DTU Nutech
Center for
Nuclear Technologies

DTU

User Manual

Radio-luminescence attachment for Risø TL/OSL reader

November 2012

Contents

1. Introduction

It has been shown that K-feldspar has an emission peak in the NIR region (865 nm) during irradiation with beta particles (Trautmann et al., 1998, 1999; Krbetschek et al., 2000). The intensity of this signal, known as the infra-red radioluminescence (IR-RL) decreases with dose; this dose-dependent characteristic suggests that the signal can be used in dosimetry. Several articles have argued that this signal does not suffer from anomalous fading (Novothny et al., 2010; Wagner et al., 2010) and as a result this signal may have considerable potential for dating older samples. A simple single-aliquot regenerative-dose protocol has been proposed to measure dose using this signal (Erfurt and Krbetschek, 2003), and an automated instrument supporting this protocol has been designed (Erfurt et al, 2003). The protocol involves the following steps:

1. Sample the intensity of the 'natural' IR-RL of an aliquot using a beta source of known dose rate for a short period.
2. Bleach the aliquot using a daylight spectrum (~30 min)
3. Wait (~1 hr) to allow for phosphorescence decay and then repeat the IR-RL measurement (same as 1) until the cumulative dose exceeds the natural dose (i.e. the IR-RL signal in 3 is smaller than that in 1).

The IR-RL curve obtained in 3 is then fitted to a stretched exponential and the integrated natural signal obtained in 1 is interpolated on this fit to estimate D_e.

A radio-luminescence attachment was first described by Bøtter-Jensen et al. (2002), but that made use of the standard PMT (ET 9245QB) used for OSL measurement, and this tube is not sensitive in the NIR region. In addition, the beta source had to be lifted by 20 mm to accommodate the optical light guide, and this led to a significant decrease in the beta dose rate. We have redesigned the RL option to be able to measure in the NIR region while minimising the reduction in the dose rate. In the new design the source is only lifted by 7 mm to allow entry of the RF light guide;

The Sequence Editor normally used to build measurement sequences for the Risø Reader has been expanded to include RL data acquisition as a standard choice. Heating during RL data acquisition is automatically available if the reader is equipped with an extra heater module, and any combination of OSL, TL and RL measurements can all be undertaken sequentially.
As discussed above, the published approach to estimating dose using IR-RL signals relies on interpolating a short duration natural measurement onto an accurate fitting of the regeneration curve; this approach cannot detect any luminescence sensitivity changes that may occur during dose measurements. We have developed an alternative method of analysis. First a natural signal is collected for a relatively long period of time to obtain a significant portion of the RL decay. The sample is then bleached in the normal manner, and a regenerated dose response curve measured. The response curve built on top of the natural RL is then shifted along the time (dose) axis onto the regenerated RL until a best fit is obtained.

A computer program RLanalyse has been developed to automate this analysis. The input of the program is a data file (BIN-file) that contains the natural and bleached curves for a number of positions. The output of the program is the time-shift between the curves based on a least square fit of the bleached sample curve and the time-shifted natural . More details details on the RL attachment may be found in Lapp et. al. (2012), and Buylaert et al. (2012),

2. Components

An overview of the RL attachment system is shown in Figure 1

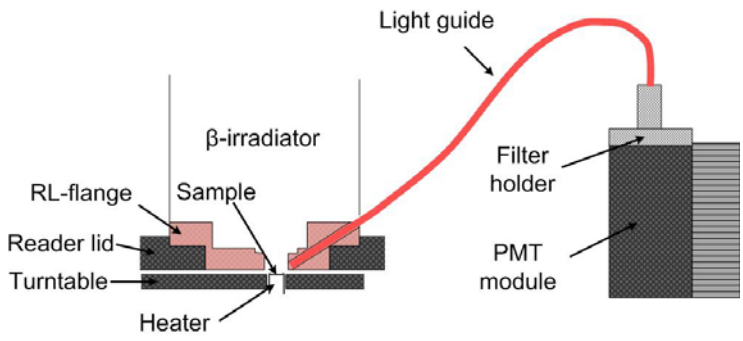


Figure 1

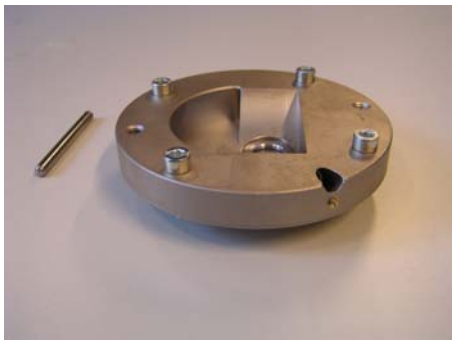
The RL attachment is installed by DTU Nutech either at Risø or on-site. The attachment is comprised of the components described below.

