FILM DOSIMETRY EXPERIMENT

CENTER FOR MEDICAL AND RADIATION PHYSICS

Film Dosimetry

Aim:

1. To evaluate the characteristics of Radiochromic film.
2. To perform the calibration and find the unknown dose using EBT3 GAFchromic film:

Equipment Required:

1. Linear Accelerator
2. EPSON 12000 XL film scanner
3. EBT3 Radiochromic film
4. Radiochromic.com web application

Theory:

In radiation dosimetry, isodose curves and depth-dose distributions are measured using ionization chambers, semiconductor detectors, thermoluminescent detectors (TLDs), and film dosimeters. The high-gradient regions require a high spatial resolution for accurate measurement. Radiographic films have a high spatial resolution but are of limited use due to their energy dependence and sensitivity to room light, non-tissue equivalence, and post-irradiation chemical processing (Darkroom processing).

The radiochromic film can produce immediate, permanent-colored images of a radiation exposure pattern. The radiochromic films consist of double-layer radiochromic sensors coated on both sides of a polyester base. The colourless, transparent film responds to ultraviolet light and ionizing radiation by turning blue/red (depending on the composition), which depends on the absorbed dose, temperature during irradiation, and post-irradiation readout process. The radiation-induced colour change is formed directly without thermal, optical, or chemical development. The original-coloured image is stable at temperatures up to about 60 °C, above which the image's colour changes abruptly from blue to red. This film has little dependence on relative humidity and dose rate during irradiation.

The radiochromic film developed early was sensitive to high doses (103 – 106 Gy) and only used for industrial dosimetry. In the mid-1980s, a new film named GAFchromic film was developed that uses first-order solid-state polymerization of the diacetylene monomer and is sensitive to doses as low as 5 Gy. The coloured polymerization chain grows in length as the exposure level increases. The post-irradiation polymerization also occurs and saturates at about 24 hours.

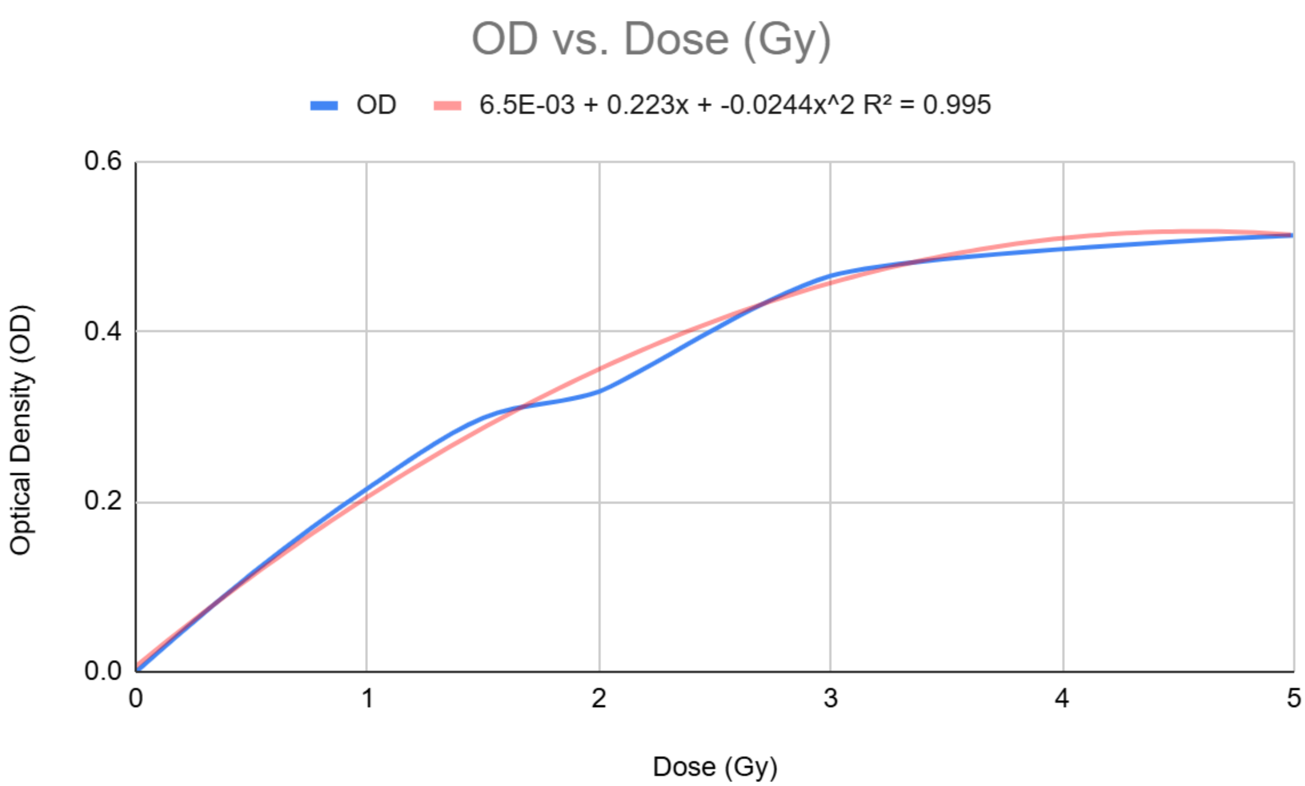
Evaluation of Characteristics of Radiochromic Film:

