X-ray photography: fogging of film stock due to x-rays

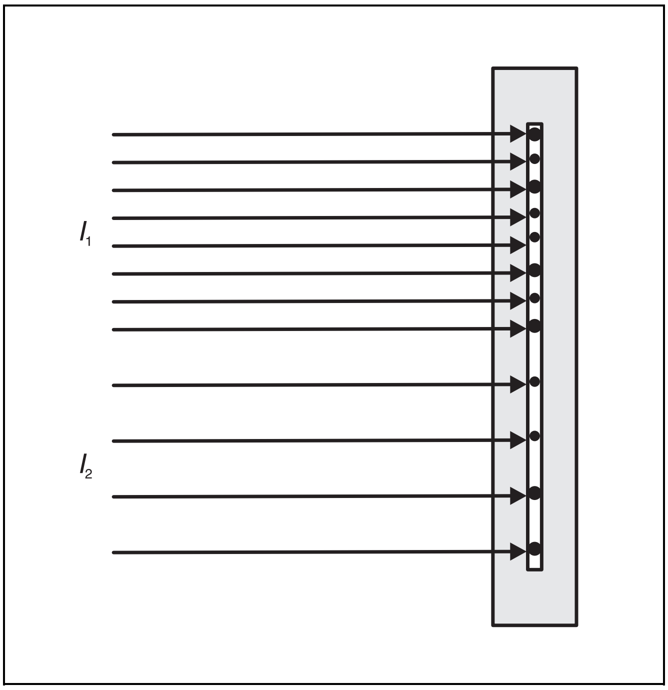
Objects of the experiment

- Detecting x-rays by means of fogging of film stock packed in light-tight envelopes.
- Investigating the relationship between the exposure dose and the degree of fogging of the film.

Principles

When x-rays strike a photosensitive layer the silver halogenide is broken down into silver atoms and halogen atoms, just as in exposure to visible light. At weak and moderate x-ray intensities, the number of seeds (silver atoms) formed is proportional to the number of incident x-ray quanta. In the process of development, silver seeds cause a fogging of the film. The degree of fogging is a measure of the intensity of x-radiation and the exposure time, i.e. the time in which the radiation could act on the film.

X-ray films can be films for daylight instant cameras as well as films requiring darkroom development. These films are exposed to the x-rays in their light-tight packaging and then developed. Alternatively, standard commercially available photographic paper can also be used. Just as in the case of x-ray film, this produces a negative, i.e. the more intensive the radiation and/or the longer the exposure time, the darker the image is.



Fogging of film stock due to x-rays

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Apparatus

1 X-ray apparatus 554 811
or
1 X-ray apparatus 554 812

1 Film holder x-ray 554 838
1 Film pack 2 (x-ray film) 554 892

Safety notes

The x-ray apparatus fulfills all regulations governing an x-ray apparatus and fully protected device for instructional use and is type approved for school use in Germany (NW 807/97 Rö).

The built-in protection and screening measures reduce the local dose rate outside of the x-ray apparatus to less than 1 μSv/h, a value which is on the order of magnitude of the natural background radiation.

- Before putting the x-ray apparatus into operation inspect it for damage and to make sure that the high voltage is shut off when the sliding doors are opened (see Instruction Sheet for x-ray apparatus).
- Keep the x-ray apparatus secure from access by unauthorized persons.

Do not allow the anode of the x-ray tube Mo to overheat.

- When switching on the x-ray apparatus, check to make sure that the ventilator in the tube chamber is turning.

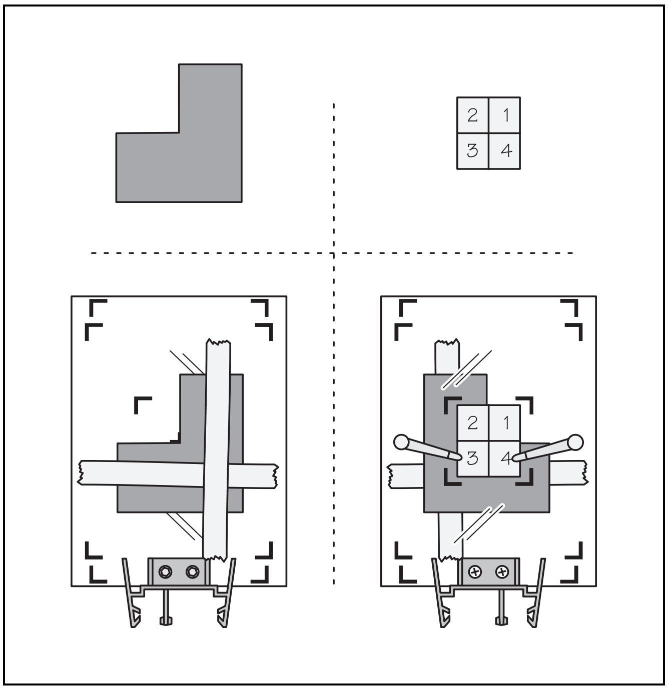

Fig. 1 Producing a film mask and preparing the x-ray film

Setup

Preparations:

– Create a film mask made of lead sheeting a least 2 mm thick as shown in Fig. 2, top left.
– Divide the packed x-ray film into four fields of equal size on both sides of the film using a soft pencil and number these from 1 to 4 (see Fig. 1 top right).