Modified beta irradiator module

The beta irradiator module is modified to make room for the light guide entering the flange

Modified radiation source flange and detection rod

The flange is 7 mm thicker than the standard flange to make room for the light guide hole. Therefore the rod that operates the " irradiation on" micro-switch also should be exchanged with one that is 7 mm longer

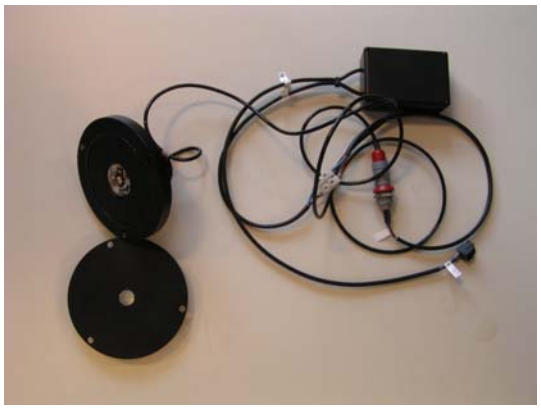


Additional lead shielding ring

The ring is needed because the flange is 7mm higher

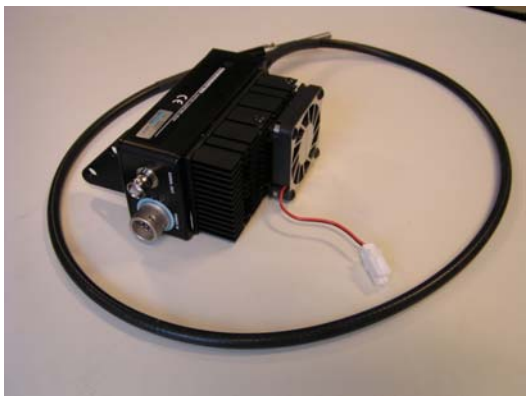
Bleaching unit

The bleaching unit is mounted on the lid in the Bleach/X-ray opening. The connector is mounted on the back of the reader box, and the bleaching power supply and control (black box) is mounted and connected inside the reader enclosure



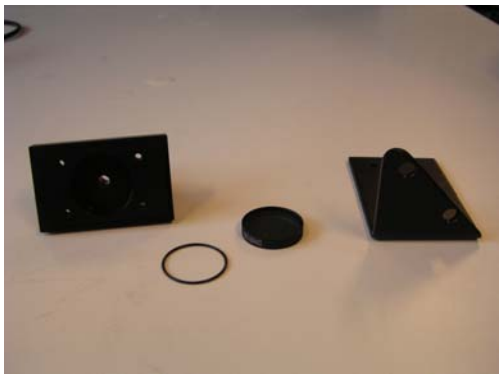
PMT module and light guide

The PMT module (Hamamatsu H7421-50 Photon Counting head) is mounted on the side of the reader. The light guide is inserted in the hole of the radiation source flange



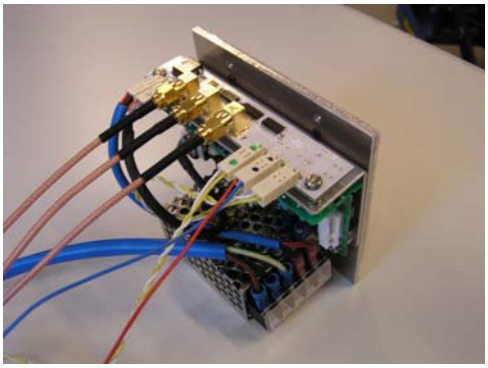
PMT module accessories

The attachment includes a bracket for mounting the module, a filter holder to hold the detection filter and connect the light guide to the PMT module, and a detection filter (Chroma D 900/100 interference filter (bandpass : 850-945 FWHM))



PMT module control

This unit is mounted inside the controller to supply the PMT module with power, to control the cooling of the unit, and to switch between counting pulses from the standard PMT and the RL- PMT



Connector to the RL PMT module

This connector is mounted on the back of the controller instead of the “OSL Power” connector, and connected to connectors inside the controller.