The characteristics of radiochromic film can be evaluated by observing the darkness of the film. We can observe that the darkness gradually increases with an increase in dose and then saturates at a very high value of doses. When one plots the dose vs response of the radiochromic film it will appear as below.
Definition of Optical Density: The response of a radiocromic film is defined by a parameter called Optical Density. Optical density gives information about the transmission of visible light through the film and is defined as the logarithmic ratio of the intensity of the incident light to the intensity of transmitted light. Mathematically, it can be expressed as a negative logarithm of Transmittance:

$$\text{Optical Density} = -\log_{10}(T) = -\log_{10}\frac{I}{I_0} \text{ or } \text{Optical Density} = \log_{10}\frac{I_0}{I}$$

Where T is transmittance, I_0 is the intensity of incident radiation, and I is the intensity of transmitted radiation.

Sr. No.	Dose (Gy)	Pixl	OD ($Log_{10}(I_0/I)$)
1	0	325459 (I_0)	0
2	0.5	24893	0.1152578968
3	1.0	19761	0.2155262177
4	1.5	16328	0.2984021442
5	2.0	15200	0.329491548
6	3.0	11116	0.4653865978
7	5.0	9957	0.5132066288



The change in the colouration of the GAFchromic film results in a change in the Optical Density (OD) of the film that is proportional to the amount of exposure. A calibration curve can be drawn by measuring the change in the OD of the irradiated film w.r.t the unirradiated one, which can further be used to estimate unknown doses.

Radiation isocenter test or Collimator / Couch Spoke test:

This test is performed to verify the alignment of the radiation beam isocenter with the mechanical isocenter. Radiation isocenter is defined as a point in space where the central rays of the radiation beams meet. Whereas mechanical isocenter is a point in space where the axes of gantry, collimator and couch meet. The mechanical isocenter can be visualised by Laser beams mounted on the walls of a linac room. But to obtain the radiation isocenter we can use a Gafchromic film. When such a film is exposed to radiation with different gantry/collimator/couch angles and a minimum field opening of approximately $(0.5x10)cm^2$ a star-like pattern can be observed on the film. Hence this test is also known as a spoke test or star pattern test. The point where the midlines of all the fields meet is the radiation isocenter. This point should be within a 2 mm dia circle. Care should be taken in order to place the film in a plane perpendicular to either gantry/collimator/couch while performing the QA respectively. Source to film distance (SFD) should be 100cm.

To locate the radiation isocenter a Gafchromic film is taped on solid slab phantom (typically on 5cm thickness for backscattering). The film should be placed in a plane perpendicular to the collimator (or couch / gantry) axis of rotation. The direction of the gantry should be marked on the film. Keeping 100cm source to film distance (SFD) a build up of 2cm of same solid phantom placed on the film. Collimator jaws are closed to minimum fields i.e approximately $(0.5x10)cm^2$. The film is then exposed to approximately 500MU with a number of different collimator angles (or couch / gantry angles). The exposed film will show a star-like pattern on it. Hence this test is also known as a spoke test or star pattern test. The point where the midlines of all the fields meet is the radiation isocenter. This point should be within 2mm dia circle. This QA test ensures delivery of radiation with high accuracy. In case of gantry spoke test the film will place vertically i,e. parallel to the collimator axis of rotation and the isocenter will place approximately in the middle of the film with the help of a laser.

