EVALUATION OF RADIOCHROMIC FILMS' POST-EXPOSURE OPTICAL DENSITY CHANGES

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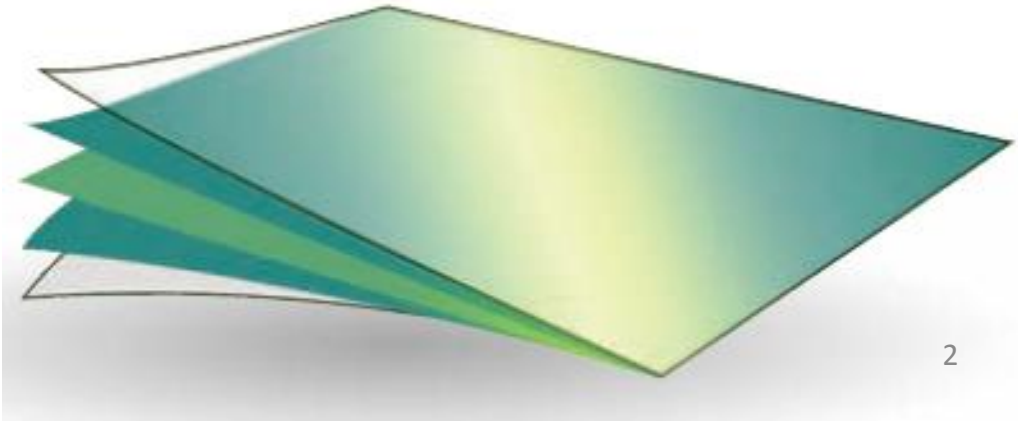
GAFCHROMIC EBT2 dosimetry film

- Provide opportunity to perform **dose measurements** for Quality Assurance (**QA**) purposes.
- The **high spatial resolution** of film makes it a useful dosimeter in QA and research.



Why GAFCHROMIC EBT2 ?

Advantages

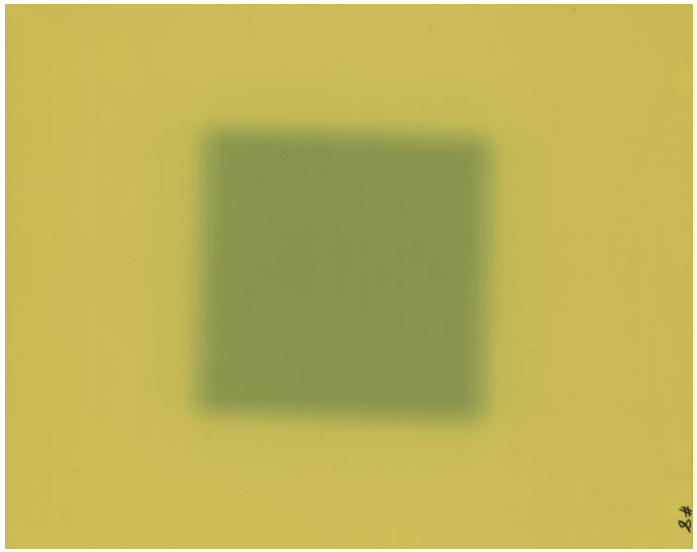
1. Suitable for external radiation dosimetry:
- Intensity Modulated Radiation Therapy (**IMRT**)
- Intensity Modulated Arc therapy
2. Measure the absorbed dose from photon beams with a **wide** dose range of 1cGy to 40 Gy.

