Depletion of the quartz OSL signal using low photon energy stimulation

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Abstract *For a given excitation photon energy, the rate of charge detrapping in quartz increases with sample temperature. This phenomenon is termed 'thermal assistance' and has been documented in a number of studies (see for example Spooner, 1994; Huntley et al., 1996; Bailey et al. 1997; Bailey 1998). An obvious consequence of this effect is that low photon energies can stimulate luminescence when sample temperature is sufficiently high. The work reported below assesses whether the signal observed from one particular quartz sample during low photon energy stimulation (at raised temperature) relates to the signal observed under blue+green stimulation. The possibility of inadvertent signal depletion due to laboratory 'safe lighting' is also discussed.*

Bleaching of quartz OSL using low energy photons

Since the appearance of the first published account of possible long wavelength stimulated luminescence from quartz, by Godfrey-Smith *et al.* in 1988 (measured at room temperature using combined 753 and 799 nm stimulation), a number of subsequent studies have produced a range of results. On the basis of emission spectra observations Huntley and Short (1992) attributed the IRSL measured in their sample (at ambient temperatures using diode stimulation centred on 950nm) not to quartz but to feldspar micro-inclusions. This conclusion is supported by the detailed bleaching spectra of Spooner (1994; ~400-900nm) where the bleaching rate of quartz was shown to be inversely related to illumination wavelength. Spooner (1994) showed that IR stimulation (~860nm) induced extremely low depletion rates, producing measurable luminescence only at temperatures greater than 70°C. Neither in this study nor in that of Bøtter-Jensen *et al* (1994; ~430-650nm) is there evidence of a long wavelength resonance, as exists in some feldspar samples at near infra-red wavelengths (Hütt *et al.*, 1988). In contrast to these findings Godfrey-Smith and Cada (1996) report the presence of an excitation resonance in quartz at similar wavelengths to the feldspar resonance (although there is the possibility, discounted by the authors, that this is indicative of significant feldspar microinclusions, as found by Huntley and Short in 1992).

In the present study, IR stimulation (using the IR-diodes mounted in a Risø-set, model TL-DA-12, emitting 875Δ80nm [1.30-1.56 eV] light at 40mW.cm^{-2} (Duller and Bøtter-Jensen, 1996)) yielded significant amounts of measurable luminescence from quartz only when the sample temperature was greater than 200°C. In light of the findings of Huntley and Short (1992), attempts were made to assess both sample purity (with respect to feldspar contamination) and the extent to which the luminescence observed under IR stimulation (at 220°C) related to the OSL signal measured when stimulating with the broad band blue+green light of the Risø-set (420-560nm [2.21-2.95 eV] at approximately 16 mW.cm^{-2}; Bøtter-Jensen and Duller, 1992).

For improved signal-to-noise ratios, a thermally sensitized sample was used (sample 317, a raised beach deposit from Tunisia - see Bailey 1998 for further details); annealing was at 650°C for 10 minutes in air. Preliminary experiments showed no significant difference between the results of annealed and non-annealed samples, with better precision achieved using thermally sensitised material. Two aliquots of the annealed quartz ('a' and 'b' respectively) were each given a β-dose of ~40Gy and preheated at 220°C for 300s. IRSL measurements of each aliquot (at 20°C), made immediately following preheating, yielded signals no higher than background levels, indicating an absence of significant feldspar contaminants. Aliquot 'a' was subjected to seven repeated cycles, each consisting of a 0.1s OSL measurement at 20°C (blue+green stimulation) followed by 500s of IR stimulation at 220°C. Aliquot ‘b’ (the ‘control’) also went through seven cycles, each consisting of a similar 0.1s OSL measurement (20°C) and storage at 220°C for 500s (with no IR illumination). Aliquot ‘b’ was used to correct aliquot ‘a’ for thermal effects (thermal erosion of the signal and any sensitivity changes) and the loss of OSL due to repeated 0.1s measurements. The results of these measurements are shown in Figure 1.

