Film Dosimetry

AIM:

1. To evaluate the characteristics of Radiochromic film image.
2. To perform Quality Assurance tests of a Teletherapy unit.

Equipment Required:

1. Radiochromic film
2. Teletherapy unit
3. EPSON 12000 XL film scanner

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 sensitivity, 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 colorless, 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 color change is formed directly without thermal, optical, or chemical development. The original-colored image is stable at temperatures up to about 60 °C, above which the image's color changes abruptly from blue to red. This film has little dependence on relative humidity and dose rate during irradiation.

The radiochromic film developed in the early was sensitive to high doses only (10^3 – 10^6 Gy) and only used for industrial dosimetry purposes. 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 colored polymerization chain grows in length as the exposure level increases. The post-irradiation polymerization also occurs and saturates at about 24 hours.

The change in the coloration 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.

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

(Fig. 1.1 - Flatbed Scanner)

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 keep the orientation with the original film sheet and place them consistently on the scanner.

  Note: One way to preserve the orientation constant is to keep the long edge of the film parallel to the long side of the scanner bed. In contrast, films can be cut into rectangular fragments where the long edge of the fragment is parallel to the long edge of the initial film sheet.

Image acquisition: How to irradiate, scan, and upload films

Step 1 (optional):

- Before irradiation, scan the films that you will be using. If films are cut into fragments, scan them after cutting.

Note: Scanning the films before and after irradiation delivers more accurate results. However, it compels the use of a frame to place the films in the same position on both occasions and, according to our experience, reduces the uncertainty of film doses by less than 0.5%. Consequently, scanning the films before irradiation is optional in this protocol.

Step 2:

- Irradiate the films.

Step 3:

- Wait for the polymerization to stabilize and scan the films.

Note: For convenience, films are usually scanned 24 hours after irradiation. Shorter waiting times are possible; however, in this case, the waiting time window should be narrower (e.g., 24 ± 2 h or 30 ± 5 min). Different waiting-time windows are associated with different sensitometric curves. We should use the same waiting time window during the calibration to prevent uncertainties. Different waiting-time windows imply more considerable uncertainties and require re-calibration correction.

Step 4:

- Upload the film scans to Radiochromic.com

How to scan films

Step 1:

- Warm up the scanner (30-45 min).

Step 2:

- Films, either entire films or film fragments, shall always keep the same orientation (i.e., portrait or landscape) on the scanner. Use the marks to place films consistently on the scanner.

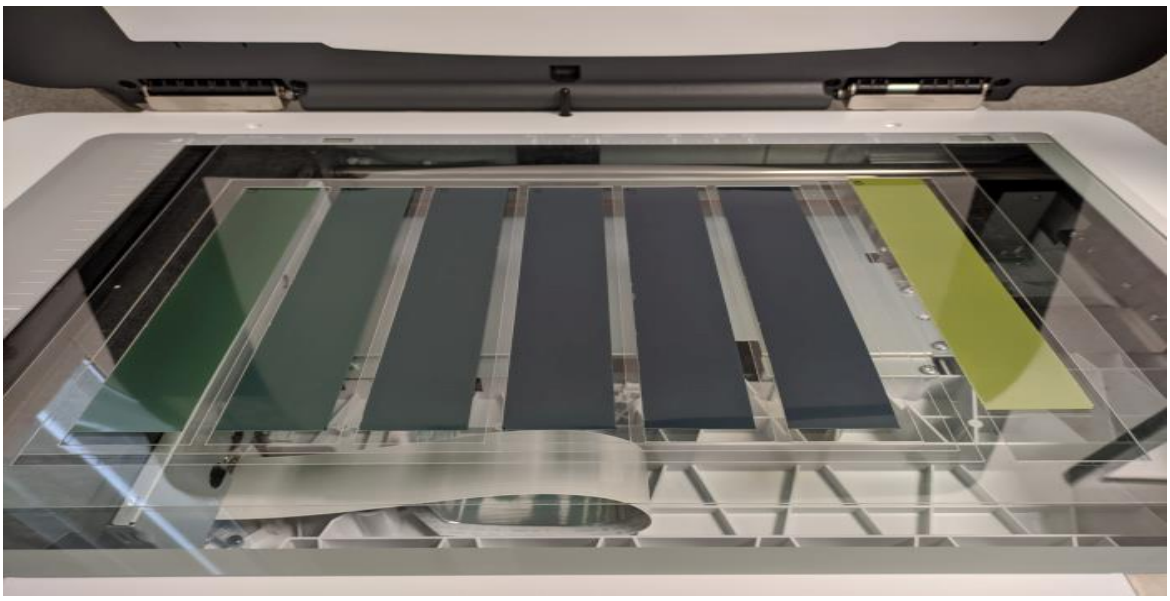
Step 3:

- Before acquisitions and after pauses, perform several (e.g., five) empty scans to stabilize the scanner lamp.

Step 4:

- Center the film on the scanner. A convenient way to do so is with a frame.

Positioning films on the scanner with a frame



(Fig 1.2 – Orientation of films during scanning)

Step 5:

- Always use the same scanning mode, either reflection or transmission, during calibration.

Step 6:

- Films shall be in perfect contact with the surface of the scanner bed to avoid curling. In transmission mode, place a 2-4 mm thick glass or PMMA sheet on top of the film. The positioning of the compression sheet shall be consistent; therefore, either cover or keep the autocalibration area for all the scans free. In reflection mode, the scanner lid itself compresses the film adequately.

Step 7:

- Select the scanning area.

Note: Maintain a fixed scanning area by saving it into the scanning software settings. In this manner, pixel positions on the film match with scanner coordinates, which is imperative when applying lateral corrections or scanning before and after irradiation.