Optical and radiation field congruence test:

This test is done to verify whether the visible light field projected by the collimator and the radiation field are in coincidence with each other or not. With the help of a Gafchromic film this test can be performed. In case of linac collimators are responsible for defining a particular field size. A light source is there inside the linac head. The collimators creates During radiation off condition of a linac a light source

The film is placed perpendicularly to the collimator axis of rotation with a source to film distance of 100cm. The film is positioned on slab phantom (typically 5cm for backscattering) with approximately 2 cm of build up keeping SFD 100cm. Before putting build up, the edges and the corners of the light field are marked with markers on the film. After the setup is completed radiation exposure is given to the film with approximately 500 MU to get proper darkening in the film. The light field edge should correspond to the radiation field edge within 2mm. Any misalignment between the light field and radiation field may indicate that the central axis of the radiation field is not aligned to the collimator axis of rotation.

Photon Beam profile:

A beam profile refers to the spatial distribution of variation of dose, at a specified depth, across the cross-section of a radiation beam, measured perpendicular to the beam's central axis. It provides information about the uniformity or flatness , symmetry, field size and penumbra of the radiation beam.

Flatness of a beam:

Field flatness for photon beams has been defined as the variation of dose relative to the central axis over the central 80% of the field size at a 10cm depth in a plane perpendicular to the central axis. As per AAPM Task group 45, flatness is the maximum percentage variation from the average dose across the central 80% of the full width at half maximum (FWHM) of the beam profile in a plane transverse to the beam axis.

Mathematically $$F = \frac{M-m}{M+m} \times 100\%$$

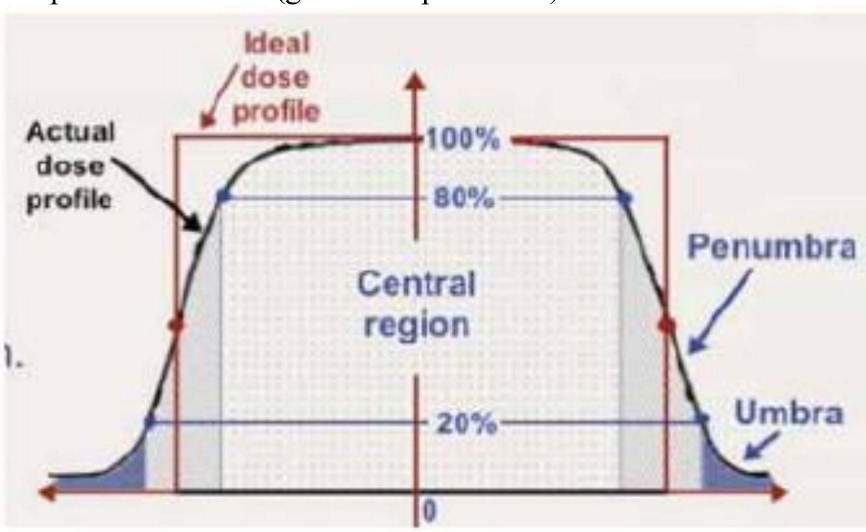
Where M and m are the maximum and minimum dose values in the central 80% of the profile. A flatness value within +/- 3% is allowed.

Symmetry of a beam:

Beam symmetry generally refers to the degree of similarity between the isodose curve on one side of the central axis versus the other. A typical symmetry specification is that any two dose points on a beam profile, equidistant from the central axis point, are within 2% of each other.

Penumbra:

The term penumbra generally defines the region at the edge of a radiation beam over which the dose rate changes rapidly as a function of distance from the beam central axis. In the penumbral region the dose fall off is generally sigmoid in shape and depends on field defining collimators(transmission penumbra), the finite size of the focal spot or source size(geometric penumbra) and the lateral electronic disequilibrium.