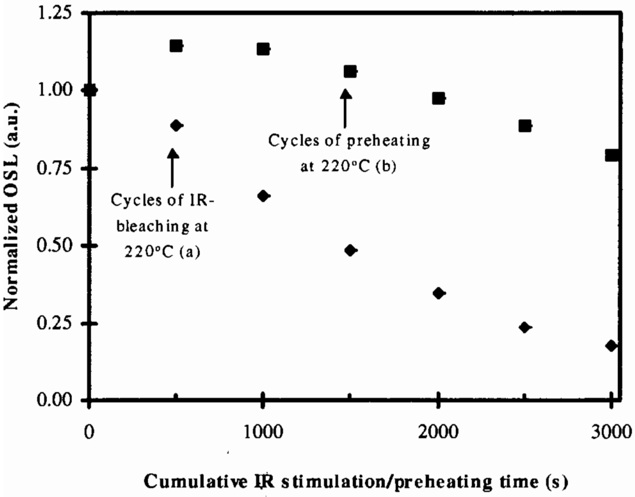

Figure 1.
Data set ‘a’: Raw OSL (minus background) remaining as a function of cumulative infra-red illumination at 220°C. Each data point represents the OSL observed during a 0.1s blue+green stimulation at 20°C (normalised to unity at t=0). The IRSL observed during each cycle is shown in Figure 3. Data set ‘b’: control aliquot for thermal effects. Standard errors are smaller than the size of the symbols in all cases. See main text for further details.

Successive 0.1s OSL measurements (blue+green excitation) suggest that IR stimulation at 220°C does indeed reduce the blue+green light stimulated signal (though at a much lower rate compared to the standard blue+green stimulation). Figure 2 shows the depletion after correction for measurement cycling and thermal effects. The data points are well fitted to a single exponential over the early part of the decay, to ~25 % of initial intensity, with a half-life of ~1,400s ($\lambda \approx 0.0005 s^{-1}$). The initial rise in the correction data (aliquot ‘b’) is attributed to thermal sensitisation not completed by the end of the initial preheat (following dosing). Further supporting evidence for the interpretation that IR stimulation at 220°C removes the OSL signal as monitored by the 0.1s measurements is illustrated in Figure 3, where the IRSL decay curves measured during each cycle are presented in series. Fitting an exponential decay yields a half-life for the IRSL decay indistinguishable from that obtained from the corrected 0.1s OSL measurements (Figure 2). Both the IRSL and the interposed 0.1s OSL (blue+green stimulation) both appear therefore to be measuring the same depletion of charge (recall that no IRSL was observed during 20°C measurements, indicating absence of feldspar contamination).

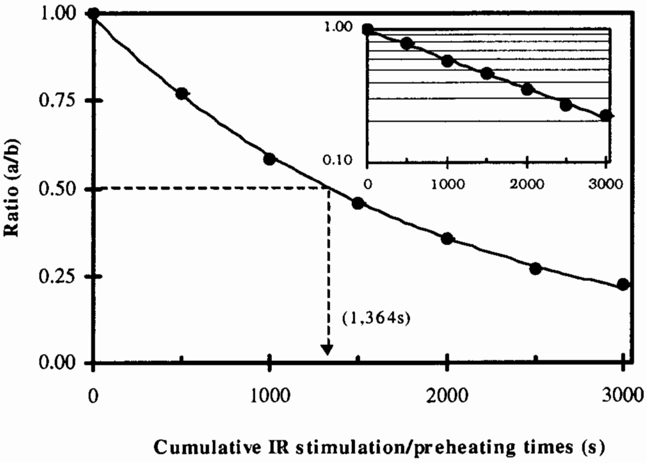

Figure 2.
Bleaching of the OSL signal (as monitored by 0.1s blue+green stimulated luminescence measurements) using IR-excitation at 220°C (data are corrected for thermal effects). ‘a’ and ‘b’ are as defined in Figure 1 and in the main text. The half-life of the fitted exponential decay is shown. Inset are the same data shown on a logarithmic vertical axis.