Notes:

Do not mark the film with a felt-tip pen, as common felt-tip inks can penetrate the film packing and affect the film.

When demonstrating film fogging, the direction in which the x-rays fall on the film is not important.

– Attach the film mask to the free side of the film holder x-ray using adhesive tape and clamp the x-ray film on the other side so that initially field 1 is visible through the mask (see Fig. 1 below).

Mounting in the x-ray apparatus:

– Remove the collimator from the experiment chamber, as well as the goniometer or plate capacitor x-ray (if mounted).
– Mount the experiment rail with film holder in the experiment chamber of the x-ray apparatus.
– Attach the film holder x-ray to the experiment rail so that the Plexiglas pane is facing the zero point of the scale and the marking bump **(a)** of the clamp rider is at the 180 mm point of the scale.

  In this case, the distance *d* from the plane of the film to the focal spot of the x-ray tube should be around 290 mm.

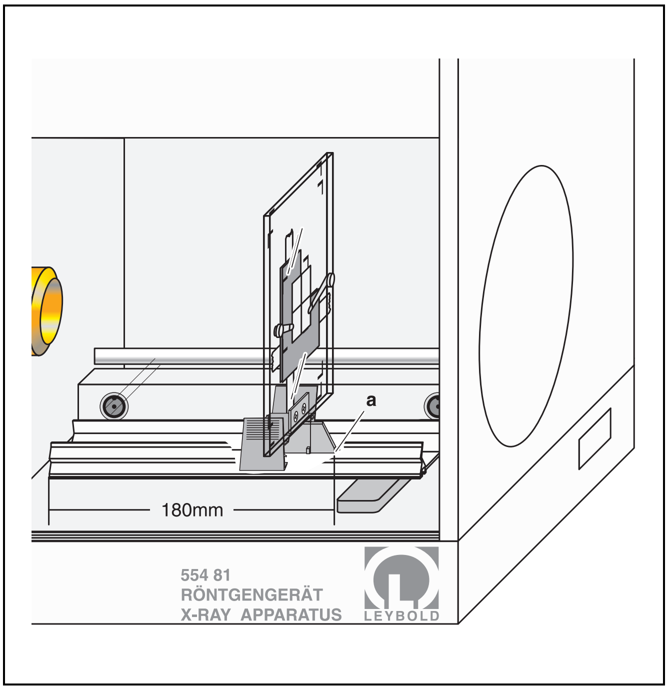

Fig. 2 Setup for investigating the fogging of film stock due to x-rays

Carrying out the experiment

a) Film fogging as a function of the emission current *I*:

– Set the tube high voltage *U* = 20 kV, measuring time Δ*t* = 20 s and Δβ = 0.0°.
– Set the emission current *I* = 0.25 mA and press SCAN to start the exposure timer.
– Turn the x-ray film so that field 2 is now exposed.
– Increase the emission current to *I* = 0.50 mA and press SCAN to start the exposure timer.
– Turn or rotate the x-ray film to expose field 3 with *I* = 0.75 mA and field 4 with *I* = 1.00 mA.
– Develop and fix the x-ray film as described in the Instruction Sheet for filmpack 2 (2.5 ml developer, developing time 1.5 min, 3.5 ml fixer, fixing time 4 min.).

b) Film fogging as a function of the exposure time Δt:

– Prepare a new x-ray film and mount it so that field 1 is exposed first.
– Set the measuring time Δ*t* = 5 s and press SCAN to start the exposure timer.
– Expose field 2 with Δ*t* = 10 s, field 3 with Δ*t* = 15 s and field 4 with Δ*t* = 20 s.
– Develop and fix your x-ray film.

c) Exposure at a constant product of emission current *I* and exposure time Δ*t*:

– Prepare a new x-ray film and mount it so that field 1 is exposed first.
– Set the emission current *I* = 0.25 mA and measuring time Δ*t* = 40 s and press SCAN to start the exposure timer.
– Expose field 2 with *I* = 0.50 mA and Δ*t* = 20 s, field 3 with *I* = 0.72 mA and Δ*t* = 15 s and field 4 with *I* = 1.00 mA and Δ*t* = = 10 s.
– Develop and fix your x-ray film.