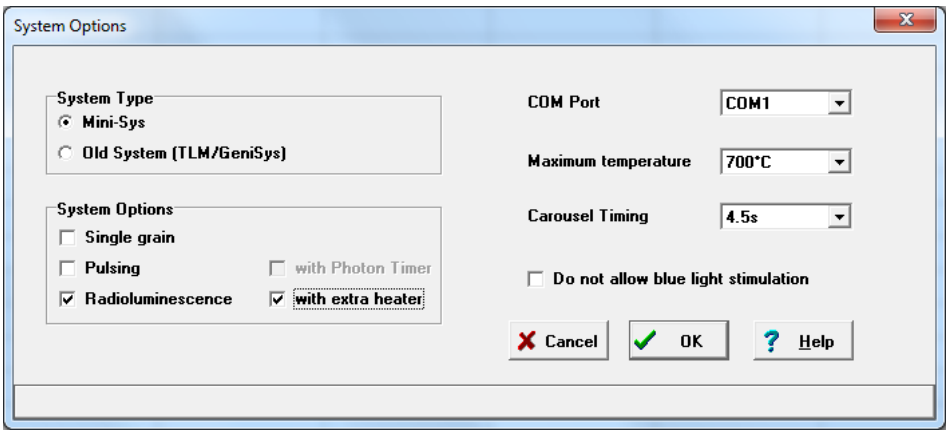
Cables

To connect RL-PMT module to the Risø Controller

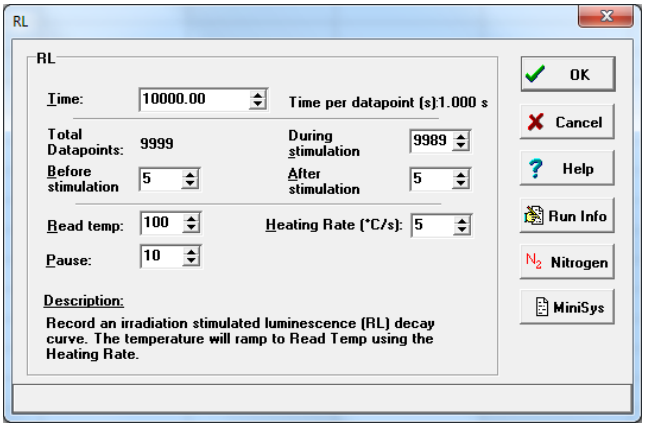
3. Data acquisition

The data acquisition is performed using the standard Risø TL/OSL Sequence editor.

In the *"System Options"* form you must tick *"Radioluminescence"*. If you have an extra heater installed at the radiation module position you should also tick *"with extra heater"*

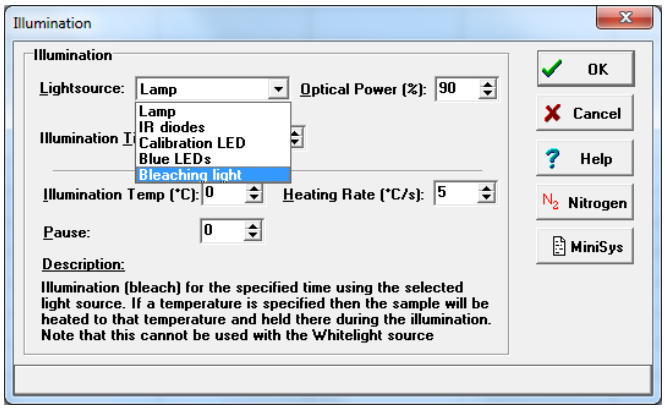


When these have been ticked, *"RL"* appears in the list of commands for a cell. The meaning of the parameters for the RL command is very similar to the parameters for TL and OSL:

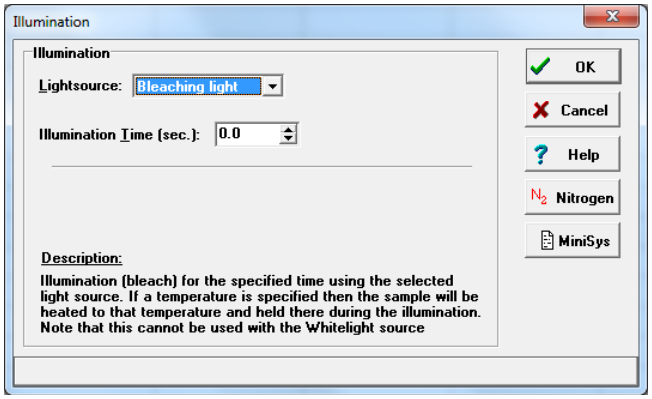


If *"with extra heater"* has been ticked, heating parameters will appear in the form.

To do the bleaching necessary for the IR-RL protocol you use the "Illum" command and chose "Bleaching light"



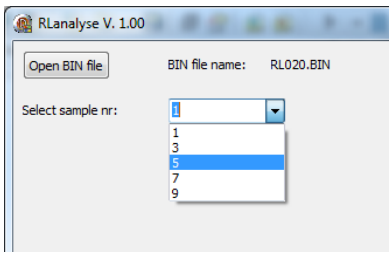
This bleaching takes place in the bleaching/X-ray position where no heating is available. Therefore the form hides these parameters when “Bleaching light” is selected



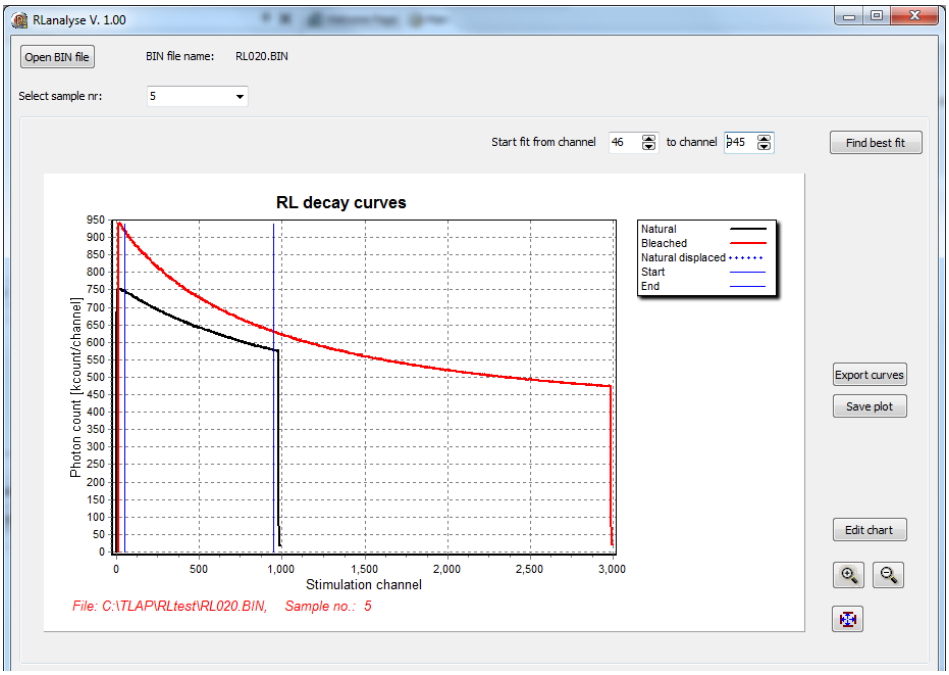
4. Data analysis

For analysis of the RL data you may use the program *RLanalyse* which implements an alternative method of analysing data acquired according to the protocol developed by Erfurt et al., 2003. The algoritm is described in Lapp et al. 2012.

