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MLC Transmission and Dosimetric Leaf Gap Measurement Using CU Values from Integrated Images of Varian VitalBeam LINAC

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Abstract

Modern dynamic radiotherapy techniques require more precision and need routine checking. However, presently available methods for Dosimetric Leaf Gap (DLG) and MLC transmission factor are highly time-consuming, so they are not feasible for busy radiotherapy centers. This analytical and observational study tried to determine the most straightforward way of simultaneously determining the transmission and DLG in the shortest time.We measured all data at 5cm depth using a Varian VitalBeam LINAC, newly installed at TMSS Cancer Center, Bogura, Bangladesh. We used three significant pieces of equipment in our experiment: an integrated Electronics Portal Imaging Device (EPID), a solid water phantom and a farmer-type ion chamber (Model: IBA FC65-P). The Eclipse? TPS was also used to make the QA plan and to analyze the images.

Index terms — electronic portal imaging device (EPID), VMAT, dosimetric leaf gap (DLG).

1 Introduction

ancerous tumors are treated with radiotherapy by a specific dose of radiation. It is impossible for 100% of the supplied radiation to be deposited in the tumor due to the physics principles governing radiation dose deposition in a medium. Therefore, radiotherapy aims to treat cancer with a therapeutic dose while keeping the amount to the nearby healthy tissues within clinically tolerable bounds. Target localization and organ-at-risk (OAR) sparing are being improved by ongoing research and development focusing on using fewer resources. Volumetric Modulated Arc Therapy (VMAT), commonly administered using a linear accelerator, was implemented, significantly advancing in the past ten years [1]. An intensity-modulated radiotherapy (IMRT) method involves dynamically adjusting the radiotherapy treatment beam aperture to create a final beam of varying intensity. This technique can be done for several beams at different gantry angles, resulting in a dose distribution throughout the patient that better adheres to the treatment goal (than a static beam) and better spares nearby OARs. Modern IMRT requires inverse planning techniques since they automatically tune dose distributions by adjusting the photon fluence in the radiation fields [2].

IMRT fields are delivered using MLCs that move while the beam is offered to change the beam aperture's shape continuously. With the MLC motions, the LINAC's dose rate is coordinated. The MLC movements and LINAC dose rate are coordinated to provide the necessary two-dimensional beam intensity fluence. Karl Otto first developed VMAT, which more recently included the IMRT principles ??2008). VMAT uses a continuous rotating gantry arc for delivery instead of IMRT, which uses a series of discrete fixed gantry angles because the MLC and dose rate are regulated. The VMAT approach alters LINAC's requirements to give the treatment. The LINAC's performance is under additional stress by these requirements, which include changing gantry speed, gantry angle-dependent dose rate modulation, and more complex MLC motions [2]. As a result, VMAT-specific QA systems must be created to check that the planned dose distributions match C Abstract-Modern dynamic radiotherapy techniques require more precision and need routine checking. However, presently available methods for Dosimetric Leaf Gap (DLG) and MLC transmission factor are highly time-consuming, so they are not feasible for busy radiotherapy centers. This analytical and observational study tried to determine the most straightforward way of simultaneously determining the transmission and DLG in the shortest time.

We measured all data at 5cm depth using a Varian VitalBeam LINAC, newly installed at TMSS Cancer Center, Bogura, Bangladesh. We used three significant pieces of equipment in our experiment: an integrated Electronics Portal Imaging Device (EPID), a solid water phantom and a farmertype ion chamber (Model: IBA FC65-P). The Eclipse? TPS was also used to make the QA plan and to analyze the images.

As per Varian machine recommendation, the transmission factor and DLG will be less than 2% and 2mm, respectively. In our measurement, using a Farmer-type ion chamber, we got the value of transmission factor of 1.46% and 1.69% and DLG of 0.98 mm and 1.13 mm for 6MV and 10MV photons, respectively. Using EPID a-Si1200, we got the transmission of 1.23% and 1.63% and DLG of 0.85 mm and 1.08 mm for 6MV and 10MV photons, respectively.

