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BSI Standards Publication

Radiological protection — Characteristics of reference pulsed radiation

Part 1: Photon radiation

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National foreword

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Part 1:
Photon radiation

Radioprotection — Caractéristiques des champs de rayonnement pulsés de référence —

Partie 1: Radiation de photons

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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The committee responsible for this document is ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

ISO/TS 18090 consists of the following parts, under the general title *Radiological protection — Characteristics of reference pulsed radiation*:

— *Part 1: Photon radiation*

Introduction

The specification and determination of the special characteristics required for radiation protection dosemeters to be used in pulsed fields of ionizing radiation have been excluded from all International Standards for personal and environmental dosemeters issued so far. Due to the increased use of pulsed radiation in medicine and industry, such International Standards are currently under development. A prerequisite for such International Standards is the availability of the required reference fields for pulsed radiation. This Technical Specification provides the necessary information for such reference fields.

The concept is based on the existing standards for radiation qualities defined in ISO and IEC standards. It only adds the parameters of the pulsed field and gives some guidance for their determination. Therefore, no new radiation qualities are defined, only the link between the parameters for pulsed radiation and the parameters for continuous radiation are given. The main required parameters for pulsed radiation fields are the following:

- radiation pulse duration, t_{pulse};
- radiation pulse air kerma rate, $\dot{K}_{\mathrm{a,pulse}}$;
- air kerma per radiation pulse, $K_{\mathrm{a,pulse}}$;
- for repeated pulses, their repetition frequency, f_{pulse}.

The pulse parameters were determined by using an equivalent trapezoidal radiation pulse, which is equivalent with respect to air kerma and air kerma rate. Reference pulsed radiation is characterized by specified maximum deviations of the given pulse from the equivalent trapezoidal radiation pulse and by requirements concerning the change of radiation quality during the given radiation pulse.

The pulse parameters with respect to the phantom related quantities were determined using conversion coefficients according to ISO 4037 (all parts).

This publication contains information for which worldwide experience is not available at the date of its development. Therefore, it was decided to publish it as a Technical Specification. It is expected that within the following years, experience will be gained and the maintenance of this Technical Specification could lead to an International Standard.

Radiological protection — Characteristics of reference pulsed radiation —

Part 1:
Photon radiation

1 Scope

This part of ISO/TS 18090 is directly applicable to pulsed X-radiation with pulse duration of 0,1 ms up to 10 s. This covers the whole range used in medical diagnostics at the time of publication. Some specifications may also be applicable for much shorter pulses; one example is the air kerma of one pulse. Such a pulse may be produced, e.g. by X-ray flash units or high-intensity femtosecond-lasers. Other specifications are not applicable for much shorter pulses; one example is the time-dependent behaviour of the air kerma rate. This may not be measurable for technical reasons as no suitable instrument is available, e.g. for pulses produced by a femtosecond-laser.

This part of ISO/TS 18090 specifies the characteristics of reference pulsed radiation for calibrating and testing radiation protection dosemeters and dose rate meters with respect to their response to pulsed radiation. The radiation characteristics includes the following:

a) time-dependent behaviour of the air kerma rate of the pulse;

b) time-dependent behaviour of the X-ray tube high voltage during the pulse;

c) uniformity of the air kerma rate within a cross-sectional area of the radiation beam;

d) air kerma of one radiation pulse;

e) air kerma rate of the radiation pulse;

f) repetition frequency.

This part of ISO/TS 18090 does not define new radiation qualities. Instead, it uses those radiation qualities specified in existing ISO and IEC standards. This part of ISO/TS 18090 gives the link between the parameters for pulsed radiation and the parameters for continuous radiation specifying the radiation qualities. It does not specify specific values or series of values for the pulsed radiation field but specifies only those limits for the relevant pulsed radiation parameters that are required for calibrating dosemeters and dose rate meters and for determining their response depending on the said parameters.

The pulse parameters with respect to the phantom-related quantities were determined using conversion coefficients according to ISO 4037 (all parts). This is possible as the radiation qualities specified in existing ISO and IEC standards are used.

A given reference pulsed X-ray facility is characterized by the parameter ranges over which the full specifications and requirements according to this part of ISO/TS 18090 are met. Therefore, not all reference pulsed X-ray facilities can produce pulses covering the same parameter ranges.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4037-1:1996, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 1: Radiation characteristics and production methods*

ISO 4037-2:1997, *X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy — Part 2: Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV*

IEC 60050-395:2014, *International Electrotechnical Vocabulary — Part 395: Nuclear instrumentation: Physical phenomena, basic concepts, instruments, systems, equipment and detectors*

IEC 61267:2005, *Medical diagnostic X-ray equipment — Radiation conditions for use in the determination of characteristics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-395:2014 and the following apply.

3.1
air kerma per radiation pulse
$K_{\mathrm{a,\,pulse}}$
air kerma value of one radiation pulse at a point in the photon radiation field

3.2
continuous radiation
<in area and individual dosimetry> ionizing radiation with a constant dose rate at a given point in space for time intervals longer than 10 s

3.3
dose equivalent per radiation pulse
H_{pulse}
dose equivalent value of one radiation pulse at a point in the photon radiation field

3.4
equivalent trapezoidal radiation pulse
trapezoidal radiation pulse that is considered to be equivalent to the given radiation pulse

3.5
field uniformity
F_{uni}
uniformity of the air kerma distribution determined across a defined area

$$F_{\mathrm{uni}} = 1 - \frac{K_{\mathrm{a,\,pulse,\,max}} - K_{\mathrm{a,\,pulse,\,min}}}{0{,}5 \times \left(K_{\mathrm{a,\,pulse,\,max}} + K_{\mathrm{a,\,pulse,\,min}}\right)}$$

where

$K_{\mathrm{a,\,pulse,\,max}}$ is the maximum air kerma value attributed to one radiation pulse occurring across the defined area;

$K_{\mathrm{a,\,pulse,\,min}}$ is the minimum air kerma value attributed to one radiation pulse occurring across the defined area.

