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Dosimetry with solid thermoluminescence detectors for photon and electron radiations in radiotherapy

Dosimétrie avec détecteurs de thermolumiscence solides pour le photon et rayonnements d'électron en radiothérapie

ICS 13.280

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Contents

Page

Foreword

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ISO 28057 was prepared by Technical Committee ISO/TC 85, , Subcommittee SC 2, .

This second/third/... edition cancels and replaces the first/second/... edition (), [clause(s) / subclause(s) / table(s) / figure(s) / annex(es)] of which [has / have] been technically revised.

Dosimetry with solid thermoluminescence detectors for photon and electron radiations in radiotherapy

1 Scope

In this standard, rules for the application of thermoluminescence dosimetry for dose measurements according to the probe method are defined. The probe method encompasses the arrangement, particularly in a water phantom or in a body-mimicking phantom, of single TL detectors or of a set of TL detectors encapsulated in a thin-walled casing. The purpose of these rules is to guarantee the reliability and the accuracy indispensable in clinical dosimetry when applied on or in the patient or phantom. They apply to the dosimetry in percutaneous radiotherapy with both photon radiation and electron radiation and in brachytherapy with photon emitters [4] [33] [34].

The dosimetry with LiF thermoluminescence detectors has several advantages. These are in particular:

small volumes of the detectors,
applicability to continous and pulsed radiation,
fairly water equivalency of the detector material,
only a few correction factors needed for absorbed dose determinations.

The main disadvantage of TL detectors is, however, that they have to be regenerated by a pre-irradiation annealing procedure. Unfortunately it is not possible to restore the former response of the detectors perfectly by this annealing. Provided, however, that all detectors of a production batch always undergo the same thermal treatment, one can at least determine the mean alteration of the response of these detectors, with sufficiently small fluctuations of the individual values. From this mean alteration, a correction factor can be derived.

The essential aim of this standard is to specify the procedures and to carry out corrections which allow to achieve, (1) a REPEATABILITY of the indicated value whithin a fraction of a percent [2], and thus (2) a total UNCERTAINTY OF MEASUREMENT (including the calibration steps tracing to the primary standards) of a few percent, like in ionization chamber dosimetry [15] [21] [24] [48] [49].

The regulations in this standard comprise special terms used in thermoluminescence dosimetry, rules for the MEASUREMENT TECHNIQUE and requirements on the MEASUREMENT SYSTEM. The defined requirements and the testing techniques can, in the whole or partially, serve as basis for STABILITY CHECKS and ACCEPTANCE TESTS. The thermoluminescence dosimetry procedures described in this standard can be used for PHOTON RADIATION within the energy range from 20 keV to 50 MeV and for ELECTRON RADIATION within the energy range from 4 MeV to 25 MeV. In order to achieve the REPEATABILITY and TOTAL UNCERTAINTY stated above, this standard is applicable in the dose range above 1 mGy. The upper limit of the minimum measuring range is in the order of magnitude of 10 to 100 Gy. In clinical dosimetry, thermoluminescence detectors (TL detectors) are either applied in response to the requirement of high spatial resolution, i.e. in the study of the dose distributions with high gradients occuring in small stereotactic radiation fields and around brachytherapy sources. The other common application is the measurement of dose distributions in large absorbers, e.g. geometrical or body-mimicking phantoms, either within the field limits or in its periphery. A further usage is the quality assurance of clinical dosimetry by postal dose intercomparison [1] [7] [9] [17] [19] [25] [26] [27] [44]. These applications are complementary to the use of ionization chambers. This standard is applicable to "TL detectors", i.e. rods and chips made from LiF:Mg,Ti or LiF:Mg,Cu,P in crystalline or polycrystalline form, and to "TL probes", i.e. sets of TL detectors arranged in PMMA casings. For clinical dosimetry, single TL detectors or TL probes are positioned and irradiated in phantoms. TLD powders are not dealt with in this standard.

In this standard, the long-standing experience in the clinical usage of thermoluminescence dosimetry, expressed in a number of protocols and recommendations, e.g. [10] [24] [28] [48] [49] has been accounted for.

