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Dosimetry with radiophotoluminescent glass dosimeters for dosimetry audit in MV X-ray radiotherapy

Dosimétrie avec dosimètres radiophotoluminescents de type verre utilisée pour l'audit dosimétrique en radiothérapie à rayons X de haute énergie

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Foreword

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This document was prepared by Technical Committee ISO/TC 85, *Nuclear energy, nuclear technologies, and radiological protection*, Subcommittee SC 2, *Radiological protection*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

A radiophotoluminescent glass dosimeter (RPLD) is a cumulative radiation dosimeter usually made of silver-activated phosphate glass. The silver atoms act as radiophotoluminescence (RPL) centres excited by ionizing radiation. The number of RPL centres excited is proportional to the absorbed dose to the RPLD. Since the first RPLD was produced in 1949, improvements have been made to the reading precision and reliability[1]. The latest products, rod-like dosimeters of a few millimetres in size, measure the absorbed dose that can be evaluated with an uncertainty of about 1 % to 2 % (k = 1) in certain conditions[2] to [5]. The RPL centres do not disappear after readout. Therefore, repeated readouts for a single exposure is possible. The results are stable and good accuracy of the signal readouts is possible. In addition, since the RPL centres once formed are hardly affected by fading, it is suitable in long-term dose measurement with retention capacity. RPLDs can be reused by annealing at high temperature.

RPLDs have been widely used for personal dosimetry and environmental radiation measurements[6] to [7].They are also used for radiation dose assessment of patients and staff in the field of radiation medicine, including interventional radiology, external radiotherapy, and brachytherapy[8] to [21]. Due to their advantages of compactness, repeatable readout, good precision, and small fading, RPLDs have been recently used as a dosimeter for dosimetric external audits in external radiotherapy with high-energy X-rays[22] to [27]. Thermoluminescent Dosimeter (TLD) and optically stimulated luminescent dosimeter (OSLD) have also been used for the audits. The three dosimeters, RPLD, TLD, and OSLD, are passive solid-state dosimeters and have some similar characteristics. However, there are variations in the handling, reading methodology, and dose evaluation, including tissue-equivalency.

This document focuses on the RPL dosimetry from the viewpoint of the dosimetry audit in MV X-ray radiotherapy highlighting the procedures for handling, reading, and corrections to the response dependency of beam quality and dose.

Dosimetry with radiophotoluminescent glass dosimeters for dosimetry audit in MV X-ray radiotherapy

1 Scope

This document specifies the dose assessment method when an RPLD is used for dosimetry audit in external high-energy X-ray beam radiotherapy.

The dosimetry for electron beams and X-ray beams of stereotactic radiotherapy, gamma-ray of brachytherapy is not included in this version.

This document addresses RPLD handling, measurement method, conversion of measured value to dose, necessary correction coefficient, and the performance requirements for RPLD systems, including the reader.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC Guide 98-3, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
absorbed dose
energy that is imparted to matter in a sufficiently small volume element by ionizing radiation divided by the mass of that volume element

3.2
background value
$M_{0,i}$
indicated value (3.11) by a non-irradiated *RPLD detector* (3.25) according to the instruction manual

3.3
batch
number of *RPLD detectors* (3.25) of the same type, which originate from the same manufacturing process, and correspond in their entirety to both the requirements defined in this document and the quality properties guaranteed by the manufacturer with regard to their response, *individual dosimeter sensitivity correction* (3.12), and *nonlinearity* (3.18)

3.4
calibration
operation that, under *reference conditions* (3.29), in a first step, establishes a relation between the quantity values with measurement uncertainties provided by measurement standards and corresponding indications with associated measurement uncertainties and, in a second step, uses this information to establish a relation for obtaining a measurement result from an *indicated value* (3.11) of an *RPLD detector* (3.25)

3.5
calibration coefficient
$N_{\mathrm{D,r}}$
relation valid under *reference conditions* (3.29)

$$N_{D,\mathrm{r}} = \frac{D_{\mathrm{w,Q_0}}}{M_{\mathrm{Q_0,r}} SCF_{\mathrm{r}} - M_{0,\mathrm{r'}} SCF_{\mathrm{r'}}}$$

where

$D_{\mathrm{w,Q_0}}$	is the conventional true value of the *measured quantity* (3.14);
$M_{\mathrm{Q_0,r}}$ and $M_{0,\mathrm{r'}}$	are the mean values of *indicated values* (3.11) of a single *RPLD detector* (3.25) of element ID r and r′ for several *sessions* (3.33), or irradiated and unirradiated element respectively;
SCF_{r} and $SCF_{\mathrm{r'}}$	are the *individual dosimeter sensitivity correction* (3.12) factors.

