INTRODUCTION OF A NEW DOSIMETRY SYSTEM BASED ON OPTICALLY STIMULATED LUMINESCENCE (OSL) IN OUR PERSONAL MONITORING SERVICE

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Abstract

The personal monitoring service named 'Auswertungsstelle' is part of the Helmholtz Zentrum München, a non-profit-making research center in Germany. As one of the four monitoring services in Germany, we have been a reliable partner in radiation protection for more than 60 years. With about 1.9 million dose assessments per year, we are the largest monitoring service in Europe**.** For dozens of years, our main dosimeter used in whole-body dosimetry has been a film dosimeter. Although its dosimetric properties are still up to date, film dosimetry won't be a sustainable technique for the use in monitoring services. Therefore, a project with the objective of investigating alternative dosimetric materials and methods was launched in the late 1990s at the Helmholtz Zentrum München. Based on this research work, the use of BeO as an OSL dosimeter was studied by the radiation physics group of the TU Dresden, by order and on account of the 'Auswertungsstelle' at the Helmholtz Zentrum München. It was shown, that ceramic BeO features promising dosimetric properties, making BeO detectors particularly suitable for being used in all applications in whole-body dosimetry measuring photons. Ceramic BeO material has an excellent resistance to environmental influences. The BeO chips are almost tissue equivalent. Therefore, these detectors show low photon energy dependence. A new personal dosimetry system based on the OSL dosimetry of BeO was developed. Applying this system, the 'Auswertungsstelle' offers OSL-dosimeters for official

monitoring of the Personal Dose Equivalent $H_p(10)$ since 2011. This OSL-System is accredited according to DIN IEC 62387 and we obtained the corresponding type-approval by the PTB, the national metrology institute in Germany. Sophisticated logistics was developed and installed. High degree of automation was achieved by robots for dosimeter assembly and machines for packing, labelling and unpacking of the dosimeters. To become a sustainable dosimetry system not only appropriate dosimetric properties and perfect logistics are required. The new OSL system needs to be well established in personal dosimetry in order to ensure substantial maintenance and further development of the system. As at January 2014, already six monitoring services scattered all over the world are carrying out personal dosimetry using these OSL-Systems. According to respective national regulations both personal dose equivalents $H_p(10)$ and $H_p(0.07)$ can be measured.

To meet that essential target to continuously increase the market share, a subsidiary company called Dosimetrics was launched in 2013 with the objective of performing the related commercial business, such as promotion and selling as well as ensuring further development and maintenance of the OSL-system.

Keywords: Optically stimulated luminescence, personal monitoring service, whole-body dosimetry, beryllium oxide

1. INTRODUCTION

Our personal monitoring service, called the "Auswertungsstelle", is part of the Helmholtz Zentrum München, German Research Center for Environmental Health, which is a public, non-profit-making research center. Currently, we are monitoring more than 150.000 people. Since the beginning in the early 1950s, our main dosimeter used in whole-body dosimetry has been a film dosimeter. These film dosimeters have been continuously improved. Still up to date relating to dosimetric properties, film dosimetry isn't a future technology. The production of appropriate dosimetric films might be stopped in some years. Therefore, a project with the objective of developing a sustainable dosimetry system was launched in the late 1990s at the Helmholtz Zentrum München. In doing so, the OSL properties of beryllium oxide (BeO) were investigated by Bulur and Göksu [1998]. Based on this work, the use of BeO as an OSL dosimeter was studied by the radiation physics group of the University of Dresden, by order and on account of the Helmholtz Zentrum München. The ceramic BeO material indicates excellent dose characteristics, such as dose linearity, energy response and an excellent resistance to environmental influences.

