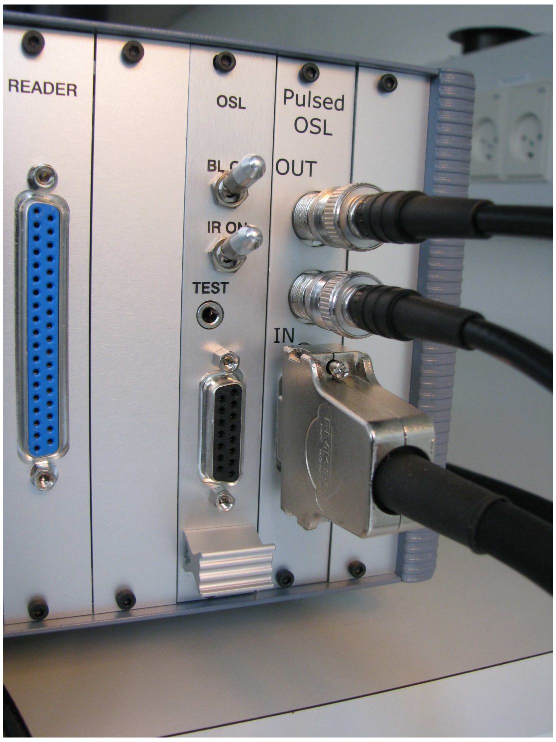
Guide to “The Risø Pulsed OSL attachment”



Risø DTU, Denmark
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1 Introduction

The Risø pulsed OSL unit is an attachment to the conventional Risø TL/OSL luminescence reader. This attachment enables measurement of pulsed optically stimulated luminescence (POSL). In POSL the stimulation light is pulsed and the OSL is only measured in between the pulses (see Figure 1). There are several reasons why it may be advantageous to measure the POSL signal.

1. Pulsing provides insight into the luminescence recombination process. The POSL signal after the stimulation pulse decays according to the lifetime of the luminescence centres being stimulated.
2. Pulsing enables reduction of the filtering required to separate the stimulation light from the emitted luminescence. More overlap between the stimulation and detection wavelengths can be tolerated for a given background.
3. Different luminescence centres have different relaxation lifetimes, which means that POSL provides an instrumental way of separating the luminescence emitted from different phosphors.

The Risø pulsed OSL attachment can be used directly with a standard TL/OSL system fitted with a standard OSL stimulation head.

2 Hardware

The Risø pulsed OSL attachment is a self-contained unit, based around an 8-bit microcontroller, with 8 kb of flash memory containing the control software. The attachment allows full user control of power level, on-time, off-time and PMT-gating settings from the Sequence Editor operating program. These settings are used to initialise the programmable timer and preset the voltage to be applied to each cluster of blue or IR diodes.The pulsed OSL attachment board is mounted in the Risø TL/OSL Controller and connected to the LED stimulation head of a standard Risø automated reader. The microcontroller detects the switch-on and switch-off signals from the Minisys for each of the blue and IR diode groups.