Note 1 to entry: The defined area can be the whole beam diameter or only parts of it, e.g. those covered by the dosemeter under test.

Note 2 to entry: Full field uniformity is equivalent to $F_{\mathrm{uni}} = 1$. No field uniformity, that is a variation of $K_{\mathrm{a,\,pulse}}$ between 0 and $K_{\mathrm{a,\,pulse,\,max}}$, is equivalent to $F_{\mathrm{uni}} = 0$.

3.6
pulse peak mean voltage

$U_{\text{pulse, peak, mean}}$

mean value of the sequence of X-ray tube voltages, U_i, measured during the radiation pulse peak time

$$U_{\text{pulse, peak, mean}} = \frac{1}{n_{\text{peak}}} \sum_{i=1}^{n_{\text{peak}}} U_i$$

where

U_i is the i-th measured value;

n_{peak} is the number of measurements of the X-ray tube voltage.

3.7
pulse repetition frequency

f_{pulse}

number of pulses in a periodic pulse train divided by the duration of the train

[SOURCE: IEV 702-03-07, modified]

Note 1 to entry: This version of this part of ISO/TS 18090 deals only with single pulses, but it might be extended in the future to repeated pulses, therefore, this definition is already given here.

3.8
pulse train

discrete sequence of a finite number of pulses

[SOURCE: IEV 702-03-11, modified]

Note 1 to entry: The sequence can be periodic or non-periodic.

3.9
pulsed radiation

<in area and individual dosimetry> ionizing radiation which never has a constant dose rate at a given point in space for time intervals longer than 10 s

3.10
radiation pulse base duration
radiation pulse base width

$t_{\text{pulse, base}}$

interval of time between the first and last instants at which the instantaneous air kerma rate value of the equivalent trapezoidal pulse deviates from zero

Note 1 to entry: The value zero of the equivalent trapezoidal pulse is equal to the baseline of the measured pulse.

3.11
radiation pulse duration
radiation pulse width

t_{pulse}

interval of time between the first and last instants at which the instantaneous air kerma rate value of the equivalent trapezoidal pulse reaches 50 % of its maximum value

3.12
radiation pulse fall time

$t_{\text{pulse, fall}}$

interval of time between the last instants at which the instantaneous air kerma rate value of the equivalent trapezoidal pulse reaches 80 % and 20 % of its maximum value

3.13
radiation pulse air kerma rate

$\dot{K}_{\text{a,pulse}}$

quotient of the air kerma per radiation pulse and the radiation pulse duration at a point in the photon radiation field

Note 1 to entry: The air kerma per radiation pulse can be measured either by an integral measurement with an ionization chamber or time resolved by a suitable instrument, both calibrated in terms of air kerma.

3.14
radiation pulse dose equivalent rate

$\dot{H}_{\text{a, pulse}}$

quotient of the dose equivalent per radiation pulse and the radiation pulse duration at a point in the photon radiation field

Note 1 to entry: The dose equivalent per radiation pulse can be measured either by an integral measurement with an ionization chamber or time resolved by a suitable instrument, both calibrated in terms of the relevant quantity.

3.15
radiation pulse peak voltage ripple

$U_{\text{pulse, peak, ripple}}$

standard deviation of the sequence of X-ray tube voltages, U_i, measured during the radiation pulse peak time

$$U_{\text{pulse, peak, ripple}} = \sqrt{\frac{1}{n_{\text{peak}} - 1} \sum_{i=1}^{n_{\text{peak}}} \left(U_i - U_{\text{pulse, peak, mean}} \right)^2}$$

where

U_i is the i-th measured value of the X-ray tube voltage;

n_{peak} is the number of measurements;

$U_{\text{pulse, peak, mean}}$ is the pulse peak mean voltage.

3.16
radiation pulse peak time
pulse peak time

$t_{\text{pulse, peak}}$

interval of time between the first and last instants at which the instantaneous air kerma rate value of the equivalent trapezoidal pulse reaches 80 % of its maximum value

Note 1 to entry: The radiation pulse peak time is the interval of time between the end of the rise time and the beginning of the fall time of the equivalent trapezoidal pulse.

3.17
radiation pulse plateau time

$t_{\text{pulse, plateau}}$

interval of time at which the instantaneous air kerma rate value of the equivalent trapezoidal pulse reaches its maximum value

3.18
radiation pulse rise time

$t_{\text{pulse, rise}}$

interval of time between the first instants at which the instantaneous air kerma rate value of the equivalent trapezoidal pulse reaches 20 % and 80 % of its maximum value

3.19
trapezoidal pulse

unidirectional pulse having a constant gradient during increase from zero to its maximum value, remains for a given time at this maximum value and having a constant gradient during its decrease from the maximum value to zero

Note 1 to entry: See Figure 1.