In accordance with the procedure proposed by the International Electrotechnical Commission (IEC) in its publications, small capitals have been used for designating defined terms.

2 Normative references

This standard contains definitions based on dated or undated references from other publications. These normativ references are quoted at the corresponding places in the text, and the publications are listed below. In the case of dated references, later modifications or revisions of these publications are only included in this standard, if they have been incorporated by alteration or revision of the publication. In the case of undated references, the last edition of the publication referred to is valid.

EN 61000-4-2:2001-12, Electromagnetic compatibility (EMV) – Part 4-2: Test and measurement procedure; Test of immunity against static electric discharges (IEC 61000-4-2:1995 + A1:1998 + A2:2000)

EN 61000-4-3:2003-03, Electromagnetic compatibility (EMV) – Part 4-3: Test and measurement procedure; Test of immunity against high-frequency electromagnetic fields (IEC 61000-4-3:2002)

EN 61000-4-4:2002-07, Electromagnetic compatibility (EMV) – Part 4-4: Test and measurement procedure; Test of immunity against rapid transient electric disturbances / bursts (IEC 61000-4-4:1995 +A1:2000 + A2:2001)

EN 61000-4-5:2001-12, Electromagnetic compatibility (EMV) – Part 4-5: Test and measurement procedure; Test of immunity against pulsed voltages (IEC 61000-4-5:1995 + A1:2000)

EN 61000-4-6:2001-12, Electromagnetic compatibility (EMV) – Part 4-6: Test and measurement procedure; Test of immunity against conducted disturbances, induced by high-frequency fields (IEC 61000-4-6:1996 + A1:2000)

EN 61000-4-8:2001-12, Electromagnetic compatibility (EMV) – Part 4-8: Test and measurement procedure; Test of immunity against magnetic fields with energy-technical frequencies (IEC 61000-4-8:1993 + A1:2000)

EN61000-4-11:2001-12, Electromagnetic compatibility (EMV) – Part 4-11: Test and measurement procedure; Test of immunity against voltage dips, short interruptions and voltage fluctuations (IEC 61000-4-11:1994 + A1:2000)

EN 61000-6-2:2002-08, Electromagnetic compatibility (EMV) – Part, 6-2: Technical basic rules; Test of immunity for the industrial sector (IEC 61000-6-2:1999, altered)

EN 61010-1:2002-08, Safety rules for electrical measurement-, steering-, adjustment- and laboratory equipment – Part 1: General requirements (IEC 61010-1:2001)

EN 60601-1:1996-03, Electromedical equipment – Part 1*:* General instructions pertaining to safety (IEC 60601-1:1988 + A1:1991 + A2:1995)

EN 61187:1995-06, Electric and electronic measurement instruments – Accompanying papers (IEC 61187:1993, altered)

ICRU 35, Radiation dosimetry: electron beams with energies between 1 and 50 MeV. International Commission on Radiation Units and Measurements (1984)

ICRU 36, Microdosimetry. International Commission on Radiation Units and Measurements (1983)

ICRU 62, Prescribing, recording and reporting photon beam therapy. International Commission on Radiation Units and Measurements (1999)

IEC 61066 - Ed.2.0:2006-6, Thermoluminescence dosimetry systems for personal and environmental monitoring (2006)

IEC 60050-88, IEV: International Electrotechnical Vocabulary. Radiology and radiological physics. (1983)

ISO/ASTM 51707: Standard Guide for Estimating Uncertainties in Dosimetry for Radiation Processing (2005) E

ISO/IEC Guide 98-3, Guide to the expression of uncertainty in measurement (GUM). International Organization for Standardization (Geneva, Switzerland) (2008)

ISO/IEC Guide 99, International vocabulary of basic and general terms in metrology (IVM). International Organization for Standardization (Geneva, Switzerland) (2007)

3 Terms, definitions and abbreviations

3.1 Terms

This list comprises special terms of thermoluminescence dosimetry as well as more general terms, specified by pointed brackets, which have been adapted to thermoluminescence dosimetry. The enclosed notes contain additional information, e.g. referring to the rules and requirements of these standards, thereby enhancing their clarity.