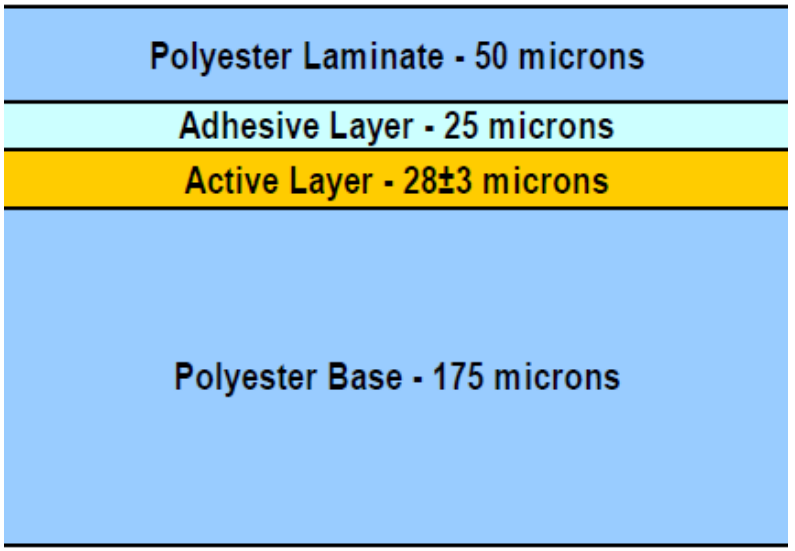
Advantages

3. Chemical composition is nearly **tissue-equivalent**
4. Limited **energy** dependence
5. High spatial **resolution**
6. No need to be **developed**
7. Can be handled in **day-light**

Structure and Composition

- Upon irradiation, this active monomer **polymerizes** to form a polymer coloured dye
- The automated **darkening** process upon irradiation with x-rays takes place.





What is wrong with it?

Polymerization can proceed **after** irradiation causing a post-exposure density growth

This process can cause an **increase** of the optical density.

These post-exposure density changes can cause **errors** in dosimetric analysis.

What manufacturer says

- The films can be measured or scanned at **any time** after exposure
- The effects of post-exposure changes in the film can be **ignored**.

However

To reduce errors it is suggested to wait for **several hours** after exposure

Necessity to evaluate errors

To implement the Gafchromic EBT 2 film-based dosimetry system in **clinical workflow**, it is necessary:

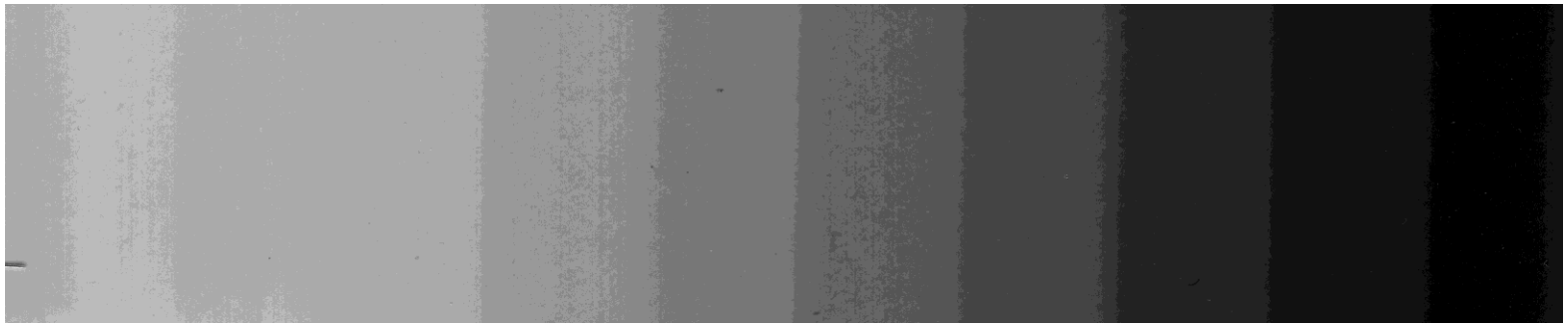
- evaluate overall **uncertainties**
- determine appropriate **scanning** time after irradiation

Methods and materials

- In order to evaluate post-exposure uncertainties, **specific methodology** and **test conditions** were formed
- To acquire data on post-exposure changes of the films, **rescanning** in several sessions was performed
- **Two** irradiation plans were prepared to simulate **low dose** and **high** dose conditions