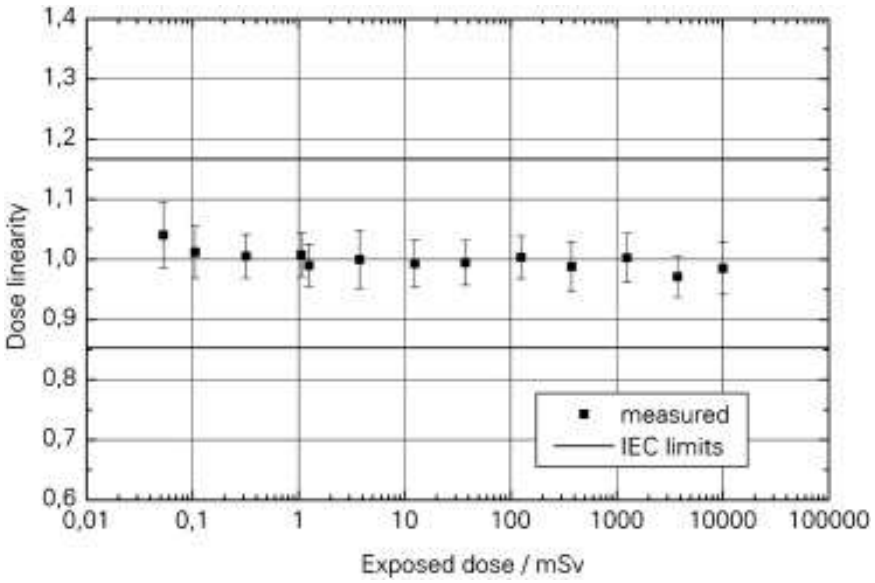

Figure 1: Linearity of dose characteristics [Sommer et al. 2011]

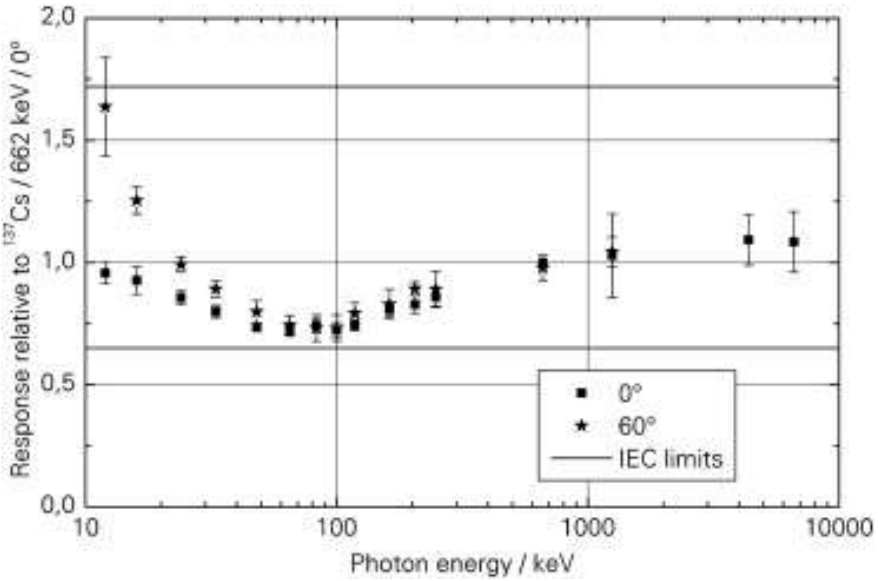

Figure 2: Energy response of the OSL dosimeter [Sommer et al. 2011]

The BeO chips are almost tissue equivalent. Therefore, these detectors show low photon energy dependence. Hence BeO detectors are particularly suitable for being used in all applications of whole-body dosimetry measuring photons [Sommer and Henninger 2006; Sommer et al. 2007; Sommer et al. 2008]. Finally, a new personal dosimetry system for measuring $H_p(10)$ and $H_p(0.07)$ photon dose based on OSL using BeO has been developed