3.1.1
Background value, M_0

<clinical TL dosimetry> INDICATED VALUE of a TLD SYSTEM during evaluation of a non-irradiated TL DETECTOR according to the OPERATING INSTRUCTIONS

NOTE A change of the BACKGROUND VALUE can be caused by a change of the TL INDICATING INSTRUMENT, by an insufficient PRE-IRRADIATION ANNEALING or by contamination of the DETECTOR.

3.1.2
Batch

<clinical TL dosimetry> Number of TL DETECTORS of the same type originating from the same manufacturing process and corresponding in their entirety both to the requirements defined in these standards and to the quality properties guaranteed by the manufacturer with regard to their RESPONSE, their INDIVIDUAL VARIATION and their NON-LINEARITY

3.1.3
Calibration

<clinical TL dosimetry> Determination of the correlation between the INDICATED VALUE of a TL DETECTOR and the conventional true value of the MEASURED QUANTITY, ABSORBED DOSE TO WATER, under REFERENCE CONDITIONS

NOTE The CALIBRATION serves to determine or check the CALIBRATION COFFICIENT. The conventional true value of the measured quantity is given by the MEASURED VALUE determined directly or indirectly with a primary standard.

3.1.4
Calibration coefficient
N_i

<clinical TL dosimetry> relation valid under REFERENCE CONDITIONS

$$N_i = \frac{D}{M_i - M_0} \quad (1)$$

In this equation, D is the conventional true value of the MEASURED QUANTITY, M_i-M_0 is the difference resulting from the INDICATED VALUE of a single TL DETECTOR *i* and the BACKGROUND VALUE.

NOTE Thus, the CALIBRATION COEFFICIENT is the reciprocal value of the RESPONSE under REFERENCE CONDITIONS.

3.1.5
Casing

Capsule, usualy made from PMMA of 1 mm front wall thickness and shaped as a flat circular cylinder, in which a small set of TL DETECTORS can be placed in the same plane.

NOTE The setup consisting of the DETECTORS and the CASING is the TL PROBE.

3.1.6
Conditioning of a batch
Conditioning

Multiple IRRADIATION and PRE-IRRADIATION ANNEALING of a BATCH of TL DETECTORS

NOTE Whether CONDITIONING is sufficient, is examined by the RE-USABILITY test according to paragraph 5.3.3

3.1.7
Correction factor

<clinical TL dosimetry> Factor applied to the INDICATED VALUE in order to compensate the measurement deviation caused by an INFLUENCE QUANTITY or by the MEASURED QUANTITY

NOTE Examples for using a CORRECTION FACTOR are the corrections for FADING, ENERGY DEPENDENCE and NON-LINEARITY (see paragraph 4.4.5).

3.1.8
Correction summand

Summand added to the INDICATED VALUE in order to compensate the measurement deviation caused by an INFLUENCE QUANTITY

NOTE The BACKGROUND VALUE is an example for corrections by using a CORRECTION SUMMAND (see paragraph 4.4.2).

3.1.9
Directional dependence

<clinical TL dosimetry> Dependence of the RESPONSE of a TL DETECTOR on the direction of radiation incidence

3.1.10
Direction of preference

Direction referring to the TL DETECTOR or TL PROBE, respectively, that is considered as a reference value for the direction of radiation incidence as an INFLUENCE QUANTITY

3.1.11
Energy dependence

Dependence of the RESPONSE of a TL DETECTOR to RADIATION QUALITY

3.1.12
Fading, *F*

Quotient of the alteration of the measured ABSORBED DOSE during the time interval between the end of the IRRADIATION and the evaluation, e.g. caused by the influence of ambient temperature, and the ABSORBED DOSE measured immediately after IRRADIATION

NOTE 1 FADING is expressed as a percentage

NOTE 2 The alteration of the measured ABSORBED DOSE may be positive (increment) or negative (decrement).