Relevance to laboratory safe-lighting

In order to minimise optical depletion of the dating signal during sample preparation, low photon energy lighting, typically in the ~600nm (~2 eV) region of the visible spectrum (orange, as listed by Aitken, 1998: Pg. ix) is commonly used for handling quartz. The observation reported above, that at raised temperature significantly less energetic IR stimulation (1.30-1.56 eV) substantially depletes quartz OSL, has a particular practical relevance to laboratory procedures. If samples exposed to laboratory ‘safe-light’ are at room temperature (~20°C) then depletion of the (blue+green stimulated) signal, over a period equal to the time needed for sample preparation and measurement is negligible (as observed in laboratory tests). However, in circumstances where sample temperature is considerably elevated (such as when samples are taken from a preheat oven), exposure to the same lighting conditions may have detrimental effects (due to thermal assistance in the detrapping process).

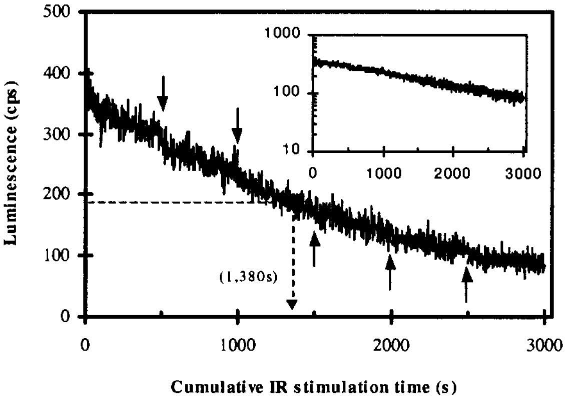

Figure 3.
Composite IRSL decay curve. Successive IRSL measurements (made at 220°C) are displayed in series against cumulative bleaching time, the beginning of each individual measurement marked by an arrow. Note that the half-life of the signal is indistinguishable from that shown in Figure 2.

An experiment was performed under what might be regarded as extreme conditions in order to gauge the likely maximum effect of 'safe-light-bleaching', as discussed above. Aliquots of naturally irradiated quartz (ca.120ka in age) were exposed to laboratory lighting for 10s at 220°C and cooled naturally to room temperature. For the purpose of this experiment, the laboratory was lit from a single 65W fluorescent tube filtered with two layers of 'Lee filters 158 Deep orange' celluloid (passing wavelengths greater than 540nm: 10% at ~560nm, 50% at ~605nm – information derived from spectral measurements), positioned approximately 1.5m vertically above the sample. Short (0.1s) OSL measurements were made both before and after 'safe-light' exposure. Once corrected for thermal effects and depletion due to measurement (using a separate aliquot that was not illuminated during heating), the signal depletion was approximately 3%, in each of two successive cycles. Clearly the induced depletion is not substantial but appears nonetheless to be present. For this reason, preheating in light-tight vessels and allowance of sufficient cooling time prior to exposure to 'safe-lighting' is advised.

Acknowledgements

I am very grateful to Professor Martin Aitken who in his role as referee provided an abundance of well targeted and helpful suggestions. I thank also Professor Ann Wintle for reading and commenting in a similar manner on an earlier version of the text.

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Reviewer
Martin Aitken

Comments :
I would like to underline the significance of Figs 1 - 3. As the author says, these results indicate that there is IR bleaching (at elevated temperature) of the traps responsible for the blue+green stimulated luminescence (BGSL) with a depletion-rate equal to that of the IRSL signal itself. This gives evidence that the BGSL and the IRSL are from the same traps --- which was not necessarily the case for the elevated temperature IRSL observed by Spooner (1994). It also confirms the absence of feldspar contamination; the absence of any above-background IRSL at 20°C is not sufficient to exclude the possibility that, due to thermal assistance, such contamination is responsible for the IRSL at elevated temperature.

Authors reply
I agree with the comments of the Reviewer.