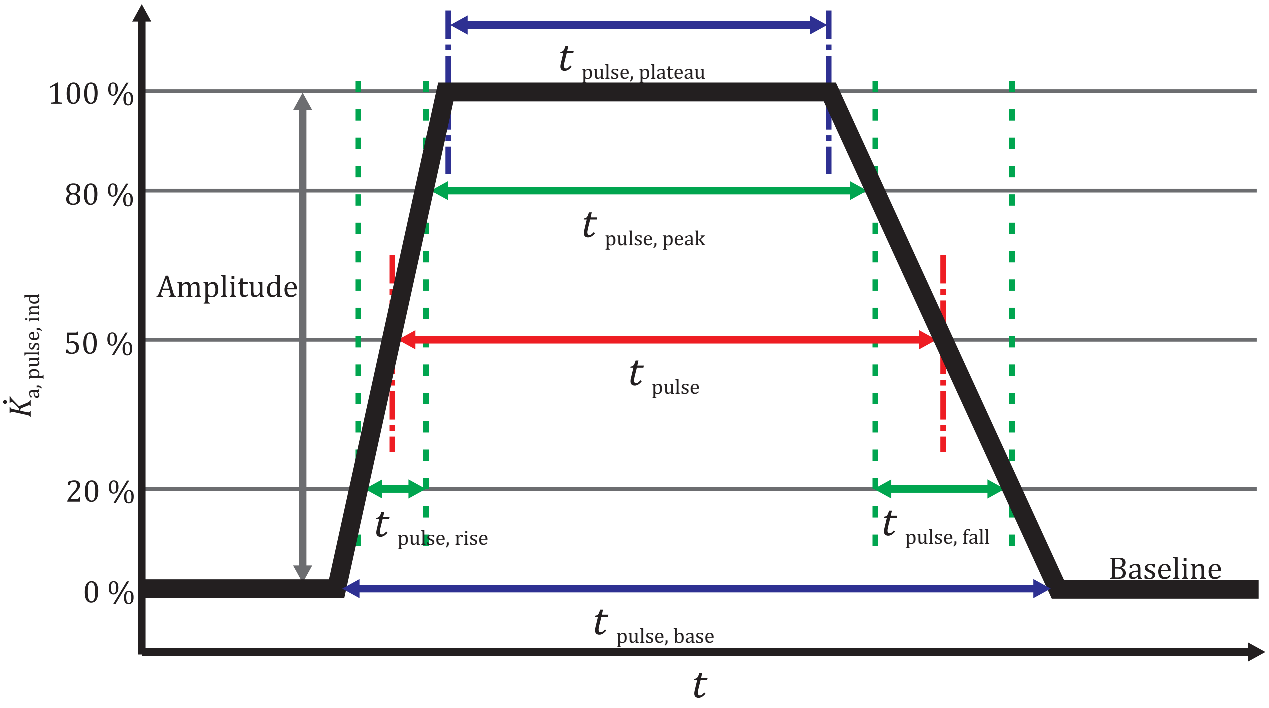


Figure 1 — Equivalent trapezoidal radiation pulse with the relevant parameters

4 Characteristics of reference pulsed radiation

4.1 General

The characterization of the radiation pulse requires the time resolved measurement of the air kerma rate and the tube high voltage during the pulse and the space resolved measurement of the air kerma of the pulse. In general, these measurements cannot be done with one single instrument.

4.2 Time-dependent air kerma rate characteristics of the radiation pulse

4.2.1 Requirements

The pulse rise time plus the pulse fall time shall not exceed 0,6 times the pulse duration:

$$t_{\text{pulse, rise}} + t_{\text{pulse, fall}} \leq 0{,}6 \times t_{\text{pulse}} \tag{1}$$

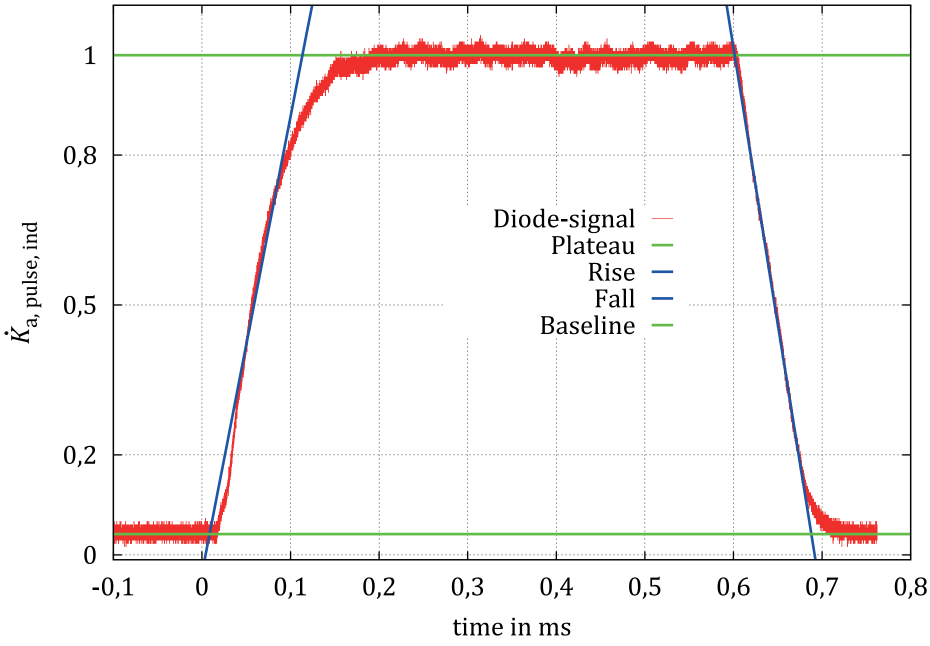
The time resolved indicated values of the air kerma pulse rate, $\dot{K}_{\text{a,pulse, ind}}$, and the radiation pulse duration, t_{pulse}, shall be determined.

