On application of low doses from beta radiation source in OSL retrospective dosimetry

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1. Introduction

The motivation of our work was to improve the accuracy of low doses administered with the help of a widely used irradiator ï shown in **Fig.1** (Markey *et al.,* 1997) based on a single beta source (namely ^{90}Strontium/^{90}Yttrium), which is attached to the popular Riso luminescence reader (model TL/OSL-DA-20, e.g.: Thomsen *et al.*, 2006 - was used in the present work)

Adjusting dose rate values to the desired level is a convenient tool in luminescence dosimetry (Kalchgruber *et al.*, where 2002; Burbidge and Duller, 2003) and dating (Göksu *et al.*,1995; Oczkowski and Przegietka, 2000; Richter *et al.* 2003), various samples, significantly differing in age, and therefore in equivalent doses, are to be measured. However, most laboratories usually have at their disposal only one beta radiation source attached to the reader. When it is used in one (presumably standard) arrangement, the source activity limits the highest achievable dose rate, while the lower possible dose is restricted by the shortest irradiation time available ï in our case 1 second. Hence the choice of activity is a compromise between the time saving associated with high dose irradiations and the accuracy of low dose administrations. The goal of this project was to test the possibilities of attenuating beta radiation source in order to achieve lower dose rates. Moreover, we aimed to determine the correction factor for short irradiations, which is caused by the finite operation speed offered by the irradiator.

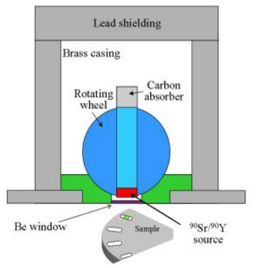


Fig.1.

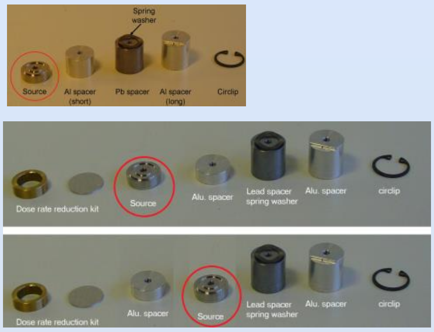
The beta irradiator [modified schematic drawing from Riso TL/OSL reader manual**].**

Tab.1. Beta irradiator arrangements [modified pictures from Riso TL/OSL reader manual] and corresponding dose rates. Nominal activity of the source was 1.48 GBq.

Standard: 133±3 mGy/s

Attenuated: 17.8±0.3 mGy/s

Extra-attenuated: 1.94±0.04 mGy/s



2. Adjusting lower dose rates

We have tried three arrangements of the irradiator (shown in **Table 1**) and carefully calibrated the corresponding dose rate values for each of them. The results are specified in **Table 1**.

A reduction of the dose rate is achieved by lowering the beta flux, which originates from an attenuator inserted between the source and the sample and an increase of the distance. This way it is possible to obtain three levels of dose rates from a single beta source, covering a range of two orders, as demonstrated in **Table 1**. In case of an extra attenuated source, fearing radiation field inhomogeneity (Spooner and Allsop, 2000; Ballarini *et al.*, 2006; Veronese *et al.*, 2007), restricting the sample position close to the central area of the disk is recommended. Admittedly, the spatial differences in dose rate at the sample position caused by the effect of narrowing the beta radiation beam can be partially compensated by a source-to-sample distance increase. However, further studies are needed to verify this assumption.

Since the main material used in our laboratory for luminescence studies and dating is quartz, the calibrations were carried out for quartz grains of the size ranging from 180 to 250 microns and irradiated with a gamma dose of 4.8 Grays. However, for different phosphors the dose rate values and reducing ratios are supposed to differ due to possible dissimilarities in the energy dependence of luminescence response. This is because the spectrum of betas entering the sample depends on the attenuator used and changes in geometry; furthermore, the contribution from x-ray radiation varies with the rearrangements (Liritzis and Galloway, 1990). Moreover, taking into account the attenuation and backscattering, one can predict that the size of the sample grains and material of the sample substrate can also influence the dose rate values (Armitage and Bailey, 2005; Mauz and Lang, 2004, Ingram *et al.*, 2001). Therefore changing any of these conditions implies the necessity of new calibration measurements.