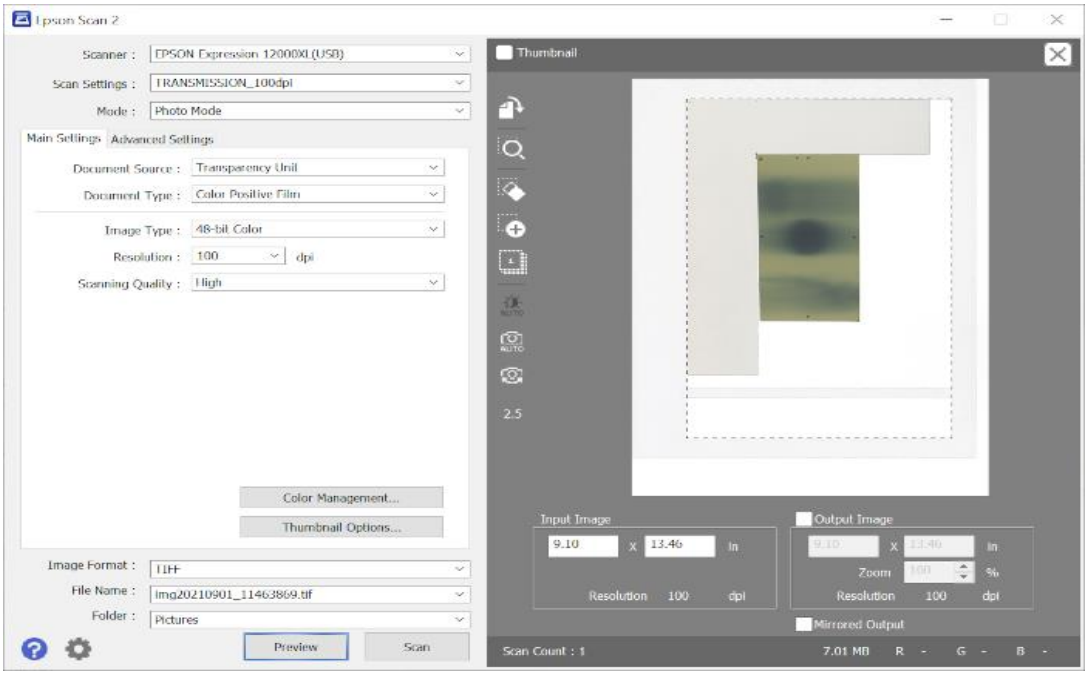
Step 8:

- Acquire images with image type set to 48-bit RGB (16 bit per channel) and image processing tools turned off. Save the data as uncompressed TIFF files.

Note: A resolution of 50-75 dpi (0.51-0.35 mm) fits most applications. While for treatments using small fields, 100-150 dpi (0.25-0.17 mm) may be necessary. Higher resolutions in this protocol are discouraged because they produce more considerable noise and slow film scanning and analysis.

Step 9:

- Perform four or five repeated scans and discard the first one for each film.



(Fig 1.3 – Scanning the films)

Lot calibration:
Calibration is necessary to convert the response of the dosimetry system into a dose distribution.
Note: Radiochromic.com employs the Multigaussian model for radiochromic film dosimetry. Sensitometric curves are adjusted with splines, associating reference doses with their median pixel values in each channel. The lateral correction is calculated following the model proposed by Lewis and Chan.

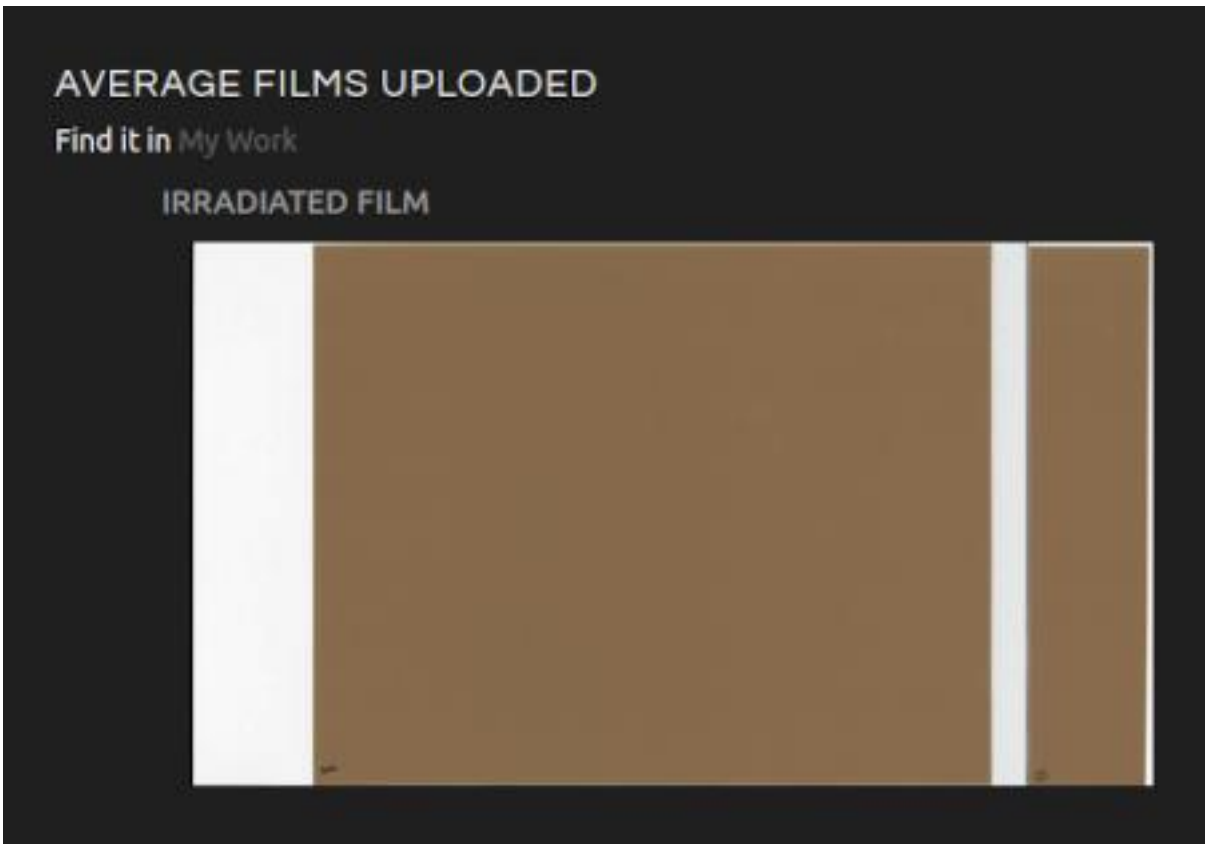
Basic principles
In this protocol, we expose a calibration procedure for external photon beams, yet other methods, radiation sources, and applications are possible, provided they observe four basic principles:

- Calibrations are valid for films from the same lot. Therefore, each lot has to be calibrated at least once. However, since films slowly autopolymerize over time, it is advisable to repeat the lot calibration from time to time. Furthermore, since film response depends on humidity and temperature, more accurate film doses can be expected when calibration and film dose measurements are done together.
- Uncertainties in the absorbed reference doses will be translated into film dose uncertainties. Hence, it is important to maximize the accuracy of the reference doses. Generally, this can be achieved by irradiating at reference conditions and selecting ROIs with homogeneous doses.
- To avoid the lateral response artifact, the ROIs with reference doses should be centered on the scan.
- The reference doses should cover the range of doses of interest to prevent extrapolations.