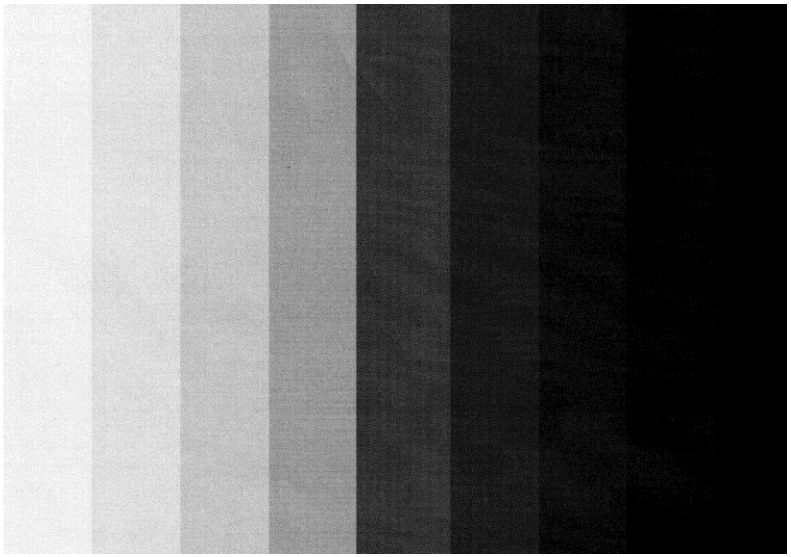
During each session following scans were acquired:

1. **Irradiated film** (low-dose and high-dose)



Example of the scanned irradiated film.