4.2.2 Method of test

The time resolved indicated air kerma rate during the pulse, $\dot{K}_{\text{a,pulse, ind}}$, shall be measured with an instrument which provides a time resolution of better than 2 % of the radiation pulse duration, t_{pulse}. It is important to synchronize the time scale with the time resolved measurements of the high voltage (see 4.3.2). The measuring quantity shall be air kerma free-in-air, K_{a}. An absolute calibration of the instrument is not required as only the relative response values are of interest. The response of the instrument with respect to the air kerma rate shall be constant within ±5 % in the required measuring range (see 5.2). The sensitive area of the instrument shall be small, at maximum 1 cm × 1 cm. An example is a semiconductor diode detector with a suitable preamplifier (see Annex A). The instrument shall be positioned at the beam axis. An example of a schematic measurement result is shown in Figure 2.

The filtration of the X-ray tube shall be at least the inherent filtration according to ISO 4037-1:1996 or IEC 61267:2005. Determine the sequence of indicated values of the air kerma rate during the radiation pulse for any pulse duration and any high voltage intended to be used irrespective of the actual filtration. From each of these sequences, the equivalent trapezoidal pulse shall be determined (see Annex B) and then the pulse duration, t_{pulse}, the value of the pulse air kerma rate, $\dot{K}_{\text{a,pulse, ind}}$, and the durations $t_{\text{pulse, rise}}$ and $t_{\text{pulse, fall}}$.

In the energy range from the maximum photon energy according to the high voltage down to one third of this energy, the air kerma response of the instrument as a function of photon energy should be as low as possible, e.g. by using an energy compensation filter.



NOTE The measured air kerma rate is transferred into an equivalent trapezoidal radiation pulse.

Figure 2 — Result of a time resolved measurement of the air kerma rate during the pulse with a semiconductor diode and an oscilloscope

NOTE Determined parameters of the pulse for Figure 2:

$t_{\text{pulse, rise}}$ = 63 µs,

$t_{\text{pulse, fall}}$ = 52 µs,

t_{pulse} = 584 µs,

$t_{\text{pulse, peak}} = 526\ \mu\text{s}$,

$t_{\text{pulse, plateau}} = 488\ \mu\text{s}$,

Area (Equivalent trapezoidal pulse) / Area (radiation pulse) = 1,0092.

4.2.3 Interpretation of the results

If for any given radiation pulse $\dot{K}_{\text{a,pulse, ind}}$, t_{pulse}, $t_{\text{pulse, rise}}$ and $t_{\text{pulse, fall}}$ are determined and the sum of rise time and fall time of the pulse does not exceed 0,6 times the pulse duration, then the requirements of 4.2.1 are met.

4.3 Time-dependent high voltage characteristics of the radiation pulse

4.3.1 Requirement

The ripple of the high voltage during the pulse peak time, $U_{\text{pulse, peak, ripple}}$, shall not exceed 0,07:

$$U_{\text{pulse, peak, ripple}} = \sqrt{\frac{1}{n_{\text{peak}}-1}\sum_{i=1}^{n_{\text{peak}}}\left(U_i - U_{\text{pulse, peak, mean}}\right)^2} \leq 0{,}07 \tag{2}$$

4.3.2 Method of test

A sequence of the high voltage values of the X-ray tube during the pulse shall be measured using a high-frequency-compensated voltage divider. The instrument shall provide a time resolution of better than 2 % of the pulse duration, t_{pulse}. It is important to synchronize the time scale with the time resolved measurements of the air kerma rate (see 4.2.2), as the pulse peak time, $t_{\text{pulse, peak}}$, is defined by the air kerma rate measurement. The radiation pulse can be generated by switching the high voltage of the generator or by using a special X-ray tube which allows current switching by an additional grid.

Determine $U_{\text{pulse, peak, mean}}$ and $U_{\text{pulse, peak, ripple}}$ for any high voltage intended to be used and any pulse duration between the minimum pulse duration adjustable at the facility and 100 times this pulse duration.

4.3.3 Interpretation of the results

If for the given radiation pulse, the ripple of the high voltage during the pulse peak time, $U_{\text{pulse, peak, ripple}}$, does not exceed 0,07, then the requirement of 4.3.1 is met for that pulse.

4.4 Space dependent air kerma characteristics of the radiation pulse

4.4.1 Requirement on field uniformity across the beam area

The field uniformity, F_{uni}, measured across the defined beam area and determined for one pulse, shall not fall below 0,85:

$$1 - \frac{K_{\text{a, pulse, max}} - K_{\text{a, pulse, min}}}{0{,}5 \times \left(K_{\text{a, pulse, max}} + K_{\text{a, pulse, min}}\right)} \geq 0{,}85 \tag{3}$$

NOTE The field uniformity is to a large extent influenced by the heel effect.