Recommended calibration procedure

Step 1 (only with lateral correction):

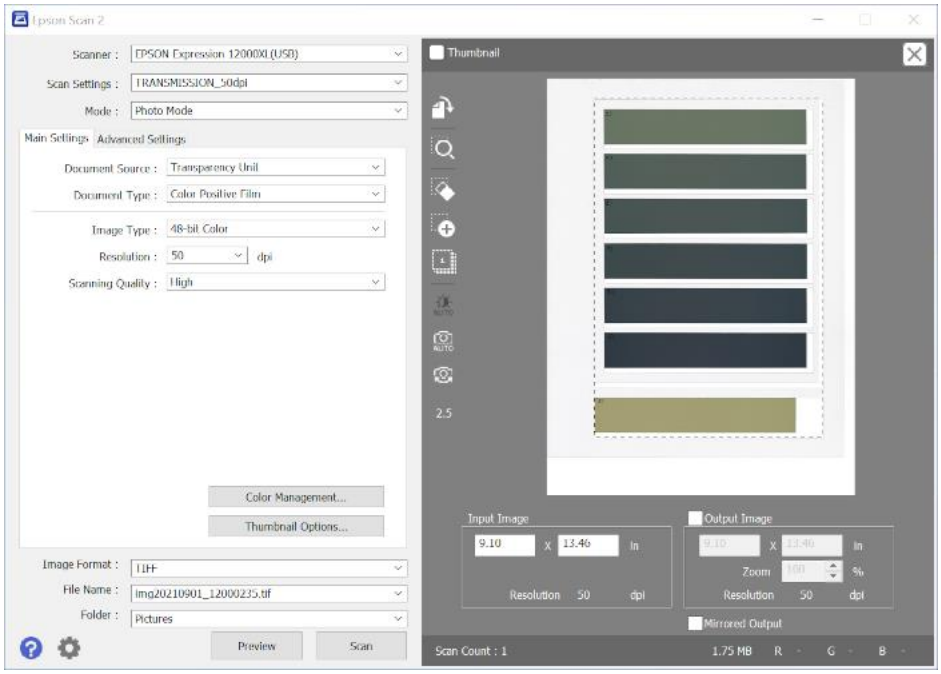
- If the calibration will include the lateral correction, acquire the image of an entire unexposed film. You can use the non-irradiated scans of a film. Upload them as irradiated scans.



(Fig 1.4 - Unexposed Film)

Step 2:

- Cut a film into several (e.g., seven) strips with the longer side of the strips parallel to the lamp.



(Fig 1.5 – Calibration strips)

Step 3 (optional):

- Scan the film fragments prior to irradiation.

Step 4:

- Irradiate all but one of the strips with known (constant) doses. The doses should go from 0 Gy (the unexposed film fragment) to approximately 120 % of the maximum dose of interest. If the calibration will include the lateral correction, irradiate the strips with approximately homogeneous doses by using a beam with a flattening filter and a 25 cm × 25 cm field.

Step 5:

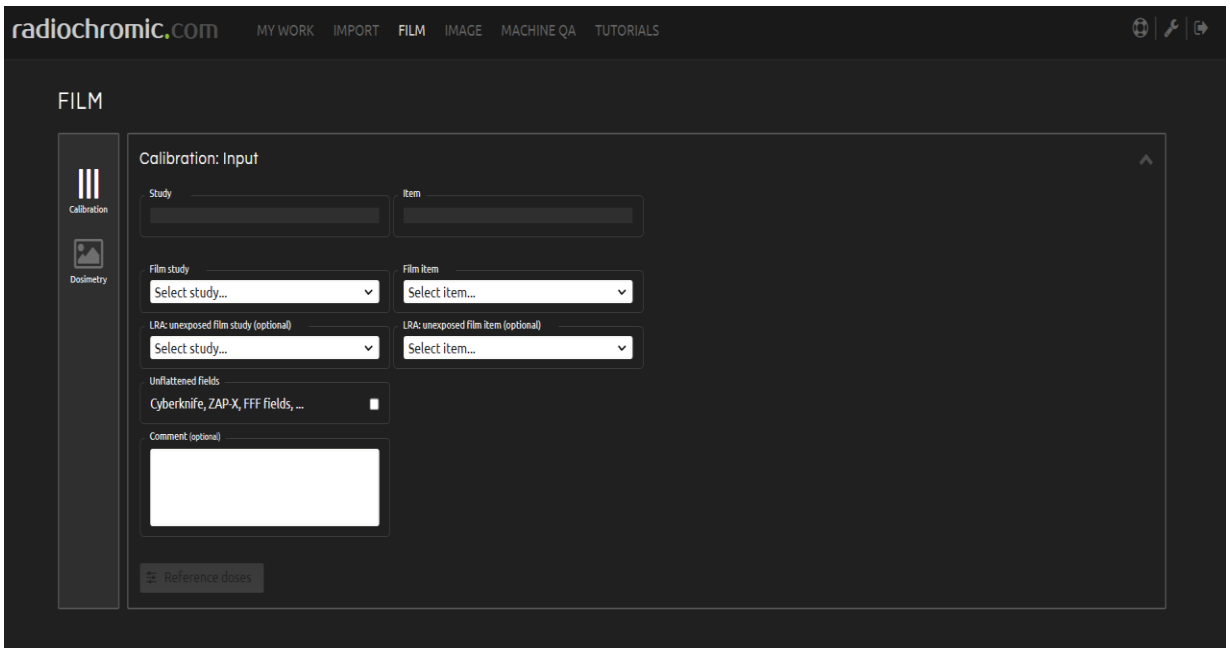
- Scan all the calibration strips simultaneously. The irradiated areas of the strips should be centered on the scan.

Step 6 (recommended):

- The unexposed strip can be used to correct inter-scan variations. We recommend keeping this fragment in the same position when scanning every film until a new calibration is made.

Step 7:

- Click on CALIBRATION.