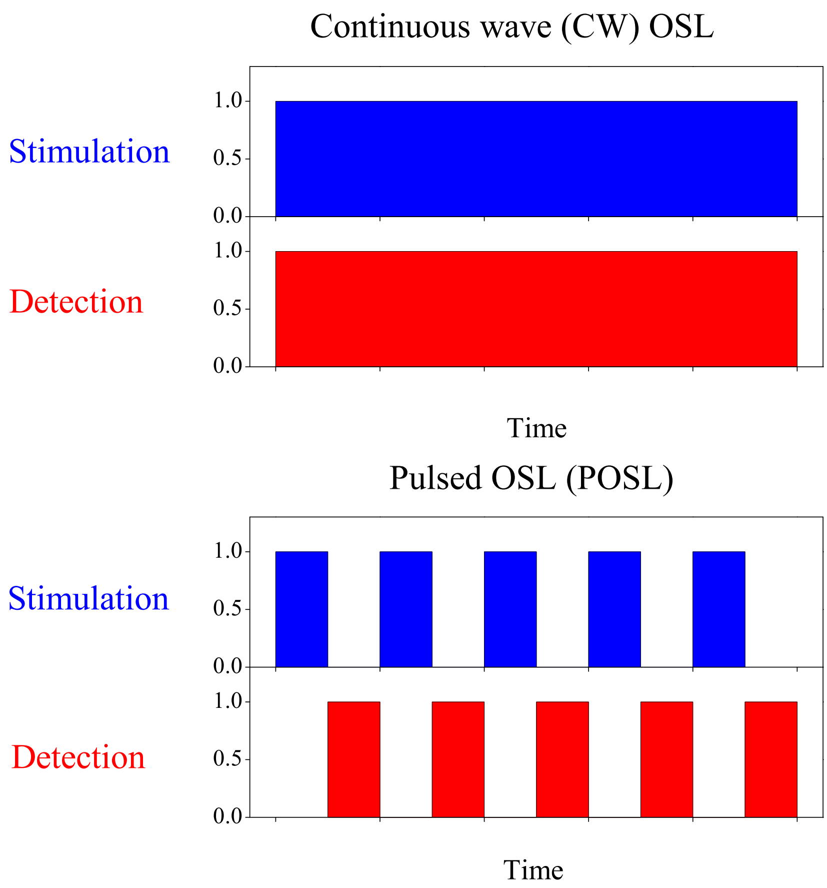

Figure 1: Top graph illustrates continuous wave (CW) mode. In CW stimulation is continuously and so is detection. In pulsed mode (POSL) stimulation is pulsed and detection takes place in between pulses.

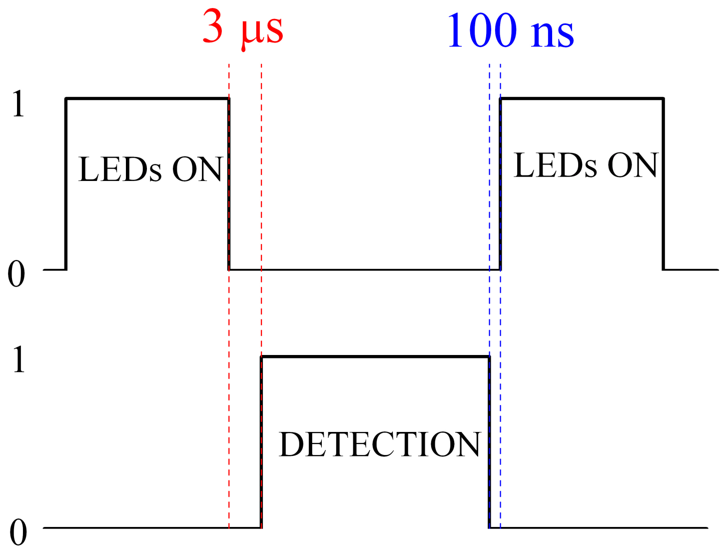

Figure 2: Schematic diagram of the pulse timing. Detection begins $3\,\mu$s after the switch-off signal has been sent to the LEDs. This delay allows the LEDs to have switched off completely before detection begins. Detection ends approximately 100 ns prior to the next LED switch-on pulse.

When a switch-on signal is received, the programmable timer begins to pulse the preset voltage connected to the selected LEDs, through a solid state switch. A delay of 800 ns is inserted between the programmable timer and this switch to allow for external/internal synchronisation. Once pulsing of the LEDs has begun the stimulation intensity is monitored using a photo-diode built into the stimulation head. This feedback signal is digitised using a 12-bit analogue to digital converter so it can be read by the microcontroller. This then compensates for any drift in stimulation intensity by adjusting the voltage applied to the LEDs accordingly. For *on* pulses of $< 100\,\mu$s this signal is monitored on a pulse by pulse basis; for longer periods, however, the pulses are monitored at regular intervals within the *on*-period itself. So that the LED pulsing unit may be used directly with the standard Minysis/Controller system, a photon-count gating circuit has been included. This provides a counting window within the *off*-period of each pulse cycle. Incoming TTL photo multiplier (PM) pulses are gated off while the LEDs are switched on, but allowed to pass (to be counted) during the LED off-period. The exact starting time of this window relative to the diode pulse is preset using the internal synchronisation mentioned above; the start time can be adjusted from ~ 500 ns prior to the LEDs being switched off, to $\sim 25\,\mu$s after. The default start time is $2.5\,\mu$s after switch-off. This setting

