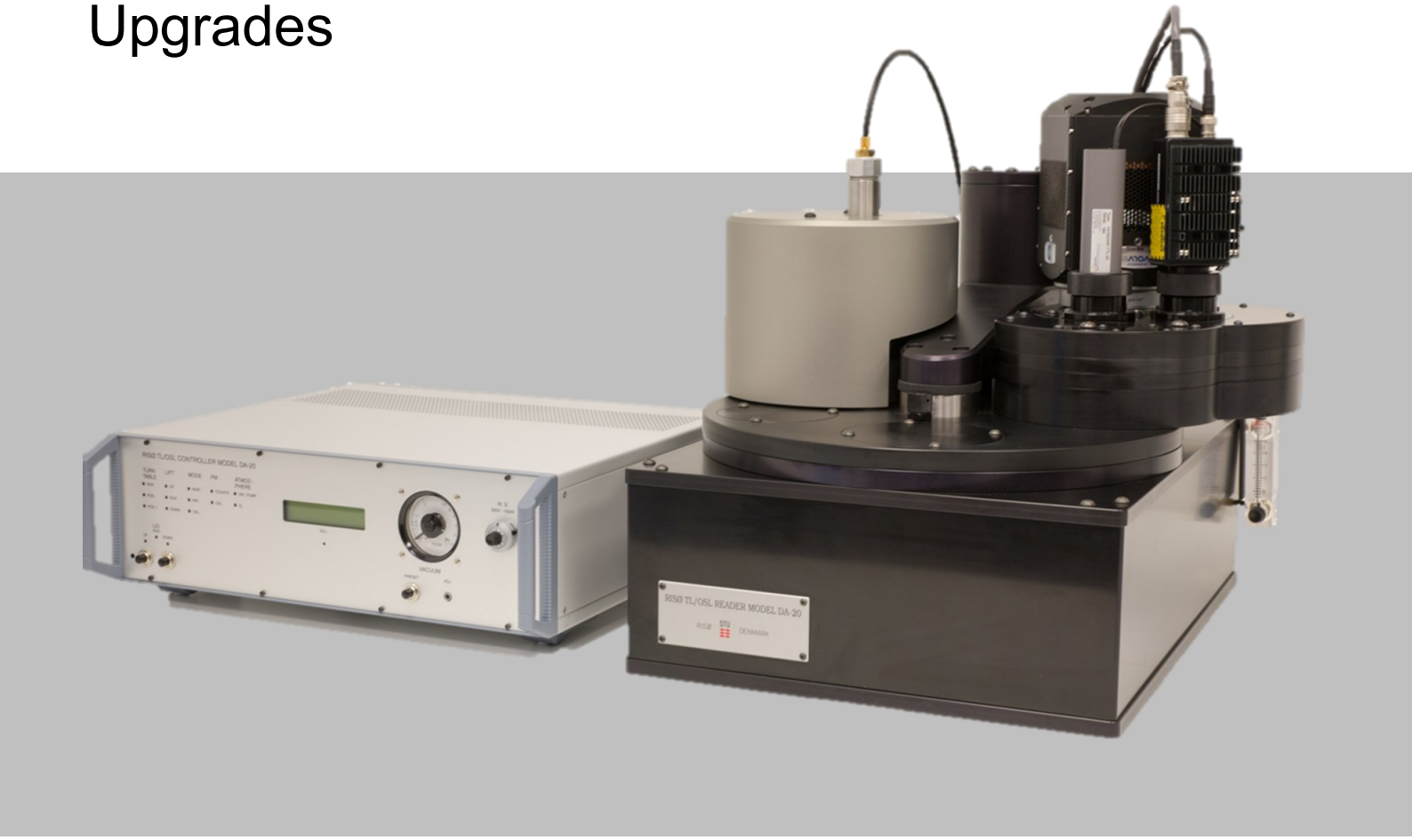
DTU Nutech
Center for Nuclear Technologies

The Risø TL/OSL Reader &
Ultra-low-level Beta GM Multicounter

Upgrades



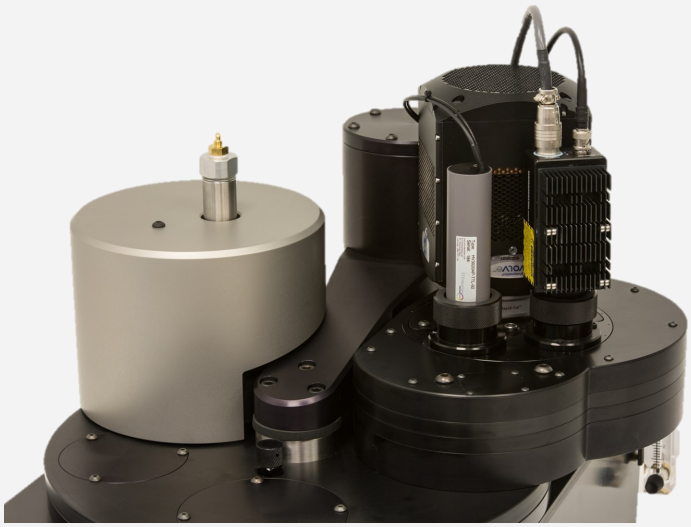
Upgrade catalogue 1710b

1000. DASH

1001. Detection and Stimulation Head (DASH)

The Detection and Stimulation Head (DASH) provides easy access to new technologies, new signals and new measurement methods. The DASH is fully automated and contains LED modules for optical stimulation, a filter changer and a detector changer (optional). The DASH can accommodate a variety of attachments such as the single grain attachment and the spectrometer. The DASH can be retrospectively fitted to existing large diameter Risø TL/OSL Readers.
The DASH is modularised into four layers:

- Optical stimulation unit (bottom layer)
- Filter changer (middle two layers)
- Detector changer (top layer; optional)

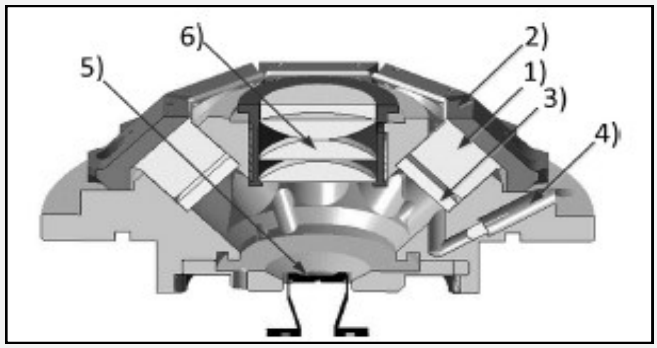


DASH shown with detector changer and mounted with the standard PMT (item 2001), a red PMT (item 2002) and the EMCCD camera (item 2004)

Optical stimulation unit

Optical stimulation is achieved using LEDs with high condensing lenses. LEDs are chosen for optical stimulation mainly because of their long lifetime and stability. The standard LED configuration is given below:

Colour	Wavelength (nm)	Bandwidth (nm)	Power density (mW/cm^2)
Blue	470	20	80
Green	525	30	40
IR	850	33	300



Cross section of the automated DASH base unit. 1) Stimulation LED with reflector, 2) LED cooler 3) stimulation filter, 4) feed-back photodiode, 5) sample heater, 6) collimating optics (Lapp et al., 2015).

The stimulation unit includes 7 locations for LEDs and one through-hole to allow the entry of an external stimulation light source.
The 8 stimulation locations are evenly distributed around the periphery of a circle centred on the sample location. The beams from the individual LEDs have an incident angle of 45° at the sample. The LEDs are mounted in close thermal contact with the aluminium framework of the DASH to provide good thermal contact with the entire reader and so ensure long LED lifetime and stability. Three of the LED positions (normally one blue, one green and one IR) have a feed-back photodiode mounted for regulation of the power during stimulation. All selections/ operations are software controlled, and can be user-selected in a measurement sequence.

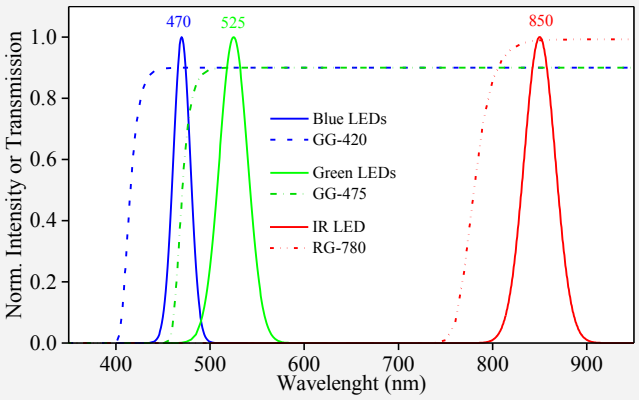
1000. DASH

1001. Detection and Stimulation Head (DASH) continued

Long-pass filters are used in front of the individual LEDs to minimise the amount of directly scattered stimulation light from reaching the light detection system.

The LED modules can be operated in

- Continuous wave (CW) mode [0-100%]
- Linear modulated (LM) mode [0-100%]
- Pulsed (POSL) mode [on/off times from 5 µs with 0.1 µs resolution]. Note that POSL measurements require the optional Pulsed OSL attachment.



Emission characteristics of the stimulation LEDs and transmission characteristics of the long-pass filters used in front of the individual LEDs.

The detection filter changer occupies the two middle layers of the DASH. In this picture the detector changer (optional) has been removed for better illustration.

Automated detection filter changer

The automated detection filter changer (Lapp et al., 2015) is an integrated part of the Detection and Stimulation Head (DASH). The filter changer enables automatic selection of detection filters during a measurement sequence. The detection filter changer consists of two filter changer wheels; each accommodating up to 4 detection filters and thus enabling the use of up to 16 filter combinations in a given measurement sequence. The detection filter changer is designed to accept individual filters (or stack of filters) up to 7.5 mm thick with a diameter of 25 mm (1 inch). The following detection filters are supplied: 5 mm Hoya U-340, 2.5 mm Hoya U-340, 2 mm Schott BG-39, 3 mm Schott BG-3 and Neutral density filter (OD 6 or 7)

In this option, the standard blue/UV PMT (item 2001) and the Automated DASH driver board (item 1002) are included as well.

1002. Automated DASH driver board

Driver board for the Controller enabling DASH operation of the Risø TL/OSL Reader

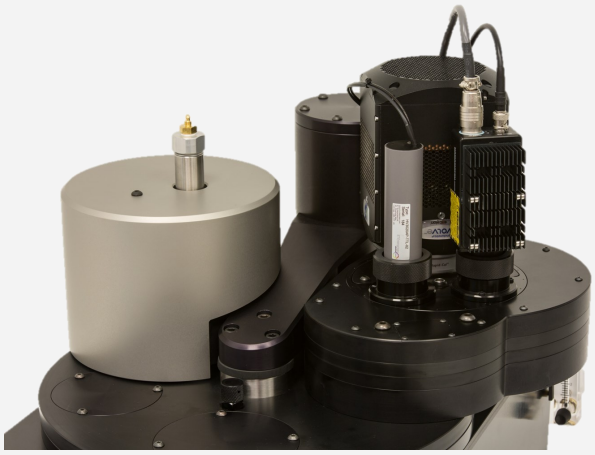
Lapp et al., 2015. A new luminescence detection and stimulation head for the Risø TL/OSL reader. Radiation Measurements 81. 178-184

1003. Automated detector changer

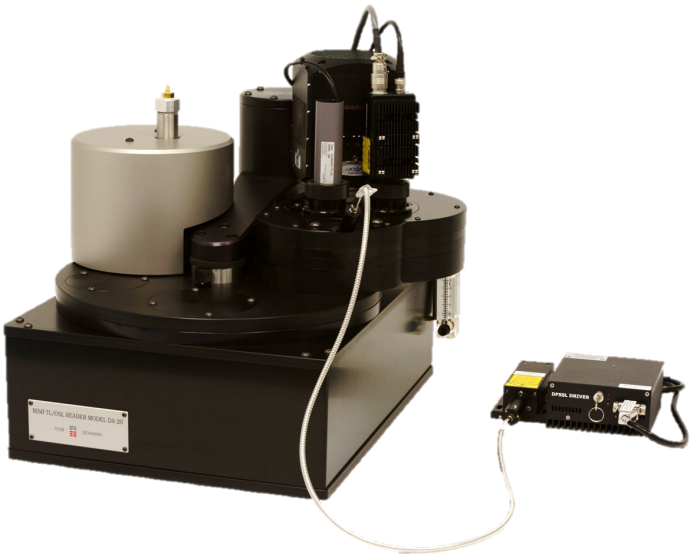
The automated detector changer enables automatic selection of detector (Lapp et al., 2015). The detector changer accommodates up to three different detectors with one position dedicated to the EMCCD attachment (see item 2004). All detectors use a common collimating lens system placed in the base unit.

