properties of the BeOSL dosimetry system in the framework of a large scale personal monitoring service

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Received month date year, amended month date year, accepted month date year

The Individual Monitoring Service of the Helmholtz Zentrum München is currently using the BeOSL dosimetry system for monitoring approx. 15000 persons per month. This dosimetry system has a modular structure and represents a complete new concept on handling dosimeters in a large scale dosimetry service. It is based on OSL (optically stimulated luminescence) dosimeters made of beryllium oxide (BeO). The dosimetric and operational properties of the system are shown and discussed.

Introduction

The working group Radiation Physics of the Technical University in Dresden has developed a new OSL (optically stimulated luminescence) dosimetry system which is based on beryllium oxide as detector material. In 2011 this dosimeter system has been introduced as official personal dosimeter in Germany by the individual monitoring service (AWST) of the Helmholtz Zentrum München. The 2-element version of the dosimeter within a blister package is officially named AWST-OSL-GD 01 and holds the type approval 23.52/11.01 of the Physikalisch-Technische Bundesanstalt (PTB). The AWST is currently (2015) monitoring 15000 occupational exposed persons with this dosimeter type. It is planned to increase this number up to 50000 until end of 2016.

The brand name of the dosimeter system is BeOSL. Dosimetrics GmbH, which is a spinoff of the Helmholtz Zentrum München, covers production, marketing, sales and technical support of the system.

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Structure of the dosimeter

The BeOSL dosimeter consists of OSL detectors made of beryllium oxide (BeO). Because the detectors are produced in sintered form they are insensitive against mechanical or environmental impact.This beryllia ceramic, in solid form and as contained in the BeOSL dosimeter, presents no special health risk.

BeO chips are widely used in electronic devices because of the high thermal conductivity of this material. BeOSL dosimeters use square chips with a thickness of 0.5 mm and an edge length of 4.7 mm.

Figure 1 shows the structure of the BeOSL dosimeter. The cover and the detector card mainly consist of ABS (acrylonitrile butadiene styrene). Detector 1 behind the "open window" is filtered by 0,5 mm (54 mg/cm2) ABS**.** This detector is used to measure *H*p(0,07). Detector 2 for measuring *H*p(10) is covered by 0,1 mm ABS of the dosimeter cover and an additional Teflon filter with a thickness of 2.35 mm, which results in a total filtration thickness of 616 mg/cm2. Due to its effective atomic number of Zeff = 7.14, BeO can be qualified as nearly tissue equivalent for dosimetric purposes. Therefore detector 2 is sufficient to fulfil the requirements of IEC 62387-11) for *H*p(10) in the energy range between 16 keV and 7 MeV.

Figure 1. Structure of a BeOSL 2-element-dosimeter.

Both detectors are mouldedinside a detector card. The card has a unique number, which is applied at one side as inverted barcode and at the other side as plain number. It is also possible to mount a RFID chip on the card as supplementary option.

The black dosimeter cover is lightproof to protect the detectors against erasing by sunlight. The structure is symmetric with identical filtration on both sides. The 2-element-dosimeter contains no metal filters.

Another dosimeter version contains two additional detectors with filters made of copper or a sandwich of lead with low content of 210Pb and tin. A linear combination is used to calculate *H*p(10) from the four element values (see Figure 2e). This flattens the energy response and delivers some additional information on the radiation quality. Higher production costs are mainly responsible for the fact that this dosimeter version is currently used by a single dosimetry service only.

The most important dosimetric properties are shown in Figure 2 for a blank dosimeter without additional packaging. Figures 2a – 2c are related to detector 2 (behind a Teflon filter), whereas Figure 2d refers to detector 1 behind the "open window". Figures 2b – 2d show the detector response, which is defined as indicated value *G* divided by the conventional true value *C* according to section 3.36 of IEC 62387-11). Figure 2e shows the dosimeter response *M / C*, where *M* is a linear combination of 4 detector values *G*. All detectors have an individual calibration factor, which is determined by the manufacturer with 137Cs, which is the reference point for the energy response.

Fig. 2: Dosimetric properties of the BeOSL dosimeter:

1. coefficient of variation for *H*p(10),
2. linearity for *H*p(10),
3. energy and angular response for *H*p(10),
4. energy and angular response for *H*p(0.07),
5. energy and angular response for *H*p(10), 4-element-dosimeter.

In Germany, the 2-element-dosimeter type AWST-OSL-GD 01 holds the PTB type approval 23.52/11.01 for the operational quantity *H*p(10) for photon radiation in the energy range from 16 keV to 7 MeV. To minimize the handling efforts at customer's site, the dosimeters are welded in a blister package to protect them against damage and pollution. A label on the front side shows personalized data (company, person, monitoring period etc.). The blister foil at the front side has a thickness of 0.25 mm and therefore modifies the energy response for lower X-ray energies. Consequently, the PTB type approval comprises the blister package, which also prevents the user from extracting the detector card from the cover, because sunlight can erase the dose information.