4.4.2 Method of test

The measuring quantity shall be air kerma free-in-air, K_{a}. An absolute calibration of the instrument is not required as only the relative air kerma values are of interest. The air kerma response of the instrument with respect to the air kerma rate shall be constant within ±5 % in the required measuring range. The spacial resolution of the instrument shall be better than 1 cm × 1 cm. An example is a flat-panel detector with a spacial resolution of about 0,25 mm × 0,25 mm. An example of a schematic measurement result is shown in Figure 3 and Figure 4.

Determine the field uniformity across the defined beam area, F_{uni}, symmetrically around the central beam axis for lowest high voltage and smallest filtration intended to be used.

4.4.3 Interpretation of the results

If the field uniformity, F_{uni}, measured across the defined beam area does not fall below 0,85, then the requirement of 4.4.1 is met.

NOTE 1 The defined beam area might have a spherical or rectangular shape.

NOTE 2 In the example shown in Figure 3 and Figure 4, this requirement is only fulfilled for the central beam with a diameter of about 1 000 pixel.

4.5 Filtration

The filtration shall be according to ISO and IEC standards, e.g. ISO 4037-1:1996, Clause 4, Tables 3 to 6 or IEC 61267:2005, Clauses 5 to 14, Tables 1 to 8. The tube potential mentioned in these standards shall be the value of $U_{\mathrm{pulse,\ peak,\ mean}}$ as determined in 4.3.2.

4.6 Equivalence of measured radiation pulse and trapezoidal pulse

4.6.1 Requirements

The quotient of the integral over the indicated air kerma rate values of the equivalent trapezoidal pulse, $K_{\mathrm{a,trapezoidal\ pulse,\ ind}}$, and the integral over the indicated air kerma rate values of the measured radiation pulse, $K_{\mathrm{a,\ pulse,ind}}$, shall not deviate from unity by more than 0,03:

$$0{,}97 \leq \frac{K_{\mathrm{a,\ trapezoidal\ pulse,\ ind}}}{K_{\mathrm{a\ ,pulse,\ ind}}} \leq 1{,}03 \tag{4}$$

where

$K_{\mathrm{a,trapezoidal\ pulse,\ ind}}$	is the integral over the indicated air kerma rate values of the equivalent trapezoidal pulse;
$K_{\mathrm{a,pulse,\ ind}}$	is the integral over the indicated air kerma rate values of the measured radiation pulse.

The integral of the equivalent trapezoidal pulse is given by

$$0{,}5 \times (t_{\mathrm{pulse,\ base}} + t_{\mathrm{pulse,\ plateau}}) \times \dot{K}_{\mathrm{a,\ trapezoidal\ pulse,\ ind}}.$$

4.6.2 Method of test

Use the measured indicated air kerma rate values and the parameters of the equivalent trapezoidal pulse as determined according to 4.2.2. Determine the integral over the indicated air kerma rate values of the trapezoidal pulse and of the measured pulse.

4.6.3 Interpretation of the results

If the quotient is within 0,97 to 1,03, then the requirement of 4.6.1 is met.

4.7 Constancy of air kerma rate during the pulse plateau time

4.7.1 Requirement

The mean indicated air kerma rate of the equivalent trapezoidal pulse shall not deviate from the mean indicated air kerma rate of the measured pulse by more than ±10 % for each third of the pulse plateau time:

$$0{,}90 \le \frac{\frac{1}{3} \times K_{\mathrm{a,\,trapezoidal\ pulse,\,ind}}}{K_{\mathrm{a\,,pulse,\,ind}\,i}} \le 1{,}10 \qquad (5)$$

where

$K_{\mathrm{a,trapezoidal\ pulse,\ ind}}$	is the integral over the indicated air kerma rate values of the equivalent trapezoidal pulse;
$K_{\mathrm{a,\,pulse,\,ind}_i}$	is the integral over the indicated air kerma rate values of the measured pulse for the i th third of the pulse plateau duration.

4.7.2 Method of test

Use the measured air kerma rate values and the parameters of the equivalent trapezoidal pulse as determined according to 4.2.2. Determine for the pulse plateau duration the integral over the indicated air kerma rate values of the equivalent trapezoidal pulse, $K_{\mathrm{a,trapezoidal\ pulse,\ ind}}$. Divide the pulse plateau time into three equal time intervals. For each time interval, determine the integral over the indicated air kerma rate values of the measured radiation pulse, $K_{\mathrm{a\,,pulse,\,ind}\,i}$. Determine for each of the three time intervals the quotient

$$\frac{\frac{1}{3} \times K_{\mathrm{a,\,trapezoidal\ pulse,\,ind}}}{K_{\mathrm{a\,,pulse,\,ind}\,i}} \qquad (6)$$

4.7.3 Interpretation of results

If for all three time intervals the quotient determined according to 4.7.2 is within 0,90 to 1,10, then the requirement of 4.7.1 is met.

