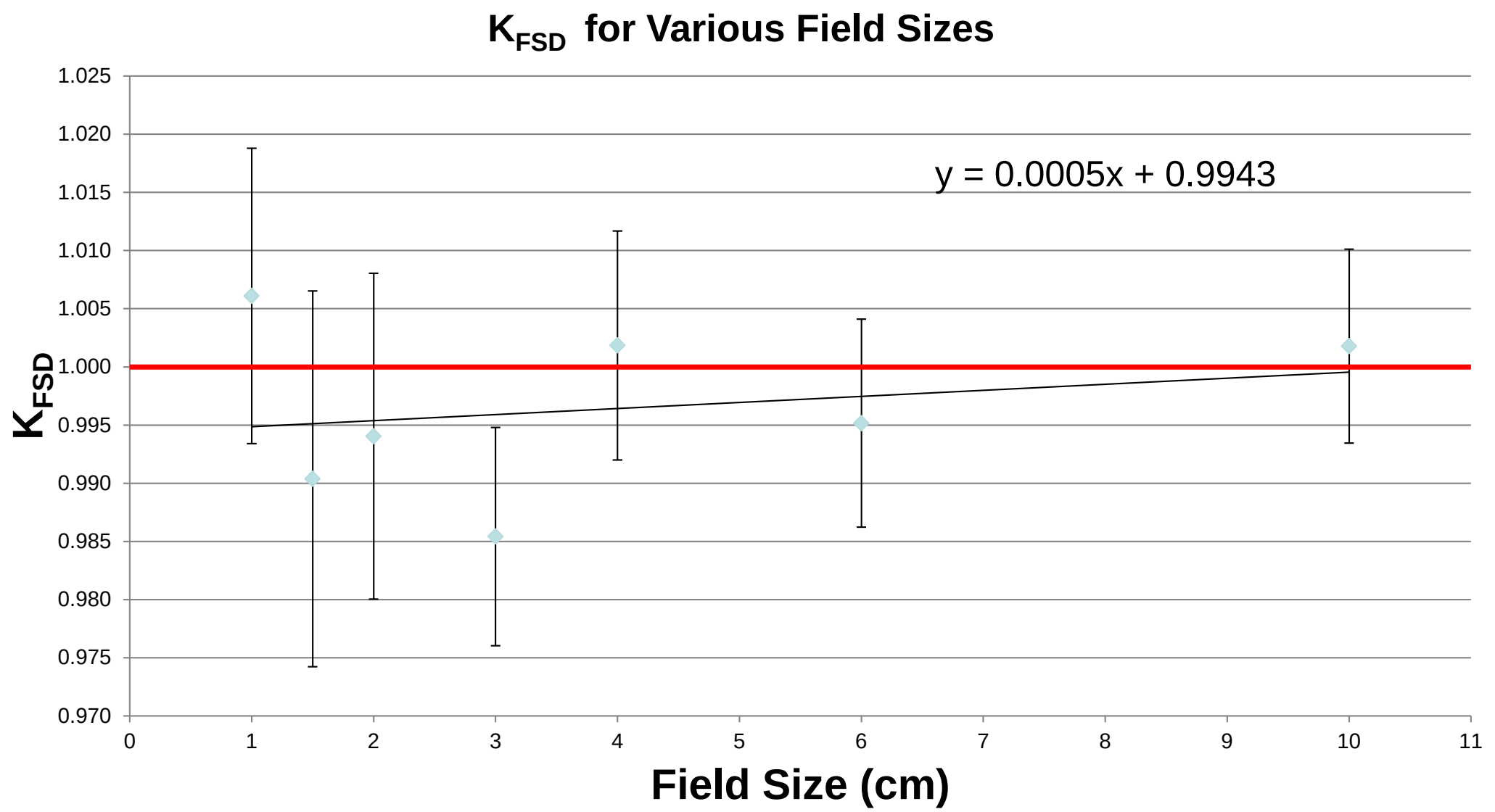

Figure 6: Field size dependent factor

K_{FSD} results were analyzed using ANOVA and linear regression models which determined the intercept was statistically significant (p<0.05) from 0, in fact very close to 1, and the slope was not significantly different than zero. Therefore K_{FSD}=1 can be used.

Previous studies have been to determine the uncertainty in the reading, ECF, Sensitivity, and K_F by Aguirre et al. [3]. Since masked OSLDs were used, verification of the reading and sensitivities were performed. Uncertainty in readings matched the stated value however sensitivity had a slightly lower uncertainty value. Uncertainty values are listed in Table 1.

Quantity	Uncertainty (%)
Reading	0.57
ECF	0
Sensitivity	0.8
K_L	1.83
K_F	0.15
$K_{E,Sc}$	1.3
Total (2σ)	**4.9**

Table 1: Uncertainty for dose measurements.

Conclusion

An estimated 4.9% 2σ uncertainty is acceptable for the RPC ±5% acceptance criteria for RPC to institution dose ratios according to Aguirre et al.[4].

This remote audit tool provides the RPC with a simple, durable, and accurate tool to verify doses delivered using small photon beam fields down to a 1cm x 1cm field size or a 10cm diameter field. If reported doses fall outside the acceptance criterion, this will be caused by either incorrect treatment planning input or incorrect localization by the user. The phantom will help ensure the RPC's mission to accurately audit institutions participating in NCI funded clinical trials.

References

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4) Kirby et al. "Uncertainty analysis of absorbed dose calculations from thermoluminescence dosimeters," Med Phys **19**, 1427-1433 (1992).

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