In the *RLanalyse* program you start by opening the bin file to be analysed. The program looks for data acquisitions of type RL and assumes that the first acquisition for a given sample is the natural signal, and the second acquisition on the same sample, is the bleached signal. When the file has been opened you may select the sample to analyse from a list of samples that fulfils the requirements (type= RL, 2 subsequent acquisitions available)



When you select a sample the two decay curves are plotted



You may chose which part of the natural decay curve you want to fit to the bleached decay curve by changing the "from channel" and "to channel" values. The vertical blue lines on the plot shows the selected fit interval.

When you press the *Find best fit* button the displacement that gives the lowest mean square deviation is found. The mean square deviation is defined as follows:

Let N_i be the photon count of the 'natural' RL and B_i be the photon count of the bleached' RL signal corresponding to a channel number *i.*

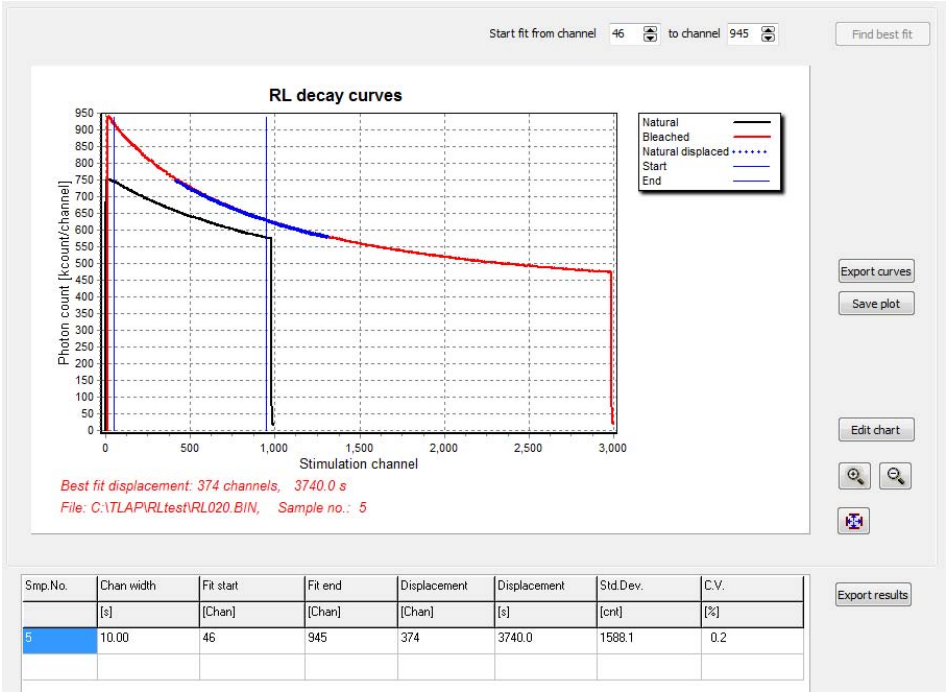
Let n_s to n_e be the start and the end indices used to define the section of the natural RL curve that is intended to be fitted on the bleached RL curve.

The fitting procedure then shifts the selected section of the natural RL curve horizontally by an amount *d*. The best fit is obtained by minimising the standard deviation (σ) between the selected section of the natural decay curve and the displaced section of the bleached decay curve. σ is calculated as

$$\sigma^2 = \frac{\sum_{i=n_s}^{n_e}(N_i - B_{i+d})^2}{n_e - n_s}$$

The fitting results are summarised in the table below the fitting plot. This table gives the optimal displacement *d* in channels and in time (i.e. $d \times$ *channel width*), the standard deviation σ as defined above, and the coefficient of variation C.V. (relative standard deviation) calculated as :