- Three detector positions
- Software controlled detector change during a measurement sequence
- Fused-silica lens system

The detector changer can only be mounted on DASH (not on a classical OSL unit).



The detector changer is the top layer of the Detection and Stimulation Head (DASH) shown to the right. Here the detector changer is equipped with a standard blue/UV PMT (item 2001), the red sensitive H7421-40 PMT (item 2002) and the EMCCD camera (item 2004).



Example of how a user-supplied external light source can be coupled to the Reader using the empty position in the DASH.

The stimulation unit in DASH (item 1001) includes 7 locations for LEDs and one through-hole to allow the entry of the single grain laser beam (see item 4001) or another external stimulation light source (e.g. item 4501 or a user-supplied light source). The picture on the right shows how a user-supplied external light source can be coupled to the Reader.

1500. Classic OSL head

1501. Refurbishment of blue and IR LEDs

Classic OSL units can be upgraded with new and more powerful LEDs. This also applies for old OSL units with IR lasers thereby making these compatible with the DA-20 Controller. This upgrade includes new glass filters and feed-back detectors in the OSL-unit. The power densities at the sample position will be >135 mW/cm^2 (IR, 870 nm) and >80 mW/cm^2 (Blue, 470 nm).

1502. Refurbishment of blue LEDs

Classic OSL units can be upgraded with new and more powerful blue LEDs. This upgrade includes new glass filters and feed-back detectors in the OSL-unit. The power density at the sample position will be >80 mW/cm^2 (Blue, 470 nm).

1503. Refurbishment of IR LEDs

Classic OSL units can be upgraded with new and more powerful IR LEDs. This also applies for old OSL units with IR lasers thereby making these compatible with the DA-20 Controller. This upgrade includes new glass filters and feed-back detectors in the OSL-unit. The power density at the sample position will be >135 mW/cm^2 (IR, 870 nm).

1504. Classic OSL head driver board

OSL driver board for the Controller enabling classic OSL head operation of the Risø TL/OSL Reader.

1505. Classic single-grain OSL head

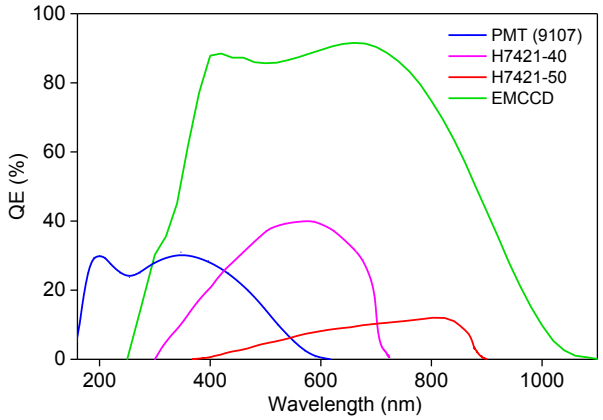
Special IRSL/OSL unit enabling IR/Blue LED stimulation of multi-grain aliquots. This special OSL unit makes use of the same diodes and provides the same power densities at the sample as the standard IRSL/OSL unit, but is designed to accommodate the single grain attachment. The light collection efficiency is reduced by approximately 40% compared to the Classic IRSL/OSL head

2000. Luminescence detectors

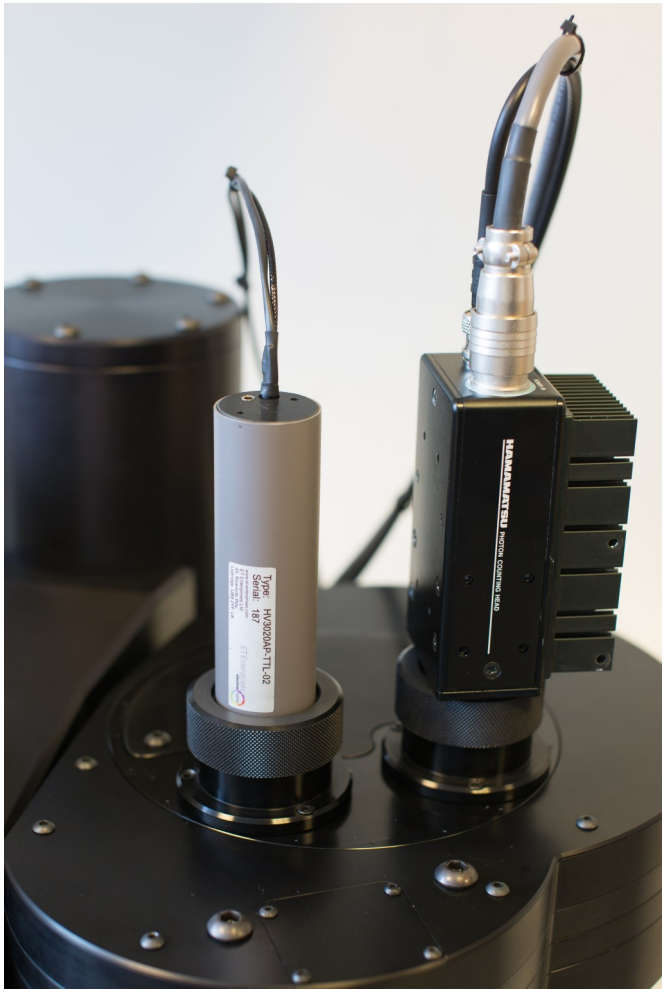
2001. Blue/UV sensitive PMT (160-630 nm)

Blue/UV sensitive Electron Tube PMT, with a maximum detection efficiency between 200 and 400 nm.

- Electron Tube PDM9107Q-AP-TTL-03 with quartz window
- Spectral range: 160-630 nm
- 25 mm diameter biakali photocathode
- Dark count typically <50 cps at 20 °C
- Dead time: ~30 ns
- Max. count rate (with dead time correction) >20 Mcps



Quantum efficiencies for items 2001 (PMT(9107)), 2002 (H7421-40), 2003 (H7421-50) and 2004 (EMCCD).



The UV/Blue sensitive PMT (item 2001) mounted for with the red sensitive PMT detection module (item 2002). The detector changer (item 1003) is a prerequisite when several detectors are mounted simultaneously.

2002. Red sensitive PMT (300-720 nm)

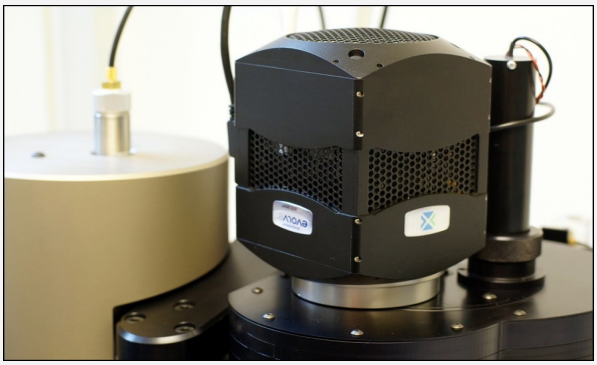
- A Hamamatsu H7421-40 Photon counting head thermoelectrically cooled to 0 °C
- Spectral range: 300-720 nm
- Quantum efficiency: 40% at peak wavelength
- Power supply and temperature controller (built into the Controller)
- Optical interface to the PMT module based on fused silica lenses
- The measurement sample area has ø =5 mm

2003. Red sensitive PMT (380-890 nm)

- A Hamamatsu H7421-50 Photon counting head thermoelectrically cooled to 0 °C
- Spectral range: 380-890 nm
- Quantum efficiency: 12% at peak wavelength
- Power supply and temperature controller (built into the Controller)
- Optical interface to the PMT module based on fused silica lenses
- The measurement sample area has ø= 5 mm

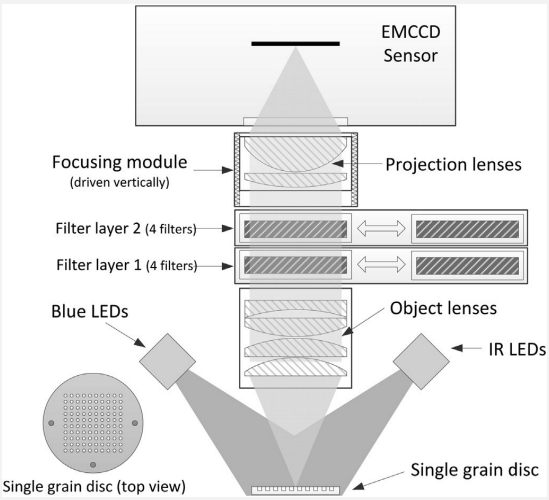
2004. EMCCD imaging attachment

Enables routine luminescence mapping.



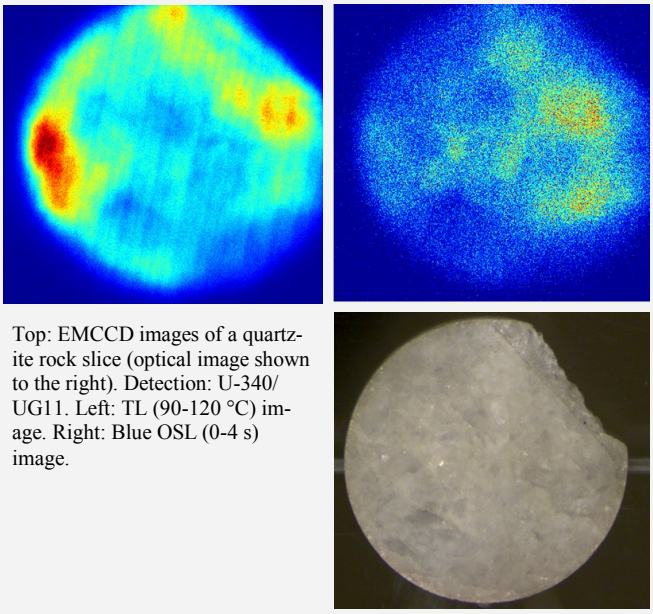
High sensitivity EMCCD imaging attachment

The detection optics is based on fused silica lenses with anti-reflection coatings, providing high UV-visible transparency, large numerical aperture (0.35) and magnification of ~0.8. One aspheric lens is used to enhance the image quality. Because the location of the focal plane is dependent on the measured wavelength, the projection lenses of the optics are mounted on a motorized focussing unit, software-controlled by the measurement sequence. The motorized focussing unit is calibrated by three LEDs, emitting at 470 nm, 525 nm and 870 nm. Sample thickness or location also affects the location of the focal plane.



Schematic diagram showing the components of the luminescence imaging system mounted on a Risø reader (from Kook et al., 2015)

The automatic focusing module utilizes a low-noise piezoelectric linear motor capable of providing a much-improved focusing precision down to 0.5 µm. The improved focusing module also includes a motorized aperture adjustment function to meet different requirements during measuring samples with ultra-low signal to very high signal.

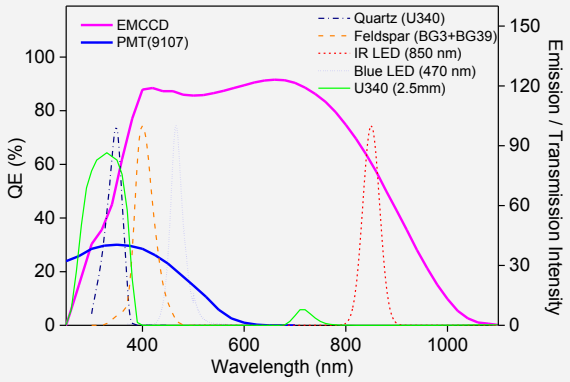


Top: EMCCD images of a quartzite rock slice (optical image shown to the right). Detection: U-340/UG11. Left: TL (90-120 °C) image. Right: Blue OSL (0-4 s) image.