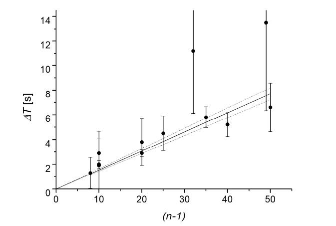
3. Improving dose accuracy for short irradiations

When short irradiations are applied, the offset time caused by the finite speed of the irradiator operation should be taken into account. In the relevant literature, there are two mutually conflicting opinions regarding this effect for the beta irradiator attached to the Riso reader model TL/OSL-DA-15. In their article published in *Radiation Measurements* in 1997, Markey *et al*. claim that the time lag in the activation of the source shortens the effective time of irradiation and therefore cuts down the deposited dose in respect to that which is administered. In contrast, Kalchgruber *et al.* reported in their paper in *Radiation Measurements* in 2002 that the absorbed dose exceeds the prescribed one and explained this effect by additional exposure of the sample to a partially shielded source during its opening.

We propose here a simple method, effective even for materials of low sensitivity like quartz, for determining the offset time. It is based on the sequence of fractional short irradiations, for which OSL response is compared to the OSL signal measured after long irradiations. Our results confirm the observations of Merkey et al. from 1997. Indeed, the effective dose resulting from short irradiation turns out to be lower than the value expected from the regular dose rate. As demonstrated by the plot in **Figure 2**, the exposure time deficiency is proportional to the difference in number of short and long irradiations. In that sense, short irradiations are less effective than longer ones, because the lag time (consumed for opening the source) considerably reduces irradiating time only for short irradiations, while in the case of longer irradiations, this effect remains negligible.

Fig.2.

The time deficiency ΔT plotted against the difference in number of irradiations *(n-1)*. For measuring the offset time caused by the finite speed of the irradiator operation the exposure time deficiency ΔT is determined by the difference between OSL response to the single long irradiation and OSL signal measured after the sequence of fractional short irradiations.



4. Results and Conclusions

Summarizing, it is demonstrated that values ranging from a few, through tens to hundreds of mGy/s are obtainable from a single beta source attached to a Riso reader. A further reduction of dose rates is possible if the method of irradiating the neighbouring positions, which takes advantage of a cross-talk effect (Markey *et al.*, 1997; Kalchgruber *et al.*, 2002; Bray *et al.,* 2002), is applied, but it needs another series of dedicated calibration measurements. The presented method is an alternative for a micro X ray generator (Thomsen *et al.*, 2006), which enables a continuous regulation of the dose rate, but is expensive and suffers from other effects.

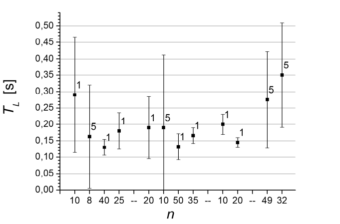
Next, the method for determining the irradiator offset time is also proposed. We have determined a time lag of 0.15 s for our irradiator. As shown in **Figure 3**, the offset time is a constant value per every single act of irradiation, no matter what its duration. We suggest that this should be taken into account for irradiations shorter than 30 seconds. Ignoring this causes an overestimation of the delivered dose in the range from 0.5% to 15%.

Concluding, we believe that our results can benefit in improving the accuracy of low beta dose irradiations applied in retrospective dosimetry surveys and luminescence studies (Przegiňtka and ChruŜciŒka, 2013).

Fig.3.

Comparison of the time lag $T_L = \Delta T/(n-1)$ results obtained for different numbers *n* and the durations of fractional irradiations (exposure time units of 1 or 5 s were used).

The average time lag T_L of the irradiator of 0.15 s should be taken into account for irradiations shorter than 30 s.



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