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A user defined command for pulsed-irradiation on Risø TL-OSL readers

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Abstract
It has recently been proposed that large laboratory radiation doses to quartz should be administered in small pulses separated by a cut-heat, rather than the conventional method of administering doses in a single pulse. This paper explains the structure of the software system used to control the Risø TL/OSL reader and presents code for a user defined command which allows pulsed-irradiation to be performed conveniently. This approach could also be used to undertake any complex sequence of operations in a flexible and straightforward manner.

Keywords
Quartz, optical dating, dose-rate, pulsed-irradiation, age, accuracy.

Introduction to the use of pulsed-irradiation
The single-aliquot regenerative-dose (SAR, Murray and Wintle, 2000) method has been used to determine the equivalent dose (D_e) to quartz from a wide range of environments. The SAR method generally yields ages which are in good agreement with independent age control (e.g. Hilgers et al. 2001, Murray and Clemmensen, 2001, Murray and Olley, 2002, Murray and Funder, 2003, Stokes et al. 2003). However, a recent study using modelled data (Bailey, 2004) indicates that the SAR method may overestimate the equivalent dose (D_e), when the D_e is greater than ~40Gy. In addition, the SAR procedure appears to produce incorrect results for individual aliquots at high equivalent doses, where the natural luminescence intensity is sometimes greater than the saturation intensity observed due to laboratory irradiation (e.g. Armitage et al. 2000, Figure 5, Yoshida et al. 2000, Class 3 grains).

According to Bailey (2004) this effect is caused by the relatively high dose rates used during laboratory irradiation, leading to the trapping of a significant population of holes at a thermally unstable, non-radiative recombination centre (R_1-centre). Consequently, during room temperature laboratory irradiation, the R_1-centre competes for charge in the conduction band, reducing the charge available for trapping at the OSL traps. The R_1-centre does not compete for charge in nature due to its low thermal stability. Consequently, the laboratory regenerated OSL signal intensity is lower per unit dose than for natural rate irradiation and hence the D_e calculated is erroneously large. By administering laboratory doses either at raised temperature, or in short pulses separated by thermal treatments (pulsed-irradiation), the malign effects of the R_1-centre can reduced. Bailey et al. (in press) present empirical data which supports the prediction by Bailey (2004) that SAR and pulsed-irradiation produce different growth curves, with the latter yielding lower equivalent doses. However no known age samples were measured in this study, precluding firm conclusions regarding the accuracy of either method.

Although a raised temperature irradiation facility is available for the Risø TL-OSL reader (Bøtter-Jensen et al. 2003), raised temperature irradiation cannot be performed in many laboratories. In addition, temperature dependent changes in the trapping cross-section of the OSL traps appear to invalidate this approach (Wallinga et al. 2002). This paper presents code for a user defined command for pulsed-irradiation, which can be performed on all Risø readers which use a MiniSys. This pulsed-irradiation command performs irradiation in a series of pulses (e.g. 10 Gy). Following each pulse, the sample is heated to a definable temperature (during which the resulting thermoluminescence is measured) and immediately allowed to cool to room temperature. The heating step releases holes trapped at the thermally unstable R_1-centre. Consequently, the R_1-centre competes less strongly for charge in the conduction band, approximating the situation found in nature and preventing an overestimate of the equivalent dose. Administering a series of radiation pulses, with intervening heating stages, is possible using conventional software, but is unwieldy since each irradiation would require many instructions. By utilising a new facility in the Risø reader, namely user defined commands, the process can be made much simpler.