(Fig 1.6 – Introducing calibration data)

Step 8:

- Select an existing study or insert a new one.

Step 9:

- Insert an identifier for the calibration.

Step 10:

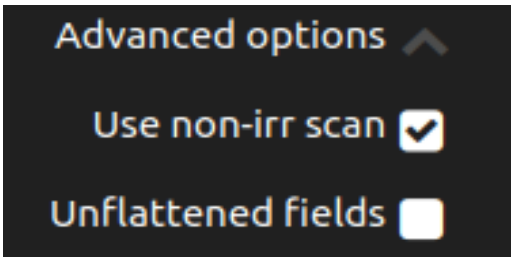
- Select the calibration film.

Optional: Use non-irr scan

- Unless unchecked, the calibration will use the information contained in the non-irradiated scan if it is present.

Optional: Unflattened fields

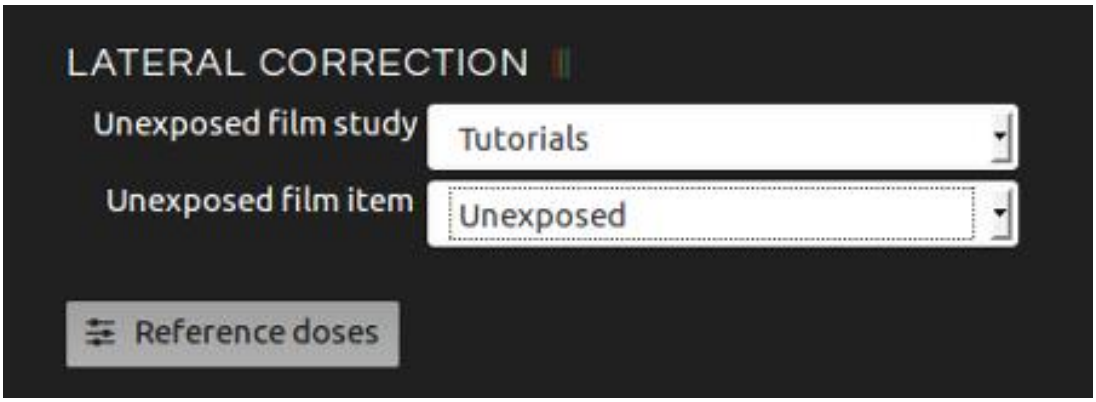
- There is a special calibration mode for films irradiated with unflattened fields (e.g., Cyberknife™, ZAP-X™, FFF fields, ...).



(Fig 1.7 - Advanced Options)

Step 11 (only with lateral correction):

- To apply lateral corrections, select an image of an entire unexposed film. Do not apply lateral corrections if the strips in your calibration film were not irradiated entirely with homogeneous doses.



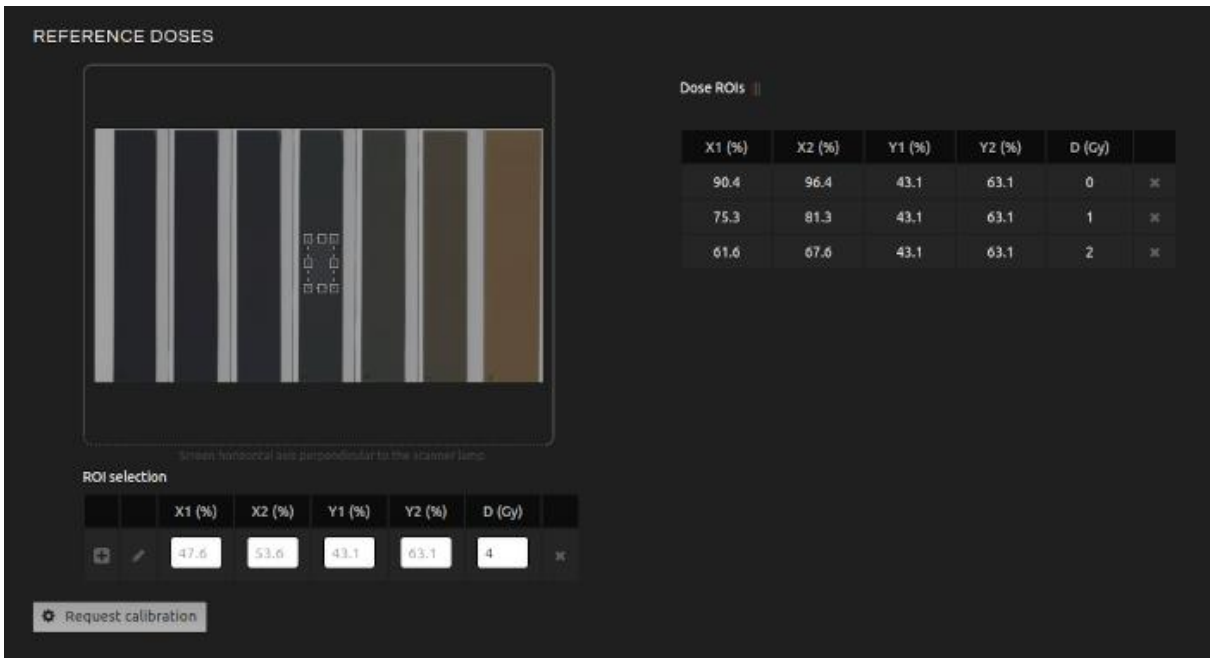
(Fig 1.8 - Lateral correction)

Step 12:

- Click on Reference doses. The 'Dose ROIs' menu will appear.

Step 13:

- Associate reference doses to ROIs. The ROIs should be centered on the image (and on the scan). 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 approximately 1-4 cm. A minimum of three dose ROIs is needed.