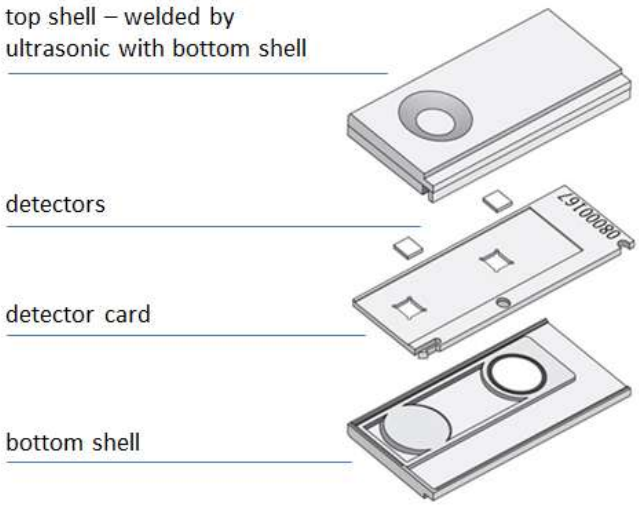

Figure 3: sketch of the dosimeter case (lightproof)

by TU Dresden, Helmholtz Zentrum München und IBA Dosimetry GmbH, Schwarzenbruck [Sommer et al. 2011]. This OSL-System is accredited according to DIN IEC 62387. The

OSL dosimeter consist of a light-tight dosimeter sheath of which the upper shell and the lower shell are ultrasonically welded, the detector card being located in the middle of the two shells. Two detector chips based on BeO are attached to the detector card.

1.1. Technical requirements

The OSL-System presented by Sommer et al [2011] is accredited according to DIN IEC 62387 and hence compliant to the essential dosimetric requirements for official personal dosimetry. In order to receive the mandatory PTB-type approval, further steps needed to be carried out. The attention was turned to data security, quality management (QM) and manipulation safety.

Routine operation of the OSL system demands a high degree on automation as well as excellent logistics.

1.2. Economic and political frame

Next to technical and dosimetric requirements, basic conditions for a new, sustainable dosimetry system were defined. The new dosimetry system needs to be well established in the world of personal dosimetry after some time in order to ensure maintenance and continuous system updates. Introducing a new dosimetry system, we want to maintain a high level of independence and carry weight in further development.

Up to now, in Germany there exists a strong regional allocation of customers in the field of official personal dosimetry, there is no competition and any personal monitoring service in Germany is a public, non-profit making facility. These conditions may change in the future.

The objective of this work was to engineer and introduce a sustainable dosimetry system in our personal monitoring service und thus being well positioned to face changing business conditions in the future.

2. PROCEDURE

2.1. Type approval by the PTB

To be offered as an official dosimeter, any personal dosimeter needs a type-approval by the PTB, the national metrology institute in Germany. The dosimetric requirements are already covered by IEC 62387-1. In addition, the PTB is looking for data security, quality management (QM), manipulation safety and more. Being the responsible individual monitoring service, we have been in charge of applying for the PTB type approval. In doing so, further development work was necessary. To avoid unrecognized manipulation by bleaching of the OSL detectors, the use of a blister packaging of the OSL dosimeter was instructed.

Besides other software adaptations, a QM – module was commissioned in order to ensure mandatory data security. This software module is checking the sensitivity of the measuring PM-tube as well as the blue stimulation LEDs. If any parameter is out of range, the QM – module is sending a message to the operator, who might start a readjustment of the reader.

2.2. Peripheral devices and logistics

Obtaining a type approval is the basic requirement for any dosimetry system for being used in official dose monitoring. Nevertheless, further steps have to be taken, before doing official dose monitoring. Besides the correct dosimetry, logistics is a main challenge of doing official personal dosimetry.

As the PTB type approval requires a blister packaging in order to avoid unrecognized manipulation of the OSL-dosimeters, packing and unpacking of the dosimeters became necessary. In order to achieve a high degree of automation, we required that work to be carried out by machines.

To do personal dosimetry, any personal dosimeter has to be assigned to the appropriate wearer. The goal to be achieved was a labelling of the dosimeter, including name and title of the wearer, his personal ID, the customer name and ID, the dosimeter ID and the wearing

period. To reuse the dosimeter, the label has to be easily removable. Also this labelling is required to be done automatically.
For shipping the dosimeter, a reusable tray with a fixed position for each dosimeter was demanded.