How the Risø reader is controlled

Current versions of the Risø TL/OSL reader consist of three functional units. The first is the reader itself, consisting of the measurement chamber, the heater plate, irradiator, other facilities and associated control electronics. This hardware is controlled by the second unit, a dedicated PC based controller called a MiniSys (Markey et al. 1997). The MiniSys directly interfaces with the hardware and continuously monitors it to check for hardware faults. The software at the heart of the MiniSys is a command interpreter. The MiniSys language consists of two character commands, each of which instruct the MiniSys to perform a single operation, e.g. "LU" instructs the MiniSys to raise the lift. Parameters can be added to these commands where appropriate, e.g. "ST 160 5" instructs the MiniSys to heat the hotplate to 160°C at a rate of 5°C per second. A full list of these commands are supplied with each Risø reader and is available from the second author. The third functional unit is a host computer running a programme that can issue sequences of MiniSys codes, and that can collect any data that is generated. The Sequence Editor programme supplied with the reader serves this function. When a command is entered in the Sequence Editor, it is stored in a .SEQ file. When a sequence is executed, the Sequence Editor translates this file into commands which are implemented by the MiniSys. A standard (or "high level") command such as "Pre-Heat" requires several low-level commands to be issued to the MiniSys (e.g. lift up, heat to temperature, pause at temperature, lift down). The Sequence Editor translates high-level commands into low-level MiniSys commands using the TLMSLL.CMD file. For each high-level command (e.g Preheat or Irradiation) this file lists the low-level commands required to perform each high-level command. An example of this is given in figure 1 which shows the section of the TLMSLL.CMD file that the Sequence Editor uses to convert the high-level 'Pre-Heat' command into MiniSys commands.

The pulsed-irradiation user defined command

In late 2000, the capability to define non-standard high-level commands was added to the Risø Sequence Editor (Duller, 2000). This allows the operator to use the low-level MiniSys language without having to write control code to issue commands and collect data. Any of these MiniSys commands can be linked together, both to control the TL/OSL reader and to collect data, and these user defined commands can then be intermixed with standard commands in a Sequence.

```
[PREHEAT]
; $1 Temp
; $2 Heat Rate
; $3 Time
;
10=PS $0
20=#RS
30=#TF
40=#WLT
50=LU
60=#RS
70=ST $1 $2
80=#RS
90=PA $3
100=#RS
110=LD
120=#RS
130=ST 0
```

Figure 1: *The section of the TLMSLL.CMD file that the Sequence Editor uses to convert the high-level command 'Preheat' into low-level MiniSys codes. To undertake a Preheat operation the Sequence Editor reads each of the numbered lines (10 to 130). A number of parameters, prefixed by the symbol '$' can be passed by the Sequence Editor. These correspond to parameters entered by the user in the Sequence Editor. In the case of the Preheat command $1 is the preheat temperature, $2 is the heating rate at which to raise the temperature and $3 is the period of time that that temperature is to be held. For all commands, the position on the carousel of the sample that is to be analysed is passed as the parameter $0. Once any parameters have been replaced by the correct numerical values, the text to the right of the equals sign is sent to the MiniSys. Thus the first operation is to send a 'PS 12' command (assuming that the current sample that is to be analysed is sample number 12). This will move the carousel so that position 12 is over the hotplate. In line 20, #RS (read status) is a metacommand that will pause the Sequence Editor until the current operation (in this case moving the carousel) is complete. #TF will check for a thermal failure and #WLT will pause until the hotplate temperature is lower than the threshold specified in the Sequence Editor (default 60°C).*

For the current example, the code for the pulsed-irradiation command is given in Figure 2. These user defined commands should be written in a separate command file called USERMSLL.CMD, to prevent accidental alteration of the standard high-level commands in TLMSLL.CMD. To be able to use this pulsed-irradiation command, the code must be added to the USERMSLL.CMD file using a text editor. The pulsed-irradiation command is then ready to be used from within the Sequence Editor.

```
[UserDef0]
; Pulsed-irradiation with cut heats in gaps
; $1 No of datapoints during cut-heat
; $3 Number of cycles required
; $4 Heating Rate (°C/s)
; $5 Maximum cut-heat temperature (°C)
; $6 Irradiation time (s)
;
10=#LOOP 1 $3
20=BP $0
30=#RS
40=BI $6
50=#RS
60=PS $0
70=#RS
80=#INITGRAPH $1
90=#TF
100=#WLT
110=LU
120=#RS
130=TL $5 $4 $1 0
140=#DATA
150=#SAVE
160=#ENDGRAPH
170=LD
180=#RS
190=#ENDLOOP
```

Figure 2: *Text for the USERMSLL.CMD file to define the pulsed-irradiation command. The #LOOP (line 10) and #ENDLOOP (line 190) commands allow the sequence of commands in between (lines 20 to 180) to be repeated a number of times. The loop counter will count from 1 to $3.*

Using the pulsed-irradiation command

Like standard high-level commands, a user defined command is selected in the Sequence Editor (selecting "User Defined"). The dialogue box shown in Figure 3 will then appear.