Measuring example

d = 290 mm, *U* = 20 kV

a) Varying the emission current *I*:

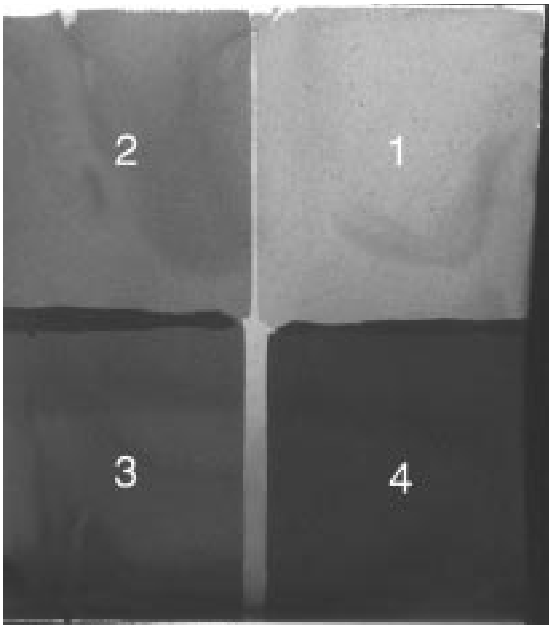

Fig. 3 Fogging intensities of the x-ray film at Δ*t* = 20 s
Field 1: *I* = 0.25 mA, field 2: *I* = 0.50 mA,
field 3: *I* = 0.75 mA, field 4: *I* = 1.00 mA

Table 1: Product of *I* · Δ*t* for the four fogged films (see Fig. 3)

Field	*I* / mA	Δ*t* / s	*I* · Δ*t* / mAs
1	0.25	20	5
2	0.5	20	10
3	0.75	20	15
4	1.00	20	20

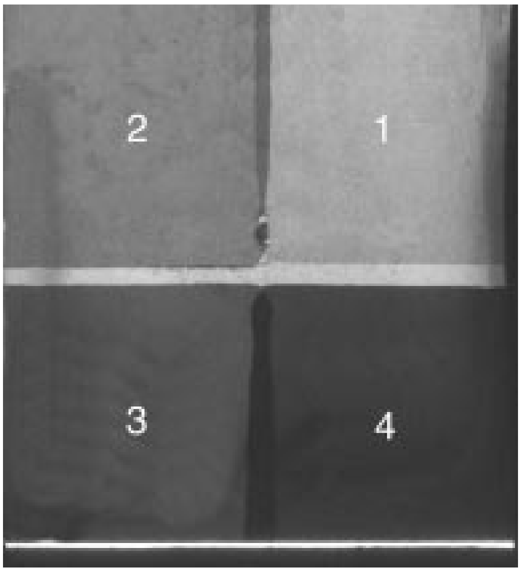

Fig. 4 Fogging intensities of the x-ray film at I = 1.00 mA
Field 1: Δt = 5 s, field 2: Δt = 10 s,
field 3: Δt = 15 s, field 4: Δt = 20 s

b) Varying the exposure time Δt:

Table 2: Product of $I \cdot \Delta t$ for the four fogged films (see Fig. 4)

Field	$\frac{I}{\text{mA}}$	$\frac{\Delta t}{\text{s}}$	$\frac{I \cdot \Delta t}{\text{mAs}}$
1	1.00	5	5
2	1.00	10	10
3	1.00	15	15
4	1.00	20	20

Fig. 5 Fogging of x-ray film at a constant product of $I \cdot \Delta t$
Field 1: I = 0.25 mA, Δt = 5 s,
Field 2: I = 0.50 mA, Δt = 10 s,
Field 3: I = 0.72 mA, Δt = 14 s,
Field 4: I = 1.00 mA, Δt = 20 s

c) Exposure at a constant product of $I \cdot \Delta t$

Table 3: Product of $I \cdot \Delta t$ for the four fogged films (see Fig. 5)

Field	$\frac{I}{\text{mA}}$	$\frac{\Delta t}{\text{s}}$	$\frac{I \cdot \Delta t}{\text{mAs}}$
1	0.25	40	10
2	0.50	20	10
3	0.72	14	10.1
4	1.00	10	10

Evaluation

The fogging of the x-ray film depends on the product of the emission current I and the exposure time Δt, and increases with the product.

As the emission current I is proportional to the exposure dose rate j of the x-rays (see experiment P6.3.1.4), the product of $I \cdot \Delta t$ is proportional to the exposure dose.

$$J = j \cdot \Delta t \qquad \text{(I).}$$

Results

The fogging of the x-ray film increases with the exposure dose J of the x-radiation.

Additional information

As the fogging of x-ray film is a measure of the time integral over the exposure dose rate, x-ray films are often used for measuring the radiation dose. The degree of fogging is registered quantitatively by means of photometric measurements.

Persons whose work exposes them to radiation hazards wear badges with packed x-ray film, called film dosimeters, so that the absorbed radiation dose can be monitored. Film dosimeters can also be used to measure the exposure dose e.g. of γ radiation.

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