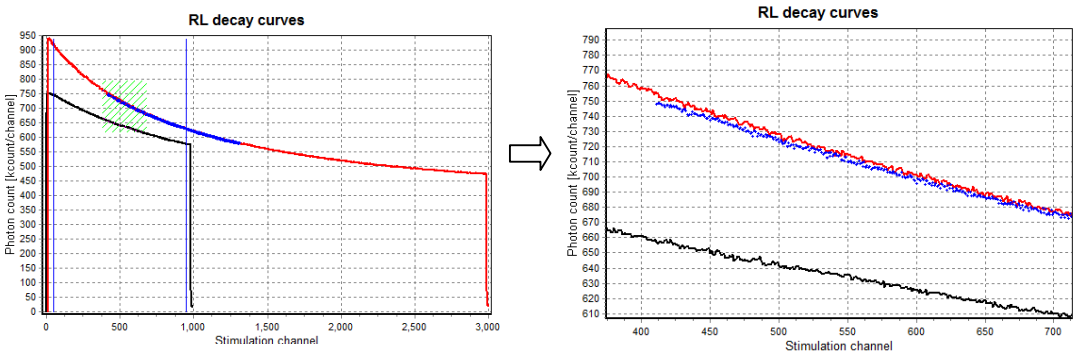
$$C.V. = \frac{\sigma}{\frac{\sum_{i=n_s}^{n_e} N_i}{(n_e - n_s)}}$$



Smp.No.	Chan width	Fit start	Fit end	Displacement	Displacement	Std.Dev.	C.V.
	[s]	[Chan]	[Chan]	[Chan]	[s]	[cnt]	[%]
5	10.00	46	945	374	3740.0	1588.1	0.2

If you make additional fits with different samples, fit start or fit end, rows with results are added to the table.

If you want to zoom in on a particular part of the plot, you simply mark the square of interest with the mouse and left mouse-button as shown below

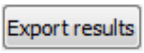


The remaining buttons on the form have the functions described below:

Export curves	Exports the data of the Natural and Bleached curves to a CSV (Comma Separated Value) file
Save plot	Saves the chart to a bmp (bitmap) file you specify
Edit chart	Makes it possible to edit detail on the chart e.g.: font size, scale, line appearance (thickness, colour, type). You may also access this functionality by double-clicking the chart
	Zoom in

Zoom out

Rescale chart



Export the results grid to a CSV file

5. References

Trautmann, T., Krbetschek, M.R., Dietrich, A., Stolz, W., 1998. Investigations of feldspar radioluminescence: potential for a new dating technique. Radiat. Meas. 29, 421-425.

Trautmann, T., Krbetschek, M.R., Dietrich, A., Stolz, W., 1999. Feldspar radioluminescence: a new dating method and its physical background. J. Lumin. 85, 45-58.

Krbetschek, M.R., Trautmann, T., Dietrich, A., Stolz, W., 2000. Radioluminescence dating of sediments: methodological aspects. Radiat. Meas. 32, 493-498.

Erfurt, G., Krbetschek, M.R., 2003. Studies on the physics of the infrared radioluminescence of potassium feldspar and on the methodology of its application to sediment dating. Radiat. Meas. 37, 505 – 510 .

Erfurt, G., Krbetschek M.R., 2003. IRSAR – A single aliquot regenerative-dose dating protocol applied to the infrared radiofluorescence (IR-RF) of coarse-grain K feldspar. Ancient TL 21, 21-28.

Novothny, A., Frechen, M., Horvath, E., Krbetschek, M.R., Tsukamoto, S., 2010. Infrared stimulated luminescence and radiofluorescence dating of Aeolian sediments from Hungary. Quat. Geochr. 5, 114–119.

Wagner, G.A., Krbetschek, M., Degering, D., Bahain, J.J., Shao, Q., Falguères, C., Voinchet, P., Dolo, J.-M., Garcia, T., Rightmire, G.P., 2010. Radiometric dating of the type-site for Homo heidelbergensis at Mauer, Germany. Proc. Natl. Acad. Sci. USA 107, 19726–19730.

Bøtter-Jensen, L., Bulur, E., Murray, A.S., Poolton, N.R.J., 2002. Enhancements in luminescence measurement techniques. Radiat. Prot. Dos. 101, 119-124.

Buylaert, J.P., Jain M., Murray, A.S, Thomsen K.J., Lapp, T., IR-RF dating of sand-sized K-feldspar extracts: a test of accuracy. Radiat. Meas. (to be published 2012)

Lapp, T., Jain, M, Thomsen, K.J., Murray, A.S., Buylaert, J.P., New Luminescence Measurement Facilities in Retrospective Dosimetry. Radiat. Meas. (to be published 2012)