Images are captured by a Peltier cooled (-80 °C) Evolve EMCCD camera (Photometrics); this uses frame transfer and electron multiplier gain (up to 1000 times). The imaging area (512×512, 16 mm pixel) of the chip is 8.2×8.2 mm, and so the object size is 10.2×10.2 mm due to the reduction of the optics. The camera is connected to the host computer by IEEE-1394 (FireWire) for highspeed communication and is triggered by a signal from the Risø controller for synchronization with stimulation light. Read-out time for all pixels is 29.5 ms, but frame-transfer operation effectively reduces this considerably. In this mode, the image array is exposed to the signal for the desired period, and then the entire image is rapidly shifted (0.7 µs vertical shift time) to the storage array. While the masked storage array is

Kook et al., 2015. A luminescence imaging system for the routine measurement of single-grain OSL dose distributions. Radn. Meas. 81, 171-177

2004. EMCCD imaging attachment continued



Comparison of EMCCD and PM tube response, LED emission and the transmission of the U340 detection filter. All curves should be read on the right hand axis except that of EMCCD and the photomultiplier tube, which are read on the quantum efficiency axis.

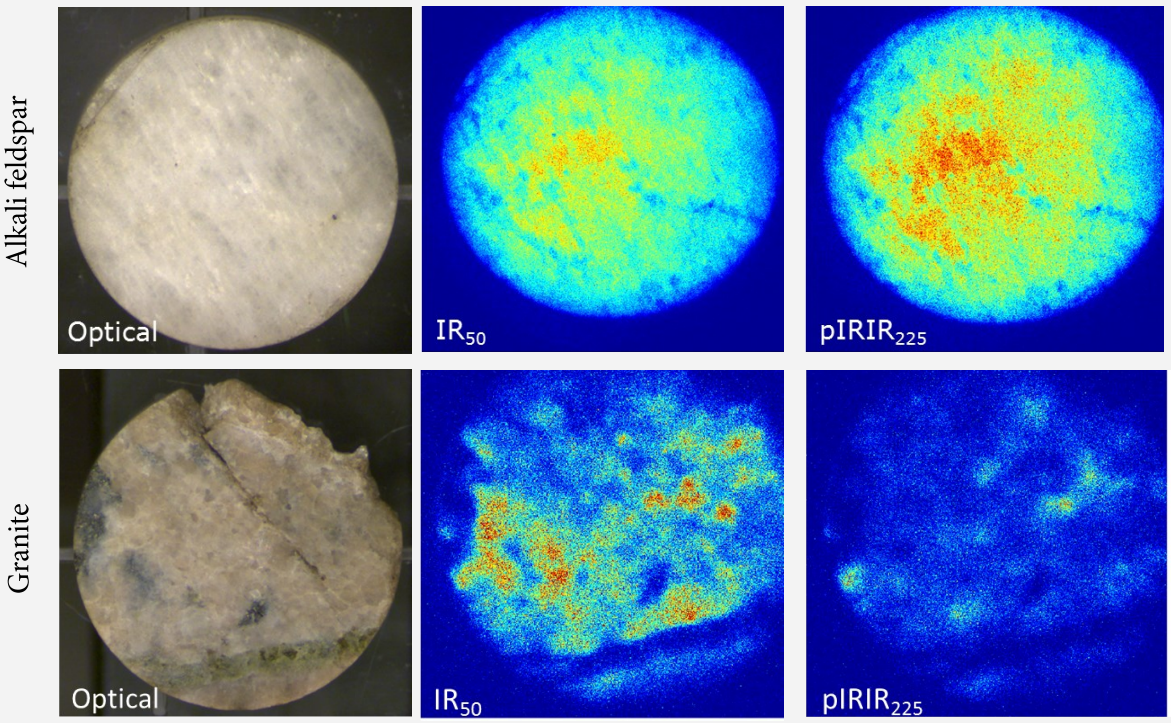
being read, the image array integrates charge for the next image, providing a minimum dead time of ~400 µs between frames.

The EMCCD has a broadband (UV to Near IR, UV-enhanced) window and a high quantum efficiency (QE) compared to a PM tube.

- EMCCD camera: Photometrics Evolve 512
- Peltier cooled, -80°C
- Frame rate: up to 30 fps
- Fused silica optics with broadband (UV-NIR) transmission
- Automated focussing and iris
- Data acquisition controlled by the Sequence Editor
- Data Analysis in Viewer+
- 50 single-grain discs (ø=300 µm, see item 6017)
- 3 mm Hoya U-340 detection filter
- 2 mm Schott coated UG11 detection filter (IR blocking)
- 2 mm Schott BG 39 detection filter
- PC

The detector changer (see item 1003) is a prerequisite for the EMCCD option, which can only be mounted on DASH.

Probing deep traps require stimulation with high energy photons (e.g. >2.6 eV), which is challenging because of



Optical and EMCCD images of rock slices of alkali feldspar and granite measured using BG3 and BG39. The luminescence images were obtained after a dose of ~120 Gy and summation of the first 4 s of IRSL.

2500. The Controller

2501. The Controller

All direct hardware control of the reader is performed by the Controller, which is responsible for maintaining proper timing, sample positioning, data acquisition, error checking, etc. The Controller is equipped with a two-line text display, which shows the current system status and the command which is currently being executed.

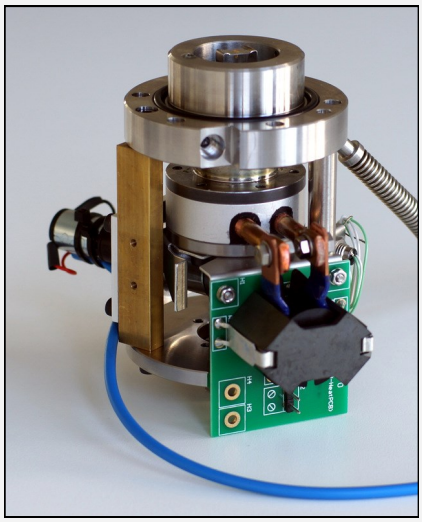
The Controller: controls all hardware

3000. Reader base upgrades

3001. Heating and lifting module

This module is mounted underneath the measurement position and enables measurement at elevated temperatures (from room temperature to 700 °C).

- Heating/lift unit enabling heating of individual samples up to 700 °C
- 30 kHz non-switching sine wave
- Type K thermocouple (Chromel-Alumel)
- cooling by a continuous gaseous flow
- linear heating rates from 0.1 to 10 °C/s.



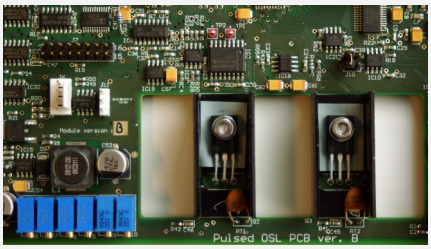
The heating and lifting module.

3002. Replacement of heater element

Replacement of the heater element in items 3001 and 5005.

3003. Reader refurbishment

Upgrade of electronics, valves and motors (incl. new control circuit board and new DC motors inside the Reader). This will enable two speed rotation, direct temperature sensing from thermocouple and the cable connections will be compatible with the current standard.



3004. Large diameter Reader lid

New Reader lid (ø=390 mm) enabling accommodation of various optional attachments. This lid size has been standard from ~1998.

3005. Small diameter Reader lid

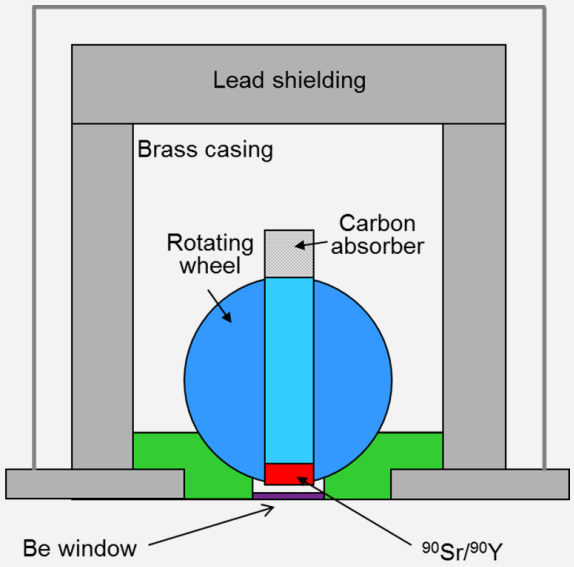
New Reader lid (ø=370 mm) accommodating the current irradiator design. This lid size has been standard prior to ~1998.

3500. Irradiation sources

Samples can be irradiated *in situ* using optional software-controlled irradiation sources: Sr-90 beta, Am-241 alpha and X-ray (50 kV, 1 mA, 50 W). Radioactive sources are delivered directly from the source manufacturer.

Beta irradiation

A detachable beta irradiator is located above the sample carousel. The irradiator is made of brass (outer diameter 10 cm) and is surrounded by 20 mm of lead on the sides, and 40 mm on the top. Furthermore, an aluminium safety helmet (outer diameter 222 mm) covers the entire irradiator and lead shielding. This irradiator accommodates a $^{90}Sr/^{90}Y$ beta source, which emits beta particles with a maximum energy of 2.27 MeV. The half life is 28 years. The radioactive source is mounted into a rotating, aluminium wheel, which is pneumatically activated. The source is placed inside the irradiator, directly followed by a 20 mm thick aluminium spacer, a 20 mm thick lead spacer, a spring washer, and finally a 25 mm thick aluminium spacer. When the source is *off* (default position) it is pointing upwards directly at a 10 mm Carbon absorber. When the source is *on* (activated position) it is pointing downwards towards the measurement chamber. A 0.125 mm beryllium window is located between the irradiator and the measurement chamber to act as vacuum interface for the measurement chamber.

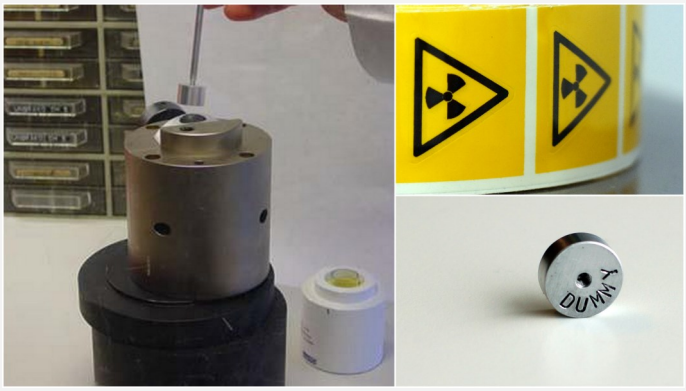


Schematic diagram of the cross section of the beta irradiator. The $^{90}Sr/^{90}Y$ source is placed in a rotating aluminium wheel, which is pneumatically activated. The source is shown in the *on* (irradiating) position. When the source is *off* the wheel is rotated 180°, so that the source points directly at the carbon absorber. Redrawn from Markey et al. (1997).

3501. Beta irradiation unit (1.48 GBq)

- Radioisotope: Sr-90 (see item 3508)
- Nominal activity: 1.48 GBq (±20%)
- Type: Ceramic source (SICB20231)
- Dose rate: ~0.10 Gy/s (in quartz on stainless steel discs)
- Detachable beta irradiator with a beryllium foil end window (see item 3507)

The radioactive source is loaded into the detachable beta irradiator on-site.



Markey al., 1997. A new flexible system for measuring thermally and optically stimulated luminescence Radiat. Meas., 27, 83-89.

3500. Irradiation sources

3502. Beta irradiation unit (37 MBq)

- Radioisotope: Sr-90 (see item 3509)
- Nominal activity: 37 MBq (±30%)
- Type: Ceramic source
- Dose rate: ~2.5 mGy/s (in quartz on stainless steel discs)
- Detachable beta irradiator with a beryllium foil end window (see item 3507)

The radioactive source is loaded into the detachable beta irradiator on-site.