MLC transmission is in good agreement with ion chamber-based dosimetry with established data. It is a little lower for the 6MV photon EPID-based result, that is, maybe for the inhomogeneity characteristics of the photon fluence in low energies and negligible. For 10MV or higher energy photons, it is almost similar. those that were delivered and to assure delivery that is dependable, stable, and reproducible [2,3].During delivery, primary control is dictated by the gantry speed. The large mass of the treatment head makes this the most challenging component to modulate and control rapidly and accurately. When less than approximately 1.8 MU/deg is required, the gantry will move at maximum speed, but the dose rate will be dropped below 600 MU/min. When a more significant MU/deg rate is delivered, the maximum dose rate will be applied, and the gantry speed will slow down [4]. LINAC Quality Assurance (QA) testing is typical practice in radiation departments for guaranteeing LINAC performance. LINAC QA procedures typically rely on established best practice guidelines. The American Association of Physicists in Medicine (AAPM) TG-142 report [5] and AAPM Medical Physics Practice Guideline 8(a) are recent examples of such protocols [6]. The AAPM released guidelines for the delivery, treatment planning, and clinical application of IMRT in 2003 [7]. The AAPM released two task group reports in 2009 pertinent to IMRT and VMAT QA. The first, AAPM TG-142 [8], offered overarching guidelines for LINAC quality assurance [9].

Modern radiotherapy system is very sophisticated and requires quality assurance randomly. Nevertheless, due to the enormous patient load in a center, physicists and dosimetrists cannot set up QA equipment for daily checking of doses and machine parameters. So it required a quick setup system for equipment, essential parameters checkups, and patient plan verification. In 1990, a radiotherapy machine company introduced an Electronic Imaging system for checkup patients positioning [18]. After an era, they developed Electronics Imaging System called EPID. Modern EPID systems have an amorphous siliconbased detector for the patient imaging system, radiotherapy plan verification systems, and machinespecific QA systems. Task Group-58 (AAPM) published a report where they informed details use of EPID. The goals of this research work are:

1. Calculation of the Transmission Factor for specific field size and DLG using conventional and EPIDbased observation.

2 Comparison of EPID-based results with other

protocols and institutional standards.

3 a) MLC Transmission

A radiation measurement has been performed with open and closed MLC for a 10x10cm 2 field at 5 cm depth, SSD = 95cm; the ratio of these measurements is the transmission factor. We made the appropriate position of the slabs of solid water phantom with the dedicated hole for the Iso-Center above 5 cm of thickness to consider backscatter. A Farmer-type chamber was fixed in the solid phantom dedicated hole, and the cable of the chamber was set on the couch. The solid water phantom was aligned and made centered using the field light of a 30x30cm 2 field. We mounted slabs for a thickness of 5 cm (chosen depth for the measurement) on the slab housing the detector. We set the SSD at 95cm, and the chamber position was in SAD at 100 cm. We took data in block field size using Leaf Bank A and B. In QA mode, we opened the TPS plan, which we had prepared previously and took data for MLC Bank A (R TA) and B (R TB), respectively.

By the equitation below, the transmission factor was determined using EPID. In that case, SAD was fixed at 100 cm or SSD at 95 cm from the EPID with a 5cm build-up.

4 ?????????????????????????? ????????????, ?? ??

= ?? ???? +?? ???? ?? ???????? ——————(1)

5 b) Dosimetric Leaf Gap (DLG)

Due to the round shape of the leaf edge and the use of the leaves in a dynamic way, a dosimetric gap is created between them for the movement of the leaves during IMRT and VMAT treatment. We will quantify this gap using EPID in this research. A pictorial representation of transmission through the rounded end of the MLC leaf is shown in Figure 1, illustrating that both the optical field size and DLG constitute a radiation field [10]. Linear regression was performed using the acquired dose values and the related gap widths to evaluate the dynamic MLC fields with gap widths ranging from 0 to 20 mm. The intercept of the regression line was the DLG.

We continued the remaining fields for the preliminary plan in QA mode using the same experimental configuration for the MLC transmission: 7 fields with various gap sizes (2,4,6,10,14,16, and 20 mm, respectively). The dose values from the electrometer display were read and recorded in an Excel file for each field. Each value was corrected while taking the RT contribution of the transmitted doses. Then we performed linear regression with the computed Rg, T and the associated gap widths. The intercept of the linear extrapolation is the DLG (dose value corresponding to gap width = 0 mm). We measured the reading from the moving gap (R g). We used 2 to 20 mm moving gap fields.?? ð ??"ð ??",?? = ?? ?? ?1 - ?? ð ??"ð ??" 120 ???????? (2)

We calculated the corrected gap reading for each gap, g, which is defined asR g' = R g -R g,T ????????**(3)**

II.

6 Materials and Method

The tools and equipment used in this study: integrated Electronic Portal Imaging Device (EPID), Farmer-Type Ionization Chamber, Electrometer, Eclipse TPS Version 16.0.1 software.