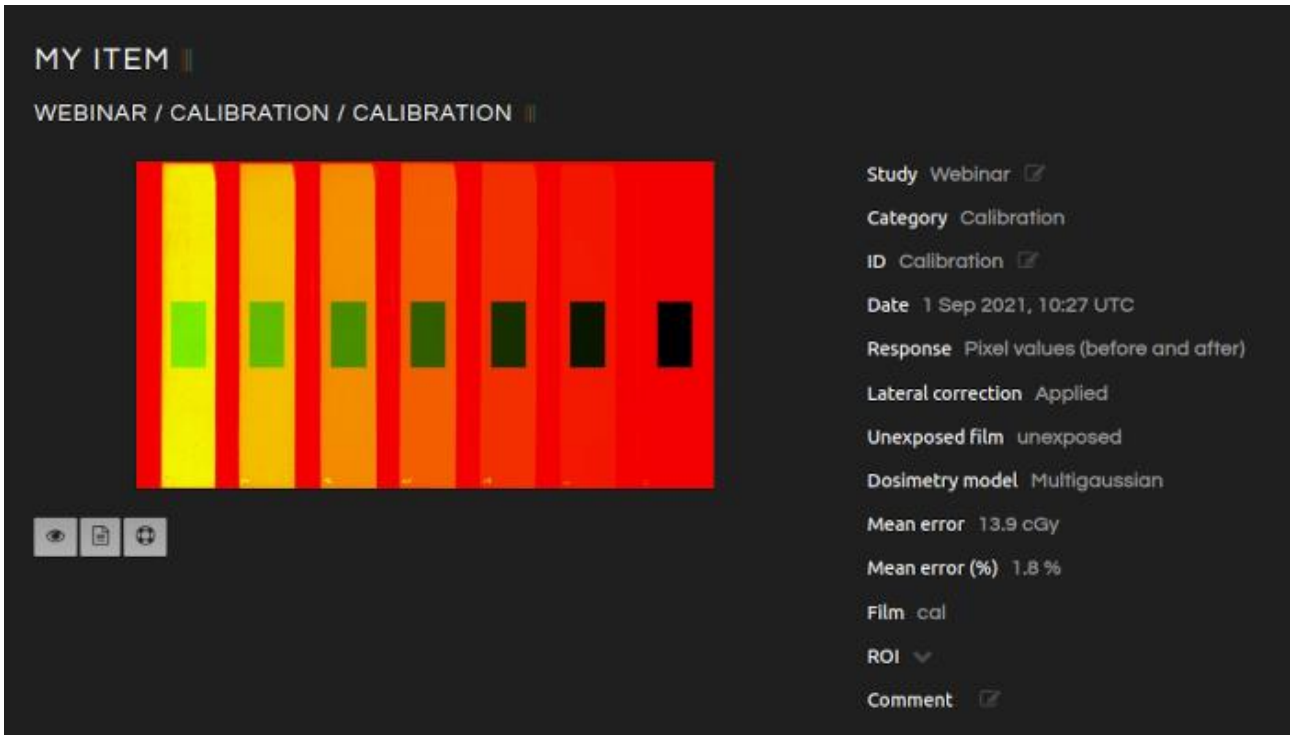
(Fig 1.9 – Dose ROIs window)

Step 14:

- Click on Request calibration.

Step 15:

- The calibration is in progress. The result will be saved in My Work.



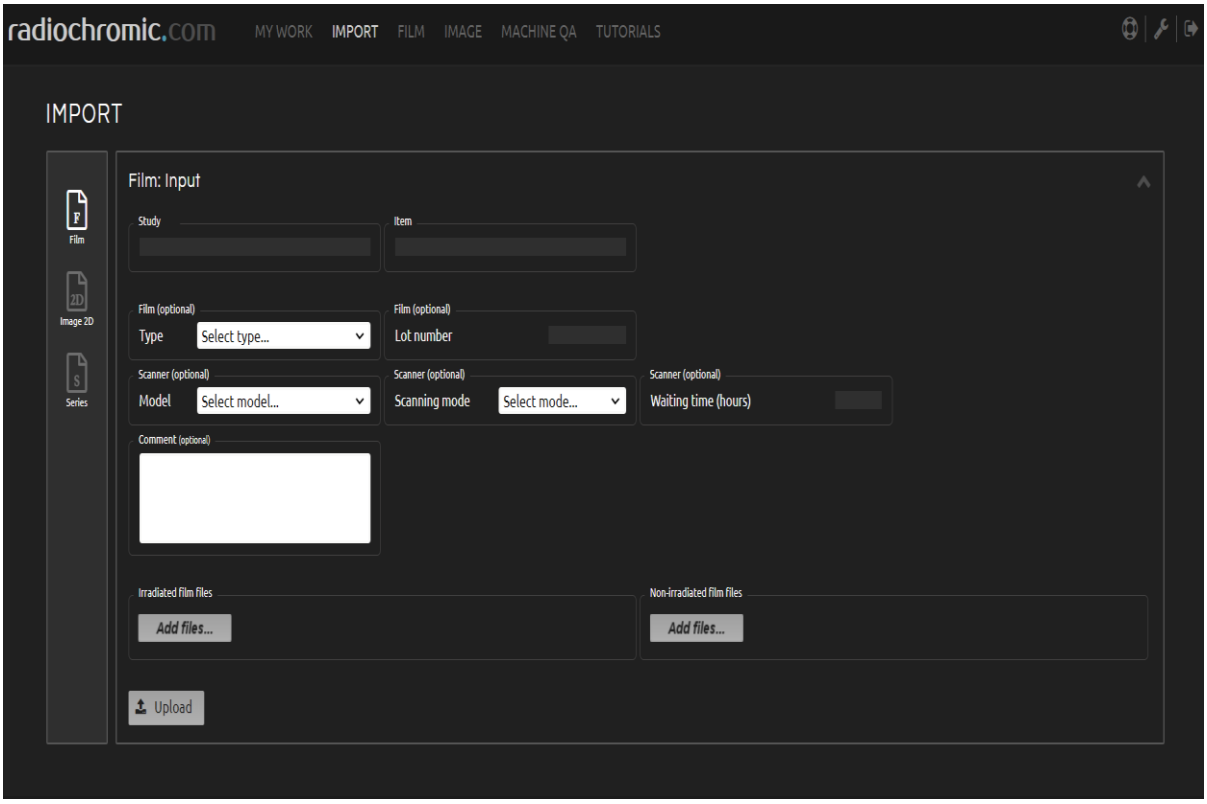
(Fig 1.10 – My work window)

Note: Radiochromic.com provides the mean error of the calibration, which computes the difference between film doses after applying the calibration and reference doses. Mostly, the calibrations have mean errors of around 1-2.5%. Larger errors may point to flaws in the procedure. Also, they can be expected for low doses since uncertainties in radiochromic film dosimetry grow fast for doses lower than 1.5 Gy. To reduce uncertainties when measuring low doses with radiochromic films, the recommendation is to scale the number of MUs.

Film upload: Upload film scans to Radiochromic.com.
Note: Up to five images can be uploaded for each series (irradiated and non-irradiated), with a maximum of 20MB or 3M pixels for each image.