3503. Beta irradiation unit (2.96 GBq)

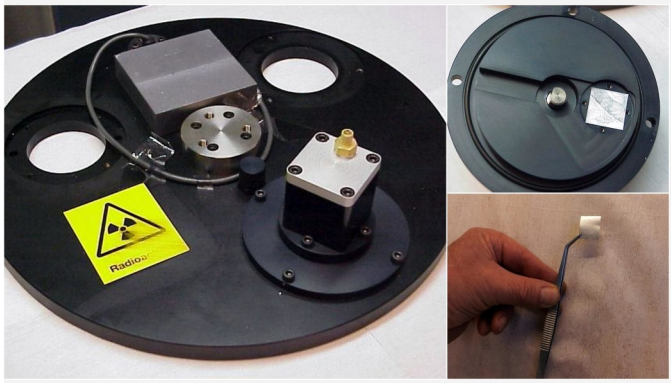
- Radioisotope: Sr-90 (see item 3510)
- Nominal activity: 2.96 GBq (±30%)
- Type: Ceramic source (SICB18447)
- Dose rate: ~0.25 Gy/s (in quartz on stainless steel discs)
- Detachable beta irradiator with a beryllium foil end window (see item 3507)

The radioactive source is loaded into the detachable beta irradiator on-site.

3504. Alpha irradiation unit (10.7 MBq)

The alpha irradiator accommodates a 10.7 MBq (290 mCi) Am-241 foil source. Am-241 is a mixed alpha/gamma emitter. The dominating alpha energy is 5.49 MeV (85.1%) and the dominating gamma energy is 59 keV.
The source is mounted behind a pneumatically controlled shutter. The alpha irradiator option is integrated with the system lid and a sealed shaft allows operation of the irradiator under vacuum.

- Radioisotope: Am-241
- Nominal activity: 10.7 MBq (±15%)
- Type: foil source type (AMMB7616)
- Detachable alpha irradiator including pneumatic control valves



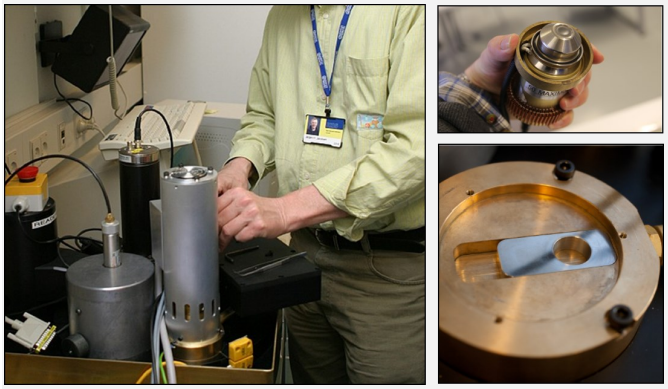
Left: Alpha irradiator mounted on a free-standing lid. Top right: Alpha irradiator seen from below showing the mounted foil alpha source . Bottom right: Foil alpha source.

The radioactive source is loaded into the detachable alpha irradiator on-site. Due to the short range of alpha particles from Am-241 the measurement chamber must be evacuated prior to irradiation. Vacuum control is part of the Risø TL/OSL Reader, but a vacuum pump must be ordered separately.

3500. Irradiation sources

3505. X-ray generator

Highly uniform and reproducible *in situ* irradiation can be performed using this 50 kV X-ray source. A mechanical shutter incorporated into the collimator prevents sample irradiation before the X-ray output has stabilised (Andersen et al., 2003).

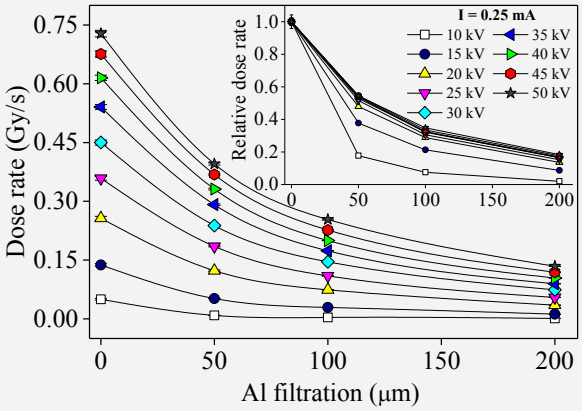


Left: The X-ray tube during testing at DTU Nutech. Top: The Varian VF-50 X-ray tube before assembly. Bottom: The X-ray collimator block with mechanical shutter.

- Shielded, air-cooled Varian VF-50J (W) industrial X-ray tube with Wolfram target
- Spellman high-voltage power-supply (a modified version of the 50 kV, 50 W XRM50P50 model with filament preheat and 2 mA maximum current)
- Stainless steel mechanical shutter (7 mm thick)
- 35 mm long brass collimator (internal diameter 10 mm) with a 50 µm Al end window at the exit

- Shielding, cooling, and interlock features
- Control electronics and low-voltage power supplies.
- Dose rate: adjustable up to ~2 Gy/s (in quartz on stainless steel discs using a exchangeable 50 µm thick Al filter in front of the X-ray tube)

The observed (Thomsen et al., 2006) dose-rate sample dependence can be removed by hardening the X-ray spectrum, e.g. by increasing the thickness of the Al foil. The effect of the thickness of the Al on the dose rate is shown below.



Dose rate as a function of Al filtration thickness. The inset shows the relative dose rate as a function of Al thickness, i.e. the dose rate has been normalised to the unfiltered dose rate (from Thomsen et al., 2006).

3506. Detachable beta irradiator without shielding

Brass beta irradiator

Designed to house a single Sr-90 source (see items 3508-3510). A beta source can be mounted into a pneumatically activated rotating, aluminium wheel.

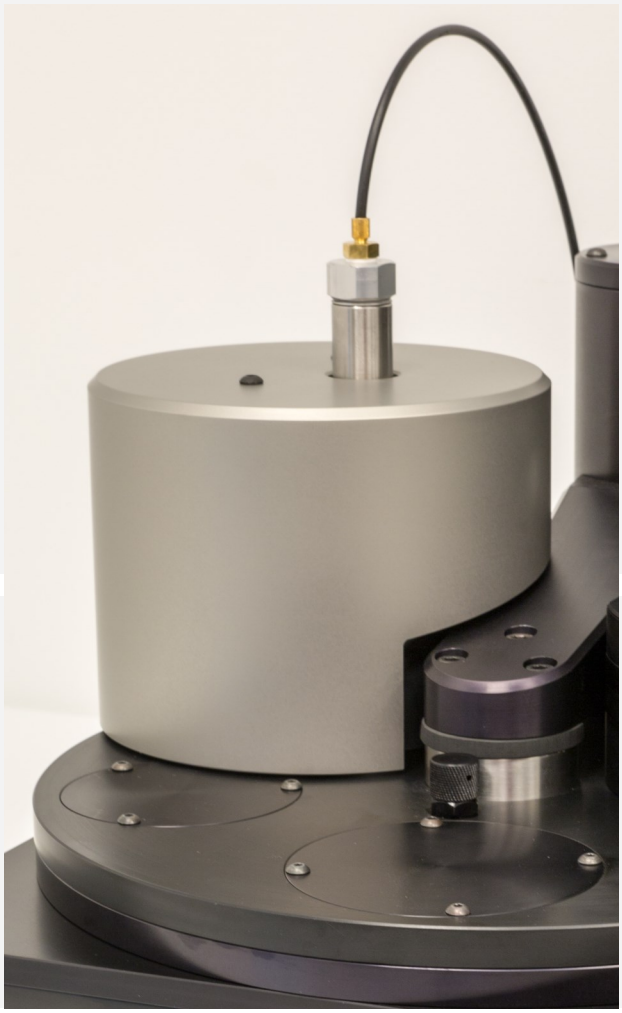
- Brass beta irradiator (outer diameter 10 cm)
- 125 µm thick beryllium end window foil

3500. Irradiation sources

3507. Detachable beta irradiator with shielding

Designed to house a single Sr-90 source (see item 3508-3510). A beta source can be mounted into a pneumatically activated rotating, aluminium wheel.

- Brass beta irradiator (outer diameter 10 cm)
- 125 µm thick beryllium end window foil
- Lead (Pb) shielding (20 mm on the sides and 40 mm on the top)
- An aluminium safety helmet (outer diameter 222 mm) covering the entire irradiator and lead shielding



3508. Sr-90 beta source (1.48 GBq)

- Radioisotope: Sr-90
- Nominal activity: 1.48 GBq (±20%)
- Type: Ceramic source (SICB20231)
- Dose rate: ~0.10 Gy/s (in quartz on stainless steel discs)

Excluding the detachable beta irradiator (item 3507)

3509. Sr-90 beta source (37 MBq)

- Radioisotope: Sr-90
- Nominal activity: 37 MBq (±30%)
- Type: Ceramic source
- Dose rate: ~2.5 mGy/s (in quartz on stainless steel discs)

Excluding the detachable beta irradiator (item 3507)

3510. Sr-90 beta source (2.96 GBq)

- Radioisotope: Sr-90
- Nominal activity: 2.96 GBq (±30%)
- Type: Ceramic source (SICB18447) Dose rate: ~0.25 Gy/s (in quartz on stainless steel discs)

Excluding the detachable beta irradiator (item 3507)

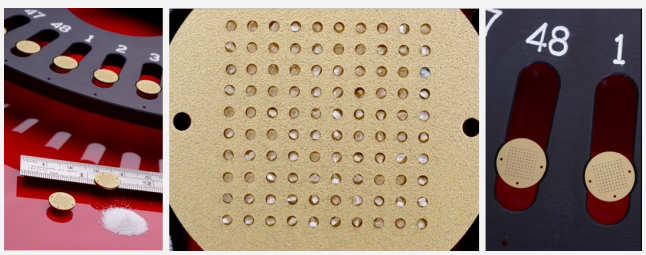
4000. Single grain OSL attachment

4001. Single laser single grain OSL attachment

Enables routine OSL measurements of individual sand-sized grains using a focused green laser (Bøtter-Jensen et al., 2003).

Individual grains are loaded in special aluminium discs containing 100 sample holes on a 10 by 10 grid with 600 µm spacing between hole centres. The diameter and depth of the individual sample hole is 300 µm (item 6017, other depths and diameters of the sample holes are available, items 6018-6021).

Irradiation and heating is performed simultaneously on all 100 grains, whereas the OSL signal can be measured separately from individual grains using a focused laser (beam diameter on the sample disc is < 20 μm). This laser spot is steered to each of the grain holes in turn and switched on. The focused laser enables a high energy fluence rate and reduces the risk of optical cross-talk by ensuring that the entire spot enters the 300 μm diameter hole. Only a small part of the grain will be stimulated directly by the laser beam, but internal reflection within the grain hole is assumed to provide a uniform illumination of the grain.



Anodized, aluminum single grain discs. Do not heat above 500 °C.

The OSL is detected by the standard Blue/UV sensitive photomultiplier tube (item 2007) and appropriate detection filters, e.g. Hoya U-340.

Three lenses are used to focus the laser beam. The laser spot is steered by two orthogonal mirrors and can be positioned arbitrarily on the sample disc. The mirrors are moved by two motor driven stages equipped with position encoders. The mirror in the x-direction is placed at an angle of 45° to the direction of the laser and the y-mirror at an angle of 22.5° to obtain an angle of incidence on the sample disc of 45°.

- Green (532 nm) 10 mW Nd:YVO4 diode-pumped solid-state laser
- An X-Y scanning device using movable mirrors mounted on software controlled encoded motorised linear stages.
- 50 single-grain discs with hole depth and width of 300 µm

DASH is a prerequisite for the Single grain attachment.

Single grain OSL attachment mounted on the Risø TL/OSL Reader.

Bøtter-Jensen et al., 2003. Developments in radiation, stimulation and observation facilities in luminescence measurements. Radiat. Meas. 37, 535-541.