7 a) Electronic Portal Imaging Device (EPID)

A 2D radiation detector integrated with the LINAC and used as a detector for both LINAC and patient-specific QA for IMRT/VMAT is called an EPID. Every time a patient is treated, the EPID is intended to assess their alignment with the radiation field [16]. Amorphous silicon-based active matrix flat panels are the now-standard EPID type (a-Si). In a 2D array, each photodiode is a single pixel that transforms incident light into an electric charge that a transistor uses to regulate signal reading [11].

Amorphous silicon EPID typically has thousands of faulty pixels (1%) in addition to the dark and flood field calibrations because of manufacturing restrictions [12]. These are adjusted by giving them the average value of the nearby pixels. Lastly, the EPID image grey scale is calibrated to LINAC Monitor Units under reference conditions for Varian patient-specific QA applications like Portal Dosimetry. The use of the Calibration Units (CU) calibration, also referred to as the dosimetry calibration on the VitalBeam LINAC, is accomplished by using the mean grey scale of an EPID image with a Region-of-Interest mean value at the central axis of 100MU under reference conditions and a designated CU value to provide a correction factor to the grey scale for the following reasons: subsequent images.

For use in dynamic treatments like IMRT and VMAT, the MLC has been the most often researched LINAC component with QA tests employing an EPID [13]. Other LINAC parts undergoing EPID testing include physical and dynamic wedges [14], gantry angle, asymmetric jaw alignment, and x-ray.

Using the Eclipse TPS, a QA plan was created to determine the transmission factor and the DLG. According to that plan, radiation was exposed to the EPID in QA mode. The MLC transmission and DLG of the machine were determined by analyzing the EPID based predicted integrated images. After the analysis, the information was processed, and the acquired data from the study were compared to VARIAN Machine Protocol and with some published data from various renowned international journals.

This thesis aims to determine how easily we can perform LINAC machine quality assurance using EPID or other array system diode-based QA devices. We tried to evaluate the DLG using EPID. The EPID system must first be configured to make it functional and usable. In the VARIAN VitalBeam Machine, the Portal Dose Image Prediction (PDIP) algorithm is usually used. Most radiotherapy centers perform Anisotropic Analytical Algorithms (AAA) to calculate the volume dose in the planning system of the LINAC machine. Some centers also use the AcurosXB algorithm. After installing a new LINAC machine, the acquired depth dose and beam profile data have been inserted into the TPS to configure it, making the machine fully commissioned and prepared for further treatment. The same data are also used to configure the PDIP.

8 b) Farmer-Type Ionization Chamber

The standard for output measurement is placing an ionization chamber like IBA FC65-P 0.6cc Farmer type chamber, positioned at 5 cm depth in a solid water phantom at 100 cm SSD. A Strontium source was used to examine the chamber response's consistency and to compare it to other Farmer-type chamber responses. The chamber response was then tracked back to the secondary standards laboratory. A solid water phantom setup with a Farmer-type ionization chamber is shown in Figure 2.

Where, y = the estimated score of the dependent variable, c = constant, b = regression co-efficient and x = the independent variable score.

9 d) Transmission and DLG Measurement from Ionization Chamber Based Data

Measurement data for MLC transmission and DLG were tabulated in Table **??** using a standard 10x10 cm 2 field size & 100 MU delivered for each energy and similar dose rates. SSD and SDD were 95 cm and 100 cm, respectively. IBA FC65-P ionization chamber and IBA Dose-1 electrometer were used. All of the data reading units were in nC charge. A graphical representation for DLG using solid water phantom with Farmer-type ionization chamber for 6MV and 10MV photons is shown in Figure 3 We fitted a linear function g(Rg') = aRg'

+ c to points given by gap size g and corrected gap reading Rg'. We extrapolated the curve linearly to zero and found the intercept of the fitted function (c). The absolute value of c is the DLG.

10 e) Transmission and DLG Measurement from EPID-Based Data

To perform any EPID-based QA-related study, first, it is necessary to calibrate the electronic portal imaging system. We calibrated EPID response to be 100MU ? 1CU. Using the PDI P technique, the beam exposer was analyzed after exposing the fields on the EPID. We utilized the iso-center CU value from our exposer field image analysis to estimate the GAP and transmission factor.

The EPID Based Measurement data for MLC transmission and DLG were given in Table **??** using a 3.8 cm solid water phantom (actually 5cm, because there is an integrated build-up of 1.2cm on the EPID) placed on top of the EPID. Measurements were taken using a standard 10x10 cm 2 field size & 100 MU was delivered for each energy. SSD, SDD and dose rates were identical to the ion chamber-based experimental setup. All of the data reading units are in CU. A graphical representation for DLG for 6MV and 10MV photons using solid water phantom with EPID is shown in Figure 5 and Figure 6, respectively. We similarly obtained the DLG to ion chamber-based curve fitting. The CU data collection procedure for the open field iso-center is shown in Figure 7 and Figure 8 for 6MV and 10MV photons, respectively. The CU data for the other jaw and MLC settings were extracted similarly from the portal images.