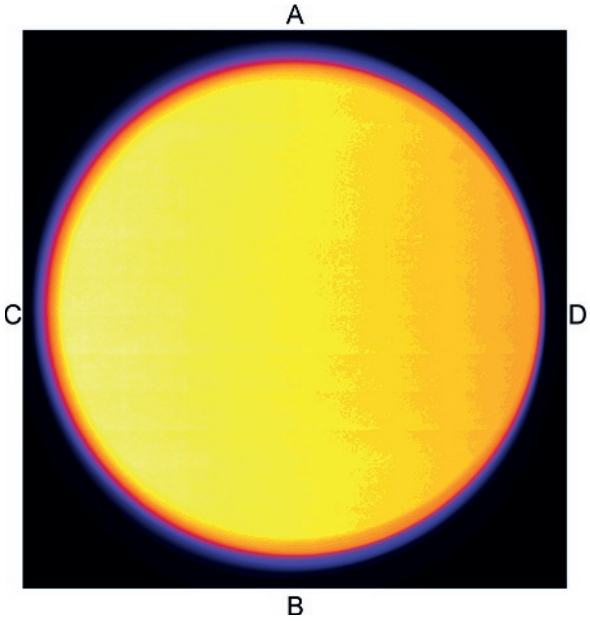
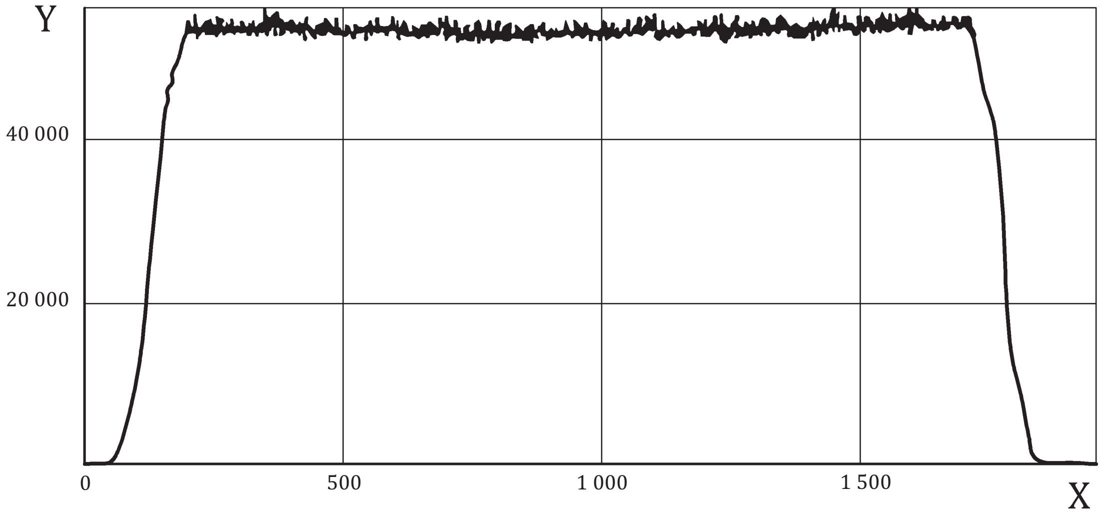
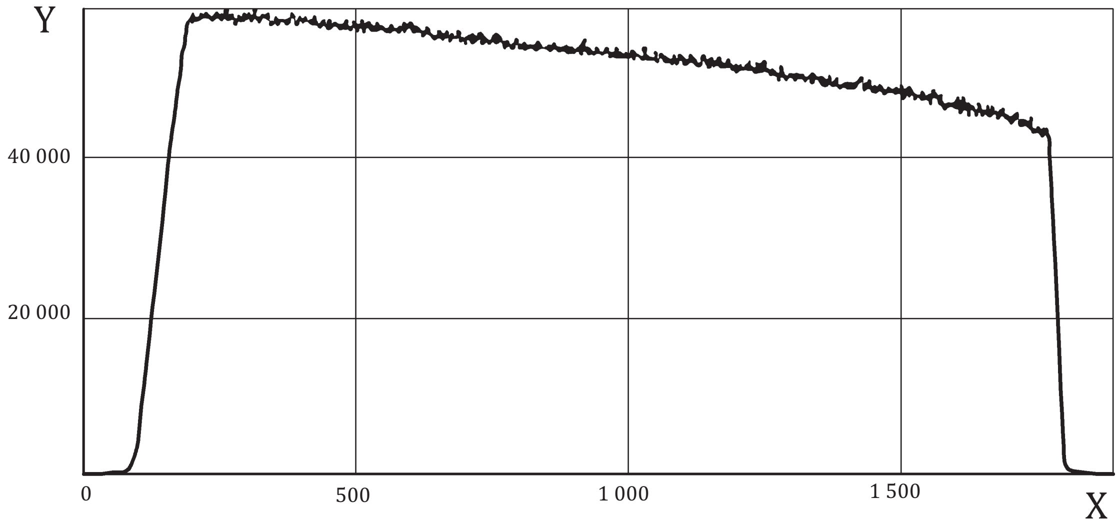


Figure 3 — Air kerma in arbitrary units measured across the beam using a flat panel detector



a) Air kerma in arbitrary units measured on the vertical line (A-B) across Figure 3



b) Air kerma in arbitrary units measured on the horizontal line (C-D) across Figure 3

NOTE 1 The impact of the heel effect is clearly visible.

NOTE 2 The radiation quality was RQR8 according to IEC 61267:2005, the tube current 14,5 mA, the pulse duration 50 ms, the distance 1,5 m and the air kerma 80 µGy.

Figure 4 — Schematic result of the measurement of the field uniformity across the beam area

5 Dosimetry of pulsed reference radiation

5.1 General requirements on the instrument

The requirements on the instrument to be used for the air kerma measurement of the pulse, $K_{\mathrm{a,\,pulse}}$, the integral air kerma of the reference radiation pulse, shall be as given in ISO 4037-2:1997, Clauses 4 and 5. In addition, if the instrument is an ionization chamber, the requirements given in ISO 4037-2:1997, Clause 6 apply.