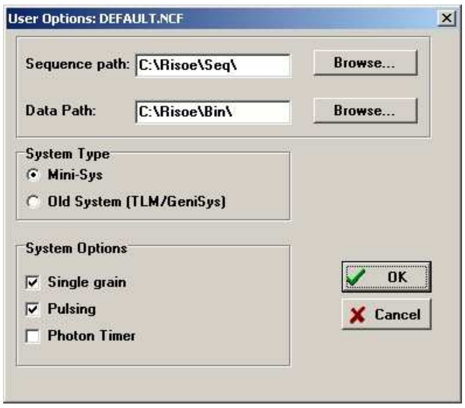

Figure 3: In User Options the availability of the pulsed OSL attachment is specified

is chosen to allow the LEDs to have switched off completely before counting begins. The counting window ends approx. 700 ns prior to the next LED switch-on pulse (see Figure 2).

3 Settings

The Sequence Editor has been updated with a POSL command where the pulsing parameters can be specified. For the POSL command to become available, you must specify that the pulsing option is available. This is specified in the *User Options* dialog of the Sequence Editor(see Figure 3).

Restrictions to the on- and off-time settings:

- Exponents factors of less than 10^{-6} are invalid
- Setting of on-time $< 0.2\,\mu$s is invalid
- Setting of off-time $< 0.6\,\mu$s is invalid
- Depending on the exponent factor of the lower of on-time and off time there are limitations to the other time setting:

Exponent factor of the lower of on-time and off time	The maximum setting of the larger of on-/off-time
10^{-6}	$1.3 \cdot 10^{-2}$ s = 13 ms
10^{-5}	$6.5 \cdot 10^{-2}$ s = 65 ms
10^{-4}	$6.5 \cdot 10^{-1}$ s = 650 ms
10^{-3}	$6.5 \cdot 10^{0}$ s = 6.5 s
10^{-2}, 10^{-1}, 10^{1}, 10^{0}	$6.5 \cdot 10^{1}$ s = 65 s

If off-time is lower than on-time and exponent factor is 10^{-2}, 10^{-3},10^{-4}, 10^{-5} the digit setting of 0.1 and 0.2 of off-time are invalid. When the on-time is below approximately 5 μs the LED pulse shape may not be as rectangular as for on-times higher than 5 μs, especially at high power settings. If rectangular pulse shape is important you should restrict on-time to above 5 μs.

Setting is only possible in steps larger than or equal to 0.2 μs; For instance a setting of 1.7 μs will effectively be 1.6 μs.

4 Adjusting the Pulsed OSL attachment

The power level of the pulsed OSL unit must be adjusted prior to use. This can be achieved by either sending the OSL stimulation head to Risø or following the instructions given below.
To adjust the power level of the unit the following items are required:

- A voltmeter with high impedance input (standard digital voltmeter, DVM)
- The pulsed OSL calibration unit (see Figure 5)

As the driver circuitry of the pulsed OSL unit is different from the driver circuitry of the CW LED unit, using the same percentage of power on the two units does not ensure that the power density on the sample is the same.

How does the regulation work?

The stimulation LEDs current is set by the microprocessor via the DAC (Digital to Analog Converter, see Figure 4). The maximum digital setting is 4095 (12-bit) and this corresponds to a maximum control voltage VI_{max} that may be adjusted by potentiometers P9/P10 (Blue/IR).

The stimulation light is detected by a photodiode, and the feed-back is converted to a digital value $\mathrm{D_{FB}}$ (0-4095) by an Analog to Digital Converter (ADC) to be read by the microprocessor. The feed-back voltage corresponding to the maximum digital output may be adjusted by potentiometers P1/P2 (Blue/IR). A low voltage corresponds to a high feed-back gain.

The microprocessor reads the power setting from the Minisys that gets the power setting from the Sequence Editor or the Control program. The power setting is converted to a desired feed-back value $\mathrm{D_{FB}}$ from the $\mathrm{D_{FB99\%}}$ stored in the microprocessor non-volatile memory, e.g. if 70% output is wanted the microprocessor regulates the output (D_I) to get a feed-back $\mathrm{D_{FB}} = 70/99 \times \mathrm{D_{FB99\%}}$.