About the Dosimetry System:

Radiochromic.com is a web application for quality assurance (QA) of medical radiation therapy systems. The dosimetry system for radiochromic film dosimetry by Radiochromic.com consists of the following:

- GAFchromic™ EBT3 films
- A flatbed scanner
- Radiochromic.com webpage

The recommended accessories are:

- Gloves
- A guillotine
- A frame to center the film on the scanner
- A transparent compression (glass) sheet when scanning in transmission mode

Film Handling:

- Keep films in a dry and dark environment.
- Do not touch them without wearing gloves to prevent marks and scratches.
- Keep films away from light whenever possible.
- If films are submerged in water, minimize the time of submersion.
- Do not bend films when cutting them.
- Use sharp scissors or, preferably, a guillotine.
- Films should always keep the same orientation (i.e., portrait or landscape) on the scanner. Mark each film or film fragment to maintain the original film sheet orientation, and place them consistently on the scanner.

(Fig 1 - Flatbed Scanner)

Procedure :

- For calibration

Irradiation of Film for calibration:

- Irradiate a film on a linear accelerator in the following setup -
- Irradiate all strips with known doses. Keep one strip without irradiating it which will be your background. The doses should go from 0 Gy (the unexposed film fragment) to approximately 120 % of the maximum dose of interest.

Energy = 6 MV photon beams

Field Size = (20x20) cm^2

SFD (source to film distance) = 100cm

Build up = 2cm

Backscatter = 5cm

Collimator angle = 0^o respectively.

Gantry and couch angle = 0^o

Scanning of irradiated Film in the EPSON Scanner:

After 24 hours of irradiation, scan the irradiated films using EPSON 12000XL Scanner. Follow the below procedure-

- Set the following parameters in the EPSON 12000XL software before scanning
  - Scanner: EPSON 12000XL
  - Scan setting: reflective / transmission
  - Mode: photo mode
  - Image type: 48-bit color
  - Resolution: 150 dpi /100 dpi / 200 dpi
  - Scanning quality: High
  - Image format: TIFF
  - File name: As per your choice
  - Folder: default is pictures

Note: By changing different scan settings and resolution take multiple scans that will help you to check how the response of the film varies with scanning parameters.

- Before scanning carefully, place all the irradiated film (except unknown dose films) along with the background film systematically as shown in figure 1(b).
- Set the above parameters and take a preview scan.
- Select your desired scan area on the preview image and click scan.
- After the scan is finished, the software will automatically pop up a message to save the scan.

Fig 2(a): EPSON 12000XL scanner. (b) Background and irradiated films arranged systematically before scanning.

Calibration of Film:

Film Upload in Radiochromic.com Software:

- Step 1: Open IMPORT in the menu.
- Step 2: Click on Film.
- Step 3: Select an existing Study or create a new one.
- Step 4: Name the Item.
- Step 5: Add the type of film.
- Step 6: Add scanner Model as EPSON 12000XL, Scanning mode as per scan (i.e transmission type or reflective type) and waiting time as 24hr. Include comments if desired.
- Step 7: Upload one or several repeated film scans taken after irradiation. Up to five images can be imported, with a maximum of 20MB or 3M pixels for each image.
- Step 8: Select film orientation. This is CRITICAL if lateral corrections are applied. For this, Click on the arrows to select the direction of movement of the scanner lamp on the film scans. If you are not applying lateral correction there is no need to change the default orientation.
- Step 10: Click on Upload. The average film scans will be calculated and uploaded. They will be saved in My Work.

Film Calibration Process:

- Step 1: Open FILM in the menu.
- Step 2: Click on Calibration.
- Step 3: Select an existing Study or create a new one.
- Step 4: Name the Item
- Step 5: Select study and item of the film that you imported for the calibration.
- Step 6 **(optional)**: In order to apply lateral corrections, select study and item of an imported unexposed film. ***Do NOT apply lateral corrections if the strips in your calibration film were not irradiated entirely with homogeneous doses.***
- Step 7 **(optional)**: Check the Unflattened fields box if you want to use the special calibration mode for films irradiated with unflattened fields (e.g., Cyberknife, ZAP-X, FFF fields, ...).
- Step 8: Click on Reference doses. The ‘Dose ROIs’ menu will appear.
- Step 9: Associate reference doses to ROIs. The ROIs should be centered on the image (and on the scan). A minimum of three dose ROIs is needed.

- Normal mode: To provide enough statistics for the calibration while avoiding the lateral artifact, the length of the ROIs on the axis parallel to the lamp should be between 1-4 cm approximately.
- Step 10: Click on Request calibration. The calibration will be calculated and saved in My Work.