11 Results and Discussion

Transmission radiation through the collimator and DLG are essential functions in modern radiotherapy dose calculation. In modern radiotherapy machines, a multi-leaf collimator (MLC) (mostly 120 leaves) is used, and this device (MLC) is used as an organ-at-risk (OAR) saving tool. According to the radiotherapy goal, a maximum dose should be delivered to the tumour and a minimum dose to OAR [15]. That is why MLC is used in radiotherapy. We can determine the transmission and DLG using a 3D or 1D water phantom, but it takes much time to prepare and set it up. So, it is not easy in busy centers to check transmission and DLG routinely or quarterly in a year. As per Varian machine recommendation, the transmission factor will be less than 2%, and DLG will be less than 2mm. IMRT or VMAT treatment modalities were extensively developed after the discovery of MLC.

This study investigated the DLG values using the FC65-P ionization chamber with a 5cm thick solid water phantom and VARIAN MV EPID 1200aSi with a similar build-up. Depending on the value of DLG, it may cause errors in dose calculation for a Millennium and High-definition MLC [10]. This parameter accounts for partial transmission through the end of the rounded leaf. It is designed for patients treated with rounded-end MLC to improve dose calculation accuracy in the advanced high-precision radiotherapy technique. Various MLC parameters must be evaluated and verified while incorporating the high-end technique as IMRT/VMAT in Treatment Planning System (TPS) [10].

In comparison with the publication of a multiinstitutional survey in Japan entitled "Inter-unit variability of multi-leaf collimator parameters for IMRT and VMAT treatment planning: a multi-institutional survey" [17]. Where they got the value of DLG for the TrueBeam machine is 1.16 ± 0.22 mm for 6MV and 1.32 ± 0.21mm for 10 MV Photon Beam. In our measurement, we got the DLG value of 0.98mm for 6MV and 1.13mm for 10MV photon beams using a Farmer-type IBA FC65-P ionchamber. But using EPID 1200aSi, we got the result 0.85mm for 6MV and 1.08mm for 10MV photon beams.

Comparing the ionization chamber and EPIDbased dosimetry result, we observed that DLG deviation is 0.13 mm for 6MV and 0.05mm for 10MV photon beam. Moreover, transmission factor deviation is 0.23% & 0.06%, respectively, for 6MV and 10MV photon beams. In the multi-institutional survey [17], the value of MLC transmission for TrueBeam Machine was 1.50% ± 0.05% for 6MV and 1.72% ± 0.06% for 10MV photon energy. In our measurement, we got the value of 1.46% for 6MV and 1.69% for 10MV using a Farmer-type IBA FC65-P ionchamber. But using EPID 1200aSi, we got the result 1.23% for 6MV and 1.63% for 10MV photon beam. The published data [17] & our measurement for MLC transmission are in good agreement with ion chamber-based dosimetry, and for EPID-based result, it is a little lower for 6MV photon, that is, maybe for the inhomogeneity characteristics of the photon fluence in low energies and negligible, and for 10MV or higher energy photon, it is almost similar. The results for transmission factor and DLG for both the ionization chamber and EPID-based dosimetry are given in Table **??**.

12 Table 3:

The results for transmission factor and DLG for both ionization chamber and EPID-based dosimetry.

IV.

13 Conclusion

In conclusion, the deviation between phantom and EPID-based DLG and transmission factor will not significantly affect actual radiotherapy patient treatment. So, we can use EPID-based DLG and transmission factor. However, the pre-requisition of EPID will be fully configured before the data acquisition, and the Portal Dose Image

Prediction (PDIP) algorithm will be fully configured. Then, we can determine the DLG and transmission factor with just a few shots. We hope that more research on these topics can be conducted in the future with more precise experimental results. Center for allowing us to use their radiotherapy and dosimetry equipment. A sincere gratitude goes to the chairman and respected teachers of Jagannath University's Physics Department for their encouragement and collaboration on this research. [1]