In order to start out with approximately the right output (D_I) a conversion from desired feed-back $\mathrm{D_{FB}}$ to approximate output (D_I) is made in the microprocessor. This conversion curve is recorded during the auto-calibration step described below.

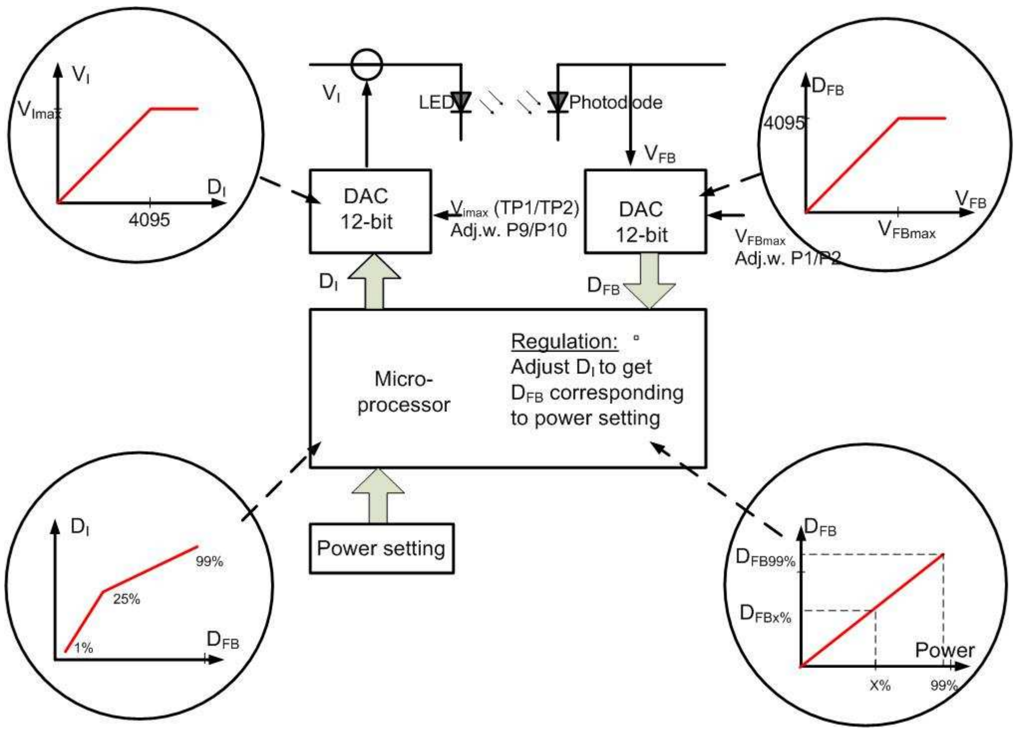

Figure 4: Regulation block diagram.

The adjustment procedure serves to adjust the potentiometers P1, P2, P9, P10 and the microprocessor parameters for optimal use of the stimulation head. Different OSL stimulation heads need different adjustment.

Adjustment procedure

A picture of the circuit board is shown in Figure 6.

First part of the procedure is to ensure that current through the LEDs do not reach a level that may damage the LEDs (item 1 to 3).

Second part of the procedure is to find the feed-back gain (V_{FBmax}) to ensure that a power setting of 99% gives maximum power and we keep within the range of the DAC and ADC (item 4 to 14).

Third part of the procedure is to find and store the points on the conversion curve that ensures that the start out output setting is right (item 15).

PART I

1. Install the pulsed OSL unit in the Risø TL/OSL Controller (but do NOT connect to the OSL head) and switch on the mains AC power.