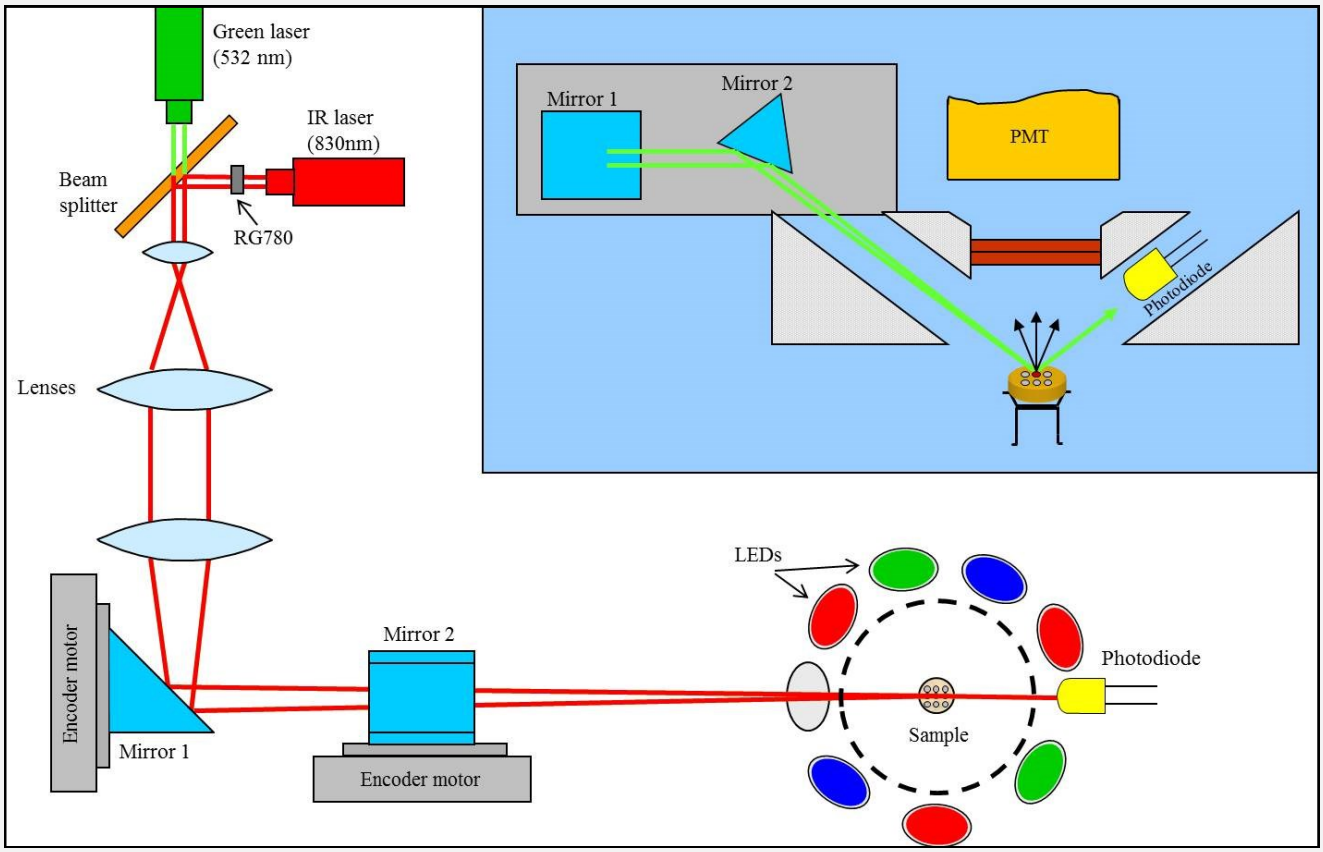
4000. Single grain OSL attachment

4002. Dual laser single grain OSL attachment

Enables routine OSL measurements of individual sand-sized grains using either a focused green or an infrared (IR) laser. A beam splitter enables the use of the same optics to focus the IR laser beam onto the sample disc as used for the green laser.

Individual grains are loaded in special aluminium discs containing 100 holes, 300 µm deep by 300 µm in diameter on a 10 by 10 grid with 600 µm spacing between hole centres (other depths and diameters available upon request). Each grain hole is stimulated individually using one of the two focussed laser. A Schott RG 780 filter is placed directly in front of the IR laser to cut a small resonance emission at 415 nm.

- Green (532 nm) 10 mW Nd:YVO4 diode-pumped solid-state laser
- IR (830 nm) 140 mW TTL modulated laser
- An X-Y scanning device using movable mirrors mounted on software controlled encoded motorised linear stages.
- 50 single-grain discs with hole depth and width of 300 µm
- 3 mm RG-780 longpass filter (mounted directly in front of the IR laser)



Schematic diagram of the dual laser single grain OSL attachment. Optical stimulation is achieved using a laser beam focused by three lenses. The position of the laser spot on the sample is controlled by moving two mirrors. Single grain OSL attachment seen from above. Inset: cross-section of the single grain OSL attachment. Adapted from Duller et al., 1999.

Duller et al., 1999. Single grain laser luminescence (SGLL) measurements using a novel automated reader. Nucl. Inst. and Meth. in Phys. Res. Section B: Beam Interactions with Materials and Atoms 155, 506-514

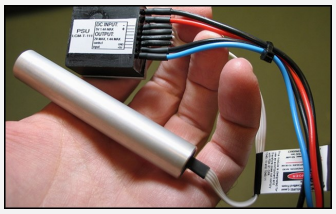
4000. Single grain OSL attachment

4003. Upgrade from existing single laser to dual laser single grain system

The standard single laser single grain attachment contains a single green (532 nm) laser. After this upgrade the single grain attachment will contain two lasers: the original green (532 nm) 10 mW stabilised DPSS laser and an IR (830 nm) 140 mW TTL modulated laser. The attachment makes use of an X-Y scanning device using movable mirrors mounted on software controlled encoded motorised linear stages. A beam splitter enables the use of the same optics to focus the IR laser beam onto the sample disc as used for the green laser. A Schott RG 780 filter is placed directly in front of the IR laser to cut a small resonance emission at 415 nm.

4004. Replacement of green laser

Replacement of green (532 nm), 10 mW stabilised DPSS laser.



4005. Replacement of IR laser

Replacement of IR diode (830 nm), 140 mW TTL modulated laser

4006. Refurbishment of the single grain OSL attachment

Replacement of rails, mirrors and print board in the single grain OSL attachment

4007. Single grain driver board

Driver board enabling the Controller to operate the single grain attachment

4500. Additional light sources

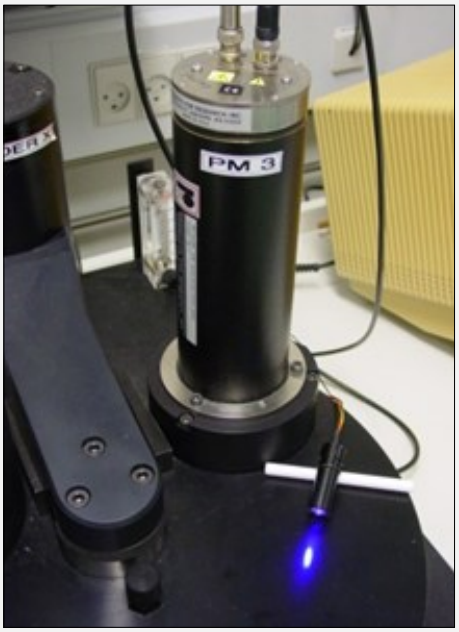
4501. Violet stimulation attachment

a general lack of powerful light sources in this energy range, and a risk of overlap between stimulation and detection windows (Jain et al., 2009).

Violet stimulation is achieved using a 405 nm laser module and the external port in the optical stimulation unit. The laser is focusable and is used with a circular diameter of 4 mm. It operates at 8 V–12 V DC and 80 mA current.

- Violet (405 nm) 100 mW laser module
- ITOS GG395 (3 mm) stimulation filter
- AHF F49-402, ET bandpass 402/15 nm stimulation filter (mounted directly in front of the laser)
- Semrock Brightline FF01-340/26 detection filter

The electronics for driving the amplifier is built into the controller. Due to physical constraints the violet stimulation attachment cannot be used simultaneously with the of the single grain systems (see items 4001 and 4002). For non-DASH systems a classic single-grain OSL unit is a prerequisite.

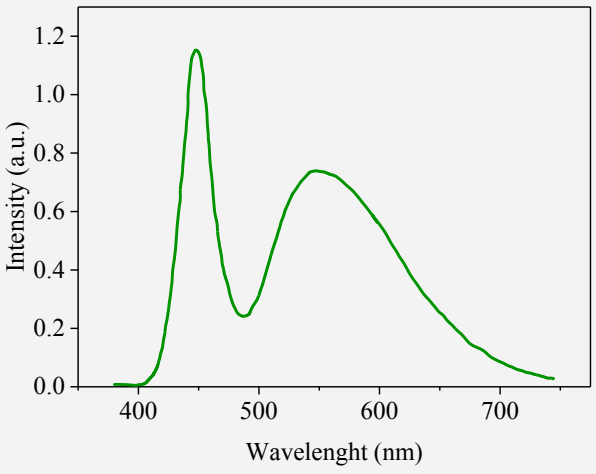


The violet laser

4502. Bleaching facility – External broadband source

Powerful external broadband LED stimulation system for fast bleaching of aliquots (no data acquisition)

- FlexiLux 4000 broadband LED system
- Spectral range: 400-750 nm
- Optical power: 65 W
- Colour temperature: 5,800 K
- Liquid light guide
- Software control (on/off)



Emission spectrum of the external broadband source

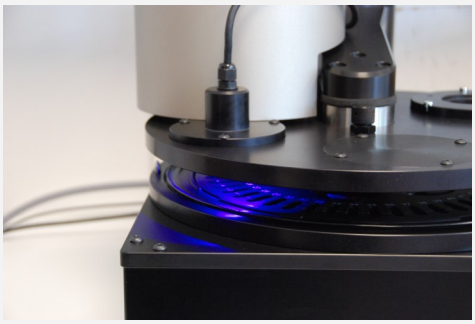
Jain, 2009. Extending the dose range: Probing deep traps in quartz with 3.06 eV photons. Radn. Meas. 44, 445-452

4500. Additional light sources

4503. Bleaching facility – Violet LED module

A powerful Violet LED system for fast bleaching of aliquots (no data acquisition)

- Peak wavelength: 400-405 nm
- FWHM: ~ 20 nm
- Optical power: 1000 mW
- Software control (on/off)

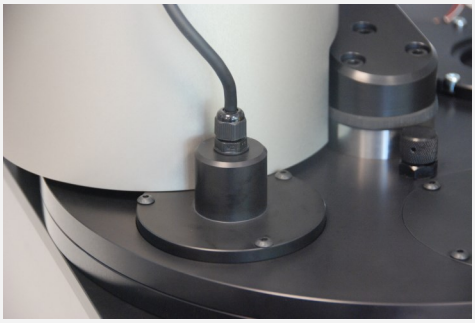


The violet bleaching facility

4504. Bleaching facility – UV LED module

A powerful UV LED system for fast bleaching of aliquots (no data acquisition)

- Peak wavelength: 385-390 nm
- FWHM: ~ 12 nm
- Optical power: 1100 mW
- Software control (on/off)



The UV bleaching facility

5000. Optional attachments

The Risø TL/OSL Reader can be equipped with a range of attachments described below. Most attachments can be retrospectively fitted to previous versions of the Risø TL/OSL Reader.

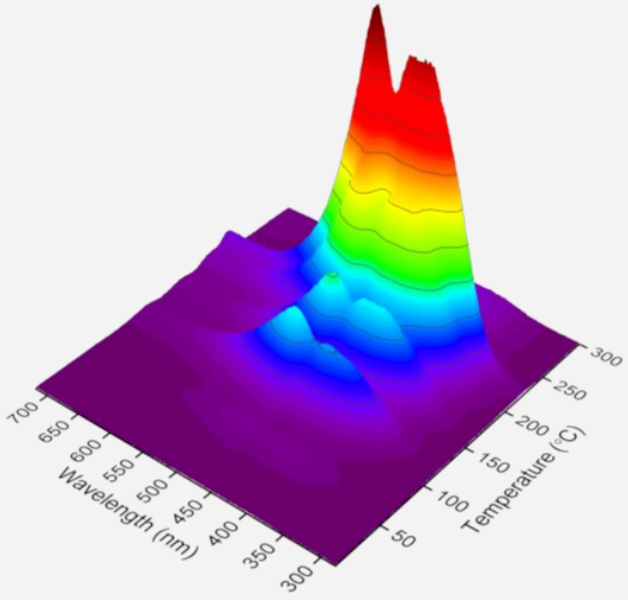
5001. High sensitivity emission spectrometer

Enables measurement of both TL and OSL emission luminescence spectra (Prasad et al., 2016)

- Andor DU-888U3-CS0-UVB EMCCD Camera, Back-illuminated 1024×1024 with standard AR coating and additional lumogen coating
- SR-193I-A Shamrock 193 imaging spectrograph base unit, 193 mm focal length, F/3.6 aperture
- 193i ruled gratings a 300 l/mm (500 nm blaze), and a 150 l/mm (500 nm) blaze giving wavelength regions of e.g. 300-700 nm and 300-850 nm (centre wavelength adjustable), mounted on a motorised dual grating turret
- Specially designed optical 3.1 mm circular fibre bundle with 114, 200 µm UV-VIS-NIR fibres, with a NA = 0.22
- Optical interface to the reader (mounted on the Automated detector changer)
- Reference Mercury/Argon calibration light source with optical fibre interface to the reader
- The Sequence Editor controls the spectrometer when acquiring TL and/or OSL spectrometer data. The spectral data may be read with Andor Solis software and Risø Viewer+ software
- PC

The Automated detector changer (see item 1003) is a prerequisite for the spectrometer attachment.