3.1.13
Fading rate
$\dot{F}$

FADING per time interval

3.1.14
Glow curve

<clinical TL dosimetry> MEASURED VALUE of the light emission of the TL DETECTOR as function of the temperature or time during the evaluation process

3.1.15
Indicated value
M

<clinical TL dosimetry> Numerical value of a parameter displayed by a TL indicating instrument (IVM)

NOTE 1 The INDICATED VALUE *M* for a TL DETECTOR is assessed from the GLOW CURVE by the TL INDICATING INSTRUMENT (see paragraph 4.3.8.3). The MEASURED VALUE of the DOSE is determined from the INDICATED VALUE by applying the CALIBRATION COEFFICIENT, the correction factors and the CORRECTION SUMMANDS (see paragraph 4.4).

NOTE 2 The INDICATED VALUE is also termed the reading of the TL INDICATING INSTRUMENT.

3.1.16
Individual variation of the response
Individual variation

Deviation of the RESPONSE of single TL DETECTORS from the mean RESPONSE of a BATCH of TL DETECTORS under identical irradiation and evaluation conditions

3.1.17
Influence quantity

<clinical TL dosimetry> A quantity which is not a MEASURED QUANTITY but nevertheless influences the RESULT OF A MEASUREMENT (IVM)

NOTE 1 INFLUENCE QUANTITIES can develop influences as external disturbances (temperature, humidity, line voltage etc.), as properties inherent to the instrument, i.e. caused by the instrument itself (zero drift, aging of the system components, STABILIZING TIME etc.) or as adjustable quantities affecting the result of the measurement (e.g. RADIATION QUALITY or direction of radiation incidence during DOSE measurement)

NOTE 2 The correction of the impact of an INFLUENCE QUANTITY may require the application to the INDICATED VALUE of a CORRECTION FACTOR (multiplicative INFLUENCE QUANTITY, e.g. FADING) or of a CORRECTION SUMMAND (additive INFLUENCE QUANTITY, e.g. BACKGROUND VALUE)

NOTE 3 If an INFLUENCE QUANTITY is not taken into account by applying a CORRECTION FACTOR or a CORRECTION SUMMAND, the CORRECTION FACTOR is set equal to one, or the CORRECTION SUMMAND is set equal to zero, respectively

3.1.18
Measured quantity

<clinical TL dosimetry> Physical quantity to be determined by the MEASURING SYSTEM

NOTE According to ICRU 62, the MEASURED QUANTITY in clinical dosimetry is the ABSORBED DOSE TO WATER at the POINT OF MEASUREMENT

3.1.19
Measured value of a TLD system
Measured value

<clinical TL dosimetry> Value of the MEASURED QUANTITY ABSORBED DOSE TO WATER determined with a TLD SYSTEM at the POINT OF MEASUREMENT

NOTE The MEASURED VALUE is determined as the product of the correction factors and the mean of the INDICATED VALUES of the single TL DETECTORS, located at and irradiated together at the same time in the TL PROBE, corrected for the BACKGROUND VALUE and multiplied by the individual CALIBRATION COEFFICIENT

3.1.20
Measurement cycle

Sequence of working steps in TL dosimetry, consisting of PRE-IRRADIATION ANNEALING, IRRADIATION, POST-IRRADIATION ANNEALING and evaluation of a TL DETECTOR

3.1.21
Measuring range

<clinical TL dosimetry> Range of DOSE values in which the TLD SYSTEM meets the requirements on the operation characteristics

NOTE The limits of the measuring range of a TLD SYSTEM are lying within the interval spanned by the smallest and the highest MEASURED VALUE.

3.1.22
Non-linearity

<clinical TL dosimetry> Change of the RESPONSE in dependence on dose

NOTE Linearity means constant RESPONSE, supra-linearity designates an increase of the RESPONSE, sub-linearity a decrease of the RESPONSE with increasing DOSE.

3.1.23
Parameters for tests

Values of INFLUENCE QUANTITIES agreed-upon for testing the impact of other INFLUENCE QUANTITIES

3.1.24
Point of measurement

<clinical TL dosimetry> The point on or in the PATIENT's body or water PHANTOM, at which the ABSORBED DOSE TO WATER is measured