Step 1:

- Click on FILM UPLOAD.



(Fig 1.11 - Introducing film data)

Step 2:

- Select an existing study or insert a new one.

Step 3:

- Insert an identifier for the film.

Step 4 (recommended):

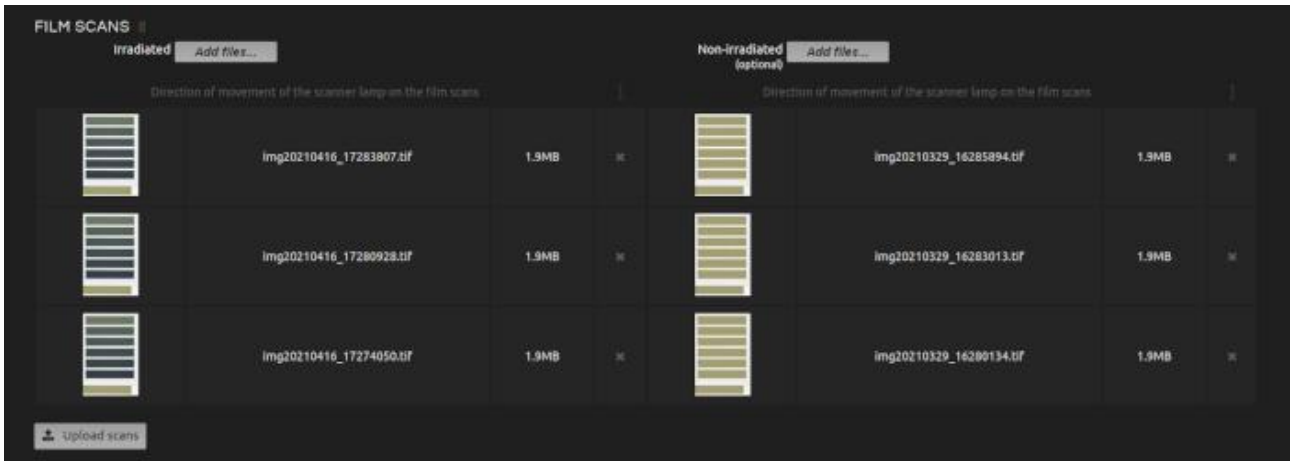
- Introduce film statistics.
- Note: Statistics assist you in describing your films. Furthermore, they are processed to improve the accuracy of your results.

Step 5:

- Upload the film scans following irradiation.

Step 6 (optional):

- Upload the film scans prior to irradiation.

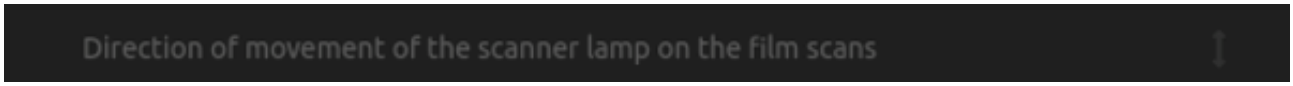


(Fig 1.12 – Film Scans)

Film scans

Step 7:

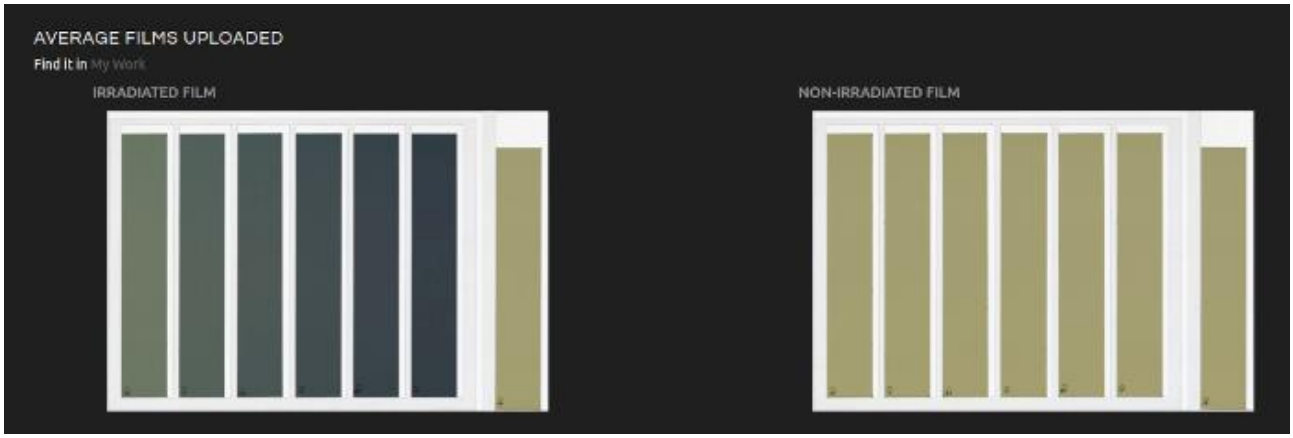
- Select film orientation. This is CRITICAL if lateral corrections are applied. Click on the arrows to select the direction of movement of the scanner lamp on the film scans.



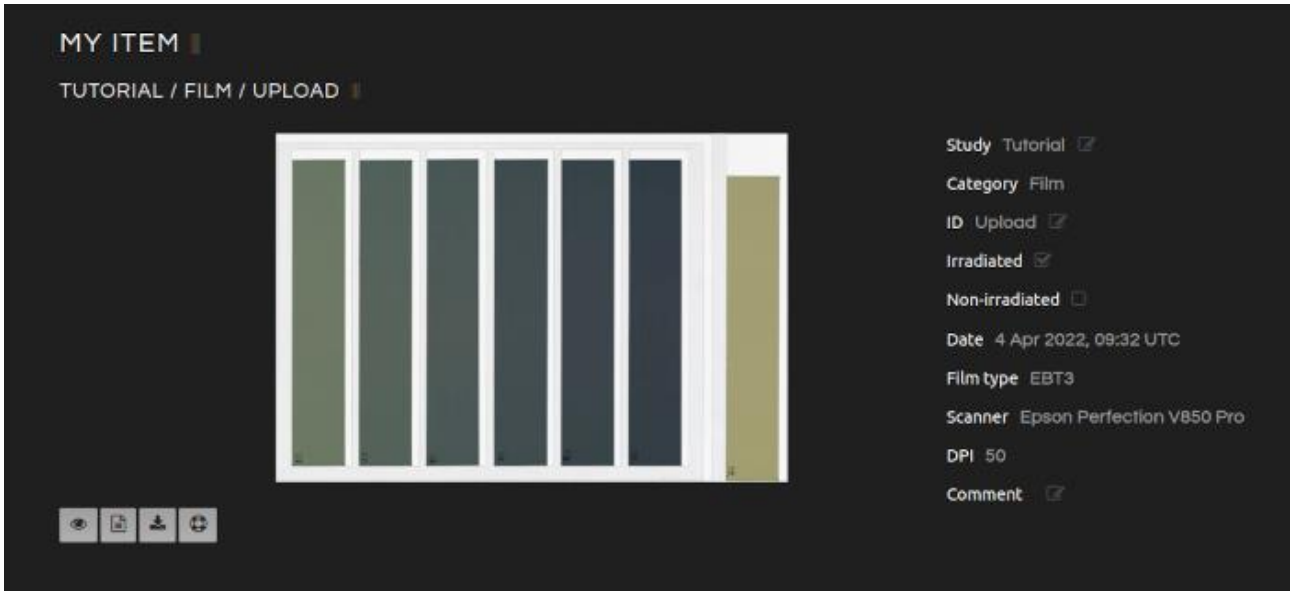
(Fig 1.13 - Film orientation)