2.3. Sustainability

To ensure the sustainability of the BeOSL-System, it is essential to establish the system in the market of personal dosimetry. Running just one of very few dosimetric systems, sooner or later no further development of the system or maintenance will be offered. We had to learn that, running four glass dosimetry systems. All over the world, only five of these systems have been sold. After many years of satisfactorily operating our glass systems, we were forced to shut down these systems in 2011. No spare parts, no more updates or maintenance have been available. For not running into the same situation again, it is of great importance to spread the BeOSL system.
Initially, we turned our attentions to cooperation with an industrial partner. Together we succeeded in generating some requests, but the promotion of the OSL system was nonsatisfying for us and finally we finished the cooperation. As we believed that a cancelation of the requests would be very obstructive concerning the future of the OSL-system, we had to find a prompt resource. Transitional, we carried on negotiating with interested parties. Concurrently, the launching of a subsidiary company was forced with the objective of performing the commercial business, such as promotion and selling as well as ensuring further development and maintenance of the OSL-system.

3. The Status Quo

In the year 2011, our Personal Monitoring Service introduced an OSL dosimetry system, called BeOSL, for official monitoring of the Personal Dose Equivalent $H_p(10)$. Meanwhile 60 customers with close to 15.000 people are monitored, using OSL dosimeters. The system is completely integrated in our routine processes.

To ensure sustainability of this OSL system, a subsidiary company, called Dosimetrics, was hived off in the year 2013, in order to perform that business, as we are not allowed to do it being a non-profit-making facility. The principle tasks of Dosimetrics are to maintain and to enhance the OSL system and to establish the system on the market.

3.1. The BeOSL dosimetry system of the "Auswertungsstelle"

Currently, our OSL system consists of four tables with overall eight readers, eight erasers and two irradiators. Two of the four tables are running in routine operation. At each table the dosimeter assembly is handled by robotics. A high degree of automation was reached. The loading capacity per table is 5.000 dosimeters. The systems can be running day and night, up to 50 hours without intervention of operator, doing 3.500 readouts per day and table.