The Risø emission spectrometer attachment and the Risø TL/OSL Reader



TL spectra from a LiF pellet.

Prasad et al., 2016. Probing luminescence centers in Na rich feldspar. Radn. Meas. 90, 292-297.

5000. Optional attachments

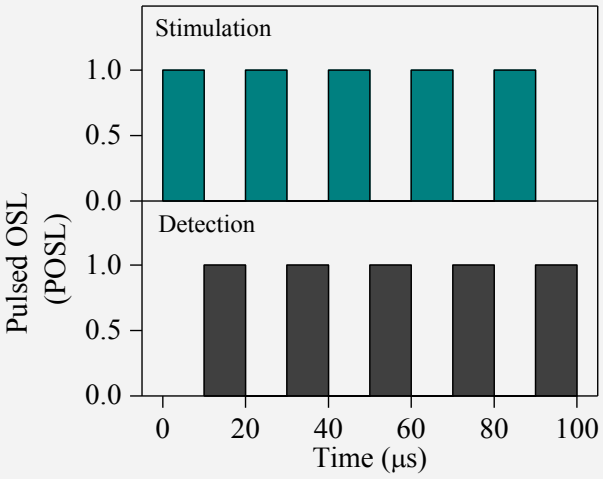
5002. Pulsed OSL

Combined blue, IR and green LED pulsed optical stimulation unit. The unit generates pulsed regulated power for the stimulation LEDs and gates the OSL signal according to specified parameters. The parameters for the pulses are set from the Sequence Editor program (Lapp et al., 2009).

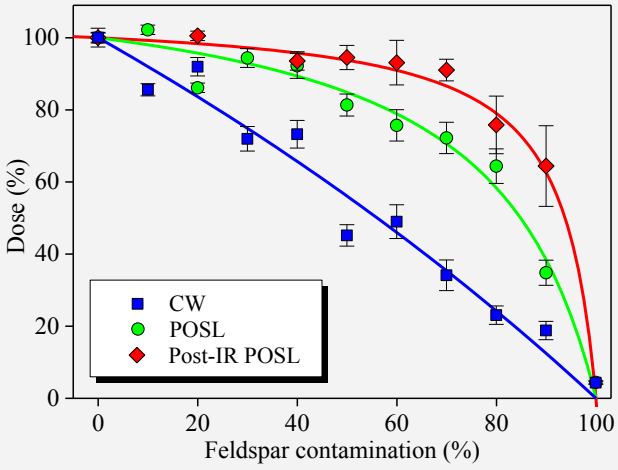
The use of the Pulsed OSL attachment does not require the TCSPC attachment (item 5003). The Pulsed OSL attachment can be ordered separately.

The unit is e.g. suitable for separating quartz from feldspar OSL signals in feldspar contaminated samples, because the life time of the feldspar OSL signal is significantly faster than that of quartz. Thus by pulsing the diodes and only detecting when most of the feldspar signal has decayed away, we can separate quartz and feldspar signals from each other in a mixed sample (e.g. Denby et al., 2006).
The figure to the bottom right, shows the results from a laboratory experiment in which dosed quartz (23 Gy) and undosed feldspar (0 Gy) were mixed together in various proportions. The mixed samples were measured in CW as well as POSL mode using the conventional blue LEDs and Hoya U-340 detection filters. In the presence of 20% of feldspar contamination the measured dose is within 5% of the true dose if only blue light POSL stimulation is used. If a bleach using the IR LEDs is used before POSL blue light stimulation then the measured dose is within 5% of the true dose when the feldspar contamination is as high as 40%.

For non-DASH systems, the Controller and Classic OSL head must be sent to DTU Nutech in advance, when upgrading to the pulsed OSL attachment.



Schematic drawing showing stimulation and detection timing for on/off times of 10/10 µs.



Normalised dose as a function of feldspar contamination (by mass) in laboratory mixed quartz/feldspar samples. Results from CW, POSL and post-IR POSL are shown (Thomsen et al., 2006)

Lapp et al., 2009. Development of pulsed stimulation and Photon Timer attachments to the Risø TL/OSL reader. Radn. Meas. 44, 571-575
Denby et al., 2006. Application of pulsed OSL to the separation of the luminescence components from a mixed quartz/feldspar sample . Radn. Meas. 41, 774-779
Thomsen et al., 2006. Developments in luminescence measurement techniques. Radn. Meas. 41, 768-773

5000. Optional attachments

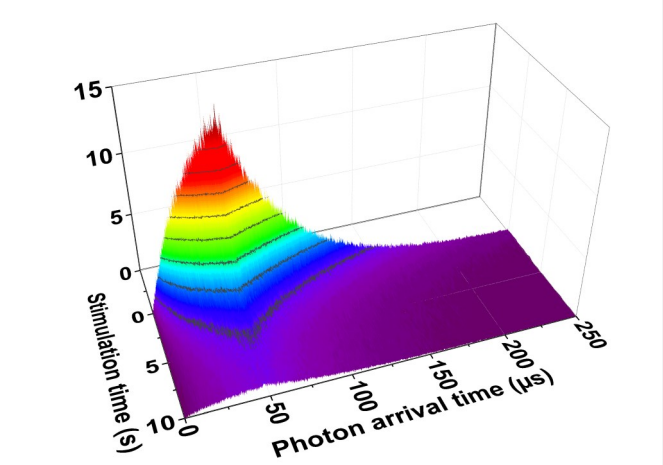
5003. The Risø Time-Correlated Single Photon Counting (TCSPC)

All individual photons can be time-stamped using this TCSPC attachment based on the PicoQuant Time harp 260 board.

The TCSPC attachment is a PC plug-in board including software for doing Time-Resolved Pulsed OSL (TR-POSL) using the Pulsed OSL attachment. The board is mounted in a PCI-Express slot of a standard desktop PC which is also supplied (without monitor). The Pulsed OSL plug-in board furthermore will be equipped with an interface for the PC Photon Timer board. All detected photons are time-stamped with respect to the start of the preceding pulse. The time-stamp resolution is 0.25 ns.

Data acquisition is controlled by the Sequence Editor program, and the software program 'PTanalyse' is used for analysing the Photon Timer data, e.g. to determine photon arrival time distribution curves, OSL decay curves with different parameters settings and to export data for further analysis (Lapp et al., 2009).

- TCSPC Plug-in board
- PC



TR-POSL surface plot of a quartz sample with on-/off-time of 50/200 µs.

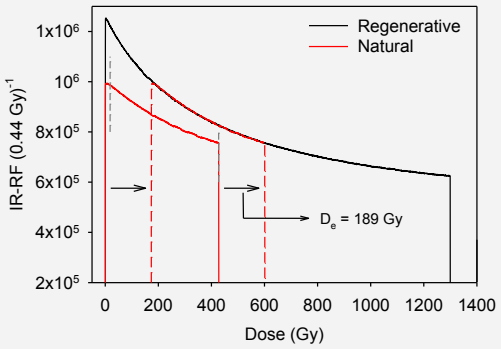
The Pulsed OSL attachment is a prerequisite for the TSCP attachment. For non-DASH systems, the Controller and Classic OSL head must be sent to DTU Nutech in advance.

Lapp et al., 2009. Development of pulsed stimulation and Photon Timer attachments to the Risø TL/OSL reader. Radn. Meas. 44, 571-575

5000. Optional attachments

5004. Radioluminescence

Radioluminescence (RL) from a sample can be measured during beta or X-ray irradiation, using a light guide and a choice of PM tubes covering 180-890 nm or the high sensitivity spectrometer (Lapp et al., 2012).
A beta irradiator is modified to facilitate detection of luminescence emitted during irradiation (RL). This modification reduces the dose rate to the sample to about half of the dose rate achievable using the standard beta irradiation unit.



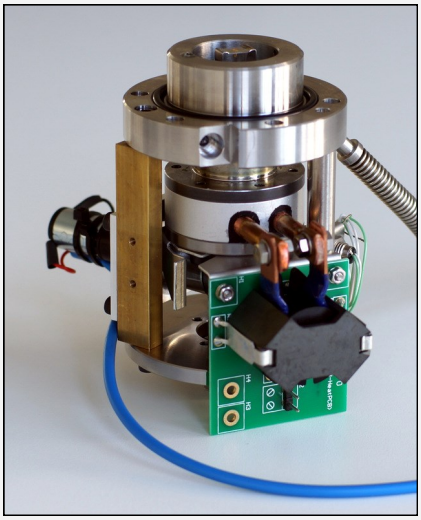
Principle of a fit of the additive dose response curve (solid red curve) onto the regenerative dose response curve (black) using *RLanalyse*; the horizontal displacement gives the D_e value. The vertical dashed grey lines indicate the region of the additive dose curve that was used for the fit. The best fit is shown using a dashed red line. (Buylaert et al., 2012)

- A Hamamatsu H7421-50 Photon counting head with spectral response 380 -890 nm, thermoelectrically cooled (see item 2003)
- Lumatec liquid light guide (Transmission range of 350-2000 nm)
- Detection filter holder and Chroma D 900/100 interference filter (bandpass: 850-945 FWHM)
- Electronics for switching between counter input from RL PMT and standard PMT (built into the Controller)
- Power supply for the Hamamatsu H7421-50 Photon counting head and thermoelectric cooler (built into the Controller)
- A powerful UV LED (395 nm, 1000 mW) placed in a special bleaching position that may be used to bleach the samples during a sequence (see item 4504)
- Dedicated software, RLanalyse, is supplied for analysing RL data.

5005. Extra heating and lifting module

This module is mounted underneath the beta irradiator/ Radioluminescence attachment and enables irradiation at elevated temperatures (from room temperature to 700 ° C). The extra lift and heating module makes it possible to heat the sample during irradiation. The heating and lifting module is similar to the heating and lifting module in the standard measuring position (see item 3001).

- Heating/lift unit enabling heating of individual samples up to 700 °C
- 30 kHz non-switching sine wave
- Type K thermocouple (Chromel-Alumel)
- cooling by a continuous gaseous flow
- linear heating rates from 0.1 to 10 °C/s.



The heating and lifting module.

Lapp et al., 2012. New luminescence measurement facilities in retrospective dosimetry. Radn. Meas. 47, 803-808
Buylaert et al., 2012. IR-RF dating of sand-sized K-feldspar extracts: A test of accuracy. Radn. Meas. 47, 759-765

5000. Optional attachments

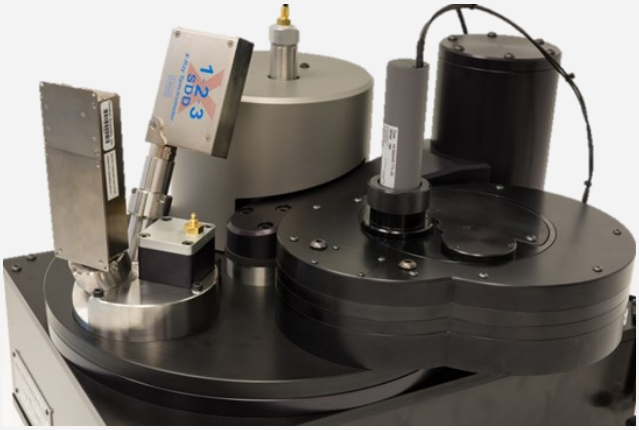
5006. X-ray Fluorescence (XRF)

The relative proportion of K-/Na-/Ca-feldspar, and the fraction of quartz in each of the up to 48 samples on a measurement wheel can be measured using this XRF attachment which is based on an Amptek Spectrometer and an Amptek mini X-ray tube.