Step 8:

- Click on Upload scans. The average film scans will be calculated and uploaded. They will be saved in My Work. Note: Radiochromic.com does not record or use patient data. Do not enter patient data to identify items or studies.



(Fig 1.14 – Average film Scans)



(Fig 1.16 - In My Work)

Film doses: Convert film pixel values into doses.
Step 1:

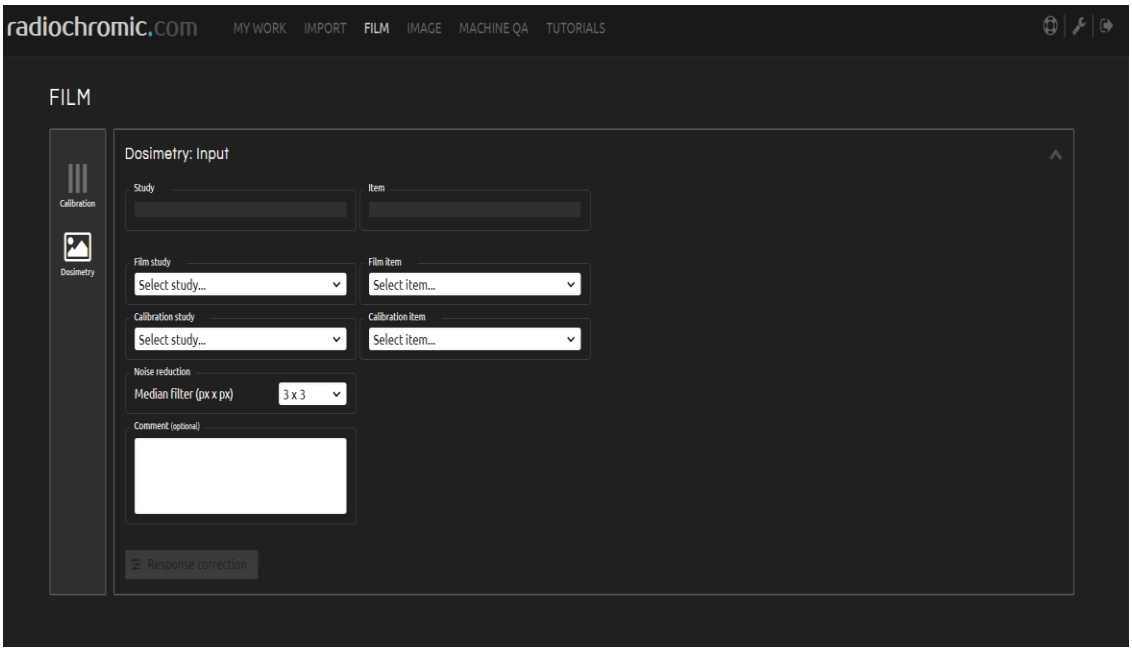
- Calibrate the film lot.

Step 2:

- Irradiate the cut-out films to various doses, scan, and upload the images.

Step 3:

- Click on DOSIMETRY.



(Fig 1.17 - Introducing dosimetry data)

Step 4:

- Select an existing study or insert a new one.

Step 5:

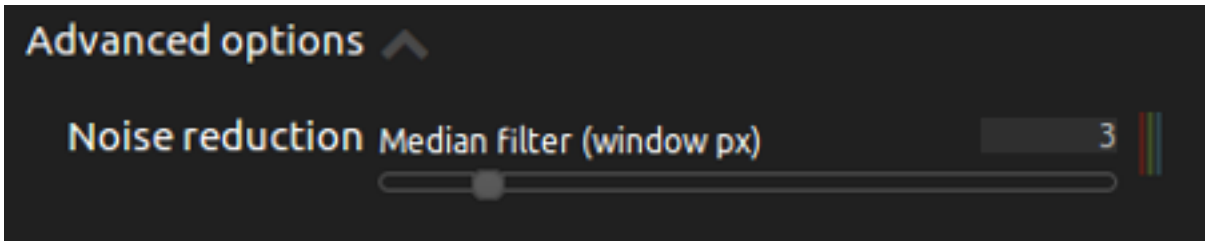
- Insert an identifier for the dosimetry.

Step 6:

- Select the film.

Step 7:

- Select the calibration.
- Optional: Noise reduction: Apply a square median filter to the dose distribution to reduce the noise (a 3×3 square median filter is recommended).



(Fig 1.18 - Advanced options)

Step 8:

- Click on Response correction.

Step 9 (recommended):

- Inter-scan correction: select an unexposed ROI to correct inter-scan variations. Use the central part of the scan to avoid the lateral artifact.
- Note: The unexposed film fragment from the calibration can be used to correct inter-scan variations. We recommend keeping this fragment in the same position when scanning every film until a new calibration is made.