Note 1 to entry: The *calibration coefficient* (3.5) is the reciprocal value of the response under *reference conditions* (3.29).

3.6
casing
capsule, usually made from resin (e.g. acrylonitrile butadiene styrene) of a suitable thickness and shaped as a columnar pipe or tube, into which a small *RPLD detector* (3.25) can be placed

3.7
correction factor
factor applied to the *indicated value* (3.11) in order to compensate for the measurement deviation caused by an influence quantity or the *measured quantity* (3.14)

Note 1 to entry: Examples of using a *correction factor* (3.7) are the corrections for *energy dependence* (3.10) and *nonlinearity* (3.18).

3.8
directional dependence
dependence of the response of an *RPLD detector* (3.25) on the direction of radiation incidence

3.9
direction of preference
direction that refers to the *RPLD detector* (3.26) and is considered as a reference value for the direction of radiation incidence as an influence quantity

3.10
energy dependence
dependence of the response of an *RPLD detector* (3.25) on the *radiation quality* (3.23)

3.11
indicated value
$M_{\mathrm{raw},i}$
displayed value by an *RPLD-indicating instrument* (3.27) of the *i*-th RPLD, which is the mean value of repetitive reading values by pulse laser irradiation

Note 1 to entry: The *measured value* (3.15) of the dose is determined from the *indicated value* (3.11) by applying the *calibration coefficient* (3.5), *correction factor* (3.7), and correction summand (see Clause 5).

Note 2 to entry: The *indicated value* (3.11) is also termed the reading of the *RPLD-indicating instrument* (3.27).

3.12
individual dosimeter sensitivity correction
SCF_i
deviation of the response of a single *RPLD detector*, *i*, (3.25) from the mean response of a *batch* (3.3) of *RPLD detectors* (3.25) under identical irradiation and evaluation conditions

3.13
internal calibration glass
internal calibration glass with a constant RPLD luminescence intensity, used for operation checks for the *RPLD-indicating instrument* (3.27) (except for the heating device)

3.14
measured quantity
physical quantity to be determined by the measuring system

Note 1 to entry: According to ICRU 62, the measured quantity in clinical dosimetry is the *absorbed dose* (3.1) to water at the *point of measurement* (3.20).

3.15
measured value
value of a *measured quantity* (3.14), *absorbed dose* (3.1) to water, determined by an *RPLD system* (3.26) at the *point of measurement* (3.20)

Note 1 to entry: The *measured value* (3.15) is determined as the product of the *correction factors* (3.7) and the mean of the *indicated values* (3.11) of the single *RPLD detectors* (3.25) that has been corrected for the background value (3.2), and then multiplied by the *calibration coefficient* (3.5).

3.16
measurement cycle
sequence of working steps in RPLD dosimetry, consisting of *pre-irradiation annealing* (3.22), irradiation, *pre-heat* (3.21), and evaluation of *RPLD detectors* (3.25)

3.17
measuring range
range of dose values in which the *RPLD system* (3.26) meets the requirements for the operation characteristics

Note 1 to entry: The limits of the measuring range of an *RPLD system* (3.26) are within the interval spanned by the smallest and the largest *measured values* (3.15).

3.18
nonlinearity
dependence of the change in response on dose

Note 1 to entry: Linearity means a constant dosimeter sensitivity on dose; supralinearity denotes an increase in dosimeter sensitivity with increasing dose; sublinearity denotes a decrease in dosimeter sensitivity with increasing dose.

3.19
parameters for tests
values of influence quantities that are agreed upon for testing the impact of other influence quantities

3.20
point of measurement
point on or in a phantom at which the *absorbed dose* (3.1) to water is measured

3.21
pre-heat
controlled heat treatment for an *RPLD detector* (3.25) after irradiation and before evaluation

Note 1 to entry: Pre-heat serves to stabilize the RPLD luminescence intensity.