2. Test object

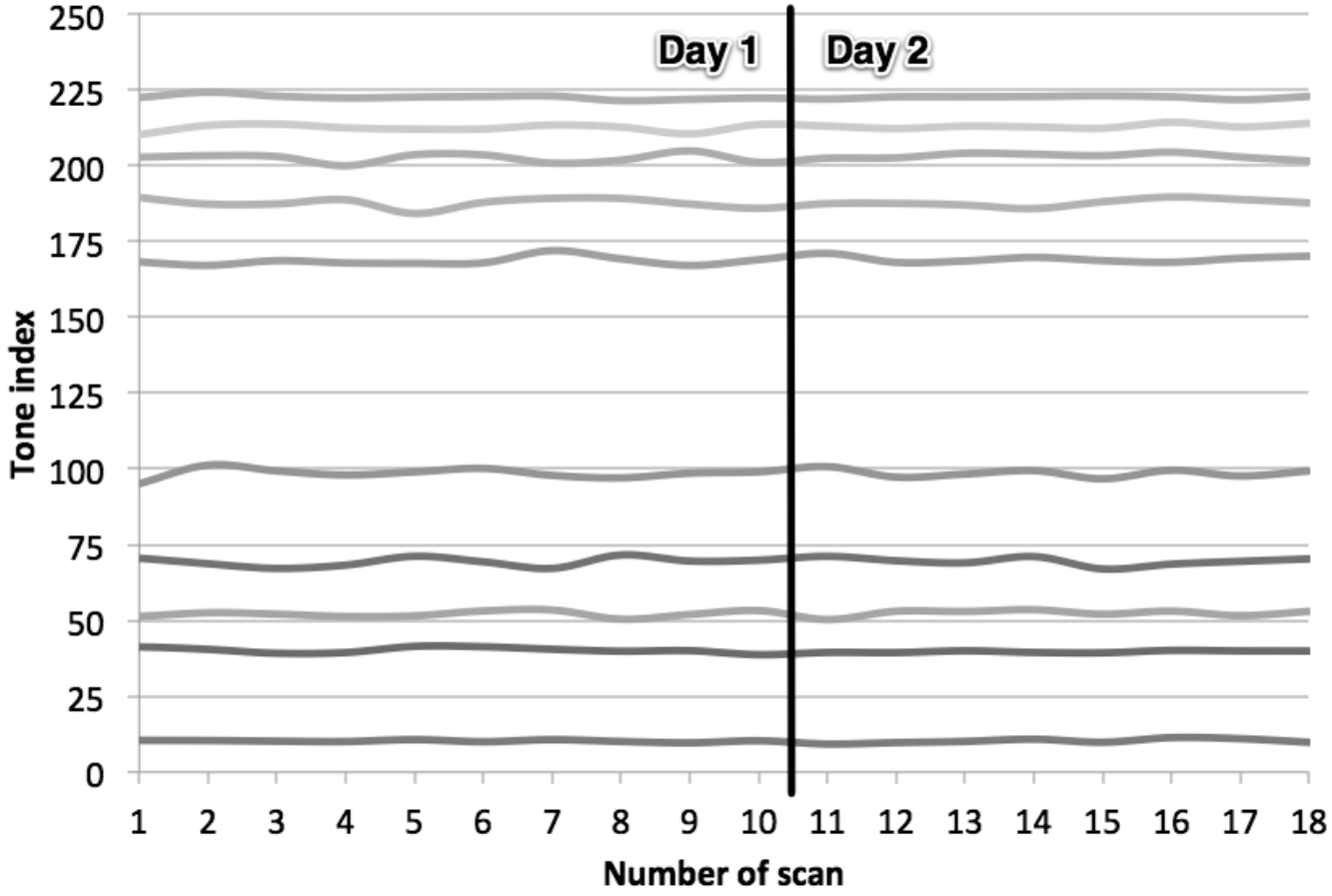


Example of scanned test object.

3. Non-irradiated film

Test object

The change of tone index value for each of the line on the **test object**



a)

- The signal drift is **not noticeable**
- Since absolute noise amplitude is rather **constant** for all indexes -

signal-to-noise ratio is **smaller** for **lower** index values (up to 10.8 % for 40 Gy and up to 12.5 % for 5 Gy)

as a result - expected uncertainty for dose determination is **larger** for **smaller** doses

Signal-to-noise ratios and expected maximal errors for **index** measurements

Without levelling		With levelling	
Signal-to-noise	Error, %	Signal-to-noise	Error, %
∞	-	5	0.5%
4	1.0%	14	0.7%
6	1.5%	16	0.9%
10	1.3%	15	1.1%
9	2.4%	16	1.6%
24	1.7%	35	1.4%
28	1.6%	35	1.6%
30	1.7%	42	1.2%
98	0.6%	52	1.1%
3750	0.0%	80	0.7%