Step 10 (optional):

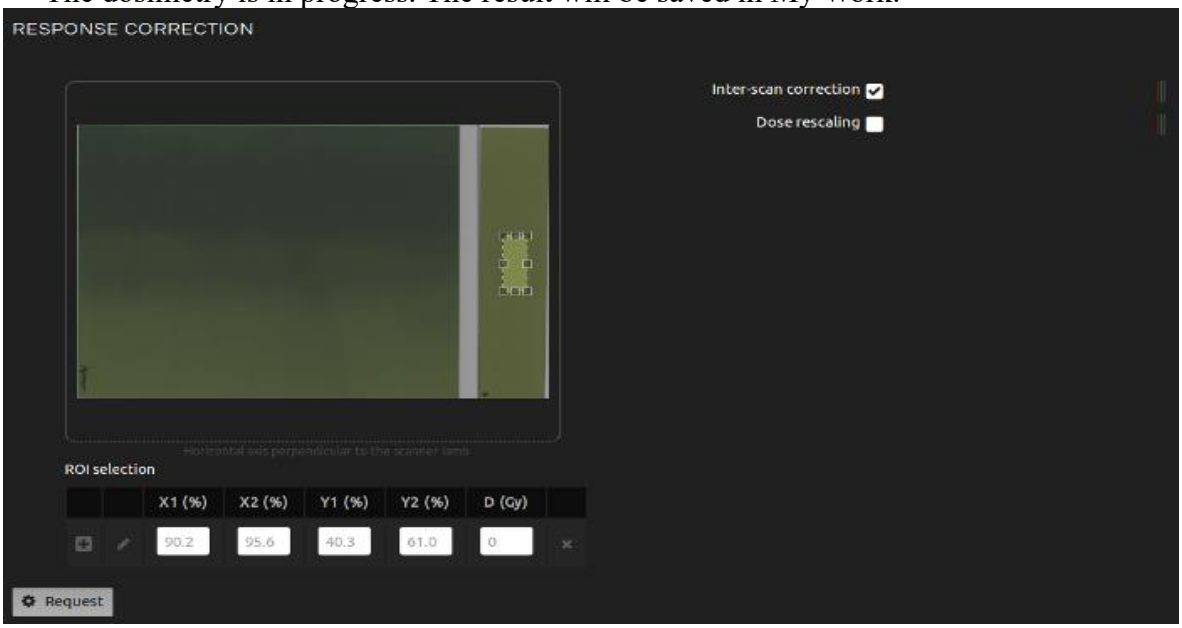
- Dose rescaling: rescale doses to match the film dose with the known dose of an ROI. To apply dose rescaling before the irradiation, cut a strip from the film to measure. This strip should be irradiated with a known homogeneous dose and scanned with the rest of the film (and the unexposed strip). Finally, select an ROI of the exposed strip centered on the scan and introduce its dose.
- Note: In Radiochromic.com, the re-calibration correction is optional and comprises of inter-scan correction and dose rescaling.

Step 11:

- Submit the request.

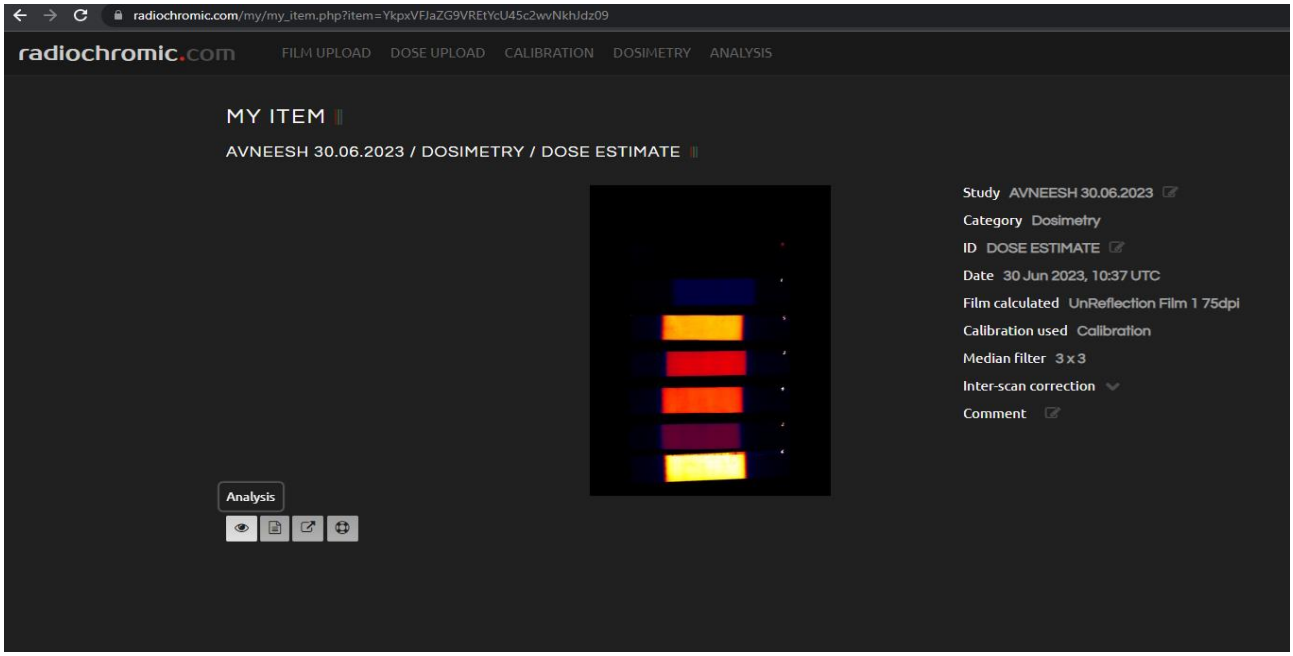
Step 12:

- The dosimetry is in progress. The result will be saved in My Work.



(Fig 1.19 - Response correction)

- Note: Radiochromic film dosimetry is affected by many sources of uncertainty. An incorrect protocol for film irradiation and scanning, as well as inherent uncertainties of the dosimetry model, may produce errors in film doses, resulting in differences between the expected dose distribution and the dose calculated with film dosimetry. Consequently, additional tests may be required to verify the accuracy of the dose distribution.
- Note: In the My Work portal, you can get your dosimetry work (Conversions of a pixel into dose) after entering your study (your file/folder) and category titles (Dosimetry).
- Note: After opening the file, you will see your scanned image, as shown below (Fig 1.20). Here, you select the analysis option.



(Fig 1.21 – Analysis window)

Note: In Analysis part, you can see the dose for an unknown film by moving your cursor on the film. You can note the dose value (Please notice the dose value at the bottom right corner). By moving the cursor on a single film, you can note the average dose value.