Up to eight user defined commands can be stored in USERMSLL.CMD, and the appropriate command is selected from the User Command drop-down menu at the top of the dialogue box. The most important point to note is that the titles for each box are only meant as suggestions for its function. The actual meaning of each parameter is specified by the user defined command in USERMSLL.CMD, with the parameter number in brackets beside each box ($1, $2, $3 etc) being the critical link. For example, in the pulsed-irradiation command presented in this paper, $6 (Ph time in Figure 3) is actually used to specify the beta irradiation time required in each pulse (see Table 1).

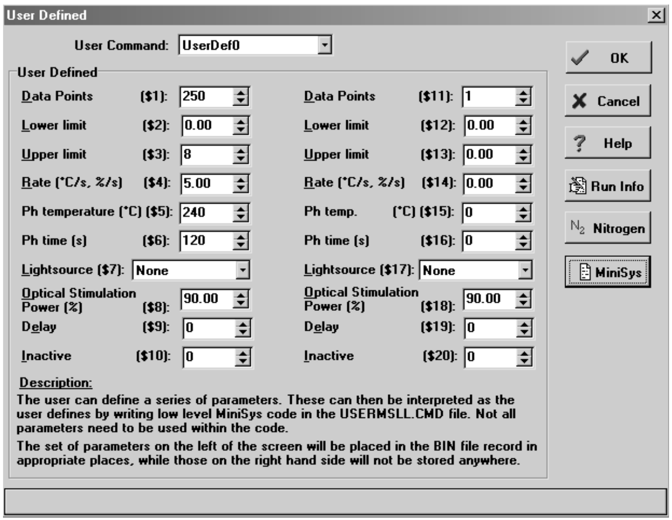

Figure 3 : *The user defined command as used for the pulsed irradiation example described in the text. This command will pass parameters $1, $3, $4, $5 and $6 to the section of the USERMSLL.CMD file. By comparing with Figure 2 it can be seen that this set of parameters will give 8 doses, each with a duration of 120 seconds. After each pulsed irradiation the sample will be heated to 240 °C at 5 °C per second, recording the TL in 250 channels.*

The pulsed-irradiation command only uses five of the available parameters. These are listed towards the top of the code in Figure 2, and constraints on their use are given in Table 1. Values for each of these parameters are entered in the same manner as for a standard high-level command. Sequence Editor will ignore all other parameters, irrespective of the values they contain. The sequence is executed in the normal manner.

Summary

The user defined command described here provides flexibility in the control of the Risø reader, beyond what is possible using the standard Sequence Editor, but without the complication of writing software to interact with the MiniSys directly. The example given here is of a command to undertake pulsed-irradiation. Such pulsing would be possible with the conventional commands within the Sequence Editor, but would require so many individual commands that only very simple irradiations could be fitted into a single sequence. More complex user defined commands can be defined involving any of the capabilities of the Risø system.

Parameter	Function	Constraints
\$1	Datapoints recorded during the cut-heat.	Must be greater than zero
\$3	The number of irradiation and heating cycles required.	Must be greater than 1, e.g. 50Gy using 10Gy pulses requires 5 cycles.
\$4	Heating rate during cut-heat (°C/s).	None, Bailey et al. (in press) used 5°C/s.
\$5	Maximum temperature reached during cut heat (°C).	None, Bailey et al. (in press) recommended ~240°C.
\$6	Beta irradiation time per pulse (s).	None, Bailey et al. (in press) recommended 10Gy.

Table 1 : *Parameters and constraints for the pulsed-irradiation user defined command.*

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Reviewer

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