3.22
pre-irradiation annealing
controlled heat treatment for an evaluated *RPLD detector* (3.25) before reuse

Note 1 to entry: Pre-irradiation annealing serves to delete the radiation-induced RPLD signal remaining after evaluation, and to approximately restore the original response.

3.23
radiation quality
parameter for the classification of the relative spectral particle fluence of a radiation type at a specified location

Note 1 to entry: In clinical dosimetry, a simply measurable parameter, such as the quality index of a photon radiation, is used for the characterization of radiation quality[28].

3.24
radiophotoluminescence
RPL

light emission in the visible range or an adjacent spectral range, which is based on the radiation-induced occupation of trapping centres by the charge carriers of certain ion crystals, and occurs when these charge carriers transit into activator levels as a consequence of UV excitation

3.25
radiophotoluminescent glass dosimeter detector
RPLD detector
detector
quantity of RPLD material of a certain chemical composition in a homogeneous matrix, e.g., silver-activated phosphate glass

Note 1 to entry: The properties of an *RPLD detector* (3.25) are determined by its material composition, mass, and shape.

3.26
radiophotoluminescent glass dosimeter system
RPLD system
system consisting of a number of *RPLD detectors* (3.25) and, if necessary, the supporting instruments, the instruction manual containing the descriptions of the evaluation procedures, and the calibration instructions for the *RPLD system* (3.26)

3.27
radiophotoluminescent glass dosimeter -indicating instrument
RPLD-indicating instrument
instrument for measuring the intensity of the luminescence emitted by an *RPLD detector* (3.25)

Note 1 to entry: The instrument is equipped with devices for exciting the *RPLD detector* (3.25) with UV light, for recording the intensity of the RPLD luminescence emitted by the *RPLD detector* (3.25), and for indicating a measurement signal proportional to the emitted light intensity.

Note 2 to entry: The *RPLD-indicating instrument* (3.27) is also called the reader.

3.28
rated range of use
variation range of an influence quantity that causes a change in response, and does not lead to a transgression of agreed upon values of the measurement deviation, or to a transgression of defined values of the correction of its influence

3.29
reference conditions
set of reference values of all influence quantities and the *measured quantity* (3.14)

Note 1 to entry: If one or more influence quantities or the *measured quantity* (3.14) deviate from their reference values, the measurement conditions are denoted as non-reference conditions.

3.30
reference point of detector
point located within or on the surface of an *RPLD detector* (3.25) whose spatial coordinates serve to specify its position respective to its surroundings

Note 1 to entry: The position of the reference point within or on the *RPLD detector* (3.25) is defined by the manufacturer. In dose measurements, the reference point of an *RPLD detector* (3.25) is placed at the *point of measurement* (3.20) either on or in the phantom. For *calibration* (3.4), the reference point of an *RPLD detector* (3.25) is placed at a point where the *absorbed dose* (3.1) to water under *reference conditions* (3.29) is known.

3.31
reference RPLD
RPLD detector (3.25) used to determine the *correction factor* (3.7) for the change in response during successive *measurement cycles* (3.16)

Note 1 to entry: See 4.7.4.

3.32
reusability
usability of *RPLD detectors* (3.25) in several successive *measurement cycles* (3.16)

3.33
session
single sequential reading of an *RPLD system* (3.26)

Note 1 to entry: A *session* (3.33) reading is expressed as $M_{\mathrm{raw},i}$ (3.11) and the mean value of the several *sessions* (3.33) of element ID i is expressed as M_i.

3.34
uncertainty of measurement
parameter obtained by measurement or calibration, which, together with the *measured value* (3.15), marks the value range where the true value of the *measured quantity* (3.14) lies

Note 1 to entry: The *uncertainty of measurement* (3.34) is the positive root obtained from the sum of the squares of the standard uncertainties, for all uncertainty components.

4 Rules for the RPLD handling/reading procedure

4.1 Principle of measurement

Most common RPLDs consist of silver-activated phosphate glass. Ionizations produced by external radiation generate RPL centres. The number of RPL centres is directly proportional to the number of generated ion pairs, as well as to the absorbed dose. The quantity of RPL centres can be determined by exciting them with a pulse type ultra-violet laser. In order to take advantage of the repeatable readout characteristics of RPLD, a pulse laser is used instead of a continuous wave laser. The RPLD emits visible orange light immediately after this excitation. Since the energy state of the RPL centres are maintained after the light emission, the RPL can be read repeatedly after the first reading.