5.2 Air kerma rate dependence of the instrument response

5.2.1 General

The dependence of the response on the air kerma rate is a critical characteristic of the instrument. On one hand, the air kerma rate within the pulse is very high, which is usually considered by selecting a low sensitive measuring range, but on the other hand the air kerma of one pulse can be quite low, which might require a high sensitive measuring range to obtain a reading with a suitable resolution. All dosimetry of pulsed reference X radiation is done with respect to the air kerma per pulse.

5.2.2 Requirement

The dependence of the response on the air kerma rate shall be less than ±5 % in the range from $\dot{K}_{\mathrm{a,\,pulse}}$ down to $0{,}01 \times \dot{K}_{\mathrm{a,\,pulse}}$.

5.2.3 Method of test and interpretation of the results

Use the values given in the calibration certificate of the instrument to be used or use other sources, e.g. for an ionization chamber the calculations given in ICRU 34,[1] to determine the dependence of the response on the air kerma rate in the range from $\dot{K}_{\text{a, pulse}}$ down to 0,01 × $\dot{K}_{\text{a, pulse}}$. If this dependence is less than ±5 %, then the requirement of 5.2.2 is met.

$\dot{K}_{\text{a, pulse}}$ is the maximum dose rate intended to be measured.

5.3 Size of the sensitive volume of the instrument

The size of the sensitive volume of the instrument shall be such that across the part of the surface of the beam which is covered by the instrument the field uniformity, $F_{\text{uni, instr}}$, is better than 95 %.

5.4 Air kerma of the radiation pulse

The air kerma per radiation pulse, $K_{\text{a, pulse}}$, shall be measured with an instrument in line with 5.1 to 5.3 for any pulse duration and any beam quality intended to be used.

5.5 Dose equivalent of the radiation pulse

The dose equivalent per radiation pulse, H_{pulse}, is determined from the air kerma per radiation pulse, $K_{\text{a, pulse}}$, by multiplication with the conversion coefficient valid for the selected phantom related quantity, the selected reference radiation quality and, if applicable, for the selected phantom. Values of the conversion coefficient or the method for their determination can be obtained from ISO 4037-3:1999.

5.6 Radiation pulse air kerma rate

The radiation pulse air kerma rate, $\dot{K}_{\text{a, pulse}}$, is determined from the pulse air kerma value, $K_{\text{a, pulse}}$, and the determined pulse duration, t_{pulse}:

$$\dot{K}_{\text{a,pulse}} = \frac{K_{\text{a,pulse}}}{t_{\text{pulse}}} \tag{7}$$

5.7 Radiation pulse dose equivalent rate

The radiation pulse dose equivalent rate, $\dot{H}_{\text{pulse}}$, is determined from the pulse dose equivalent value, H_{pulse}, and the determined pulse duration, t_{pulse}:

$$\dot{H}_{\text{pulse}} = \frac{H_{\text{pulse}}}{t_{\text{pulse}}} \tag{8}$$

Annex A
(informative)

Diode-detector and associated amplifier

For the necessary measurements of short radiation pulses, described in this standard, a semiconductor diode with an adapted amplifier can be used. To measure the correct pulse parameters, some points have to be considered in the electronic set-up. A sketch for a principal circuit, consisting of a semiconductor diode and an amplifier, is shown in Figure A.1.

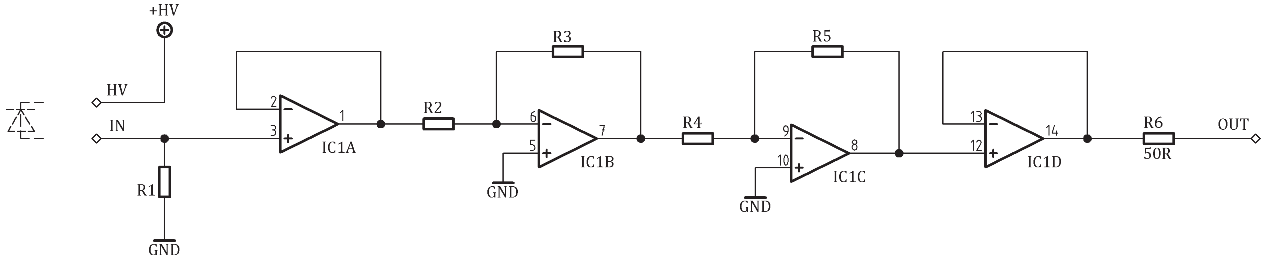


Figure A.1 — Sketch of a principal circuit for measurements of short radiation pulses with a semiconductor diode (left) and an amplifier including line driver

The diode is operated under a reverse bias voltage. The first and the last operational amplifiers serve as impedance converters, the second and third as signal amplifier. The splitting of the amplification into two operational amplifiers enhances the bandwidth of the complete amplifier, as the gain-bandwidth product is a given constant for an operational amplifier.