- Amptek X-123 SDD Complete X-Ray Spectrometer
  - Silicon Drift Diode (SDD)
  - Detector Area: 25 mm^2 (collimator area 17 mm^2)
  - Detector Thickness: 500 µm
  - Detector Window: C1
  - 1.5" Detector Extension
  - Thermoelectric Cooler: 2-Stage (85° ΔT_{max})
  - Internal Multilayer Collimator)

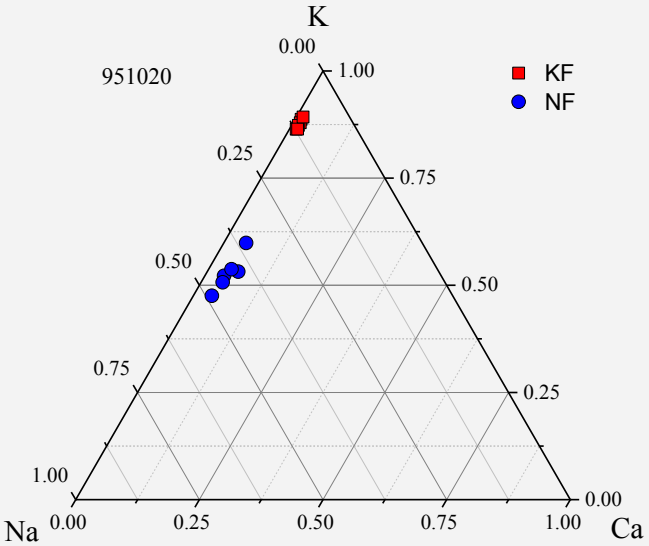
- Amptek MINI-X Miniature X-Ray Tube
  - 50 kV/80 µA
  - Gold (Au) Transmission Target
  - High Voltage Power Supply
  - Beryllium end window
  - USB Controller
  - Molybdenum (Mo) sample cups (200 pcs)
  - Reference samples for making and maintaining the K-/Na-/Ca-feldspar calibration
  - Shielding and interlock features

Software:
A dedicated PC program for analysis of XRF data and converting this to position in the ternary diagram of K-/Na/-Ca-feldspar and giving estimated quartz contamination will be supplied. The standard data acquisition software "Sequence Editor" will include support for making data acquisition from the XRF unit.



XRF-attachment used in Guralnik et al., 2015, Porat et al., 2015

XRF measurements require vacuum (vacuum pump and vacuum accessories not included). The XRF spectrometer occupies the same position as the alpha irradiator (item 3504), so the two units cannot be mounted simultaneously. The XRF and the single grain attachments (items 4001-4003) cannot be mounted simultaneously.



Ternary diagram showing the results for K-feldspar rich ($\rho < 2.58$ g cm^{-3}) and Na-rich extracts (2.58 g $cm^{-3} < \rho < 2.63$ g cm^{-3}) measured with the Risø XRF-attachment. Six multi-grain aliquots were measured per extract. The 180-250 µm feldspar grains were extracted using conventional sample preparation techniques (HCl, H_2O_2, HF, heavy liquids) from sediment from Greenland.

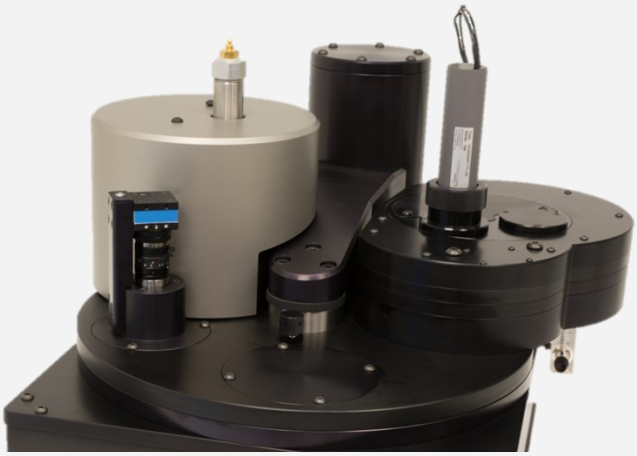
Guralnik et al., 2015. OSL-thermochronometry of feldspar from the KTB borehole, Germany. Earth and Planetary Science Letters 423, 232–243
Porat et al., 2015. Re-examination of common extraction and purification methods of quartz and feldspar for luminescence dating. Ancient TL 33, 22-30

5000. Optional attachments

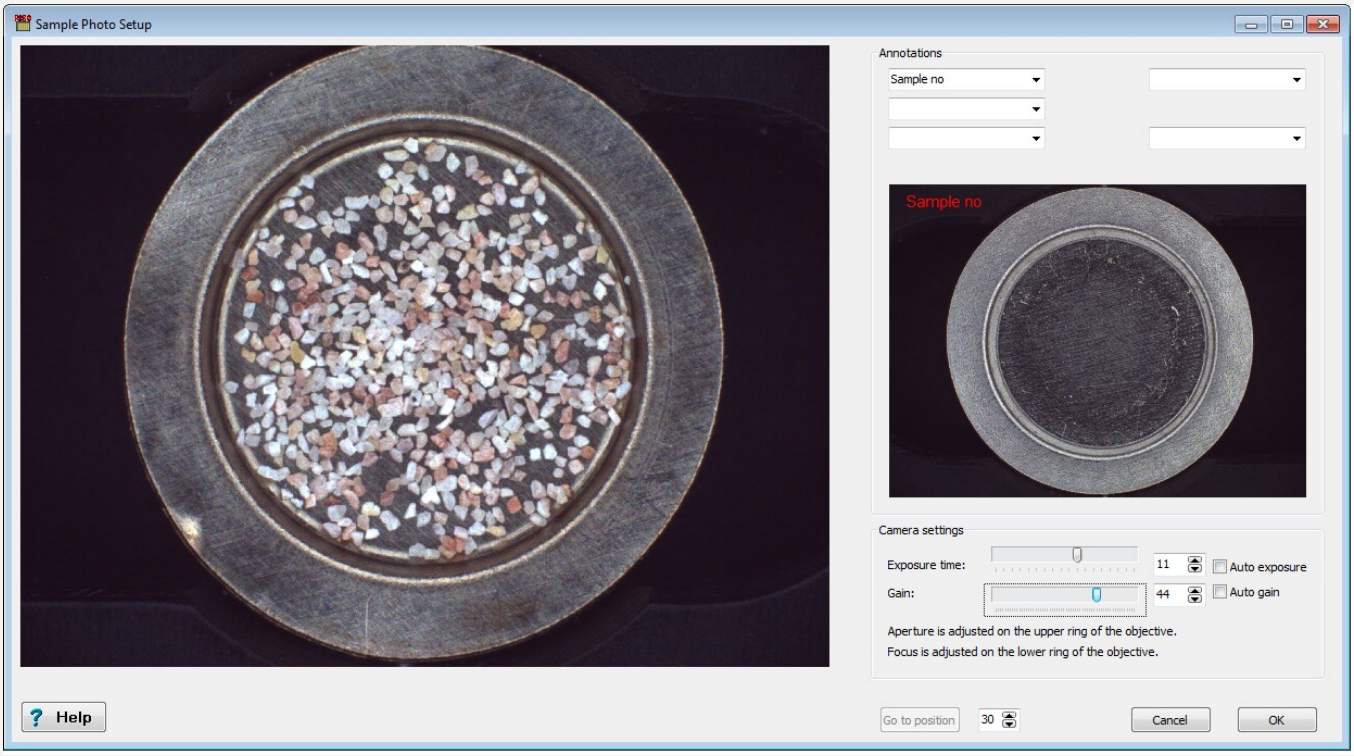
5007. Sample camera

An optical image of a sample on the measurement wheel can be collected as part of the luminescence measurement sequence allowing evaluation of the number and spatial location of grains on a sample disc.

- The Imaging Source 1/2.5" Micron CMOS sensor, 2952×1944 (5 mega pixel)
- Computar f=25 mm, F1.8, ultra-low distortion lens
- Vacuum and light-tight mechanical fixture holding a diffuse light illumination system to ensure proper white light illumination of the samples that are photographed
- Driver for the illumination light (built into the Controller)
- The "Sequence Editor" allows collection of optical pictures during measurement sequences



Sample camera attachment mounted in front of the beta irradiator



Screenshot from the Sequence Editor showing an optical image taken using the sample camera attachment of a sample cup with sedimentary feldspar

5500. Installation and Training

5501./5502. On location installation

Two-day installation, testing and commissioning by a DTU Nutech representative on location at your laboratory. The availability of this option will depend on Danish authorities' recommendations for travel.

Unpacking the Reader

5503. Training

DTU Nutech and Aarhus University (through the Nordic Centre for Luminescence Research) jointly offer a two week course and training for one person in retrospective dosimetry using optically stimulated luminescence. The course will take place at DTU Nutech's facilities at Risø, Roskilde, Denmark.

The course covers basic OSL theory and introduces the participants to the two main aspects of retrospective dosimetry: dose and dose-rate determination. The course consists of a series of lectures covering theory as well as practical exercises. The participant will gain hands-on experience in operating the Risø TL/OSL reader; including installation and maintenance. At the end of the two week course the participants should confidently be able to determine a luminescence age.

DTU Nutech, Risø Campus, Roskilde, Denmark

Course Outline

Basics of luminescence and OSL dating
Choice of dosimeter material, mineral separation and dose response

Installation and use of the Risø TL/OSL Reader
Detailed description of how to install the reader, use of hardware and software, and instrument maintenance.

Dose estimation
The Single Aliquot Regenerative-Dose (SAR) protocol

Origins and determination of dose rate
Gamma spectroscopy and beta counting

Age calculation
Includes uncertainty analysis

Dating of young sediments
Problems and case studies

Dating of old sediments
Problems and case studies (age limits etc.)

Rock surface dating
Theory and case studies

Course fee includes course compendium, refreshments and lunches but not accommodation and transportation to and from Denmark.

Sampling for luminescence dating

6000. Accessories

Calibration quartz

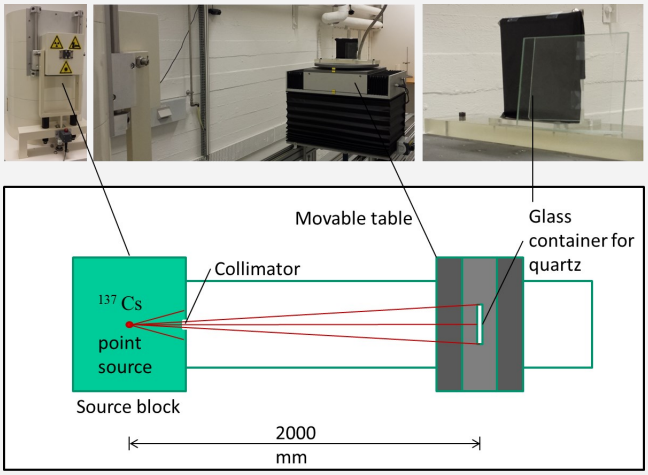
Sedimentary quartz sieved to 180 to 250 µm or 4-11 µm with usual initial preparation. Annealed at 700°C for one hour, given a ~2 kGy gamma dose and then annealed at 450°C for one hour. Stored in the dark prior to use. Packed into glass flat pack 100×100 mm, 1.9 mm wall thickness, 1 mm spacing between walls. Irradiated in the dark, normal to plane of pack (Hansen et al., 2015).

Dose in air = 5.000±0.005 Gy

Attenuation in pack: Assuming 0.3 mm of glass required to produce secondary electron equilibrium, remaining wall thickness (1.6 mm) attenuates the beam. For normal irradiation, assume half mean path length through packed quartz is 0.5 mm. This also attenuates beam.

Using 0.0770 cm^2/g for quartz/glass mass attenuation coefficient at 662 keV, and density of 2.66 g/cm^3 (glass) and 2.0 g/cm^3 (packed quartz), gives overall attenuation factor of 0.960±0.010 (estimated error).

Calculated dose to quartz: Ratio of mass absorption coefficient of quartz to that of air is 1.0008 at 662 keV. Dose in quartz is thus 5.000 × 1.0008 × 0.960 Gy, i.e. 4.81±0.07 Gy.



6001. Coarse grain calibration quartz

1 bag of calibration quartz, ~0.25 g, 4.81 Gy, 180-250 µm
Also included is an undosed portion of the sample which can be used for dose recovery testing.