Notes: Radiochromic.com provides the mean calibration error, which is the difference between film doses after applying the calibration and the reference doses. In our experience, calibrations have mean errors of around 1-2.5%. Larger errors may point to flaws in the procedure. Also, they can be expected at low doses, since uncertainties in radiochromic film dosimetry increase rapidly below 1.5 Gy. To reduce uncertainties when measuring low doses with radiochromic films, we recommend scaling the number of MUs.

Determination of Unknown Dose:

- Step 1: Make sure the film calibration part is done prior to this procedure.
- Step 2: Irradiate, scan, and upload the film just like previous procedures.
- Step 3: Open FILM in the menu.
- Step 4: Click on Dosimetry.
- Step 5: Select an existing Study or create a new one.
- Step 6: Name the Item.
- Step 7: Select the film study and film item that you imported or uploaded to radiochromic.com for dosimetry.
- Step 8: Select study and item file of the calibration that you did in the previous step.
- Step 9: Select Noise reduction filter. Noise reduction applies a square median filter to the dose distribution to reduce the noise (a 3 × 3 filter is recommended).
- Step 10: Click on Response correction i.e optional if needed.
    - *Inter-scan correction (optional): Select an unexposed ROI in order to correct inter-scan variations. Use the central part of the scan to avoid the lateral artifact. The unexposed film fragment from the calibration can be used to correct inter-scan variations. To do so, you may keep this fragment in the same position when scanning every film until a new calibration is made.*
    - *Dose rescaling (optional): Rescale doses in order to match the film dose with the known dose of a ROI. To apply dose rescaling, before the irradiation, cut a strip from the film to measure. This strip should be irradiated with a known homogeneous dose and scanned together with the rest of the film. Finally, select a ROI of the exposed strip centered on the scan and introduce its dose.*
- Step 11: Click on Request dosimetry. The dosimetry will be calculated and saved in My Work.
- Step 12: Open it for analysis and align the central axis at the center of the film. Check the dose it is giving.
- Step 13: Repeat the procedure for both transmission and reflection modes of scan and check the difference.

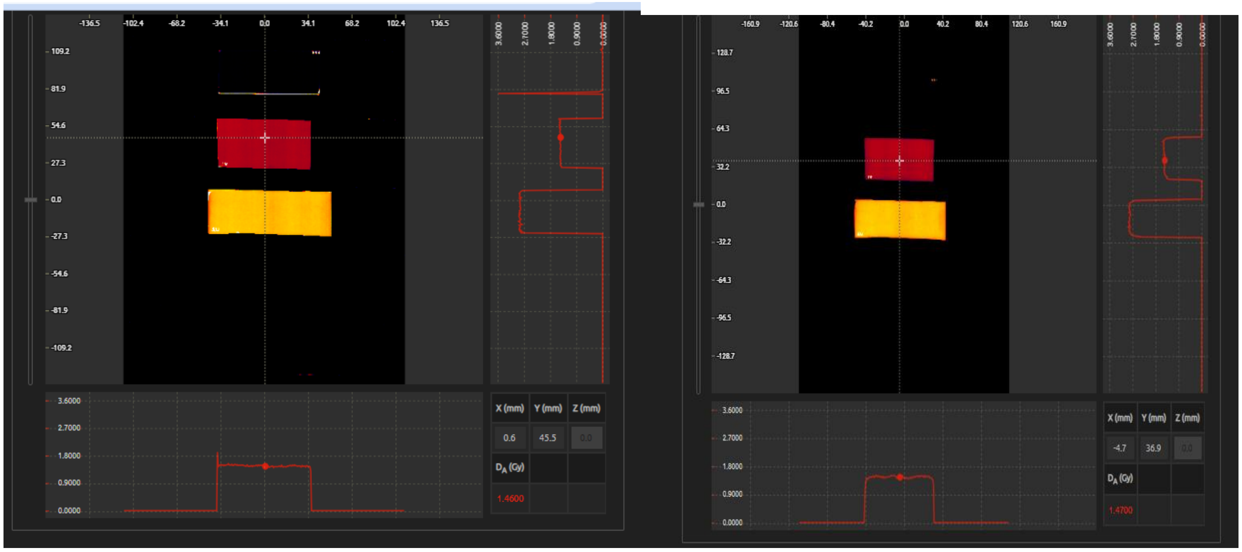


Fig 3: Unknown dose showing right corner of the screen in both for (a) transmission mode scan (b) Reflective mode scan