1

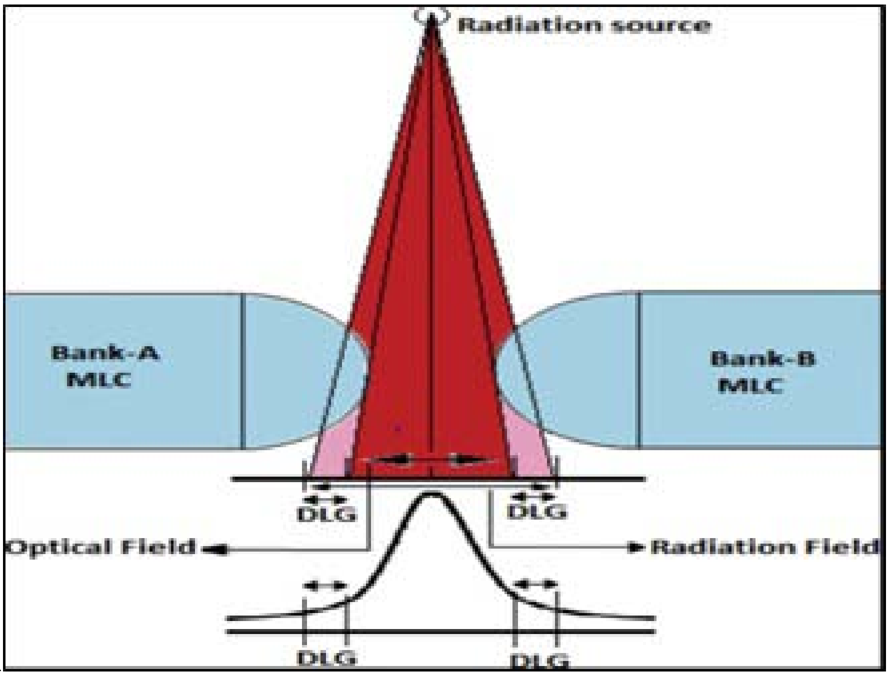


Figure 1: Figure 1 :

[1] Year 2023

2 

Figure 2: Figure 2 :

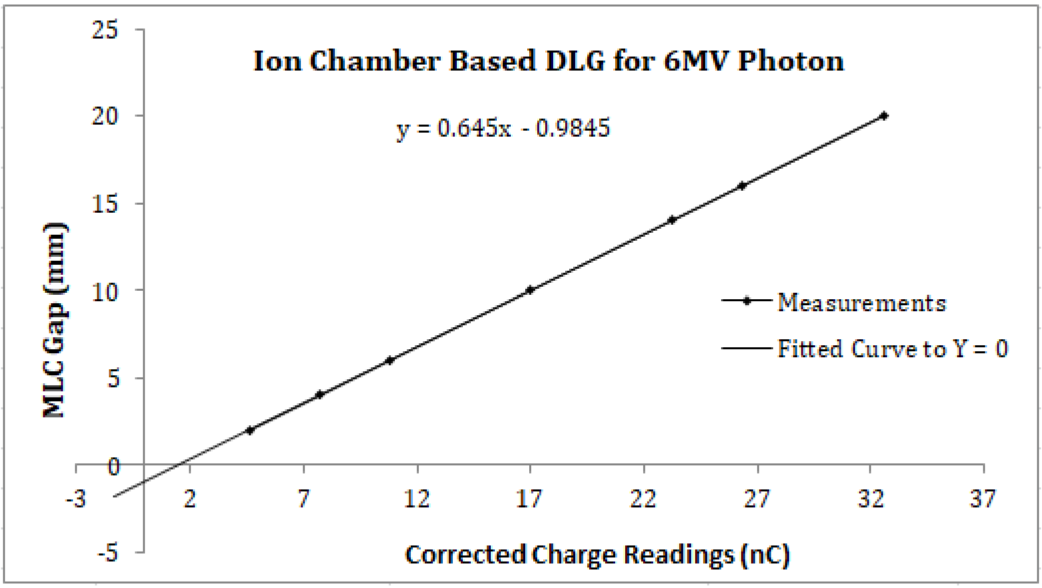
1 

Figure 3: Table 1 :