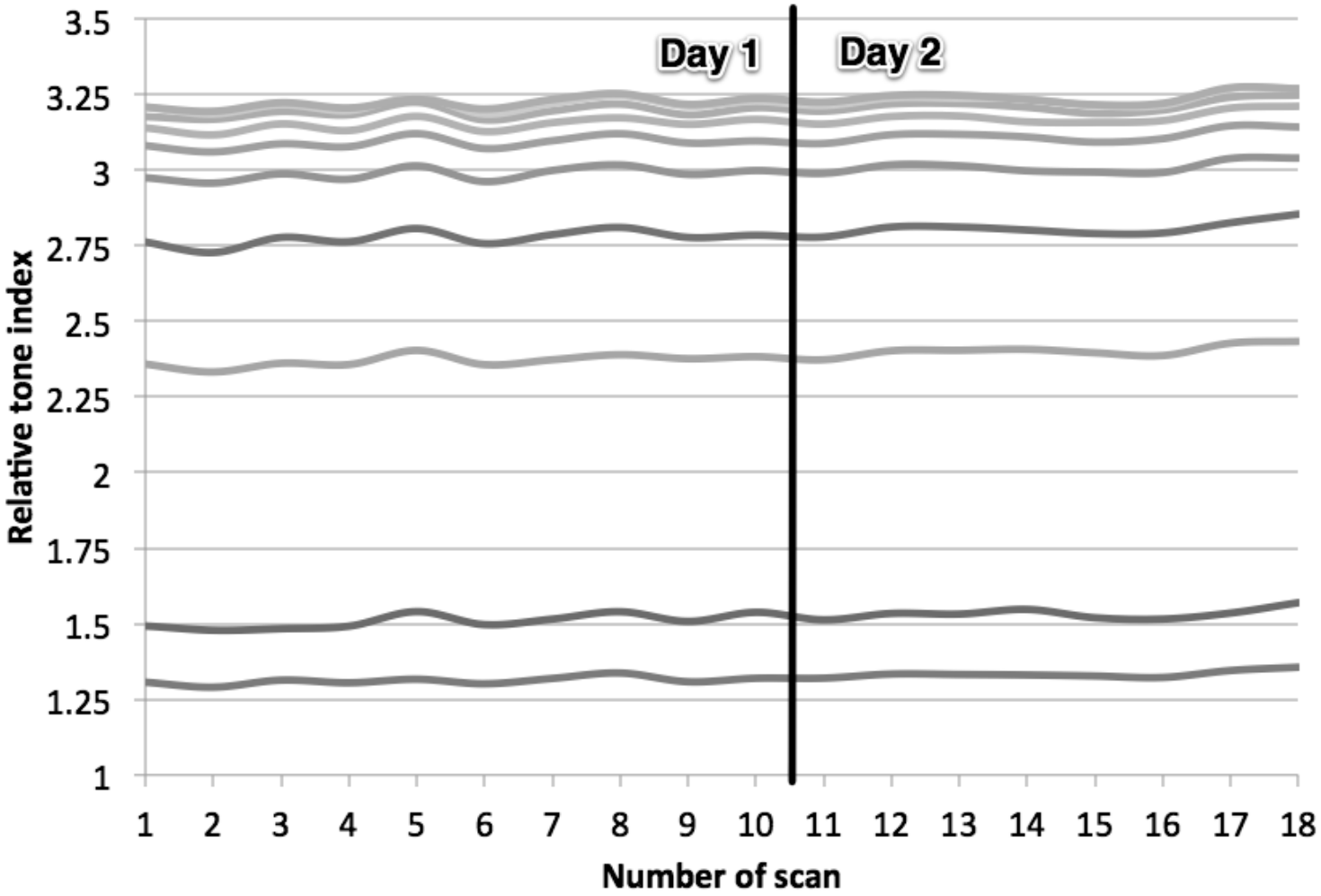
Irradiated films

- Scanning of the **two films** (high-dose and low-dose films) was performed over the period of 37 hours.

- Both films have **10** different dose levels.

- Measurements are performed as a **relative** measurement

Relative tone index values for each of the measured dose level



b)

The **signal-to-noise** ratio for **irradiated** films measurements

	Low-dose	High-dose
Dose level	Without levelling	With levelling
1	15	20
2	26	17
3	22	24
4	22	22
5	17	36
6	17	36
7	20	33
8	25	39
9	23	38
10	28	41

Additional uncertainties

- **Increase of noise** level in case of film scans can be observed.
- It can be caused by **post-exposure** changes of films' optical density.
- Comparing signal-to-noise ratios of **Day 1** to noise ratio for **Day 2** the increase in signal-to-noise ratio during **Day 2** is **noticeable**.
- It is expected that post-exposure **stabilization** of optical density occurs.

Signal-to-noise ratio changes between days.

	Signal-to-noise ratio		
Dose level	Day 1	Day 2	Increase, %
1	28	37	26.4%
2	25	27	8.2%
3	33	39	16.4%
4	34	37	9.8%
5	50	59	17.1%
6	51	53	2.5%
7	52	54	4.0%
8	55	53	-3.8%
9	54	57	5.4%
10	55	58	3.9%