For the practical realization of such a circuit, the following points have to be taken into account:

— the operational amplifiers used have to be low-noise and have to be adjusted to the bandwidth of the expected signals;

— in order to achieve the maximum slew rate, the time constant of the input stage is to keep as small as possible. Therefore, the capacity of the diode used, the input capacity of the operational amplifier, the parasitic capacitances and the resistor R1 should be chosen as small as possible;

— for choosing the diode, it has to be considered, that the output signal of the diode is increasing with its active area, but its capacity too. The same is valid for the resistor R1, increasing the resistance increases the signal but at the same time it reduces the slew rate. Short cable connection between diode and operational amplifier input are needed to maximize the possible bandwidth;

— the total amplification, A, can be calculated according to the following equation: $A = (R3/R2) \times (R5/R4)$. To adjust the resulting gain of this two-stage amplification, the resistors in the feedback loop can be made switchable (R3 and R5);

— the operational amplifier IC1D serves as a 50 ohm line driver;

— it is important to separate the signal ground from the power ground. In general ground connections should only be realized in a star shape;

— in order to reduce the line length which is sensitive to disturbances, the regulation of the power supplies should be integrated on the circuit board. Sufficient filtration of the supply voltage against additional interference, such as high frequency disturbances, is needed too.

For the measurements shown in Figure 2, the following parts were used:

Si PIN photodiode with

Active area:	10 mm × 10 mm
Depletion depth:	0,3 mm
Dark current	4 nA at 100 V reverse bias voltage
Terminal capacitance	40 pF at 100 V reverse bias voltage

Quad Precision High Speed Operational Amplifier with

Slew rate:	170 V/µs
Gain-bandwidth product:	28 MHz
Settling time:	<200 ns to 0,01 %
Offset voltage:	<500 µV
Voltage noise density:	<6 nV/√Hz
Unity-gain stable	

Resistors

R1:	100 kΩ
R2:	10 kΩ
R3:	20 kΩ
R4:	10 kΩ
R5:	20 kΩ
R5:	50 Ω

Annex B
(informative)

Determination of the equivalent trapezoid radiation pulse

B.1 Determination of the baseline and the plateau of the equivalent trapezoid pulse

The pulse shall be measured using a digital oscilloscope. It is presupposed that the pulse has a distinctive plateau form so that two levels can be identified, the baseline and the plateau. Both can be described by straight lines with a gradient set equal to zero. The position of both straight lines can be determined from the time resolved measurement of the pulse air kerma rate by counting and summarizing the measured data points with the same signal value. Out of this, a histogram of the measured pulse values (frequency distribution) can be created.

The measuring ranges of the oscilloscope shall be selected such that the measurement resolution of the signal is at least 2 % of the plateau level and that the pulse has at least 30 signal values above the baseline value for (t_{rise} + t_{fall}).

All measured data values are sorted by their signal value into the histogram intervals.

B.2 Maxima of the histogram distribution

Two relative maxima should be detectable in this histogram (see example in Figure B.1). The relative maximum with the lower value corresponds to the baseline, those with the higher value to the plateau value of the equivalent trapezoid pulse.

The amplitude of the equivalent trapezoid pulse is then defined as difference between the plateau value and the baseline value.

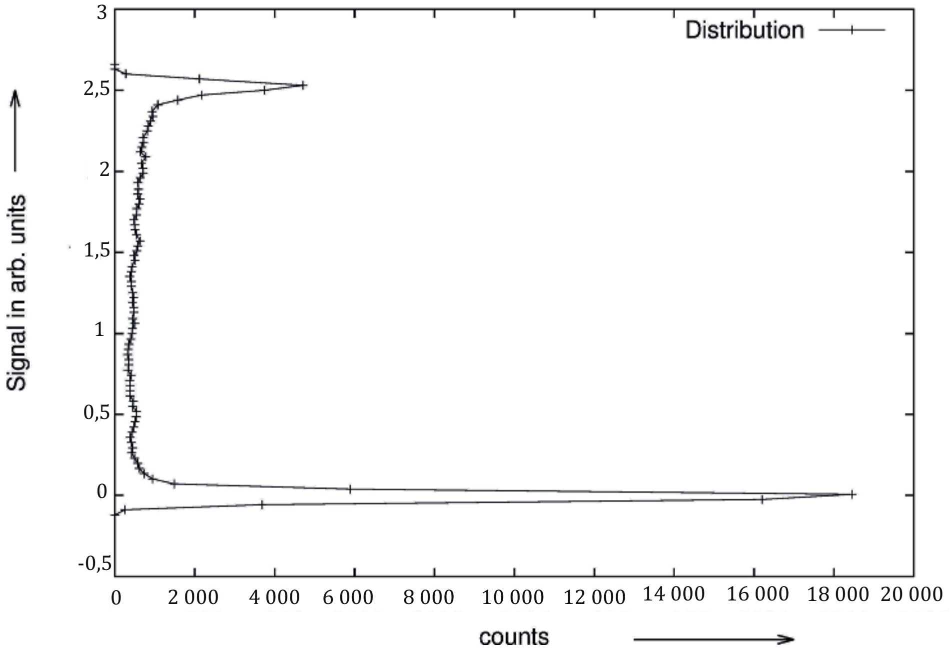


Figure B.1 — Histogram of the measured signal values

B.3 Determination of the rising and falling edges of the equivalent trapezoid pulse

With the knowledge of the amplitude and the baseline (see Figure B.1), the time values where the measured pulse reaches the signal values corresponding to 20 % and 80 % of the amplitude can be determined for the rising edge and the falling edge. From these points in the time resolved measurement of the air kerma rate of the pulse (see e.g. Figure 2), the corresponding linear rising and falling edge of the equivalent trapezoidal pulse can be calculated.

In practice, the signal is often interfered by noise. In such cases, it is recommended to smooth out the signal data until the values corresponding to 20 % and 80 % of the amplitude can be unambiguously determined.

The combination of the straight lines for the baseline and the plateau and for both edges results in the equivalent trapezoidal pulse.

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