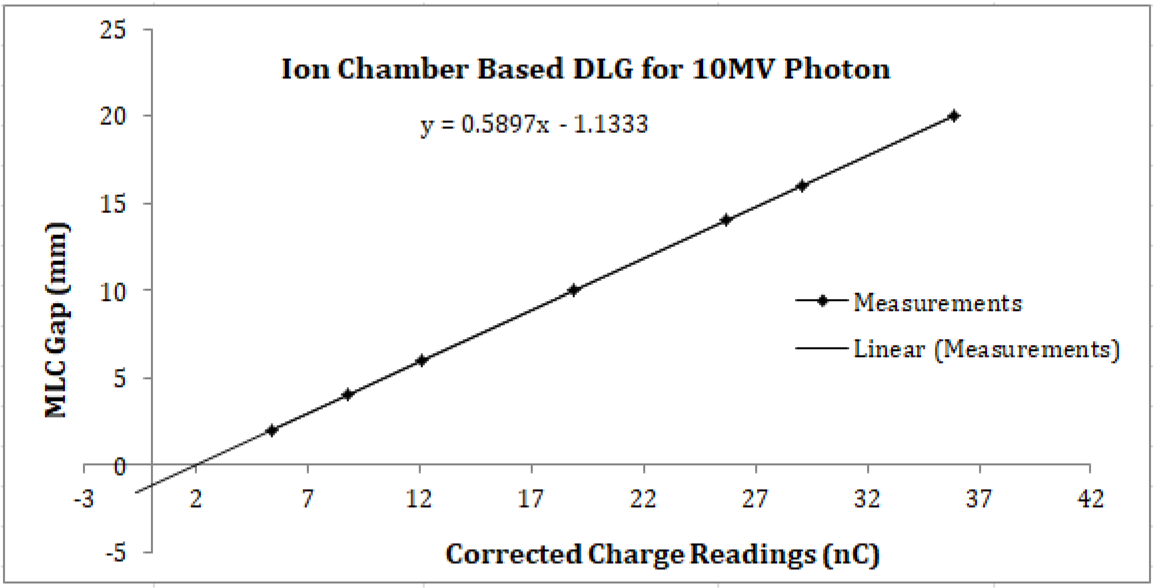
3 

Figure 4: Figure 3 :

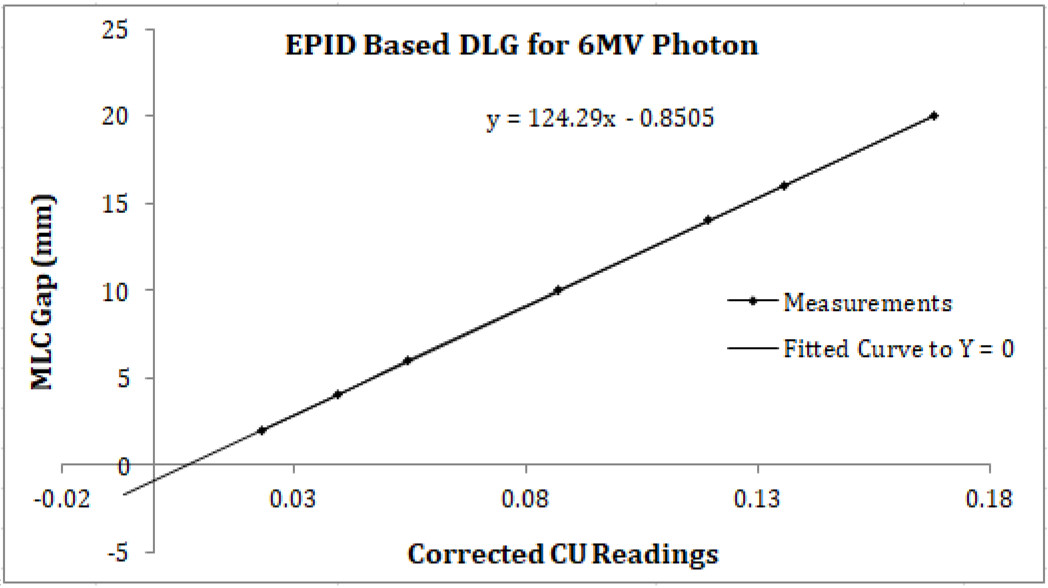
4 

Figure 5: Figure 4 :