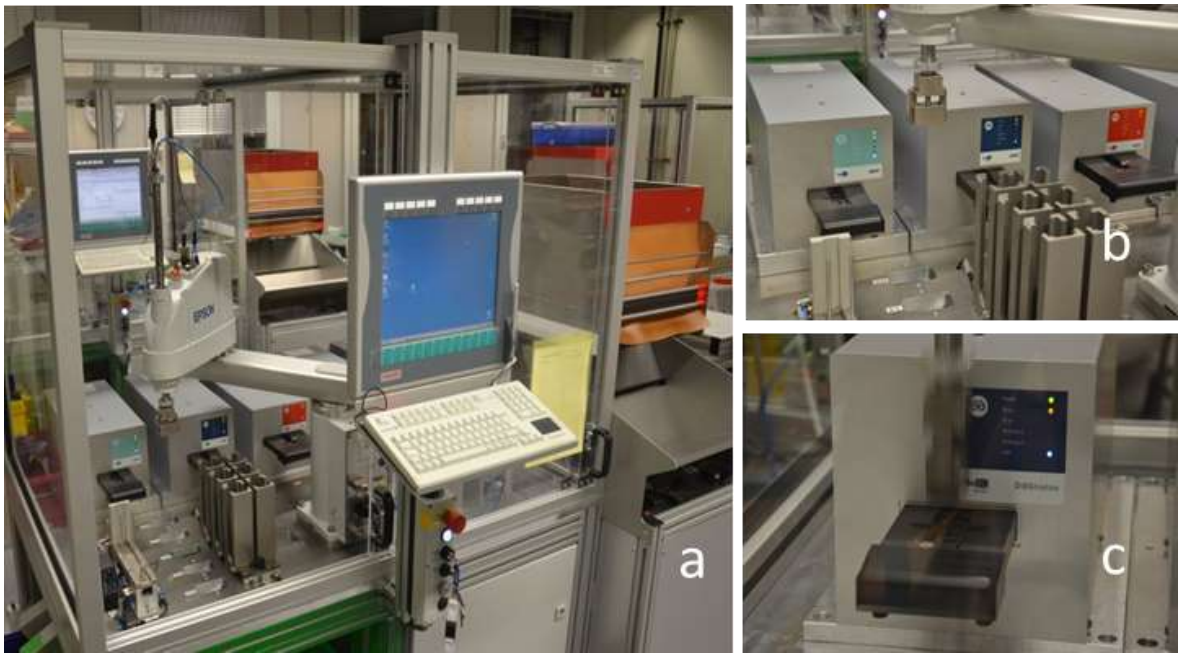

Figure 4: BeOSL system, a: table with robot, 2 readers, 2 erasers and 1 irradiator;
b: reader, eraser and irradiator in detail; c: assembly of the reader

The PTB type approval requires a packing of the dosimeter in order to avoid unrecognized manipulation of the dosimeter. In addition packing will protect the dosimeter from environmental impacts, such as contamination with dirt or radioactive matter. Inspired by

food manufacturing industry, we installed a blister packing machine. The throughput is 1.500 dosimeters per hour. The packing machine is filled with dosimeters as loose cargo, its output are blistered and labelled dosimeters in shipping trays. The label includes the following data: name and title of the wearer, personal ID, customer name and customer ID, dosimeter ID and the wearing period. If required by the customer, also the name of a department can be printed. The dosimeter ID is also printed on the label using 2D data matrix code.

Figure 5: packing; a: overview; b: blister package; c: printing the labels

The dosimeters are shipped in reusable trays. Each tray can be filled with 25 dosimeters. The dosimeter position in the tray is angled in a way that all wearer names are readable at first sight. After taking out random dosimeters, all other dosimeters will remain in fixed position, which means a practical advantage for many radiation safety officers of customers. When getting them back from our customers, the dosimeters have to be separated from the blister package. This is done by an unpacking machine. The blistered dosimeters are filled in as loose cargo, the output are unpacked dosimeters separated from the dissected blister. The throughput of the unpacking machine is 2.000 dosimeters per hour. Shredding of the blister waste ensures data privacy by destroying the link between wearers name and the corresponding dosimeter ID, visible on the label on the blister.

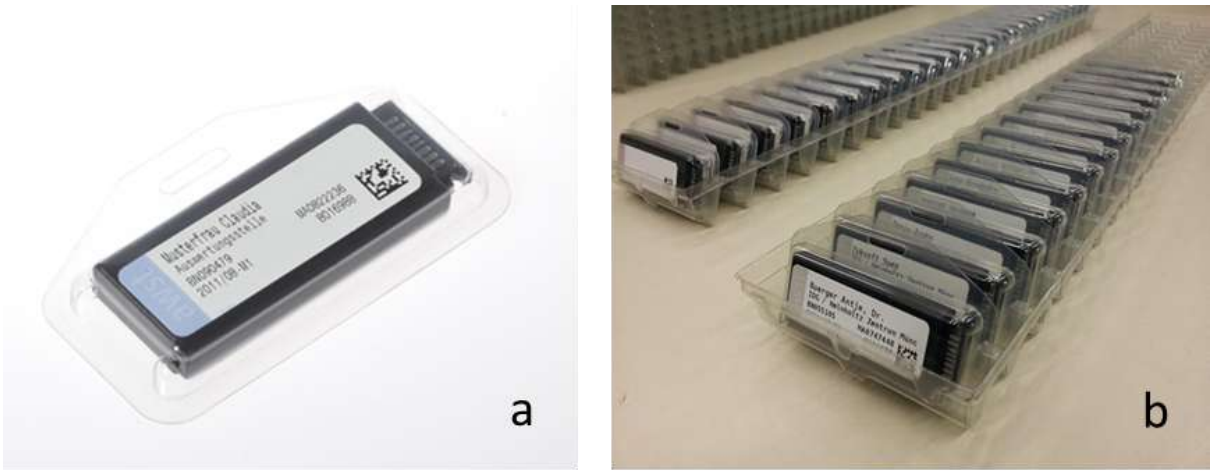

Figure 6: a: dosimeter in blister package with label; b: dosimeters in shipping trays