Figure 3: BeOSL dosimeter:

1. standard version with attachment clip,
2. plugged in an optional, colored carrier frame.

Evaluation SysteM

Hardware modules

The BeOSL evaluation system has a modular structure which enables the user to scale it to its own requests.

The main components are a reader for dose evaluation, an eraser for erasing the residual signal and an irradiator for verifying the individual dosimeter calibration factors.

The principal structure of a reader is shown in Figure 4. The reader has a drawer for loading a dosimeter by an operator or by a robot. By closing the drawer the detector card is extracted from the cover. Stimulation and reading of the luminescence light are performed from opposite sides of the detector, so that short distances can be achieved between stimulation source, dosimeter and light sensor to reduce external influences. The BeO chips are stimulated from below using intensive blue (455 nm) light emitting diodes. The small UV part of the LED emission is removed by simple UV absorption foils. Optical filters in front of the photo sensor module avoid light of the stimulation diodes from reaching the photomultiplier, which are placed above the drawer. Details of the measurement method are described in Ref. 2) and 3).

Figure 4: Principal structure of a BeOSL reader.

Figure 5 shows a decay curve of the luminescence light, which has a nearly exponential form. Stimulation with blue light is performed continuously over several time periods4). The effective stimulation time amounts 0.5 sec and this causes a signal loss of only 3%. Therefore repeated measurements, e.g. for the validation of a measurement are possible.

Figure 5: Decay curve of the OSL luminescence light.

The eraser has a similar structure as the reader, but the intensity of the emission light is much higher to enable a fast erasing process, which lasts 15 seconds on average.

The irradiator contains four 90Sr sources with a total activity of 80 MBq to irradiate the detectors from both sides for checking the individual calibration factors of the detectors on a regular basis.

The BeOSL readout system can be operated with individual modules or the modules are used as components of a workstation with a robot system. The basic BeOSL system consists of a reader and an eraser, which are operated manually.

A BeOSL workstation mainly consists of a table with a robot handling system inside of a safety cabinet. Up to five different evaluation modules can be placed on the countertop of the table.

The standard configuration which is operated by the AWST consists of 2 readers, 2 erasers and 1 irradiator. This configuration provides a great flexibility for the adaptation of the evaluation process to the internal processes of the monitoring service.

Reading and erasing can be performed in a complete process, which comprises the steps: reading the dose signal *ML*, erasing, reading the residual zero signal *M0*. At the end of this process the dosimeters are thrown out with the status "ReadyForWearing". The average duration of this process amounts 20 s and therefore approx. 180 dosimeters can be evaluated per hour with one workstation in its standard configuration with 2 readers and 2 erasers.

Another adaptation executes the first step only, reading of the dose signal *ML*. This adaptation is used for enabling a high throughput in a short period (375 dosimeters per hour with 2 readers), while the erasing process can be carried out later in a separate step.

Software

Each hardware module is operated by a dedicated software module: ReaderControl, EraserControl or IrradiatorControl. ReaderControl, which calculates the dose values, fulfils the requirements of the WELMEC software guide, version 7.2, issue 45) for an instrument type U under risk class C. ReaderControl controls a reader by consuming its firmware protocol via a direct USB connection. It offers services for device control and measurement via a web service interface. ReaderControl generates indicated measurement result values that are securely signed for protection against manipulation and for authenticity. All three modules communicate with a master program, the BeOSL ControlSystem*,* which controls the modules and stores all data in a database system. There exist two versions of the BeOSL ControlSystem. The basic version is used for managing manually operated systems consisting of individual stand-alone modules and has an extremely intuitive GUI (graphical user interface) to provide the operator with current information on the status of the evaluation process and on the next required step, e.g. to feed the eraser with the dosimeter.

The full version of the BeOSL ControlSystem can manage one or several workstations simultaneously. It is possible to control all workstations of the dosimetry service from one PC remotely. All steps are carried out automatically by the robot and several dosimeters are processed simultaneously. It is not necessary to wait for the completion of a dosimeter evaluation before the evaluation of another dosimeter can be started. It is therefore possible to scale the dosimetry system from a few thousands dosimeters per month with one workstation to a principally unlimited number with several workstations.

Each evaluation process is starting by feeding a dosimeter to the reader. After reading the barcode the status is checked by sending the number to the BeOSL ControlSystemwhich makes a decision on the next step, which may be erasing instead of reading.

Operational features

Contrary to most of other commercially available readout systems BeOSL dosimeters can be processed as bulk material in large boxes and not as single dosimeters in magazines. This provides unequaled advantages for larger dosimetry services, for automation and optimizing the complete dosimeter processing. The AWST has chosen additional components such as blister and deblister machines that fully support the bulk material concept of the BeOSL system.

summary and outlook

The BeOSL dosimetry system has been running in the AWST for four years and has proven its superior design concept. It is planned to develop a thin layer detector to extend the BeOSL dosimetry system for measuring *H*p(0,07) with extremity dosimeters and *H*p(3) with eye lens dosimeters for photon and beta radiation.

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