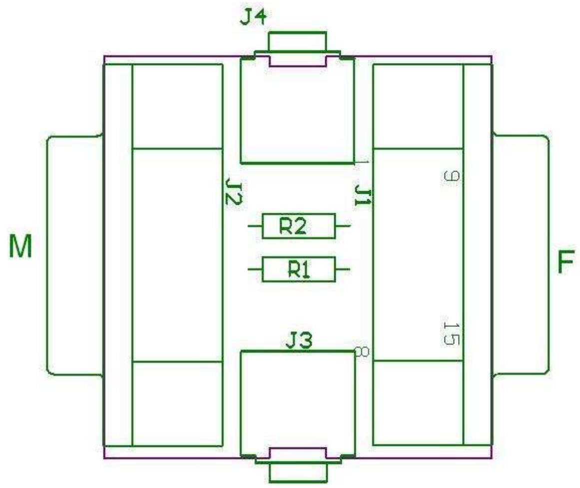

Figure 5: Layout diagram of the pulsed OSL calibration unit. “J3” IR diodes current monitor Jack socket. “J4” Blue diode current monitor Jack socket. “M” Male connector to pulsing unit. “F” Female connector to OSL head.

2. measure the voltage between “ground” and “TP1”(see Figure 6). Adjust “P9” to give -8.0 V ($\pm$0.05 V)

3. measure the voltage between “ground”and “TP2”. Adjust “P10” to give -4.0 V ($\pm$0.05 V).

PART II

4. Ensure that both “P1” and “P2” are fully rotated ($>$ 20 turns)anticlockwise. This ensures that the photodiode gain is set to a maximum.

5. Now adjust the maximum diode current to final values. Adjust the parameter settings in the Risø Control Program (see Figure 7):
   Optical power (%) = 99
   On time (s) = 5.0×10^{-5}
   Off time (s) = 5.0×10^{-5}
   Check these settings carefully! Incorrect setting may damage the OSL unit.

6. Connect one end of the pulsed OSL calibration unit (Figure 5) to pulsed OSL unit; the socket on the pulsed unit which normally connects to the OSL head plug) and connect the other end to the OSL head itself.