Figure 8: unpacking; a: overview; b: filling; c, d: unpacked dosimeters

Besides this, the volume of waste is reduced by the factor of twenty. Recycling of the waste is scheduled.

To face customer demands, a holder, which can be easily fixed on cloths using a clip, was developed. It enables a facile change of the dosimeter at the end of the wearing period. Besides this, the customer may fix his own additional label on the holder. As the frame is continuously in use, this has only to be done once. The holder is available in four different colors.

3.2. Establishment

We are making good progress in establishing the BeOSL System. Besides the described OSL system introduced in our personal monitoring service, some more systems are already running at different facilities, as it is shown in table 1. Since 2011, one BeOSL table is successfully running in routine mode at Aib Vinçotte Controlatom (AVC), a personal monitoring service in Belgium. In January 2014, another complete OSL-table was installed at the Australian Radiation Protection and Nuclear Safety Agency (ARPANS) in Melbourne, Australia. Test mode operation has started. Soon another table will be installed

Table 1: dispersal of the BeOSL dosimtry system (as of January 2014)

location	equipment	operation mode
AWST, Germany	4 tables	2 tables in routine operation
AVC, Belgium	1 table	routine operation
ARPANSA, Australia	1 table	test mode operation
Radkor, Turkey	2 reader, 2 eraser	routine operation, manual asseambly
VKTA, Germany	1 reader	Research operation
Chiyoda Technol, Japan	1 reader	test mode operation

at the "Landesanstalt für Personendosimetrie und Strahlenschutzausbildung" (LPS), the personal monitoring service of the German Federal State of Mecklenburg-West Pomerania, located in Berlin.

So far, the dispersal of the BeOSL system was mainly initiated and done by the Helmholtz Zentrum München. Being a non-profit-making facility, it is impossible to do further promotion and selling of the system ourselves. Dosimetrics, founded end of 2013, overtook the commercial business of promoting and selling the BeOSL system in order to sustainably establish this OSL dosimetry system on the market.