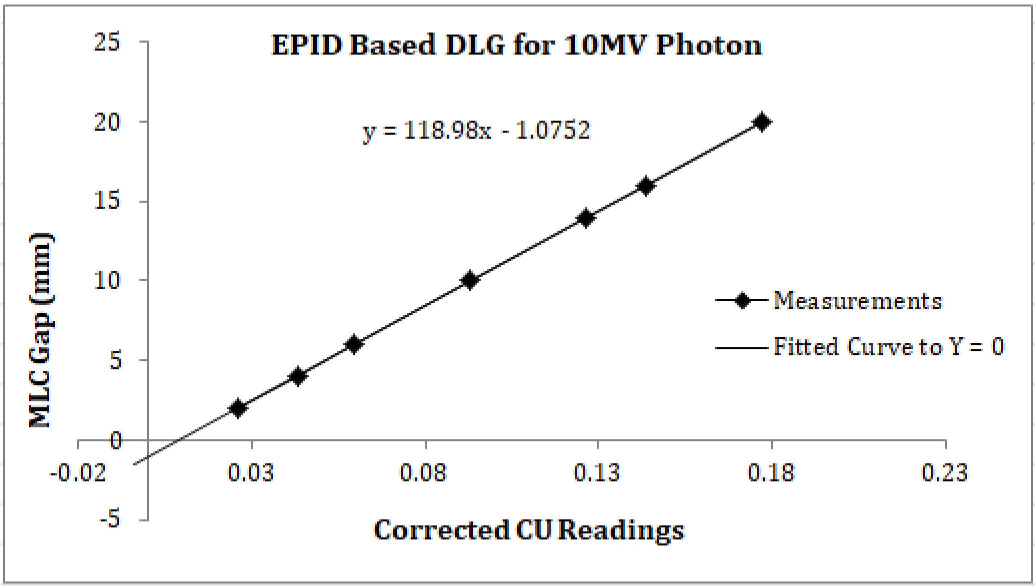
2 

Figure 6: Table 2 :

5

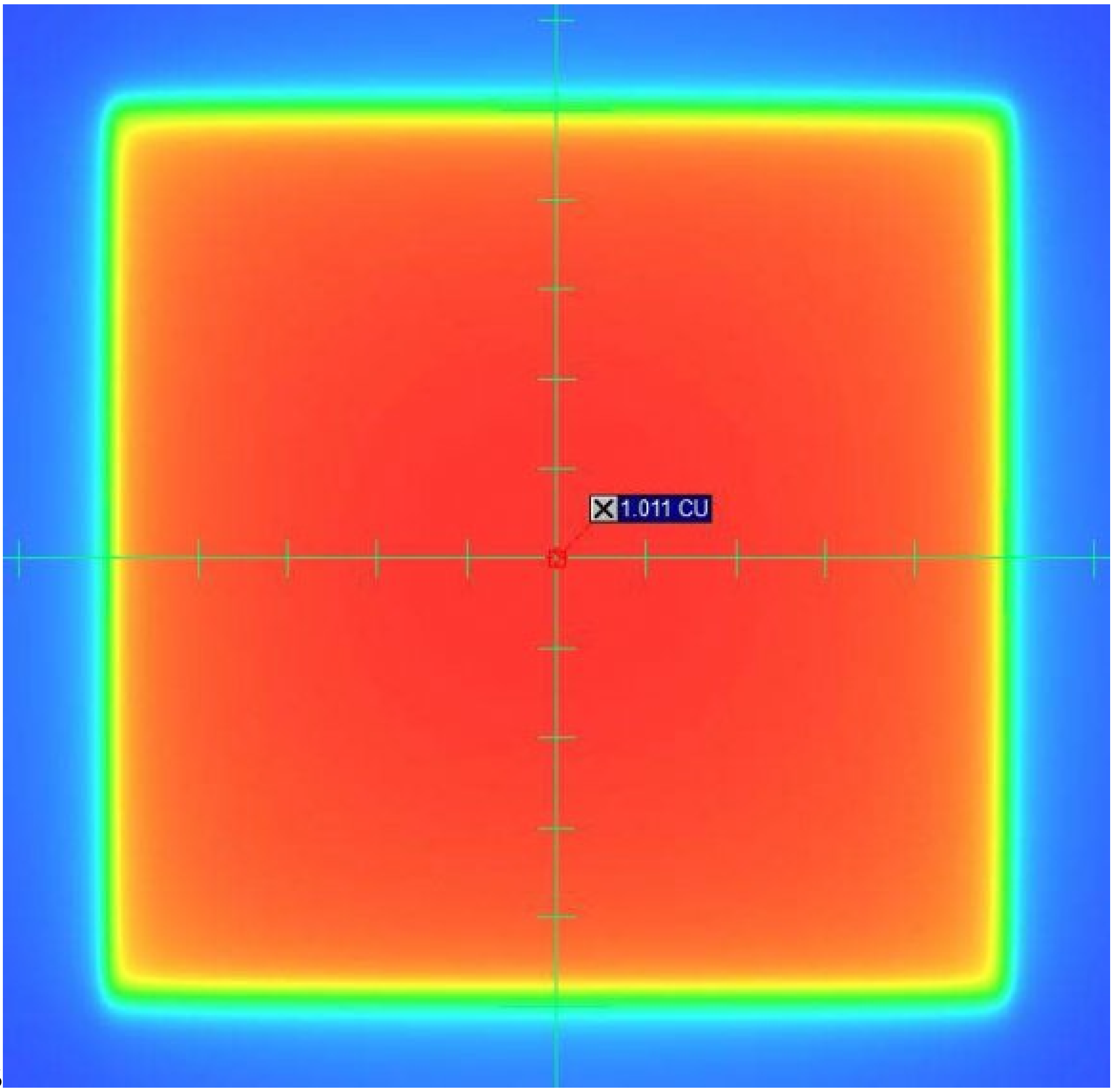


Figure 7: Figure 5 :