6002. Fine grain calibration quartz

1 bag of calibration quartz, 0.25 g, 4.81 Gy, 4-11 µm
Also included is an undosed portion of the sample which can be used for dose recovery testing.

Other calibration materials (e.g. solid quartz slices 1 mm thick, 9.7 mm diameter) are under development.

DTU Nutech can, in some circumstances, also arrange custom irradiation of non-standard materials/geometries. Please enquire at osl@ntech.dtu.dk for further details.

Hansen et al., 2015. A new irradiated quartz for beta source calibration. Radn. Meas. 81, 123-127

6000. Accessories

Detection filters

The intensity of the stimulation light is ~10^{18} orders of magnitude larger than the emitted luminescence. In order to be able to measure the emitted luminescence, detection filters must be used to prevent scattered stimulation light from reaching the PMT, and the spectral stimulation and detection windows must be well separated.

6003-6005. U-340 detection filter

Band pass filter transmitting in the ultraviolet. Transmission centred on 340 nm (FWHM ~70 nm).

6003	t7.5 mm	ø=45 mm	(classic OSL head)
6004	t5 mm	ø=25 mm	(DASH)
6005	t2.5 mm	ø=25 mm	(DASH)

6006-6007. Schott BG-39 detection filter

Ionically coloured glass, Band pass filter centred on ~500 nm (FWHM ~260 nm).

6006	t2 mm	ø=45 mm	(classic OSL head)
6007	t2 mm	ø=25 mm	(DASH)

6008-6009. Schott BG-3 detection filter

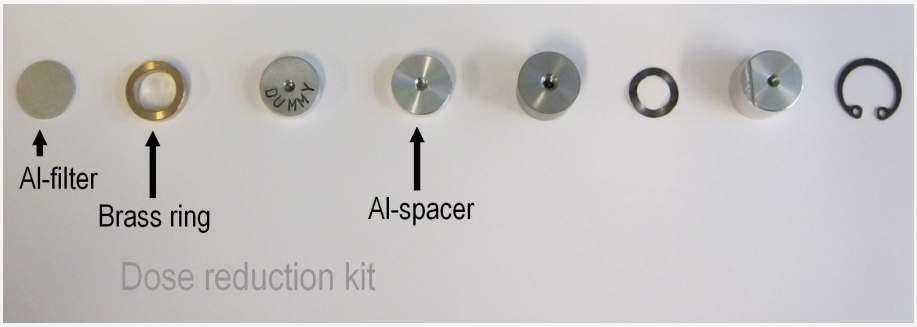
Ionically coloured glass, Band pass filter centred on ~350 nm (FWHM ~190 nm).

6008	t3 mm	ø=45 mm	(classic OSL head)
6009	t3 mm	ø=25 mm	(DASH)

6000. Accessories

6010. Dose reduction kit

The dose reduction kit reduces the dose rate of the Sr-90 beta source by a factor of ~10. The kit consists of rings and spacers and is inserted into the source module before the beta source.



6011. PC and monitor

Personal computer with Windows and special application software installed, monitor and UK keyboard

Note: The Risø Reader is run using a standard PC, which is not automatically included in the Reader configuration, except when explicitly mentioned. It can be supplied by the customer or purchased through DTU Nutech.

6012. Piezoelectric ultrasonic cleaner

Ultrasonic scaler for cleaning of single grain discs in order to release trapped grains from sample holes.

Output tip vibration frequency: 30 ± 3 kHz

Output half-excursion force: <2N

Output primary tip vibration excursion: ≤100µm

Holder for 24 single grain discs is provided

6000. Accessories

Sample holders

Samples are either mounted on 9.7 mm diameter flat discs (stainless steel or aluminium) using silicone oil as an adhesive or poured (as loose grains) into sample cups (ø=11.7 mm; stainless steel or aluminium). Sample holders are loaded onto an exchangeable sample carousel (items 6022, 6023) that can accommodate up to 48 sample holders.

6013. Stainless steel sample cups

11.7 mm diameter stainless steel sample cups

6015. Stainless steel sample discs

9.7 mm diameter stainless steel sample discs

6014. Aluminium sample cups

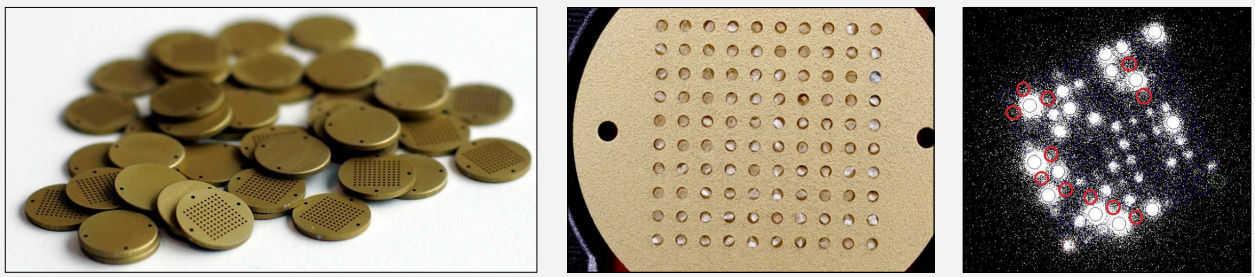
11.7 mm diameter aluminium sample cups

6016. Aluminium sample discs

9.7 mm diameter aluminium sample discs

6017-6021. Single grain discs

The aluminium sample discs designed for mounting single grains are 1 mm thick and have a diameter of 9.7 mm (i.e. same surface area as the conventional sample discs). The individual grains are placed in 100 holes drilled into the surface of the sample discs. These holes are x µm deep by x µm in diameter (x=100, 150, 200, 250 or 300) on a 10 by 10 grid with 600 µm spacing between hole centres.



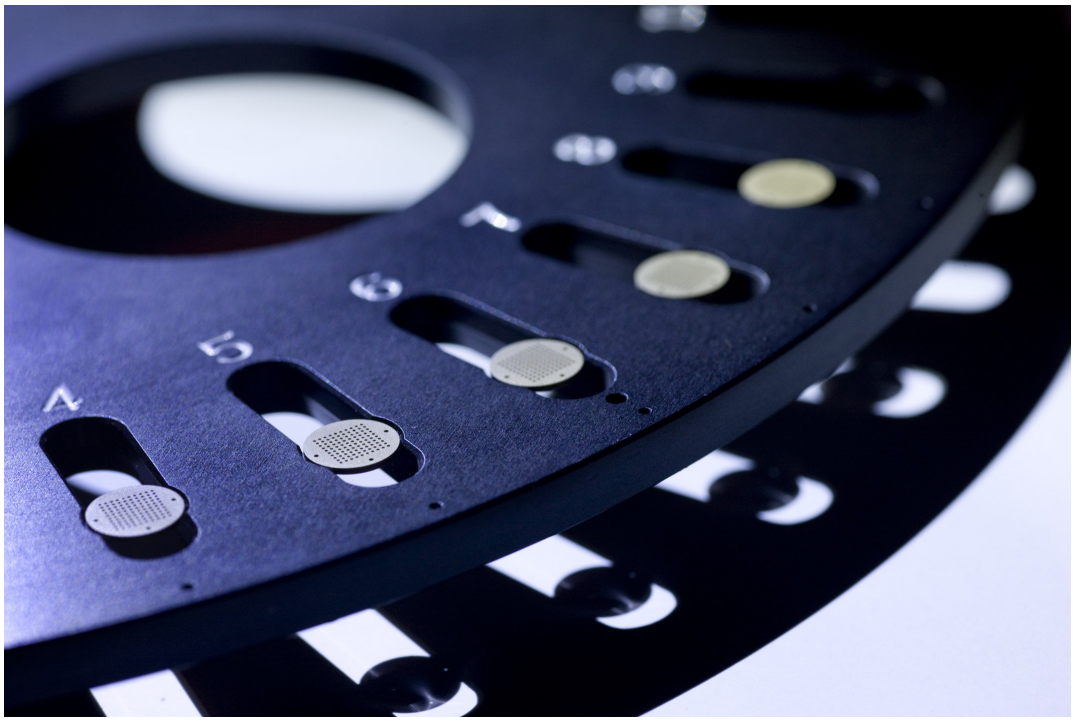
Standard single grain discs with depth and diameter of 300 µm. Picture on the right shows blue stimulated quartz OSL recorded with the EMCCD option (item 2004; Thomsen et al., 2015).

Thomsen et al., 2015. Single-grain results from an EMCCD-based imaging system. Radn. Meas. 81, 185-191

6000. Accessories

Sample carrousel

Samples are loaded onto an exchangeable sample carousel (ø=306 mm) that can accommodate up to 48 samples. Two types of sample carrousels are available: one for flat sample discs (ø=9.7 mm) and one for sample cups (ø=11.7 mm)



6022. Disc carrousel

Exchangeable sample carrousel for flat 9.7 mm sample discs (items 6015-6021)

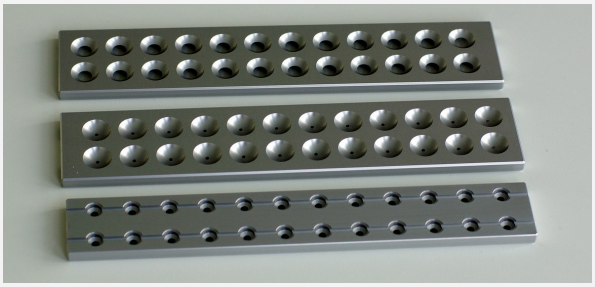
6023. Cup carrousel

Exchangeable sample carrousel for 11.7 mm sample cups (items 6013, 6014)

6024. Spray masks

When mounting sample grains using e.g. silicone oil as an adhesive (e.g. to ensure that the grains are presented in a monolayer), the spot size should be controlled.

Set containing one base plate and two masks with holes with diameters of 2 and 8 mm, respectively.



6000. Accessories

6025. Vacuum pump

Leybold DB4 vacuum pump with an AR 4-8 Exhaust filter

The Risø TL/OSL reader enables measurements of both TL and OSL in vacuum (down to 0.2 mbar), but a vacuum pump is not included in the standard configuration. If the Risø TL/OSL reader is equipped with an alpha source or XRF attachment, the measurement chamber should be evacuated before alpha irradiation/XRF measurement is undertaken.

6026. Vacuum accessories

Relay box and vacuum extension tube (1 m)

The Relay box is necessary for automatic software control of atmosphere in sample chamber as is the flexible steel vacuum extension tube which is used to connect the vacuum pump to the Risø TL/OSL Reader

6500. Environmental dose rate instruments

6501. USB interface for the ultra-low-level Beta GM Multicounter

USB interface box for upgrading of existing beta counter

6502. Electronic box for the ultra-low-level Beta GM Multicounter

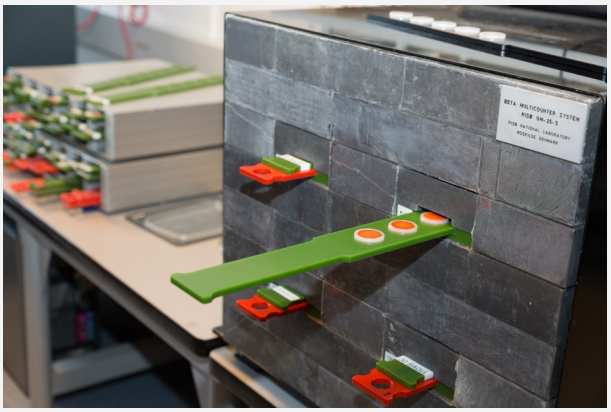
Electronic box for the Risø GM-25-5 betacounter (with software and USB Connection)

6503. Lead shielding for the ultra-low-level Beta GM Multicounter

Complete 100 mm thick lead shielding made up of low contaminated lead bricks.

Note that two specifically machined lead-fittings for the ends of the counter is included when purchasing the ultra-low-level Beta GM Multicounter and therefore do not need to be ordered separately.

Lead fittings for the ends of the counter.



Beta counter is mounted in a lead castle. A sample slide is partially inserted into the counter.

6504. Sample holders for the ultra-low-level Beta GM Multicounter

Nylon sample holders (disc and ring) made according to Health and Safety Laboratory procedures manual HASL-300 USAEC.

Sample holder for the beta counter