7. Connect the voltmeter to “J4” using the Jack plug to banana plug lead

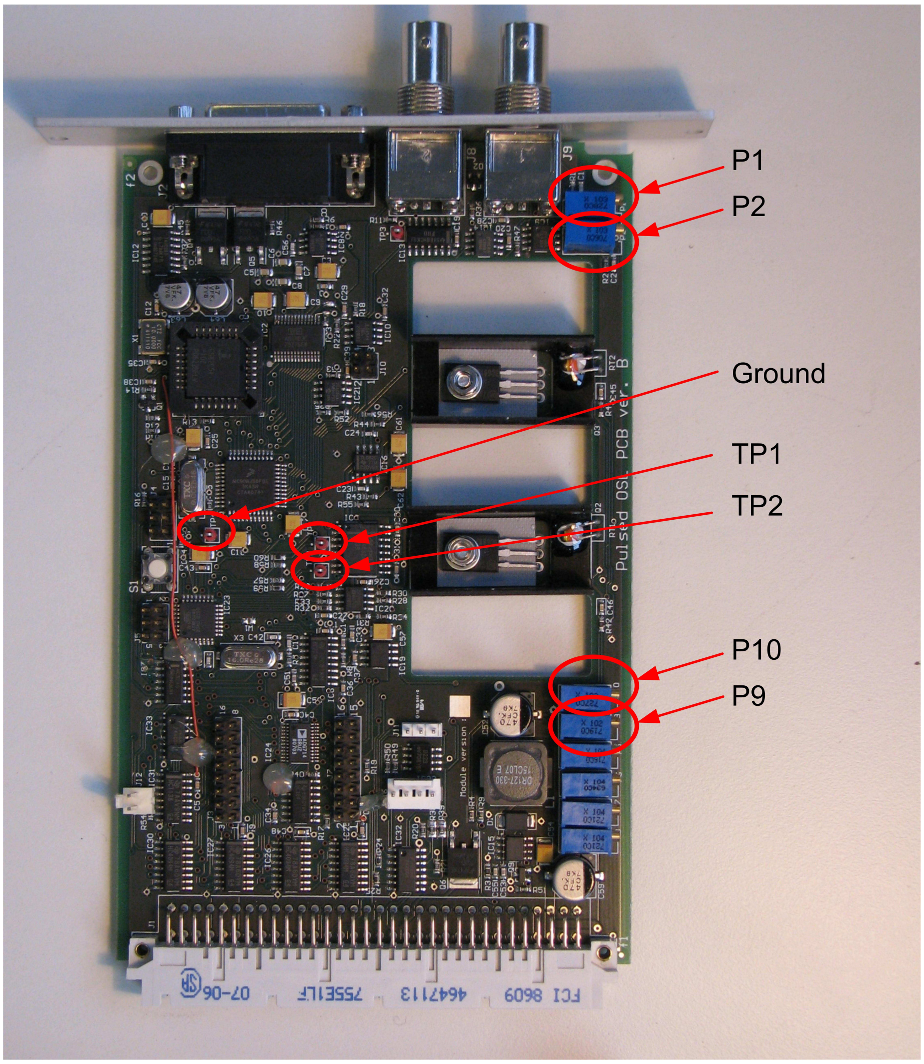

Figure 6: Picture of the circuit board. Please note the positions of “ground”, “TP1”, “TP2”, “P1”, “P2”, “P9” and “P10”

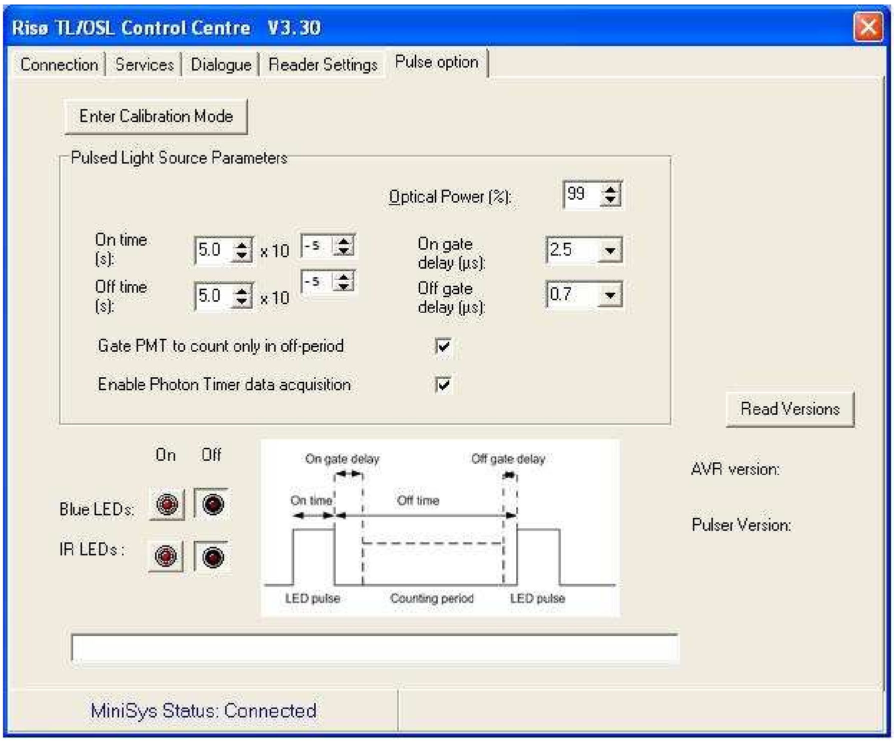

Figure 7: Control program - Pulse Option tab.

provided (i.e. across “R2”) on the calibration unit. This will show the current through the blue diodes.

8. Switch on the blue diodes in the Risø Control program
9. Adjust “P1” (photo detector gain) clockwise. The DVM voltage will slowly increase. Continue to adjust “P1” until the DVM just stops increasing (the voltage must not exceed 0.22 V). If the voltage cannot exceed 0.185 V then adjust “P9” approximately 0.5 turn clockwise. If it is still not possible to exceed 0.185 V then adjust “P9” further approximately 0.5 turn clockwise (this may be repeated a number of times if necessary).
10. Turn “P1” anticlockwise to set the voltage to 0.185 V (within 0.180 and 0.190 V).
11. Now adjust the IR diodes. Move the jack plug to “J3” on the OSL calibration unit. In the Risø Control Program switch off the blue diodes and switch on the IR diodes instead
12. Adjust “P2”(photo detector gain) clockwise. The DVM voltage will slowly increase. Continue to adjust “P2” until the DVM just stops increasing

(The voltage must not exceed 0.58 V). If the voltage cannot exceed 0.48 V then adjust “P10” approximately 0.5 turn clockwise. If it is still not is possible to exceed 0.48 V the adjust “P10” further approximately 0.5 turn (this may be repeated a number of times if necessary).