6

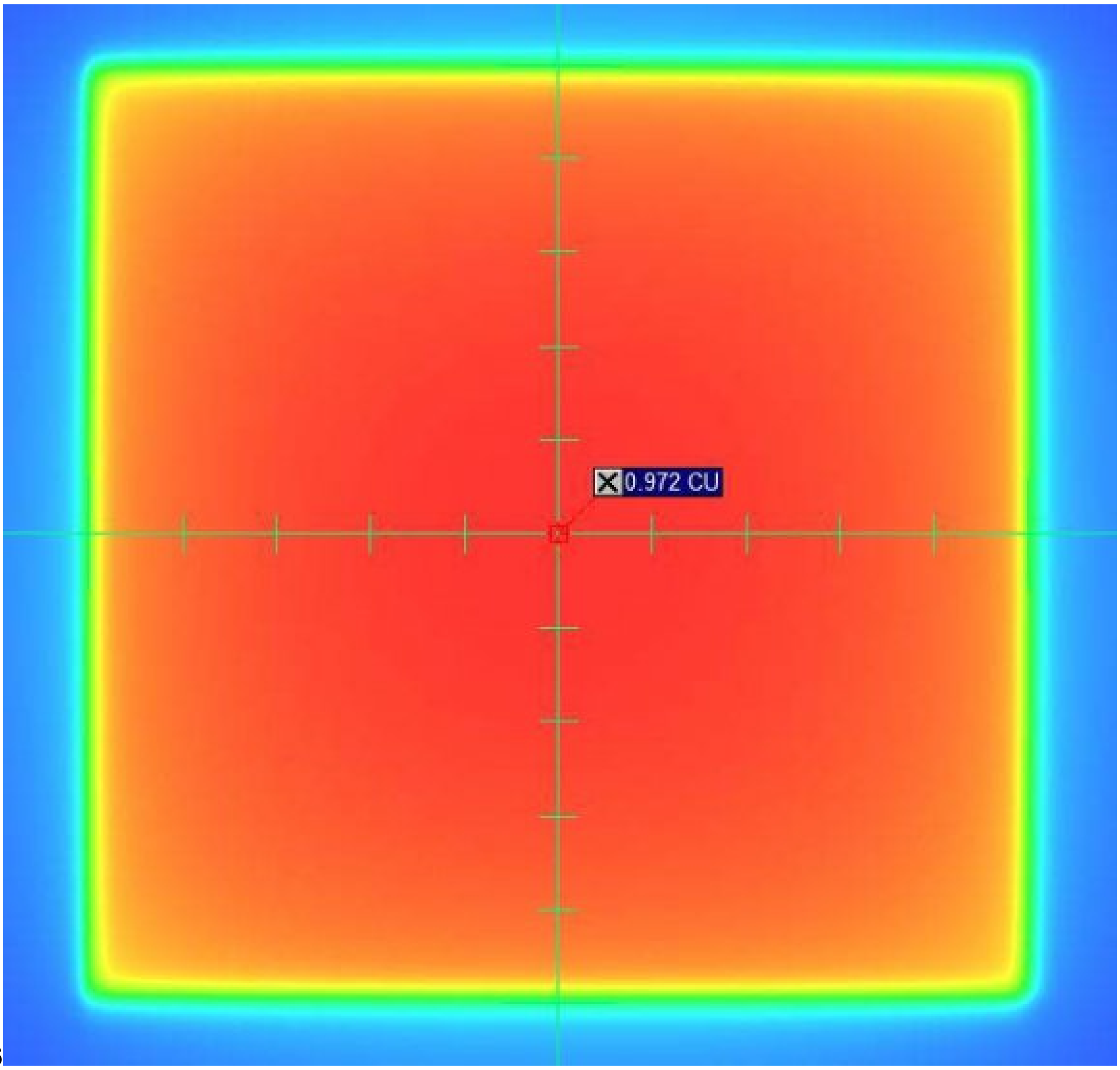


Figure 8: Figure 6 :

Energy	DLG with Ion Chamber (mm)	DLG with EPID (mm)	Transmission Factor with Ion Chamber	Transmission Factor with EPID
6 MV	0.98	0.85	1.46%	1.23%
10 MV	1.13	1.08	1.70%	1.63%

Figure 9:

.1 Acknowledgements

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