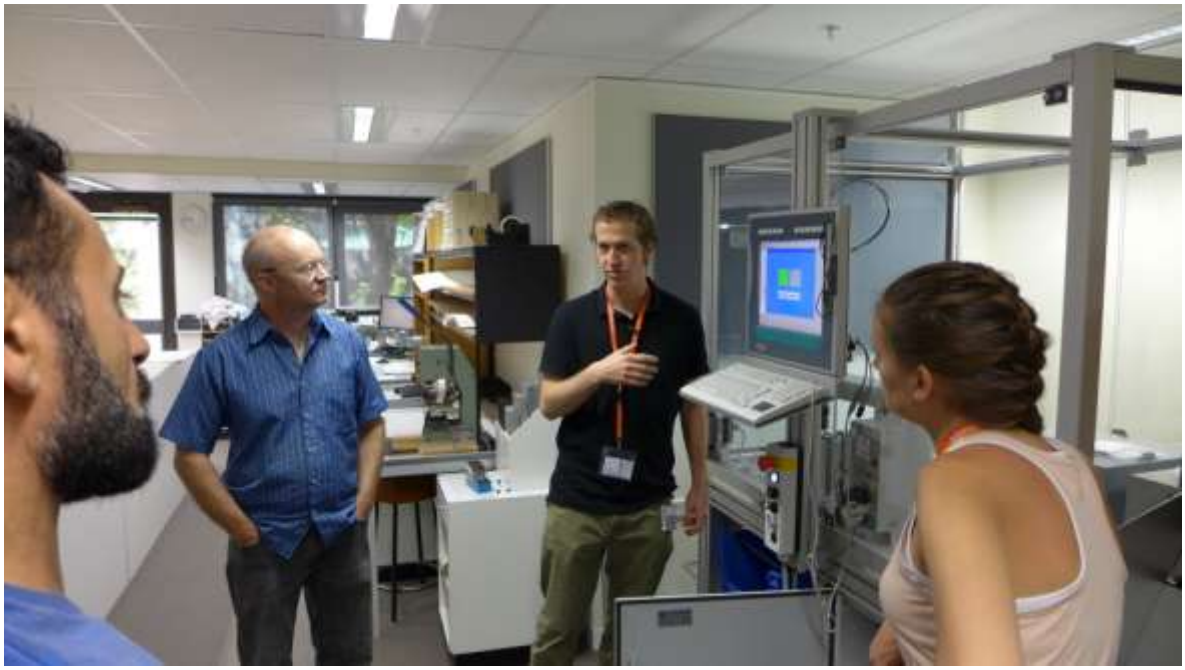

Figure 9: instruction on the BeOSL system at ARPANSA, Melbourne

3.3. Projected enhancements and maintenance

Besides ongoing improvements, different enhancements of the BeOSL-system are projected in order to establish the BeOSL system on the market of personal dosimetry. Based on customer requests and the knowledge of existing dosimetric equipment of many individual monitoring services we are convinced of the need for extension of the current BeOSL-

system. Therefore, additional modules for measuring extremity dose as well as ambient dose are projected. Next to the expansion of the dosimetric portfolio, the focus of further developments is to be able to offer OSL-system to medium-sized personal monitoring services. Hence the construction of a semi-automatic processing unit is initiated in order to serve the gap between manual table version and automated robot version. An overview of the projected enhancements is shown in Table 2. The referring regulatory framework and business conditions are more or less the same doing promotion and selling. Starting in January 2014, any commercial business concerning this matter will be done by Dosimetrics. The close collaboration with our technical department is regulated by a cooperation treaty between the Helmholtz Zentrum München and Dosimetrics.

Table 2: projected enhancements of the BeOSL-system

Further development	Intended purpose
OSL ring system	to measure extremity dose
OSL ambient dosimeter	to measure ambient dose
semiautomatic processing unit	to offer a proper system to medium-sized personal monitoring services
blister sealing station	to enable blister packing to smaller and medium-sized personal monitoring services
ongoing improvements	to keep the system up-to-date

4. CONCLUSIONS

We successfully introduced a new, state-of-the-art OSL dosimetry system, called BeOSL in our personal monitoring service. Based on a high degree of automation, sophisticated logistics was realized. By now, BeOSL systems are running in six different facilities.

Enhancements are projected in order to encourage the establishment and thus the sustainability of the system. Due to being a non-profit organization, the subsidiary company Dosimetrics was founded in order to provide further establishment of the BeOSL system and doing commercial business concerning this matter.

REFERENCES

Bulur E; Göksu Y (1998). *OSL from BeO ceramics: new observations from an old material*. Radiation Measurements **29**: 639-650.

Sommer M; Henninger J (2006). *Investigation of a BeO.based optically stimulation luminescence dosimeter*. Radiation Protection Dosimetry **119**: 394-397.

Sommer M; Freudenberg R; Henninger J (2007). *New aspects of a BeO-based optically stimulation luminescence dosimeter*. Radiation Measurements **42**: 617-620.

Sommer M; Jahn A; Henninger J (2008). *Beryllium oxide as optically stimulation luminescence dosimeter*. Radiation Measurements **43**: 353-356.

Sommer M; Jahn A; Henninger J (2011). *A new personal dosimetry system for Hp(19) and Hp(0.07) photon dose based on OSL-dosimetry of beryllium oxide.* Radiation Measurements **46**: 1818-1821.