13. Turn “P2” anticlockwise to set the voltage to 0.495 V (within 0.480 and 0.510 V)

14. Switch off the IR diodes in the Risø Control program

PART III

15. Run a calibration routine after the OSL calibration unit has been removed. This is done by pressing the “Enter Calibration mode” button in the Control program (see Figure 6). The unit will now start an automatic calibration routine. After approximately 1 minute the calibration ends. If the calibration is not completed try to repeat the process carefully. If the calibration procedure is still unsuccessful contact Risø Support (+45 4677 4935 or osl@risoe.dk)

5 Connection

Installation of the built-in pulsed OSL board is described in the following.

The PMT signal that feeds into the Controller is pre-amplified and shaped before it is directed to the counter of the Controller . As the Pulsed OSL board is gating the PMT signal, the preamplified and shaped PMT signal has to be directed to the Pulsed OSL board to be gated and then directed back to the Controller counter. Therefore the internal connection between preamplifier output and counter input has to be disconnected and instead these two connector are connected to the back of the Controller from where they can be connected to the Pulsed OSL board. This is illustrated in see Figures 8, 9 and 10

The pulsed OSL board is installed in an empty slot in the right side of the backplane and the following external connections are made:

”Preamp out” to Pulsed OSL ”In” ”Counter in” to Pulsed OSL ”Gated out”

Furthermore the cable to the OSL stimulation head must moved from the connector on the OSL board to the connector on the Pulsed OSL board. The external connections are shown in Figure 10 When doing standard continuous wave OSL (CW-OSL). The OSL head cable connector should be moved back to the OSL board, but the signal cable connector need not be removed as the gating on the Pulsed OSL board is disabled when doing CW-OSL.

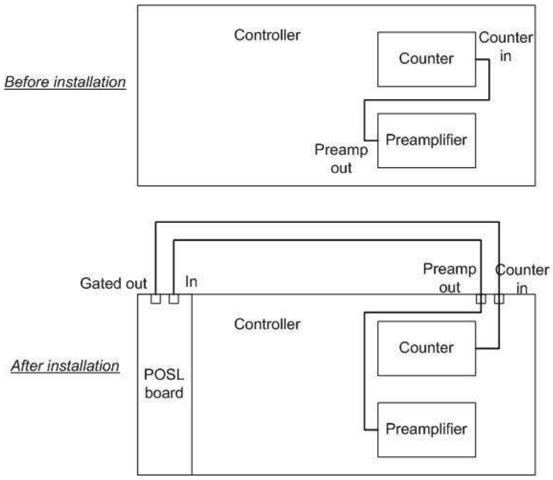

Figure 8: Schematic drawing of the connections between Reader, Controller and POSL board.

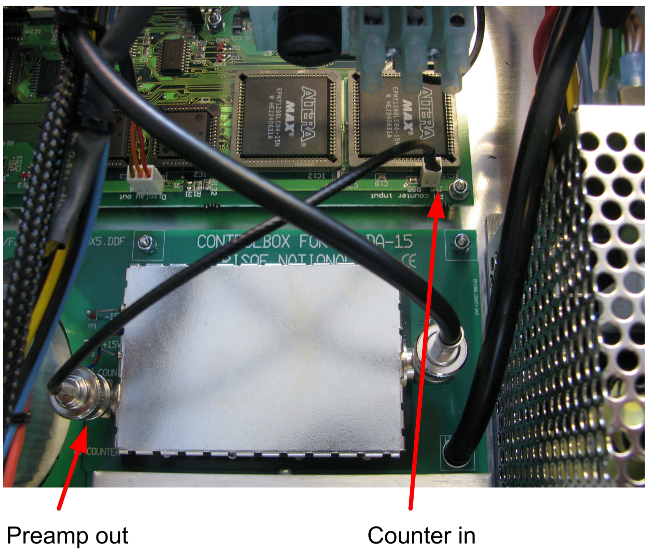

Figure 9: Photo of the interior of the Controller showing the connection between preamplifier and counter.

Figure 10: Photo showing the connections on the back of the controller.