Dependence on time

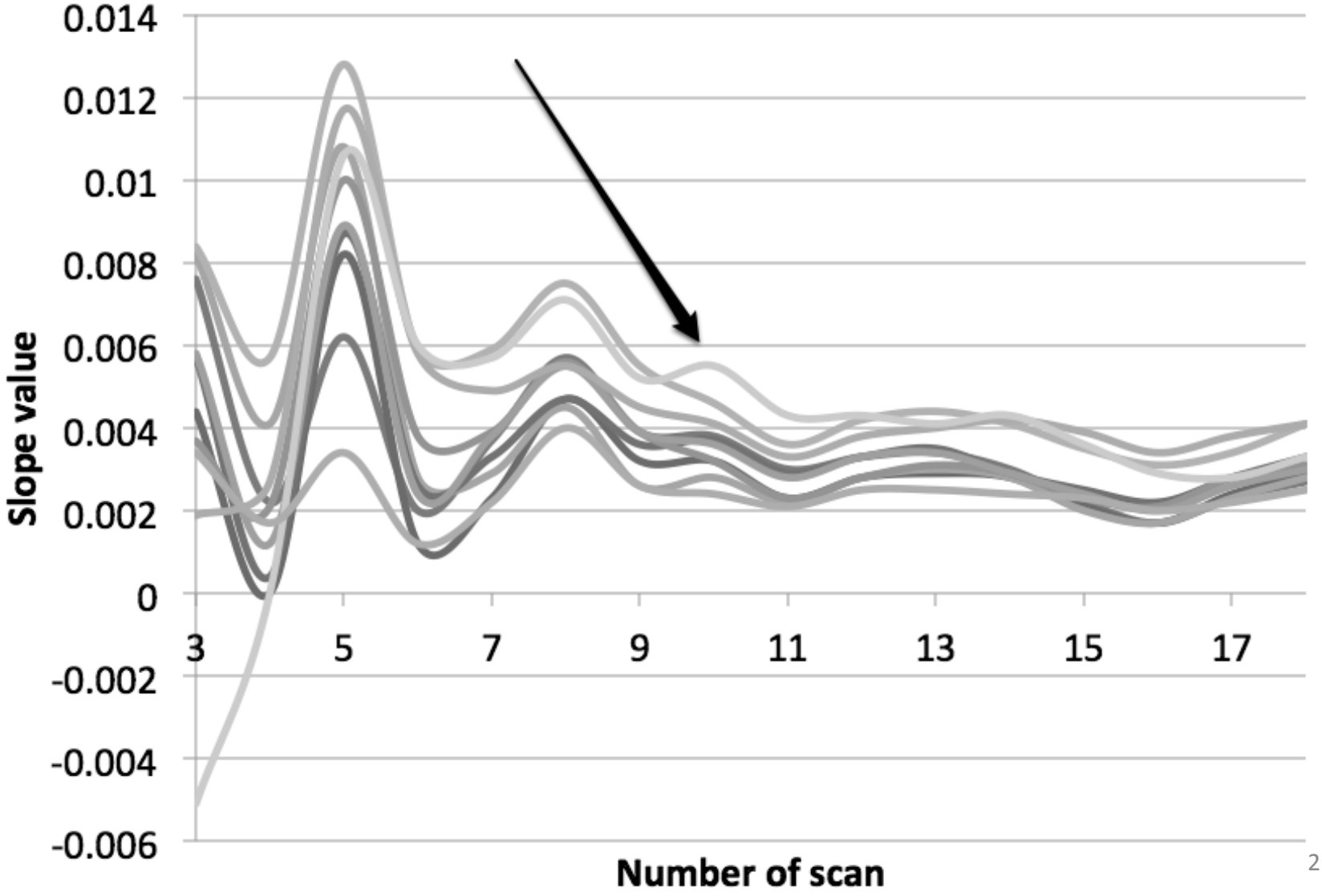
- The expected **errors:**

  1.9 % on **Day 1**

  1.6 % on **Day 2**.

- The process of optical density stabilization can also be observed **analyzing slope value** changes of index measurements' approximation line.

Fig. 5. Slope value changes between following scans.



Conclusions

1. Post-exposure changes in optical density for films have to be taken into account to choose **appropriate time** for scanning, thus reducing **uncertainties**
2. Noise levels on film scans occur as a result of both: limited repeatability of **scanner** and **post-exposure** optical density changes

3. It is recommended to perform film processing on the **next day** after irradiation, but no earlier than 11 hours past the irradiation
4. **Error** of dose determination can reach up to **1.9 %** of maximal measured dose
5. Developed methodology can be **universally applied** for hospital-based evaluation of implemented film dosimetry systems.

Thank you for your attention!